Contemporary Trends in the Regenerative and Sustainable Built Environment: Technical and Managerial Aspects

Workshop Proceedings

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Edited by:

Marjan Sarshar Driscoll, Anton Ianakiev, and Begum Sertyesilisik

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Preface

As the world's living conditions are deteriorating, the need for the regenerative and sustainable built environment is increasing. Establishment of the regenerative and sustainable built environment requires interdisciplinary work and research. For this reason, our workshop "Low carbon Buildings and Communities in the Sustainable Built Environment" supported by the British Council Researcher Links as well as our workshop "Novel Energy for the Regenerative Built Environment: Technical and Managerial Aspects" supported by the Turkish Science Foundation (TÜBİTAK) play an important role in bringing the academics from various disciplines together. This workshop proceedings book provides the proceedings of these two workshops.

We would like to thank all participants for their contribution to our workshops which will act as an efficient tool for enhancing our collaboration.

We would like to thank the British Council and the Turkish Science Foundation for supporting and enabling these workshops.

Kindest regards,

Prof. Marjan Sarshar
Dr. Anton Ianakiev
Assoc. Prof. Begum Sertyesilisik

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Contemporary Trends in the Regenerative and Sustainable Built Environment: Technical Aspects

Building Performance (In a Changing Climate)

Mark Mulville
University of Greenwich, m.mulville@gre.ac.uk

Abstract

The delivery of a sustainable built environments both for domestic and commercial buildings be it new build or refurbishment has for some time been the focus of much attention within the construction indusrty. Governments have increasingly saught to reduce the impact of the built environment (associated with resource depltion, CO_2 emissions and running costs) through the implimentation of increasingly stringent regulations. These regulations are largely focused on mitigation through technical interventions (building fabric, efficient services and renewables) and are further supported by environmental assessment methods encouraging consideration of the wider 'sustainability' agenda and isuses such as transporation, ecology and mangement.

Although the above approach is not without merit there is perhaps a danger that considerations of life time performance of the building in terms of the occupants health, comfort and productivity may be sidelined (although environmental assessment methods may consider these issues the weightings used place a high level of importance on energy consumption and associated emissions) and this could result in buildings that are at risk of premature obsolescnece, be it technical, financial or social.

This paper considers how the prevailing approach could impact on the life time performacne of the built environment, particularly in relation to health, productivity, well-being and energy efficiency, when isuses such as the energy performance gap, the likely impact of climate change and occupant behaviour are taken into consdieration. The paper, by tying together existing and ongoing areas of research, suggests how innovative approaches to lifecycle planning and risk based performacne predictions could help avoid these issues, presenting the potential impacts as a theorethical model.

Key Words: *Building Performance, Climate Change, Obsolescence, Adaptation, Occupant Behaviour*

1. BUILDING PERFORMANCE

Historically buildings have been a place of shelter offering a secure refuge and aiming to provide a comfortable and healthy environment while encouraging creativitiy and bringing happyness. In this context it can be argued that the fabric of the building acts as a filter allowing for instance, a view of the outside world while protecting occupants from the extremes of climate. As it is estimated that in the developed world people spend up to 90% of their time indoors (Batterman, 2014) the environment that our buildings provide is of increasing importance. Given that buildings are responsible one third of global greenhouse gas emissions (United Nations Environment Programme, 2009) there is understandably a drive to reduce these emissions in order to mitigate the impacts of climate change, this has resulted (in cool or temperate climates) in measures to reduce heat loss and increase efficieny. There is however a body of evidence that recently constructed and refurbished buildings suffer from poor internal air quality (Spengler and Chen, 2000) and overheating (Dengel & Swainson, 2012) which may have negative impacts on comfort, health and productivity. In addition many buildings suffer from an 'energy performance gap' (de Wilde, 2014) where desired targets are significantly exceeded. Arguably occupant behaviour and interactions with the building may contribute significantly to this gap (Menezes et al. 2012). When considered together this suggests that there are significant deficencies in building performacne and as such the 'performacne gap' exists not only in terms of regulated energy but also in terms of comfort, health, wellbeing and productivity (de Wilde 2014). There is an argument that the drive for energy efficiency (in relation to 'regulated energy') although not wihtout its merits, has resulted in buildings that may not be fit for purpose and as such may struggle to provide many of the criteria they have historically been associated with. When considered in conjunction with the potential impacts of climate change which are expected to have a significant impact on energy and the internal environment (Jenkins et al. 2009) the performance of buildings becomes a moving target and if our building stock to be truly sustainable it must be both resiliant and adaptable.

2. KEY FACTORS

As noted by Thomsen and der Flier (2011) obsolescence in the built environment is commonly considered the beginning of the end of life phase of the building and can be considered gap created due to declining performance and growing expectations. Although in theory this is a simple concept when the potential range of contributory factors are taken into consideration (physical, economic, financial, functional, location, environmental, political etc. (Thomsen and der Flier, 2011)), be they intrinsic or extrinsic factors (Pinder & Wilkinson, 2001) along with their interrelationships it can become a much more complicated matter. As further noted by Thomsen and de Flier (2011) as buildings are long lasting, immobile and capital intensive, minimising obsolescence is of significant importance.

Concurrent to considerations of building obsolescence there is as noted by de Wilde (2014) growing concern within the construction industry regarding the observed gap between predicted and measured energy performance. As noted by Menezes et al. (2012) this gap in energy terms can be up to 2.5 times the original prediction. In the context of the above discussion this 'performance gap' has the potential to contribute to building obsolescence. The cause of this gap may originate from the design, construction or operational stages of the building lifecycle (de Wilde 2014), and each in turn has the potential to contribute towards premature building obsolescence. As noted by Mulville et al. (2013) the energy consumption of building occupants particularly in relation to unregulated energy can vary significantly between individuals, in practice this observed variation may be a contributory factor to performance gaps occurring during the operational stage of the building lifecycle. Several authors (*Tetlow et al. 2013, Gulbinas & Taylor 2014, Murtagh et al. 2013*) have noted the potential for behavioural change interventions to reduce energy consumption and the level of variation between individuals. Currently 'performance gap' studies generally concentrate on technical interventions and regulated energy, however as regulations set increasingly stringent targets the impact of unregulated energy and occupant behaviour becomes increasingly important. de Wilde (2014) argues that the observed energy performance gap is likely to apply in other areas, such as indoor air quality, acoustics, thermal comfort and daylighting, these factors in turn have been shown to have the potential to have a significant impact on occupant health, wellbeing and ultimately productivity (Singh et al. 2010, World Green Building Council 2014 and Fisk, 2010). Furthermore where in the commercial sector, staff costs can significantly exceed energy costs (Fuller, 2010) a focus on health, well-being and productivity (along with energy) is required if the business case for the delivery of sustainable built environments is to be supported. A similar argument can be made in the residential sector where proportionally higher energy costs may result in fuel poverty.

There is broad scientific consensus that climate change is highly likely to have significant impacts on both human society and the built environment. As noted by Jenkins et al. (2014) by the 2030s (in the UK) up to 76% of flats and 29% of detached dwellings may be at risk of overheating and commercial buildings are predicted to have similar problems (Jones et al. 2014). In the short term technical interventions may be able to solve some of these issues, but as we move further into future predictions, the level of overheating risk is likely to further increase (Roaf et al. 2015) and as a result behavioural adaptations may also be required if a growing performance gap and as noted by Desai & Jones (2010) premature obsolescence is to be avoided. However as with any future prediction climate change impact studies are inherently uncertain (Kershaw et al. 2011) and as such a balanced approach to potential interventions is required if they are to avoid having negative impacts in terms of building performance.

During the design, construction and operational stage of the building lifecycle key decisions taken have the potential to impact on building performance in relation to energy, health, wellbeing and productivity. Climate change impacts and occupant behaviour are considerations not normally embedded in the lifecycle planning of the building but have the potential to contribute to the building ‘performance gap’. Given the level of uncertainty that can be associated with these criteria risk based assessments are needed to consider a range of potential scenarios so that sustainable built environments can be delivered.

A backcasting approach as noted by Jones et al. (2014), where the desired performance at a given point in the future is established and then pathways looking backwards to achieving that performance developed, could be a practical method of achieving such an outcome. As noted by Hojer and Mattson (2000) (cited in Jones et al. 2014) a forecasting approach used to quantify how interventions can bring about a desired future combined with backcasting to define that desired future can be successfully implimented. An example of how such an approach can be applied is given by Jones et al. (2014) in relation to an educational building, this demonstrates how the design team can, when engaged with the theoretical predictions, produce practical solutions to abstract or uncertain future scenarios (such as climate change).

3. THEORETHICAL MODEL

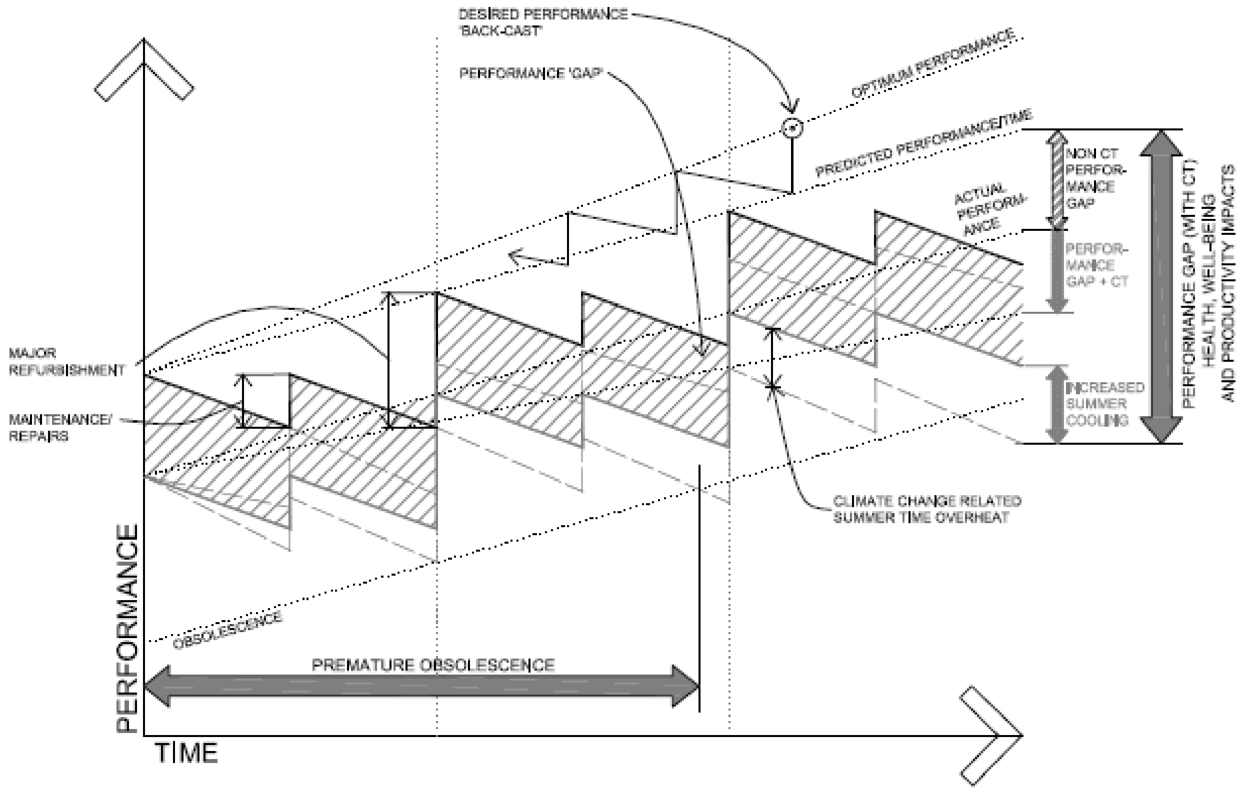


Figure 1. Building Performance Model (adapted from Butt et al. 2010 – Model of Maintenance and Refurbishment Lifecycle)

The interrelationships between obsolescence, maintenance, refurbishment, along with the impact of performance gaps and the predicted impact of climate change on health, well-being, and general building performance are difficult to visualise. Indeed the concept of obsolescence alone although relatively clearly defined has so many potential contributory factors that absolute definitions may be either highly complex or simply incorrect. With this in mind a conceptual model of building performance over time, mapped against a model of maintenance and refurbishment as presented by Butt et al. (2010) has been developed.

The model, depicted in figure 1, suggests how the presumed maintenance and refurbishment cycle (top dark line) may be skewed by the impact of a building performance gap (middle solid grey line). This performance gap could relate to energy use and/or health, well-being and productivity impacts, which ultimately have the potential to skew the business case for thinking around whole of life building performance, as, if predictions are known to be unrealistic, no confidence can be placed in estimated returns on investment (be it energy, health and well-being in the home or productivity etc.in the workplace). As the model demonstrates the impact of climate change has the potential to amplify this affect and this may be stretched even further if assumptions regarding climate change and occupant behaviour prove unreliable.

As in both scenarios (performance gap and climate impact) the predictions are inherently uncertain they need to be approached with caution and as such should be considered in the context of risk based assessments. In the conceptual model the element of risk could be represented by a range of scenarios (these are excluded from the diagram for clarity). For the energy performance gap such predictions can be drawn from the existing evidence base provided by post-occupancy evaluation studies (see Carbon Buzz[1] and the Usable Buildings Trust[2]) where certain building types (such as highly complex buildings) have been observed to result in larger performance gaps. The development of a regulatory framework for risk based assessment of the energy performance gap is subject to ongoing research by this author.

Building on issues of building performance Jenkins et al. (2013) notes the importance of considering climate change impact studies in a probabilistic manner in order to ensure they reflect the true range of possibilities. This could be approached again as a risk based assessment, with high risk buildings (such as light weight single sided flats in the case of dwellings or highly glazed buildings in the case of commercial buildings) forced to carry out adaptation planning studies similar to that outlined by Jones et al. (2014). As can be seen in the model when the performance gap and likely impact of climate change are combined this has the potential to render the building prematurely obsolete due to either technical (overheating), financial (running costs, income/value limitations) or function (unable to adapt) reasons.

The issues considered in the theoretical model largely focus on those related to the original design, regulation and construction in combination with the assumptions made regarding occupant behavior, climate and lifetime performance. This all stems from the building at the point of handover, it can however be argued that this focus on the point of handover, even when the inherent uncertainty in future performance predictions are taken into account, may be short sighted when decisions at this stage have the potential to make such long term impacts. 'Backcasting' provides an alternative approach that makes allowances for such uncertainty, where a desired performance at a given point in the future is established and, taking into account a range of possible or probable scenarios a route is 'backcast' from that target noting critical interventions points. The theoretical model detailed here notes this as a desired performance point, plotting interventions backwards. As previously noted and detailed by Jones et al (2014) when combined with more traditional forecasting approaches to facilities management such methods embedded in the design process can enable the team to conceptualize potential risks and make informed assessments and decisions (such as assessing the cost of damage to critical infrastructure due to an extreme weather event) with the aim of avoiding the premature obsolescence of the building.

When combined with risk based assessment/ regulation in relation to the predicted performance gap and the impact of climate change (not only in terms of energy but also occupant health, wellbeing and productivity) a backcasting approach to performance evaluation at the design stage has the potential to help deliver 'performance primed' buildings that embed resilience and adaptability. The result is buildings that, accepting the inherent uncertainty of future predictions, are primed to deliver life time performance and sustainable built environments.

4. CONCLUSIONS AND RECOMMENDATIONS

A theoretical model for the delivery lifetime building performance has been set out considering how the inherent uncertainty in future predictions can be addressed in terms of risk based assessments/regulation combined with a backcasting approach embedded in the design and delivery process. For the approach to be successful it requires the combination of traditional design and construction methods with facilities management theories and current and

[1] http://www.carbonbuzz.org
[2] http://www.usablebuildings.co.uk

emerging research. Such an approach must be occupant centered focusing on health, well-being and productivity along with energy efficiency.

As the model is based on recent and ongoing research further refinement and development is needed to move it from the conceptual to the practical. Although there is a large body of research in relation to health, wellbeing and productivity in buildings, multiple methods and metrics are used making comparison difficult. To aid the approach outlined here a repeatable methodology that enables measurement of key criteria in a range of building types is required to enable a data base of comparable information to be developed, which in turn can inform the design process. This could be combined with an understanding of the issues that contribute to performance gaps and climate change related overheating providing a valuable resource aiding the delivery of 'performance primed' buildings.

5. REFERENCES

Batterman, S., Su, F. C., Li, S., Mukherjee, B., & Jia, C. (2014). Personal exposure to mixtures of volatile organic compounds: modeling and further analysis of the RIOPA data. *Research report (Health Effects Institute)*, (181), 3-63.

Butt, T., Bonny, B.N. & Jones, K. (2010). Sustainable development and climate change induced obsolescence in the built environment. *Proceedings from the Sixteenth Annual International Sustainable Development Research Conference, 30th May – 1st June 2010, Hong Kong, China*.

Dengel, A. & Swainson, M. (2012).Overheating in new homes: A review of the evidence. IHS BRE Press on behalf of NHBC foundation.

Desai, A & Jones, K. (2010). Examination of existing facilities manager's attitudes to climate change. *Proceedings of CIB W70 – Facilities Management in the Experience Economy, 13-15th September 2010, Sao Paulo, Brazil.*

de Wilde, P. (2014). The gap between predicted and measured energy performance of buildings: A framework for investigation. *Automation in Construction,* (41), 40-49.

Fisk, W. (2000). Review of health and productivity gains from better IEQ. *Proceedings from Healthy Buildings 2000, Helsinki, Finland.*

Fuller, S. (2010). Life-Cycle Cost Analysis (LCCA). *National Institute of Standards and Technology.* http://www.wbdg.org/resources/lcca.php, accessed 30.05.15.

Gulbinas, R & Taylor, J. (2014). Effects of real-time eco-feedback and organizational network dynamics on energy efficient behaviour in commercial buildings. *Energy and Buildings,* (84), 493-500.

Hojer, M. & Mattsson, L. (2000). Historical determinism and back casting in future studies, Futures, (32), 613 -634.

Jenkins, D.P., Ingram, V. & Patidar, S. (2013). Methods for assessing overheating for future building regulation compliance. *Energy Policy,* (56), 684-692.

Jenkins, D. P., Singh, H., & Eames, P. C. (2009). Interventions for large-scale carbon emission reduction in future UK offices. *Energy and Buildings*, (41), 1374–1380.

Jenkins, K., Hall, J., Glenis, V., Kilsby, C., McCarthy, M., Goodess, C. & Birkin, M. (2014). Probabilistic spatial risk assessment of heat impacts and adaptations for London. *Climatic change*, (*124*), 105-117.

Jones, K., Desai, A. & Mulville, M. (2014). Employing backcasting principles for the formation of long term built asset management strategies – A theoretical approach. *Proceedings of CIB W70 – Using Facilities Management in an Open World Creating Value for all Stakeholders, 21-23rd May 2014, Copenhagen, Denmark.*

Kershaw, T., Eames, M. & Coley, D. (2011). Assessing the risk of climate change for buildings. A comparison between multi-year probabilistic reference year simulations. *Buildings and Environment,* (46), 1303-1308.

Menezes, A. C., Cripps, A., Bouchlaghem, D., & Buswell, R. (2012). Predicted vs. actual energy performance of non-domestic buildings: Using post-occupancy evaluation data to reduce the performance gap. *Applied Energy*, (97), 355–364.

Mulville, M., Jones, K. & Huebner, G. (2013). The Potential for Energy Reduction in UK Commercial Offices through Effective Management and Behaviour Change. *Journal of Architectural Engineering and Design Management*, (10), 79-90.

Murtagh, N., Nati, M., Hadley, W.R., Gatersleben, B., Gluhak, A., Ali Imran, M. & Uzzell, D. (2013). Individual energy use and feedback in an office setting: A field trial. *Energy Policy,* (62), 717-728.

Pinder, J. & Wilkinson, S.J. (2001). Measuring the Obsolescence of Office Property through User-Based Apprasial of Building Quality. In proceedings of CIB World Building Congress: Performance in Product and Practice 2nd - 6th April 2001, Wellington, New Zealand.

Roaf, S., Brotas, L., Nicol, F. (2015). Counting the cost of comfort. *Building R*esearch & Information, (43), 269-273.

Singh, A., M.S, Syal., Grady, S.C, Korkmaz, S (2010). Effects of Green Buildings on Employee Health and Productivity. *American Journal of Public Health*, DOI: http://dx.doi.org/10.2105/AJPH.2009.180687

Spengler, JD. & Chen, QY. (2009). Indoor Air Quality Factors in Designing a Healthy Building. Energy and the Environment, (25), 567-600.

Tetlow, R.M., Beaman, C.P., Elmualim, A.A & Couling, K. 2013. Targeting automatic behaviour to reduce small power electricity consumption in office buildings. *4th Annual TSBE EngD Conference Proceedings.* University of Reading.

Thomsen, A. & der Flier, K. (2011). Understanding Obsolescence: A conceptual model for buildings. *Building Research and Information*, (39), 4.

United Nations Environment Programme (2009). Buildings and Climate Change: Summary for Decision makers. UNEP, Paris.

World Green Building Council. (2014). Health, wellbeing and productivity; the next chapter for green building. *The World Green Building Council.*

Energy use and indoor environment in a sample of monitored domestic buildings in the UK

Dr Jia (Michelle) Cui
Nottingham Trent University, michelle.cui@ntu.ac.uk

Abstract

This paper is based on the low-cost approaches and transferable techniques that were applied in a PhD reserch project on energy-related occupancy activities. The strengths of qualitative and quantitative research strategies were combined for the study of this socio-technical research topic. Long-term field measurement was conducted for data acquisition using self-configured monitoring schemes. Case study was selected as the research approach. Building characteristics and household features in each case study group were purposefully selected to deploy same-standard monitoring schemes. Comparable monitoring results were pre-processed following identical procedures to implement the selected data analysis methods. The inspection results provided the researcher and the associated project partners with a novel perspective to interpret the difference in actual energy consumption and indoor environment within and between the case study groups. The research methodology and moitoring approach are covered in this paper that also presents the macro-scale monitoring results of energy use and indoor environment in two case study groups. The micro-scale presentation and algorithm-based examination will be covered in other academic papers. This paper demonstrates the huge potential for some commonly applied building assessment methods to be improved by objectively considering currently overlooked aspects, such as the low-tech design and construction of heavy-weight thermal mass houses and the largely varied occupancy activities. Future work reating to the comparision of actural monitoring data with simulation results is pointed out at the end of the paper.

Key Words: *energy use, indoor environment, occupancy activities, building characteristics, mixed methods research.*

1. INTRODUCTION

Global issues related to energy use are on the rise, ranging from climate change and energy security to fuel poverty. Targets to reduce the future atmospheric concentration of greenhouse gases, especially carbon dioxide (CO_2) emissions from fossil fuel, have been set and discussed worldwide in the Kyoto Protocol and the Stern Review (United Nations, 1998; Stern, 2007). The Climate Change Act (2008, c.27) is aiming for a reduction of the net UK carbon emissions by 80 per cent from the 1990 baseline by the year 2050. However, the costs of mitigation, especially against the backdrop of an economic downturn, make these targets difficult to achieve (House, et al., 2008). Energy saving in buildings is one of the most cost-effective sectors where CO_2 reductions can be achieved, due to the technologically simple measures that can improve energy efficiency of buildings (Ürge-Vorsatz and Metz, 2009). The effectiveness in improving efficiency gains and reducing environmental impact can be achieved on a larger scale beyond an individual study of domestic builidngs. This is mainly due to the large proportion of domestic energy use in the UK, where energy consumption in the domestic sector accounts for approximately 30 per cent of overall energy use according to the annually published energy consumption statistics of the Department of Energy & Climate Change (DECC) (2014b).

Buildings are usually graded using assessment systems such as Standard Assessment Procedure (SAP), Energy Performance Certificates (EPCs), Building Research Establishment Environmental Assessment Methodology (BREEAM), and Leadership in Energy and Environmental Design (LEED). Under the expectations of these assessment systems, houses that are graded as energy-efficient should outperform lower-graded and older ones. However, this is not the case when comparing the actual energy performance of respective buildings (Sommerville and Sorrell, 2007). One main reason for the discrepancy can be connected to the evidence that predicted performance of identically built homes does not match actual energy use (Emery and Kippenhan, 2006; Ingle, et al., 2014). Domestic energy use and indoor environment are determined by multiple non-technological factors, such as the occupants' lifestyle and activities, which can even offset the effect from energy-efficiency technologies (Sunikka-Blank and Galvin, 2012). To assess the impact of occupancy activities on actual efficiency gains can potentially provide the industry and academia with a 'twin-track approach', which involves both technology and occupancy behaviours in efficiency improvement (Gram-Hanssen, 2014). However, acquiring the actual occupancy data associated with energy use, indoor environments, building characteristics, and occupancy statuses in a uniform format to generate comparable and representative information is challenging (Energy Saving Trust, 2009; 2011). The low-cost approaches and transferable techniques that were applied in a PhD reserch project on energy-related occupancy activities are introduced in this paper.

2. METHODOLOGY

It is important to select appropriate methods, the methodological features of which can suit the socio-technical characteristics of the research subject and data profiles. Three interactive factors, including energy-related occupancy activities, fabric and service performance, and external environment, were considered in the selection of case studies.

- geographically vicinal building sites with similar external temperatures enables the comparison of performance difference from the perspective of the other two factors;
- The identical fabric and service performance of houses within the same case study group highlights the impact of different energy-related occupancy activities on actual energy use and indoor environment;
- The distinctive fabric and service features between the two case study groups enables a holistic assessment of energy-related occupancy activities based on different building characteristics.

The mixed methods research approach advocated by Bryman (2012), which combines quantitative and qualitative strengths, was applied in the process of data acquisition and analysis.

- The monitoring approach: for the purpose of acquiring physical measurements by applying the properly configured monitoring scheme in the selected case study homes;
- The sociological approach: for the purpose of enhancing the monitoring approach by using occupancy diaries with the assistance of formal and informal interviews;
- The mathematical approach: for the purpose of performing effective data pre-processing, presentation, and analysis by applying statistics and artificial intelligence methods.

3. TWO CASE STUDY GROUPS

3.1 Hockerton Housing Project (HHP) case study

The HHP case study consisted of three unconventionally built houses from the Hockerton Housing Project Trading Ltd. (HHP). The Hockerton Housing Project is among the first multi-dwelling, earth-sheltered, and self-sufficient ecological housing developments in the UK (HHP, 2011). Consisting of a terrace of five earth-sheltered and single-storey dwellings and an office annex, the self-built HHP community has been planned, designed, constructed and operated to be as 'autonomous[3]' as possible. Designed in the year 1994 by Prof. Brenda Vale and Dr. Robert Vale, the five dwellings were constructed in 1996 on a 25-hectare agricultural site outside the village of Hockerton in the northeast of rural Nottinghamshire. With no mains gas and central heating system on site, the buildings mainly rely on passive solar radiation, residents' body heat and incidental gains from electrical appliances for space heating from November to February. The thermally heavy design, which features high levels of thermal mass (2.3 tonnes of concrete and blocks per square metres) and insulation, keeps the indoor environment within a stable comfort zone.

However, the Energy Performance Certificate (EPC) produced in 2008 for one HHP house using the Reduced Standard Assessment Procedure (RdSAP) 2005 gave an energy efficiency rating at F. The assessment result mainly derived from shortcomings in the assessment approach that fails to acknowledge heavy-weight thermal mass and passive solar gain. Homes adopting similar design approaches to the HHP autonomous houses will be barred from 2016 and existing dwellings such as the low-cost and free-floating HHP houses cannot be let from 2018 or join in the feed-in tariff for solar PV microgeneration without installing unnecessary heating systems.

3.2 Nottingham City Homes (NCH) case study

In partnership with Nottingham City Homes (NCH), this case study was conducted as one part of an overarching Decent Homes programme, known in Nottingham as the Secure, Warm, Modern (SWM) programme. Since their construction around 1977, the two selected houses of NCHA and NCHB have been the homes of two retired couples. Both NCH houses were developed by Walter Llewellyn and Sons Ltd. in Eastbourne and retrofitted to same standard in the SWM programme. The Llewellyn system, also called Quikbild, was one of the 34 major types of system-built timber frame dwellings that were widely used in the public sector from 1965 to 1980 (Harrison, et al., 2004). Although having no sufficient thermal mass to store heat as is the case in the autonomous houses in the HHP case study, the energy efficiency of the NCH house was rated C in the EPC, which prioritises the retrofitted features in terms of insulation and boiler efficiency.

4. DATA ACQUİSİTİON

Mixed-method approaches were applied for the required data profiles. The physical measurements included energy use, real-time power draws, hygrothermal conditions, and occupancy statuses. Informal interviews and occupancy diaries were used in different monitoring stages to validate and explain the acquired physical data. Three adjacent HHP houses were selected as the monitoring subjects of this case study, including the seven-bay central house HHP3, the six-bay mid-terrace house HHP4, and the six-bay end-terrace house HHP5. The three households had different family profiles, including single occupant in HHP3, adult couple in HHP4, and young couple with two children in HHP5. From December 2010,

[3] Houses built to the autonomous standard are designed to be self-sufficient without the need for mains connection apart from grid-linked electricity (Vale and Vale, 2000).

the monitoring equipment was deployed in phases. The equipment, at an average cost around £1,350 per house, was officially moved out of the HHP houses in June 2013. The NCH case study started one month later than the HHP monitoring project, in January 2011, and officially ended in August 2012. The less numbers of occupancy status loggers used in the NCH homes lowered the monitoring system cost to around £900 per house.

The major criteria for the device selection and system configuration are:

- The selected devices should be non-intrusive or less-intrusive in terms of installation and maintenance;
- The selected devices should facilitate the improvised technological solutions that are required by the actual conditions in monitored homes;
- The configured system should feature low costs in terms of equipment procurement and post-installation maintenance;
- The configured system should feature transferable techniques that enable the straightforward application of the system in other similar monitoring environments.

A direct advantage of a non-intrusive or less-intrusive monitoring system is that the equipment has no or limited visible aesthetic impact on the monitored households. An indirect but crucial benefit is that the residents are expected to behave naturally under the monitoring circumstances. The actual behaviours revealed by the measuring results are thus insusceptible to the impact of psychological attention paid by the monitored house residents.

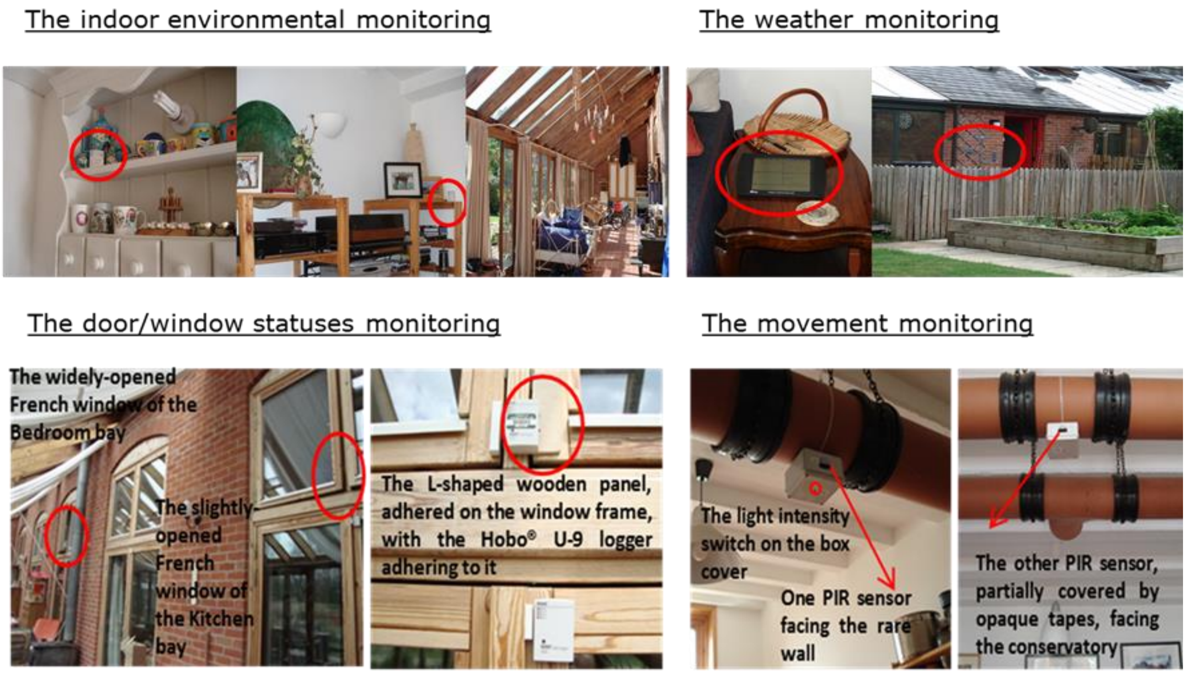


Figure 1 Monitoring devices for hygrothermal conditions and occupancy statuses in the HHP homes

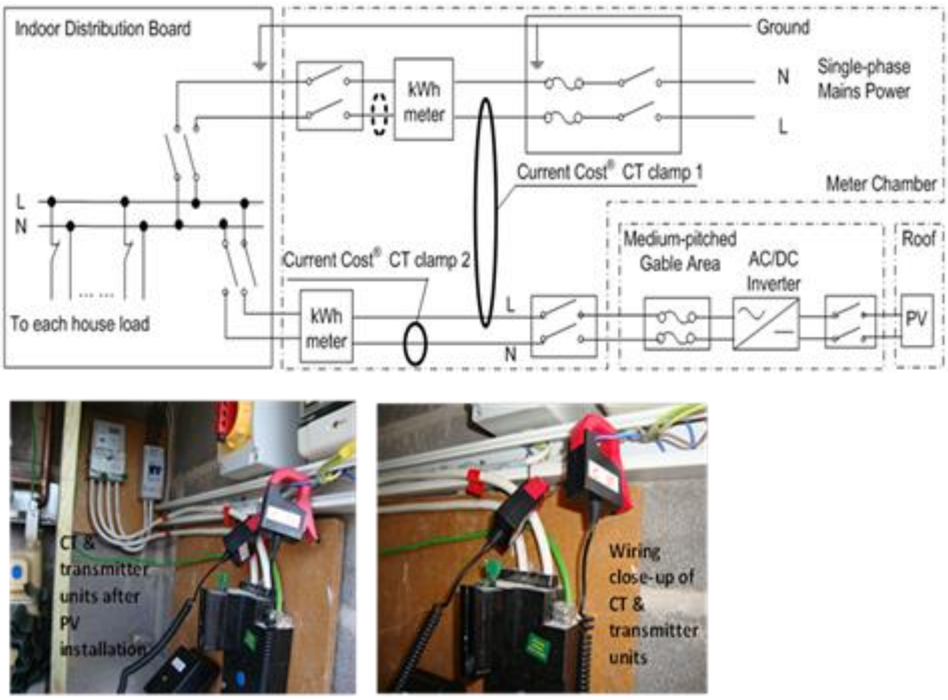


Figure 2 Improvised solution to remove the impact of PV retrofit on the power profile monitoring in one NCH house

Unable to detect current directions, the Current Cost® CT & transmitter unit in the original position as shown by the dash-line elliptical circle in Figure 2 could not correctly measure house use after PV installation in one NCH home. When more energy was used than being generated, what the CT unit monitored was the import power from the grid. When more energy was generated, what the CT unit detected was the export power to the grid. Depending on the actual conditions of house use and microgeneration, the real-time import and export power that could not be differentiated was found to distort power profiles of house use. The clamping of mains power cables and PV feed-in within one CT unit as shown in Figure 2 is an improvised solution that applies Ampère's circuital law of electromagnetic induction. The result from the overlapping induction is a magnetic field that removes the net export from total microgeneration. The current inducted by the CT unit is the separated portion that flows into the distribution board for house use. Therefore, the house use power profile at five-minute interval can be correctly measured without the influence of PV microgeneration.

5. DATA USE

The major difference in energy use within the HHP community was expected to arise from the respective household compositions, since every home adopted an energy-conscious lifestyle. In contrast, the NCH case study featured two similar family profiles of retired couples, who differed largely in their energy use habits. Homes having identical household profiles were expected to feature comparable ownership of domestic appliances and similar categories of energy-related activities. The difference in actual energy use was thus potentially due to the different intensity levels of energy-related occupancy activities in each NCH home. The acquired data profiles were pre-processed to facilitate appropriate approaches to data presentations and analyses by comprehensively examining the multi-category measurements of each case study. The visualisation-based examinations of measurements in each case study were conducted on different scales to reveal the impact of energy-related occupancy activities. The major data categories were separately examined prior to the comprehensive and micro-scale inspections conducted on measurements of exemplary days that featured special weather conditions and relatively complete data profiles for each case study. More systematic analyses based on visualisation-based examinations were conducted using two types of algorithm-based inspection methods of statistics and artificial intelligence. The box plots and mean comparison graphs generated by the ANOVA process were effective analysis approaches to enhance the visualisation-based examinations. The pre-processed power measurements were used to extract targeted end-use events from the measurements of total house use and major energy-intensive appliances and to examine interrelations between energy use occupancy activities in the monitored household. The Adaptive Neuro-Fuzzy Inference System (ANFIS) was selected as a methodological trial to extract targeted appliance use. These presentation and analysis examples will be covered in other academic papers. This workshop proceeding paper only presents the manual meter-readings of all case study homes over the period shown in Figure 3 and the long-term temperature measurements shown in Figure 4.

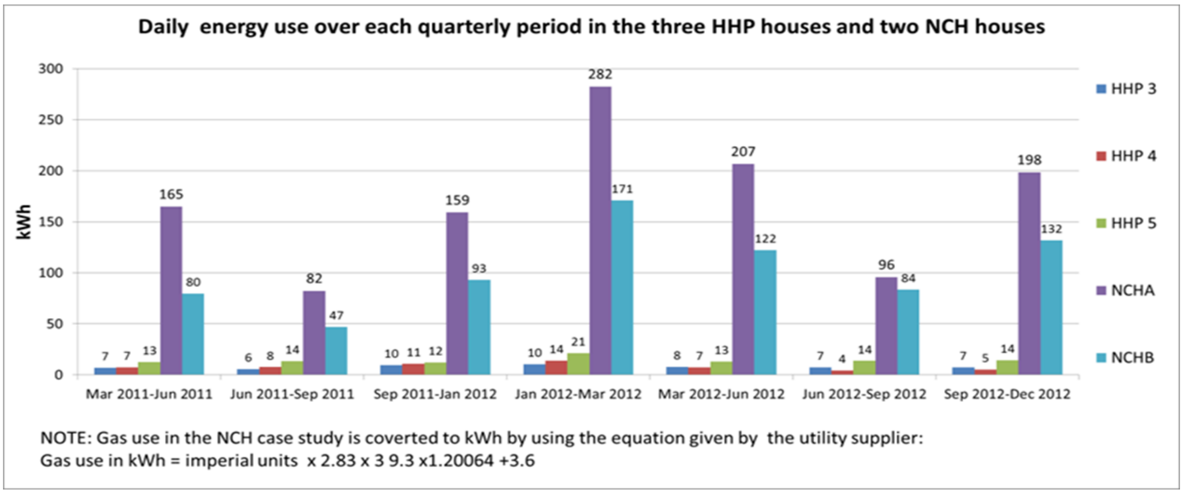
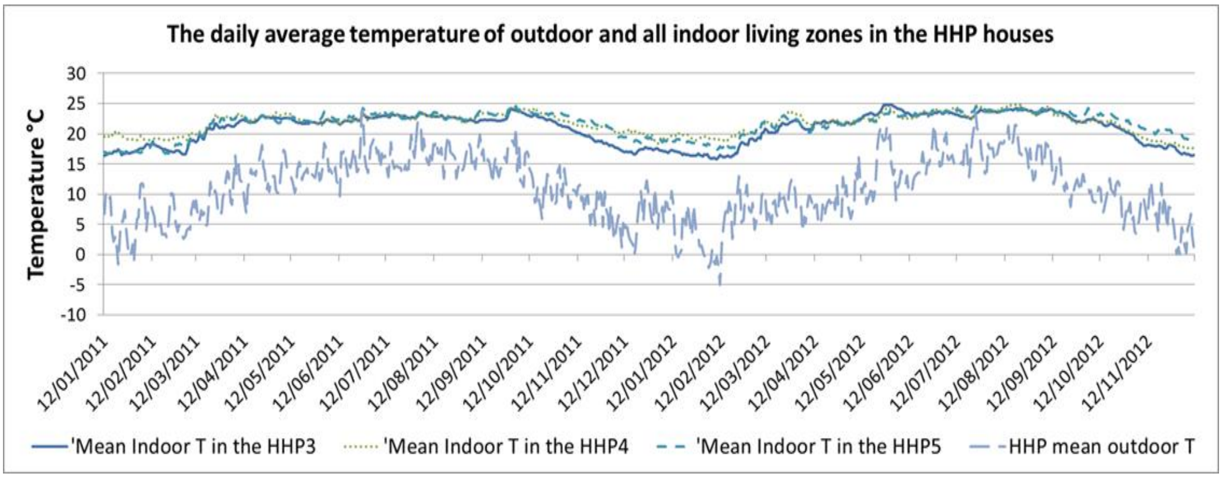


Figure 3 Daily energy use over the period of seven quarterly periods from March 2011 to December 2012 in the five houses of the two case studies

The distinctive difference in actual energy use within the NCH case study group was consistent with the temperature monitoring results shown in Figure 4. Although gas use was not directly measurable, the HDD regressions presented a difference in the baseline outdoor temperatures of the two NCH homes, 20 ºC for NCHA and 18 ºC for NCHB. The two degree difference in baseline temperatures reflected the longer period of space heating use and larger amount of gas use in NCHA. The different baseline temperatures in HHD regressions coincide with the one to four degrees of difference in the long-term indoor average temperatures of the two homes. With the assistance of the window status measurements, a micro-scale inspection and an algorithm-based examination of the data profiles of the two NCH homes were conducted. The application of these monitoring and analysis approaches was thus attested to be effective in investigating the actual difference in energy use and indoor environment from the perspective of energy-related occupancy activities. Regarding electricity use, the representative daily power profiles revealed the more frequent use of energy-intensive appliances, including tumble dryer, dishwasher, and washing machine with high temperature settings, in NCHA. This household used around twice the electricity consumed by NCHB. The information acquired from the formal and informal interviews during NCH site visits revealed that the NCHA residents preferred to heat the entire house continuously with the windows being frequently opened.



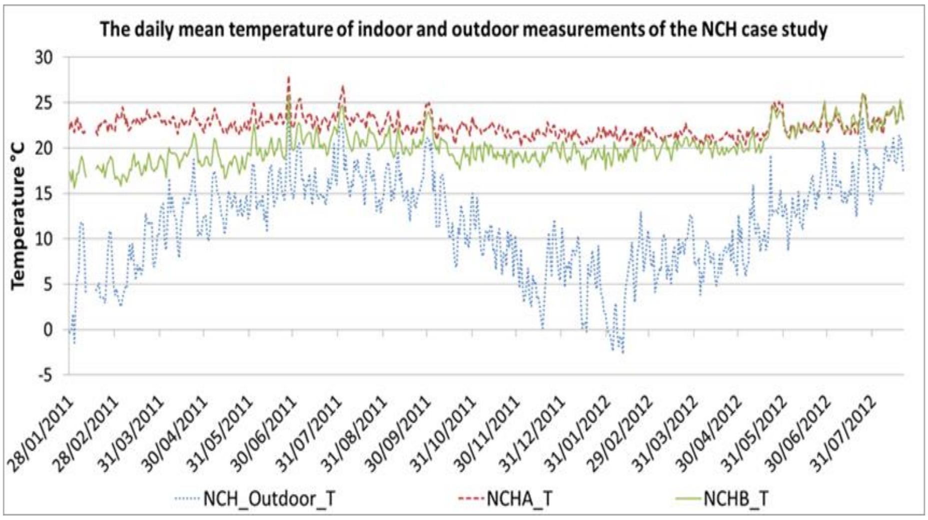


Figure 4 Monitored indoor / outdoor temperatures for the two case studies

In contrast, by removing the need for a space heating system in the autonomous HHP houses, electricity was the only energy resource in the HHP case study. The use of immersion water heaters accounted for 2.0 kWh to 8.0 kWh in the daily energy use of monitored houses, depending on the operational mode of the heater that was either timer-controlled or thermostat-operated. The supplementary heating using mobile heaters under cold weather conditions increased electricity use over winter time by about 4.0 to 16.0 kW in HHP3 and HHP4. The multi-occupancy of the household and frequent use of washing machine and dish washer made HHP5 use the highest amount of electricity among the three monitored HHP houses. The daily average of total energy use in HHP5 shown in Figure 9 was only nine per cent of that in the more energy-conscious NCHA and 17 per cent of that in NCHB.

The heavy-weight thermal mass construction in the autonomous houses functions as a 'rechargeable battery' that allows heat to be stored and released not only diurnally but inter-seasonally (HHP, 2012). The cross-comparison of the hygrothermal condition of all case study houses assisted in assessing the energy performance of the two distinctive built forms. The energy performance of the heavy-weight thermal mass construction in the HHP case study has been proven to outperform that of the retrofitted timber-frame house in the NCH case study against similar outdoor conditions. However, the energy-saving features of the autonomous house are not credited by the Energy Performance Certificate (EPC) that is produced on the basis of the Standard Assessment Procedure (SAP) and Reduced Standard Assessment Procedure (RdSAP). The ratings clearly do not truthfully reflect the de-facto energy use and environmental impact based on the empirical results obtained in this study. Active appeals for more objective assessment principles were raised by the Hockerton Housing Project, Ltd. (HHP, 2012). The evidential results from this research are expected to assist in their future appeal process.

6. CONCLUSION AND FUTURE WORK

Energy-saving effectiveness in the domestic sector cannot purely depend on the installation of new technologies and renewable energy microgeneration. In addition to building characteristics that play an important role in energy savings and carbon mitigations, energy-related occupancy activities also make a large difference to the actual energy performance of identically built or retrofitted houses. The long-term monitoring and selected analysis techniques introduced in this paper made knowledge contributions from practical and methodological perspectives. There is huge potential for some commonly applied building assessment methods to be improved by objectively considering currently overlooked aspects, such as the low-tech design and construction of free-running autonomous houses and the largely varied occupancy activities.

The socio-technical characteristics of the research subject require a mixed methods research approach in the processes of data acquisition and analysis, including physical monitoring techniques, supplementary sociological instruments, and multidisciplinary analytical methods. To rationally utilise the limited research resources, the selection of case study groups should consider the between-group and within-group differences and similarities in terms of building characteristics and household profiles. Within each case study group, the variations in indoor environment and energy use directly resulted from different activity patterns of each household. For example, the intensive energy use recorded in the NCHA case study house was approximately twice that of NCHB. Between the two case study groups, the variations also derived from the different building characteristics of house designs, such as the heavy-weight thermal mass featured by the autonomous HHP houses and the light-weight thermal mass represented by the retrofitted timber-frame NCH houses. The geometry build and dynamic building energy simulation for case study houses have been extended to the research stage after the PhD research to compare the simulation results and field monitoring data in the following academic papers.

REFERENCES

Bryman, A., 2012. *Social research methods*. 4th ed. Oxford: Oxford University Press.

Department of Energy & Climate Change (DECC), 2014b. *Energy consumption in the UK (ECUK): domestic data tables 2014 update*. [online] Available at: < https://www.gov.uk/government/publications/energy-consumption-in-the-uk> [Accessed 1 August 2014].

Emery, A. F. and Kippenhan, C. J. 2006, A long term study of residential home heating consumption and the effect of occupant behavior on homes in the pacific northwest constructed according to improved thermal standards. *Energy*, 31(5), pp.677-693.

Energy Saving Trust (EST), 2009. *Evaluating energy and carbon performance in the 'Retrofit for the Future' demonstrator projects*. [pdf] London: EST. Available at < http://www.energysavingtrust.org.uk/Publications2/Housing-professionals/Monitoring/EST-TSB-Retrofit-for-the-Future-monitoring-guidance-document > [Accessed 1 May 2014].

Energy Saving Trust (EST), 2011. *Monitoring energy and carbon performance in new homes (2008 edition).* [pdf] London: EST. Available at < http://www.energysavingtrust.org.uk/Publications2/Housing-professionals/Monitoring/Monitoring-energy-and-carbon-performance-in-new-homes-2008-edition > [Accessed 1 May 2014].

Gram-Hanssen, K., 2014. Retrofitting owner-occupied housing: remember the people. *Building Research and Information,* 42(4), pp.393-39.

Harrison, H. W., Mullin, S., Reeves, B. and Stevens, A., 2004. *Non-traditional houses: identifying non-traditional houses in the UK 1918-75. BRE 469.* Watford: BRE Bookshop.

Hockerton Housing Project (HHP), 2012. Response to the energy efficiency deployment office (EEDO) call for evidence. (s.l.):(s.n.).

House, J. I., Huntingford, C., Knorr, W., Cornell, S. E., Cox, P.M., Harris, G. R., Jones, C. D., Lowe, J. A. and Prentice, I. C., 2008. What do recent advances in quantifying climate and carbon cycle uncertainties mean for climate policy? *Environmental Research Letters*, 3(4), pp.1-6.

Ingle, A., Moezzi, M., Lutzenhiser, L. and Diamond, R., 2014. Better home energy audit modelling: incorporating inhabitant behaviours. *Building Research and Information,* 42(4), pp.409-421.

Sommerville, M. and Sorrell, S., 2007. *Technical report 1: Sapce heating energy efficiency program evaluation report (draft): evidence from evaluation studies.* [pdf] London: Energy Research Centre. Available at: < http://www.ukerc.ac.uk/support/ReboundEffect > [Accessed 2 March 2013].

Stern, N. H., 2007. *The economics of climate change: the Stern review*. Cambridge: Cambridge University Press.

Sunikka-Blank, M. and Galvin, R., 2012. Introducing the pre-bound effect: the gap between performance and actual energy consumption. *Building Research and Information*, 40(3), pp.260-273.

The Parliament of the United Kingdom, 2008, *Climate Change Act 2008* (chapter 27). [online] Available at: < http://www.legislation.gov.uk/ukpga/2008/27/contents> [Accessed 8 July 2011].

United Nations (UN), 1998. *Kyoto protocol to the United Nations framework convention on climate change* [online] Available at:< http://www.geminidataloggers.com/ > [Accessed 8 June 2010].

Ürge-Vorsatz, D., Novikova, A., Köppel, S. and Boza-Kiss, B., 2009b. Bottom-up assessment of potentials and costs of CO_2 emission mitigation in the buildings sector: insights into the missing elements. *Energy Efficiency*, 2(4), pp.293-316.

Vale, B. and Vale, R., 2000. *The new autonomous house: design and planning for sustainability*. London: Thames & Hudson Ltd.

Optimization of an Envelope Retrofit Strategy: Case Study for an Existing Office Building

Başak Güçyeter
Asst. Prof. Dr., Eskişehir Osmangazi University, Faculty of Engineering and Architecture, Department of Architecture, bgucyeter@ogu.edu.tr

Abstract

Energy efficient retrofit of existing buildings is recognized as an essential intervention in reducing the environmental impacts of the built environment. However, the decision-making process for effective retrofit strategies turns out to be vital when the aim is to achieve expected reductions for resource consumption, CO_2 emissions, and improvement of the indoor thermal environment. Furthermore, cost considerations are of key importance, since economics of energy efficiency improvements is one of the main impetuses for the contractors and property owners. In this research, the main objective is to evaluate and optimize envelope retrofit strategies through a calibrated simulation approach. In order to limit the performance gap, the study focuses on the energy performance audit and monitoring of an existing office building, thus founds its main emphasis on the relationship between the importance of actual measurement and the validity of simulation models. In addition, the study highlights the necessity to evaluate the performance levels for basic energy conservation measures (ECMs) proposed to achieve the expected performance improvements through retrofit interventions.

Key Words: *Retrofit, calibrated simulation, optimization, building envelope, energy conservation measures.*

1. INTRODUCTION

Technological and industrial growth of the last decades resulted in an increasing trend of fossil fuel consumption. Along with this increase, CO_2 emissions have risen drastically, causing significant levels of environmental degradation that may endanger the life of future generations (D'haeseleer, 2003; Juan, Gao and Wang, 2010). The need to reduce fossil fuel consumption and CO_2 emissions instigated research on energy performance of buildings due to implementation of possible energy conservation measures (Poel, Van Crutchen and Balaras, 2007; Kaklauskas, Zavadskas and Raslanas, 2005; Diakaki et al., 2010).

Around 40% of world energy is consumed in buildings, through services such as space heating, cooling and air handling, water heating, lighting, and utilities (IEA, 2010). Reducing consumption levels is important to reduce environmental impact of the built environment. International and national initiatives developed certain methodologies to determine energy performance of buildings and propose methodologies for performance improvement of new and existing buildings. Yet, the performance gap between predicted and actual performance of buildings is one of the most important issues in assessment and improvement of energy performance (Menezes, Cripps, Bouchlaghem and Buswell, 2012). Performance gap originates from methodological approaches such as the nature of calculations used in performance assessment (steady-state, dynamic) or over simplification of building behavior in simulation environments (De Wilde, 2014). This research, therefore, aims to conduct a detailed methodology on energy efficient retrofitting of an existing building envelope via the use of monitoring data, calibrated simulation and optimization approaches. A case building in the campus area of Izmir Institute of Technology, Turkey is monitored for a full year, including on site climate data, indoor temperature and humidity, energy consumption, efficiency of active systems and CO_2 emissions. The research aims to utilize a building energy simulation tool in order to replicate the base-case energy performance of the existing building and propose energy conservation measures (ECMs) targeting the improvement of the building envelope.

2. METHODOLOGY

Buildings are complex and unique systems, comprised of physical, functional, and environmental characteristics. This level of complexity necessitates a holistic approach in assessment and improvement of a building's performance (Kaklauskas, Zavadskas and Raslanas, 2005; Rey, 2002; Flourentzou and Roulet, 2002). Hence, decision-making for retrofit strategies is of vital importance, where investment costs are high and payback periods are long for such improvements (Huang, Niu and Chung, 2012). This research aims to establish a methodical approach for optimization of an energy-efficient retrofit strategy composed of different ECMs. In order to bridge the performance gap, a dynamic energy simulation approach is employed. Building audit and energy performance monitoring of an existing building is the first step in the methodology. In the second step, audit data is used to calibrate a base-case simulation model in order to represent the existing building's energy performance within the possible maximum accuracy. Third step covers suggestions for pre-assessed ECMs and retrofit strategies, and the strategies are examined through the calibrated base-case model. In the last step, a single retrofit strategy is optimized via sensitivity of ECMs on annual consumption levels and investment payback analysis (Figure 1).

2.1 Energy Performance Assessment: Audit and Monitoring

Through building audit, information on building characteristics such as location, orientation, environmental factors, envelope characteristics, installation systems, comfort ranges, and schedules and occupancy are collected (Caccavelli and Gugerli, 2002; CRES, 2000a; Butala and Novak, 1999). Case building is located in Izmir Institute of Technology campus area, and predominantly accommodates office functions. The building has a reinforced concrete structure with filled-in brick walls and has no insulation layers on the exterior envelope except the roof structure. Detailed information could be found in the previously published article of Güçyeter and Günaydın (2012).

Detailed and continuous measurements for indoor and outdoor parameters are crucial to obtain accurate results to assess indoor thermal profiles (Santamouris, 2005). Thus, the case building is monitored for a full year for indoor temperature and humidity values, electricity and fuel consumption, microclimate data, and CO_2 emissions. Table 1 presents measurement type, intervals, and equipment used throughout the building energy performance monitoring.

Monitoring data is analyzed through the percentage of hours outside comfort range analysis for heating, cooling, and free-running periods for 2520 occupancy hours in a year (CEN, 2007). Ratio of the hourly temperature averages to the total hours of occupancy is obtained. The results yield that spaces oriented north distinctly have larger ratios for hours below the comfort range (average 40–45%). North oriented spaces present poorer indoor temperature profiles during heating season due to the lack of thermal insulation in building envelope. In addition, data analysis pointed out that area of heat loss surfaces and the variation of materials in wall sections (especially reinforced concrete walls) affect the indoor temperature profiles as well. First floor spaces are largely affected by overheating during summer and the percentage of hours over comfort range is relatively high in comparison to the ground floor. Relatedly, spaces in the ground floor present lower indoor temperatures during heating season due to heat losses through the non-insulated concrete floor on ground.

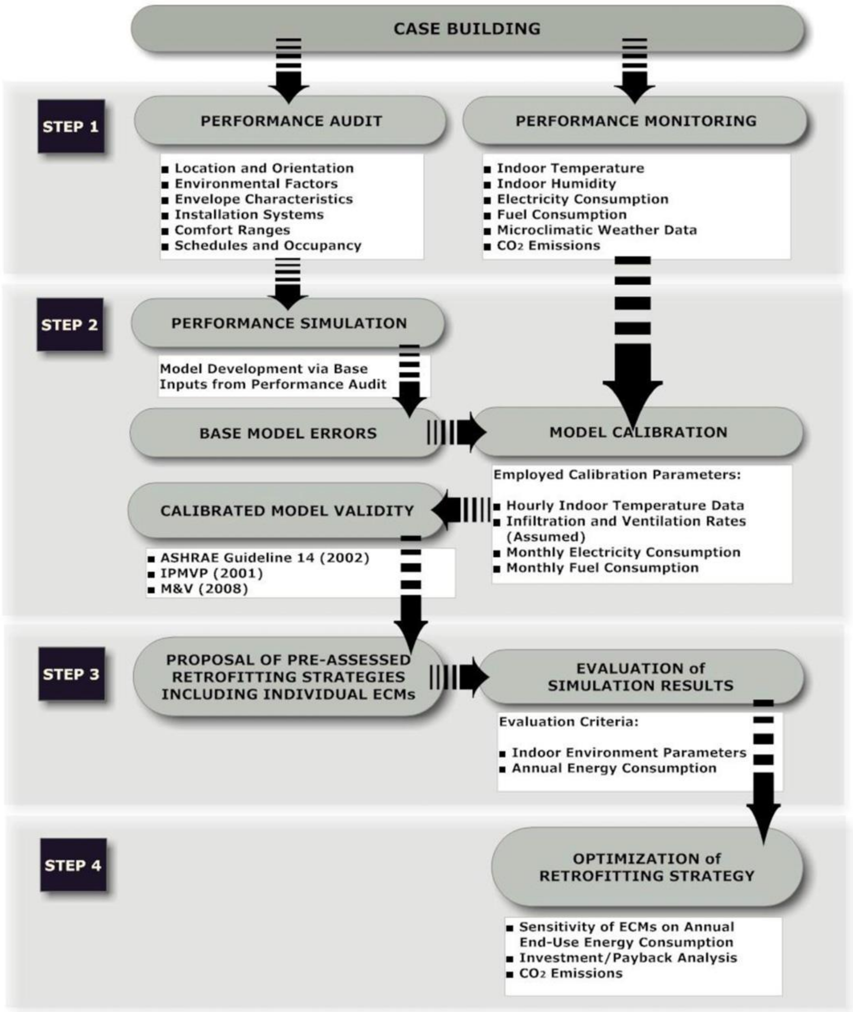


Figure 1. Steps in optimization of a retrofit strategy with performance monitoring and calibrated simulation approach.

Table 1. Monitored building energy performance parameters

Monitored building energy performance parameters	Measurement type	Measurement interval	Measurement equipment
Indoor temperature	Sequential/continuous	10 min	Data loggers
Indoor humidity	Sequential/continuous	10 min	Data loggers
Electricity consumption	Sequential/continuous	Daily	Power analyzer
Fuel consumption	Manual readings	Daily	Flow meter
Outdoor temperature (◦C) Outdoor relative humidity (%) Global horizontal solar radiation (W/m^2) Wind speed (m/s) Wind direction (◦) Cloudiness (0–1)	Sequential/continuous	10 min	Microclimatic weather station
CO_2 emission	Once		Combustion gas measurement

2.2 Energy Performance Simulation: Modeling and Calibration

Energy performance of an existing building could be assessed by different tools, yet a certain deviation is expected in predictions as energy performance is a complex physical process based on building characteristics (envelope, orientation, etc.), environmental effects (climate, shading, etc.), and occupancy patterns. Thus, it is possible to argue that assessment methods predict the actual state with a deviation, since it is challenging to repeat the real context, which is composed of diverse factors (Pan, Huang, Wu and Chen, 2006). In this research, base-case model is simulated for a full year using EDSL Tas software (EDSL, 2010). A multi-zone simulation model is developed, in order to make comparisons between measured and simulated data. Results of the preliminary run are obtained and the initial comparison on the accuracy of the base-case model pointed out a large deviation from the monitoring data. Simulation results that deviate within an acceptable error margin typically originate from the calculation methodology, algorithm in handling extensive parameter sets or factors that are assumed. Yet, the preliminary run of the base-case simulation model presents discrepancies up to 25–30%, which are unacceptable in predicting effects of ECMs (Clarke, Strachan and Pernot, 1993).

To bridge such a gap in energy performance assessment, the base-case model is calibrated with the following approach: (a) adjustment of assumed parameters (occupancy, equipment gains, infiltration and ventilation rates), (b) examination of hourly simulation results, according to their level of accuracy for indoor space temperatures and relative humidity levels, (c) comparison of simulated energy consumption and demands with monitored monthly data, (d) re-adjustment of the calibration parameters in the first step according to the analyses conducted in steps two and three, to achieve predicted results reasonably close to the monitored data (IPMVP, 2001; M&V, 2008).

Calibrated base-case model is obtained in 13 runs via the above steps. Two approaches are employed in testing acceptable error margins for the final model. First is a linear correlation analysis based on hour-to-hour correspondence of simulated and measured temperatures for a full year (Figure 2). Second approach is an error analysis that intends to check the deviation of simulated temperatures from the monitoring data with root mean square error (RMSE) and mean bias error (MBE) (Table 2). The results help to assert that the model presents accuracy in predicting heating and cooling energy consumption within benchmark margins. Further outcomes that compare monthly energy consumption values are specified in Güçyeter and Günaydın (2012).

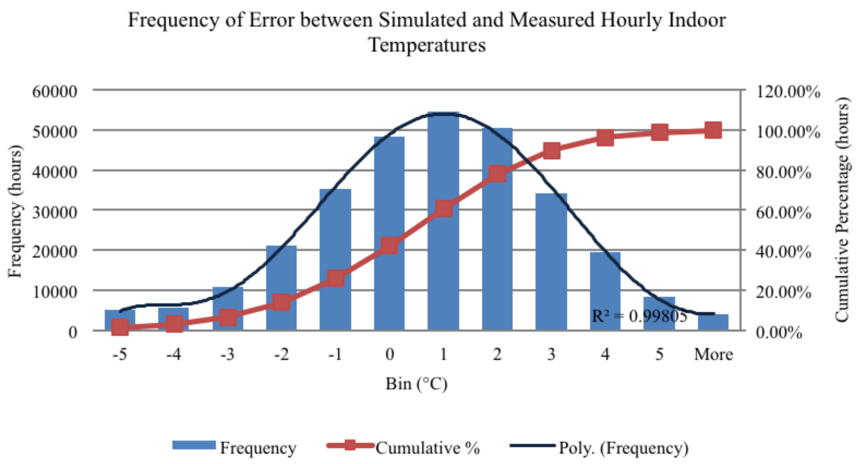


Figure 2. Steps in optimization of a retrofit strategy with performance monitoring and calibrated simulation approach

Table 2. Acceptable values for simulation calibration

Calibration Benchmarks						
Calibration Type	Acceptable Value*					
	ASHRAE (2002)		IPMVP (2001)		M&V (2008)	
	MBE	RMSE	MBE	RMSE	MBE	RMSE
Hourly	±10%	30%	-	10-20%	±10%	30%
Monthly	±5%	15%	±20%	-	±5%	15%
* Lower values indicate better calibration (M&V, 2008)						

Case Building Hourly Calibration with Indoor Environment Parameters	Indoor Temperature	Heating Energy Consumption	Cooling Energy Consumption
MBE	1,38%	7,78%	-9,00%
RMSE	9,78%	11,24%	13,67%

2.3 Retrofit: Simulation for ECMs Evaluation

In this research, several ECMs for envelope retrofit are proposed according to pre-defined qualitative and quantitative criteria, which include insulation of opaque elements, improvement of windowpanes, reduction of infiltration rate, and use of mass or ventilated walls etc. The main objective is to define a set of coherent interventions on the envelope with adequate levels of retrofit measures. Strategies initiate a minor level and integrate or replace one/two ECMs in defining the next level of intervention. Via this approach, three different levels of interventions are defined. Consequently, retrofit strategies are simulated through the calibrated model, by integrating ECMs to the existing envelope. Results are evaluated according to the frequency of hours outside comfort range and annual energy consumption for heating and cooling. Figure 3 presents an example for the frequency analysis obtained from the simulation of ECMs. Major indication is high percentage of hours over 26°C for west oriented spaces, with a value of 32.00%. This value decreases to 21.42% due to the improvement by low-e glazing replacement inherent to strategy S1. Undoubtedly, S2 and S3 maintain similar levels of improvement due to the presence of this ECM. Further analysis into simulation results of the strategies could be found in Güçyeter and Günaydın (2012).

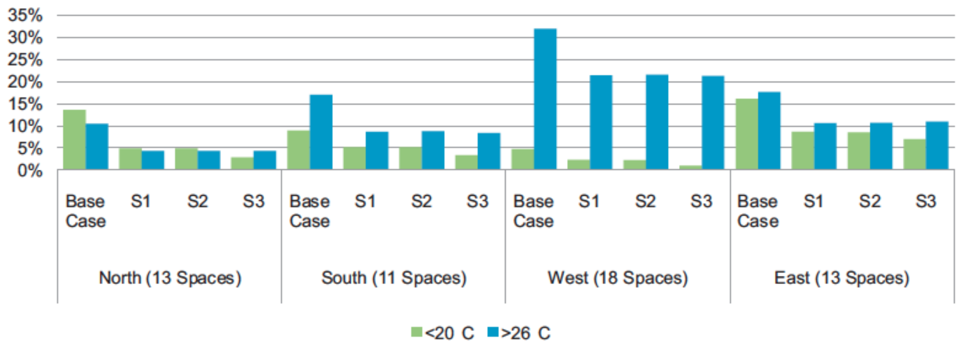


Figure 3. Frequency of hours outside comfort range for heating and cooling season

2.4 Optimization: Final Retrofit Strategy

Pre-assessed retrofit strategies may not be the most pertinent combination of measures. ECMs proposed for retrofit may not result with the expected level of efficiency or may require high investment costs, which may not be compensated in a short payback period. In this study, a similar result is obtained: three strategies yield close results and ambiguity in decision-making is evident; since indoor parameters and more efficient consumption levels are obtained for each strategy, the results of two scenarios were merely close (S1 and S2) and the third scenario S3 is distinguished due to the improvements proposed for the floor on ground. Thus, the need to use an optimization approach, regarding both efficiency levels and return on investment, is apparent. In order to acquire an optimized retrofit strategy, initially, the effects of ECMs on annual energy consumption for space heating and cooling are investigated. Decrease in annual energy consumption is normalized with the error margins (MBEs) determined in Section 2.2, with a purpose to obtain more realistic results for return on investment analysis (Figure 4). Later, an investment/payback analysis for each ECM is conducted (Table 3).

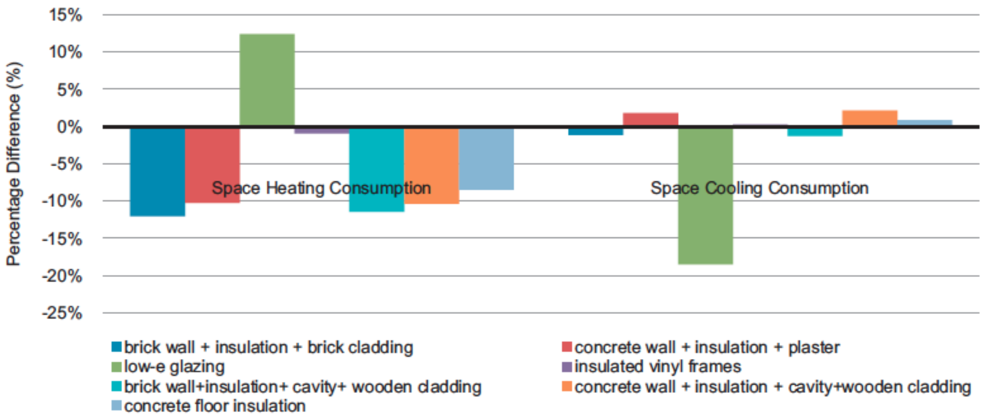


Figure 4. Effects of ECMs on annual energy consumption

Table 3. Payback periods obtained by NPV analysis for individual measures

Individual Measure	Investment Cost (TL)	Annual Saving (TL)		Total Annual Saving (TL)	Payback Period by NPV (years)
		Fuel	Electricity		
Brick wall + insulation + brick cladding	43333	2282	184	2465	9,05
Concrete wall + insulation + plaster	23371	1943	-288	1655	7,75
Low-e glazing	33580	-2355	2941	586	-
Insulated vinyl frames	12000	180	-45	135	13,04
Brick wall + insulation + cavity + wooden cladding	45128	2167	199	2366	9,34
Concrete wall + insulation + cavity + wooden cladding	46215	1974	-346	1628	9,81
Concrete floor insulation	84241	1610	-142	1468	12,25

Consequently, regarding the effects of ECMs on annual energy consumption and investment/payback analysis results, an optimized strategy is defined with the following criteria: (1) provide shorter payback period, (2) provide larger decrease in annual energy consumption, (3) provide better performing indoor environment.

Optimized retrofit strategy includes the envelope retrofit with brick wall + insulation + brick cladding as of shorter payback period, larger decrease in annual energy consumption, and better performing indoor environment. For reinforced concrete walls, concrete wall + insulation + plaster improvement is integrated into the strategy regarding shorter payback period, good level of decrease in annual energy consumption and less increase on cooling energy consumption. Low-e glazing is incorporated as a measure in the optimized strategy, since it offers high levels of decrease in cooling loads. Insulated vinyl frames is integrated in the strategy as well due to its low investment costs and effectiveness in detailing facade components (opaque wall and glazing improvements) as a whole (Verbeeck and Hens 2005).

3. RESULTS AND DISCUSSION

Optimized retrofit strategy is simulated through the calibrated simulation model, with a purpose to demonstrate its effects on reductions in annual energy consumption and CO_2 emissions, improvement in indoor environment parameters, and determination of payback period of retrofit investment. According to final simulation results, annual energy consumption for space heating and cooling decreases by 12.32% and 19.42%, respectively, due to the application of optimized retrofit strategy. In addition, annual reduction in CO_2 emissions of the building is assessed as 19.27%, in comparison to the base-case (Figure 5). Good levels of improvement for indoor temperature profiles were also observed between the simulation results of the optimized strategy and the base case model (Güçyeter and Günaydın, 2012).

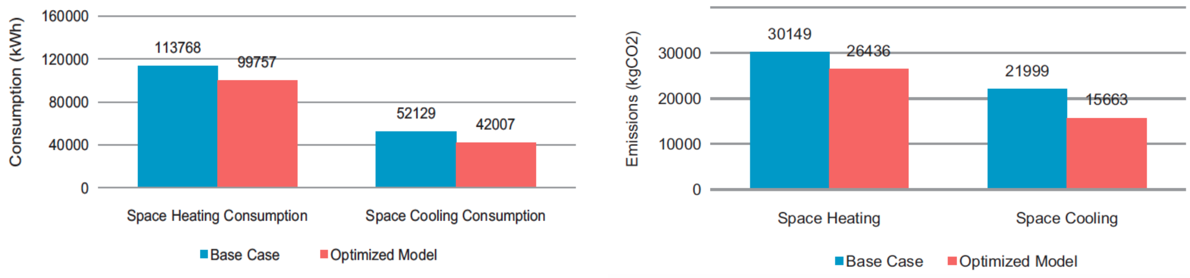


Figure 5. Annual energy consumption and CO_2 emissions for base-case and optimized model

According to the net present value (NPV) evaluation of investment and savings, payback period for the investment is determined as 11.5 years. Usually, energy-efficiency improvements for the building envelope are costly and payback periods for holistic improvements are long. However, long payback periods and high investment cost are acceptable when compared to energy savings, improvement in indoor environment, reduction of CO2 emissions, etc. (CRES, 2000b). In this study, the retrofit measures are assumed to have a lifecycle of 25 - 30 years (Rey, 2002), where the building is expected to have a minimum of 50 years service life. Thus, it is possible to assert that payback period result for optimized retrofit strategy is promising and have close results to parallel studies (Dascalaki and Santamouris, 2002; Hestnes and Kofoed, 2002; Al-Ragom, 2003).

4. CONCLUSIONS AND RECOMMENDATIONS

This research emerged due to the lack of dynamic calculation approaches in building energy performance assessments and evaluation of envelope retrofit strategies within the current Turkish regulations. The necessity to define a systematic approach for energy-efficient retrofit of existing building envelopes, where a large portion of the building stock is non-insulated, led this research to explore the use of energy performance monitoring and calibrated dynamic simulation approach in defining energy-efficient envelope retrofit measures.

The main findings of this study demonstrate that assessment of the energy performance of an existing building is important in terms of evaluating the effects of ECMs on annual energy consumption. A detailed field study aiming to obtain extensive data on building energy performance analysis is essential. Whole year monitoring facilitates further accuracy in interpreting existing energy performance and evaluating proposed ECMs. Furthermore, monitoring data is beneficial in terms of calibrating the simulation model to increase the accuracy levels. Since energy-efficient retrofit strategies aim to decrease energy consumption, improve indoor thermal environment, and reduce CO_2 emissions of an existing building, it is possible to propose a number of ECMs for improvement of a particular envelope component. However, the ECMs might provide close results for decreasing the energy consumption. In this framework, it is fundamental to discern the most feasible strategy through evaluations such as annual reduction in consumption profiles, reduction in CO_2 emissions, improvement in indoor thermal profiles, and investment/payback analysis.

The scope of this research does include shortcomings, since it solely deals with energy-efficient improvement of the building envelope. Other energy consumption end-uses in a building, such as artificial lighting, mechanical ventilation, heating and cooling installations might be subject to retrofit to enhance the efficiency obtained. In particular, implementing building integrated renewable energy technologies in existing buildings is a subject for further research. With all these aspects integrated, a more holistic perspective could be evaluated through the use of calibrated simulation approach.

ACKNOWLEDGEMENTS

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5. REFERENCES

Al-Ragom, F. (2003). Retrofitting residential buildings in hot and arid climates. *Energy Conversion and Management*, 44, 2309–2319.

Butala, V. and Novak, P. (1999). Energy consumption and potential energy savings in old school buildings. *Energy and Buildings*, 29, 241–246.

Caccavelli, D. and Gugerli, H. (2002). TOBUS—a European diagnosis and decision-making tool for office building upgrading. *Energy and Buildings*, 34, 113–119.

CEN. (2007). European standard EN 15251. *Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings Addressing Indoor Air Quality, Thermal Environment, Lighting and Acoustics.*

Clarke, J.A., Strachan, P., Pernot, C. (1993). An approach to the calibration of building energy simulation models, *ASHRAE Transactions,* 99(2). 917–927.

CRES. (2000a). Energy Audit Guide Part A: Methodology and Technics. *Centre for Renewable Energy Sources*, Athens.

CRES. (2000b).Energy Audit Guide Part B: System Retrofits for Energy Efficiency, Centre for Renewable Energy Sources, Athens, 2000.

D’haeseleer, W.D. (2003) The overall energy issue, in: J. Carmeliet, H. Hens, G. Vermeir (Eds.), Research in Building Physics, A.A. Balkema Publishers, Lisse, pp. 3–10.

Dascalaki, E. and Santamouris, M. (2002). On the potential of retrofitting scenarios for offices. *Building and Environment*, 37, 557–567.

De Wilde, P. (2014). The gap between predicted and measured energy performance of buildings: A framework for investigation. *Automation in Construction*, 41, 40–49.

Diakaki C., et al. (2010). A multi-objective decision model for the improvement of energy efficiency in buildings. *Energy*, 35, 5483–5496.

EDSL. (2010). EDSL Tas - Environmental Design Solutions Limited Thermal Analysis Software [online], http://www.edsl.net/main/ (accessed 2010).

Flourentzou, F. and Roulet, C.A. (2002). Elaboration of retrofit scenarios. *Energy and Buildings,* 34, 185–192.

Güçyeter, B. and Günaydın, H.M. (2012). Optimization of an envelope retrofit strategy for an existing office building. *Energy and Buildings*, 55, 647–659.

Hestnes, A.G. and Kofoed, N.U. (2002). Effective retrofitting scenarios for energy efficiency and comfort: results of the design and evaluation activities within the OFFICE project. *Building and Environment*, 37, 569–574.

Huang, Y., Niu, J. and Chung T. (2012). Energy and carbon emission payback analysis for energy efficient retrofitting in buildings—Overhang shading option. *Energy and Buildings,* 44, 94–103.

IEA, (2010). IEA Policy Pathway: Energy Performance Certification of Buildings, Paris.

IPMVP. (2001). International Performance Measurement & Verification Protocol—Concepts and Options for Determining Energy and Water Savings, Volume I, Oak Ridge.

Juan, Y., Gao P. and Wang, J. (2010). A hybrid decision support system for sustainable office building renovation and energy performance improvement. *Energy and Buildings*, 42, 290–297.

Kaklauskas, A., Zavadskas, E.K. and Raslanas, S. (2005). Multivariant design and multiple criteria analysis of building refurbishments. *Energy and Buildings,* 37, 361–372.

M&V. (2008). Measurement and Verification for Federal Energy Projects Version 3.0.

Menezes, A.C., Cripps, A., Bouchlaghem, D. and Buswell R. (2012). Predicted vs. actual energy performance of non-domestic buildings: Using post-occupancy evaluation data to reduce the performance gap. *Applied Energy*, 97, 355–364.

Pan, Y., Huang, Z., Wu, G. and Chen, C. (2006). The application of building energy simulation and calibration in two high-rise commercial buildings in Shanghai, *in: Proceedings of SimBuild 2006*, Cambridge, MA.

Poel, B., Van Crutchen, G. and Balaras C.A. (2007). Energy performance assessment of existing dwellings. *Energy and Buildings,* 39, 393–403.

Rey, E. (2002). Office building retrofitting strategies: multicriteria approach of an architectural and technical issue. *Energy and Buildings*, 36, 367–372.

Santamouris, M. (2005). Energy Performance of Residential Buildings: A Practical Guide or Energy Rating and Efficiency, Earthscan, London.

Verbeeck, G. and Hens, H. (2005). Energy savings in retrofitted dwellings: economically viable? *Energy and Buildings*, 37, 747–754.

Optimizing thermal performance of high-rise office buildings in mediterranean climate by taking passive house approach

Neslihan Korkmaz, Mark Mulville, Begum Sertyesilisik

Abstract

As the built environment constitutes a big portion of global energy consumption, increasing building energy performance gains importance in the fight against climate change. 40% of total energy consumed and 30% of global annual green house gas emissions are caused by the built environment (SUN, 2009). Office buildings in Europe consume 26% of the total energy usage among non-residential buildings (Buildings Performance Institute Europe, 2011). Istanbul is a megacity which develops very quickly. Office stock area in Istanbul is approximately 3 million m^2, and it is expected to be 6.5 million m^2 within the next 3 years (Karaman, 2014). As there is a rising trend towards highrise office buildings, there is need for enhancing their energy efficiency. For this reason, this paper aims to contribute to the energy efficient highrise office building design for the optimization of thermal performance of highrise office buildings inIstanbul. With this aim, following the literature review, three different models have been created in Ecotect such as notional building model providing information on current performance, Passive House construction model showing how the Passive House principles work under Istanbul's conditions and optimized building model showing how much progress could be made compared to the first model. The findings revealed that achieving Passive House's targets requires more than application of regular Passive House principles for office buildings inIstanbul.

Key Words: *Istanbul, high rise office buildings, thermal performance, Passive House, ecotect*

1. INTRODUCTION

Energy consumption of high-rise office buildings is an important issue in many countries. In USA 18%, in UK 11% and in Spain 8% of non-residential energy consumption is caused by commercial buildings (Pérez-Lombard et al., 2008). Majority of this consumption is caused by megacities which carry most of the high-rise office building stock. As being the most crowded city in Turkey, Istanbul is also one of the megacities. In the world, the trend of constructing high-rise buildings increased resulting in the changes of the in Istanbul's silhouette. Therefore, energy performance of high-rise buildings gained importance. In this study, energy performance is examined from thermal aspects point of view as in office buildings, high levels of comfort and well being is essential to keep employees more productive. In office buildings where thermal comfort is not achieved, health complaints (e.g. burning eyes, headache, blocked nose, coughing and dry throat) appear (Hens, 2008). As thermal comfort is one of the most essential factors to be considered and optimized, Passive House (PH) Standard can be a useful tool as it covers issues such as heating/cooling loads, primary energy and air tightness targets. Despite of the fact that it has been developed for Northern European climate conditions, studies are carried out to adapt it to warmer climate conditions. This paper concentrates on the energy efficient high-rise office building design for the optimization of thermal performance of high-rise office buildings in Istanbul with the help of the PH standards.

2. RESEARCH METHOD

This study aims to contribute to the energy efficient high-rise office building design for the optimization of thermal performance of high-rise office buildings in Istanbul. Considering the fact that thermal performance is the main issue in this study and PH standards are mainly focused on thermal aspects, PH is found to be a preferable option. Only problem that PH Standard had in terms of suitability was the lack of office buildings applications. To date there is only one PH certified high-rise office building which is in Vienna (Lang Consulting, n.d.). This study, however, may be helpful for understanding the challenges in future PH office building constructions in Istanbul. Based on the literature survey, this paper provides information on the PH principles and their potential application in warm climates, PH standards for high-rise buildings, glazing technologies and building energy consumption.

3. LITERATURE REVIEW

PH principles and their potential application in warm climates, PH standards for high-rise buildings, glazing technologies and building energy consumption topics have been analysed in this section.

3.1 Passive House Principles and Their Applications In Warmer Climates

PH can be defined as *"… a standard and a scientific design tool that achieves exceptionally comfortable and healty living and working conditions combined with low energy demand and minimum carbon emissions."* (Bere, 2013). Principles and methods used to achieve PH Standards can enable up to 90% energy saving (PH Institute, n.d.) especially due to passive principles (i.e building shape and fabric) covered in the standards. As PH standards have been developed especially for cool climate conditions of the Northern Europe, there are currently studies (e.g. Passive-on project) focusing on the adaptability of the PH standards to warm climate. As Passive House mostly depends on building physics, adaptability principles can be mainly explained as protecting the building from unwanted impact of solar heating and benefiting from the natural ventilation as much as possible.

3.2 Comparison of Glazing Technologies Considering Istanbul's Climate Conditions

World's first fully glazed high-rise office building having PH certification has been built in Vienna and it has 80% less heating and cooling demand compared to traditionally built high-rise buildings (Lang Consulting, n.d.). Considering the amount of heat loss and solar gain caused by the windows, heat balance in a fully glazed building seems to be difficult. Quality of the glass is however more important than the amount of glass used in a building (Benzing as quoted from Pearson, 2013). For this reason, glazing components play an important role in the PH implementations on high-rise buildings due to amount of glazing area. As heat gains in summer season and heat losses in winter season needs to be minimised to achieve thermally well performing buildings. Glazing options that has been considered are solar control glazing, coated and low-e glazing, triple glazing, double glazing and vacuum glazing.

- Solar Control Glazing

Solar control glazing (SCG) technology is developed to radiate and reflect away a large amount of the heat that comes from the sun while letting the sunlight pass through the façade or the window (Pilkington, 2014). In warm climate conditions, SCG helps to reduce internal heat gains by reflecting solar radiation whereas in cold climate, it equalises the solar heat gain with natural light.

- Coated and Low-e Glazing

Coatings on glass are used to minimise solar gain within a building by increasing reflection and absorption, or augmenting the thermal insulation by reducing the surface emissivity (Alderson, 2006). Coated glass, low-e coated glazing can be designed for lowering or increasing the heat gain by different light transmission level adjustments.

- Triple Glazing

Triple glazing is the most common window application in PH as it minimises heat losses in Northern Europe. On the other hand, in mild climate conditions, minimisation of the heat losses is not enough due to the need for cooling and sun protection, having lower g-value is essential (Passipedia, n.d.).

- Double Glazing

Double glazing system tend to be preferred to triple glazing due to its cost level and better energy ratings achieved with additional low-e units, argon gas fillings and insulated spacers compared to conventional triple glazed windows (Enerinfo, n.d.). If plain double glazed windows are not sufficient due to relatively high u-value and lack of reflectance properties, building will experience overheating problems due to solar heat gain in the summer and heat loss problems in the winter.

- Vacuum Glazing

Vacuum glazing systems contain two parallel glass sheets which are separated by an array of support pillars under the impact of atmospheric pressure and a sealed vacuum gap which minimizes the air heat conduction and convection across the glazing (Fang. et al., 2014).
Usage of vacuum glazing system may not affect the heat gains caused by solar radiation. In a fully glazed building, amount of solar heat gain is a big factor in cooling load increase. Therefore using vacuum glazing technology only is not a preferable option.
This information on glazing information provides a general idea of a glazing option that can be used during optimisation section but more detailed calculation based on their performance difference is essential for choosing between the technologies.

3.3 Building Energy Consumption in Turkey and Determination of Similar Climate Areas

35% of total energy consumption in Turkey is caused by buildings and it is possible to save 30% - 40% of this energy based on latest studies (Soner, 2012). Commercial buildings present only a minority when it comes to total energy consumption in Turkey. As Turkey is a developing country, commercial buildings are expected to increase in number resulting in the need for keeping up with sustainability agendas and recognizing current performance conditions and future targets. As for thermal performance of commercial buildings, related legislation is tied to the Turkish Standard 825 entitled as "Thermal Insulation Requirements for Buildings". However it is too early to benchmark thermal performance of buildings in Istanbul because these standards and regulations have been recently set. Therefore already benchmarked performance information of an area with a similar climate has been researched. For finding an area with matching climate conditions, World Map of Köppen - Geiger Climate Classification is used. It has been found that, California and Istanbul have similar climate conditions which are classified as Csa. Csa stands for a climate that is warm temperate, steppe and has a hot summer (Institute of Veterinary Public Health, 2011). Therefore, to find supporting information based on thermal performance of high-rise buildings that are located in areas with similar climates, academic studies are searched as "High-rise Office Buildings in California".

4. DISCUSSION & CONCLUSION

This research aimed at optimizing the thermal performance of high-rise office buildings in Mediterranean Climates by taking Passive House approach. Findings of literature review section show that despite the fact that PH standard is appropriate for Northern European climate conditions, studies have been made for adapting the standard for Istanbul's climate. Based on building physics principles, with the help of appropriate applications, targets of PH standards can be also achievable in mild climates. Glazing technology has a big role in building's thermal performance. Especially if the glazing amount of a high-rise office building is considered, amount of solar heat gain and heat loss through the fabric makes this situation a very important issue. In a climate such as Istanbul's, and in a situation that involves office building, internal loads such as equipment and metabolic are very important. Minimization of cooling loads must be a priority when it comes to optimising thermal performance. Usage of solar control, tinted or low-e glass technologies affect the cooling loads dramatically.

REFERENCES

'A Review on Buildings Energy Consumption Information', 2008, *Energy and Buildings,*40, pp. 394-398 [Online]. Available at: *http://www.esi2.us.es/~jfc/Descargas/ARTICULOS/PAPER_LPL_1_OFF-PRINT.pdf* (Accessed: 22nd April 2015).

Ann Alderson (2006) *Specifiers' Handbooks for Inclusive Design Glass in Buildings*, London: RIBA Publishing

Arthur D. Little Inc (2002) *Cooling, Heating, and Power (CHP) for Commercial Buildings Benefits Analysis*, U.S: U.S Department of Energy

Banasch, R. (2006) *The Pilkington Solar Control Product Range: Case Studies,*Available at: *http://www.pilkington.com/resources/glassinbuildinguk.pdf* (Accessed: 26th August 2014).

Bere, J. (2013) *An Introduction to Passive House*, London: RIBA Publishing

BRE (2011) *Passivhaus: Outline Specification,* Available at: *http://www.passivhaus.org.uk/standard.jsp?id=18* (Accessed: 9th September 2014)

Buildings Performance Institute Europ (2011) *Europe's buildings under the microscope: A country-by-country review of the energy performance of buildings.* [Online]. Available at:*http://www.institutebe.com/InstituteBE/media/Library/Resources/Existing%20Building%20Retrofits/Europes-Buildings-Under-the-Microscope-BPIE.pdf* (Accessed: 22nd April 2015).

Candace Pearson (2013) '20-Story Building Takes Passive House to New Heights',*Building Green,* 3 September

Cho, J., Yoo, C., Kim, Y. (2014) 'Viability of Exterior Shading Devices for High-rise Residential Buildings: Case Study for Cooling Energy Saving and Economic Feasibility Analysis', *Energy and Buildings,* 82, pp. 771-785

CIBSE (2009) *Guide A*, CIBSE Publications: Norwich

Cotterell, J., Dadeby, A. (2012) *The Passivhaus Handbook*, Cambridge: Green Books
Enerinfo (n.d.) *Selecting Energy-Efficient Windows*, : Enerinfo

Fang, Y., Hyde, T.J., Arya, F., Hewitt, N., Eames, P.C., Norton, B., Miller, S. (2014) 'Indium alloy-sealedvacuumglazingdevelopmentandcontext', *Renewable and Sustainable Energy Reviews,* 37(1364-0321), pp. 480

Glass For Europe (n.d.) *The Smart Use of Glass in Sustainable Buildings,* Available at: *http://www.glassforeurope.com/images/cont/165_90167_file.pdf* (Accessed: 26th August 2014)

Hens, H. (2008) 'Thermal Comfort in Office Buildings: Two Case Studies Commented',*Building and Environment,* 44, pp. 1399-1408

Institute for Veterinary Public Health (2011) *World Map of the Köppen-Geiger Climate Classification Updated,* Available at: *http://koeppen-geiger.vu-wien.ac.at/present.htm* (Accessed: 30th August 2014)

Karaman, Y. (2014) *İstanbul ofis alanı 3 milyon m2 artacak,* Available at:*http://www.milliyet.com.tr/istanbul-ofis-alani-3-milyon-m2/ekonomi/detay/1818218/default.htm* (Accessed: 17th December 2014).

Kennett, S. (2014) *Something for the Panes: Vacuum Glazing,* Available at: *http://www.building.co.uk/something-for-the-panes-vacuum-glazing/3139081.article* (Accessed: 27th August 2014)

Lamond, W., Tuohy, P. (2011) *Investigation of Summer Overheating of the Passive House Design in the Scottish Climate,* Available at: *http://www.esru.strath.ac.uk/Documents/MSc_2011/Lamond.pdf* (Accessed: 9th September 2014)

Lang Consulting (n.d.) *Worldwide first Passive House office tower certified,* Available at: *http://www.langconsulting.at/index.php/en/news-en/246-world-s-first-passive-house-office-tower-certified* (Accessed: 20th August 2014)

McLeod, R., S., Hopfe, C., J., Kwan, A. (2013) 'An Investigation Into Future Performance and Overheating Risks in Passivhaus Dwellings', *Building and Environment,* 70, pp. 189-209

Passipedia (n.d.) *Passive House in Mixed Humid Climates,* Available at: *http://www.passipedia.org/passipedia_en/basics/passive_houses_in_different_climates/passive_house_in_mixed_humid_climates?s[]=triple&s[]=glazing* (Accessed: 26th August 2014)

Passive House Institute (n.d.) *Passive House Definition,* Available at: *http://www.passipedia.org/passipedia_en/basics/what_is_a_passive_house* (Accessed: 15th August 2014)

Passive House Institute (2014) *What is a Passive House,* Available at: http://passipedia.passiv.de/passipedia_en/basics/what_is_a_passive_house (Accessed: 15th July 2014)

Pilkington (n.d.) *Helping You Meet Part L of Government Building Regulations,* Available at: http://www.pilkington.com/resources/defaulttable.pdf (Accessed: 9th September 2014)

Pilkington (2012) *Pilkington Energikare Triple and Pilkington Insulight Triple High Window Energy Rating*, United Kingdom: Pilkington

Pilkington (2013) *Pilkington Suncool Data Sheet*, Pilkington: United Kingdom

Pilkington (2014) *Solar Control Glass,* Available at: http://www.pilkington.com/en-gb/uk/architects/types-of-glass/solar-control-glass (Accessed: 25th August 2014)

Pilkington (2012) *The Width of Single Glazing the Warmth of Double Glazing*, United Kingdom: Pilkington

Porritt, S., M., Cropper, P., C., Shao, L., Goodier, C., I. (2012) 'Ranking of Interventions to Reduce Dwelling Overheating During Heat Waves', *Energy and Buildings,* 55, pp. 16-27

Schneiders, J. (2007) 'The Passivhaus Standard in European Warm Climates: Design Guidelines for Comfortable Low Energy Homes: Part 3. Comfort, Climate and Passive Strategies', pp. 29-51

Soner, T., SÖĞÜT, Z. (2012) *Türkiye'de Bina Sektöründe Enerji Verimlilik Projeksiyonu ve Çevresel Performanslarının Değerlendirilmesi*, Istanbul: X. ULUSLARARASI YAPIDA TESİSAT TEKONOLOJİSİ SEMPOZYUMU

Standards Policy and Strategy Committee (2005) *Glazing for buildings — Part 2: Code of practice for energy, light and sound*, London: British Standards

Sullivan, L., Rydin, Y., Buchanan, C. (2014) *Frameworks for assessing the sustainability of the built environment with a focus at the neighbourhood level,* Available at: http://www.ucl.ac.uk/usar/wps/USARWPS01-Sullivan-Neighbourhoods-PDF(Accessed: 22nd April 2015).

Sustainable United Nations (2009) *Buildings and Climate Change: Summary for Decision-Makers. United Nations Environment Programme* [Online]. Available at:http://www.unep.org/sbci/pdfs/SBCI-BCCSummary.pdf (Accessed: 22nd April 2015).

Szokolay, S., V. (2011) *Introduction to Architectural Science: The Basis of Sustainable Design*, 2nd edn., Oxford: Elsevier

TMMOB Makina Mühendisleri Odası (n.d.) *Binalarda Nerji Performansı Yönetmeliği,*Available at: http://www.mmo.org.tr/resimler/dosya_ekler/f32f4847a3c7344_ek.pdf?tipi=68&turu=X&sube=15 (Accessed: 30th August 2014)

Türk Standartları Enstitüsü (2009) *TS 825 Thermal Insulation Requirements for Buildings*, Ankara: Türk Standartları Enstitüsü

University of Strathclyde (n.d.) *Passive Design,* Available at: *http://www.esru.strath.ac.uk/EandE/Web_sites/09-10/Hybrid_systems/passivedesign.pdf* (Accessed: 3rd September 2014)

PhD Synopsis: Quantifying and Evaluating the Risk Posed to Straw Bale Constructions from Moisture

Dr. Julian Robinson
Nottingham Trent University, julian.robinson02@ntu.ac.uk

Abstract

This paper provides a synopsis of the PhD thesis titled 'Quantifying and Evaluating the Risk Posed to Straw Bale Constructions From Moisture'. The thesis reviews the potential for straw bale construction to aid the construction industry in reducing carbon emissions whilst promoting social and environmental values, and decreasing the reliance on non-renewable resources. Straw is however susceptible to degradation, under certain conditions. The thesis reviews different monitoring devices and the interaction of moisture with straw and presents a three part model aimed at promoting confidence in the construction method.

Key Words: *Straw Bale, Sustainable Construction, Moisture, Modeling.*

1. INTRODUCTION

The Kyoto Protocol, an international agreement adopted in 1997 by 37 countries committed to reducing greenhouse gas (GHG) emissions, has focused the world's attention on harmful atmosphere emissions. 47% of all carbon dioxide (CO_2) emissions in the UK are attributed to the construction industry (BIS 2010) and 27% originate from housing; 73% of which comes from heating space and water alone (Moore et al. 2007). Therefore, by designing housing to be more energy efficient, and striving to achieve greater sustainability in the construction industry, reductions in GHG emissions can be made.

Straw bales construction offers a means by which to provide energy efficient buildings whilst providing a sustainable method of construction; utilising a natural material that can be locally sourced, that has a low embodied energy, and a natural life cycle, combined with low thermal conductivity values of between 0.055-0.065 W/mK (Sutton et al. 2011).
The main concern regarding straw bale construction is with moisture ingress and the risk of microbial activity decomposing the material. This paper provides a synopsis of the Ph.D. thesis titled 'Quantifying and Evaluating the Risk Posed to Straw Bale Constructions from Moisture' (Robinson, 2014) which began by laying out aims and objectives:

- "To confirm the point at which moisture becomes an issue to the straw", (Robinson, 2014)
- To assess different monitoring devices,
- To describe the interaction of moisture with straw, and
- To produce "a visual identification system and model to promote confidence in different monitoring techniques".

2. POPULATION IMPACT

Human populations are set to rise, globally, from 6.1 billion in 2000 to 9.22 billion in 2075 (UN 2004), placing additional pressure on the built environment, ecosystem services, pollution reduction initiatives, and resource acquisition. Furedi (1997) suggests that vital resources will run out because at some point in the future technological improvements will be unable to support the growing population. The UK will require the construction of around 240,000 new houses per year until 2026 (NHPAU 2007) to house the increasing population, and new-build developments will also be required to be carbon zero from 2016 onward. Housing is therefore required to be more energy efficient, sustainable, adequate for future needs of the population, and rely less on non-renewable resources.

2.1 Straw as a resource

Straw is an annually grown renewable resource and a potential carbon store but is also seen as a byproduct of the agricultural industry. Harvested from rye, oats, barley, rice or wheat, straw has been used in construction as a thatching material, and as a composite to improve the tensile strengths of bricks and renders (Lacinski, 2000) for thousands of years. Yet, it is the grain that is the valuable resource and has, throughout human civilisation, been closely linked with nutrition (Evans et al. 1981, p.149). Watson (2010) estimates that the UK has a surplus four million tonnes of straw each year, enough to produce 450,000 new houses, of $150m^2$ (Bigland-Pritchard and Pitts 2006). Baled straw's low thermal conductivity has the potential to increase energy efficiency of walls thereby reducing the dependence for space heating, and reducing the negative effects of transportation associated with the construction industry; if the material is locally sourced.

2.2 Straw Bale Construction

There are two basic forms of straw bale construction:

- 'Nebraskan style' involving the unsupported stacking of bales to form walls, developed in Nebraska, USA; also referred to as load-bearing, and
- Non-load bearing: a framework is constructed and the bales are used as an infill material.

In the construction of straw bale buildings, unskilled labour has been employed around the world, addressing social concerns through inclusion and participation, appealing to a "sense of belonging and a connection to place" (Bigland-Pritchard and Pitts 2006. pp. 374). The Ecovillages and Sustainable Communities Conference, 1994, concluded that communities require highly developed social skills, encompassing consideration for the ecosystem, built environment, economics and government, and group visions supporting the health of residents. Straw bale constructions can be erected with little prior construction knowledge or experience, although it is advised that at least one skilled person on-site. The construction method can also form part of an educational tool offering people a mechanism to reconnect with nature and decrease the impact of the negative influences of the built environment on fundamental ecosystem services.

2.3 Problems with Straw

Straw bales are not standardised and can vary by up to ±7.2% in size, ±25.1% in weight and ±21% in density (Carfrae et al. 2011) leading to the analogical term 'fuzzy building blocks'.

The lack of standardisation is not generally an issue as the material is easy to work with and can be shaped using rudimentary tools; hedge trimmers and mallets for example. The presence of moisture in elevated levels however, is a problem; given the correct conditions micro-organism will break organic material down. Other issues including fire resistance, vermin resistance and structural performance are reviewed by Lawrence et al. (2009). Moisture together with optimum temperatures between 20^{o}C and 28^{o}C (Jolly, 2000) are required for the degradation yet, if the straw is protected from moisture, by render, cladding or topography, the risk of decay can be decreased. A potential question is therefore; at what moisture content is straw susceptible to decay?

Figure 5 illustrates the uncertainty surrounding the issue of moisture and temperature; the majority of the literature agree that moisture contents of 15% and below render the straw safe from decay. Straw with moisture contents exceeding 25%, Lawrence (2009) suggests, are at risk of degradation, with Goodhew (2010) providing evidence to suggest straw held at up to 37% for short periods of time was undamaged. Moisture contents between 20 and 25% are rarely commented on in literature but, under certain conditions may be assumed to be at risk.

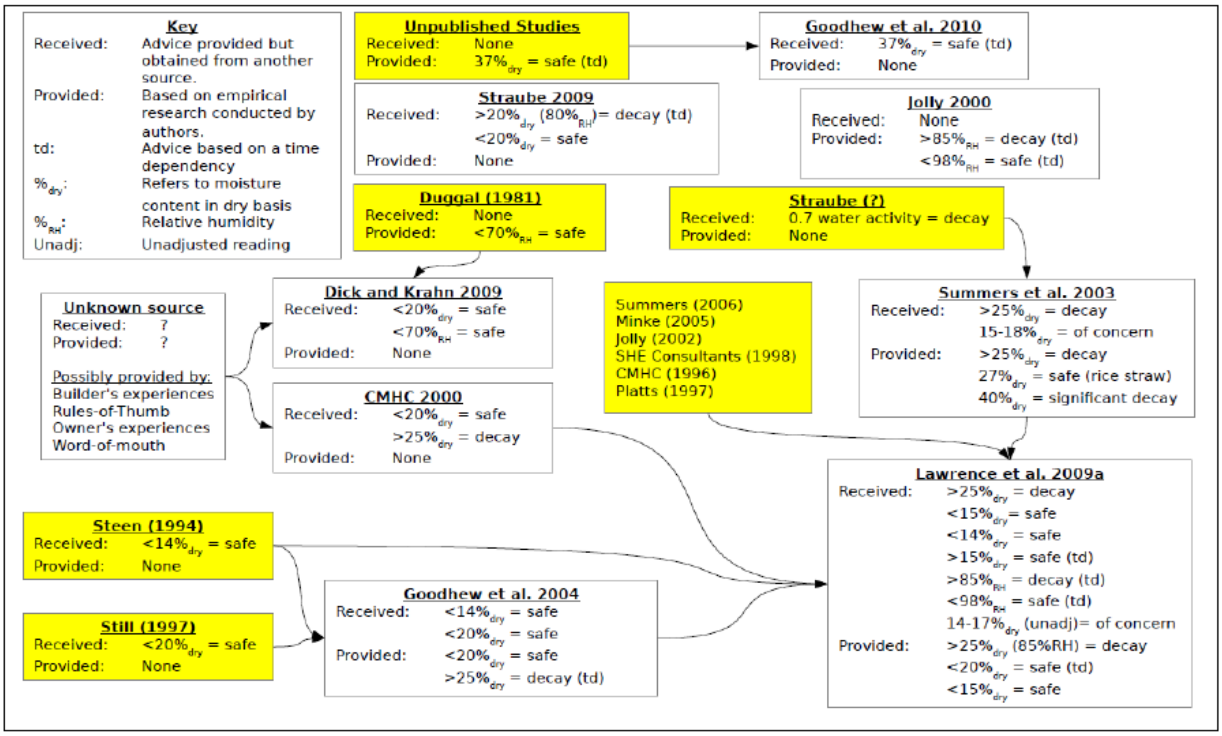


Figure 5. Risks posed to straw from moisture and temperature (Robinson, 2014)

In conclusion the literature is unclear, different experiments and observation providing differing results. The thesis identified the issue of uncertainty and sought to provide a model to address it.

3. METHODOLOGICAL APPROACH

The thesis identified six main research questions based upon the literature review concerning the interpretation of monitoring device measurements, risk posed to straw from moisture, definition of the term 'risk', defining moisture's interaction with straw, and describing the way in which moisture is transferred through a bale. This sections reviews the main findings and observations concerning monitoring methods together with the development of the model.

3.1 Monitoring Methods

In order to gauge the moisture content of straw established monitoring methods were tested, assessing limitations and accuracy of the data.

3.2 **Gravimetric Analysis**

A destructive form of analysis in the field; involving the removal and weighing of a sample of straw from a wall, placing it in an oven at 105^{o}C until a constant mass is achieved. The difference between the masses equates to the moisture content.

3.2.1 Resistance Meters

Resistance meters convert the resistance of a material to an equivalent moisture reading, but results vary in accordance with the material's dialetric properties and temperature.

Figure 6 Timbermaster, Balemaster, Balemaster Probe, Digital Thermometer and Thermocouple (Robinson, 2014)

Figure 2 illustrates the Timbermater and Balemaster meters with the Bale master probe which is inserted into a bale and linked to either of the meters to provide a moisture reading. During the study it was discovered that the meters relay the straw surface moisture level only, and require additional compensation for density and temperature. The thesis provides equations to correct for errors concerning straw.

3.2.2 Wood-Block Probes

Wood-block probes (Figure 3) offer a simple, cheap and robust method of monitoring the moisture content of straw and can be used in conjunction with resistance meters. However, using wood-block probes assumes that timber reflects the same moisture values as straw due to the organic nature.

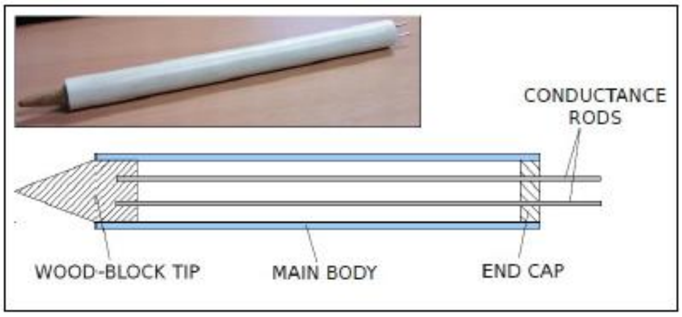


Figure 7 Wood-Block Probe (Robinson, 2014)

Laboratory experiments and field trials, conducted during the research programme, demonstrated a time lag under rapidly rising moisture regimes when compared to straw. Other identified issues included maintaining effective electrical contact between the wood-block tip and the conductance rods, and correcting the resistance meter reading for temperature.

3.2.3 Relative Humidity Sensors and Isothermal Studies

Relative humidity sensors analyse the amount of moisture in the surrounding atmosphere for a given temperature. In conjunction with Isothermal Studies, a relative humidity reading can be converted into an equivalent moisture content. Field trials and laboratory experiments conducted during the research programme demonstrated that in dynamic environment's however, the relative humidity of a bale is not directly related to the moisture content of the straw.

3.2.4 Isopleth Studies

Humidity sensors can also be used in conjunction with Isopleth Studies. Isopleth Studies use the relationship between temperature and humidity to predict mycellium growth (Figure 4) and spore germination times (Figure 5) of mould species.

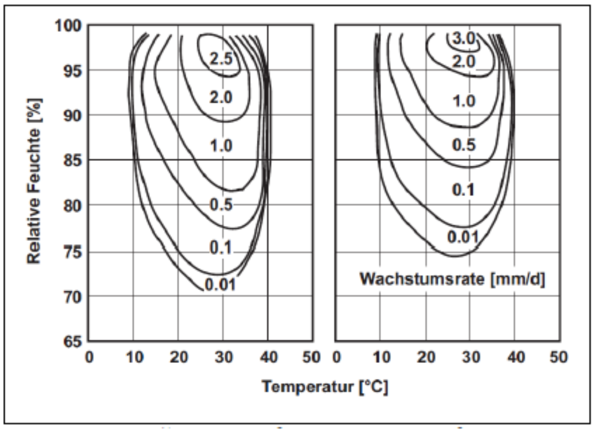


Figure 8 Mycelium development (Wieland 2004)

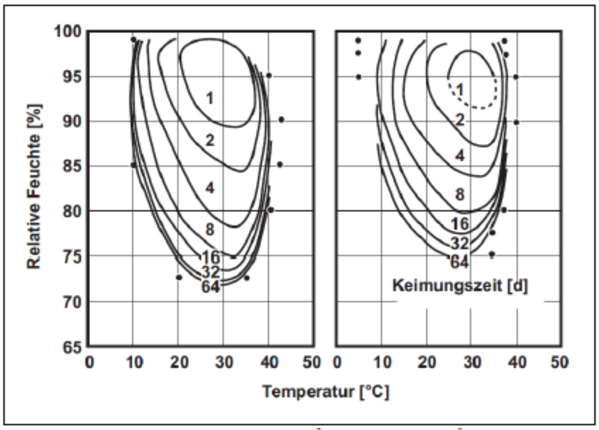


Figure 9 Germination of spores (Wieland 2004)

The isopleth diagrams can be used to predict the development of mould, but it is important to note that Figure 8 and 3 were produced with two highly xerophilic moulds. Isopleth studies "overpredict mould growth" (Bronsema, 2010, pp.45) and therefore, offer a worst case scenario yet, the diagrams and data can be used as an early warning system within a model.

3.2.5 Compressed Straw Probes

The Compressed Straw Probe (Figure 6) was designed to address the weaknesses inherent in other monitoring methods and aimed to be a "cheap, robust, easy to use and install, reliable and accurate way to assess the moisture content of a bale" (Robinson, 2014).

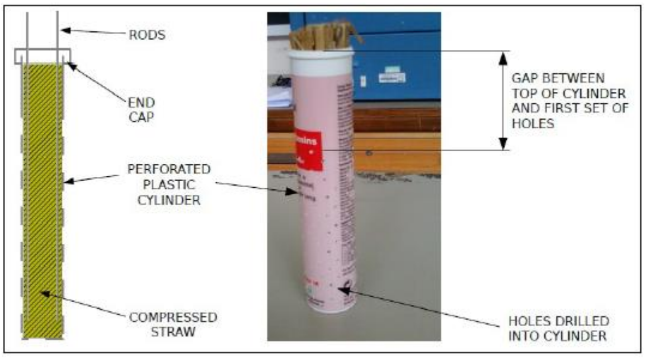


Figure 10 Compressed straw probe Prototype 01 (Robinson, 2014)

The benefit of the compressed straw probe was in the ability to obtain a moisture content results based on multiple measurement methods; gravimetric analysis, and resistance meter readings. The probe also has the advantage of visual and olfactory inspection of the straw, as the probe can be removed from the wall and inspected for signs of degradation; noting changes in colour and smell.

3.3 Models

To quantify and evaluate the risk posed to a straw bale construction from moisture the development of a model was required.

3.3.1 Contour Plots

In order to portray the results of the moisture monitoring devices used during the experimentation phases, a contour plot was developed (Figure 7).

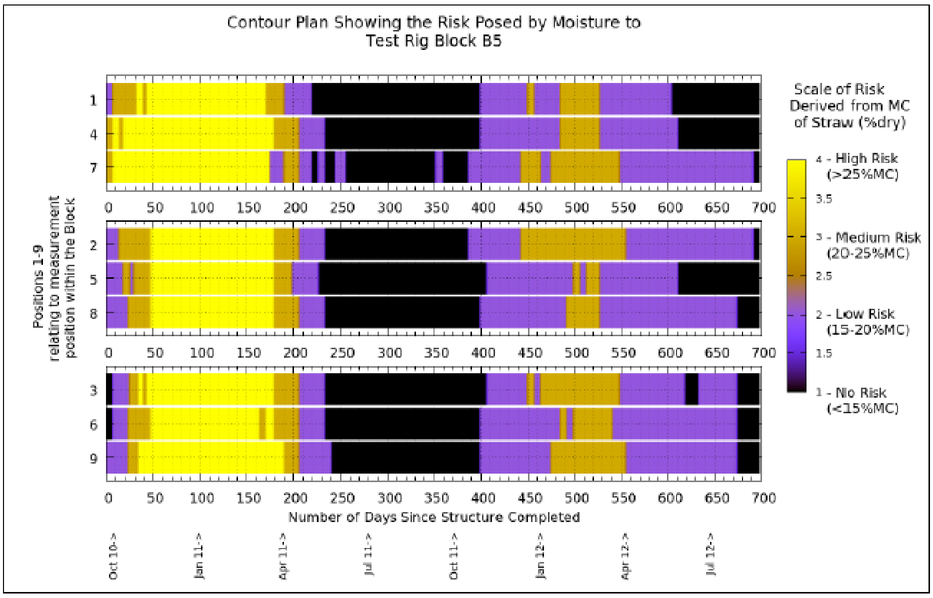


Figure 11 Contour plot showing Test Rig results (Robinson, 2014)

The plot utilises a simple traffic light system as a visual indicator to the risk posed to the straw in a wall. The plot illustrates three sections of wall, each with three monitoring devices along the y-axis. The x-axis shows the date, the z-axis represents associated risk. From Figure 7 it is possible to evaluate the risk posed to the straw; in January 2011 (day 100) all positions show high moisture values which drop to safe values (No Risk) in June 2011 (day 250). The plot provides a quick visual representation of the risk however, it does not provide detailed analysis of the wall as the traffic light system is too simplistic.

3.3.2 Fuzzy Risk Assessment

In developing a model to describe the risk posed to straw from moisture a simple traffic light system combined with fuzzy logic was devised (Figure 8).

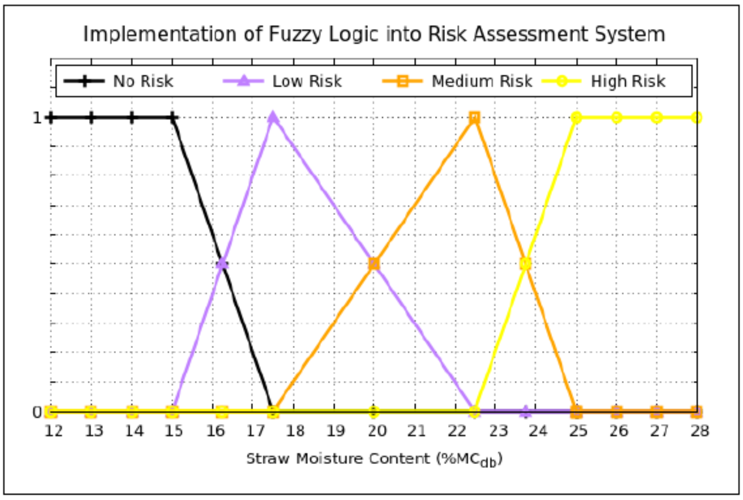


Figure 12 Implementing Fuzzy Risk Assessment System (Robinson, 2014)

The graph shows moisture content along the x-axis and a probability decision along the y-axis. The graph allows a more informed judgment to be made by utilising descriptive language (where 'MC' relates to moisture content); “It is generally accepted that readings of below 15%MC are safe from decay, but it is more informative to say that a reading of 19%MC is quite concerning (70% Low Risk) and a little unsafe (30% Medium Risk).” (Robinson, 2014). The fuzzy risk assessment system and contour plot form only two parts of an overall model, as no provision for temperature is given.

3.3.3 **Main Model**

The main model (Figure 9) relies on the collection and correct interpretation of data from single or multiple monitoring devices to make an informed decision as to the risk posed to straw. The flow diagram offers advise based on the associated risk.

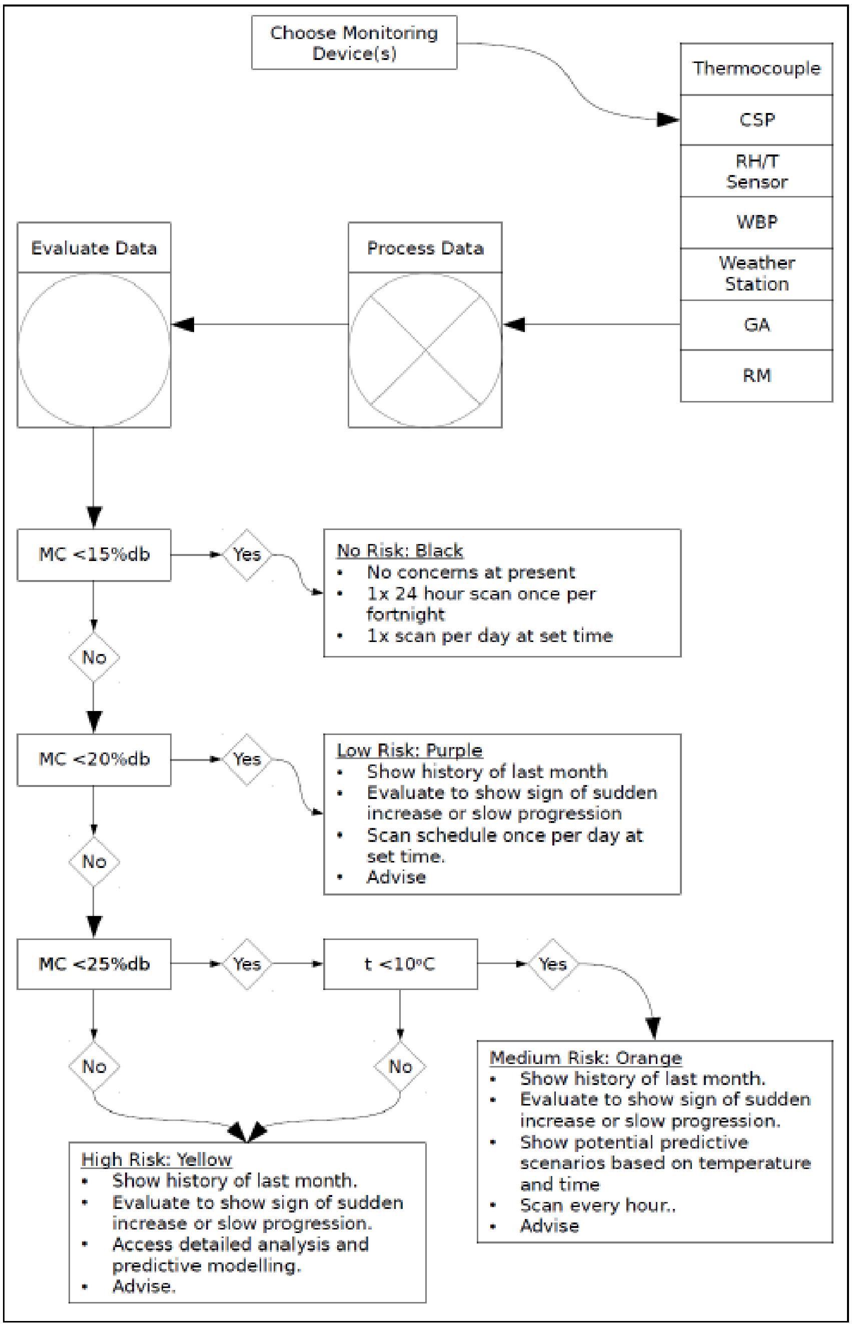


Figure 13 Main Model (Robinson, 2014)

4. CONCLUSIONS AND RECOMMENDATIONS

The Ph.D. research sought to “Quantify and Evaluate the Risk Posed to Straw Bale Construction from moisture”. The thesis provides a model to explain the risk posed to straw from moisture by way of the Fuzzy Risk Assessment System (Figure 8) and evaluates the strengths of each monitoring device leading to the development of the Compressed Straw Probe (Figure 6). The interaction of moisture with straw is explained within the thesis and is based on field and laboratory experiments. Finally the contour plot and main model offer a visual identification system, and utilising descriptive terminology can advise on the risk posed to a construction.

The thesis concludes, stating that although straw bale construction is not an established method of construction, it is sustainable, provides a method of carbon capture, can reduce the negative impact of material transportation, contains no inherent toxic elements, is widely available, and has a low thermal conductivity. Therefore, the model and definition of the monitoring methods promote confidence in the construction method and if straw bale construction was to be accepted as a main stream method it would help increase building energy efficiencies and therefore reduce CO_2 emissions.

5. REFERENCES

Bigland-Pritchard, M., and Pitts, A., (2006). *Evaluation of Strawbale Building: Benefits and Risks*. Architectural Science Review. 49(4), pp. 372-384.

BIS (Department for Business, Innovation and Skills), (2010). *Estimating the amount of CO2 emissions that the construction industry can influence*. London: Department for Business, Innovation and Skills.

Bronsema, N. R., (2010). *Moisture Movement and Mould Management in Straw Bale Walls for a Cold Climate*. M.A. Thesis, University of Waterloo.

Carfrae, J., (2011). *The moisture performance of straw bale construction in a temperate maritime climate*. Ph.D. thesis, University of Plymouth.

CMHC (Canadian Mortgage Housing Corporation), (2000). *Straw Bale House Moisture Research*. Ottawa, Canada: The Canadian Mortgage and Housing Corporation.

Evans, L.T., Peacock, W.J., Frankel, O.H. & Commonwealth Scientific and Industrial Research Organization- Division of Plant Industry (1981). *Wheat science - today and tomorrow*. Cambridge, Cambridge University Press .

Furedi, F., (1997). *Population and development: A critical introduction*. Cambridge, Polity Press.

Goodhew, S., Carfrae, J. and De Wilde, P., (2010). *Briefing: Challenges related to straw bale construction*. The Institute of Civil Engineers: Engineering Sustainability 163 (ES4), pp 185-189.

Jolly, R., (2000). *Strawbale moisture monitoring report*. Ottawa, Canadian Mortgage and Housing Corporation.

Lakinski, P, and Bergeron, M., (2000). *Serious Straw Bale: A construction guide for all climates*. Canada: Chelsea Green Publishing Company.

Lawrence M., Heath A., and Walker P. (2009). *Determining moisture levels in straw bale construction*. Elsevier: Construction and Building Materials. Vol.23 pp. 2763–2768

NHPAU (2007). *Developing a target range for the supply of new homes in England*. Fareham, National Housing and Planning Advice Unit.

Robinson, J. A. (2014) *Quantify and Evaluate the Risk Posed to Straw Bale Construction from moisture*, Ph.D. thesis, Nottingham Trent University

Sutton, A., Black, D. and Walker, P. (2011) *STRAW BALE: An introduction to low-impact building materials*. BRE, Watford.

United Nations, (2004). *World population to 2300*. United Nations, New York.

Watson, M., (2010). *Do straw bales offer a realistic construction method?* [online]. London: Equal Planet. Available at: http://equalplanet.co.uk/http:/equalplanet.co.uk/sustainability/building-materials/straw-bales-building-materials/are-straw-bales-offer-a-realistic-construction-method/ [accessed 14-05-2015]

Enhanced phase change emulsions for air conditioning systems

Jingjing Shao,* Jo Darkwa

Faculty of Engineering, University of Nottingham
University Park, Nottingham, NG7 2RD
*Corresponding email: epxjs5@nottingham.ac.uk

Abstract

Phase Change Emulsion (PCME) is a multifunctional fluid consisting of a Phase Change Material (PCM) and a carrier fluid. PCMEs can store or transfer amounts of thermal energy by using the latent heat capacity of the PCM. In this paper, a combination of paraffin (RT10) and water known as PCE-10 has been developed and evaluated. The properties and its application for air conditioning systems have been examined during both the storage and discharge period in a dedicated test rig. The results indicate good stability and low sub-cooling behaviour but the viscosity was much higher than that of water. Further improvement and experimental studies into its flow characteristics is therefore being encouraged.

Key Words: Phase change material emulsion; sub-cooling; stability; viscosity

1. INTRODUCTION

Chilled water system is one of the most popular air conditioning systems world-wide due to its relatively low running cost (Zhen and Qian, 2007). However, circulating pumps are responsible for roughly 15%-30% of their overall energy consumption (Zhong, 2004). To this end, some researchers have suggested replacing water with phase change emulsion (PCME) since they possess higher heat capacities and therefore able to reduce volume flow rates and energy consumption in pumps (Xu, 2005). PCMEs can also simultaneously act as cold storage for shifting peak-load to off-peak time and thereby improving the coefficient of performance (COP) of air conditioning systems (Zhang and Ma, 2012). However, most of the commercially available phase change emulsions do experience problems with sub-cooling and instability. This study was therefore intended to develop paraffin/water emulsion capable of minimising the effects of those highlighted barriers.

2. PCME DEVELOPMENT

Paraffin materials such as tetradecane (T_m=5.8°C, Δh_f=227kJ/kg) and pentadecane (T_m= 9.9°C, Δh_f=206 kJ/kg) are typical pure organic PCMs which may be utilized for cooling applications within a phase transition temperature range of 7-12°C. However, due to the relatively high cost of pure PCM, cheaper blended paraffin such as RT6 and RT10 may be considered. As shown in Table 1, RT10 has a better melting temperature range of 6-11°C with a higher heat of fusion for air conditioning application and for these reasons, it was selected as the core material for the novel PCME. Since paraffin and water are immiscible, two blends of surfactants (Tween60 and Brij52) were added to the emulsion to ensure stability. As shown in Figure 1, the developed sample was named as PCE-10 and could be described as a white milky Oil-in-Water emulsion with density of about 0.94g/cm^3.

Table 1: Thermo-physical properties of RT6 and RT10

	Melting temperature range T_e (°C)	Freezing temperature range $T_{p,f}$ (°C)	Subcooling (°C)	Heat of fusion (kJ/kg)	Conductivity (W/mK)
RT6	2.8-8.3	3.5-7.2	1.1	132	0.19
RT10	2.3-12	5.1-11.8	0.2	135	0.21

Figure 14: Developed PCME sample PCE-10

3. CHARACTERISATION OF DEVELOPED EMULSION (PCE-10)

3.1 Particle Sizing

According to various publications such as Schramm et al. (2005) the size and characteristics of particles do affect the stability, viscosity and thermal properties of emulsions. In this regard, a laser particle size analyser- was used to establish the size of the PCE-10 and also as a reference for the stability test. As presented in Figure 2, the mean particle size was obtained as 3.14µm.

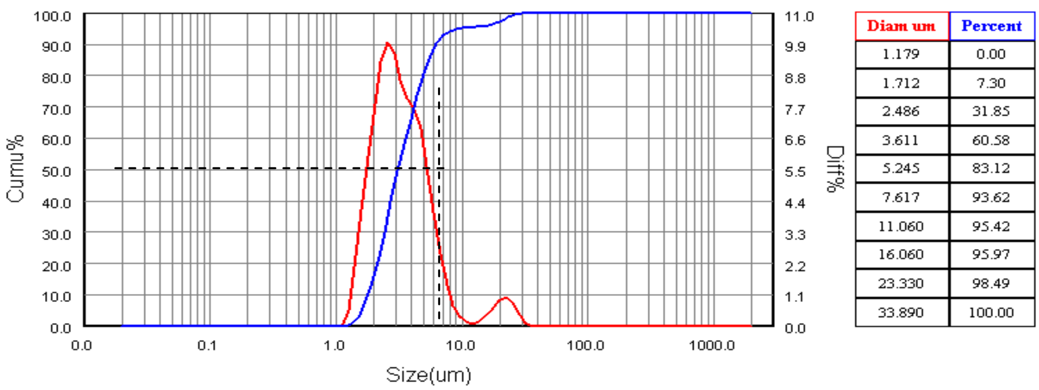


Figure 15 Laser Particle sizing of PCE-10

3.2 Thermal Conductivity

The thermal conductivity of the sample was determined with a KD2 Pro Thermal Properties Analyser which is able to test liquid samples with accuracy of ±5%. As shown in Table 2, the average thermal conductivity of PCE-10 after repeated tests was obtained as 0.4W/(mK) at a temperature of 25°C.

Table 2. Thermal Conductivity Results

Test No.	Temperature (°C)	Thermal Conductivity (W/mK)
1	24.94	0.409
2	25	0.406
3	25.22	0.4
Average	25.11	0.4026

3.3 Phase Transition Temperature and Heat Capacity

The phase change temperature and the heat of fusion of the emulsion were determined with a Differential Scanning Calorimetry (DSC) apparatus at a scanning rate of 1°C/min and was tested few more times to ensure reliability of the results. As presented in Figure 3, the heat of fusion was obtained as 30.5 kJ/kg with average phase change temperature range between 4 °C and 11.94°C.

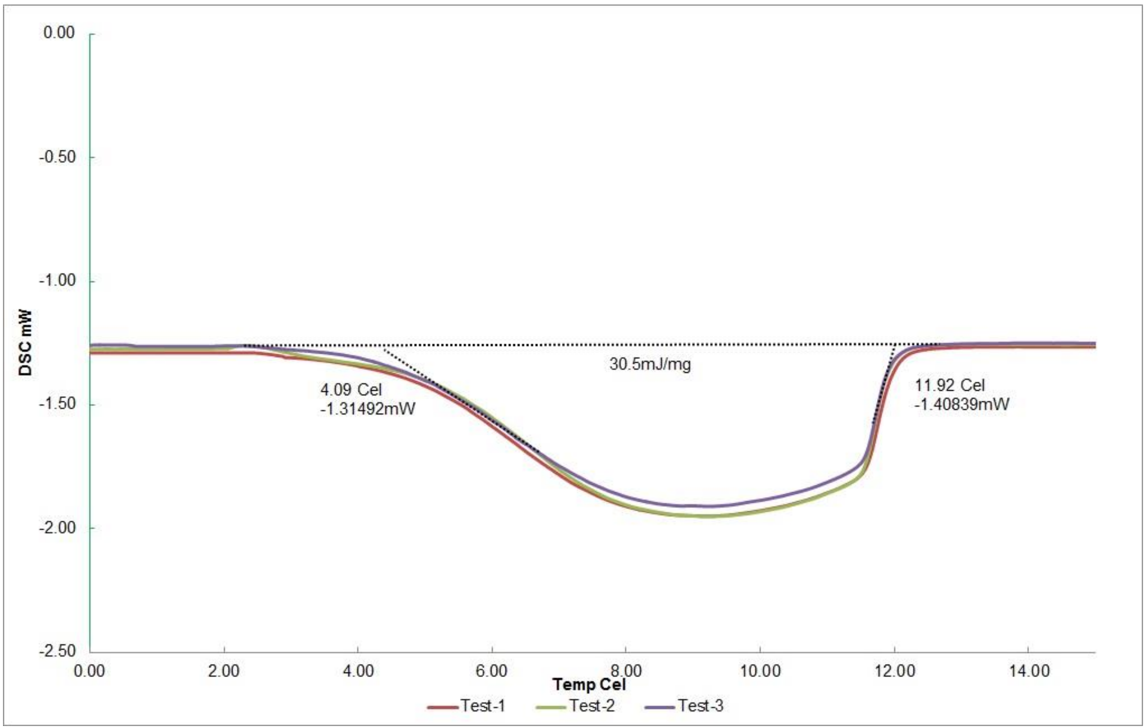


Figure 16 DSC curves of PCE-10

The total heat capacity of the developed emulsion consists of not only the heat of fusion of the paraffin, but also the sensible heat capacity of the water as expressed as follows (Huang et al., 2010):

$$\Delta h_e = \Delta h_{f,e} + \Delta h_w + \Delta h_{PCM} = X_{PCM} \Delta h_{f,PCM} + X_W C_{p,W} (T_2 - T_1) + X_{PCM} C_{p,PCM} (T_2 - T_1) \quad (1)$$

Where, X_w and X_{PCM} are the weight fractions of paraffin and water, $\Delta h_{f,p}$ is the heat of fusion of paraffin in the temperature range of T_1 to T_2. $C_{p,w}$ and $C_{p,PCM}$ are the specific heat capacity of water and the average specific heat capacity of the paraffin, respectively.

In the temperature range of 7–12°C, water has a sensible heat capacity of 20.9kJ/kg, while 25wt% PCME has a total heat capacity around 40kJ/kg, which is almost 2 times as high as that of water.

3.4 Sub-cooling Temperature

The sub-cooling test was conducted based on the T-history method which is normally used in measuring thermal properties of bulk materials (Zhang et al., 1999). As illustrated in Figure 4, one of the test tubes was filled with PCM and the other with a reference material, usually water, due to its well-known thermo-physical properties. The tubes were then preheated above the melting temperature of the PCM and then simultaneously exposed to the ambient temperature to obtain their temperature history (T versus t) as presented in Figure 5. Analysis of the curves achieved a small sub-cooling of 0.2°C in the developed sample.

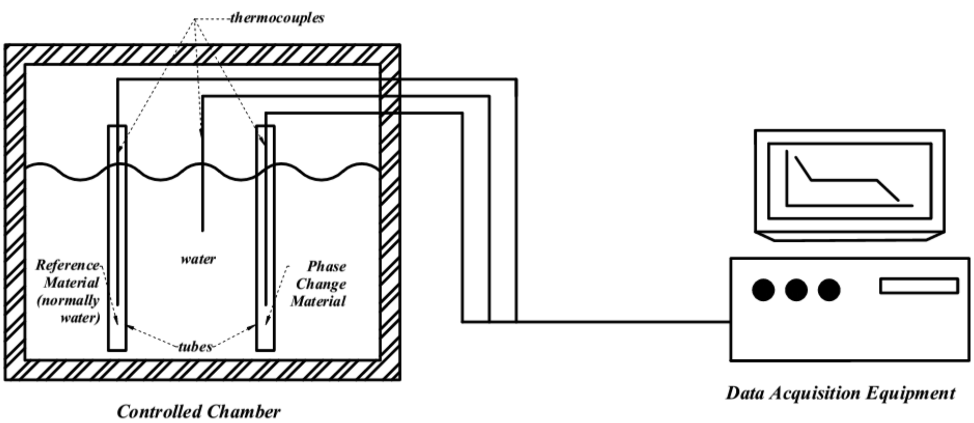


Figure 17: Schematic setup for T-history method

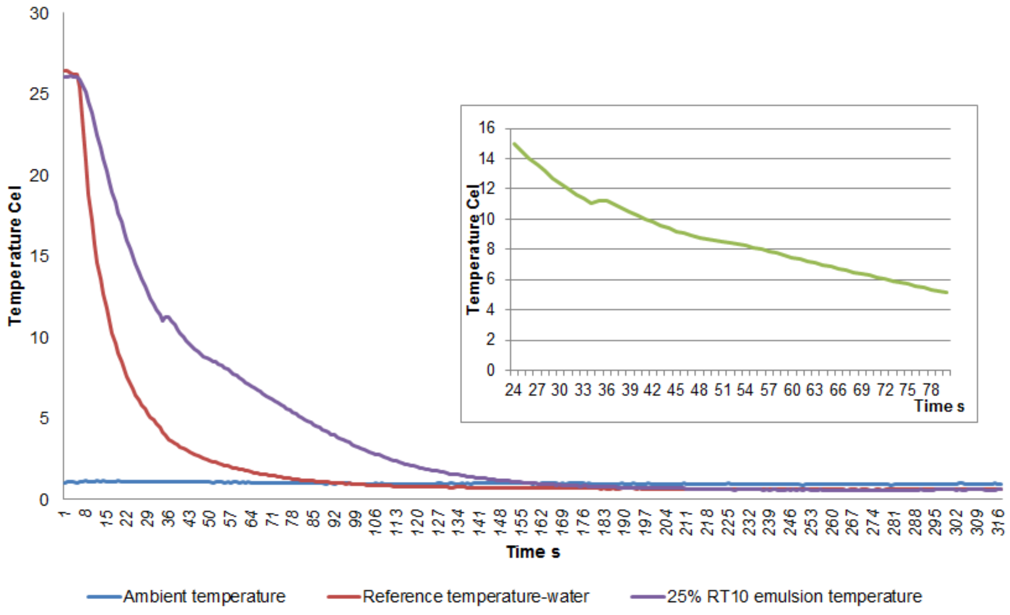


Figure 18: T-history curve of PCE-10

3.5 Viscosity Test

Rheological test was carried out to determine the viscosity of the developed sample. Figure 6 illustrates the relationship between viscosity and shear rate for the developed PCME at 25°C. It is quite clear that the viscosity of the emulsion reduced rapidly but stabilised at around 13mPas after 400s-1. However, the viscosity appears quite high since it is about 13 times higher than that of water.

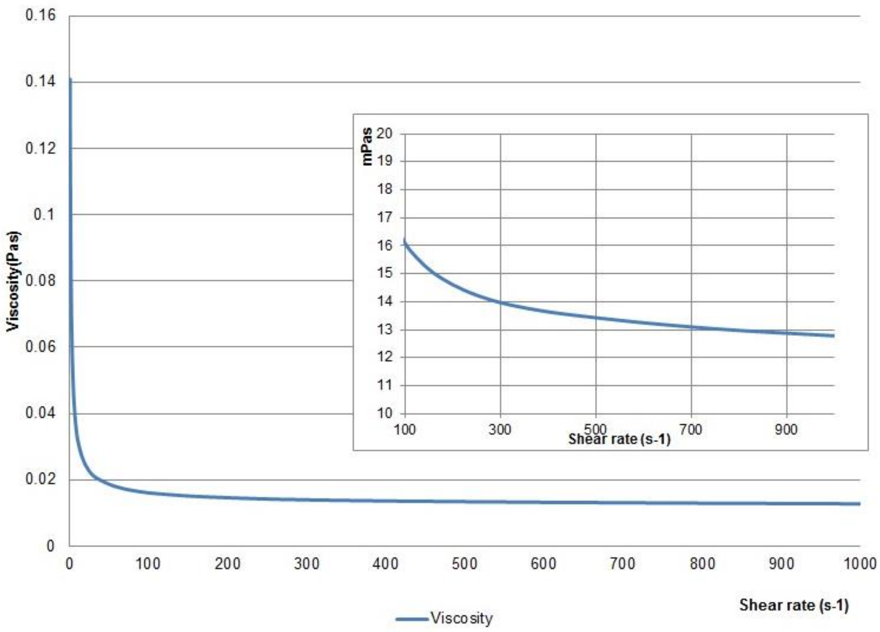
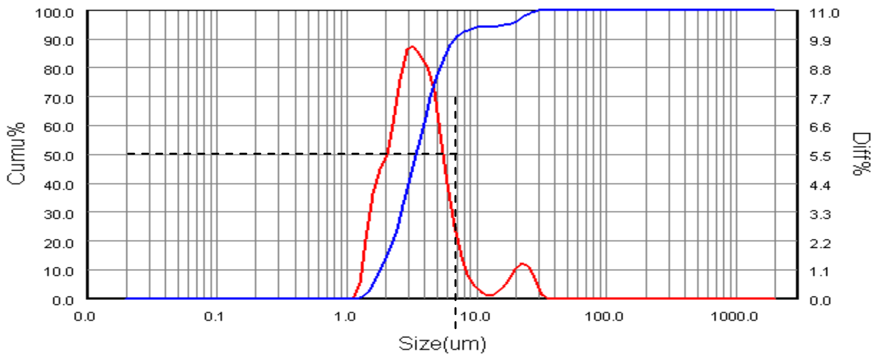


Figure 19: Relationship between viscosity and shear rate for PCE-10 at 25°C

3.6 Stability Test

3.6.1 Storage mode

The sample was stored at room temperature. Separation started to occur after 120 days of storage and by the end of 270 days there was a clear separation between the upper and lower layers which was attributed to different densities. Further test was carried out to determine the particle size of the upper layer of the sample after the end of the storage period. The result shows a value of 3.41μm (see Fig. 7) as compared with the original value of 3.14μm. This indicates the presence of oil droplets coalescence.

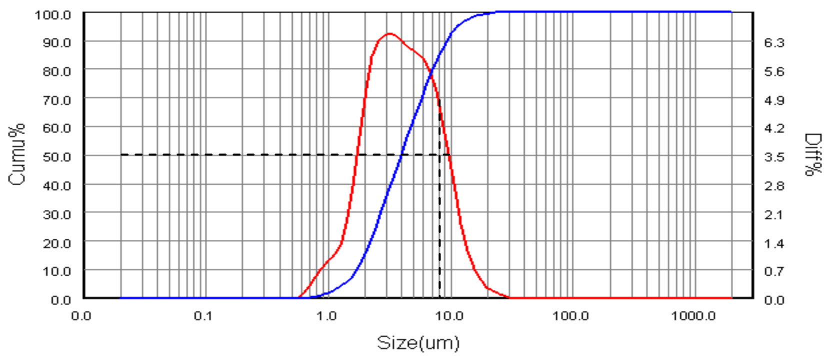


Diam um	Percent
1.179	0.00
1.712	7.36
2.486	25.63
3.611	54.38
5.245	80.30
7.617	91.83
11.060	94.10
16.060	94.71
23.330	97.80
33.890	100.00

Figure 20. Particle sizing of PCE-10 after 270-day storage

3.6.2 Cycling mode

The stability of the sample under thermal mechanical load was examined in a pressurised test rig under repeated melting and freezing cycles. After 500 thermal cycles, a clear layer of oil was observed at the surface of the emulsion which was a sign of separation of the base material (RT10) from the emulsion. Particle sizing analysis was also conducted on the sample. The result in Figure 8 indicates the presence of coalescence, as the droplet size increased slightly from the original size of 3.14μm to 3.93μm after the test.



Diam um	Percent
0.574	0.00
0.891	1.27
1.383	5.29
2.147	18.31
3.333	41.19
5.175	64.12
8.034	84.70
12.470	96.47
19.360	99.49
30.060	100.00

Figure 21: Laser Particle sizing after 500 freeze-thaw cycles

There are several data that have been published about stability of PCME under thermal-mechanical load. For example, Schalbart et al. (2010) tested tetradecane and water emulsion and achieved good storage stability at room temperature for few weeks and also displayed no sign of degradation after about 100 melting/freezing cycles. In comparison with these results, it could be stated that the developed PCME has good potential.

4. CONCLUSION

In this paper, a novel paraffin and water emulsion (PCE-10) has been developed and tested. The particle size was obtained as 3μm with a heat capacity of twice as much as that of water. Surfactant blends of Tween60 and Brij52 were found to be capable of minimizing the effect of sub-cooling to a negligible level. The level of stability especially under series of thermal-mechanical loadings was found to be comparable with other developed PCMEs. However, the viscosity was much higher than that of water and therefore needs to be improved. Experimental study into heat transfer performance and flow behaviour of the PCE-10 in cooling coils is also necessary and encouraged. Experimental study into heat transfer performance and flow behaviour of the PCE-10 in cooling coils is also encouraged.

6. REFERENCES

Huang, L. Noeres, P. Petermann, M. and Doetsch, C. (2010). Experimental study on heat capacity of paraffin/water phase change emulsion, Energy Conversion and Management, 51 (6), 1264-1269.

Schalbart, P., Kawaji, M., Fumoto, K. (2010). Formation of tetradecane nanoemulsion by low-energy emulsification methods, International Journal of Refrigeration, 33 (8), 1612-1624.

Schramm, L.L. (2005). Emulsion, foams and suspensions, Weinheim: Wiley-VCH Verlag Gmbh & Co.

Xu, Y. (2005) Study the saving energy method for fan-coil unit system, Master thiese, Construction and Civil Engineering, Xi,an University of Architecture and Technology, 2005.

Zhang, Y., Jiang, Y., Jiang, Y. (1999). A simple method, the T-history method, of determining the heat of fusion, specific heat and thermal conductivity of phase-change materials, Measurement and Science Technology, 10, 201–205.

Zhang, P., and Ma, Z.W. (2012). An overview of fundamental studies and applications of phase change material slurries to secondary loop refrigeration and air conditioning systems, Renewable and Sustainable Energy Reviews, 16 (7), 5021-5058.

Zhen, Q., and Qian, H. (2007). Overview of fan coil air conditioning system, Science Information, 16, 73 In Chinese.

Zhong, W. (2004). Building air conditioning energy consumption and energy saving measures in China, Master thiese, Environment engineering, MSc Chongqing University.

Development of a binary microencapsulated phase change material

Weiguang Su[1], Jo Darkwa[2], Georgios Kokogiannakis[3]
1. University of Nottingham Ningbo China, Weiguang.SU@nottingham.edu.cn
2. University of Nottingham, UK, J.Darkwa@nottingham.ac.uk
3. University of Wollongong, Australia, gkg@uow.edu.au

Abstract

Microencapsulated phase change material (MEPCM) has been recognized as potential building energy saving material. However, performance of current materials are limited to specific phase change temperatures and therefore not suitable for flexible application. To this end a binary MEPCM based on combining two individual MEPCMs was developed and obtained a latent heat value of 186 kJ/kg with two melting points of 23.36℃ and 34.51℃. Analysis of the results show that the sample is capable of being applied in moderating thermal conditions in buildings. There is however the need to optimize the weight percentages of individual components towards future practical evaluation.

Key Words: *binary, microencapsulated phase change material, energy storage, building.*

1. INTRODUCTION

Currently the building sector consumes approximately 40% of the world's electricity supply (Neto and Fiorelli 2008). Meanwhile, about 85% of a building's energy consumption is caused by heating, cooling and lighting activities with commercial buildings producing approximately a third of energy related carbon emissions (IEA 2011). Microencapsulation phase change materials (MEPCMs) have been recognized as potential energy saving materials because they could balance heating and cooling loads in buildings (Tyagi, Kaushik et al. 2011, Zhao and Zhang 2011, Whiffen and Riffat 2012). For instance, Schossig (Schossig, Henning et al. 2005) investigated the thermal performance of lightweight buildings integrated with two different MEPCM wallboards. The test results for a whole year showed that the wall boards were effective in reducing the cooling demand as well as increasing the comfort of levels in the buildings. Other test conducted on MEPCM plaster by C. Voelker (Voelker, Kornadt et al. 2008) showed that it was able to reduce the peak temperature of the testing chamber by about 3℃. Experimental investigation (Kuznik and Virgone 2009) carried out on copolymer composite MEPCM wallboard also achieved air temperature reduction of 4.2 °C.

However, the above MEPCMs did operate at specific phase change temperatures and therefore unable to satisfy all year seasonal thermal energy storage application with wide range ambient conditions. For example, the ambient temperature of Hangzhou in China ranges from -3 to 38℃ (Yi 2005) with the minimum daily temperature well over 25℃ during most of the time in July and August. To this end binary phase change materials based on two types of microencapsulated phase change material (MEPCM) with different melting points were developed in this study. Their thermal properties (melting point, latent heat, thermal stability) have also been analysed and compared with the theoretical values.

2. DEVELOPMENT PROCESS

Based on a typical thermal comfort range and corresponding weather data, n-octadecane and n-eicosane were selected as the core materials. The in-situ polymerization method was then adopted for the encapsulation process being the commonest approach normally used for encapsulation. Meanwhile a differential scanning calorimetric (DSC) equipment was used to determine the melting temperature (M_t) and thermal energy storage capacity (H) of the core materials and the developed MEPCMs at a heating rate of 2℃/min from 5 to 50℃ and under atmospheric pressure. Their thermal stabilities (T_s) were also examined by thermogravimetric analysis which was carried out under nitrogen gas protection, covering a heating range of 50 °C to 500 °C and at a heating rate of 10 °C /min.

As summarized in Table 1, the melting points and latent capacities were reduced after encapsulation but their thermal stabilities were significantly enhanced by the polymer shell. Finally, the two MEPCMs were mixed together with type SFM-2 Kejing Group mixing machine for 30 min and at a speed of 200 rpm to obtain the binary MEPCM sample.

Table 1. Thermal properties of PCMs and MEPCMs

Name	M_t (℃)	H (kJ/kg)	T_s(℃)
n-octadecane	24.26	213.0	147.1
n-eicosane	35.63	252.0	184.2
MEPCM-oct	23.54	179.0	207.6
MEPCM-eic	34.99	194.0	222.9

3. RESULTS AND DISCUSSIONS

3.1 Latent heat of binary MEPCM

The latent heat of binary MEPCM can be calculated based on weight percentages of components as following:

$$H_{MEMPCM} = H_{MEPCM-oct} * Wt_{MEPCM-oct} + H_{MEPCM-eic} * Wt_{MEPCM-eic} \quad (1)$$

Where H is the latent heat, and Wt is the weight percentage of the component.

Therefore, based on 50% weight for each component of MEPCM-oct and MEPCM-eic, a latent heat value of 186.5kJ/kg was obtained for the binary MEPCM.

3.2 Thermal properties of binary MEPCM

With the aid of a DSC equipment, the melting points and latent heat of the binary were established. As shown in Figure 1, the two melting processes occurred at 23.36℃ and 34.51℃ respectively with total latent value of 186kJ/kg. This demonstrates that the binary MEPCM could operate over a wide temperature range for cooling and heating application in buildings as compared with single MEPCM. By comparing with the theoretical values in Table 2, it can be seen that the two melting points were slightly reduced by 0.18℃and 0.48℃ but there was virtually no change in the latent heat value. The experimental results have also confirmed that thermal energy storage capacity of binary MEPCM is mainly dependent on the weight percentages of individual components and their latent heats capacity.

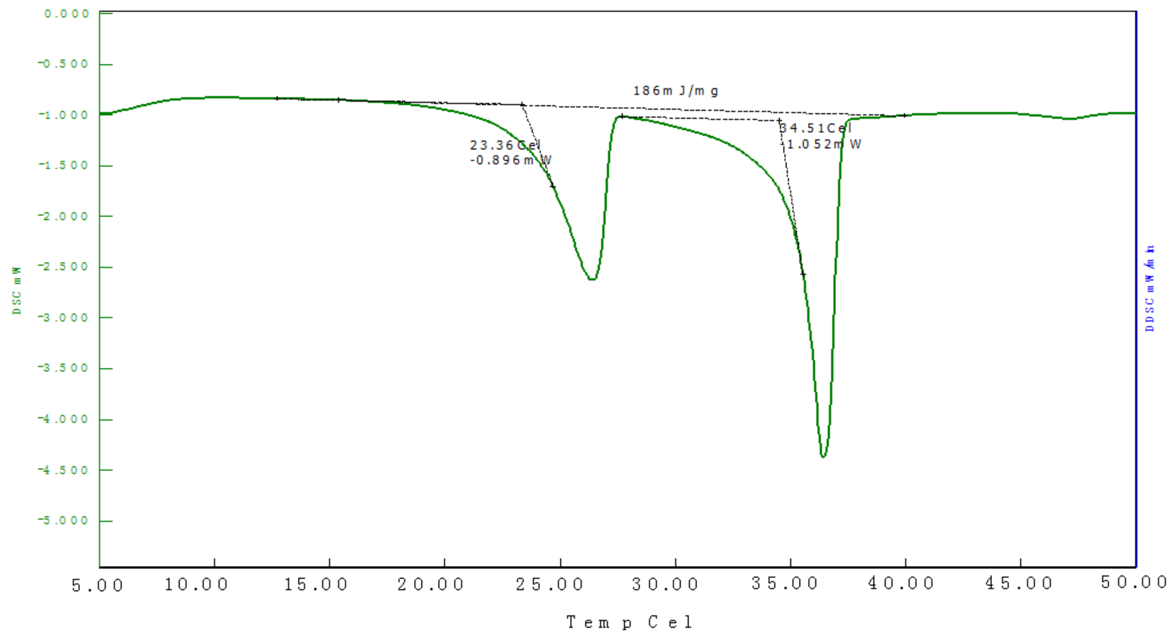


Figure 1. DSC curve of binary MECPMs

Table 2. Theoretical and experimental thermal properties of binary MEPCM

Items	MEPCM-oct (wt. %)	MEPCM-eic (wt. %)	M_{t1} (℃)	M_{t2} (℃)	H (kJ/kg)
Theoretical	50	50	23.54	34.99	186.5
Experimental	50	50	23.36	34.51	186.0

3.3 Thermal stability analysis

Thermal stability of the binary MEPCM was evaluated through the same procedure adopted under the heading 2. As shown in Figure 2, the weight loss or thermal instability in the composite MEPCM material started to occur at a temperature as high as 196.8°C. This is far higher than any natural ambient temperature and therefore satisfies the normal environmental requirements for buildings. The thermal stability was however reduced about 10°C when compared with MEPCM-oct and MEPCM-eic.

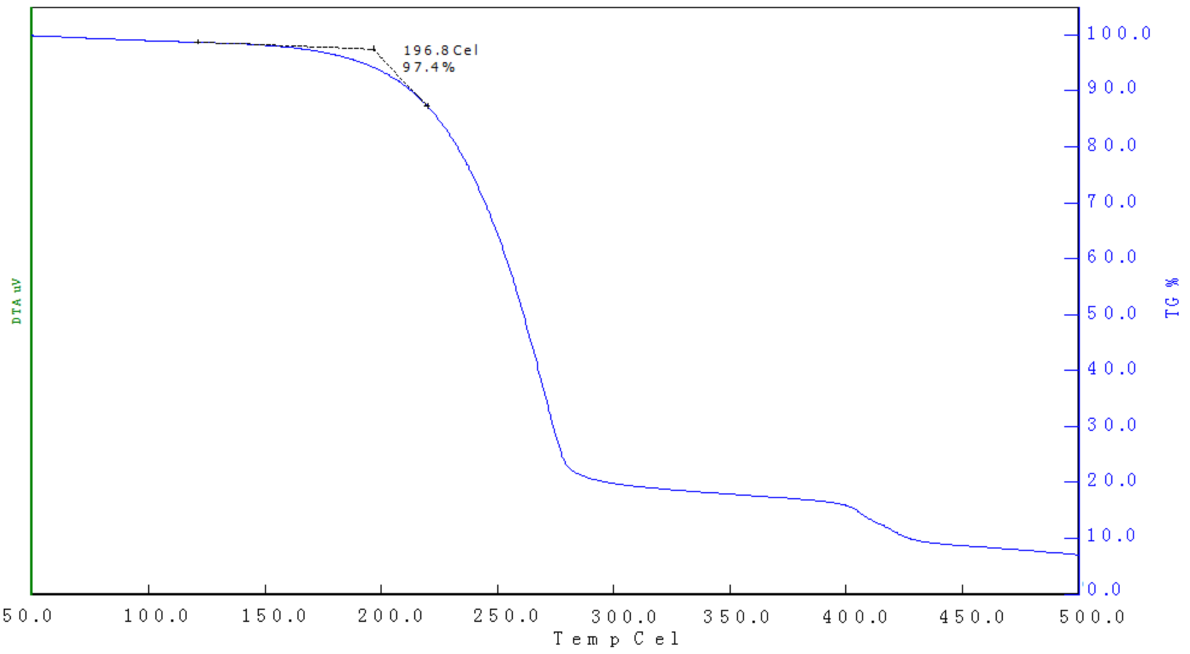


Figure 2. TG curves of binary MEPCM

4. CONCLUSIONS

Based on assumed temperature range and selected phase change materials (n-octadecane and n-eiocsane) a binary MEPCM was successfuly developed. A total latent heat value of 186 kJ/kg was obtained with two melting points of 23.36℃ and 34.51℃. The overall analysis of the experimental and theoretical results clearly show that the thermal properties of the binary MEPCM were dependent on the weight percentages of individual components and that it is capable of being applied for moderating thermal conditions in buildings. Optimization of weight percentages of various components is however recommended towards future practical evaluation.

5. REFERENCES

IEA (2011). Technology Roadmaps - Energy-efficient Buildings: Heating and Cooling Equipment.

IWEC, I. W. f. E. C. (2015). "Izmir 172180 (IWEC)." from http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data3.cfm/region=6_europe_wmo_region_6/country=TUR/cname=Turkey.

Kuznik, F. and J. Virgone (2009). "Experimental assessment of a phase change material for wall building use." Applied Energy 86(10), 2038-2046.

Neto, A. H. and F. A. S. Fiorelli (2008). "Comparison between detailed model simulation and artificial neural network for forecasting building energy consumption." Energy and Buildings 40(12), 2169-2176.

Schossig, P., H. M. Henning, S. Gschwander and T. Haussmann (2005). "Micro-encapsulated phase-change materials integrated into construction materials." Solar Energy Materials and Solar Cells 89(2–3), 297-306.

Tyagi, V. V., S. C. Kaushik, S. K. Tyagi and T. Akiyama (2011). "Development of phase change materials based microencapsulated technology for buildings: A review." Renewable and Sustainable Energy Reviews 15(2), 1373-1391.

Voelker, C., O. Kornadt and M. Ostry (2008). "Temperature reduction due to the application of phase change materials." Energy and Buildings 40(5), 937-944.

Whiffen, T. R. and S. B. Riffat (2012). "A review of PCM technology for thermal energy storage in the built environment: Part I." International Journal of Low-Carbon Technologies.

Yi, J. (2005). China Standard Weather Data for Analyzing Building Thermal Conditions. Beijing, China Building Industry Publishing House.

Zhao, C. Y. and G. H. Zhang (2011). "Review on microencapsulated phase change materials (MEPCMs): Fabrication, characterization and applications." Renewable and Sustainable Energy Reviews 15(8), 3813-3832.

Development of Raised Access Floor Panel by Optimisation Techniques

Hooi. C. Cheah
Nottingham Trent University, hooi.cheah@ntu.ac.uk

Abstract

Raised access floor panels currently have a chipboard core and are encapsulated within thin layer of galvanised steel. Two key problems with these raised access floor panels are that they are heavy because of the chipboard and expensive, as the cost of steel has increased significantly over the past few years. The consequence of the raised access floor panel's mass is that they are difficult to handle, they are expensive to transport and they add considerably to the load on a structures foundation. Glass fibre filled epoxy of floor panels were designed and optimised to achieve lighter weights without compromising their strength using Altair Hypermesh software. A material weight reduction of the glass fibre filled epoxy floor panel was achieved by optimised design of the panes using an evolutionary structural optimisation (ESO) method and the introduction of panel ribs. The lighter weight of new raised floors panel would have a significant impact on the loadings of buildings foundation and allow architects to reduce the carbon footprint of a building resulting in reduced construction costs. In addition, a reduction in the weight of the new raised access floor panels would reduce the transportation costs of the panels.

Key Words: *Glass fibre filled epoxy, Evolutionary structural optimisation*

1. INTRODUCTION

New office buildings require desks, chairs, telephones, computer systems, power and data cables. Raised access floor systems have become popular due to the flexibility of the flooring system which allows the services such as electrical and computer cables to be routed under the floor to create a safe and tidy working environment which has the flexibility to be changed as required when the function of the space alters (Zhang et al. 2002).

A raised access flooring system is defined in Platform Floors (Raised Access Floors) – Performance Specification as "load bearing fixed or removable panels supported by adjustable pedestals to provide an underfloor space for the housing and distribution services" (PSA Specialist Services 1992). A raised floor system is an array of elevated removable floor panels of dimension 600mm x 600mm x 30 mm, installed over the top of the buildings concrete slab and supported on pedestals. The plenum space between the concrete slab and the raised floor typically provides the space for the building services such as electrical supply, data and security cables to be routed (Schiavon et al. 2010).

Lighter floor panels would have a significant impact on the loadings on buildings structure, allowing architects to reduce footings. This would result in a reduction in the overall construction costs of a building. The existing floor panels are made of chipboard encapsulated with galvanised steel which are heavy and costly particularly as the prices of galvanised steel has increased significantly in recent years. The weight of the raised access floor panels causes manual handling problems and increases the cost of transporting them to site. At present if traditional panels are transported in a standard container, only 50% of the containers capacity is used due to the weight at the panels being so high (Burgess 2009). Manufacturing new raised floor panels from lighter materials would be beneficial to the environment and reduce the carbon impact of the building.

2. STRUCTURAL OPTIMISATION METHODS

Optimisation means minimisation or maximisation. Design optimisation is always based on a criterion such as cost, strength, size, weight, reliability, or performance. A functional design is one that meets all of the pre-established design requirements, but allows for improvements to be made in certain areas of the design. Another important fact to keep in mind is that while an engineering system consists of various components, optimising individual components that make up a system does not necessarily lead to an optimised system (Moaveni 2008).

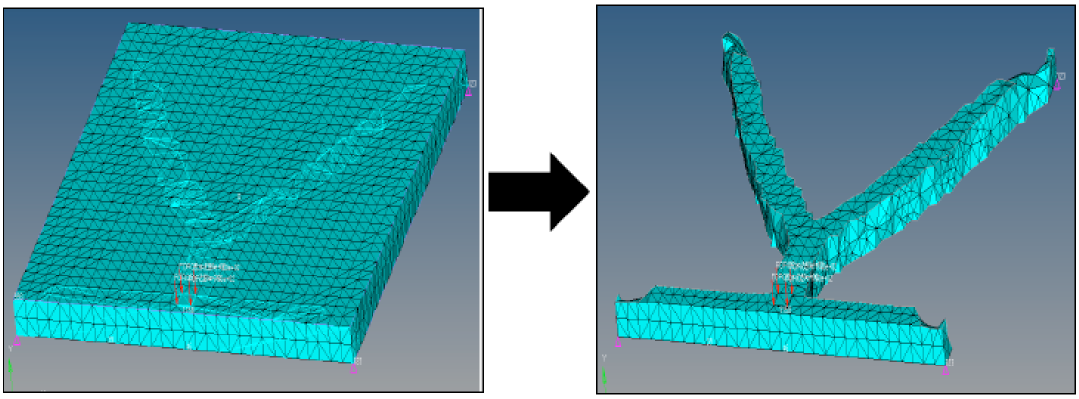
An evolutionary structural optimization (ESO) method was used to find the best way to design an optimised shape for the raised access floor panel. The shape optimisation of raised access floor panels was focused only on the weight of floor panel as an optimisation criterion. The shape optimisation procedure of the raised access floor panels involved making an initial design, performing analysis, evaluating the results and deciding whether or not initial design could be improved until the final design and optimised design was achieved. The initial design of the raised access floor panels was obtained based on the topology optimisation, which could be optimised to the shape of floor panels. This initial design of the raised access floor panel underwent a finite element analysis to inspect the stress concentrations on the panel and deflection of the panel in order to check that it met the British Standard BS EN 12825: 2001 Raised Access Floors and PSA MOB PF2 PS/SPU Raised Access Floors: Performance Specification for raised access floor panels. Design modification of the raised access floor panel took place and the analysis performed again. This was repeated until optimisation achieved a light weight panel which met the required strength criteria.

2.1 SHAPE OPTIMISATION ANALYSIS

Altair OptiStruct, which is in the Altair Hypermesh software, was the method of shape optimisation analysis used in the optimisation of the raised access floor panels. The criteria used for optimisation of the panels were topology, sizing and shape optimisation in finite element analysis. The design process for the optimisation of the panels had to meet the requirements of deflection and stress as given in the British Standard requirements.

The design optimisation process was carried out in two phases. In the first phase, a topology optimisation was performed to obtain a first view of an optimal configuration for the structure as an initial design with optimal load paths. The resulting configuration was interpreted to form an engineering design (Krog et al. 2002). In the second phase, the design process for topology, sizing and shape optimisation took place, which gave a good initial design for the new raised floors panel based on the topology optimisation. This two-phase design processes also gives an indication of the weight savings, which can be achieved on the raised floor panels.

The boundary conditions used in the shape optimisation analysis represent a single load at the edge of the floor panel, which was supported by four pedestals. The result for the optimisation of the raised floor panel is shown in Figure 1. The load at the edge of the panel is directed linearly to the two closest pedestals and to the other two pedestals in a V-shaped as shown in Figure 1(b). Substantial material from the panel was removed and the optimisation was very effective but is only valid for this single load case. If the load was to move to the other three edges the load pattern will rotate correspondingly. For a load at the centre of the panel an X-shape loading pattern is developed. If loads are applied at a number of random positions the optimisation will be less effective. The results of this optimisation analysis suggest the best design for a floor panel would be one, which contains ribbing.



(a) **(b)**

Figure 1: Topology, Sizing and Shape Optimisation Process for design of raised access floor panel.

2.2 OPTIMISED FLOOR PANEL

In order to reflect manufacturing requirements for minimum production time, the thickness of the ribs and edges should be kept to a minimum of equal to or less than 10 mm. This could be achieved by designing ribs, which were 20 mm or 30 mm apart as shown in Figure 2 and also produce a structure with a rectangular array of cavities as shown in Figure 3.

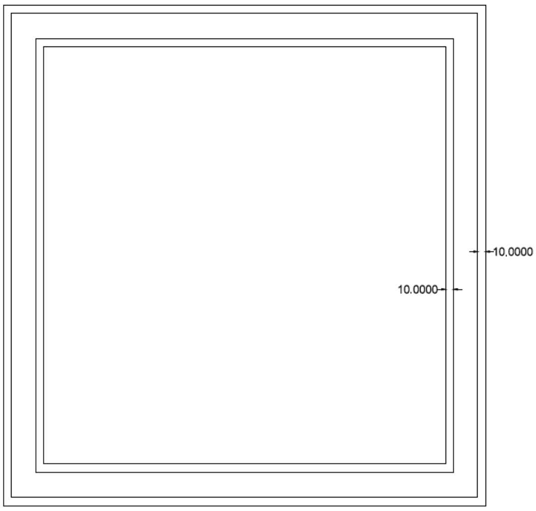


Figure 2: Ideal thickness of the ribbing for optimised panel

The optimum design of the raised access floor panel was constructed based on having a strong edge along the periphery of the panel with sides connected by ribs as shown in Figure 3. This panel has a parametric array of different sizes rectangles with 10mm ribs between them.

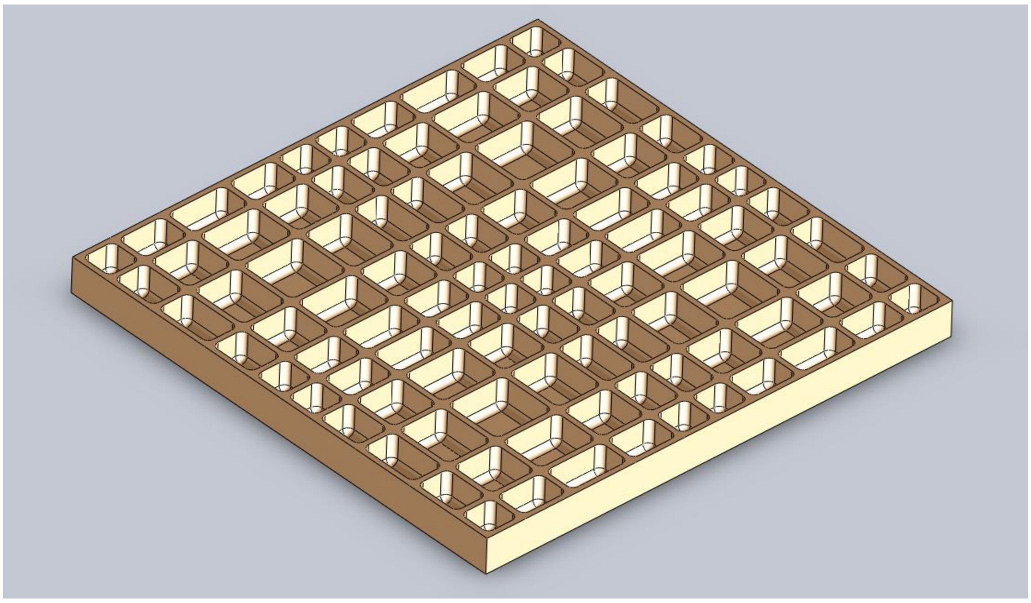


Figure 3: Structure with a rectangular array of cavities

A parabola physical shape optimised was added to the results for the panel to see if the weight could be reduced further. The floor panel is shown in Figure 4. This panel had a weight of approximately 6.5 kg compare to 11 kg of the traditional floor panel and achieved the British Standard and PSA specification for deflection and loading.

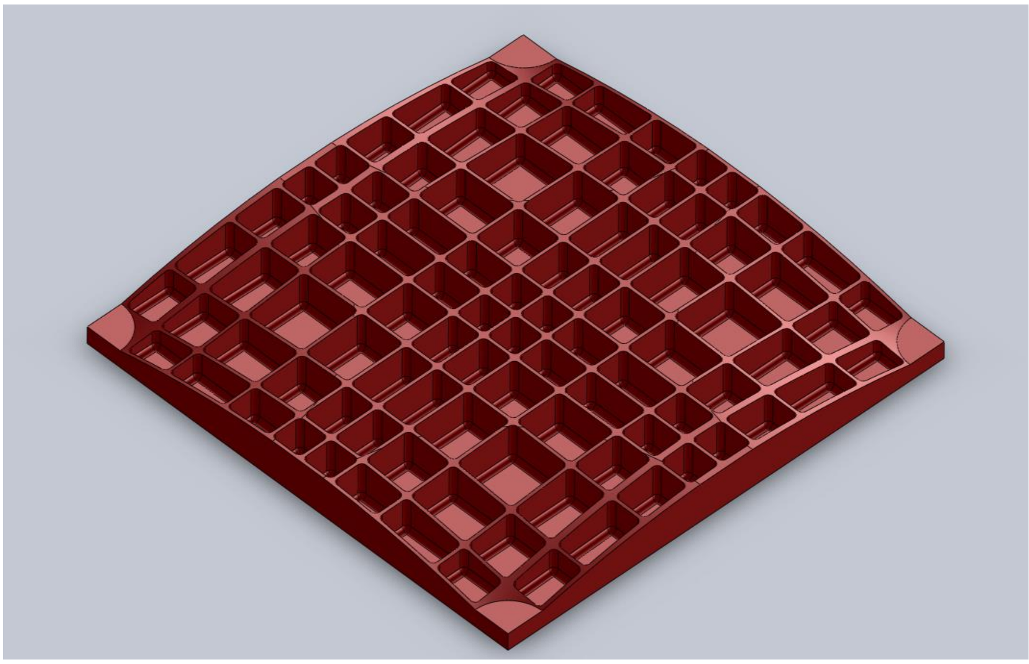


Figure 4: Optimum design of raised floors panel

3. DISCUSSION

Finite element based topology, sizing and shape optimisation tools have been used to design and develop new raised access floor panels. The method is consists of a two phase design process. Firstly, a topology optimisation was performed on the raised access floor systems in order to obtain a first view on an optimal configuration for the raised access floor panel structure, which is important to give the initial design with optimal load paths. Secondly, the suggested configuration of the raised access floor panel structure was interpreted to form an engineering design and this design was then optimised using sizing and shape optimisation analysis to meet British Standard raised access floor panel requirements. When considering topological optimisation it has to be connected with respect to the manufacturing requirements and costs. The topology optimised design of raised access floor panel was obtained from the shape optimisation analysis as was enhanced by appropriate ribbing scheme to further reduce the overall weight of panel and make it manufacturing friendly and cost effective.

4. CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the research led to the development of a new raised access floor panel designed to be more easily manufactured and 40% lighter than the standard form of floor panel currently used in industry. This new raised access floor panel has the economic advantages of being lighter in weight and requiring less material to manufacturing them than traditional raised access floor panels. Therefore, the new raised access floor panel has significant impact to reduce the total cost of building with improved manual handling on the construction site and reduced transportation costs, which add to the sustainability of the product.

The recommendation is the optimised design of raised access floor panel should be tested on the existing raised access flooring system in order to confirm that this optimised design can provide efficient stress and stability component designs even though shape optimisation tools have been successfully used in so many industries.

5. REFERENCES

Burgess (2009). KTP Project – To design and develop an advanced new access flooring panel system. Burgess Architectural Products Ltd.

Krog, L., Tucker, A. and Rollema, G. (2002). Application of topology, sizing and shape optimisation methods to optimal design of aircraft components. Altair Engineering Ltd.

Moaveni, S. (2008). Finite Element Analysis: Theory and Application with ANSYS, Third Edition. Pearson International Edition.

PSA Specialist Services (1992). MOB PF2 PS/SPU Platform Floors (Raised Access Floors): Performance Specification. PSA Specialist Services.

Schiavon, S., Lee, K. H., Bauman, F. and Webster, T. (2010). Influence of raised floor on zone design cooling load in commercial buildings. Energy and Buildings 42, 1182-119.

Zhang, G., Yang, J. and Sidwell, A. C. (2002). Raised floor system: a paradigm of future office building fitout? Advances in Building Technology 1577–1584.

Deployable Structures in the Built Environment

Osahon Joshua Umweni
Nottingham Trent University,
Osahon.umweni@ntu.ac.uk

Abstract

The occurrence of natural disasters has been on the increase for the last decade. One of the most prominent incidences has been the occurrence of floods which has been experienced in developing and developed countries. This has been the experience of Turkey and the United Kingdom. The world has also experienced hurricanes and earthquakes in the recent times. Global temperature change has been blamed for many of these natural disaster occurrences. Man-made disaster incidences have also been recorded such as wars, chemical plant explosions, building failure/collapse and have been on the increase. The consequences of these occurrences have resulted in the loss of lives and properties, displaced communities/stranded communities and also economic stagnation. It is therefore imperative that there should be structures or ways to mitigate the loss of general infrastructures especially housing. These structures should be readily available and meet the temporary needs of the community. Deployable structures are known to be light-weight in nature and characteristic reduced time frame to deploy in its predetermined configuration.

Key Words: *Deployable structures, disaster, lightweight structures.*

1. INTRODUCTION

Disasters can occur at any time in a year. They can occur naturally or man-made. Most of the mitigation methods have been generally non-structural in their approach to disaster mitigation. It also includes providing barriers against an impending disaster. But as seen in certain parts of the UK, floods for example went over the flood defence system because of the rise in water levels which many schools of thought have attributed to global warming. The aftermath of these disasters have led to displaced communities, stranded communities, financial ruins and other knock-on effects. For example, Turkey is mainly prone to three (3) forms of natural disasters which are Earthquakes, Floods and Landslides. Deployable structures tend to provide part of the palliative measures during the aftermath of these natural and man-made disasters.

They are generally structures that have the capacity or capability to change geometry from a compact configuration to an operational configuration and still be able to withstand service loads safely. This main characteristic makes it easy to transport and store. They have been employed in various scenarios, especially as solutions for space related problems. However, their applications as solutions to environmental problems seem to be unknown or have not been fully researched into. This paper is in response to the global climate change experienced in the built environment that has been said to be the cause of most natural disasters in the last decade. It is also to propose ways to overcome these boundaries to improve the sustainability of structures during the aftermath of these natural disasters using deployable structures.

When disasters occur, displaced communities are most times placed in tents which are usually designed for a few days to months. However, the reality is that communities remain in those tents for years as it takes a considerable long time for communities to be given housing or relocated. The tents therefore become dilapidated and in many cases destroyed. These tents also are not energy efficient and therefore occupants are susceptible to diseases as seen in the case of the Haiti disaster a few years ago. It is therefore necessary to design deployable structures to have a considerable life span to give government agencies adequate time to rebuild structures. The materials necessary during the construction of these structures need to be readily available to the local community and also recyclable. The ease of construction of these proposed deployable structures will also have to be low skill. Another consideration should also the flexibility and adaptability of the structural concept. A one solution model is imperative to meet the demands of the changing and dynamic situations after the occurrence of disasters.

In some situations where there is a break out of wars or other forms of man-made disasters (wars and conflicts, explosions, fire outbreaks, poor construction methods and designs) that causes an unexpected destruction of the buildings and infrastructures. Popular solutions provided usually included temporary protective covers, relief materials, temporary shelters, temporary storage and other situations. During the provision of theses, time is consumed to make available and therefore it is imperative that structures that are needed to readily solve the aforementioned issues should be readily available.

Deployable structures is proposed to be the reasonable solution in disaster ravaged communities most importantly in scenarios where it is necessary to evacuate people or to minimize the impact of the flood on the economic activities of communities especially when the main infrastructures have been damaged. "*Deployable structures can be defined as structures that have the capability to be transformed from a bundle of compact configuration to an enlarged operational configuration that can carry load safely under service loads"*. (Umweni, 2011: 9). When deployed into their operational geometry, they can ease storage and/or transportation.

2. GENERAL PRINCIPLE OF PANTOGRAPHS

There are numerous ideological schools of thought on the groups of deployable structures, however, this paper will be concerned with the Pantograph deployable structures. Pantographs usually consist of scissor-link units also known as duplets which is a combination of two uniplets. A duplet element consists of three nodes on the pin-jointed and rotating on their pivot node with one degree of freedom. "*No torsion is produced in the members, axial forces and bending moments can be developed"* (Kaveh & Davaran, 1996).

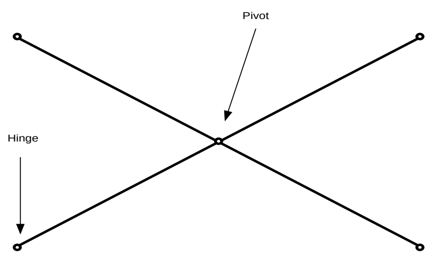


Figure 1: A duplet (by author)

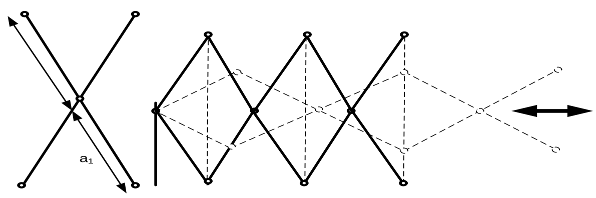


Figure 2: A duplet and a Pantograph (direction of deployment) (by author)

The concept of the pantograph to proffer a solution in form of a deployable bridge or modified for a deployable shelter will be discussed. It can be applied in disaster ravaged communities in developing countries like Nigeria and other similar scenarios in other countries such as

Turkey who are disaster prone. To attain this arrangement, the duplet units must be parallel to each other before and after deployment process.

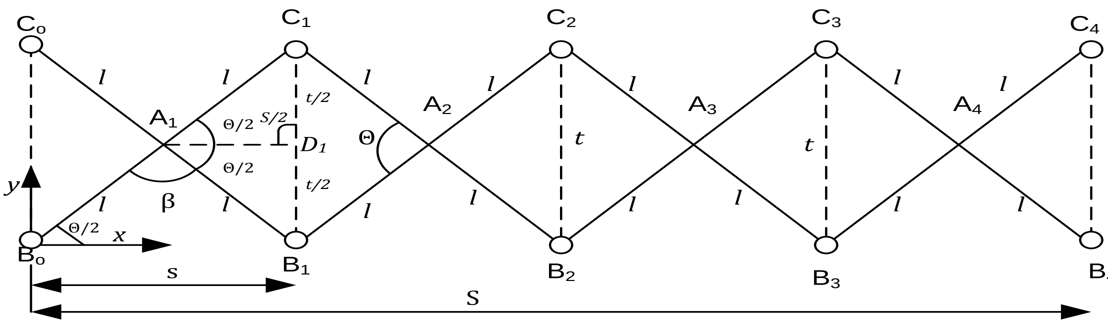


Figure 3: Rectilinear Scissors Mechanism (by author)

In a rectilinear scissors structural mechanism, the scissors-like units have bars that have the same length and the pivot is at the midpoint of the bars as shown in the figure above. Based on this configuration, a perfect planar surface is attained. Its deployment criteria is given by:
$a_{i-1} = b_{i-1} = a_i = b_i = a_{i+1}$

$$= b_{i+1} = \cdots = a_n = b_n = l \text{..........................} 1$$

Where *(s)* is the span of a duplet, *(N)* is the number of duplets, *(θ)* is the angle between beams or bars, *(S)* is the span of the entire pantograph structure, *(β)* is the deployment angle, *(t)* is the unit thickness and *(L)* is the length of beams or bars. If at least three of the variables are known, analysis can be carried out for the other unknowns. Since L$(2l)$, *S* and *θ are* known, and angles *θ* and *β* the same by geometry;
Hence, the span *(s)* of a duplet is given by

$$s = 2l\cos\frac{\emptyset}{2} \text{................................} 2$$

Based on the above equation *N* can therefore be calculated. Consequently the cosine rule of triangles can be applied for triangles $A_1B_0B_1$, and β can be obtained using the equation below

$$N = \frac{S}{s} \text{.................................} 3$$

$$\beta = \cos^{-1}\left[1 - \frac{s^2}{2l^2}\right] \text{...........................} 4$$

The thickness of a duplet *t* can be derived using Pythagoras' theorem of triangles $C_1A_1D_1$. Other variables for the ***Nth*** duplet units can be derived in accordance to origin B_0 of the system:

$$t = 2\sqrt{l^2 - \frac{s^2}{4}} \text{................................} 5$$

$$x_{B_N} = x_{C_N} = N2l\cos\frac{\emptyset}{2} \text{...........................} 6 \text{ for nth number of spans in the x- direction}$$

$$y_{B_N} = 0 \text{ and } y_{C_N} = 2l\sin\frac{\emptyset}{2} \text{..................................} 7 \text{ for nth number in the y-direction}$$

3. NOVEL DEPLOYABBLE BRIDGE STRUCTURE PROPOSAL FOR A DEPLOYABLE SCISSORS UNIT

Adaptability is the ability of an element to accommodate different requirements for different situations or changes in the lifetime of the structure. The adaptability concept can be categorised into five main strategies (Moffatt and Russell 2001);

- Flexibility
- Convertibility
- Expandability
- Durability
- Design for disassembly.

This proposal is as a result of the study of pantographs as deployable structures. The structure is characterized by a novel topology for the Scissors like element MG-SLE (Modified gear-SLE). This will enhance the scissors structure to provide a wide variety of configurations with the same span to cover and also a multiple applications in various or as when needed scenarios. The MG-SLE morphology is expected to provide a framework for the design of deployable structures and static structures in general. It will also allow the concept of sustainability to be integrated into structural engineering designs.

For pantograph structures, their form and ability to change position for the resulting structures is determined by the topology and geometry of the Scissors element. There have been three main topologies identified for pantographs influenced by the shape of bars and position of hinge. They could be rectilinear, polar and angulated. Through these topologies, lines and grinds, arches and vaults, domes have been designed for deployable structures by various designers. These topologies were the foundation for the new forms of Scissors element Solutions or alternatives for deployable structures. Yenal Akgun (2011) proposed to include a hinge on each bar of the Scissors element. This allowed changing from a rectilinear to angulated scissors like elements.

Daniel Rosenberg (2009) design a scissors structure where the middle hinge between the bars for an oblong union is switched from a symmetric to an asymmetric unit. Sala and Sastre (2013) proposed that the use of a telescopic system in combination with the scissor like mechanism. The resulting structure was able to switch from a symmetrical to an asymmetrical units by changing the length of the bars. Most of the designers noticed that from changing the basic Scissors element or duplet, it is possible to alternate the shape and find formal options with a single structural solution. Even with this knowledge, most topologies have only catered for deployable roofing systems. One of the forms of pantograph mechanisms is the rectilinear pantograph mechanism. Below is a footbridge spanning 5m (with 1.5m in width x 2m high) by using the above equations. The ANSYS workbench software was used to model the bridge.

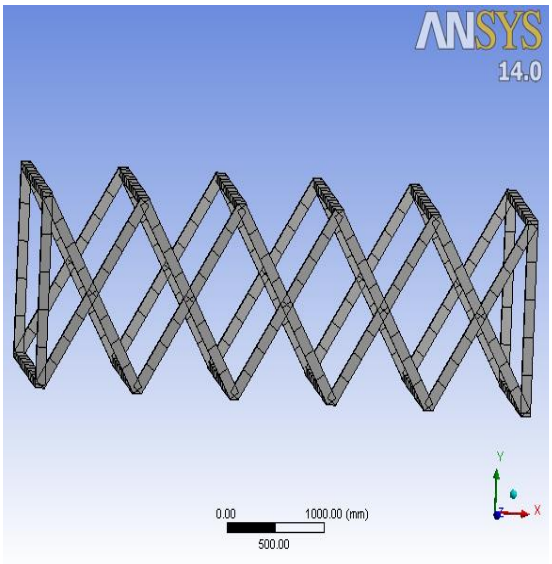


Figure 4: 3-D model of Bridge model

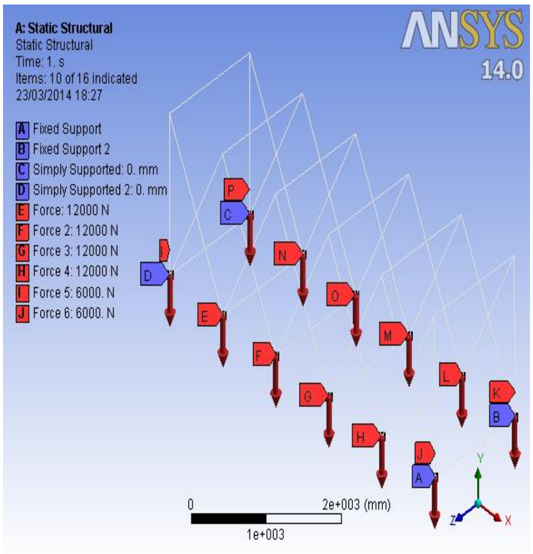


Figure 5: Forces applied to structure

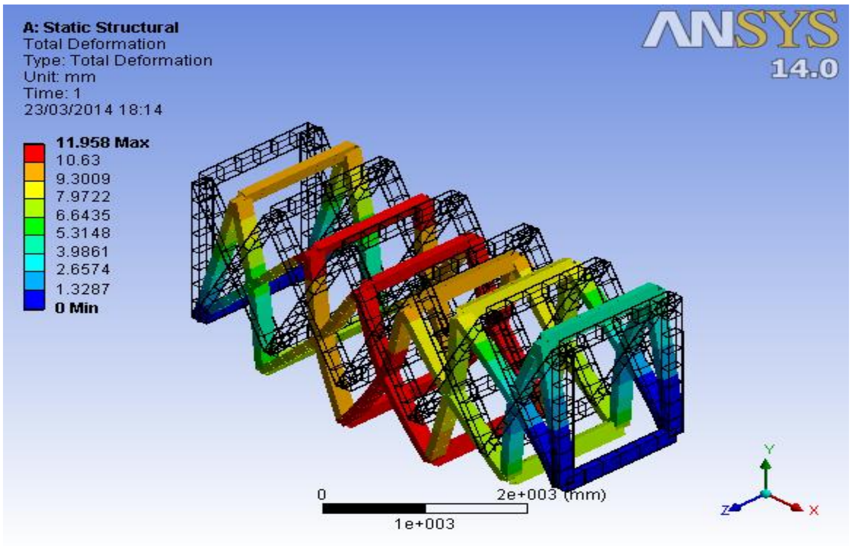


Figure 6: Total Deflection of Novel Deployable Bridge

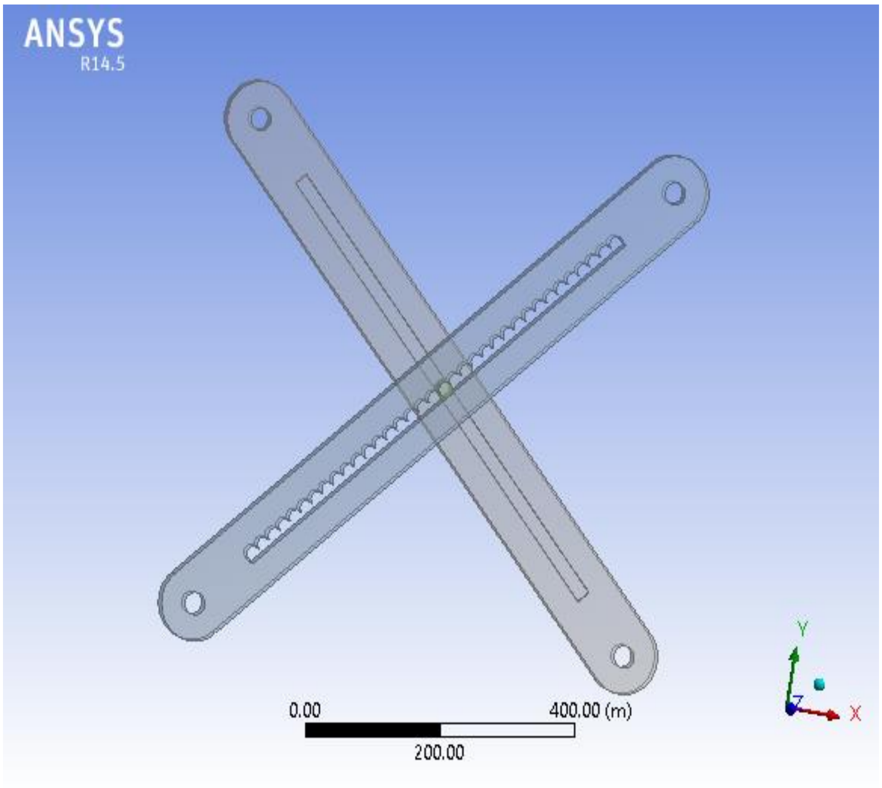


Figure 7: MG-SLE model (author)

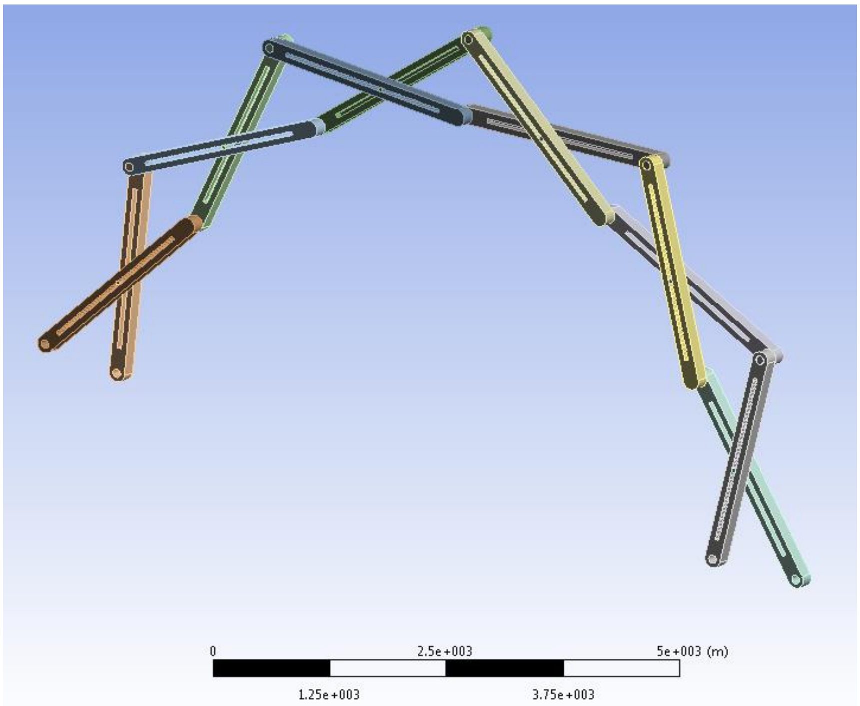


Figure 8: Deployable Shelter model (author)

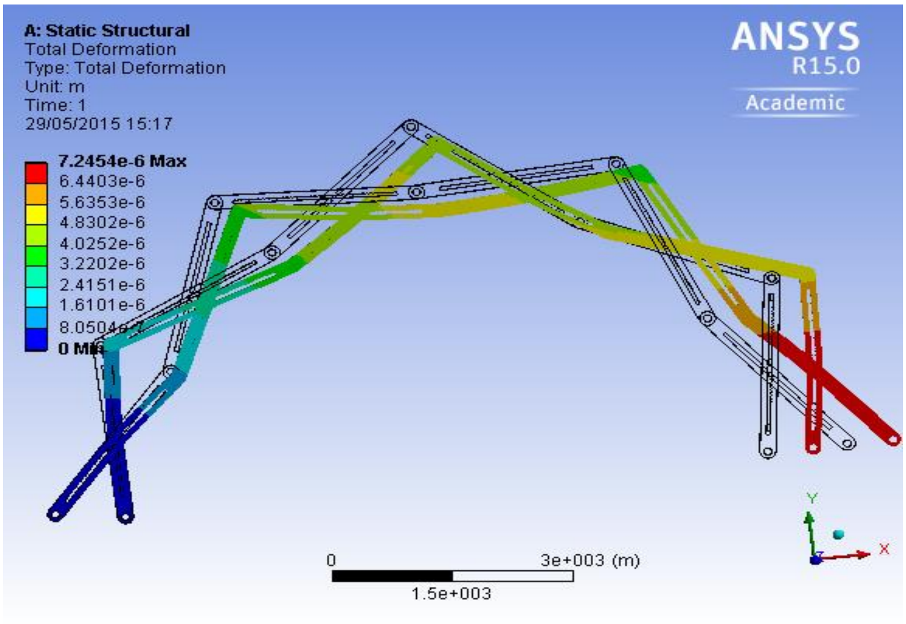


Figure 9: Deployable Shelter model (author)

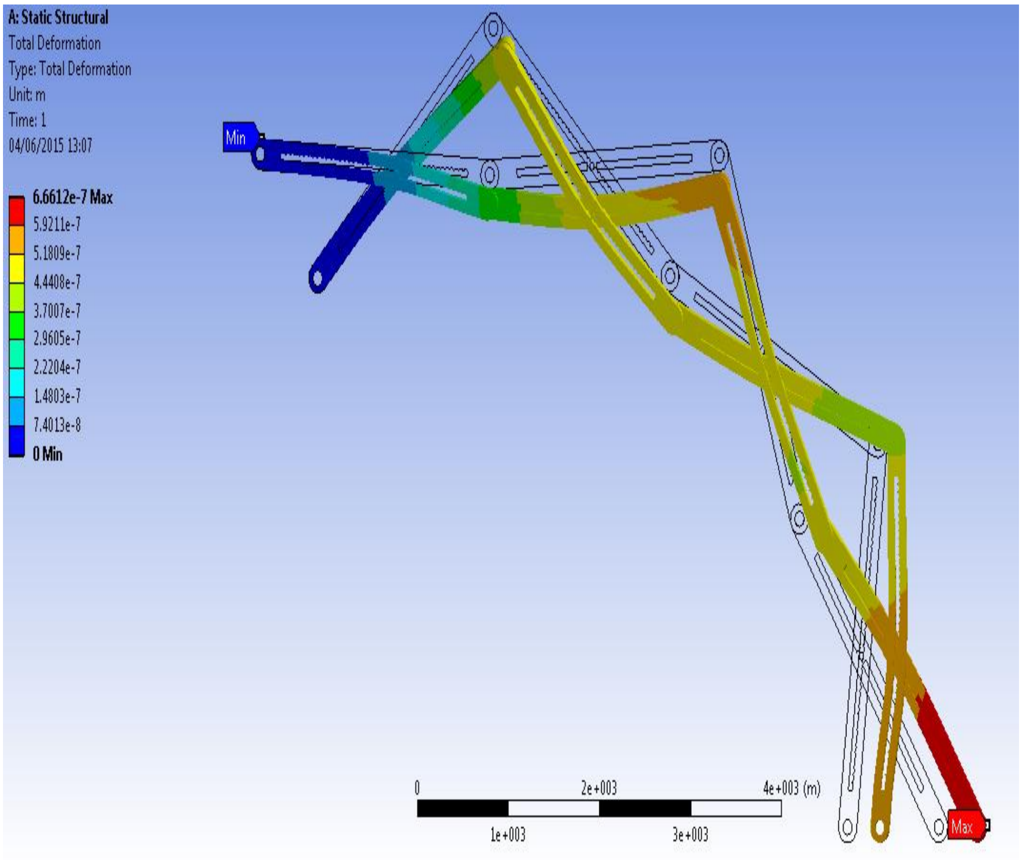


Figure 10: Deployable Canopy model (author)

4. CONCLUSION AND FURTHER RESEARCH

The purpose of the work presented is to develop a novel concept for deployable bar structures for the challenges experienced today which is a variation from existing concepts.

This will lead to an architectural, sustainable and structurally viable solution for deployable applications. Another objective was to provide designers with the means for deciding on how to cover a space or overcome barriers in a disaster aftermath or as part of a static structure with a rapidly erectable deployable structure, based on the geometry of pantograph structures. Finally, further research is beening undertaken for material and structural optimisation with the use of lighter materials such as fibre reinforced plastics as deployable structures should be as light and foldable as possible.

5. REFERENCES

Ballard, E. (2011) Britons Facing Floodwaters May be left without insurance, Aug 19, 2011. http://www.bloomberg.com/news/2011-08-18/britons-facing-rising-floodwaters-may-be-left-without-insurance.html Assessed on January 24th 2014.

Dow, K. and Downing, T. E. (2006) *The Atlas of Climate Change: Mapping the World's Greatest Change*. Brighton: Earthscan; pp. 64-67

Ezema O. (2013) Flood menace in Nigeria: Plateau state disaster, Nigerian Institute of Civil Engineers NICE, Jos 03/03/2013 Assessed on January 10, 2014 http://www.nice-nigeria.org/component/jumi/news-in-full?id=123

Francis C. (2011), Flooding warnings: nearly 500,000 people may face significant flood risk' http://www.telegraph.co.uk/earth/earthnews/8257445/Flood-warnings-nearly-500000-people-now-face-a-significant-flood-risk.html Assessed on January 10 2014

Kaveh, A & Davaran, A. (1996) Analysis of pantograph foldable structures. Computers & Structures, 59(1), 131-140.

Kershi, J and Simon, R. (2005) *The Essentials of the Environment*. London: Hodder Arnold; pp 30 -39.

Major Flood Disasters around Nigeria in 2012, http://premiumtimesng.com/slideshows/major-flood-disasters-around-nigeria-2012 Assessed on January 24th 2014.

Muhammad A. (2012) Plateau State flood kills 33, Assessed on January 10 2014 http://www.bbc.co.uk/news/world-africa-19261581 Nigerian flood kills 363 people and displaces 2.1 million 2012 – Agency. Assessed on January 10, 2014. *http://in.reuters.com/article/2012/11/05/nigeria-floods-idINDEE8A40EH20121105*

Recent natural disaster (2012) Natural Disasters List August 13, 2012-Landslip in Black Sea province, Turkey http://www.disaster-report.com/2012/08/recent-natural-disasters-list-august-13-2012.html accessed on June 20th 2015.

Shah, A. (2013) "Climate Change and Global Warming Introduction." *Global Issues*. 11 Nov. 2013. Web. 27 Jan. 2014. <*http://www.globalissues.org/article/233/climate-change-and-global-warming-introduction*>.

Turgut. P (2011). Times MagazineTurkey's Earthquake Toll a Grim Reminder of Lessons Not Learned http://content.time.com/time/world/article/0,8599,2097898,00.html accessed on June 20, 2015.

Umweni, O. J. (2011) Folding Techniques of deployable structures using the pantograph system and the novel deployable cable chain structural systems as case studies (Masters Degree), University of Salford, Manchester, United Kingdom; pp.9.

Understanding the eco-geomorphological functionality of riparian vegetation for developing sustainable river management strategies

Oral Yagci
Istanbul Technical University, Civil Engineering Faculty, Division of Hydraulics, 34469 Maslak, Istanbul, Turkey
E-mail: yagciora@itu.edu.tr

Abstract

In the last century, most of the natural rivers have been extensively altered by human made engineering structures. The primary reason behind this alteration was the industrialization induced urbanization and the varied production patterns in the society. Nevertheless, towards the end of the last century it has been also witnessed that the river engineering projects were unsuccessful in creating a sustainable ecosystem and they simply omitted the ecological balances in riverine systems. Afterwards a new concept, "river restoration" emerged and considerable efforts have been devoted in this field, especially in the last two decades. In this paper, the summary about the river engineering concept and the new trends in river restoration is very briefly summarized.

Key Words: *River management, Flood, Bank/floodplain vegetation, Living rivers, Ecogeomorphology.*

1. INTRODUCTION

Production patterns, population distribution, as well as the land use have changed dramatically on earth since the beginning of the industrial revolution. During this industrialization process, the increased human-labor demand in the cities caused a shift of the populations from countryside to the cities. The urbanized populations started to demand more and better quality of water. Also, especially in the second half of the last century, as an extension of the technological advances, the energy demand of the societies increased dramatically as well. Because of these reasons, today natural rivers are modified/fragmented by hard engineering structures such as dams, hydropower stations, pumping stations, and weirs.

Moreover, as a result of the urbanization, urban boundaries enlarged towards agricultural land. Due to the ongoing urbanization process permeable zones in basins are replaced by impervious surfaces (e.g. roads, rooftops, parking lots etc.). The enlargement of the impervious surfaces and the installation of sewerage and stormwater systems increase the velocity of water transmission in channels or surface water sewers. This leads to increase in volume of runoff for a given rainfall and generates flashier runoff regime with shorter lag times and higher peak discharges (Brierly and Fryirs, 2005).

Urbanization also affects the sediment yield in the basin in two phases. At the early stages, due to the urban development, fine sediment is generated from construction activities in the basin (Finkenbine et al, 2000; Yorke and Herb, 1978; Wolman and Schick, 1967). Once a watershed has been urbanized, and the channel has adjusted itself to the imposed flow regime, it will no longer be subjected to high sediment load (Finkenbine et al, 2000; Wolman and Schick, 1967) and bed coarsening is observed (Robinson, 1976).

Urbanization induced fragmentation of rivers, increased flood discharges due to the spread of the impervious surfaces in the basin, and modified sediment regime in rivers has a significant impact on riverine ecosystem. The primary objective of this paper is to discuss about the influence of these factors on riverine ecosystems and to deal with the new river management concept, which has emerged during the last three decades as an alternative to the traditional river engineering concept.

2. THE IMPACT OF URBANIZATION ON RIVERS

Particularly just after the industrial revolution the idea that "nature could be transformed, its resources utilized and exploited for the benefit of humanity" was widely adopted by most of the societies. From this motivation, most of the natural ecosystems have been modified due to the reasons presented in previous section. However, it was experienced that systematic degradation of natural ecosystem as an extension of unplanned urbanization, and lack of sustainable development strategies resulted in developing cities vulnerable to flood disasters. Due to the increased flood risks, all around the world, extensive channelization programs have been extensively practiced in different ways by the relevant government authorities. The geomorphic impacts of channelization procedures are summarized in Table 1.

As summarized in Table1, with the traditional river engineering concept, civil engineers attempted to divert, control, fragment and channelize the rivers on earth owing to many different reasons such as to utilize the floodplains, to prevent floods, to irrigate fields, to generate power, to supply water to cities. However, river ecosystems are extremely fragile systems, which cannot simply absorb all these hard engineering structures.
The case study by Callow and Smettem (2007) constitutes an extremely good example in terms of demonstrating the river ecosystems fragility. In this example, in Kent River located in Western Australia, replacement of native deep-rooted perennial vegetation with shallow rooted seasonal crops influenced the ecological, geomorphological as well as the hydrological feature of the catchment. Given the replaced vegetation was less water demanding species, recharge of the groundwater increased dramatically. Due to this reason, rising groundwater led to mobilization of the salt stores and stream salinity increased to a considerable degree. This decrease in the flow resistance in river resulted in channel expansion, bank incision and removal of uncohesive material (Callow and Smettem, 2007).

In the last century, civil engineers have irreversibly modified river ecosystems by applying the methods summarized in Table 1 based on the concept of "river engineering". Today, the world's many natural rivers have been transformed into concrete canals and their ecological and morphological functionality have been underestimated during this process. Nevertheless, the scientific evidence is demonstrating that the major river engineering works have been the main cause of environmental degradation of river and estuarine ecosystems, and a significant factor in the loss of global biodiversity (Williams, 2001). In 1960s, river engineering concept started to be discussed in the society. Environmental activists blamed river engineers owing to the obvious ecological consequences of their channelization and fragmentation practices. Then a new concept titled "river restoration" recently emerged as an alternative to "river engineering" concept. Williams (2001) summarized this concept with the term of "living rivers concept". This concept put into the center of physical and ecological integrity that is intrinsic to a river ecosystem. Williams (2001) compared the two concepts, i.e. river engineering and river restoration (or management), as given below.

Table 1: Traditional river engineering applications: Geomorphic impacts of channelization procedures (modified/summarized/compiled from Brierly and Fryirs, 2005 p. 214; Knighton, 1998, p. 312; Mays, 2010)

Methods	Description	Purpose	Impacts
Overwidening	Widening and deepening of the channel	Increase conveyance capacity and reduce flooding	Reduced velocity, Reduced sediment transport capacity at the reach(deposition) due to the deposition reduced main channel capacity
Channel stabilization and bank protection	Utilization of structures such as paving, concrete lining, gabions, steel sheet piles, mattressing, dikes	Control bank erosion	Loss of bank/floodplain vegetation. No stream variability within the cross-section (vital for fish population).
Levee and floodwall construction	Raise channel banks, increasing channel capacity	Flood protection Confine floodwaters Maintain irrigation channels	Altered bed slope. Reduced floodplain inundation Increased flooding area at the downstream.
Regulation of flow by series of weirs	Channel spanning structures	Flood retention Regulate slope for navigation	Altered bed slope. Reduced sediment conveyance capacity. Modified flow patterns at the downstream. Altered water temperature at the downstream.
Straightening plus concrete lining (realignment)	River is shortened artificial by cutoffs	Flood protection	Reduced lateral connectivity (decreased groundwater recharge). Increased flow velocities and sediment transport rates. Increased flooding area and bank incision at the downstream of the channelized section. Increased variability of water temperature. Stream variability (vital for fish population). Loss of aquatic and riparian vegetation.

Table 2: The comparison between two river engineering and river restoration (direct quotation from Williams, 2001)

River Engineering	River management
Single purpose	Multi-objective
Engineering expertise	Interdisciplinary
Construction focus	Continuum of interventions
Reach scale	Watershed scale
Hydraulics time scale	Geomorphic time scale
Monitoring externalized	Monitoring internalized
Limited accountability	Long term commitment
Maintenance divorced from design	Maintenance is management activity

3. FUNCTIONALITY OF RIPARIAN AND AQUATIC VEGETATION IN RIVER ECOSYSTEMS

As described above, the channel conveyance capacity of rivers was modified by hard engineering structures and the lateral connectivity between main channel and bank was reduced due to the concrete linings. One of the serious consequences of these alterations was the modification of the return periods of bankful flows and loss of the functional role of the floods. Essentially, floods are the part of natural hydrological-morphological-ecological processes and play significant role in the creation of a sustainable riverine ecosystem. Floods recharge the groundwater, replenish the topsoil and nutrient supplies on floodplain, provide water to seedlings and trees requiring periodic inundation, flush out anoxic or saline waters or deposits of fine sediment, nourish riverfront forests (best habitat of all for wildlife) (Palmer, 2014; Gordon et al, 2004; Ifuku and Shiono, K, 2005). In addition to the adverse effect of channelization practices, fragmentation of rivers also affected the riverine ecosystem appreciably. The inherent streamflow variability is recognized as a major driver for most processes occurring in fluvial and ecological processes (Doulatyari et al, 2014). In the pertinent literature there is a general agreement that increased temporal and spatial variability in streamflow generate wider aquatic-zones and contribute in regeneration of fish and other aquatic population. However, presently most of the streamflow on Earth is regulated by the dams and hydropower stations. The applied daily hydropeaking prevents the generation of the armor layer in river bed, which can be regarded as the self defense mechanism of a river against erosion (Laronne et al., 1994; Reid and Laronne, 1995; Reid et al., 1996; Hassan et al., 2006).

Recent findings highlighted the significance of creating living rivers for the sustainable river management strategies. Indeed vegetation is a ubiquitous agent in river ecosystems and provides indispensable ecological services. Riparian and bank vegetation increases the bank stability and prevent bank incision, provides habitat for animals, improves water quality (removing nutrients and releasing oxygen to the water), traps suspended sediments (stabilizing sediments) and heavy metal, promotes biodiversity (creates different habitats, spatial heterogeneity in stream velocity), regulates water temperature (Luhar, 2008; Chen, 2012)

4. CONCLUSION

In the last century, the World rivers have been tremendously modified by different hard engineering structures due to several reasons. This subsequently altered the river ecosystem to a great extent and led to some irreversible ecological and morphological consequences. After the observation of undesirable outcomes of river modification, especially in the last two decades an explosion of interest in creation of sustainable river management strategies was observed. This increasing ecological and hydrological awareness brings a better understanding of crucial role of riparian vegetation which is geomorphological agents, ubiquitous at the interface between terrestrial and aquatic zone.

Past experiences clearly denoted that river are highly fragile systems, once damaged the rehabilitation of the system is extremely hard, expensive, labor demanding and carbon producing process. From this perspective, for the future, it is recommended that planning, design, and operation of hard engineering structures should consider the soft engineering approaches which involves creating and restoring a sustainable ecosystem that has value to both humans and nature.

5. REFERENCES

Brierly, G. J. Fryirs, K. A. (2005). Geomorphology and River Management, 801 Blackwell Publishing,.

Callow, J.N., KRJ Smettem, (2007). Channel response to a new hydrological regime in southwestern Australia Geomorphology, 3-4, 254-276.

Chen, Z., A. Ortiz, L. Zong and H. Nepf. (2012). The wake structure behind a porous obstruction and its implications for deposition near a finite patch of emergent vegetation. Water Res. Res., 48, W09517, doi:10.1029/2012WR012224.

Doulatyari, B., Basso, S., Schirmer, M., Botter, G., (2014). River flow regimes and vegetation dynamics along a river transect. Advances in Water Resources, 73, 30-43.

Finkenbine, J. K., J. W. Atwater, and D. S. Mavinic. (2000). Stream health after urbanization. Journal of the American Water Resources Association 36:1149–1160.

Gordon, N.D., McMahon, T.A., Finlayson, B.L., Gippel, C.J., Nathan, R.J., (2004). Stream Hydrology: An Introduction for Ecologists, 2nd Edition, 448p.

Hassan, M.A., Egozi, R., and Parker, G., (2006). Experiments on the effect of hydrograph characteristics on vertical grain sorting in gravel bed rivers. Water Resources Research, VOL. 42, W09408, doi:10.1029/2005WR004707.

Ifuku, M, Shiono, K., (2005). Prediction of turbulence flow structure in compound channel with roughened floodplain using Large Eddy Simulation. Proceedings of the 4th International Symposium on Environmental Hydraulics & 14th Congress of Asia and Pacific Division, International Association of Hydraulic Engineering and Research, 15-18 December 2004, Hong Kong.

Knighton, A.D., (1998). Fluvial forms and Processes: A new perspective. Arnold, London.

Laronne, J. B., I. Reid, Y. Yitshak, and L. E. Frostick (1994), The nonlayering of gravel streambeds under ephemeral flood regimes, J. Hydrol., 159, 353– 363.

Luhar, M., Rominger, J., Nepf, H. (2008). Interaction between flow, transport and vegetation spatial structure, Environ. Fluid Mech. 8 (5-6) , 423{439. doi:http://dx.doi.org/10.1007/s10652-008-9080-9.

Mays, L.W., (2005). Water Resources Research, Wiley, 842 p.

Palmer, T. (2014). FEMA Flood Control Policy in Desperate Need of Overhaul.

Reid, I, Laronne, J.B.. (1995). Bed load sediment transport in an ephemeral stream and a comparison with seasonal and perennial counterparts. Water resources research, 31(3), 773-781.

Reid, I, Powell, D.M., Laronne, J.B., (1996). Prediction of bed-load transport by desert flash floods. Journal of Hydraulic Eng., 122(3), 171-173.

Robinson, A. M., (1976). The Effects of Urbanization on Stream Channel Morphology. In: National Symposium on Urban Hydrology, Hydraulics, and Sediment Control. University of Kentucky, Lexington, Kentucky, pp. 115-127.

Wolman, M. G. and A. P. Schick, (1967). Effects of Construction on Fluvial Sediment, Urban and Suburban Area of Maryland. Water Resources Research: 451-464.

Williams, (2001). River engineering versus river restoration, ASCE Wetlands Engineering & River Restoration Conference, Reno, Nevada, August 28, 2001

Yorke, T. H. and W. J. Herb, (1978). Effect of Urbanization on Streamflow and Sediment Transport in the Rock Creek and Anacostia River Basin, Montgomery County, Maryland, 1962-74. Geological Survey Professional Paper 1003, U.S. Government Printing Office, Washington, D.C.

Sustainable assessment of structures and materials using ground penetrating radar (GPR)

Robert Evans
Nottingham Trent University, robert.evans@ntu.ac.uk

Abstract

Ground penetrating radar (GPR) is a non-destructive, non-invasive device that can be used to investigate materials in buildings, structures and the ground. Its use relies on recording the reflections of radar waves that are transmitted into materials. This paper provides an overview of GPR, a brief explanation of its principles of operation and application, suggests areas where its use may be appropriate in the context of buildings and structures, and includes some case studies from engineering investigations conducted by the author to highlight examples of the information it can provide. The technical information that GPR can commonly provide includes material depths and thicknesses, locations of excessive moisture or deterioration, and the location of steelwork within construction materials. Whilst reducing uncertainty in data obtained from building and structural investigations, other advantages compared to alternative intrusive investigations include less time and costs for investigations, less disruption to users of the building / structure, and less material required for subsequent repair and maintenance work. This paper also highlights, however, some limitations of the technique which should be considered in order to optimise the success of GPR investigations, such as the necessity for specialist knowledge in operation and data interpretation, and the limited GPR signal penetration within certain materials. Overall, the potential for use of GPR in the determination of material and structural properties in the built environment is highlighted.

Key Words: *Ground penetrating radar, maintenance, material assessment, non-destructive, non-invasive.*

1. INTRODUCTION

The assessment of the conditions and properties of existing buildings, structures and engineering materials is a common requirement in a number of areas of the built environment sector. Obtaining accurate information can sometimes be problematic because of a lack of, or uncertainty with, exisiting records. A potential solution is through the application of ground pentrating radar (GPR) which, in comparison to other investigations methods, can reduce time, costs and damage to materials when assessing existing structures and materials and can also increase certainty (i.e. reduce risk) in knowledge of existing conditions of buildings and structures.

GPR is a material investigation technique which has the potential for sustainable built environment applications such as the assessment of the current condition of structures for maintenance or retrofit, identification of pipework locations, leaks and areas for repair within underground heat distribution networks, and overall can reduce the need for destructive investigations of existing building materials whilst obtaining information concerning their properties and condition. Typically, the type of information that is obtained from GPR includes the thickness / depth of materials, the presence of steel work, location of voids, location of areas of excess moisture and it may also be possible to determine a general appraisal of the overall condition of materials e.g. sound or deteriorated.

This paper provides an overview of GPR, a brief explanation of its principles of operation and application, suggests areas within the built environment where its use may be appropriate in the context of buildings and structures, and includes some case studies from wider engineering investigations conducted by the author to highlight examples of the nature of the information it can provide.

1.1. What is ground penetrating radar (GPR)?

GPR is a non-destructive, non-invasive device that relies on recording the reflections of radar waves that are transmitted into materials. A lack of appreciation and knowledge regarding GPR has in the past led to its capabilities sometimes being overstated, or to it being applied in an inappropriate manner, which can lead to disappointing results. Hence, its use requires specialist knowledge and careful interpretation of data. However, when applied correctly, it is one of the most versatile and useful investigation tools available to the civil engineer. Daniels (2004) provides a comprehensive overview of the technique, including its main applications, limitations and data processing procedures.

Radar waves are a type of electro-magnetic (EM) wave, and there are many different types of EM wave (e.g. gamma-rays, infra-red, ultra-violet, visible light, microwaves, radio waves). GPR EM signals (waves) operate at the radio and microwave frequencies, which is where the acronym “radar” originates (RAdio Detection And Ranging). GPR waves travel through most solid (and liquid) materials, such as concrete, asphalt, brick, rock, soil, fresh water, etc., and when the EM radar signal travels from one material into a second material (e.g. from soil in to rock, or asphalt to concrete, or air to water), some of the radar signal is reflected back from the material boundary and some of the signal continues into the second material (see Figure 1). Note: the reflection of GPR signals at the boundary of two different materials occurs in most situations, but not always. This is discussed further below.

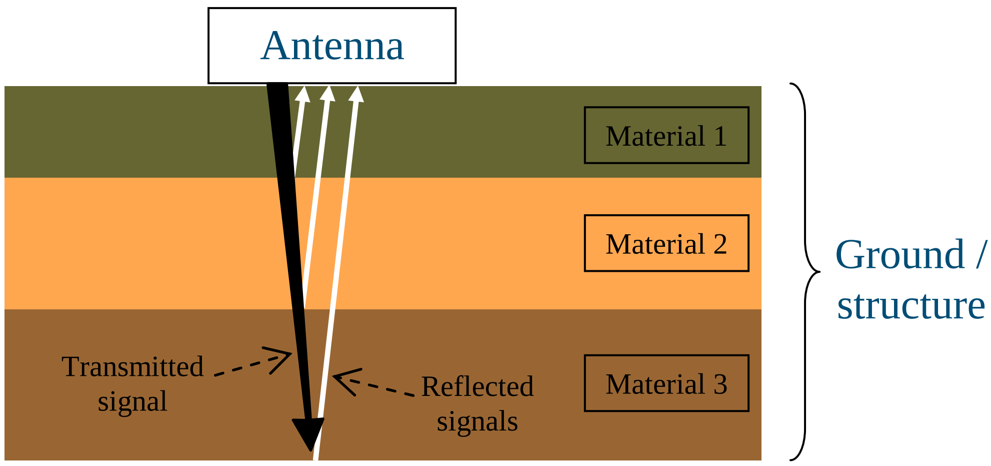


Figure 2. General principle of reflections of GPR signals from a layered structure

1.2. What governs the data obtained from GPR?

The passage of GPR signals through a material are largely governed the materials 'electrical permittivity' (i.e. its ability to store (i.e. 'permit') an electric field (i.e. EM energy) that has been applied to it). This property is often reported as the ratio of the permittivity of the material relative to the permittivity of a vacuum, known as the 'relative electrical permittivity' or the 'dielectric constant' (ε_r). The velocity of a radar wave and the amount of radar energy reflected from a material boundary is governed by the contrast in ε_r values of the two materials.

Another material property which affects GPR signal propagation is electrical conductivity (σ). The higher the electrical conductivity of a material, the more that GPR signals will be attenuated (i.e. signal amplitude will reduce rapidly as it travels through the material). Factors that increase conductivity include a high amount of salts present in water in the material, and the presence of clay minerals. Hence, the presence of water and clay minerals can reduce the effective penetration depth of a GPR investigation.

The frequency and velocity of GPR signals will determine the wavelength (distance between successive EM 'waves'). The higher the frequency of the radar signal, the shorter the wavelength and hence the better the resolution (i.e. precision of data) but the less signal penetration (i.e. shallower depth to which can be 'seen'). However, signal frequency also influences the attenuation of the GPR wave. For example, typical GPR signal penetration depths for a damp sandy soil might be perhaps 0.5m for a signal frequency of 1500MHz, but perhaps 5m at a lower signal frequency of 100MHz. So, there is a compromise: Higher frequency of radar signal provides better data precision but less depth penetration.

1.3. What data can GPR provide?

The type of information that GPR can provide has been outlined above. Common applications where GPR investigations are utilized include in the utility sector for location and condition checks of pipework, road pavement and bridge evaluations for quality assurance or maintenance investigation, archaeological investigations before excavations are conducted, establishing geological settings for geotechnical and mining projects, and for the investigation of ice and snow – for example to monitor glacier thickness. The use of GPR for structural and building investigation is a growing area commercially but one in which there is perhaps not widespread appreciation.

The potential data that GPR can provide is wide ranging, and when considering the entire life cycle and scope of a building or community, there may be several instances where it is essential to establish material or structural properties (e.g. site investigations before construction commences, quality assurance checks during the construction phase, establishment of existing conditions for planning of retrofits, and condition assessments for planning of maintenance works). By providing examples and case studies below (see Section 2) it is hoped that the ability of GPR, as well as its limitations, can be highlighted and that lessons can be drawn on the applicability of GPR in the built environment sector, specifically for its application in relation to sustainable buildings and communities.

Usually, the collection of data involves the GPR antenna being moved along the material surface as distinct 'pulses' are transmitted into the material at set distances apart. A 'detailed' GPR survey might involve pulses transmitted every cm along a survey line. The travel time and amplitude for reflections of the pulses to be recorded back at the antenna are then used to build up a cross section of GPR data on the material being investigated. The travel time of reflected signals can be converted into a depth (if the speed of the GPR signal within the material is known, via calibration or estimation).

2. EXAMPLES OF APPLICATIONS OF GPR

The following section provides some examples taken from the authors experience of structural and material investigation, where several parameters were investigated successfully, but also in which limitations and uncertainties of the technique are highlighted.

2.1. Investigation for maintenance works

Various methods can be used to assess the condition of road pavements, so that maintenance can be prioritized and planned. The ability to acquire accurate information regarding the existing condition of pavements allows the use of finances, materials and resources to be optimized, so that the overall pavement maintenance schedule can be conducted, and the budget targeted, in the most sustainable manner. One key parameter used in road condition assessments is the thickness of the upper structural and lower foundation layers in the pavement (typically asphalt or concrete, and aggregate or soil respectively). For major roads in the UK, a common approach is for a core sample to be extracted from the upper road pavement, along the length of the road of interest, perhaps every few hundred meters (or closer), typically taking 30 minutes to an hour to extract the material and repair each core-hole.

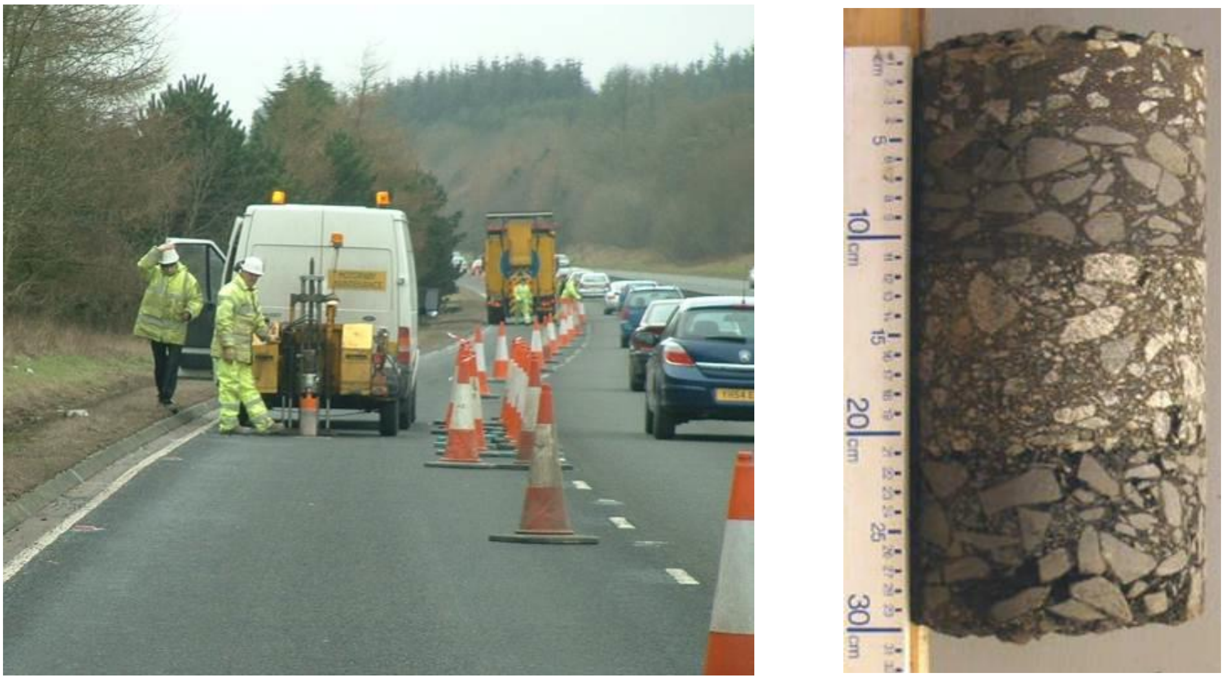


Figure 2. Coring rig extracting asphalt (left), and 300mm thick asphalt core taken from pavement (right)

There are a number of applications of GPR for road pavement assessment (Evans et al, 2008, Saarenketo & Scullion, 2000) and its use along the length of the road pavement prior to coring provides a number of advantages. The speed at which a GPR antenna can be moved along a survey line depends on the density of data collection required (typically for 'detailed' GPR surveys, with radar scans every cm along the survey line, speed of movement is limited to a few km per hour - perhaps walking pace - and for less detailed surveys with scans every 0.5m movement can be at normal traffic speed). Traffic speeds surveys can be conducted by attaching the GPR to a vehicle and pulling the antenna along the length of the road of interest without the need to close the lane. Even if the GPR survey is conducted within a lane closure, several km of survey line data can be collected within an hour (the time it may take to extract a single core sample and repair the hole).

Figures 3a & 3b below show GPR data, representing cross-sections, taken from 600m and 400m lengths of trunk road asphalt pavement respectively (scale along the x-axis). The signal travel time, which is a pseudo-depth scale, is plotted down the y-axis. In the plots, a travel time of 10ns is equivalent to a depth in the pavement of approximately 500mm. Figure 3a shows data from a pavement structure that has two distinct layer interfaces at approximately consistent depths along the full length of the cross section. Figure 3b however shows a pavement where multiple layers at varying depths can be identified.

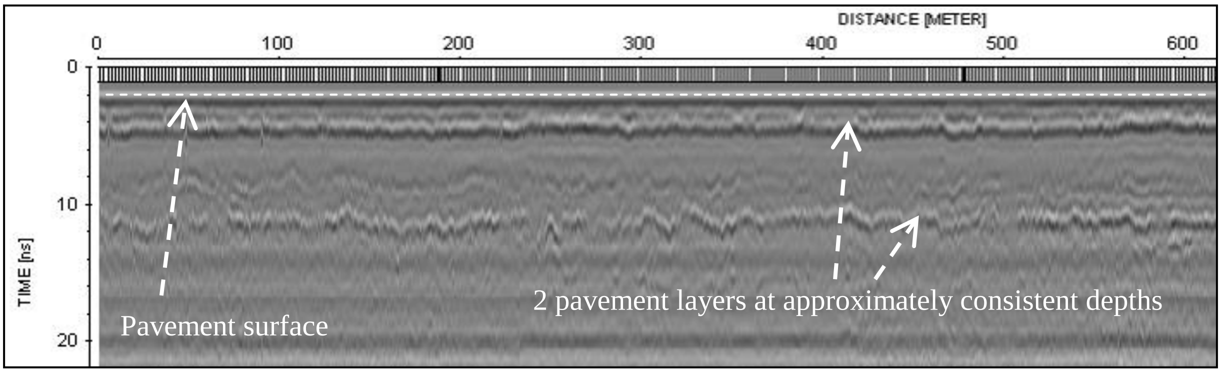


Figure 3a. GPR cross section of homogenous pavement construction

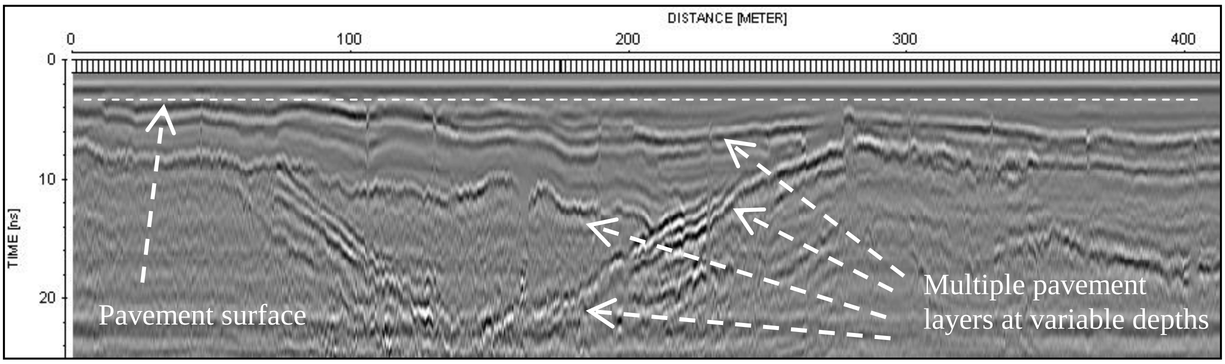


Figure 3b. GPR cross section of variable pavement construction

The data in Figures 3a & 3b can be used to reduce the overall need for coring or to target specific locations for coring that, from the GPR data, appear to be of most interest or uncertainty. A single core taken from the pavement in Figure 3a would likely be representative of the entire pavement structure as there appears to be little variation along its length and so there is no requirement for coring at 100m intervals (which otherwise might be typical). Intrusive coring of the pavement, for both of the examples shown, involving associated costs, time, materials and road closures can be targeted and optimized. In addition to this, depth calibration of the GPR data with any cores that are taken allows accurate pavement layer depths to be determined for the entire pavement length (coring alone only provides depth data at the specific locations where cores are taken), thus reducing uncertainty and providing a much larger data set for the pavement structure.

An important further use of depth data in pavement maintenance assessment is during the determination of the structural capacity of the existing pavement. The thickness of material layers is required to perform calculations of material stiffness, which are then used to assess structural condition and plan maintenance interventions. With core-only data, large assumptions have to be made about the thickness of layers along the pavement length, but GPR data provides a continuous record of layer depths along the entire pavement length, and so the uncertainty in stiffness calculations, and hence in the assessment of structural pavement capacity and subsequent planning of maintenance works, is hugely reduced.

2.2. Moisture within materials

The presence of water within materials can alter their dielectric properties, and hence GPR investigations can provide a way to identify 'wet' or 'dry' areas of the same material. Excessive moisture within a number of engineering materials can lead to detrimental changes in their properties, e.g. 'stripping' of the bitumen binder from the aggregate, freeze-thaw cycles and salt crystallization damage in natural stone and strength reduction of soils. Climate change may also have an on-going effect on such issues, for example a summary of recent work regarding UK historical climatic records has shown that there is strong evidence of a trend towards larger rainfall totals and an increase in the frequency of very wet weather (Osborn & Maraun, 2008, Jenkins et al. 2009). Hence, the ability to detect areas of excessive moisture, or where moisture ingress into buildings and structures is occurring, is likely to be even more important in the future.

The dielectric contrast between materials is enhanced when there are areas of relatively 'dry' and 'wet' material. Materials containing elevated amounts of moisture, relative to adjacent material, produce high amplitude GPR signal reflections and recording this effect during a GPR survey can be indicative of areas where moisture has accumulated.

Sections 2.2.1 & 2.2.2 below briefly illustrate examples of GPR investigations into moisture presence and ingress into structures.

2.2.1. Eastway tunnel, London, UK

The Eastway road tunnel in London suffered from a small area, towards one of the tunnel portals, where water had entered the pavement material and caused damage to the road structure. Visual inspection provided information on surface water accumulation, but inconclusive evidence of the path of water ingress, or of water accumulation within the pavement, and so a GPR investigation was conducted.

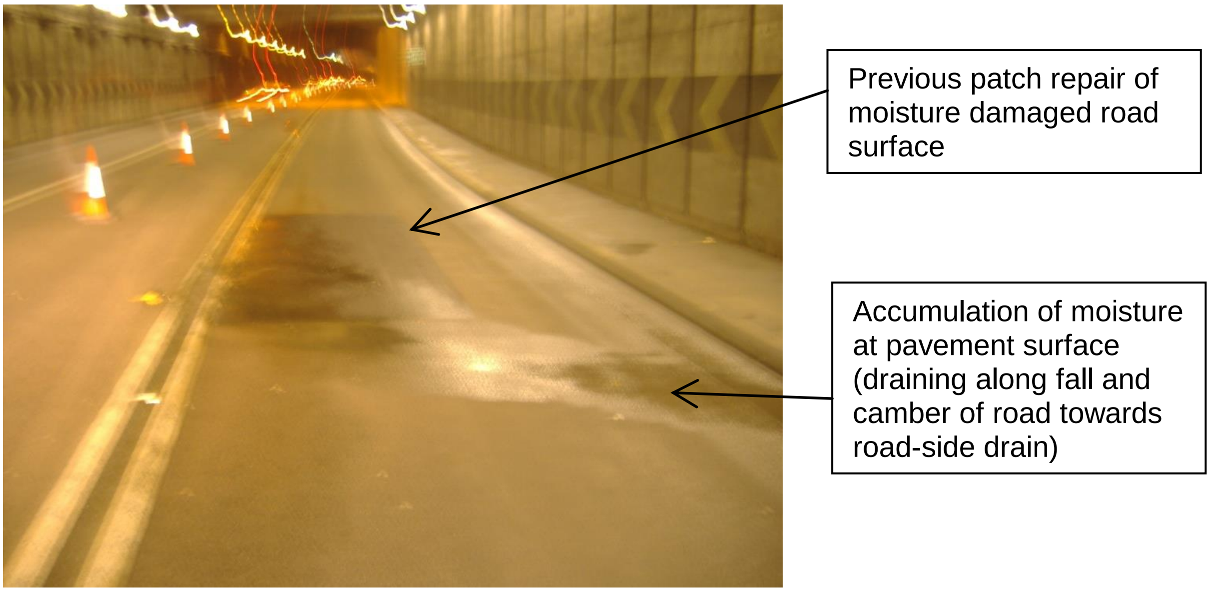


Figure 4. Water accumulation at pavement surface

The road construction was a 'composite' pavement, which is characterized by a layer of asphalt on top of a layer of concrete (on top of the road foundation). GPR investigations were conducted on survey lines extending along and beyond the area of the road surface where moisture was present. These investigations indicated a number of discrete locations below the pavement surface where GPR signal reflections from the interface between the asphalt and concrete were of greater amplitude than in other areas (indicating a greater dielectric contrast between materials, thus indicating areas of elevated moisture content). In this way it was possible to identify the areas below the surface where moisture was entering and accumulating within the road structure.

An example of a cross section of GPR data taken from a 10m length of pavement is shown in Figure 5. The pavement structure consisted of approximately 200mm of asphalt overlying a reinforced concrete slab. The specific locations where the amplitude of the signal reflection from the asphalt-concrete boundary was increased could be identified as 'brighter' areas on the GPR data (see Figure 5). By conducting a number of survey runs in a grid pattern over the pavement surface, the area affected by moisture ingress could be identified.

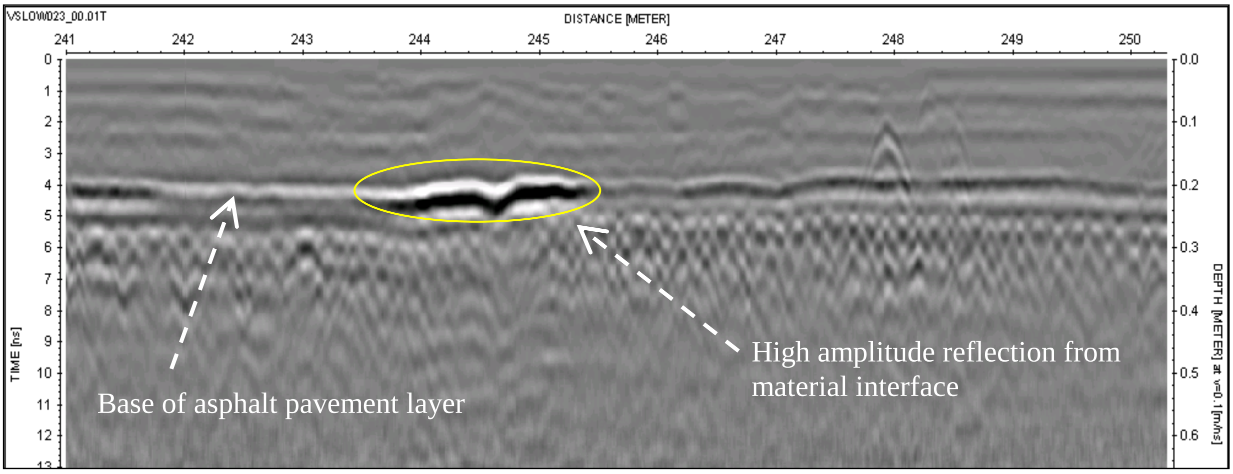


Figure 5. GPR cross section showing presence of moisture at pavement layer interface

Following the GPR investigation maintenance works could be designed and targeted, which resulted in a saving of time, cost and materials for the repair of moisture damage compared to alternative investigation methods (i.e. exploratory excavation or coring).

2.2.2. A2 motorway, Poland

Following the construction of the A2 motorway between Poznan and Warsaw, in Poland, some sections of the newly constructed pavement showed signs of deterioration much sooner than would normally be expected. Initial visual and intrusive coring investigations indicted that moisture was entering the pavement structure at some locations along the motorway, within the upper asphalt layer, and remaining present within the asphalt for a period of time, hence producing the increased rate of deterioration of the structural integrity of the pavement.

A large scale GPR investigation was conducted along several km of the motorway with the aims of identifying any possible defective areas, establishing the integrity of the pavement and finding the cause of the moisture being retained within the pavement layers. As with the investigation on the Eastway Tunnel (see Section 2.2.1), discrete locations within the pavement could be identified where high amplitude GPR reflections were occurring. However, rather than occurring at material boundaries (as with the asphalt-concrete boundary in the Eastway Tunnel), the high amplitude reflections occurred within the asphalt layer itself.

During pavement construction, the asphalt pavement is constructed by compacting thin individual layers of asphalt to create the final thicker upper asphalt layer. High amplitude reflections occurred from a generally consistent depth within the pavement (60 to 180mm depth), and so it appeared that one of the individual asphalt layers contained excessive moisture whilst those above and below it did not. The GPR signal reflections were created by the contrast between ‘wet’ asphalt and ‘dry’ asphalt layers. Such a scenario may result from inappropriate material design (too many void spaces in the material), poor compaction of a layer during construction, or possibly inadequate drainage for the pavement.

A number of parallel GPR survey runs were conducted along the length of the motorway, which allowed comprehensive identification of locations of high amplitude reflection (i.e. moisture). Rather than presenting GPR data in a number of cross sections, the GPR data was presented by analyzing the data from a plan-view perspective. On the plan view, the locations along each survey run where moisture was indicted were marked and a ‘map’ of moisture locations (detected at 60-180mm depth) was created. Figure 6 shows one of the ‘moisture maps’ created, along a 100m length (and 6m width) of motorway pavement.

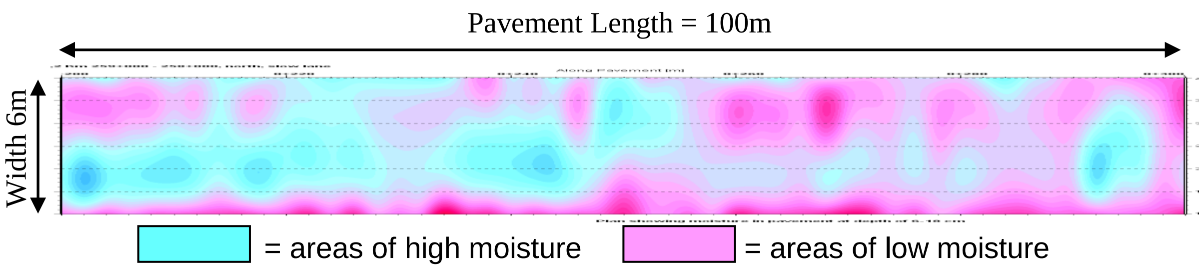


Figure 6. GPR cross section showing presence of moisture at pavement layer interface

The ‘dry’ layers appearing above the ‘wet’ layer indicated moisture ingress was not from the pavement surface, and the GPR investigation allowed areas of moisture ingress and moisture presence to be identified within the asphalt layer. Poor drainage at the sides of motorway was identified as the source of ingress, and targeted cores in the pavement confirmed the findings of the GPR investigation. The use of GPR reduced uncertainty about the source and location of moisture removed the need for costly and time consuming intrusive exploratory excavation work, also reducing the requirement for materials used for repair work

2.3. Investigation for redevelopment of existing structure

Staythorpe power station in Nottinghamshire, UK, is a 1650MW gas fired power station that began full commercial operation in 2010. Previously the site had housed two coal fired power stations and so the re-development of the site required extensive demolition and construction work. Part of the work included an investigation of the structural capacity of the existing water pumping house, to assess whether it could be re-developed as part of the new gas power station or whether it was to be demolished.

Records of the bearing capacity and structural form of the floor slabs were incomplete and so a GPR investigation was conducted as part of the floor slab assessment. An example of data from the GPR investigation is shown in Figure 7, which shows a 7m length of one of the GPR survey lines taken from the pump house floor. The cross section shown identified that there were two types of floor slab (unreinforced and reinforced), which was previously unknown from visual inspection and existing records, and allowed a determination of the thickness of the unreinforced slab, and of the location of steel reinforcement within the reinforced slab.

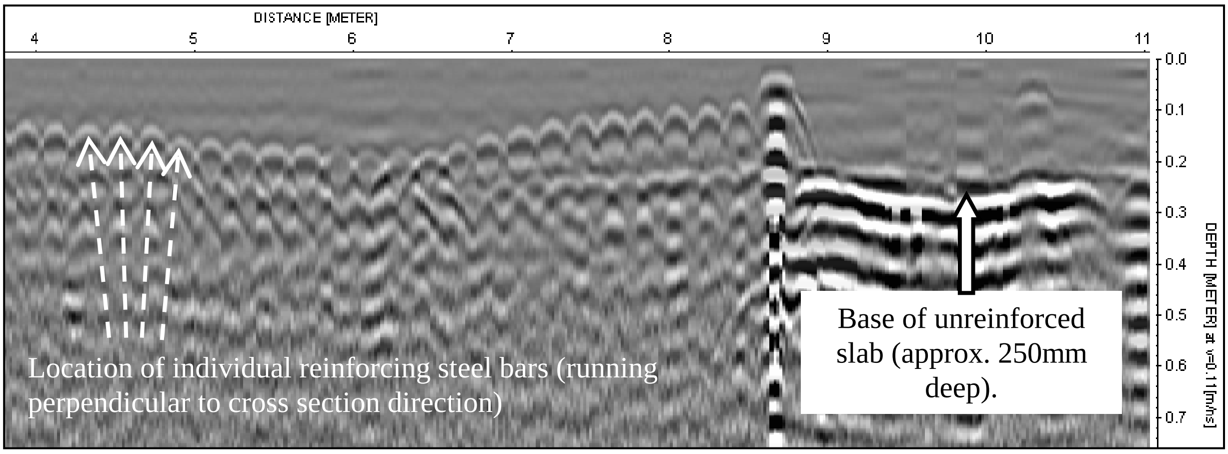


Figure 7. GPR cross section showing features within a concrete slab floor

Figure 7 also highlights one of the limitations of GPR investigation. For the reinforced slab, although the size of the reinforcing bars can be estimated, and locations and depths accurately determined (the variation in depth can be clearly seen), the metal reinforcing bars themselves prevent much of the GPR signal from penetrating further in to the slab, and so information from below the level of dense reinforcement is inconclusive.

3. DISCUSSION

The examples described in Section 2 illustrate some of the applications of GPR for structural and material assessment. The uses described include:

- Depth / thickness determination of material layers.
- Presence of moisture within construction material.
- Location of steel work within construction material.
- Identification of discrete locations within materials which contain differing properties.

These applications have been conducted to establish the existing conditions within structures and materials with several aims in mind, including:

- Identification of material defects and deterioration.
- Provision of input data for structural assessments.
- Planning of detailed intrusive investigations.
- Planning of maintenance treatment.
- Planning of re-use of existing structures.

Other uses not covered in detail in Section 2, but which also may have relevance for use within the context of buildings and structures, include the locations of pipes and utilities and potential identification of defects or leaks within pipe networks, and for general site and ground investigations before construction work commences.

The accuracy to which GPR can locate features within structures or the ground depends on the GPR system settings and GPR antenna frequency (which are decided by the GPR operator), but also on the nature of the materials being investigated (which are beyond the control of the operator). Generally, for shallow investigations (perhaps up to a meter deep) depths and thicknesses can be located to within 1-2cm accuracy, but it should be noted, as stated earlier, that certain materials may inhibit the passage of GPR signals (e.g. high clay content soils, high moisture content materials, dense reinforcement / metalwork).

4. CONCLUSIONS AND RECOMMENDATIONS

GPR has huge potential for use in the determination of material and structural properties in the built environment. Advantages provided by the use of GPR (compared to alternative intrusive investigations) include:

- Less damage (i.e. less requirement for intrusive material investigations).
- Less use of materials (e.g. less requirement to repair damage from intrusive investigation, improved targeting of locations for repair of existing material).
- Less time taken for investigation.
- Less disruption to public or users of the structure under investigation.
- Improved certainty in data obtained (compared to alternative inspection methods).

GPR provides a viable option for the sustainable assessment of buildings and structures, but several important limitations should also be noted, including:

- It is a specialist technique which requires specialist knowledge of GPR systems and data processing.
- The accuracy of GPR depth data is improved if calibration (with known thickness data) is possible.
- Some material types & conditions inhibit the passage of GPR signals and are therefore less likely to provide successful GPR investigation results.

5. REFERENCES

Daniels, D. J. (2004) *Ground Penetrating Radar*, 2nd edition. The Institution of Electrical Engineers, London, U.K.

Evans, R. & Frost, M. (2011) The effect of moisture on ground penetrating radar data from asphalt pavements. Proceedings of the 5th International Conference on Bituminous Mixtures and Pavements, Thessaloniki, Greece, 2011.

Evans, R., Frost, M., Stonecliffe-Jones, M. & Dixon, N. (2008). A review of pavement assessment using ground penetrating radar (GPR). Proceedings of the 12th International Conference on Ground Penetrating Radar, Birmingham, UK. 2008.

Jenkins, G., Perry, M. & Prior, J. (2009). The climate of the United Kingdom and recent trends. Met Office Hadley Centre. Exeter, UK. http://ukclimateprojections.metoffice.gov.uk/22530., accessed on 24.04.2015.

Osborn, T. & Maraun, D. (2008) Changing intensity of rainfall over Britain. Climatic Research Unit Information Sheet No.15, University of East Anglia, UK.

Saarenketo, T. & Scullion, T. Road evaluation with ground penetrating radar. *Journal of Applied Geophysics*, pp119-138, v43. 2000.

Finite Element Modelling of interaction between surface and Darcy flow regimes through soils

Bahareh Kaveh
Nottingham Trent University, bahareh.kaveh@ntu.ac.uk

Abstract

The present work deals with the impact of surface flow on hydrodynamic conditions in saturated underground domains. A three dimensional finite element analysis of water flow has been used to obtain the required simulations. The results clearly show the effects of the surface flow on the hydrodynamic conditions of the subsurface porous regions. This analysis is an important prerequisite for the prediction of contaminant mobility in soils and hence provides a convenient tool for the prediction of environmentally important subsurface flow processes. For low permeability cases, considered here, governing equations consist of water continuity and Darcy equations. These equations are solved using a robust and reliable finite element procedure.

Key Words: Underground flow, Hydrodynamics, Darcy flow, Finite element modelling, Three dimensional porous flow.

1. INTRODUCTION

Seepage in soils is an essential topic of study in many civil engineering and environmental protection processes. For example, in the design of earth dams and retaining structures, that require quantification of drainage, amount of seepage need to be identified. Similarly seepage is the determining factor in the contaminants mobility as leachates in subsurface domains. Seepage flow models have been developed by many researchers (e.g. see Cedergren, 1994; Reddi, 2003). These investigations have shown that seepage regimes often have complicated characteristics mainly because of the heterogeneity of soils through which water flows. Heterogeneity of soil media arises for various reasons such as the presence of staggered layers of soil with different porosity. Therefore reliable mathematical description and modelling of seepage flow requires formulation of realistic features of the problem and the boundary conditions affecting the flow. Transport equations describing flow through porous media depend on the properties of the fluid and factors such as permeability and porosity of media (Bear, *et al*. 1991). In this regard it is important to distinguish between saturated and unsaturated domains. Seepage flow in unsaturated lands has been the subject of many studies (e.g. Troldborg, 2009; Uromeihy, 2007). However, unlike the unsaturated situations, the influence of surface flow on saturated domains has not been widely studied. This may be due to the common belief that surface flow makes only small contribution to the changes of hydrodynamic conditions under the ground in saturated domains. However as the results of this research show, there is a significant link between surface flow and subsurface conditions in saturated lands. Simulations obtained in this work can therefore be considered as quantitative analysis of the link between surface and subsurface flows for saturated cases.
The flow through porous soils is affected by hydraulic gradient and the coefficient of soil permeability. Permeability is a function of the range of grain size and shape, stratification, consolidation and cementation of the material. The rate of flow is commonly assumed to be directly proportional to the hydraulic gradient, however this is not always true under realistic

conditions. Theoretically, due to the increasing load, permeability of soils decreases with increasing depths. Therefore a layered heterogeneous strata is the common feature of flow domain in most environmental studies. In table 1 a typical range of soil permeability used in the present study is shown.

Table 1 Values of soil permeability

Degree of permeability	Range coefficient of permeability (m^2/s)	Soil Type
High	10^{-6}	Medium and coarse gravel
Medium	10^{-6}-10^{-8}	Fine gravel; coarse; medium and fine sand; dune sand; clean sand – gravel mixtures
Low	10^{-8}-10^{-10}	Very fine sand, silty sand, loose silt, loess, well fissured clays
Very low	10^{-10}-10^{-12}	Dense silt, dense loess clayed silt, poorly fissured clays
Impermeable	10^{-12}	Unfissured clays

Porous flow under the ground is governed by hydraulic head. Hydraulic head consists of the velocity, pressure and elevation heads. The velocity head in soils is usually negligible in comparison with the other heads, therefore here the main driving force is taken to be combined elevation and pressure heads, which for simplicity is represented by a single pressure term. Saturated flow in a porous medium should be modelled using either Darcy (Darcy, 1856); or Brinkman (Brinkman, 1947) equations depending on the permeability/porosity of the medium and flow Reynolds number (Wakeman and Tarleton, 2005). For very low Reynolds number (creeping flow) and porosity less than 0.6, the most suitable equation is Darcy's equation. This is the dominant situation in most types of seepage flow of water in soils. In a previous paper the validation of the Darcy's law for isotropic, homogenous, incompressible, saturated and isothermal porous media was considered (Kulkarni, et al. 2008). The Darcy equation inherently implies perfect slip conditions at domain boundary walls and does not include any wall effects (Ishizawa and Hori, 1966). Therefore an accurate solution scheme for this equation should be capable of yielding a slip velocity on the porous domains. The finite element scheme used in the present work can very effectively cope with such boundary conditions. This technique can also very effectively cope with irregular geometries. However, considering the large scale of lands where environmental phenomena needs to be studied, any irregularity of the domain walls can be ignored. In this work we have used a block as a representative section of a typical underground flow domain.

2. MODEL EQUATION

The governing model equations for the seepage flow of an incompressible Newtonian fluid such as water are represented as:

2.1. Equation of Continuity

The continuity equation (i.e. expression of conservation of mass) for an incompressible fluid is represented (using vector notations) as:

$$\nabla \cdot \vec{u} = 0 \qquad (1)$$

Where $\vec{u}$ is the velocity vector.

2.2. Equation of Flow

As mentioned earlier we have selected the Darcy equation to represent the flow equation (i.e. expression of conservation of momentum). Using vector notation this equation (Nield and Bejan, 1992) is written as:

$$\rho \frac{\partial \vec{u}}{\partial t} + \nabla p + \frac{\mu}{K} \cdot \vec{u} = 0 \qquad (2)$$

Where ρ is fluid density, p is the pressure, μ is viscosity of the fluid and K is the permeability of the porous medium. In its most general description K should be regarded as a second order tensor which is represented, in a matrix form, as:

$$K = \begin{bmatrix} K_{xx} & 0 & 0 \\ 0 & K_{yy} & 0 \\ 0 & 0 & K_{zz} \end{bmatrix} \qquad (3)$$

Where K_{xx}, K_{yy} and K_{zz} are the principle components of the permeability tensor along the x, y and z directions of a Cartesian coordinate system. Any anisotropy in a porous medium can hence be taken into account by assigning appropriate values to the components of the permeability tensor.
Conjunctive solution of equations (1) and (2) poses a mathematical problem as the first equation does not include a pressure term. Full mathematical analysis of the problem is somewhat obscure and requires lengthy explanations. However, it has been shown that a stable and accurate solution for these equations can be obtained provided that the solution scheme satisfies a condition known as the LBB condition (Reddy, 1986). A convenient way of satisfying this condition is to replace equation (1), which is the expression of incompressibility, with a modified form (Zienkiewicz and Wu 1991) as:

$$\frac{1}{\rho c^2} \frac{\partial P}{\partial t} + \nabla \cdot \vec{u} = 0 \qquad (4)$$

Where c is the speed of sound in the fluid. Equation (4) represents conservation of mass for a slightly compressible fluid.

3. BOUNDARY CONDITIONS

In the present work simulations of underground flow of water are obtained by the conjunctive finite element solution of equations (2) and (4) in a three-dimensional domain subject to the following boundary conditions:

1. Top surface: Constant velocity tangent to the surface.
2. Side walls: Perfect slip conditions.
3. Bottom surface: Perfect slip conditions.
4. Downstream surface: Zero pressure set as an arbitrary datum.

4. SOLUTION ALGORITHM

Numerical solution of equations (2) and (4) via the finite element method starts with the domain discretization into a computational mesh. Selection of a particular type of element is of importance in generating reliable results. In this work we have used 8 noded (brick elements) which generate tri-linear approximations for both pressure and velocity fields.

Application of the Galerkin finite element technique (Nassehi, 2002) generates a set of working equations which can be used according to the algorithm shown in Fig. 1 to obtain the required numerical results.

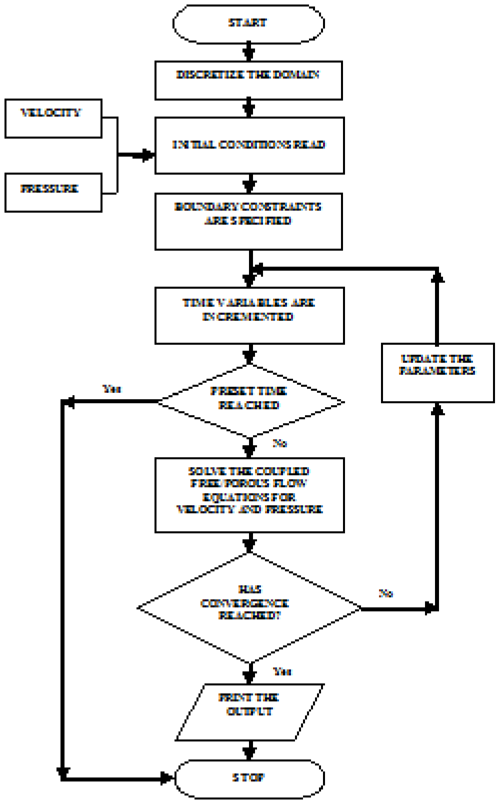


Figure 1: The solution algorithm implemented using the in-house developed program

5. COMPUTATIONAL RESULTS AND DISCUSSION

In this section the results obtained for a block domain (prism) subject to varying surface slope are presented and discussed.
In these simulations, the fluid under consideration is water with properties at 200 C, as viscosity= 0.001 $Kgm^{-1}s^{-1}$ and density = 1000 Kgm^{-3}. The velocity of sound in water is taken to be approximately as 10000 ms^{-1} .Depending upon the property of the permeable medium (which can be isotropic or anisotropic), appropriate values of permeability are used to cover a range of realistic situations. The time increment (Δt) used in the solution scheme is 20 seconds.

5.1. Block domain consisting of isotropic permeable medium

A block domain of 60 m width (W) x 60 m height (H) along x, y in one side of the domain and 60 m (W) x 30 m (H) along x, y in the other side of the domain and 200m length (L) along z axis is modelled. Therefore initially a surface slope of 8.53° is considered. The magnitude of surface velocity is 0.2 ms^{-1} .The computational grid used to simulate porous flow in this domain comprises of 5760 eight node brick elements and 6929 nodes, as shown in figure 2. The permeability coefficient for this homogeneous isotropic porous domain is taken as:

$(K_{xx} = K_{yy} = K_{zz} = 10^{-9} m^2)$ The schematic representations of the boundary conditions imposed over the different sides of this domain are shown in figures 3 and 4.

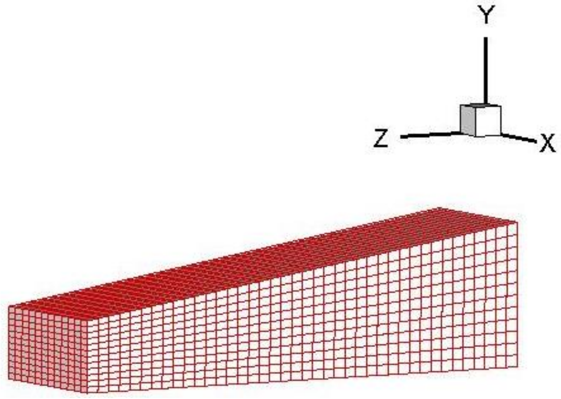


Figure 2: Finite element mesh for the homogeneous domain

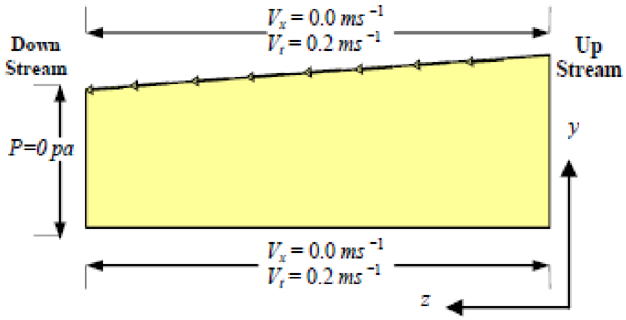


Figure 3: Schematic representation of the boundary condition in the yz plane

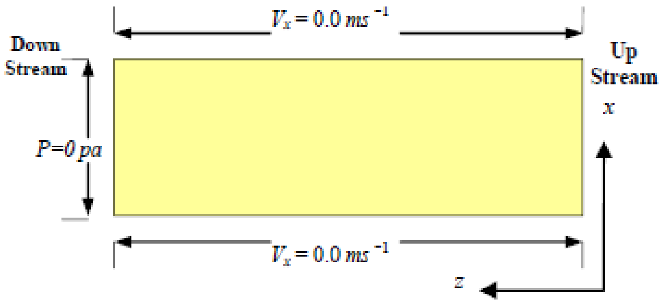


Figure 4: Schematic representation of the boundary condition in the xz plane

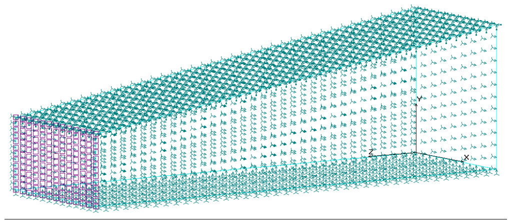


Figure 5: Three dimensional schematic representation of the boundary points at different faces of the domain

Figure 5 shows the position of the boundary nodes on the faces of the permeable domain under consideration. In addition to the top surface flow velocity (0.2 ms^{-1}) at the downstream exit a zero pressure datum is prescribed. Slip wall boundary conditions are imposed on the sides of the domain. This means that velocity components vertical to each wall is set to be zero whilst the other components are left to be free.

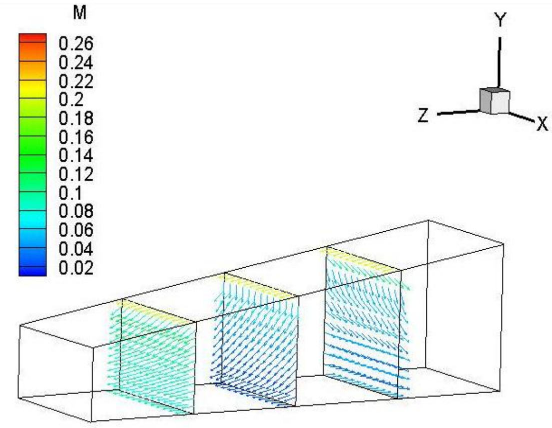


Figure 6: Velocity vector plot on three sample cross sections

To make the representation of the velocity field clearer, only the computed velocity vectors on three sample cross sections are shown in figure 6. The corresponding nodal pressures and magnitude of velocity are shown in figures 7 and 8, respectively. This result shows that, as intended, viscous stress associated with the bulk matrix of the fluid is transferred to the solid porous matrix.

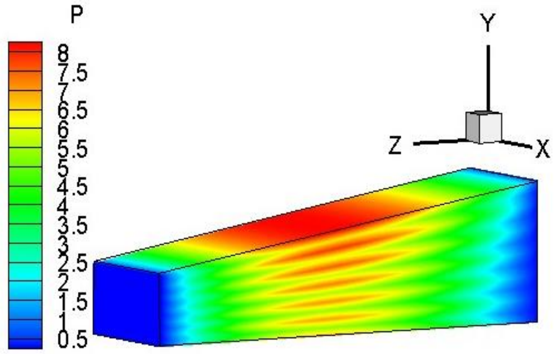


Figure 7: Pressure plot in the domain

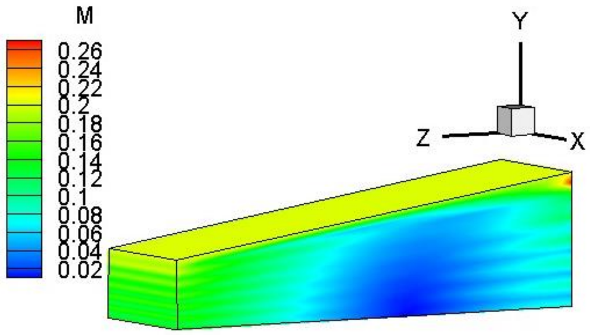


Figure 8: Velocity contour in the domain

Figure 9 clearly shows that despite the ground being saturated significant flow under the ground is generated by the imposed surface flow and, therefore, causing distribution of any existing contaminants in all directions.

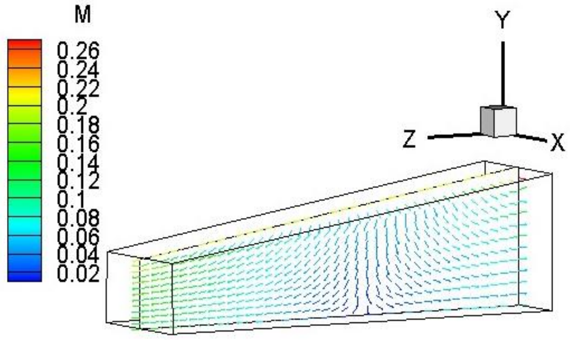


Figure 9: Velocity vector in the section parallel to the zy plane at x=30 m in the domain

To study the influence of the surface slope on the intensity of underground circulation by the surface flow, a second domain which has a different surface slope of 12.68˚ is also simulated. All other boundary conditions are kept to be similar to the previous case. Simulation results shown in figures 10 and 11 indicate the strong relation between the surface slope and the underground circulations caused by the surface flow. For example despite showing a pattern of circulation similar to the previous case, velocities have increased by as much as 38%. Velocity vector shown in Figure 12 indicate the same pattern of flow circulation compared to the previous case.

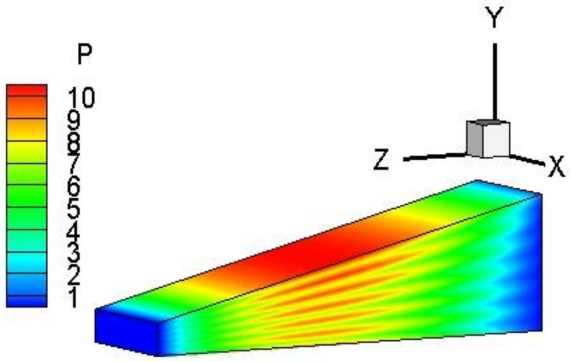


Figure 10: Pressure plot in the second domain

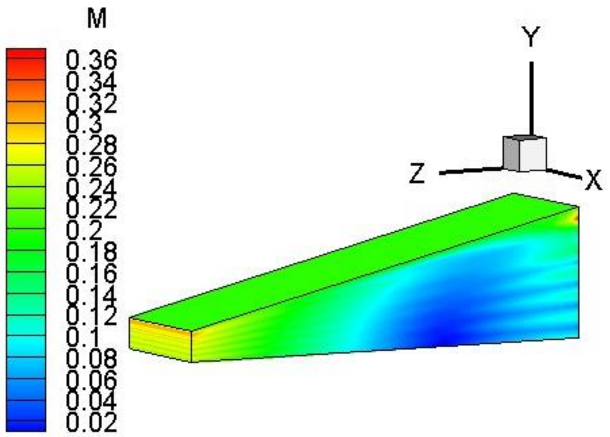


Figure 11: Velocity contour in the second domain

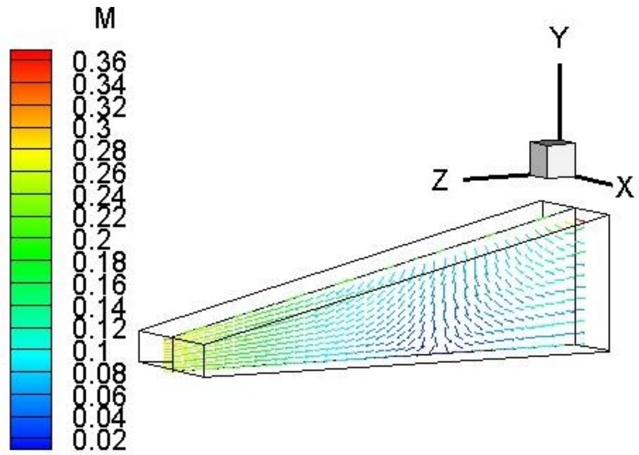


Figure 12: Velocity vector in the section parallel to the zy plane at x=30 m in the second domain

6. CONCLUSIONS AND RECOMMENDATIONS

The described simulation is based on the finite element solution of three dimensional Darcy and continuity equations. This provides a powerful means for the investigation of seepage flow of water in subsurface regions. The accuracy of the model is verified by its ability to preserve the agreement between the predicted velocity and pressure results with the theoretical expectations.

The simulations have shown that despite the land being saturated, rain water flow over the ground results in significant disturbance of the hydrodynamic equilibrium under the ground and hence causes movement of contaminants. It is also shown that water circulation under the ground is significantly affected by the surface flow velocity and the surface slope. As shown by these results underground flow direction is not dependent on the predominant direction of the flow over the surface and multi-directional flow established under the ground can occur in directions opposite to the direction of surface flow. A tentative conclusion is that flow under the ground can be in all directions and the reason for not detecting significant flow currents in the transverse directions in the simulations shown in this work is the imposition of solid wall conditions on the sides of the problem domains considered here. Closer examination of the described conclusions reveals the importance of the results obtained during the present project. For example considering that in many heavily industrialised regions of the world land is saturated, at least during winter months, a semi-circulatory flow under the ground caused by rainfall can cause contaminants migration in unexpected directions. Therefore costly underground reactive barriers which are increasingly used to stop migration of contaminants under the ground may become ineffective if underground flow patterns have not been correctly recognized. An additional problem which potentially has much more immediate impact on the civil environmental projects is the management of landfill sites. Landfill sites are usually underground domains of high permeability which can be easily saturated and by nature are unstable from physico-chemical and hydrodynamical points of view. An incorrect analysis of impact of rainfall on these sites can have devastating results on environmental safety.

The model can be used to consider a wider variety of boundary conditions than used in this work. Selection of different boundary conditions can be based on the actual situations in any given problem. The scheme is proven to be very flexible and there is no doubt that it can handle a large number of exterior boundary conditions. There is no theoretical difficulty that may prevent the extension of the methodology described in this paper to heterogeneous lands. Experimental work was beyond the scope of the present project, nevertheless, a simple methodology which can be used to obtain an ultimate verification for this model is proposed. A rig consisting of a reasonably large glass box can be filled with soil and water added to a level that it becomes saturated. A source of tracer, such as a dye, can be left at a point inside the soil surface. Experiments based on running water over the surface of such a rig and dismantling and observing the dispersion of the tracer within the soil matrix should readily establish the underground flow pattern caused by the surface flow.

REFERENCES

Bear, J., Buchlin, J., Vonkarman institute for fluid dynamics, (1991). “Modelling and applications of transport phenomena in porous media”. Dordrecht, Boston, Kluwer Academic Publishers.

Brinkman, H.C., (1947). “On the permeability of media consisting of closely packed porous particles”. Appl. Sci. Res. A1, pp. 81-86.

Cedertgren, H.R., (1989). ‘’Seepage, Drainage, and Flow Nets’’, John Wiley and Sons, New York

Darcy, H.P.G., (1856). “Les Fontaines Publiques de la Ville de Dijon, Exposition et Application des Principes à Suivre et des Furmules à Employer dans les Questions de Distribution d'Eau.” *Victor Dalmont, .*

Das, D.B., Nassehi, V. and Wakeman, R.J., (2002). “A finite volume model for the hydrodynamics of combined free and porous flow in sub-surface regions”. *Advances in Environmental Research*, 7(1), pp. 35-58.

Ishizawa, S. and Hori, E., (1966). “The flow of viscous fluid through a porous wall into a narrow gap” (a consideration of the slip of fluid on porous wall surface). *Japanese Society of Mechanical Engineers*, 9, pp. 719.

Kulkarni, A., et al, (2008). ‘’finite element modelling of underground flow in low permeability land’’. ISC Lyon, France.

Nassehi, V. and Das, D.B., (2007). “Computational methods in the management of hydro-environmental systems”. London, UK, IWA Publishing.

Nassehi, V. (2002).“Practical Aspects of Finite Element Modelling of Polymer Processing”. John Wiley & Sons, Inc., West Sussex.

Nield, D.A. and Bejan, A., (1992). “Convection in porous media”. New York, Springer -Verlag.

Reddy, J. N.(Junuthula Narasimha) 1984. “An Introduction to the Finite Element Method”, McGraw - Hill Book Company, New York.

Reddi, L.N. (2003), ‘’Seepage in soils, principles and applications’’ John Wiley, Hoboken, N.J.; Great Britain.

Troldborg, M., et al, (2009). ‘’Unsaturated zone leaching models for assessing risk to groundwater of contaminated sites’’. *Journal of contaminant hydrology,* 105(1), pp. 28-37.

Uromeihy, A., (2007). ‘’Evaluation and treatment of seepage problems at Chapar-Abad Dam’’, Iran

Wakeman, R.J. and Tarleton, E.S.,(2005). "Solid/liquid separation - Principles of industrial filtration", Oxford, Elsevier.

Zienkiewicz, O.C. and Wu, J., (1991). "Incompressibility without tears", How to avoid restrictions of mixed formulation. *International Journal for Numerical Methods in Engineering,* 32(6), pp. 1189-1203.

Integration of Renewable Energy Sources in Urban Energy Systems

Ursula Eicker
Stuttgart University of Applied Sciences, Centre of Applied Research – Sustainable Energy Technology (zafh.net), e-mail: ursula.eicker@hft-stuttgart.de

Abstract

District heating networks with low temperature levels offer good integration potentials for solar thermal energy. The hydraulic behavior of the network and the interaction between different head sources (pumps) has not been discussed yet. The first part of the paper presents simulation results obtained with the program spHeat (Ben Hassine 2012), which was first developed within the European project POLYCITY as part of the CONCERTO initiative for energy efficient cities (Eicker 2004). It was designed for the hydraulic and thermal simulation of networks with multiple loop topologies. spHeat has been further developed to enable the integration of distributed solar thermal (ST) heat surplus into the network model. In accordance to (SDH 2012) "distributed" or "decentralised" means that the solar plant is not close located to another major heat generator like a biomass or fossil fuel fired plant. In the second part of the paper a new test facility for heat substations is discussed. It will be used to implement the feed-in schemes discussed above, to test the suitability of different components (pumps, valves) for bidirectional heat transfer, to test control algorithms and to validate the substation model developed. The extension of the district heating analysis tool spHeat is described in this paper. The so far separated models for supply and return sub-networks have been merged into one model. The integration of head sources became easier. First static calculations show that critical differential pressure driven operation of the district pump is much more difficult in the case of return→feed heat integration. The planned test rig for bidirectional heat transfer stations is presented. The first phase of the installation has been completed.

Key words: *district heating networks with low temperature levels; the hydraulic behavior of the network; bidirectional heat transfer; the integration of head sources.*

1. INTRODUCTION

District heating networks with low temperature levels offer good integration potentials for solar thermal energy. Only few authors use system simulations for thermal networks in combination with solar collector models to predict the solar gains with different solar system sizes (Fink2007 and Vetrsek2010). The hydraulic behavior of the network and the interaction between different head sources (pumps) has not been discussed yet.

The first part of the paper presents simulation results obtained with the program spHeat (Ben Hassine 2012), which was first developed within the European project POLYCITY as part of the CONCERTO initiative for energy efficient cities (Eicker 2004). It was designed for the hydraulic and thermal simulation of networks with multiple loop topologies. spHeat has been further developed to enable the integration of distributed solar thermal (ST) heat surplus into the network model. In accordance to (SDH 2012) “distributed” or “decentralised” means that the solar plant is not close located to another major heat generator like a biomass or fossil fuel fired plant. The feed-in principles described in (Bucar 2006) are shown in Figure 22. The feed-in return→flow is the most challenging concept from a hydraulic point of view. The additional pump has to overcome the pressure differential between both lines. The simulation study carried out in this paper only focuses on this integration scheme. The purpose of the study is to investigate the effect of the integration on the flow control characteristic. By means of static simulations some weaknesses of two “conventional” control ways are shown.

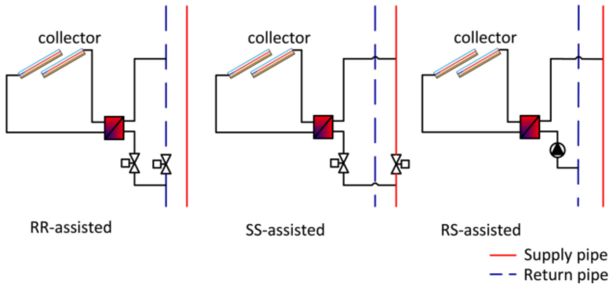


Figure 22: Decentralised supply principles

In the second part of the paper a new test facility for heat substations is discussed. It will be used to implement the feed-in schemes discussed above, to test the suitability of different components (pumps, valves) for bidirectional heat transfer, to test control algorithms and to validate the substation model developed.

2. THE SIMULATION FRAMEWORK

2.1 Network description

The studied network is located in Sonnenberg near Stuttgart in Germany. Sonnenberg is subdivided into two quarters; Southeast and Southwest (Figure 23). As it currently stands, construction is completed in the Southeast quarter and residences are already occupied.

Figure 23: The map of Sonnenberg

The quarters' heat demand is partially supplied by a geothermal plant located at the southern end of the quarter, with distribution via a DH network. Water is heated from 40 to 70°C. One of the measures to enhance the primary energy factor of the whole system consists of integrating renewable energy sources. In several Canadian and Swedish sites decentralised solar thermal heat has been successfully integrated. First monitoring results show good system performances. In Sonnenberg the lack of areas to install large collector fields near the heating plant makes central solar integration difficult to realise. The decentralised principle of heat supply is considered to be more realistic.

2.2 Model development

The network description in spHeat is based on a graph-theoretical method. The main components of the graph are edges (pipes) and nodes (consumer or plant) as shown in Figure 24. The Newton algorithm (horneber1985) was used for solving the system of non linear equations. The model is based on a quasi-dynamic approach, where the flow and pressure are calculated using a static flow model in the sub-program spHydro. The temperature is calculated dynamically in spThermo depending on the flow velocity and several boundary conditions like ground and ambient temperatures. The backward-difference method is implemented to solve the differential equations of heat transfer along the pipes. In spHeat the network is divided into feed and return levels. Both sub-networks are calculated separately and the resulting return temperature at each house stations is determined based on an energy balance equation. The plant head elevation dictates the mass flow distribution in the network and therefore the temperature propagation. In the case of decentralised integration, supplementary head elevations from return to supply influence the flow direction and have to be taken into account. The separation of the network into its two levels is not suitable.

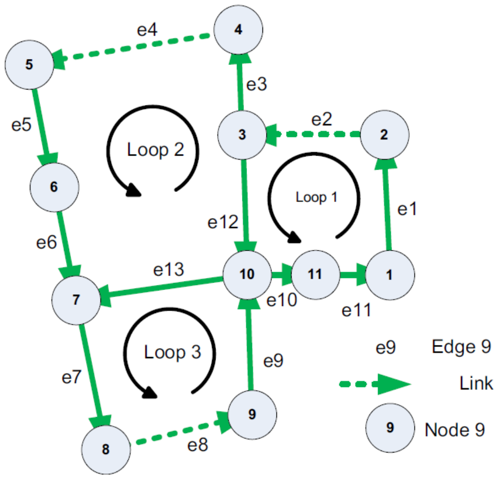


Figure 24: A simplified network graph

The network model in spHeat was therefore extended with the edges ‘consumer substations’ to form a closed topology. The system of equations describing the network was enlarged by *n* equations, where *n* is the number of consumer nodes. The law of conservation of energy is applied for every loop defined between two consecutive substations (Figure 25). The exponential formula (based on the Darcy-Weisbach equation (Larock1999)) was applied to account for the head loss Δp around the substation as a function of discharge $\dot{V}$:

$$\Delta p = k_v \dot{V}^{nv} + k_x \dot{V}^{nx} \qquad \text{(eq.1)}$$

with the flow dependent coefficient k_x of heat exchanger, the valve travel dependent coefficient k_v, the corresponding exponents *nx* and *nv* and the discharge $\dot{V}$. In the case of feed-in return→flow this equation is replaced by a head source equation:

$$\Delta p = \Delta ph \,. \qquad \text{(eq.2)}$$

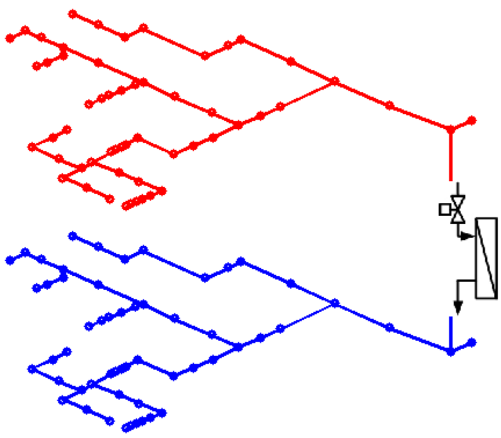


Figure 25: Merge of feed and return sub-networks (a substation model corresponds to each two nodes)

3. THE SIMULATIVE STUDY

In DH networks hot water is pumped by variable speed pumps to the different stations. Open loop control of the head elevation in the supply plant is still applied in many installations leading to unnecessary high pressure differentials during the low demand season. (Ben Hassine2011) shows the optimization potential for the pump energy consumption by operating in closed loop. Closed loop algorithms use the measured pressure differential at a critical consumer (generally the most distant) to adapt the head elevation of plant pumps.

A second -more advanced- closed loop algorithm uses the plant pressure differential as control variable. In this case the total volume flow is feed-forwarded to the pump drive. The required head elevation is calculated in a way to approximate the supply characteristic curve $\Delta p = f(\dot{V})$ – the curve which theoretically guarantees a minimum delta p at the critical consumer. Costs for sensor maintenance and signal transmission can be avoided.

The influence of decentralised heat integration on these two closed loop operation modes is discussed on the base of static hydraulic calculations of the network in Sonnenberg. Figure 26 shows the pressure differential between feed and return line along the network. The same course is also represented in Figure 27 with the dotted line. Consumer 56 at the left bottom side of the figure has the minimum value of 0,5bars around its heat exchanger and fully opened valve.

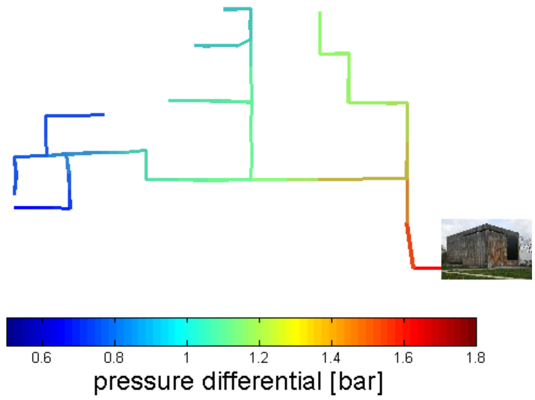


Figure 26: The calculated pipe differential pressure

Assuming that consumer 56 has heat surplus to be feed-in with a constant volume flow of 3l/s, the critical station moves to node 50. Keeping the same pump frequency leads to unnecessary high pressures (blue continuous curve in Figure 27). If the pressure differential of node 50 is then used as control variable, the plant pump frequency is reduced to match the minimum value of 0.5bar at this node (red dot). This may lead to insufficiently supplied stations (red curve). The critical consumer changes its location dependant on a) the feed-in point and b) the demand of all other consumers. Pressure differential driven control with a reasonable number of pressure transmitters doesn´t guarantee a satisfying/safe operation.

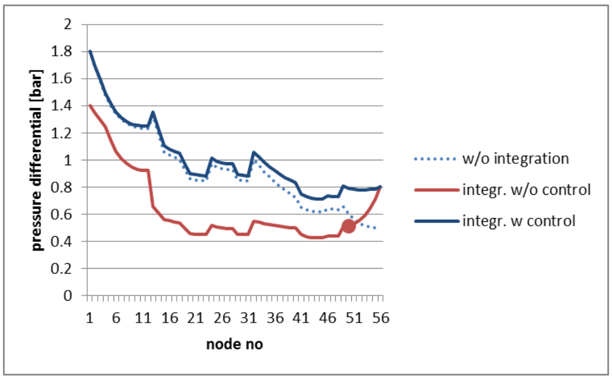


Figure 27: Evolution of the node differential pressure

By varying the consumer valves´ travel (i.e. the demand volume flow) and adapting the central head elevation the supply characteristic curve of Sonnenberg can be determined in spHeat (continuous blue curve in Figure 28). The pressure drop caused by the supplying unit (heat exchanger, storage tank, valves etc.) is not considered. An approximation of this curve may be used in the second closed loop control method explained earlier. Assuming solar heat integration in the same node 56 and following the characteristic curve (w/o integration) also leads to unnecessary high pressures as shown in Figure 29. The head level increases for almost all nodes through the decentralised integration.

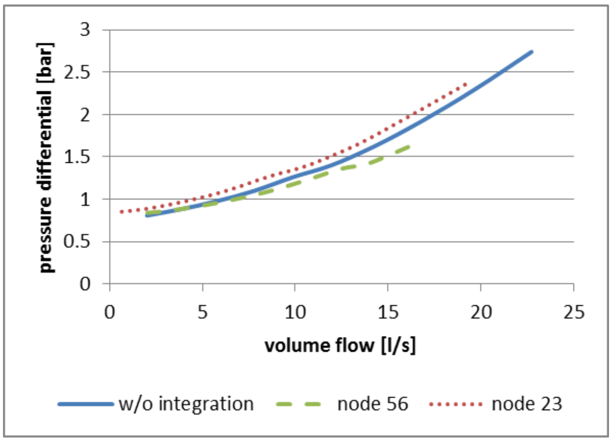


Figure 28: The central pump characteristic curve

Figure 28 also shows the supply characteristic curves obtained in spHeat for two different integration points (dotted for node 56 and dashed for node 23 in the upper left side of the network). In both cases a constant feed-in flow rate of approx. 3l/s has been applied. To minimise the consumption of the major pump a slightly ‘adapted’ characteristic curve should be applied. In a network with several integration candidates a trade-off between pump energy savings and curve adaptation effort has to be taken. The dependency of the characteristic curve on the amount (e.g. number and capacity of nodes) of heat being integrated will be studied in future simulations.

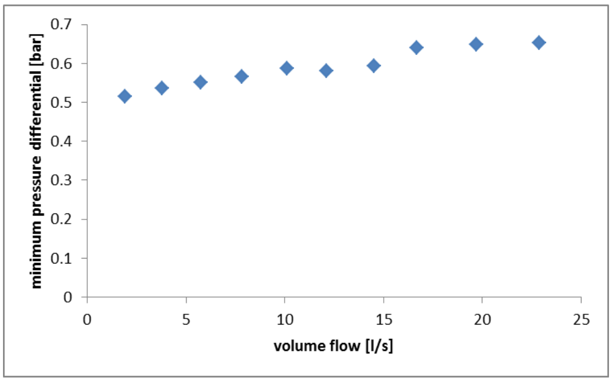


Figure 29: The critical nodal differential pressure

4. THE TEST FACILITY

4.1 The general layout

The test facility is being built as part of a running EnEff:Wärme project funded by the German Federal Ministry of Economics and Technology. It is designed to develop and test heat substations under different operational conditions (differential pressure and feed temperature). The first part of the rig has been already built to emulate a small heating network with six connections. Hot water is heated up electrically (right side of Figure 30). The estimated storage heat capacity is 36kWh. The differential pressure is maintained by a circulation pump with PID-controlled speed. The final hot water temperature is controlled by a PI-controlled 3-way mixing valve. Different valves are used along the supply and return line to simulate different pressure levels within the network.

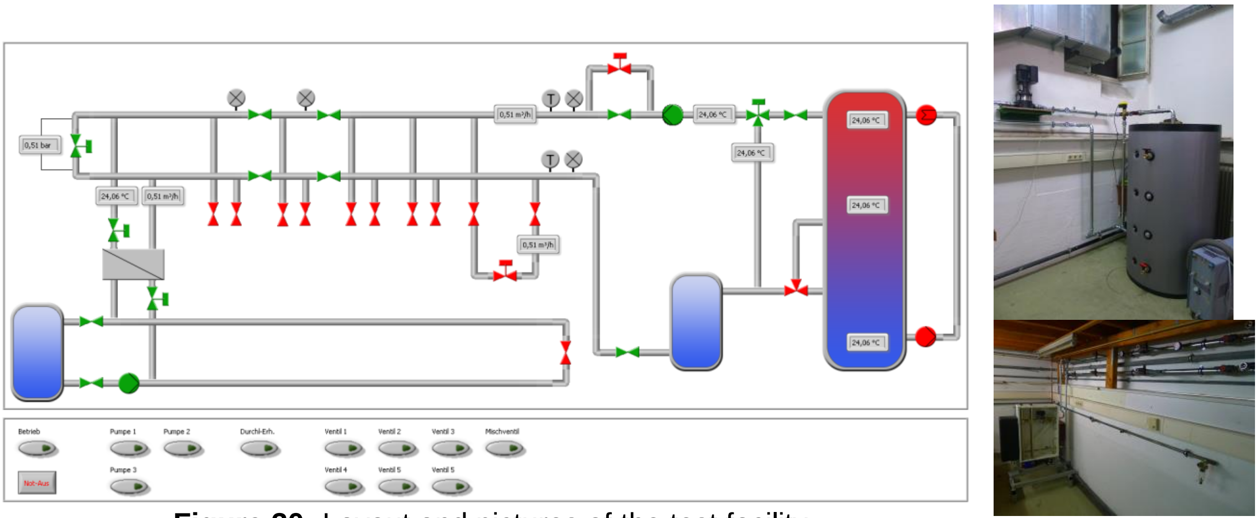


Figure 30: Layout and pictures of the test facility

The test object(s) can be connected close to measurement point for differential pressure or even closer to the pump. The cooling of the test objects is provided by a separate sub-network which is cooled by a fan coil. Differential pressure up to 3.0bar and supply temperatures up to 100°C can be reached. The test rig is designed for small stations with up to 15kW transfer capacity and the expected flow rate does not exceed 4m³/h.

4.2 The test topics

As mentioned in the introduction, the feed-in return→flow principle is challenging from a hydraulic point of view. In the few works like [Jure] found about this kind of integration the hydraulic aspect remains unexplored. The main questions to be answered by testing are:

- Which components are suitable for bidirectional heat exchange?
- How can the needed effort to feed-in surplus heat in DH networks be quantified?
- Under which operational conditions can decentralised heat integration be economic?
- Which feed-in principle is suitable under which operational conditions?

Furthermore control algorithms to overcome fast flow and temperature changes from solar side in direct integration circuits will be implemented. Cascade control and feed-forward of the solar side temperature are some of the planned schemes.

Heat metering also presents an important topic. Current costs for a bidirectional solution amount to around 2500€ with ultrasonic transmitters. The accuracy of valve bridges in combination with flow meters will be investigated (Figure 31). Also constant flow valves for use in the feed-in direction will be considered. The strategy to adjust own load and surplus heat is also one of the key issues in decentralised solar heat integration. The integration of this kind of strategies in the supply management of the whole DH system will be addressed.

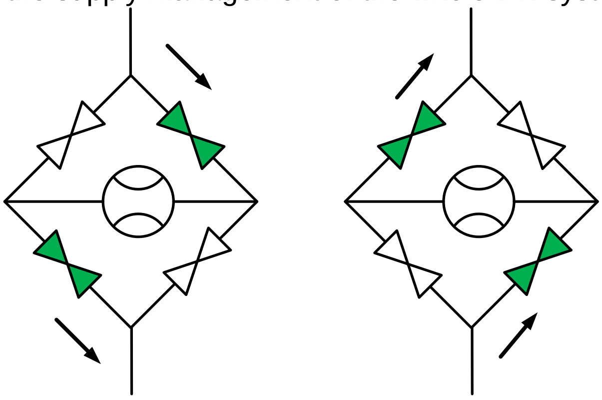


Figure 31: Valve bridge

5. CONCLUSIONS

The extension of the district heating analysis tool spHeat is described in this paper. The so far separated models for supply and return sub-networks have been merged into one model. The integration of head sources became easier. First static calculations show that critical differential pressure driven operation of the district pump is much more difficult in the case of return→feed heat integration. The planned test rig for bidirectional heat transfer stations is presented. The first phase of the installation has been completed.

REFERENCES

Ben Hassine I. and Eicker U. (2012) Impact of load structure variation and solar thermal energy integration on an existing district heating network Applied Thermal Engineering, Online 2 January 2012, ISSN 1359-4311

Eicker U. (2004) POLYCITY – Europäische Energieforschung für Kommunen. Solares Bauen. Sonderheft der Sonnenenergie.

SDH (2012) Solar district heating guidelines, collection of fact sheets, WP3-D3.1 & D3.2, IEE

G. Bucar et al. (2006): Dezentrale erneuerbare Energie für bestehende Fernwärmenetze. Berichte aus Energie- und Umweltforschung. Grazer Energieagentur

C. Fink et al. (2007): MOSOL-NET: Entwicklung von modular erweiterbaren technischen Lösungen, die eine Wärmeversorgung von Neubaugebieten über solar unterstützte Nahwärmenetze ermöglichen, Endbericht AEE-Intec, Geilsdorf

Vetrsek J. (2010) district heating system optimization with integration of distributed heat generation from renewable sources and demand site measures, School for Renewable Energy Sciences, Akureyri, Island

Horneber, E.-H. (1985) Simulation elektrischer Schaltungen auf dem Rechner. Fachberichte Simulation Bd. 5. Springer-Verlag

Bruce E. *Larock*, Roland W. Jeppson, Gary Z. Watters (1999) Hydraulics of Pipeline Systems, ISBN-10: 0849318068, edition 1

Ben Hassine I. and Eicker, U. (2011): Simulation and optimization of the district heating network in Scharnhauser Park. In Proceedings of 2nd Polygeneration conference, Tarragona, 30.3.-1.4.2011, ISBN 978-84-614-9844-4

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Structure and Activities of the Research Institute Zafh.net at the Hochschule für Technik-Stuttgart (HfT)

Dietrich Schneider
Hochschule für Technik-Stuttgart, e-mail: dietrich.schneider@hft-stuttgart.de

Abstract

This presentation gives an overview of the structure, history, activities and facilities of the zafh.net in order to ease the definition of common points of research interest for future activities as well as show opportunities of synergetic research collaboration. The zafh.net is divided into the management board headed by Prof. Dr. Ursula Eicker and three thematic research groups, which closely interact on demand. The first group "Urban Energy Concepts" mainly deals with large scale demonstration sites, such as city quarters and big company sites and focuses on all aspects of energy saving supply strategies, distribution systems and integration of renewables in such strategies. The "Renewable Energy Technology" section is involved in the development and optimization of renewable energy supply systems incorporating e.g. PV, solar thermal, thermal and PV cooling, biomass combustion as well as advanced storage technologies. The third group "Innovative Buildings" deals with all energy related topics on the building scale. Besides the expertise in the above mentioned fields represented by a total of 30 full time scientists, the zafh.net offers a large number of labs and test facilities, such as solar test fields, Air conditioning rigs, control development lab, PVT-test fields and electronic-chemical and software labs as well as a big selection of energy and thermo dynamics related simulation tools.

Key words: *Research structure, zafh.net, urban energy concepts, renewable energy technology, innovative buildings*

1. ZAFHNET STRUCTURE

The research institute zafh.net originally developed from a group of research interested Universities in the province of Baden Württemberg, Germany formed in 2001 for a time span of 3 years. From this group the HfT decided to carry on renewable energy related research taking over the name of the former group and started to form a ever since growing research institute. The rapid growth of the institute demanded for a structure and the research activities where divided into three main research fields: Urban energy concepts, renewable energy technology and innovative buildings (Figure 1)

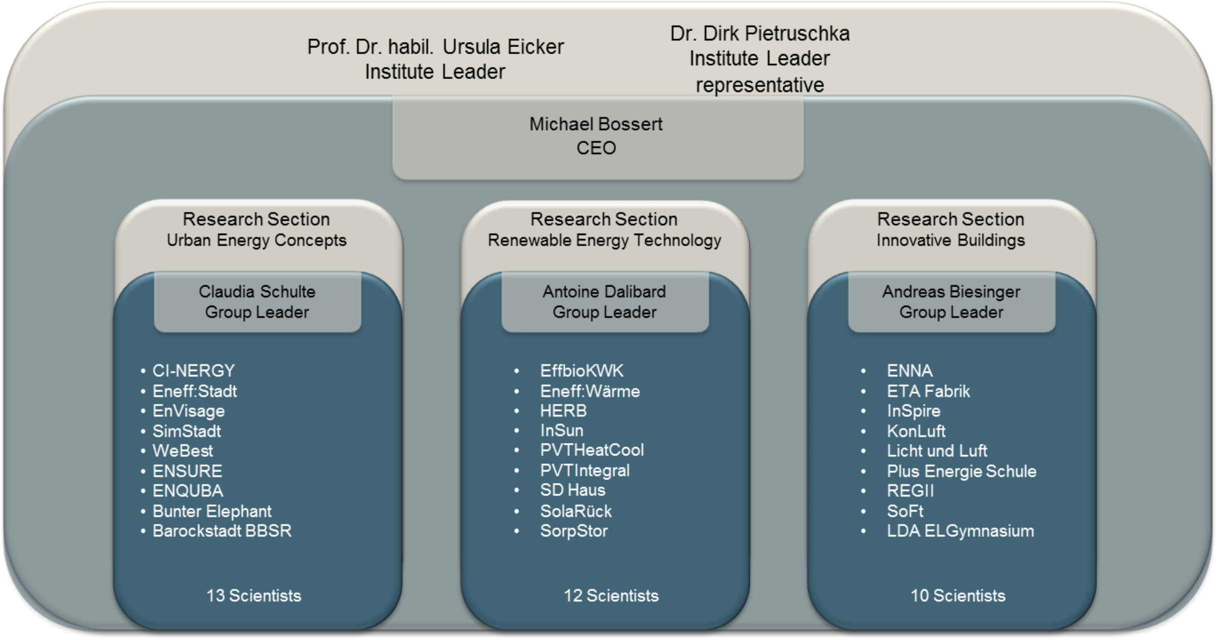


Figure 1: Structure of zafh.net

As the focus point of the planned collaboration of the consortium was put on the demonstration as well as optimization of renewable energy technologies the role and activities of the Renewable energy group (REG) of the zafh.net was described closer. This group presently works on more than 10 EU, governmentally, provincially and commercially funded projects with 10 full time scientists (Figure 2).

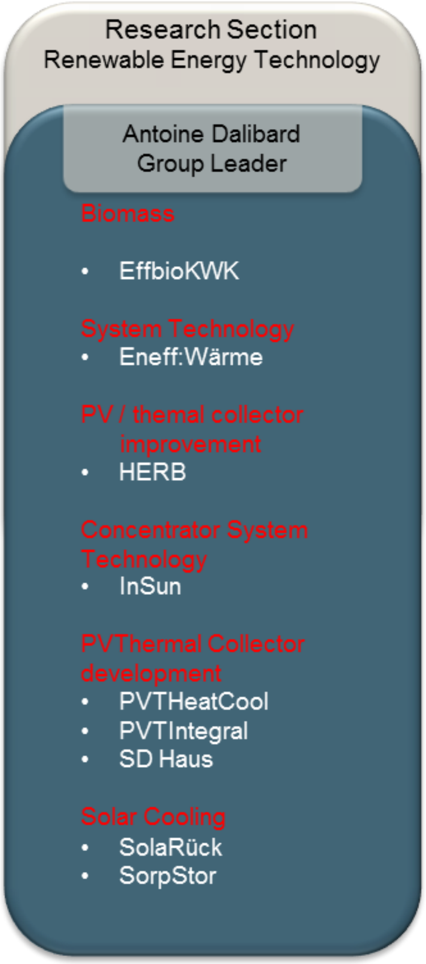


Figure 2: Research fields and project activities of the Renewable technology group of zafh.net

2. RESEARCH FOCUS POINTS OF REG

In order to give a closer insight into the specific research activities some example fields were described more closely.

2.1 Biomass

Under the biomass topic mainly the improvement, design and modelling of biomass combustion processes, the development and implementation of innovative control strategies, the development and implementation and demonstration of energy efficiency improvement measures for biomass power plants and low temperature steam processes (ORC) as well as monitoring and performance analysis are carried out at different district sized biomass CHPs (up to 10 MW heating performance) mostly combined with district heating systems and ORC electricity production (Figure 3).

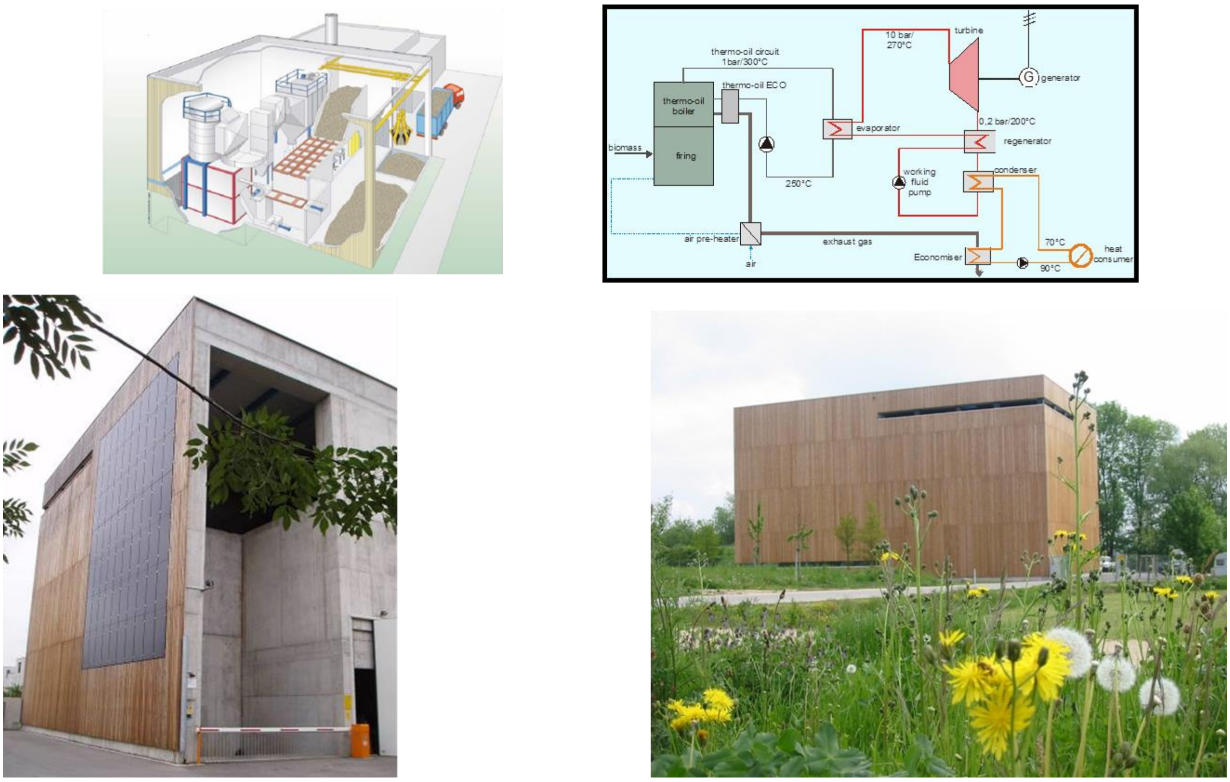


Figure 3: Test-Biomass facility 1: Scharnhauser Park

2.2 System technology

A second field of research of the REG is the development of advanced technology combinations, such as the improvement, design and modelling of district heating systems, solar power plants, solar cooling systems, the development and implementation of innovative control strategies, the development and implementation of energy efficient hydraulic combinations of different energy supply systems (Figure 4)

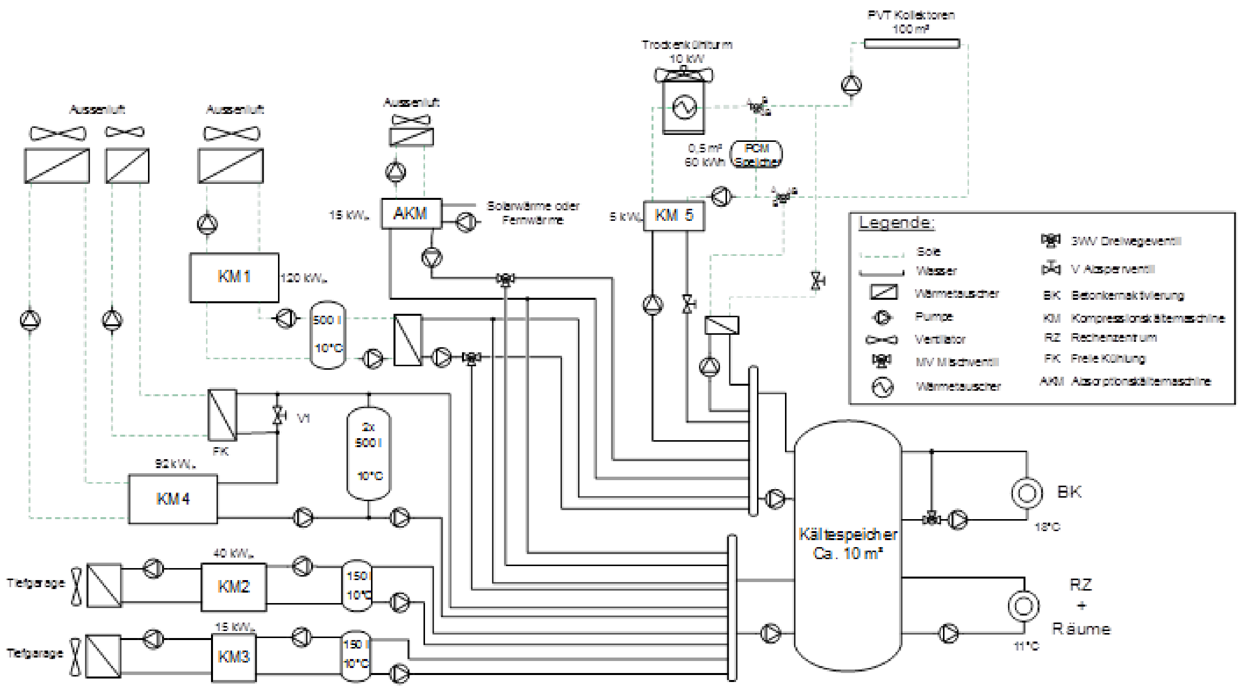
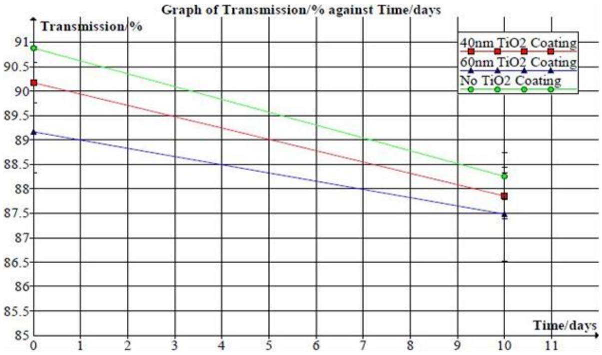


Figure 4: Improved hydraulical cold supply configuration for the HfT-Campus

2.3 PV and solar thermal Collector Optimization

Another research field of the REG was defined on the optimization and further development of PV and solarthermal collectortechnologies e.g. the performance optimization of PV and thermal collector performance by nano-coatings, the development and implementation of innovative control strategies for solar systems, the development of energy efficient medium temperature low concentrating thermal flat collectors and by monitoring and performance analysis (Figure 5).



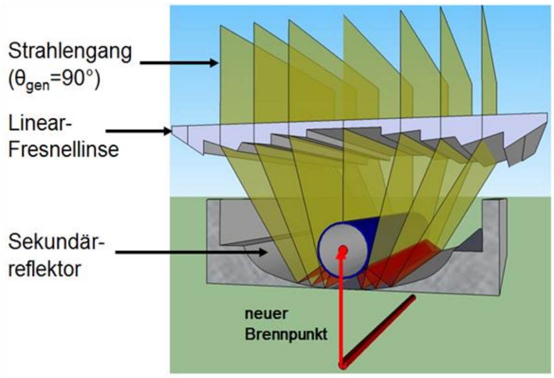


Figure 5: Results of coating investigations and optical analysis of low concentrating fresnell-cpc combinations

2.4 High temperature concentrating solar systems

In this research field performance optimization of Fresnel and parabolic solar power plants and process heat supply systems, development and implementation of innovative control strategies, implementation and demonstration of improved SPP and process heat generators as well as the development and implementation of energy efficient hydraulic schemes for steam and thermo-oil high temperature solar systems is carried out (Figure 6).

Impression of the thermal oil driven collecor field

Solar thermal collector field with direct steam generation

Figure 6: Demonstration sites of REG monitored high temperature solar fields

2.5 PVT Collector development

A further research focus of the REG is represented by own developments and improvement of market available PVT-Collectors resulting in recognized competition prices (Solar Decathlon 2012, 2013). Main activities are the performance analysis of PVT-collectors, development and implementation of innovative hybrid PV-thermal collectors and the implementation and Demonstration of improved PVT-systems (Figure 7).

SOLAR DECATHLON EUROPE 2010
HFT Stuttgart (3^{rd} place)

Figure 7: PVT demonstration sites and test facilities

2.6 Solar cooling

Finally all relevant solar cooling technologies are investigated in this research field focusing on development, analysis and improvement of Absorption Systems (NH3/H2O, development, analysis and improvement of open liquid absorption systems (LiCl / CaCl), development, analysis and improvement of high density low loss storage systems (liquid: solution storage/ NH3/H2O: ice storage), definition and analysis of non or low corrosive sorbents for liquid sorption systems (ionic fluids / other salt solutions), implementation and demonstration of solar assisted open adsorption systems (DEC) and development of energy saving heat rejection strategies and technologies (Figure 8).

Figure 8: Demo sites of REG solar cooling installations

3. LAB FACILITIES

For further detailling of research oportunities the Labstructure of the REG was detailled and consisits of the following facilities:

- Air conditioning rig (humidity and temperature, volume flow up to 3000 m^3 / h)
- thermal cooling test bench (electric heaters, wet cooling tower, solar system)
- Lab-DEC system
- LabView based monitoring and control development platforms (several FieldPoint systems)
- PVT-test field
- Experimental air collector (20 m^2) and vacuum tube collector fields (40 and 20m^2)
- Electronic, chemical and software lab

Building energy efficiency with climate envelopes

Arda Karasu
Technische Universität Berlin, Karasu@tu-berlin.de

Abstract

A climate envelope is a place for living. It offers comfortable conditions, protected from the changing outside world. In other words, it is a permanently „climate-adapted“ living space. From an architectural point of view, the term climate envelope describes the combination of a building with an additional transparent external envelope. The envelope is utilised as an architectural means of adapting to climate change and to mitigating the effects thereof.

Key words: *Climate Envelope, Energy Efficient Architecture*

1. BUILDING WITH CLIMATE ENVELOPES

Residential districts located on larger roads, beside railways or near airports have to contend with noise and poor air quality. Rooftop and facade greenhouses, greenhouses close to buildings or large transparent climate envelopes that span a number of buildings can create new urban living spaces with reduced noise and purified air.

It all began in 1960 with the visionary idea of the American architect Buckminster Fuller. He designed a glass shell for New York that was to cover the whole of Manhattan. The project, certainly intended to be provocative, was never implemented. The popularity of the idea derives from the architect‘s message that its implementation seemed fundamentally possible in terms of construction and building technology – even if not at the scale originally envisioned. Over fifty years later Fuller‘s vision serves as an important foundation for the new paradigm „Building with Climate Envelopes“ and provides equal inspiration for architects, engineers, and urban ecologists.

The investigation of the individual parameters of this typology clearly shows that new technical and design challenges for architecture and building technology are presented by the creation of a climate envelope in which people should, at least at times, live, work and spend time. These challenges concern themes such as energy supply, noise insulation, solar protection, ventilation, construction, vegetation technology and many more.

Numerous studies have already demonstrated that, based on increasingly developed technical capabilities, this utopia can be made reality at a number of different scales, ranging from an individual house to a completely covered estate. In addition to the ecological advantages the focus here is on the creation of better living and working conditions.

1.1 Increased Energy Efficiency

The energy principle of the climate envelope is based primarily on the Watergy technology: the air in the climate envelope is warmed and humidified by solar radiation and plants and is dehumidified and thus further heated over a liquid desiccant. When solar radiation is low this thermal potential can be directly passed on to the building in the form of warm air. When solar radiation is high heat can be stored in the liquid desiccant to be used in the building at night or on subsequent low radiation days. This principle can be combined with further active measures such as the cooling of buildings, water reclamation and the intensive cultivation of plants, and enables higher overall energy efficiency with reduced consumption of resources.

Buildings inside a climate envelope can be designed to differ both in terms of architecture and construction from freestanding buildings due to the favourable microclimatic conditions that prevail. The transparent envelope provides complete protection against wind and rain, so that inside the envelope significantly lighter materials and simpler construction solutions can be used. Furthermore, simulations have shown that the surface temperature of roofs and facades under a climate envelope can be 7–8 degrees lower in summer and 11–14 degrees higher in winter. For more than ten months the temperature under a climate envelope reaches around 18 degrees Celsius.

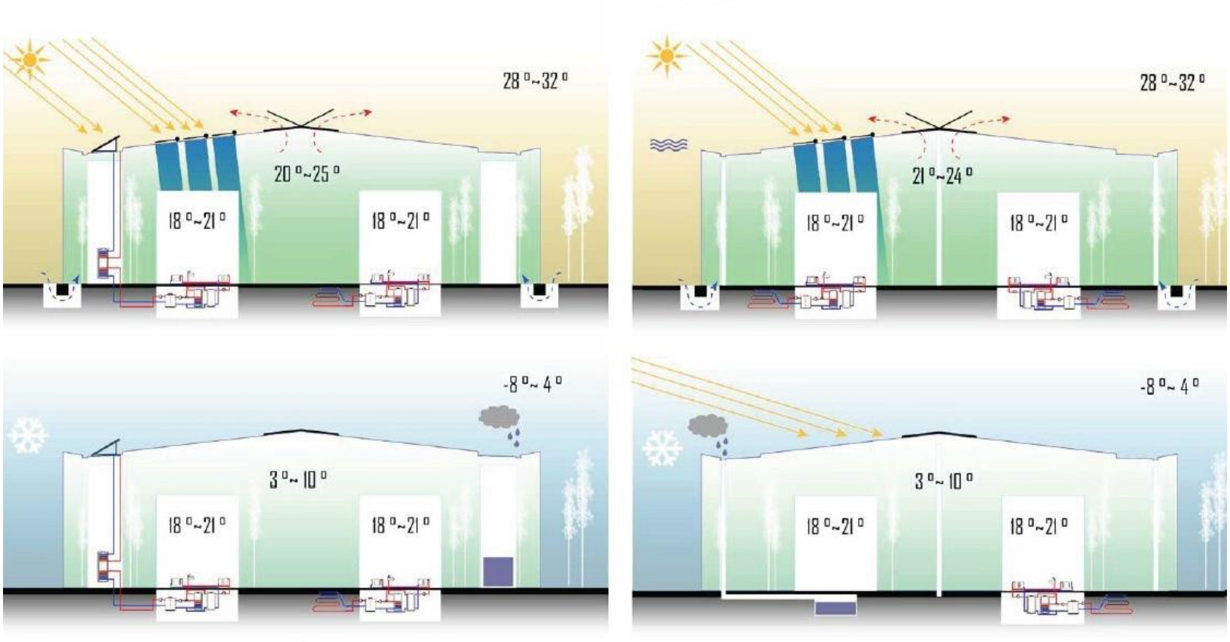


Figure 3. Temperature differences between outside, under the climate envelope and inside the building: Climate envelope as thermal barrier reduces both cooling and heating energy demand.

1.2 Noise Mitigation

In many inner-city locations residents suffer from excessive noise pollution. Traffic on roads, rails and in the air is a particular source of extrinsic insomnia, which can lead to tiredness, lack of concentration and even serious heart problems. A climate envelope as an outer layer could significantly reduce the noise. The starting point here is controlled ventilation, which not only provides hygienic air conditions in the buildings but also abolishes the noise factor related to uncontrolled natural ventilation via windows.

Numerous studies and publications have demonstrated the noise mitigating characteristics of climate envelopes. An appropriate choice of construction and materials can lead to a maximum sound level of 83 dB(A) being reduced to a maximum of 28 dB(A) in the interior space of a building under the climate envelope, without further noise insulation measures being necessary in the building itself.

Acoustic resonance problems from internal sources of noise in the interior of the envelope can be avoided by simple acoustic measures on the building exterior. Extensive green areas, that also play an important role for temperature control under the climate envelope, and the minimum possible proportion of sealed surfaces have a notably positive influence on the noise atmosphere.

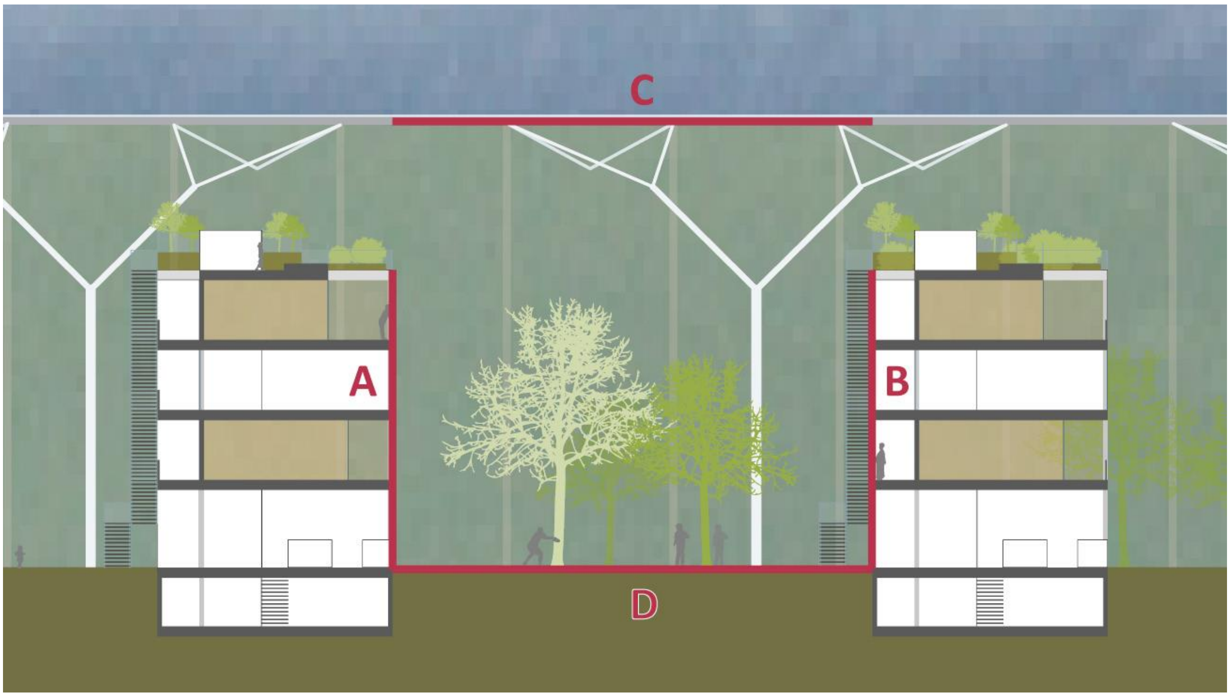


Figure 2. The climate envelope, the facades of the inside building and the free spaces should harmonise with each other acoustically: It is possible to achieve around 20dB reduction through the climate envelope that leads to lower noise level for indoor compared with German standards.

1.3 Additional living space

The climate envelope gives the building an additional space that can serve various purposes. The difference between a conventional conservatory and a climate envelope is the regulated air circulation and air humidity, which allows the period of utilisation to be extended and enables other forms of use as well as providing additional living space. An example of this are „rooftop greenhouses with integrated urban agriculture“. Here people that use the building can establish a garden inside the climate envelope. On large urban rooftop surfaces the utilisation of the space by a professional gardening firm is also a possibility.

1.4 Economic viability

The economic viability of the climate envelope results from the higher quality of the building (in terms of usage, design, noise mitigation and air quality, particularly at locations exposed to high noise and emission levels), from the heat produced in the climate envelope, and, as desired, from the reclaimed (condensed) water and cultivated food.

1.5 Field of use

The concept of climate envelopes is today still largely based on theoretical deliberations and ideas. It seems likely that climate envelopes will become increasingly important in light of their many possible applications in the context of the quality of residential environments, the long winter in northern cities, problems involved in developing land on major traffic arteries, new possibilities associated with energy-efficient construction, solar energy exploitation, water recovery in arid climate and the possibility of urban gardening and recycling.

2. PROTOTYPE

The Climate Envelope is based on two main architectural elements: a greenhouse as the outer shelter and a container representing the building adjacent to the climate envelope. The prototype envelope is constructed under use of double glazing, allowing reducing thermal energy losses and noise transmission. It is equipped with a smart desiccant system developed by Watergy for humidification- and temperature control, with potential for renewable energy storage (or re-use of industrial waste heat). Detailed components of the structure are as follows:

Figure 2. left: the first location in Blankenfelde-Mahlow. Right: the second location in the campus of TU Berlin

- The 6-9 m greenhouse has an aluminum construction. It has a gable roof with a ridge height of 410cm, where the height of vertical walls 268cm is. Both of the glazing for the façade (4-4-4) and the roof (6-4-4) have an U-value of 2 W/m^{2}K. According to the German building regulations, the width of the window panes on the roof has been kept narrow. Laminated safety glass with a width of 49cm has been used for the roof, whereas the façade panes have the double width.
- A standard 20′ office container with a glass façade will be used as an enclosed space in the prototype. The U-values for the façade and the roof of the container are 0.44 W/m^{2}K and 0.36 W/m^{2}K, respectively.
- There is a podium around the container to enable the usage of the exterior walls of the container for the exhibition and have a closer look to the greenhouse part. The podium in the southern part has been kept larger to emphasize the entrance. With 2m it is two times larger than the corridor around the container.
- The space between the container and the southern façade of the greenhouse of the container will be covered with plants to supply humid air for the ventilation system.

Heating, cooling and humidification in the Climate Envelope prototype has been developed in collaboration with the start-up, Watergy, established in 2008. Watergy designs and produces heat and humidity management systems based on special saline solutions called “Smart Desiccants” to provide seasonal and day/night storage for renewable air conditioning and heating in housing and greenhouses. Watergy’s patented system has been further developed and tested within the Climate-KIC funded N-DEMO project for use in conjunction with the Climate Envelope. The Building, Technology and Design team at TU-Berlin developed a climate control system for humidity to heat conversion to enable space heating and cooling supply using Watergy's dessicant system. This system was then tested in the Climate Envelope prototype.

The smart dessicant system offers a new phase change material storage system suitable to greenhouse temperature control using an inexpensive salt hydrate material. It operates by using a buoyancy-driven air-cycle heat exchanger, in direct contact with the phase change material, using low temperature heat whilst minimizing electric power needed for pumping and ventilation, making it a low-cost, low-energy solution.

3. CONCLUSIONS

The altered climatic conditions in climate envelopes enable a change of thinking when planning buildings. Under a climate envelope the various requirements involved in the conventional planning of buildings can be viewed as a comprehensive package, as these requirements significantly influence one another. This complexity provides new challenges for all planners and especially for architects.

4. REFERENCES

Karasu A, Buchholz M, Steffan C (2013), *Bauen mit Klimahüllen-Building with Climate Envelopes*, Universitätsverlag TU-Berlin, Berlin, ISBN 978-3-7983-2648-4

Karasu A, Buchholz M, Buchholz R (2013), *Regional Thermal Energy Network Based on Waste Energy with Desiccants: Pilot Project within a Climate Envelope*, Climate Change and Regional Response Conference, Dresden

Karasu A, Buchholz M, Jakob A (2012), *BIG: Building Integrated Greenhouses*, Energy Forum Bressanone, Italy

Watergy - a new HVAC system

Martin Buchholz

Watergy GmbH, Berlin and
Technische Universität Berlin
martin.buchholz@watergy.de

1. Heat recovery and humidity regulation in buildings

Humid air in buildings accures through showering, cooking and drying laundry, as well as the breathing of the inhabitants and plants. This humidity holds heat energy that is usually lost when airing the rooms of the building. The humidity itself, however, must be removed as otherwise condensation develops on the windows or cold walls. On the other hand, when well-insulated rooms are heated the air in them is usually much too dry.

In order to improve energy efficiency and air quality the humidity is taken up by a liquid desiccant in a recirculation or extraction unit. This abolishes the need for unwieldy and unhygienic ventilation pipes in the building, as the air from the air supply and extraction units can flow freely through the rooms.

The liquid desiccant is thereby heated and transported to the air supply unit to heat and humidify the air flowing into the building. Humidity peaks are thus taken up by the exhaust air, while in the interests of health a minimum humidity is always maintained.

Germs and dust in the air supply and in the interior air are also taken up and neutralised by the liquid desiccant, or are removed with a direct contact water-to-air filter.

2. Cooling buildings with water as a renewable energy source

In the summer water can be evaporated in the air extraction unit. Due to the evaporation the water is cooled. The cold water is conveyed over a heat exchanger and thus to the air supply unit. The liquid desiccant in the air supply unit is thereby indirectly cooled and can dehumidify and cool the supply air in a targeted manner.

The heat taken up by the liquid desiccant during the day is retained in a storage unit. This heat can be used at night and the water taken up by the liquid desiccant is[Unbekannt1] thereby once again evaporated. The evaporation of water in the extraction unit also continues during night. This allows cold to be retained in the same storage unit for use in cooling the building the next day. One storage unit is thus employed for the simultaneous retention of heat (regeneration of the liquid desiccant at night) and of cold (for air conditioning of the building).

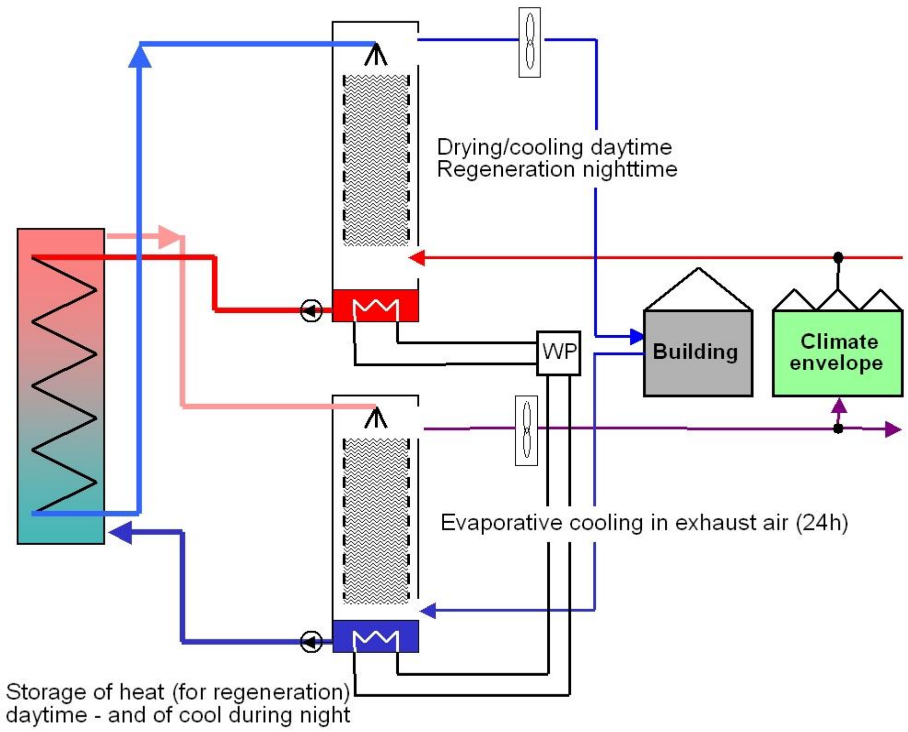


Figure 1: Liquid desiccant system for combined sorptive/evaporative cooling including a thermal storage for cool and heat accumulation

3. Climate envelope as a solar thermal collector

A rooftop or facade greenhouse can, with the help of the Watergy Absorberbox, be used as a solar thermal collector. Due to solar energy warm air develops in the greenhouse and is humidified by the plants. Energy is present in both the heat and the humidity.

Heating with air from the greenhouse: in winter temperatures reach 15-20°C even with light and diffuse solar radiation. By dehumidifying the air in the Watergy Box the temperature is increased to 20-28°C and can then be directly used for heating in the building.

Loading the storage unit with energy from the greenhouse: On really sunny days temperatures reach about 35°C in winter. The liquid desiccant heats up as it takes up humidity from the air in the greenhouse, and reaches temperatures of about 40-45°C. This stored heat can then be used for heating the building at other times, for instance at night or on days with no sunshine.

4. Climate envelopes for the production of water

In a completely closed greenhouse the water vapour evaporated by plants is taken up by the Watergy Absorberbox.

The heat taken up by the liquid desiccant is retained in the storage unit until night. The plants can thus continue to evaporate water throughout the day and with the help of this effect, the temperature of the greenhouse is contoled.

At night the heat from the storage unit is used to reheat the liquid desiccant. The water that has been taken up is evaporated and released into the air of the greenhouse. Finally the water condenses on the inside of the greenhouse walls and can thus be recovered.

This solution is being tested as a pilot project in Cairo, Egypt by the Technical University Berlin and Watergy in cooperation with Cairo University, and is a particularly promising option for agriculture and water supply in cities in arid regions.

A further interesting feature is the possibility of using pre-treated greywater for irrigation, while the recovered condensation can be upgraded to high-quality drinking water through the use of simple filters. This is made possible by the complete removal of the bacteria present in the greywater through combined evaporation and condensation.

The recovered condensation contains no minerals, and is thus most suitable for use in the production of evaporative cooling. High concentrations of minerals would quickly clog the evaporation unit. Alternatively, distilled water or water filtered through a membrane can be used; this is, however, relatively expensive. Rainwater can also be used but is not always available, especially in the summer months when the demand for cooling is higher. Large tanks that can store the rainwater for months at a time can be more expensive than water processing equipment.

5. New energy network with climate envelopes, the liquid desiccant network

There is a great amount of low temperature waste heat available at many urban locations. The will to use this heat exists but there is a lack of appropriate heat sinks. The solution to this problem can be found by using the heat to increase concentrations in the hygroscopic liquid desiccant.

Absorption materials based on hygroscopic salt solutions can be utilised for the dehumidifying processes and for applications to recover latent heat from industry and buildings. Urban solar greenhouses represent the field of application with the greatest potential for growth.

The ability of the liquid desiccant to absorb water uses the thermo-chemical characteristics of the salt solution, which in contrast to district heating is maintained during transport and storage. The energetic density reached is also about three times greater. Through the absorption of humidity the liquid desiccant is diluted. The ability to absorb water thereby decreases. When a certain level of dilution is reached the desiccant needs regenerating, i.e. it must be made more concentrated.

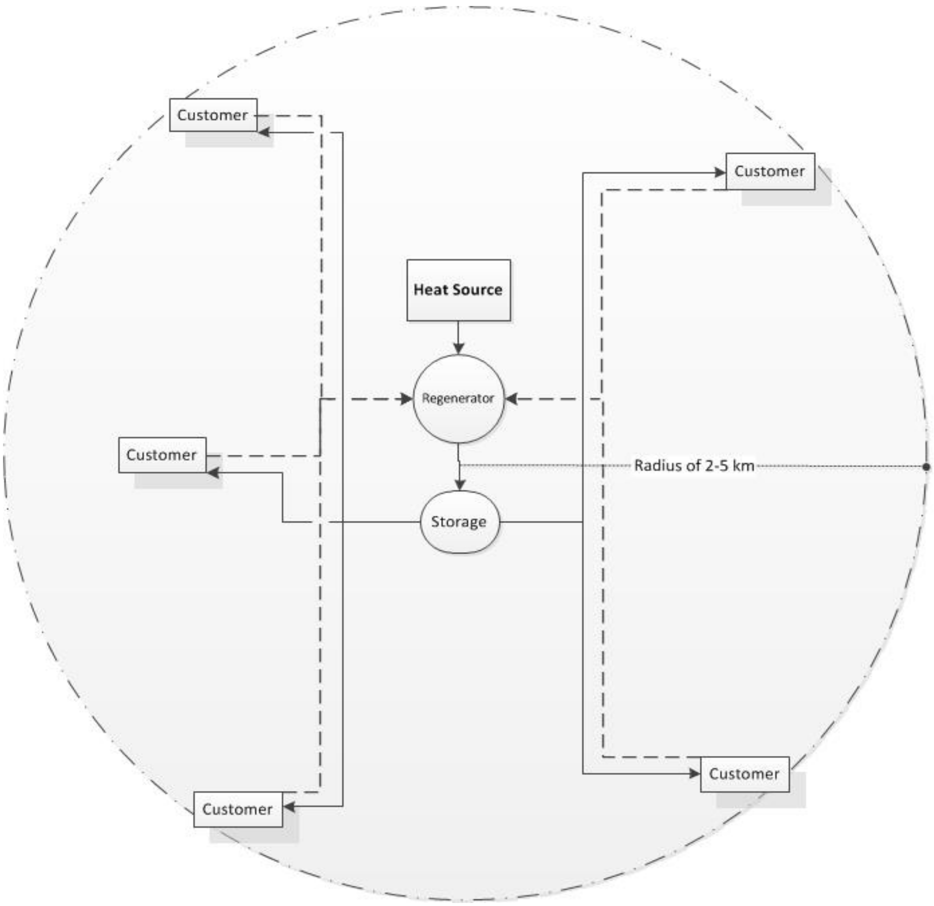


Figure 2: Concept of a desiccant network, using waste heat for desiccant regeneration

Through the introduction of heat the water is once again removed from the solution: it is "desorbed" and can be released to the outside air as water vapour. The relative humidity of the outside air is determined by the climate of the surroundings.

High levels of humidity can be reduced by heating. Industrial processes or the cooling towers of power plants, and also waste heat from cooling systems, decentralised co-generation units and solar power installations are suitable for this. In winter the regeneration of the liquid desiccant can also be carried out at very low temperatures (10–25 °C) as the humidity of the cold outside air is correspondingly low. In this way aquifer and near-surface ground stores with seasonally stored heat can be utilised without the need for heat pumps as required in conventional systems. Network distances of up to 50km are made possible by the high energetic density and the storage ability of the liquid desiccant, thus allowing the exploitation of more remote heat sources that may only exist at certain times.

How Effective Could Be The Thermal Insulation Of Buildings In Mediterranean Climate?

Ahmet Arisoy, Burhan Yoruk
İstanbul Technical University, arisoyah@itu.edu.tr

Abstract

High performance buildings usually have thick thermal insulation from the outside. Especially net or nearly zero energy buildings (nZEB) or passive houses are required very thick insulation for North European countries. In some cases thickness of insulation can reach 0.5 m value. However in case of cooling, such high insulation thicknesses can cause reverse effects. Night cooling of this type of buildings cannot be possible. The other effecting parameter is place of the insulation. Depending on the applying insulation layer to inside the wall or outside the wall changes the cooling energy demand considerably in summer time. In Mediterranean climate high performing building design require some peculiar elements apart from the North Europe.

A case study has been considered for this purpose and these parameters will be studied theoretically by the help of a building simulation program. HAP program of the Carrier Company will be used for this purpose. Another special and simple program will also be developed by us and it will be used to check the HAP simulation results.

Key words: *Thermal insulation, Nearly Zero Energy Building, Building simulation, Mass effect, Climate effect.*

1. INTRODUCTION

Energy efficiency is the first consideration in building and its HVAC system design today. EPBD has brought the target of nZEB concept recently (1). Nearly zero energy building requires that building's energy consumption from fossil sources should be reduced to the nearly zero. This target can be reached firstly redesigning outer skin of the building. Nearly zero energy building design methodology is being worked extensively in all European countries recently. But this methodology should be differentiated based on climate. Single solution cannot be applied in all over the Europe successfully.

Cold North Europe countries may stress the outer thermal insulation of the building. It is gainful to increase insulation thicknesses as much as possible in winter conditions. However this is not a good strategy in summer conditions. When it is needed to cool the building, thickness of the insulation, application of this insulation from inside or outside, mass of the wall, window type and area and shading are effective on the heat gain and consumed energy.

In this study thickness of the thermal insulation on building thermal performance for different climates has been investigated. In summer condition, which is important for Mediterranean climate, wall mass, insulation thickness and its application have been also investigated. Lastly window has been considered and comparing wall importance of window studied for Mediterranean climate.

An Excel program has been developed to investigate the insulated wall performance. Heat loads have been calculated for different wall types and insulation thicknesses for winter season and the summer season by this program. Mass effect and place of insulation layer have also been investigated.

Secondly EnergyPlus package program has been used to simulate the building performance. A sample building with four stories have been considered. One story has only walls as the outer skin without windows and the other one has windows. The building is seen in Figure 1. Internal loads have been omitted and only external loads due to sun and temperature difference are considered. Comparison of the performances for different climates have been studied.

2. CALCULATIONS AND DISCUSSIONS

2.1 Insulation Thickness

A heating weighted climate has been considered. As the representative of such climate Ankara has been selected. Weather data for Ankara has been taken from IWEC (International Weather Data for Energy Calculation) database. For winter and summer design days calculated heat loads are plotted in Figure 2. Heat gain from sun light which hits on the outer surface of the wall has been considered in this calculation. Wall is concrete and 10 cm thick. The investigated parameter is thickness of the insulation layer. When thickness of the insulation increases, the heat loads decrease both in winter and in summer design days. Insulation thickness increases starting from 5 cm to 2 meters.

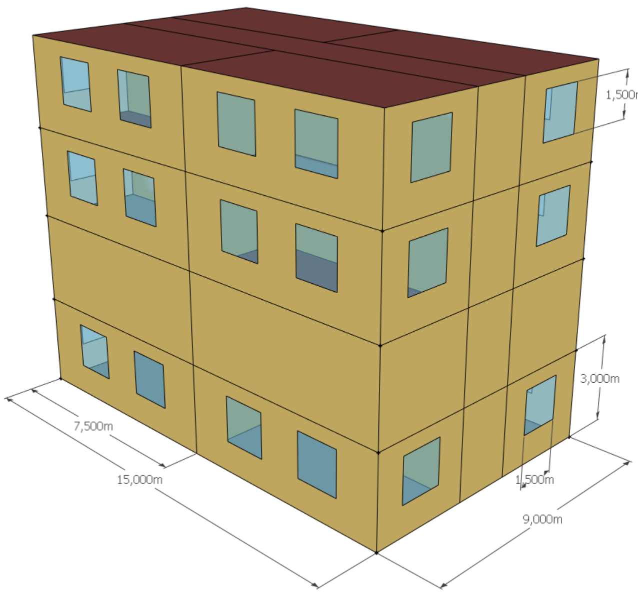


Figure 4. Sample building and its dimensions

Thickness of insulation is very important in winter conditions. Increasing thickness from 5 cm to 20 cm, decreases heat loss from 1305 kj/m^2 to 397 kj/m^2 values which corresponds to heat conservation of 900 kj/m^2. However conservation from cooling load is not that big in summer. Only 170 kj/m^2 energy can be conserved for same insulation thicknesses in summer conditions. In according to Figure 2, heat insulation of outer skin doesn't help too much in hot climates; it has a very limited effect. For heating weighted North Europe countries, increasing wall thermal insulation thickness is a good strategy and it is recommended as an important tool in nZEB design for this region. However increasing insulation thicknesses is not useful for Mediterranean region where cooling weighted

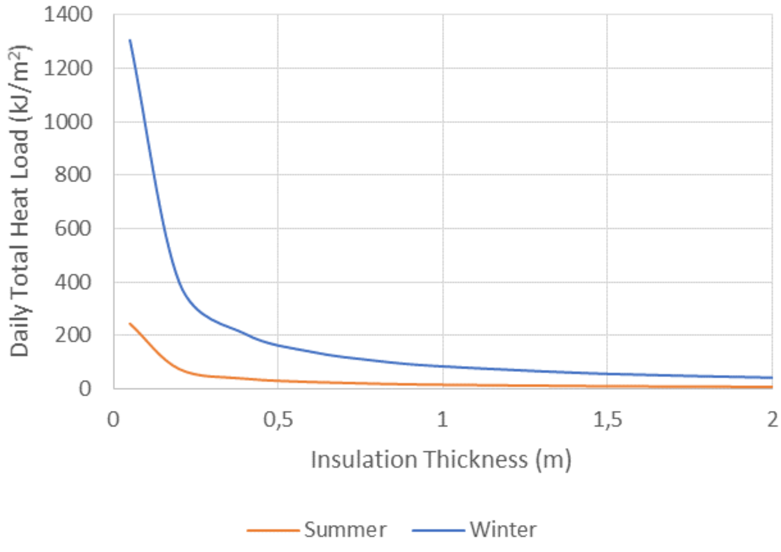


Figure 2. Ankara winter and summer design heat load from Wall versus insulation thickness

2.2 Applying thermal insulation to inside or to outside

Applying the insulation to inside of the wall or to outside of the wall is not effective on total daily heat loads in winter or summer, omitting thermal bridges (Figure 3). When we consider the hourly variation of outdoor temperature in winter this is true again. During day and night heat loss value doesn't change in cases application of insulation to inside or outside. However in summer daily variation of temperature is important and for in land cities daily temperature variation is big enough. In this case during day heat gain occurs and during night heat loss occurs. In such cases applying insulation to inside or to outside is effective. This can be seen in Figure 4. In such a climate, day time heat gain is less when outside insulation is applied. This benefit increases with increasing wall mass. However heat loss and cooling effect during night time increases when inside insulation is applied. This cooling effect in night period decreases with the thermal mass.

From this figure it can be seen that a dynamic insulation would be beneficial for in land hot climates. During the summer if insulation layer can be changed from inside to outside in turn during day and night, total daily heat gain value can be decreased. Mass of the wall should be optimized for this purpose. If this can be realized, benefit would be 67 kJ/m^2; for 20 cm concrete wall and 5 cm insulation case in Ankara.

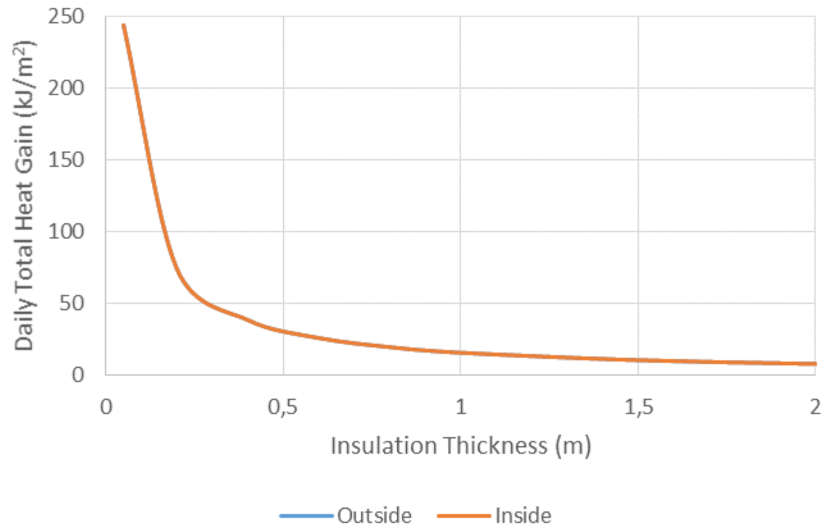
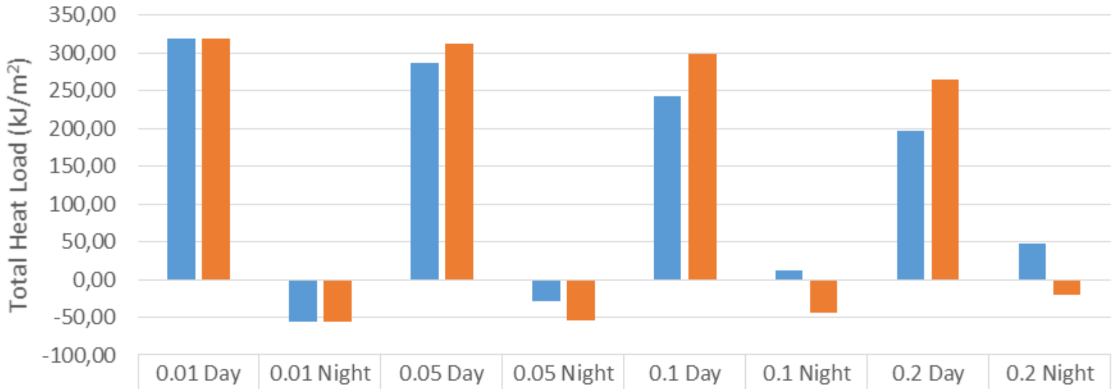


Figure 3. Comparison of insulation from inside or outside for Ankara



	0.01 Day	0.01 Night	0.05 Day	0.05 Night	0.1 Day	0.1 Night	0.2 Day	0.2 Night
Outside	319,39	-56,08	287,81	-28,72	242,52	11,48	197,37	47,02
Inside	319,95	-56,64	312,63	-53,54	298,59	-44,59	264,30	-19,90

Wall Thickness (m)

Figure 4. Ankara; total heat load for 5 cm thick insulation applied to inside or outside with changing concrete Wall thickness (mass)

Dynamic behavior of the wall can be seen well in Figure 5. When insulation is applied to outside, mean temperature of wall is close to the indoor temperature and it is very stable. However the when insulation is applied to inside, mean temperature of the wall varies along the outdoor temperature and drops below the indoor temperature. In this case during the night period heat is lost.

2.3 Building simulations and windows

The building which is seen in Figure 1 is modelled by using EnergyPlus. Building consists of 4 stories and there are 4 rooms and one corridor at each floor. Rooms are defined in according to the direction which they are facing; as SW room, SE room, NW room and NE room. Only two of the stories have been modelled. Total area of the each floor is 135 m^2. Second Floor has only walls as the outer skin without windows and the third floor has windows. Window dimension is 1.5x1.5 m and there are totally 12 windows at the third floor. Windows are double glazed and clear glass and no shading is considered. Internal loads have been omitted and only external loads are considered. Temperature difference and the solar heat gain are the only external loads, infiltration is also omitted. Two different cities in two different climates have been considered. These cities are Ankara in Turkey and Seville in Spain. Comparison of the performances of two different stories in two different climates have been used to evaluate the importance of the windows in hot climates.

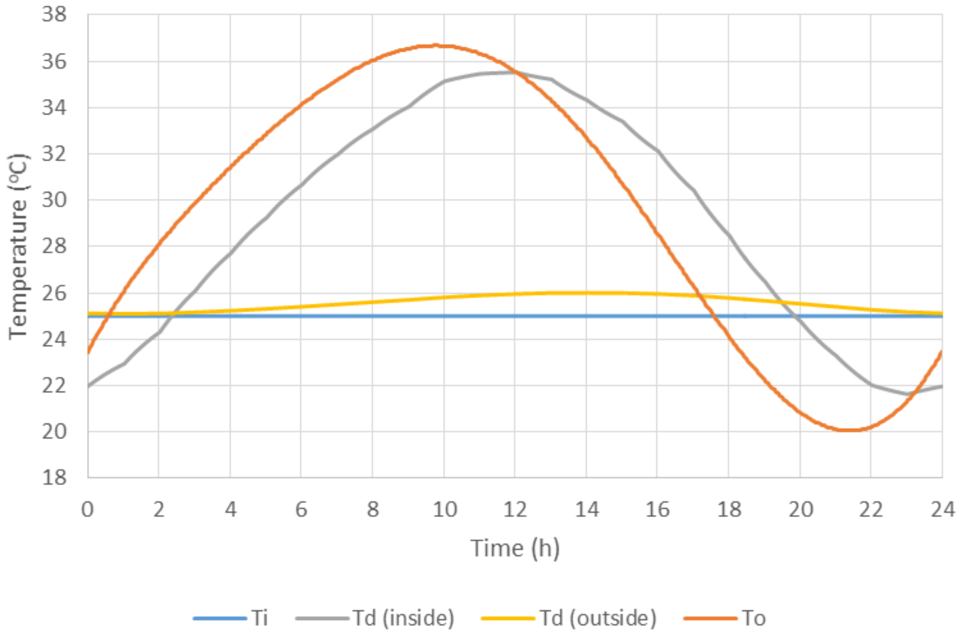


Figure 5. Wall temperature versus time variation in cases inside or outside insulation layers

2.3.1 Summer Daily Performances

Summer time performances of walls and windows have been calculated for two cities and for two insulation thicknesses at a sample day. Hourly variation of heat gains for each room in Ankara with 0.05 m insulation thickness have been given in Figure 6. In according to this figure, peak heat gain of 972 W occurs at SW room at the third floor with windows. If this room has not any windows (SW room at the second floor), heat gain reduces to the 237 W. Heat gain for NE room with windows at the same hour is 460 W.

Hourly variation of heat gains for each room in Ankara with 0.20 m insulation thickness have been given in Figure 7. In according to this figure, peak heat gain of 860 W occurs at SW room at the third floor with windows. If this room has not any windows (SW room at the second floor), heat gain reduces to the 82 W. Heat gain for NE room with windows at the same hour is 420 W.

It can be concluded that heat gain via windows much higher comparing with the walls in the summer conditions. This is true even for colder climates in summer. For the purpose of energy efficient building design in hot climates window design is much more important. Instead of investing on wall insulation, windows should be improved in cooling weighted climates. Investing on thermal insulation saves only 152 W at peak hour in summer conditions. However there are much larger energy saving potential in windows. By using coated glasses and by shading solar gains from windows can be halved that means up to 500 W energy savings would be possible.

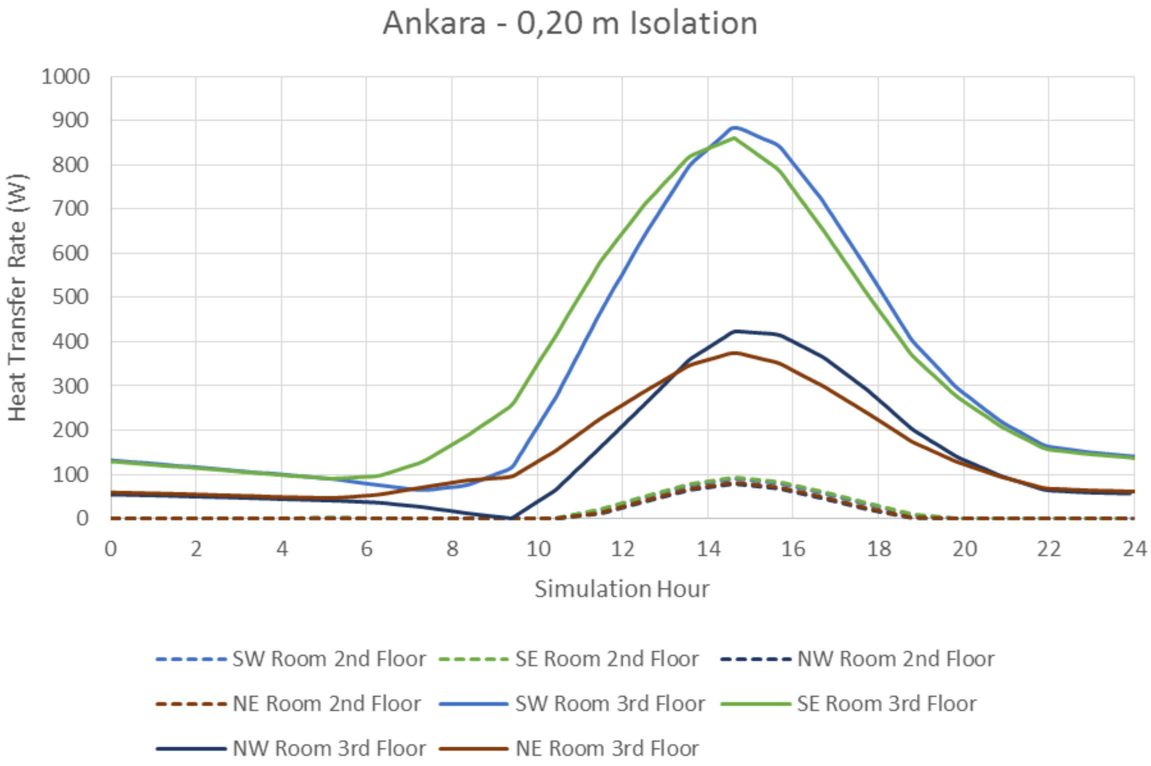


Figure 6. Hourly variation of heat gains for each room in Ankara with 0.05 m insulation thickness.

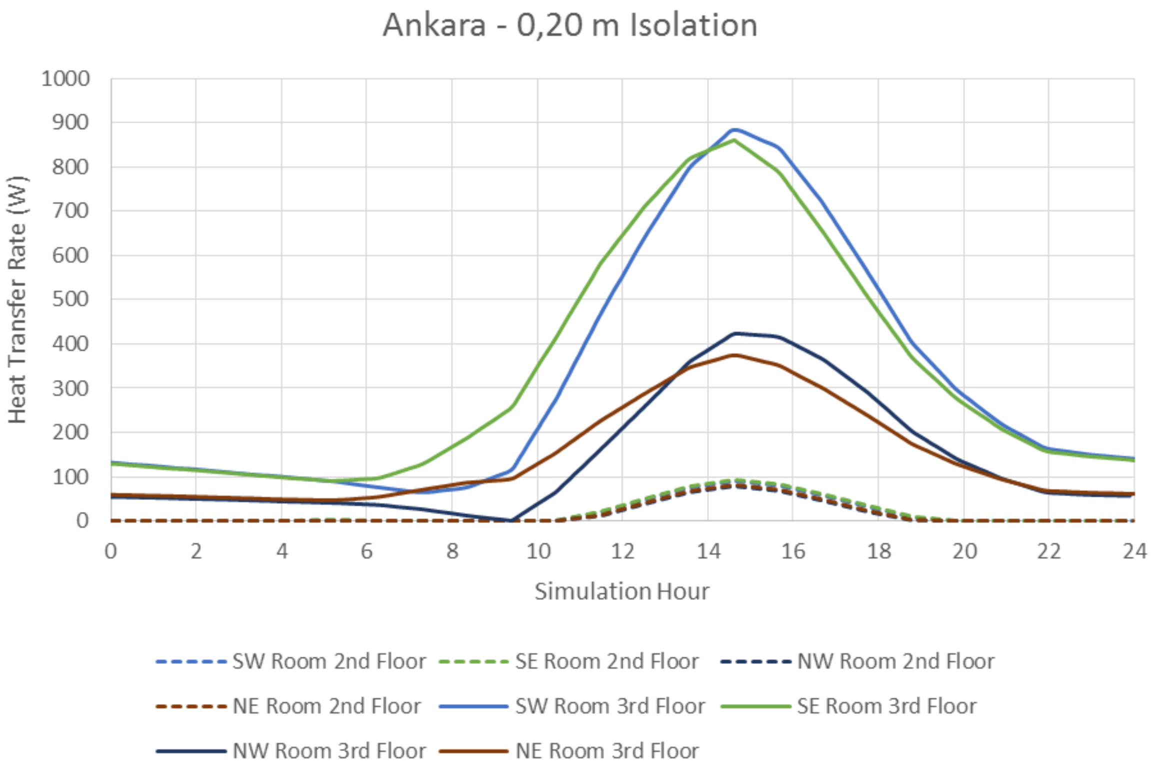


Figure 7. Hourly variation of heat gains for each room in Ankara with 0.20 m insulation thickness

Hourly variation of heat gains for each room in Seville with 0.05 m insulation thickness have been given in Figure 8. In according to this figure, peak heat gain of 1331 W occurs at SW room at the third floor with windows. If this room has not any windows (SW room at the second floor), heat gain reduces to the 326 W. Heat gain for NE room with windows at the same hour is 837 W.

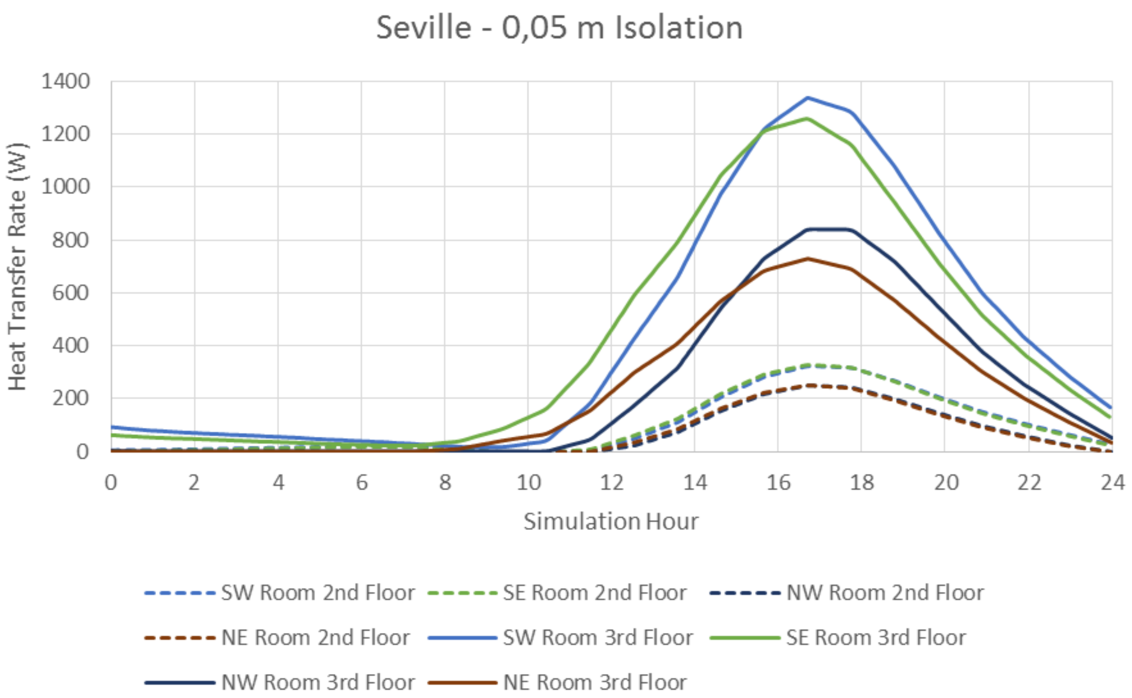


Figure 8. Hourly heat gains for each room in Seville with 0.05 m insulation thickness

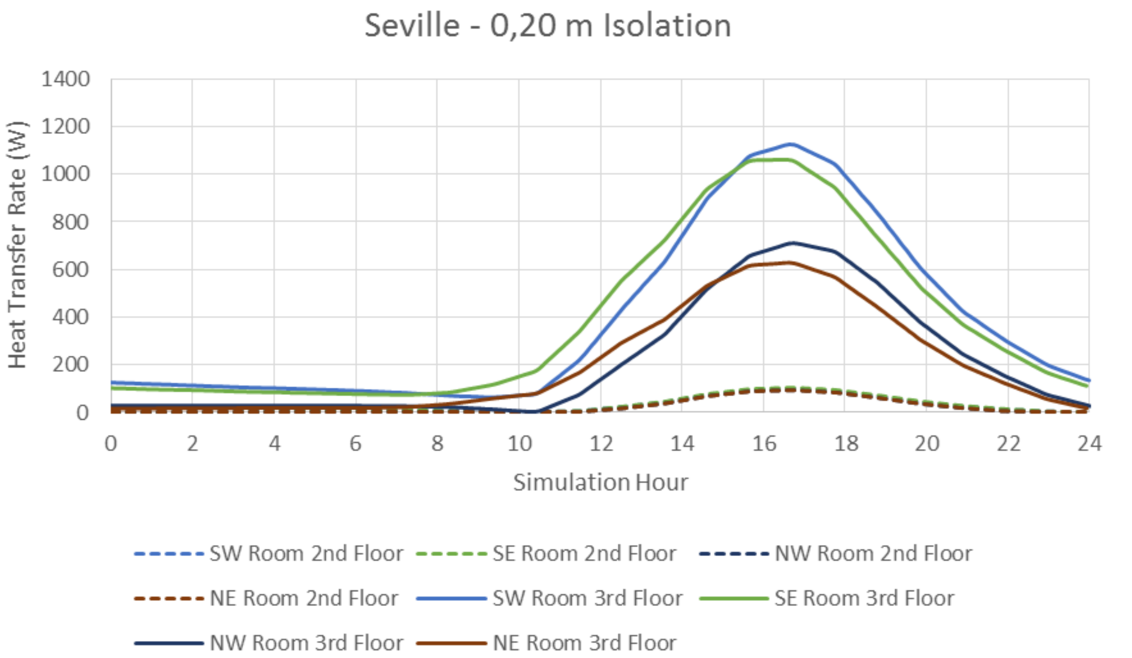


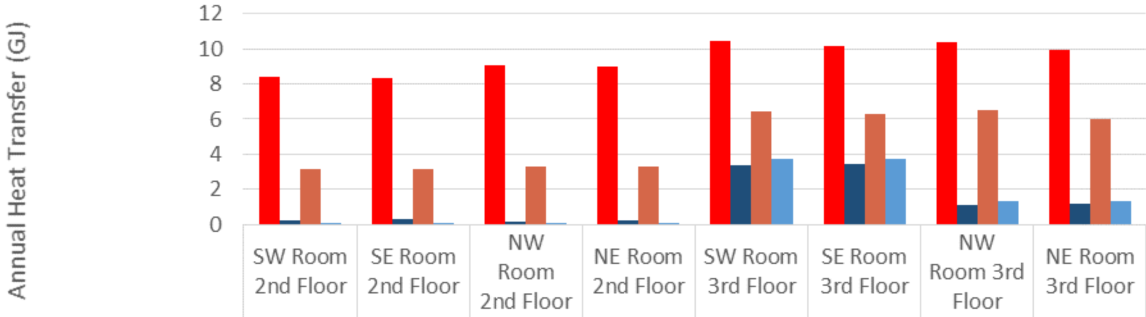
Figure 9. Hourly heat gains for each room in Seville with 0.20 m insulation thickness

Hourly variation of heat gains for each room in Seville with 0.20 m insulation thickness have been given in Figure 9. In according to this figure, peak heat gain of 1116 W occurs at SW room at the third floor with windows. If this room has not any windows (SW room at the second floor), heat gain reduces to the 94 W. Heat gain for NE room with windows at the same hour is 710 W.

As can be expected windows are more important in hot climates. For the purpose of energy efficient building design in hot climates window design is much more important. Investing on thermal insulation saves only 232 W at peak hour in summer conditions. However improving windows up to 650 W energy savings would be possible.

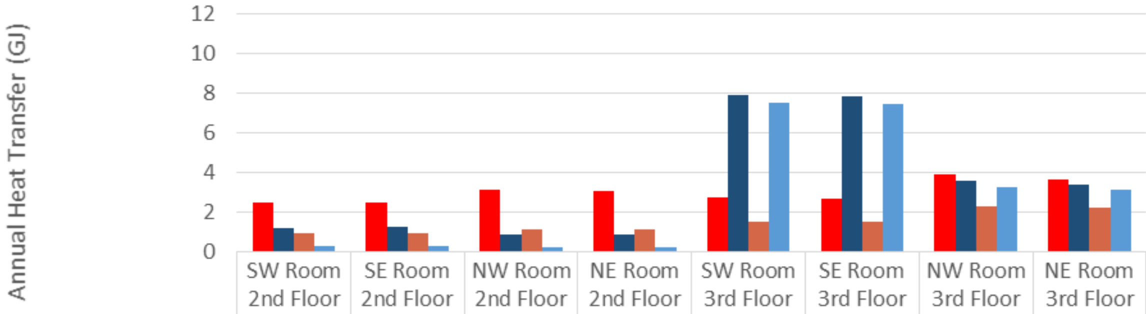
2.3.2 Yearly Performance of outer skin

Yearly heating and cooling loads of outer skin of stories have been calculated for two cities and for two insulation thicknesses. Total heating and cooling loads of each room are given in Figure 10 for Ankara. Total heating load of 3rd floor is 40.9 Gj/a and total cooling load of 3rd floor is 9.04 Gj/a if the wall insulation thickness is 0.05 m. These values can be calculated from Figure 10. Annual heating load is much bigger than the annual cooling load for Ankara.



	SW Room 2nd Floor	SE Room 2nd Floor	NW Room 2nd Floor	NE Room 2nd Floor	SW Room 3rd Floor	SE Room 3rd Floor	NW Room 3rd Floor	NE Room 3rd Floor
0.05 Ankara Heating	8,38	8,32	9,08	9,01	10,46	10,15	10,37	9,92
0.05 Ankara Cooling	0,25	0,27	0,17	0,19	3,37	3,42	1,1	1,15
0.3 Ankara Heating	3,18	3,16	3,33	3,31	6,43	6,26	6,54	6,02
0.3 Ankara Cooling	0,06	0,06	0,05	0,05	3,73	3,77	1,31	1,29

Figure 10. Total annual heating and cooling loads of each room for Ankara



	SW Room 2nd Floor	SE Room 2nd Floor	NW Room 2nd Floor	NE Room 2nd Floor	SW Room 3rd Floor	SE Room 3rd Floor	NW Room 3rd Floor	NE Room 3rd Floor
0.05 Sevilla Heating	2,5	2,48	3,14	3,06	2,75	2,72	3,89	3,65
0.05 Sevilla Cooling	1,22	1,24	0,9	0,9	7,93	7,85	3,59	3,38
0.3 Sevilla Heating	0,97	0,97	1,13	1,13	1,53	1,51	2,33	2,25
0.3 Sevilla Cooling	0,28	0,29	0,25	0,25	7,54	7,45	3,27	3,15

Figure 11. Total annual heating and cooling loads of each room for Seville

As the result, annual energy load of 3rd floor is 49.94 Gj for 0.05 m insulation. When insulation thickness is increased to the 0.30 m value, total heating load of 3rd floor is 25.25 Gj/a and total cooling load of 3rd floor is 10.1 Gj/a.

As the result, annual energy load of 3rd floor is 35.35 Gj for 0.30 m insulation. By increasing thickness of wall insulation extremely, annual savings can reach to the value of 14.59 Gj/a. This corresponds to a 29% energy saving annually.

Total heating and cooling loads of each room are given in Figure 11 for Seville. Total heating load of 3rd floor is 13.01 Gj/a and total cooling load of 3rd floor is 22.75 Gj/a if the wall insulation thickness is 0.05 m. Annual cooling load is much bigger than the annual heating load for Seville. Annual total energy load of 3rd floor in Seville is 35.76 Gj for 0.05 m insulation. When insulation thickness is increased from 0.05 m to the 0.30 m value, total heating load of 3rd floor is 7.62 Gj/a and total cooling load of 3rd floor is 21.41 Gj/a. As the result, annual energy load of 3rd floor is 29.03 Gj for 0.30 m insulation. By increasing thickness of wall insulation extremely, annual saving can reach to the value of 6.73 Gj/a for Seville. This corresponds to a 19% energy saving annually. However energy saving potential from windows is almost twice of the energy saving potential from wall insulation in this city.

3. CONCLUSIONS

Thickness of insulation is very important in winter conditions. However conservation from cooling load is not that big in summer.

For heating weighted North Europe countries, increasing wall thermal insulation thickness is a good strategy and it is recommended as an important tool in nZEB design. However increasing insulation thicknesses is not useful for Mediterranean region.

In summer time daily variation of temperature is important. In this case during day heat gain occurs and during night heat loss occurs. In such cases applying insulation to inside or to outside is effective.

A dynamic insulation would be beneficial for in land hot climates. During the summer if insulation layer can be changed from inside to outside in turn during day and night, total daily heat gain value can be decreased.

It can be concluded that heat gain via windows much higher comparing with the walls in the summer conditions. For the purpose of energy efficient building design in hot climates window design is much more important.
Annual heating load is much bigger than the annual cooling load for Ankara. Annual energy load of sample floor is 49.94 Gj for 0.05 m insulation. Annual energy load of same floor is 35.35 Gj for 0.30 m insulation. Increasing thickness of wall insulation extremely annual saving can reach to the value of 14.59 Gj/a. This corresponds to a 29% energy saving annually.

Annual cooling load is much bigger than the annual heating load for Seville. Annual energy load of sample floor is 35.76 Gj for 0.05 m insulation. Annual energy load of same floor is 29.03 Gj for 0.30 m insulation. Increasing thickness of wall insulation extremely annual saving can reach to the value of 6.73 Gj/a. This corresponds to a 19% energy saving annually.

Annually energy saving potential of windows is almost twice to the energy saving potential of wall insulation in Mediterranean climate.

4. REFERENCES

Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings, Official Journal of the European Union, L.153, 2010.

Windcatchers

Murat Çakan
Istanbul Technical University, cakanmu@itu.edu.tr

Abstract

Windcatchers are natural ventilation devices that are used to deliver fresh outside air to a building interior and extract stale air from it. These devices had been in use as vernacular architectural elements around İranian plateau, in cities such as Kerman, Yazd and Bam where the climate is arid and diurnal temperature differences are very strong. The main task of windcatchers is to direct fresh and cool air downward using direct wind entry. When it is placed on the roof of a building, a blowing wind generates high pressure on the windward side of the windcatcher, and lower pressures inside the building and on the leeward side of the windcatcher. Windcatchers are also used, when there is no wind, to direct warm air upward using solar assisted temperature gradient. Traditionally windcatchers are used in two kinds of buildings: houses and water reservoirs. Lately, windcatchers are becoming more and more favorable in modern architectural designs which tend to minimize the role of mechanical ventilation devices. Moreover windcatchers start becoming tools that harness energy from the wind and eventually produce electricity.

Key Words: *windcatcher, vernacular, natural ventilation*

1. USE OF WIND

Natural and environmental conditions have always shaped the built environment in a way that humans can adapt themselves to the milieu they are forced or they chose to live. Wind, for many centuries, have served as an important environmental parameter in the hands of man. There are numerous historical hints and proofs on the use of windmills to grind grain in the Mediterranean basin and Arabic Gulf region. Estharki a 10th century Persian geographer who created the earliest account of windmills claimed that horizontal windmills (Figure 1) were used as early as 4th century AD in the Persian Peninsula [1986-2].

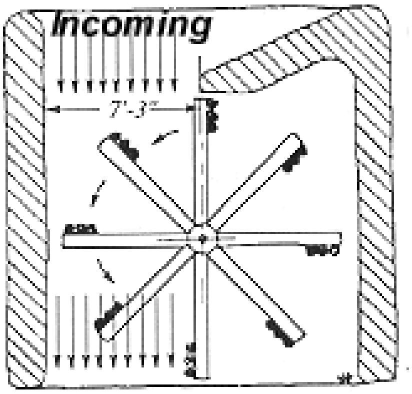


Figure 5. Persian horizontal windmill (a) view from the top, (b) general view

Horizontal windmills were also built in small numbers in the 18th century Europe. Although certain diversions are present, historians usually agree that Middle Eastern and Persian horizontal windmills triggered the original development of European vertical windmills mainly due to the interactions between civilizations during the Crusades.

2. WINDCATCHERS

A second tool in the usage of wind related technology is the windcatcher. As in the case of windmills, windcatchers were initially developed in the Mediterranean Basin and Arabic Peninsula. One of the wall paintings from the tomb of Nebamun, an ancient Egyptian scribe, in Thebes dating back 13th century BC exhibits a dwelling instrumented with a windcatcher (Figure 2). House models recovered from Old Kingdom tombs reveal columned porticoes in the front of the multi-storied houses on each floor. Figure 3 depicts the reconstruction of one of these houses (1954). As clearly seen; the rooms behind the porticoes were ventilated by half-cupolas emerging from the terrace floor and facing the direction of the prevailing winds. These structures served as "windcatchers"and aerated the rooms below.

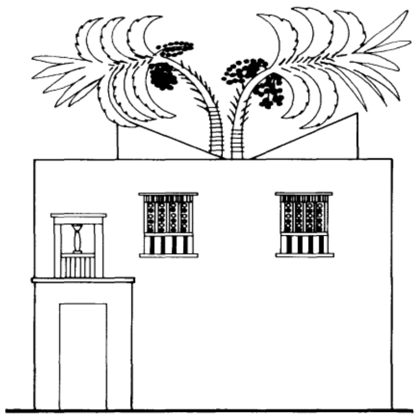


Figure 6. Malqaf (windcatcher) of the Pharaonic house of Neb-Amun, from a painting on his tomb 19th Dynasty (c. 1300 B.C.).

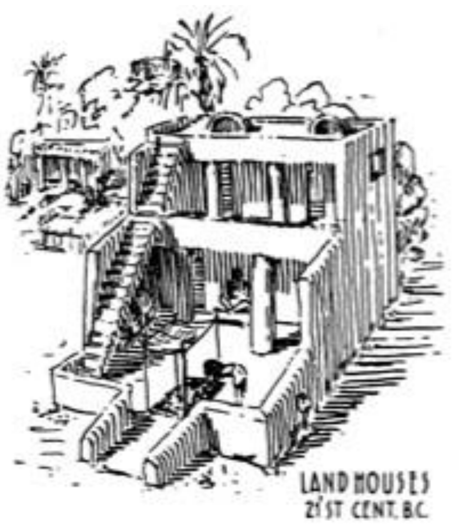


Figure 3 Restored perspective of two-storied Egyptian house model (6th to 11th Dynasties, c. 2200 B.C.) [1954]

Windcatchers of Persia differ from the ones that are found among the North African vernacular architectural heritage in their sizes and general usage. Figure 4 shows the Iranian city of Yazd whose skyline is dominated by windcatchers (badgir in Farsi) and . The windcatchers that are still in use in arid and hot regions of Iran and Afganisthan make use of natural ventilation phenomenon in two distinct areas: houses and water reservoirs. In houses, the wind captured by the windward facing windcatcher is first fed into the interior spaces to cool the room temperatures down and to decrease humidity and is eventually discharged through the leeward facing hole (low atmospheric pressure region) of the windcatcher (Figure 5, a-b). The pressure differences between high and low pressure zones are often sufficient to drive the fresh air from the wind into the building and extract stale interior air out.

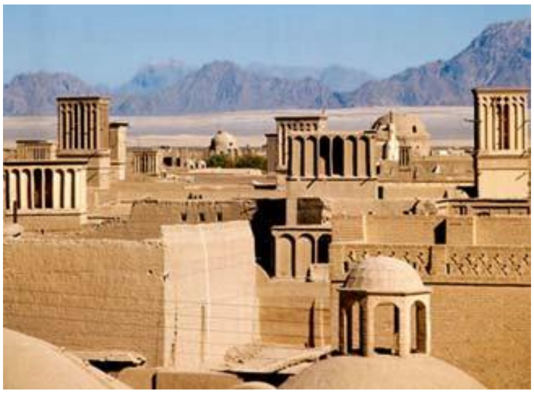


Figure 4 Windcatchers in Yazd, Iran

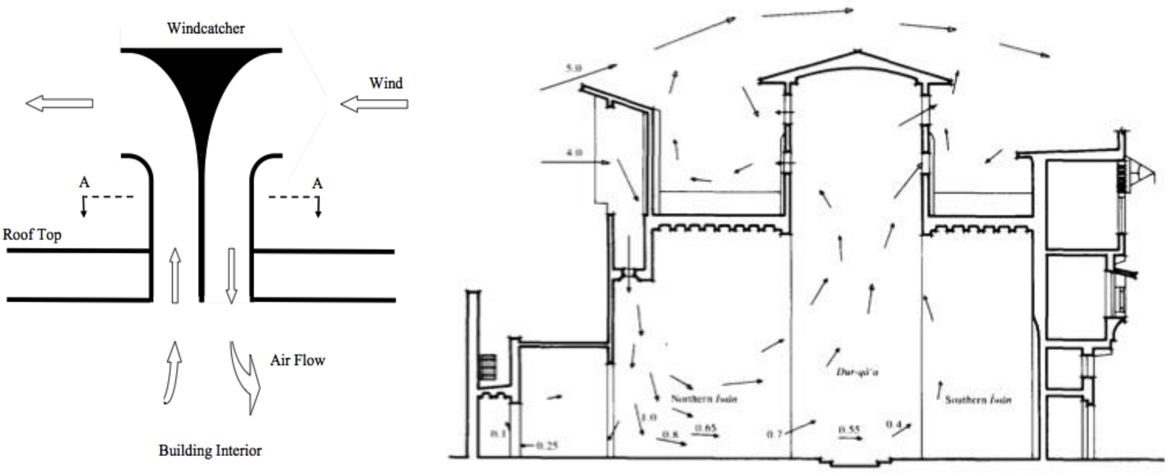


Figure 5 Ventilation flow via a windcatcher due to wind-generated pressure differences (a) general principle, (b) Muhib-Ad Din House, Cairo [1986-1]

The second benefit of windcatchers in houses emanates from strong diurnal temperature differences observed in continental climatic regions. In these regions, the temperature differences between day and night trigger the divertion of cold outside air at night into the warm interior spaces. The heat exchange between this cold and fresh air and the interior objects make the air warm up and rise before it is discharged through a rear window or chimney like building structure (Figure 6-a). During the day, the wall of the windcatcher is heated by the sun. Heated air within the stack rises up creating an underpressure in the interior space. This low pressure zone then sucks in the wind flow through the unheated side of the windcatcher (Figure 6-b).

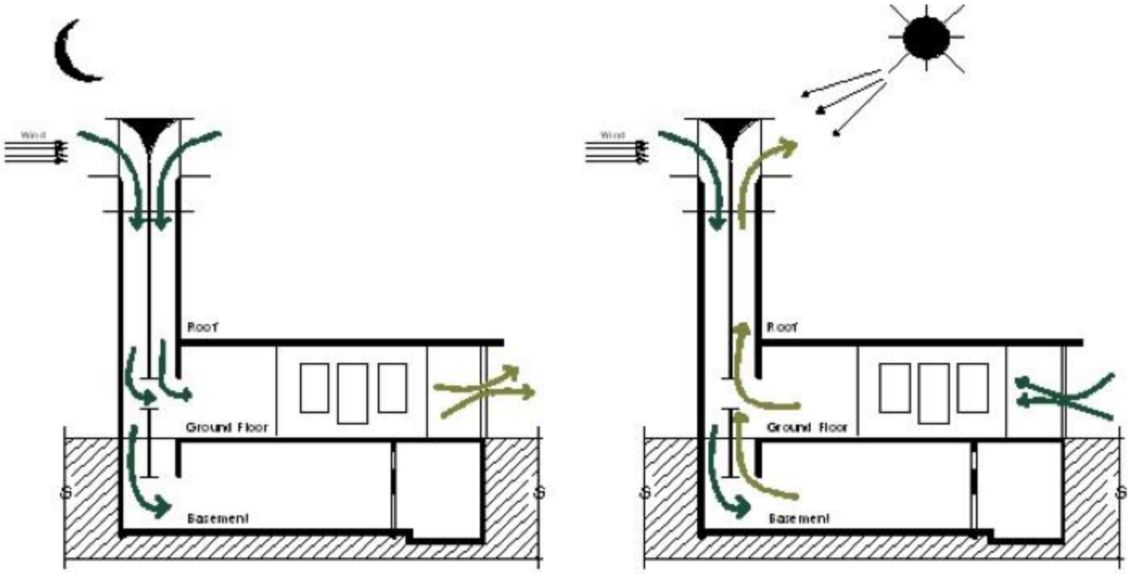


Figure 6: Windcatcher function during (a) the night and (b) day [2012]

The windcatchers can also be used in pairs or four at a time to cool underground water reservoirs (ab anbar). The way windcatchers work is that the moving air masses (wind, breeze, etc.) at the top of windcatchers create a pressure gradient between the top of the windcatcher and its base, inside, at the bottom of the shaft. This pressure gradient sucks out rising hot air from inside the shaft while the colder dense air remains. The superb heat-resistant material of the walls of the ab anbar further create an insulating effect that tends to lower the temperature inside an ab anbar, similar to a cave. The ventilating effect of the windcatchers prevent any stagnant air and hence any dew or humidity from forming inside, and the overall effect is pure, clean, cold water all year round (Figure 7).

Figure 7: Windcatcher and water reservoir (ab anbar)

3. CONCLUSIONS

Finding sound solutions to the unfavorable effects of climate change requires the implementation of clever solution strategies to our problems. These strategies must comprise of fundamental physics once used by our ancestors as well as high tech solutions of today. Systems making use of evaporative cooling methods going hand in hand with natural ventilation strategies for example may bring unexpectedly positive results in terms of power savings in unprivileged parts of our world.

4. REFERENCES

Badawy, A. (1954) A History of Egyptian Architecture. *Studio Misr*.

Fathy, H. (1986-2) Natural Energy and Vernacular Architecture: Principles and Examples with Reference to Hot Arid Climates, *University of Chicago Press*

Hassan, A.Y. and Routledge, D. (1986-1) Islamic Technology: An Illustrated history. *Cambridge University Press*, p. 54.

Masrour, M. M.; Abbasi, M. and Hallaj, H. M. (2012) Study Of Windcatchers: The Mass Flow Rate And Inlet Air To The Building In Traditional Windcatchers. Australian Journal of Basic and Applied Sciences, 6(10): 159-165

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Biomimicry, biophilic design, & whole systems Approach to the built environment

Isilay Civan
HOK, Inc., Isilay.civan@hok.com

Abstract

Biomimicry is a science that studies nature's systems and processes and then imitates or takes inspiration from them to solve human problems. By rethinking the built environment as an ecosystem we are able to align with both the wisdom and "genius of the place" (the natural environment), and how we have settled that place. It helps us fit-in by modeling nature's local best practices, and leveraging those latent strategies, functions, and opportunities. This process allows us to be able to look to the local/regional biomes and ask, "What are the regional realities that we can look to, and then relate to what we are doing." In this paper, Dr. Isilay Civan, Senior Strategy Consultant with the global architectural firm HOK, discusses how biomimicry applies to architectural design and outline project lessons from HOK's alliance with the Biomimicry Guild and Biomimicry Chicago.

Key Words: *Biomimicry, Biophilic Design, Whole Systems Approach, Genius of Place, Fully Integrated Design^{TM}.*

1. LIFE'S PRINCIPLES

As John C. Sawhill famously said " In the end, our society will be defined not only by what we create, but by what we refuse to destroy." In today's world and with our greater understanding of the life's principles we do indeed have the opportunity to make a difference in the way we design and create truly long lasting built environments.

If we summarize the life's principles as identified by Biomimicry Guild in 2008, we would need to start with earth's three operating conditions:

- Earth is Water-Based
- Earth is Subject to Limits and Boundaries
- Earth is in a Dynamic State of Equilibrium

Keeping these three operating conditions in mind, we then need to remember the life's principles that are basically twofold: life creates conditions that are conducive to life and life adapts and evolves.

1.1 Life creates conditions that are conducive to life

When we say life creates conditions that are conducive to life we are talking about the fact that life:

- Optimizes rather than maximizes, by utilizing multi-functional design, always fitting form to function and recycling all materials,
- Leverages Interdependence by self-organizing and fostering cooperative relationships,
- Uses Benign manufacturing processes by life friendly materials, water-based chemistry and self-assembly.

1.2 Life adapts and evolves

When we talk about the fact that life adapts and evolves, we basically emphasize its following characteristics:
- Locally attuned and responsive; life is resourceful and opportunistic, uses free energy and simple common building blocks with an antenna, signal, response system,
- Integrates cyclic processes through feedback loops; cross-pollination and mutation and learning and imitating,
- Resilient; due to its diverse mix, decentralized and distributed structure and optimized redundancy.

All these life's principles, as depicted above, are evidence as to why biomimicry is the potential gateway from mal-adapted buildings to well-adapted designs that are even beyond LEED, Net Zero, Living Building Challenge, or even Regenerative Design concepts and has the potential to take us all the way into fully integrated thinking (FIT^{TM}) as developed by HOK, Inc.

2. BIOMIMICRY & BIOPHILIC DESIGN

When we talk about life, we are actually talking about 3.85 million years of experience that is tested throughout 30-100 million species. Hence if studied thoroughly, the wealth of knowledge leading to well-adapted design is boundless. Per their varying degrees of depth and emphasis we will cover three different types of such studies that are used to inform design.

2.1 Bio-morphic

First one of such studies is called biomorphic design and it uses living organisms and natural systems as literal inspirations for actual forms and design of the built environment. Biomorphic design only uses the image/outer shell to inform the design and does not study the reasoning behind a form or question functionality implications.

2.2 Bio-philic

On the other hand, biophilic design studies human beings attraction to and their need to be connected to the elements of nature. As one of the petals for Living Building Challenge, Biophilic Design is considered to have three pillars & 14 patterns:

1. Nature in Space: plants , water, animals, daylight in the built environment;
    a. Visual Connection with Nature
    b. Non-Visual Connection with Nature
    c. Non-Rhythmic Sensory Stimuli
    d. Access to Thermal & Airflow Variability
    e. Access to Water
    f. Dynamic & Diffuse Light
    g. Connection with Natural Systems
2. Natural Analogues: objects, materials, and patterns that evoke nature;
    a. Biomorphic Forms & Patterns
    b. Material Connection with Nature
    c. Complexity & Order
3. Nature of the Space: differing spatial configurations of the built environment;
    a. Prospect
    b. Refuge
    c. Mystery
    d. Risk/Peril

2.3 Bio-mimicry

Third study that we will cover is biomimicry and it is defined as a branch of knowledge that deals with living organisms and vital processes. First part of the word, Bio, studies the plant and animal life of a region or environment and through the life processes of an organism or a group determines design inputs informing the process and the output for a life imitating and well-adapted design. Second part, mimicry, means to follow as a pattern or a model and deals with possessing some of the attributes of a transcendent idea (a.k.a. cognitive modeling).
In 1992, Janine Benyus described biomimicry as a new way of viewing and valuing nature, based not on what we can extract from the natural world, but on what we can learn from it; which is also the definitive differentiator of Biomimmicry and Biomorphic Design. In Buckminster Fuller's words "We do not seek to imitate nature, but rather to find the principles she uses." When it comes to the difference between biomimicry and biophilia one needs to remember that biomimicry is about learning from nature to reproduce nature's patterns rather than the focus on the relationship between people and nature.
Main link between biology and design is determination of function. That is why, while dealing with biomimicry we tend to question the function that we would like to perform and seek out our answers from the nature's own designs to date.

There are two possible approaches to finding the solution we are seeking.
1. Identify a challenge and research the solution in the nature
One example to this approach would be the bullet train where the challenge was to optimize high-speed movement of the trains and by identifying the natural organisms that do this, a solution was found to the problem.
2. Discover/recognize a concept and explore application opportunities
An example to this approach would be the Velcro, which is a combination of the two French words velours (velvet) and crochet (hook), which was inspired by burrs that became a huge phenomenon in the industrial applications for sticking things together.

3. CONCLUSIONS AND RECOMMENDATIONS

In summary, earth and life itself have many lessons for us, designers, if we take the time to study, learn, and implement. At HOK, we are dedicated to sustainable design. Considering our huge impact to the built environment on an annual basis (+/- 240 million square feet of designed space), we are also acutely aware of the "HOK effect" and our responsibility, not just to our Clients but also to the many generations to come. Hence we developed a transformative, restorative and interconnected systems approach to design that we call "Fully integrated Thinking". It is HOK's design philosophy that covers 15 fundamental aspects for truly sustainable design, covering the triple bottom line categories of Environmental, Social, and Economic. We have developed 14 HOK FIT Demonstration Projects that covers 8 countries over 5 biomes, including new construction and retrofit projects, as well as regional, new community, building and park scales; and published them as a report titled: "Genius of Biome: Temperate Broadleaf Forest. It provides natural systems inspired design ideas and is a collaborative effort of HOK and the Biomimicry Group.

4. REFERENCES

Benyus, J. (1992) *Biomimicry: Innovation Inspired by Nature*, US.

Civan, I. (2014) Biomimicry, Biophilic Design, & Whole Systems Approach to the Built Environment, Novel Energy in the Regenerative Built Environment, ITU Workshop, 4 March 2014 presentation.

HOK & Biomimicry Group (2011) *Genius of Biome: Temperate Broadleaf Forest*.

Sturgeon, A. (2013) Biophilia: From Design to Reality. 2013 Greenbuild Conference, Philadelphia.

Contemporary Trends in the Regenerative and Sustainable Built Environment: Managerial Aspects

Managerial Aspects of the Regenerative Construction Projects

Begum Sertyesilisik
Istanbul Technical University, begum_sertyesilisik@hotmail.com

Abstract

The world's habitat is being deteriorated despite of the precautions undertaken (e.g. green building certificates etc.). There is need for regenerative built environment which provides positive impact to the world instead of deteriorating it. Establishment of regenerative built environment requires effective project management which suits to the needs of the regenerative constructions. This study provides brief information on and requirements for the regenerative principles, as well as on the developed frameworks which will affect the project management process.

Key Words: *regenerative built environment, regenerative design, construction Project management.*

1. INTRODUCTION

The world's habitat is being deteriorated especially due to overconsumption of the natural resources, and industrialization. The climate change occurs as a result of the increase in the global temperature caused by green house gas emissions. Humanbeings have started to search for alternative living habitats (i.e. terraformation activities of Mars) due to deterioration on the world's habitat, need for natural resouces and increase in the world's population. As the world's living conditions continue to become deteriorated (i.e. climate change, loss in biodiversity), despite of the precautions undertaken (i.e. Kyoto Protokol, Rio+20, green building certificates…), there is need for more effective sollutions.

Construction industry plays an important role in exploitation of world's resources.There has been an effort to make the construction outputs "green" in order to reduce adverse effects of the construction to the environment. Key green building (Cole, 2012: 40):

- reduces damage to natural or sensitive sites
- reduces the need for new infrastructure
- reduces the impacts on natural features and site ecology during construction
- reduces the potential environmental damage from emissions and outflows
- reduces the contributions to global environmental damage
- reduces resource use-energy, water, materials
- minimizes the discomfort of building occupants
- minimizes harmful substances and irritants within building interiors

Following the "green" movement, the "sustainable" output and "sustainable" construction process emerged to enable the construction to cause zero negative impact to the environment. There is need for transition towards regenerative thinking (Mang and Reed, 2012: 27). There is the need for transforming the construction project management and the outputs of the construction activities into regenerative modes. The main principle supporting this regeneration movement is Benyus (1997)'s statement that 'life creates the conditions that are conducive to life'.

2. REGENERATION PRINCIPLES BASED CONSTRUCTION PROJECT MANAGEMENT

Regenerative built environment is based on the three main pillards (Hoxie, et al., 2012):

- Uniqueness of place
- Community engagement
- Creation of a story of the place within the community

The regenerative project management needs to be based on these three pillards. These pillards reveal the importance of design phase and the main differences between the project management of regenerative projects and other projects to be related with the design phase.

Regenerative design phase is more complicated than design of green or sustainable constructions. "Regenerative design . . . requires a fundamental re-conceptualization of the act of building design…Regenerative design prioritizes the understanding and engaging in the unique qualities of place." (Cole, 2012: 45-47). Place's uniqueness and the notion of 'glocal' play important role in the design as quoted by Cole (2012: 45-47):

> *"architectural outcomes within a regenerative approach emerge from a thoughtful response to the unique social, cultural and ecological opportunities and constraints of place, drawing equally on the appropriate use of broader contemporary technological capabilities. That a fully matured global information system and culture may instigate and permit the creation of regionally and place-based practices is central to the notion of 'glocal'. Derived from global and local, 'glocal' recognizes the need for balance between 'the invisible global forces' and the 'actual sense of place and culture' (Nagashima, 1999)." (Cole, 2012: 45-47)*

Shift from green to regenerative design requires (Cole, 2012):

- re-establishment of the regional design practices
- establishment of common ground with diverse stakeholders, as well as
- change in the responsibilities and skills of designers

There are two main tools which can be useful for the regenerative project management. These tools are: LENSES (Living Environments in Natural, Social and Economic Systems) Framework and REGEN.

2.1 LENSES (Living Environments in Natural, Social, and Economic Systems) Framework

LENSES is designed to be a guidance tool that will lead users to appropriate, contextual, and regenerative decisions and actions (Plaut et al., 2012). LENSES can be used as a complement to other green building tools and rating systems by offering on-going guidance during the design, construction and operations (Plaut et al., 2012). LENSES attempts to uncover and address elements that go beyond other sustainable development guidance tools and systems (Cole, 2012). The strength of LENSES lies in its ability to (Plaut et al., 2012:

112): help groups consider concepts and elements often missing in other development frameworks such as financial sourcing, cultural resources, regional context, education, shared authority and governance. LENSES framework consists of three lenses (Plaut et al., 2012):

- **Foundation Lenses**: The application of the Foundation Lens is most intensive during the Discovery phase of a project and can also be utilized when new players are introduced or when a project seems to be veering off track.

- **Place Lens** addresses critical Built environment issues and helps to define project outcomes based on a scale ranging from degenerative to regenerative. to identify the project outcomes

- **Flow Lens**The Aspects are primarily physical accounts and attributes, while the flows are focused on movement and relationship.The flows through a site or place change over time.

The five phases and activities of a project life cycle are (Plaut et al., 2012):

- Discovery/conception: exploration, finding out about something, the genesis of ideas.
- Design/gestation: development of an idea; creating a detailed plan.
- Implement/birth: to carry out or fulfil something; the emergence of life.
- Operate/life: the period during which something continues to function or work.
- Decay/death: decline; the end of something implies the beginning if a new cycle.

2.2. REGEN

Being the conceptual regenerative design framework, REGEN has been proposed by the US architectural practice Berkebile Nelson Immenschuh McDowell (BNIM) for the US Green Building Council (USGBC) (Cole, 2012). REGEN is web-based, data-rich and values-based framework to guide dialogue and help professionals to practice regenerative design (Svec et al., 2012 : 83) and it does not propose a strict, universal definition of regenerative design or development and it does not propose a specific process for carrying out regenerative projects (Svec et al., 2012). REGEN is based on (Svec et al., 2012): LEED 2012 impact categories; the Living Building Challenge imperatives; One planet living principles; and Laws of nature or principles of biomimicry. The tool, if developed further, has the potential for openning the possibility of providing the complement to LEED’s emphasis on reducing the adverse impacts of buildings (e.g. mitigation) to one that offers strategic direction to create positive outcomes (e.g. reversing climate change). (Cole, 2012).

3. CONCLUSIONS AND RECOMMENDATIONS

Main change in the project management process to adapt the regenerative principles and to caary out regenerative construction projects is observed in the design phase which is more iterative and which requires more participation of the community. It requires detailed investigation of the local place to sustain co-evalution. The regenerative development and design phase takes longer time than other design phases as explained by Mang and Reed (2012: 34):

> Regenerative development and design does not end with the delivery of the final drawings and approvals, or even with construction of a project. (Mang and Reed, 2012: 34). The responsibility of a regenerative designer includes putting in place, during the design and development process, what is required to ensure that the ongoing regenerative capacity of the project, and the people who inhabit and manage it, is sustained through time. (Mang and Reed, 2012: 34)

Regenerative Project management will introduce new concepts and change the scope of the old concepts. Regeneration principles need to be adapted in the strategic management of the companies, and in the whole supply chain management.

4. REFERENCES

Cole, R.J. (2012). Transitioning from green to regenerative design. Building Research and Information, 40(1), 39-53.

Du Plessis, C. (2012). Towards a regenerative paradigm for the built environment. Building Research and Information, 40(1), 7-22.

Hoxie, C., Berkebile, R., and Todd, J.A. (2012). Stimulating regenerative development through community dialogue. Building Research and Information, 40(1), 65-80.

Mang, P. and Reed, B. (2012). Designing from place: a regenerative framework and methodology. Building Research and Information, 40(1), 23-38.

Plaut, J.M., Dunbar, B., Wackerman, A., and Hodgin, S. (2012). Regenerative design: the LENSES Framework for buildings and communities. Building Research and Information, 40(1), 112-122.

Svec, P., Berkebile, R., and Todd, A. (2012). REGEN: toward a tool for regenerative thinking. Building Research and Information, 40(1), 81-94.

Zari, M.P. (2012). Ecosystem services analysis for the design of regenerative built environments. Building Research and Information, 40(1), 54-64.

Sustainable Project Development Process and Total Quality Management

Husnu Murat Gunaydin
ITU, gunaydinhm@gmail.com

Gulfer Topcu Oraz
ITU, oraz@itu.edu.tr

Abstract

Sustainable project development process and total quality management philopsophy share many structural similaraties. Systemic approach, decision making techniques, proactive development goals and stakeholder participation are important aspects of the both. Evidence from literature review suggests that we can consider sustainability as a specific application of TQM in building Project development process.

Key words: *Sustainability, total quality management*

1. THE PILLARS OF SUSTAINABILITY AND TQM

Sustainability is itself one of the major dimentions of quality when it comes to design and construction of the built environment. Total Quality Management (TQM) philosophy simply focuses on the processes of the product manufacturing or service supplying. Sustainability principles also underline importance of the processes for both design and construction of buildings. According to Joiner (1994) decision making process for sound quality levels covers following three criteria:

1. Definition of quality for the required service or product is important. This definition covers all aspects and is clear. For a building we may suggest that the performance and functional criteria are clear and complete. And all parties involved have the same understanding.
2. All stakeholders involved participate the decision making process by a proper methodology. This approach creates a beneficial all one team environment. Principles of group thinking also valid for any sustainable design process.
3. Project team members use Data and scientific methods for the decision making process. This way, we can eliminate personal, emotional and biased inputs. Sound design practice requires the use of scientific methods for better functioning buildings.

2. THE DYNAMICS

We can elaborate on these dimensions further. Definition of the quality levels for a building covers the scope and functions, the required performance criteria, clients' expectations and perceptions, etc. All these requirements are sine qua non for a high quality building. Designers work on these and translating of them into design is an art. This process requires intense communication and recording as well as research.

Using intellectual capital of all stakeholders is one of the best ways to be sustainable at every stage of the project development. Group thinking is an effective way of doing this, however the disadvantages of this, such one person dominating the group, should be considered by the design team.

Data driven decision making is the safest way to reduce risks and prevent costly errors. Evaluating the data at the hand and further looking for solid evidence and facts about a problem can increase the quality of decisions and therefore actions.

Systemic approach to sustainable projects requires a well-defined goal or goals and a set of interdependent units that are working to achieve this common goal. Data driven, well defined, team based goals can contribute great amount of value to the project. Organizing effectively and productively solves majority of problems at the initial stages of the project.

3. THE SIMILAR FUNCTIONS OF SUSTAINABILITY AND TQM

7group and Reed (2009) show the complexity of the process by saying 'For the sake of argument, let us say that a scenario describes a twenty-million-dollar building. How many people were involved in the building design process from beginning of the programming effort to the day the bidding documents are put out on the street? Definitely dozens, even hundreds, if we include all of the equipment manufacturers and product representatives involved.' And also they underline difficulty of transferring the knowledge produced about the project to the construction professionals. This might be an evidence or experimental studies in the sustainable development. Especially pilot studies can show the potential problem areas and risk beforehand to the design team. Final full-scale projects might benefit from these pilot studies.

The economic benefits of sustainable design are as follows (http://www.oregonsolutions.net/govt/group.cfm):

- Lower (or Equal) First Costs
- Annual Energy Cost Savings
- Annual Water Cost Savings
- Lower Costs of Facility Maintenance and Repair
- Lower Churn Costs
- Lower Absenteeism and Improved Productivity

Close examination of these cost savings presents a well-defined area for TQM implementations. Majority of TQM implementations aim to reduce cycle time and costs by focusing on processes. Sustainable design process basicly can reach this by utilizing some of the tools of TQM:

- Statistical models
- Cause effect diagrams
- Scatter diagrams
- Simulation models
- Control charts

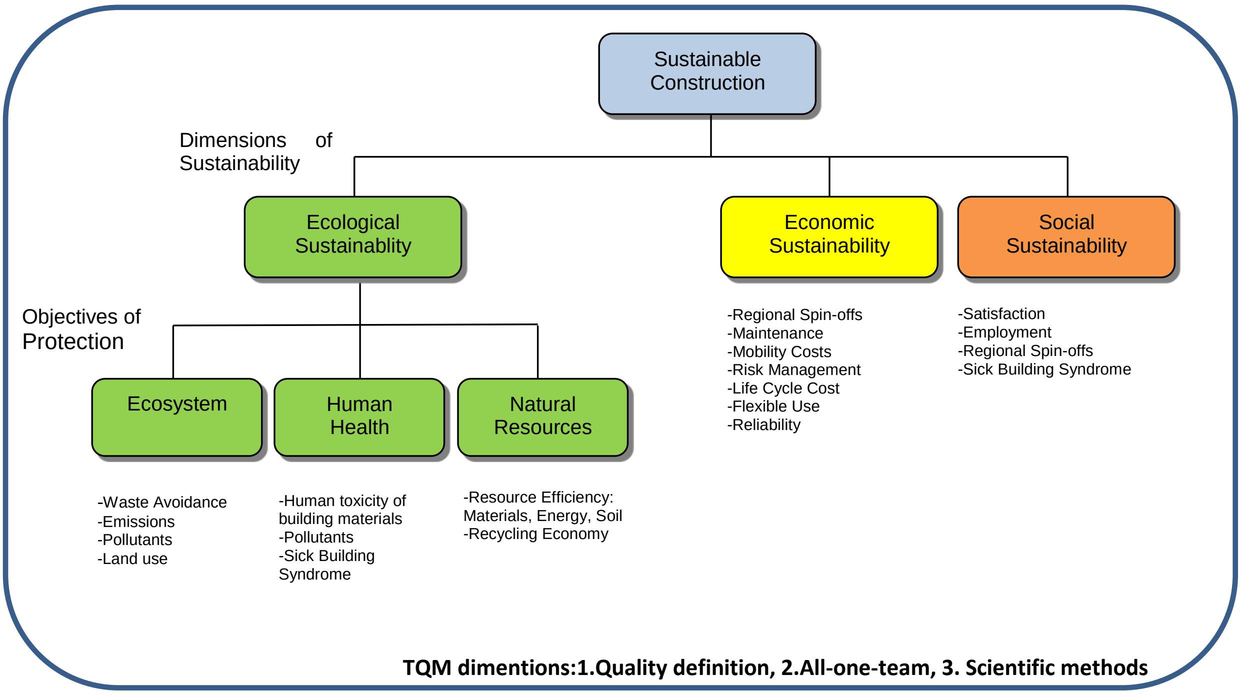


Figure 1. Dimensions of sustainability and objectives of protection - *adapted from El-Mikawi, M.A. (2007)*

Dimensions of sustainability show ecological, economic, and social aspects, if we want to integrate TQM in to this figure, we should cover it with three decision making criteria namely; definition of quality, all-one-team, and scientific methods.

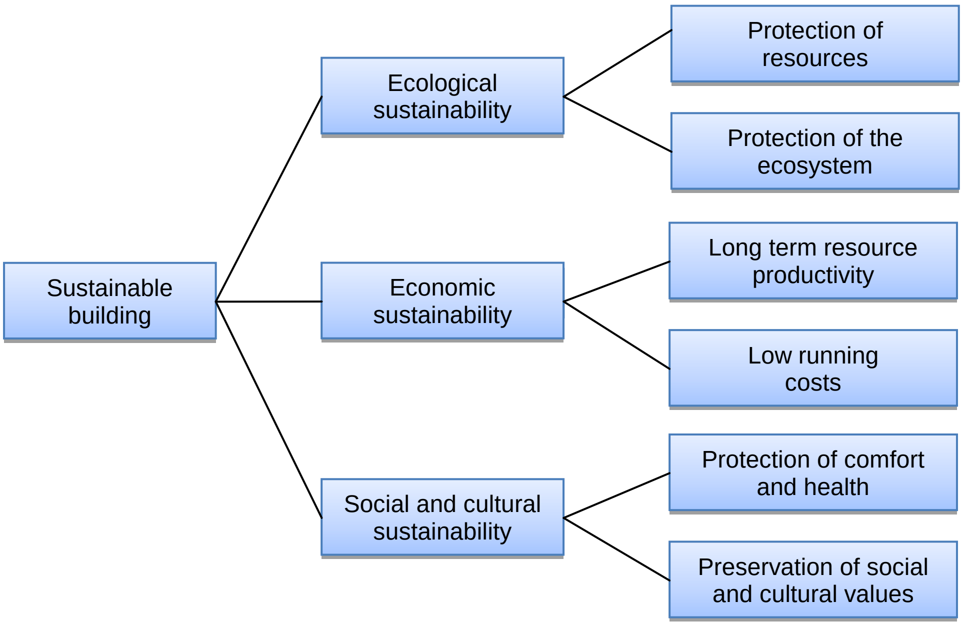


Figure 2. Sustainable building - *adapted from Kohler, 1999*. *Kaynak: Persson, U. (2009)*

Kohler's (1999) sustainable building diagram identifies six items as protection of resources and ecosystem, long term resource productivity, low running costs, protection of comfort and health, preservation of social and cultural values transfer to TQM philosophy as follows:

Sustainable building criteria	**TQM criteria**
Protection of resources	Through planning for productive processes
Protection of ecosystem	Waste reduction and development of environment
Long term resource productivity	İncreased resource productivity
Low running costs	Operation and maintenance cost optimization
Protection of comfort and health	Continuous betterment of comfort and health
Preservation of social and cultural values	Development of better cultural values

As one can observe, TQM philosophy is much more proactive, rather then protection focus is on continuous development for all processes. From this we might say that sustainable design and construction are both very related to TQM approaches. Continuous improvement of TQM gets benefits of:

- Customer satisfaction
- Supplier involvement
- Process improvement
- Focus on employees
- Teamwork
- Commitment of upper level management

Close investigation of these topics makes it clear that very principles are valid for sustainable project development process. Furthermore emphasis on design and planning processes is inseparable for both approaches.

4. CONCLUSIONS

The structure of sustainable design and TQM as well as the techniques used are indeed show great similarity for the design process. Focusing on cost and cycle time reductions, underlying the importance of operation and maintenance phases are showing clear evidences. Furthermore TQM philosophy is much more proactive then sustainable design approach in the case of environment protection, since TQM mainly focuses on environmental development. Both approaches value stakeholder participation and the use of scientific methods in decision making. We can argue that sustainable design is a specific application of TQM philosophy in to design process, in other words they are the two sides of the same coin.

5. REFERENCES

7group and Reed, B. (2009.) *The Integrative Design Guide to Green Building*, John Wiley & Sons, USA.

Behnisch, S. (2011). Sustainability, in Yeang, K. and Spector, A. (eds) *Green Design from Theory to Practice*, Black Dog Publishing, London.

El-Mikawi, M.A. (2007). Sustainable development in construction. In: Peter Claisse, Sadeghi-Pouya, Tarun.R. Naik, Yoon-moon Chun, ed.*Proc. Int. Conf: Sustainable construction materials and technologies*, 11-13 June 2007 Coventry, Supplementary proceedings., Pub. UW Milwaukee CBU, , p110-121.

Persson, U. (2009). Management of Sustainability in Construction Works, Doctoral Dissertation,

RSMeans (2006). Green Building: Project Planning & Cost Estimating, 2th Edn.,USA.

The Economic Benefits of Sustainable Design, http://www.oregonsolutions.net/govt/group.cfm., accessed on 01.03.2014.

Corporate Social Responsibility From the Perspective of Construction Industry

Dilek Ulutaş Duman
Istanbul Technical University, ulutasd@itu.edu.tr

Heyecan Giritli
Istanbul Technical University, giritli@itu.edu.tr

Abstract

Increased awareness in corporate social responsibility (CSR) in global area makes the CSR integration inevitable for the construction industry, because there is huge public demand and stakeholder expectation to act in responsible manner in economic, social and environmental dimensions. Since the construction sector has huge impact in triple bottom line and great supply chain relations in its business process, CSR concerns all types of organizations in the industry. The aim of this paper is to understand how the term of CSR takes place in construction industry. Research starts with presenting the origins and emergence of the corporate social responsibility in general, then analyse the term of CSR within the context of construction industry.

Key Words: *Corporate Social Responsibility, construction industry*

1. FIRST PROCEEDING CORPORATE SOCİAL RESPONSİBİLİTY FROM THE PERSPECTİVE OF CONSTRUCTİON INDUSTRY

Corporate social responsibility (CSR) has emerged as a significant agenda in parallel with the increased importance of sustainable development. It has evolved to a key business driver, which plays important role in strategic decisions of organizations (Murray & Dainty, 2009), although the roots of the CSR has come from philanthropic activities and the idea of contributing to society among the economic activities (Carroll & Buchholtz, 2006). Due to the increased public interest, business organizations have been forced to be more transparent to stakeholders, government and society. In this regard, CSR has come to the forefront as a holistic way to communicate with business partners and society. Therefore, it turned to a key subject not only in academic area but also in business organisations and government agencies.

The term CSR has not a single accepted definition despite the growing importance and long historical background of the theory. Starting from the 1950's until the present various definitions of CSR have been developed by the scholars (Bowen, 1953; Davis, 1973, Carroll, 1979; Wood, 1991; Porter & Kramer, 2006). Although, they lay emphasis on different definitions, Carroll's four-part definition has been a base definition for other research papers in literature (i.e: Wartick and Cochran, 1985; Wood, 1991; Lewin et al., 1995: Visser, W, 2007), in which CSR is defined as:

"The social responsibility of business encompasses the economic, legal, ethical, and discretionary expectations that society has of organizations at a given point in time" (Carroll, 1979).

This definition starts with economic expectations as a starting point and go through to the discretionary activities. It has similar approach with the idea of being responsible in triple bottom line as stated in all sustainable development discussions. It is common idea that CSR is rather a new term; however, literature is abounded with the studies, which discusses one of the sub-titles or detailed components of those subtitles. The difference of CSR is that it considers all dimensions and provides opportunity to the business organizations to evaluate their activities and the impacts of those activities from a holistic perspective.

Besides theoretical improvements, there has been great development about standards, management systems and guidelines about CSR. Increased attention on sustainable development and sensitivity to environmental, social and economic sustainability accelerated the importance of CSR. For instance, it has been an important agenda for the EU and CSR is defined as "...a concept whereby companies integrate social and environmental concerns in their business operations and in their interaction with their stakeholders on a voluntary basis'' in Green Paper Report (EU, 2001).

Another important step was the foundation of the Global Reporting initiative in 1997 and introduction of a sustainability-reporting framework, which is widely acclaimed around the world. (GRI, 2010) The main topics in the latest guidelines published by GRI suggest organisations to explain themselves within the strategy and profile, economic, environmental, social, labour practices and decent work, human rights, society and product responsibility titles. GRI framework provides companies sharing their activities in a structured system, benchmark with other standards and management systems, and compare with other organisations. Besides, Global Compact was initiated by United Nations to promote the sustainability and social responsibility of the business. It is a strategic policy initiative with ten principles focusing four main areas as human rights, labour, environment and anti-corruption which business organisations can adopt and report their alignment with it voluntarily (UNGC, 1999).

Many business and non-governmental organizations were established to produce frameworks, assessment systems to manage and measure corporate social activities. Mainly they could be listed from very beginning with London Benchmarking Group, 1994; the Corporate Citizenship Company, 1997; BITC Corporate Social Responsibility Index, 1998; The Dow Jones Sustainability Index, 1999; AccountAbility1000, 1999; Good Corporation Company, 2000; FTSE4GoodIndex, 2001 (Barthorpe, 2010); CSR Academy, 2004; ISO26000, 2010 and many others with an increased development. The main problem of these frameworks is that their implementation is confusing for organizations and they create incomprehensibility especially when it is considered from the perspective of SMEs. One of the recent improvements about CSR is the publication of ISO26000: Guidance on Responsibility which gives voluntary guidelines in CSR adoption with seven core subjects which are community involvement and development, organisational governance, human rights, labour practices, environment, fair operating practices, and consumer issues (ISO, 2010).

As a result of numerous definitions there is still confusion about the CSR in the strict sense. However, there are five common dimensions mentioned in all definitions, which are environmental, social, economic, stakeholders and voluntarism (Dalsrud, 2008). For this reason corporate social responsibility can be defined as a business system, which define the impact of our business on our stakeholders and the triple bottom line -economy, society and environment- on a voluntary basis.

Generally speaking, construction sector has been one of the most important sectors within the economy. One of the main reasons of this importance is that it generates infrastructure for other sectors (Martunizzi et al, 2010). Also, it has a wide range of activity areas from groundwork to finishing details as well as the sub-sectors providing materials for construction activities. For this reason, it creates large impact on the natural and built environment with the consumption of energy and resources, waste material output, contamination, quarrying, extraction of sand and gravel, changes on the existing impact and increased production in built environment (Jones et all, 2006). Due to the its great impact on environment, economy and society, the construction industry has found itself interested in CSR subject (Murray & Dainty, 2009).

There is an increased coercion to produce socially responsible products and services by stakeholders and also high risk to be boycotted if the company has failed to satisfy the anticipations (Herridge, 2003). Owing to the stakeholders increased criticism on unethical performances such as environment destruction, exploitation of workforce and detriment on communities, there has been transformation of the nature and significance of CSR idea. It turned to a crucial business driver affecting strategic primary issues from being a subject of corporate philanthropy. (Murray& Dainty, 2009)

There has been an increasing awareness in construction companies to adopt CSR policies in their business strategies and it could be an option to look into their strategies for other companies that intend to integrate the CSR in their business as well as using the CSR frameworks constituted some initiatives such as DIT, BITC. (Randles & Price, 2008) and also the standards like FTSE Good Index, SRI, GRI (Herridge, 2003).

Although, main sub-titles of CSR theory such as ethics, environmental sustainability have been important research areas in construction industry for many years, there is a lack in literature viewing the CSR theory as a whole concept in construction industry likewise other sectors. Murray and Dainty (2008) evaluates the term CSR from the perspective of construction industry and defines it as: "...the responsibility an organization takes for the impact of its corporate activities on environment and the various stakeholders with whom it effects." Another researcher from the construction sector, Barthorpe (2004) states, "CSR could be considered as an "umbrella" term, incorporating the tenets of; environmental sustainability, business ethics, governance, public relations, stakeholder analysis and relationship marketing".

Randles and Price (2008) consider the sustainable construction and design trends as a starting point criticizing the slow adoption attitude of the construction industry while mentioning the change need to keep up with stakeholder anticipations. Also, they state that adopting sustainability is not enough to meet the CSR theory among the sustainable trends construction needs to develop social conscience in its business strategy (2008).

The general trend in explaining CSR activities in construction sector is to demonstrate best case studies from different construction companies web sites. For instance, *Jones et al* evaluated the construction company reports and identified the common headings of CSR activities as environment, health and safety, human resources, supply chain management, customers & communities and governance and ethics (2006). Besides, Lazarevic proposed to list the construction industry CSR activities as moral obligation to be a good citizen; sustainability; reputation; relationship with employees and unions; relationship with suppliers and community representatives; and commitment to reporting on CSR (2008). Also, recent improvement about CSR specific for construction industry is the publication of sector-based toolkit as a result of the BRC Project by EU (EU, 2010). The project demonstrates four main areas of CSR activities in construction sector as health and safety, supply chain, eco-compatibility and equal opportunities; and uses Porter's Value Chain Model to explain the relationship between a company and its stakeholders and presents the interdependence between a company and society with using inside-out linkages and outside-in linkages (EU, 2010). To approach the term of CSR specific for the construction sector it could be suitable to use BRC Project's four main heading to questioning the CSR from the perspective of construction industry.

As seen in above discussions construction industry organizations should adopt CSR theory to their business systems in order to respond the expectations of stakeholders and public in general. Although, there are many different approaches in CSR application, most of them have similar focal point on the responsible economic, social and environmental impact of the business activities. In order to have an effective role in CSR application, companies should consider their business systems, company scale, and operations and evaluate what kind of approaches they could successfully adopt.

6. CONCLUSIONS AND RECOMMENDATIONS

CSR is one of the main subjects, which should be integrated in the business to cope with the increased expectations for responsible business. Despite the late awareness and implication of CSR in the construction sector, the increasing pressure of the governmental agencies, business units, and stakeholders has turned the CSR adoption into a crucial agenda for all types of construction organizations. In order to keep effectiveness in changing business environment, companies should adopt CSR in their activities. Despite the increased publications and implications about the CSR, there is a need for effective and clear solutions specific for construction industry. The conducted researches so far have focused on company reports, relevant standards, indexes and general awareness of the CSR in multinational companies, and there is a need to clarify the subject from the perspective of companies of all sizes. This study presented a summary of its origins in general and its application in construction industry from the perspective of both academic and professional studies. Future studies could focus on explaining the CSR activities of construction organizations from the perspective of different geographies and company scales rather than discussing the theory from a general perspective.

REFERENCES

Bowen, H.R. (1953) Social responsibilities of the businessman. New York: Harper &Row.

Barthorpe, S., James, R. and Taylor, S. (2004).Corporate social responsibility – an imperative or imposition on the UK construction industry?, paper presented at the CIB World Building Congress, Toronto.

Barthorpe, S. (2010).Implementing corporate social responsibility in the UK construction industry, *Property Management*, 28(1), p: 4-17.

Carroll, A. B. (1979), Three-Dimensional Conceptual Model of Corporate Performance, *The Academy of Management Review*, 4(4) pp. 497-505.

Carroll, A. B. & Buchholtz, A. K. (2006) Business & Society: Ethics and Stakeholder Management Ohio: South-Western.

Commission of the European Communities. (2001). Green Paper: Promoting A European Framework For Corporate Social Responsibility.
http://eurlex.europa.eu/LexUriServ/site/en/com/2001/com2001_0366en01.pdf (07.03.2014)

Commission of the European Communities (2010) CSR Europe: *BRC Project Building Responsible Competitiveness: Guidelines to Enhance CSR in the Construction Sector* [Pdf download]http://www.csreurope.org/data/files/brc_guideline_ eng_web.pdf

Dahlsrud, A. (2008). How Corporate Social Responsibility is Defined: An Analyses of 37 Definitions, *Corporate Social Responsibility and Environmental Management*, 15, pp:1-13.

Davis, K. 1973. The Case for and against business assumption of social responsibilities, The Academy of Management Journal, 16 (2), pp: 312-322

Global Reporting Institute(2006) Surdurulebilirlik Raporlamasi Ilkeleri. ttp://www.globalreporting.org/NR/rdonlyres/660631D6-2A39-4850-9C0457436E4768BD/0/G31 GuidelinesinclTechnicalProtocolFinal.pdf (23.02.2011).

Herridge, J. (2003). The Potential Benefits of Corporate Social Responsibilityin the Construction Industry, *Construction Information Quarterly*, 5(3), pp:12-16.

International Standart Organization. (2010). ISO26000: 2010-Guidance on Responsibility. http://www.iso.org/iso/catalogue_detail?csnumber =42546 (12.03.2011)

Jones,P., Comfort, D. and Hillier, D. (2006). “Corporate Social Responsibility and UK Construction Industry”, *Journal of Corporate Real Estate,* 8(3), pp: 134-150.

Lazeravic, S. P.,(2008) “The Development Of Corporate Social Responsibility In The Australian Construction Industry”, Construction Management and Economics, February(6), p:93-101.

Lewin, A. Y., Sakano, T. Stephen, C. U. and Victor, B. (1995), ‘‘Corporate citizenship in Japan: survey from Japanese firms’’, *Journal of Business Ethics*, Vol. 14 No. 2, pp. 83-101.

Martinuzzi, A., Gisch-Boie, S. and Wiman, A. (2010). “Corporate Responsibility Pay Off? Exploring the links between CSR and competitiveness in Europe’s industrial sectors”, *Research Institute for Managing Sustainability on behalf of the European Commission, Directorate- General for Enterprise and Industry* http://ec.europa.eu/enterprise/newsroom/cf/_getdocument.cfm?doc_id=6311 (18.02.2011)

Murray, M. & Dainty, A.(2009). Evaluation of Corporate Social Responsibility in the Construction Industry. In Murray, M. & Dainty, A. (eds).Corporate Social Responsibility in the Construction Industry. London: Taylor& Francis.

Porter, M. E. & Kramer, M. R. (2006). “Strategy and Society: The link between Competitive Advantage and Corporate Social Responsibility”. *Harvard Business Review* 84(12): 78-92.

Randles, L. & Price, A.(2009). A Business Case for Developing a Corporate Social Responsibility. In Murray, M. & Dainty, A. (eds).Corporate Social Responsibility in the Construction Industry. London: Taylor& Francis.

United Nations Global Compact (1999). The Ten Principles. http://www.unglobalcompact.org/AboutTheGC/TheTenPrinciples/index.html (12.02.2011)

Visser, W. (2007) Revisiting Carroll’s CSR Pyramid: An African perspective, In A. Crane & D. Matten (eds.), *Corporate Social Responsibility: Three Volume Set*, London: Sage, 195-212.

Wood, D.J. (1991) Corporate Social Performance Revisited, *Academy of Management Review, 16(4), pp:691-718*

Wartick, S. L. and Cochran, P. L. (1985) The Evolution of the Corporate Social Performance Model *The Academy of Management Review*, Vol. 10, No. 4, pp. 758-769.

Energy, Sustainable Development and Importance of Worlwide Cooperation

A.Beril Tugrul
Istanbul Technical University-Energy Institute, email: beril@itu.edu.tr

Abstract

Energy has a pivotal role in every society, touching upon all aspects of life and creating, in particular, an accelerated sustainable economic and social development, which in turn enhances the welfare of people and consolidates the country's standing in the world. Usage and management of energy is an important measuring criteria for the countries in the view of evaluation for developing statute in the world. World electricity demand is projected to grow more rapidly than total energy over the next 20 years. It seems that the fossil fuels may be major fuel in that period. Undesirable results due to using fosil fuels like as greenhouse effects, climate change it should be support the researches and development (R&D) activities strongly. Sustainability is important for the liveable earth. Therefore, the inter-relationship of natural and man-made elements in the environment is the basis for planning aimed towards improved quality of life. For reduction of CO_2 emission could be realized with increasing nuclear and renewables energy usage, and efficiencies on fuel, power, electricity and fossil fuels. In here "ecosystems approach" is vital importance. Worldwide cooperation is the most important with the concepts of 6 C's (Credibility, Capability, Continuity, Creativity, Consistency and Commitment). Then, it can be success development on sustainability, sharing with public, strategy & culture, procedures & evaluation together with 6 C's. Some actions related with energy for sustainable development should be via; residential actions energy saving actions, industrial actions, country's actions and global actions

Key Words: *Energy, Sustainability, Sustainable development, Cooperation, Urban civilization*

1. INTRODUCTION

Usage and management of energy is an important measuring criteria for the countries in the view of evaluation for developing statute in the world. Therefore, reach out the energy resources or producing of it is an important target for all over the world. Access to the energy and/or energy resources, in particular providing energy sources in large scale, has become an indispensable requirement for the countries

2. ENERGY DEMAND

World primary energy consumption is projected to grow by 1.6% p.a. over the period 2010 to 2030. This is huge amount indeed. That means many of power plant will be built. Figure 1 shows world demand for long term energy sources.

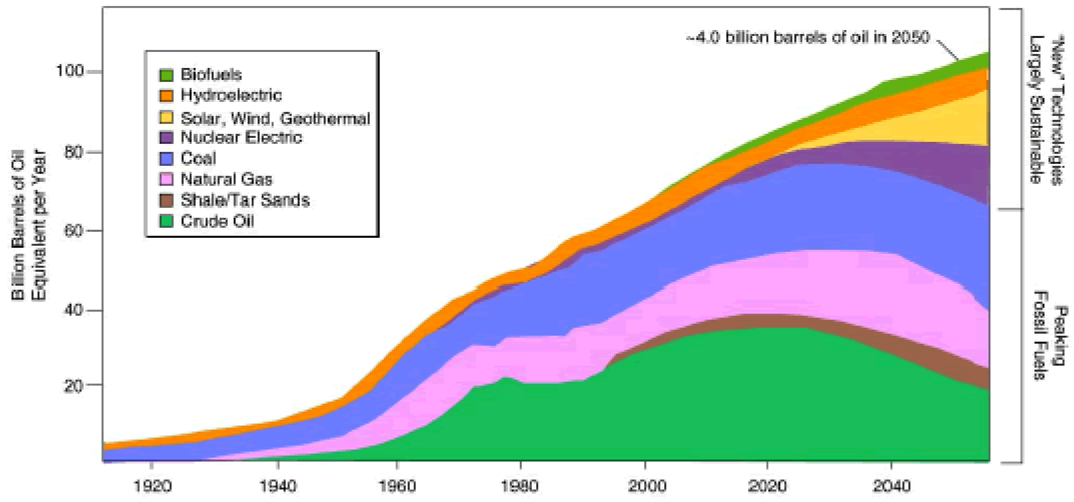


Figure 7. World Demand for Long Term Energy Sources (Orr, 2010)

World electricity demand is projected to grow more rapidly than total energy over the next 20 years. It seems that the fossil fuels may be major fuel in that period (Tugrul & Cimen, 2013). Then, greenhouse effect will be more affected of course. Over the next decade coal is still the largest contributor to the growth of power fuels, (accounting for 39 %,) but non-fossil fuels are rapidly catching up. In aggregate hydro & other renewables and also nuclear, contribute as much as coal (Tugrul, 2011). The growing role of non-fossil fuels becomes even clearer in the following decade to 2030. Meanwhile the contribution of gas remains relatively steady at around 31% through the decades.

Undesirable results due to using fosil fuels like as greenhouse effects, climate change it should be support the researches and development (R&D) activities strongly. But it can be understood that supporting of R&D efforts nat so much in the present (Figure 2)

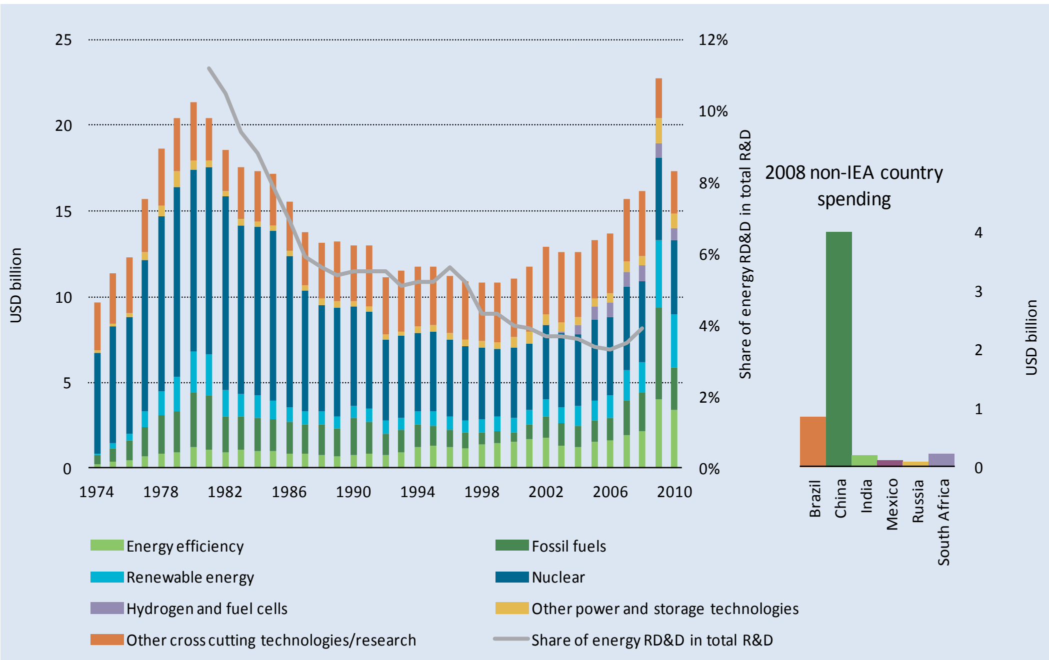


Figure 2 Public Spending on R&D (Jones, 2012)

3. SUSTAINABLE DEVELOPMENT

Sustainability is important for the liveable earth. As known that; "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (WCED, 1987). "[The] word sustainable has been used in too many situations today, and ecological sustainability is one of those terms that confuse a lot of people. You hear about sustainable development, sustainable growth, sustainable economies, sustainable societies, and sustainable agriculture. Everything is sustainable

Renewable and nuclear power are the more environmentally benign way of producing electricity on a large scale. Nuclear power provides about 11% of the world's electricity, and 21% of electricity in OECD countries. Renewable energy sources other than hydro have high generating costs. But can be helpful at the margin in providing clean power.

Environmental sustainability is the process of making sure current processes of interaction with the environment. Thus, environmental sustainability demands that society designs activities to meet human needs while indefinitely preserving the life support systems of the planet

Cities occupy 3% of the Earth’s land surface, and house 75% of the human population. Cities account for a considerable portion of a country’s energy consumption. *[2/ of worldwide energy usage and GHG emissions]*. Most production, trade and transportation activities usually are located in these areas. *[80% of Asia’s GDP is produced by Asian cities].* Figure 3 shows per capita carbon emission for selected cities in the world

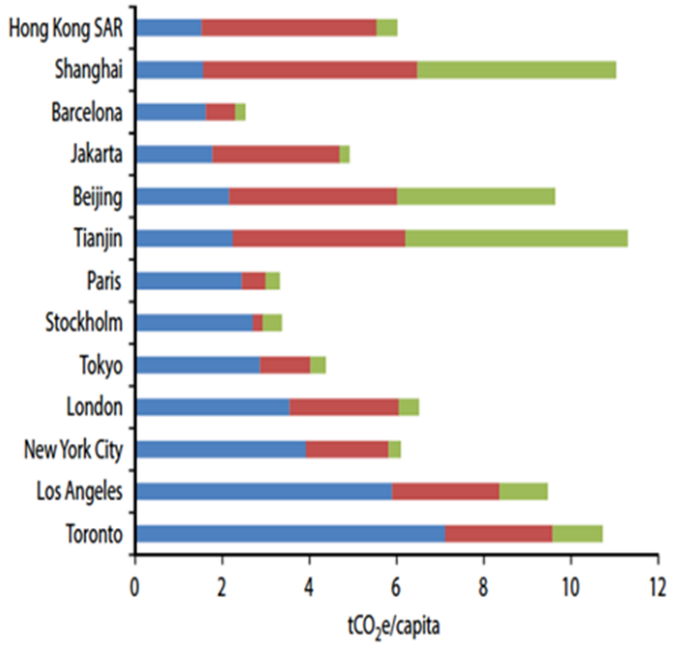


Figure 3 Per Capita Carbon Emission for Selected Cities in The World (WB,2010)

Sustainable energy is important for welfare of the countries. Therefore sustainable energy that is energy solutions that address development issues related to economic growth, environment and social equity simultaneously is vital for our earth. Figure 4 represents energy sustainability in the total sustainability concept [5].

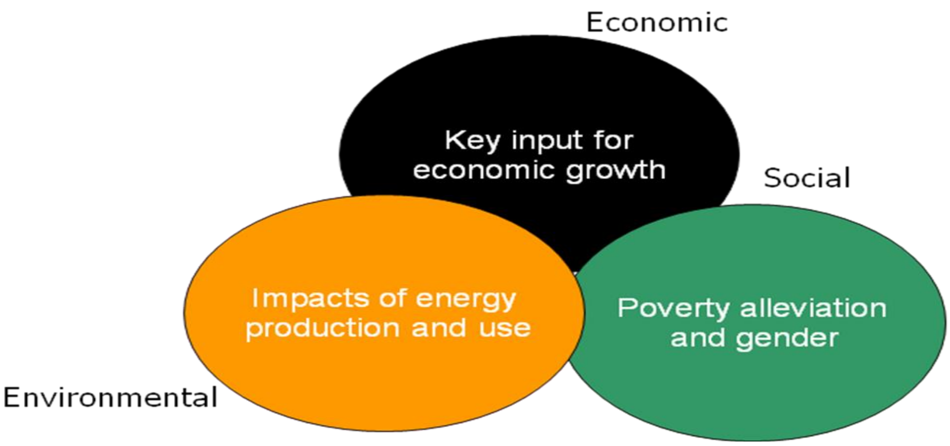


Figure 4 Energy Sustainability in the Total Sustainability Concept (Soriano, 2012)

Energy needs stimulate new developments. It should be applied by organizational and systematic activities. Fig. 5 shows the actions of energy with feedback effects.

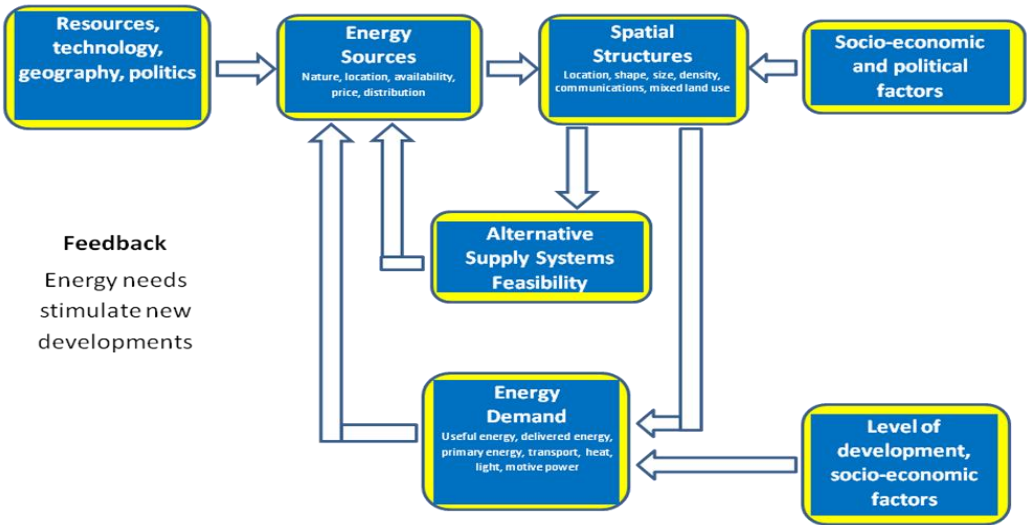


Figure 5 Actions of Energy With Feedback Effects (Owens, 1986)

Some important tricks there are for low carbon emission for urban communities. These are summarized that;

- Urban Systems – Infrastructures; resource intensive (energy, water, materials and land); Difficult and costly to modify.
- Traffic congestion - Inadequate road & transport infrastructures - cost can be as high as 10% of the city's GDP.
- Typical buildings – non-energy efficient - can account for 40% of a city's total energy consumption and 30% of GHG emissions.
- Expansion of infrastructures (rapid urbanization; fast economic growth; increased competitiveness, etc.).
- The way a city is planned, designed, operated and maintained will influence its future energy usage and emissions (GHG & pollutants).

It is not so easy to applied on many of the big cities of the world. Figure 6 shows the annual carbon emission of a city.

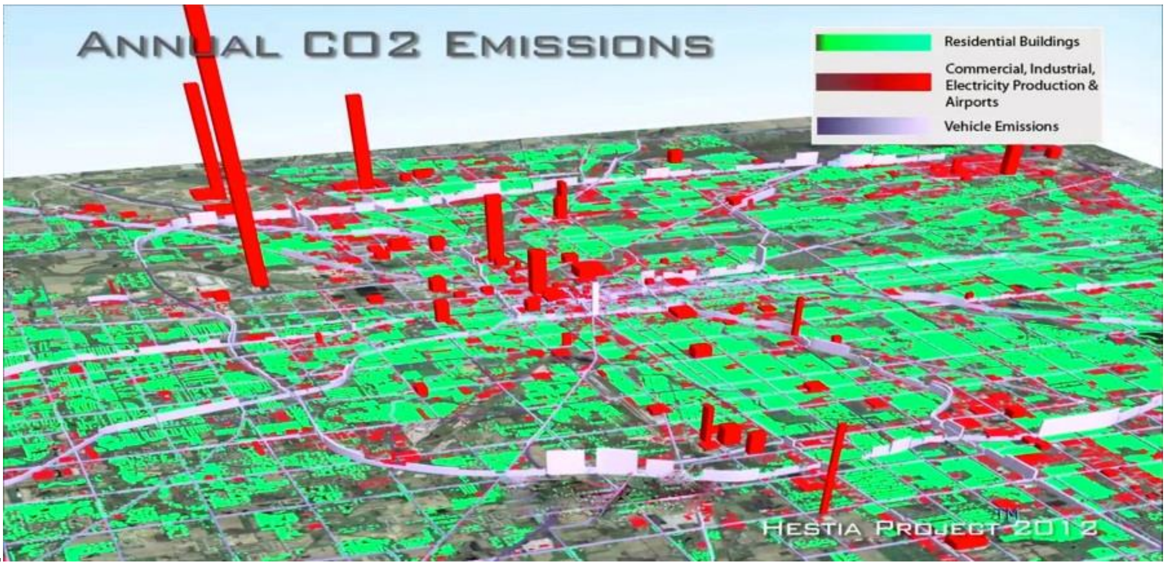


Figure 6 Annual Carbon Emmision of a City (Hesta, 2012)

In the present time, energy and raw materials are essential input for civilization and then heat and high wastes & toxics are outputs of course. That is “One-way flow energy and materials that is shown in Figure 7 schematically.

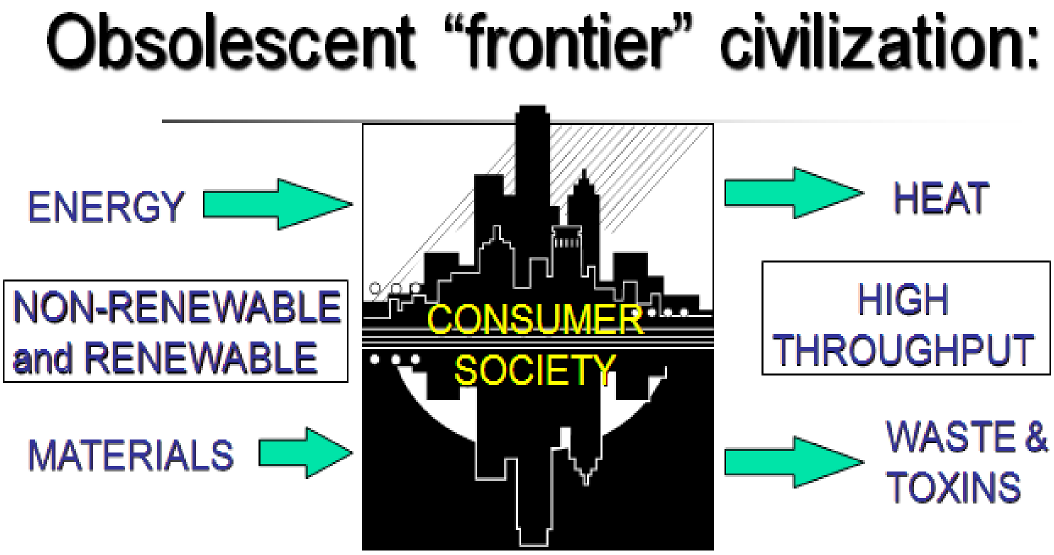


Figure 7 “One-way flow energy and materials (TREN, 1990)

After years by years with applying one-way flow applications have caused the heat index of the world going up and now has reached at the dangerous levels (Fig. 8).

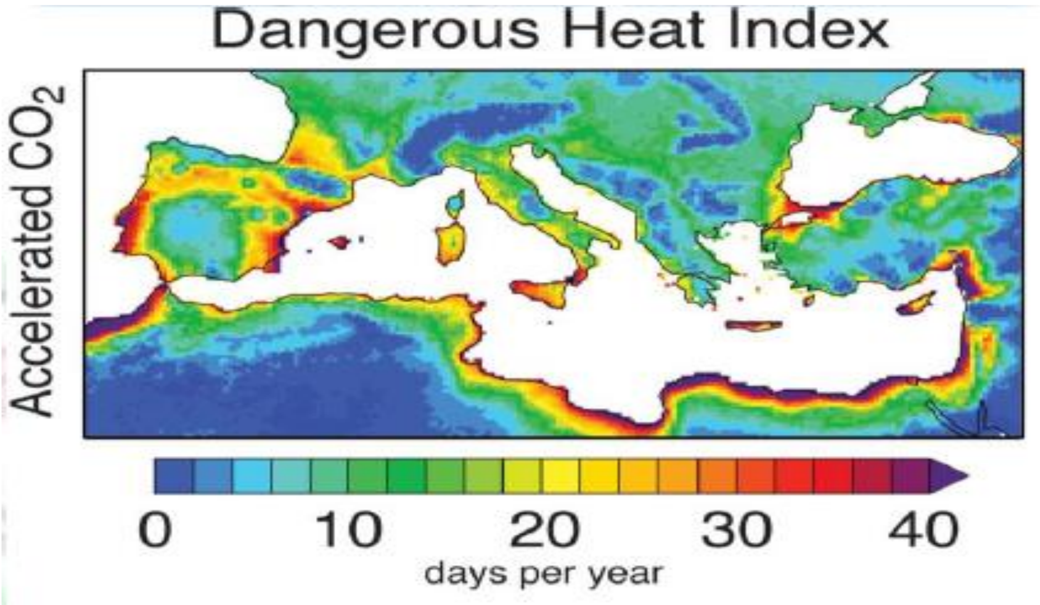


Figure 8 Dangerous Haeat Index for Mediterranean Region
(http://news.uns.purdue.edu/UNS//images/+2007/diffenbaugh-heat2.jpg.,2013)

One-way flow applications should be turned as sustainable civilization by applying by cyclical flows of materials and appropriate energy usage (Figure 9).

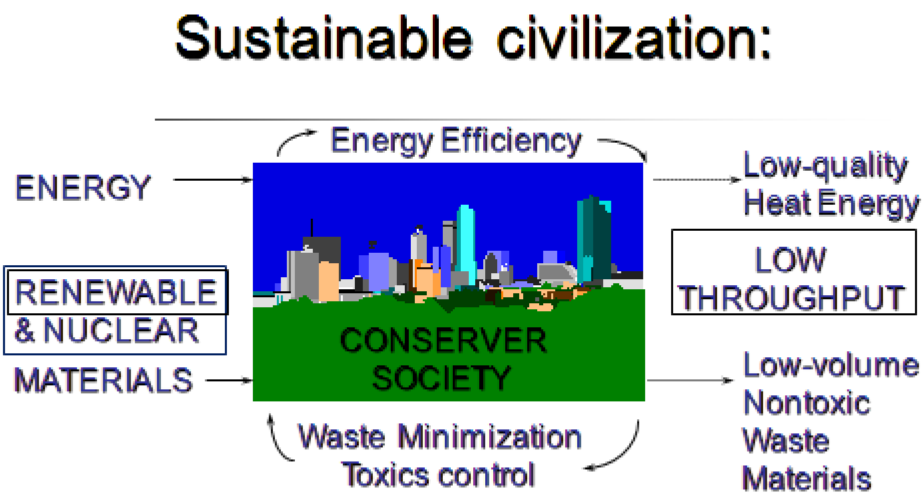


Figure 9 Sustainable Civilization (TREN, 1990)

In here "ecosystems approach" is vital importance. Therefore, the inter-relationship of natural and man-made elements in the environment is the basis for planning aimed towards improved quality of city life. Energy technologies must developed with usin available resources , resource utilization. Waste conversion and recycling should be applied on all waste materials Then, low carbon development of urban communities may be occur easily. Urban Systems require energy to function with related; solid waste management systems, communication systems, building systems, water supply systems, transport systems, parks & waterways systems, waste water systems in the concept of sustainability.

OECD/IEA developed alternative policy scenarios for reduction of CO_2 emmission with increasing nuclear and renewables energy usage, and efficiencies on fuel, power, electricty and fossil fuels (Figure 10).

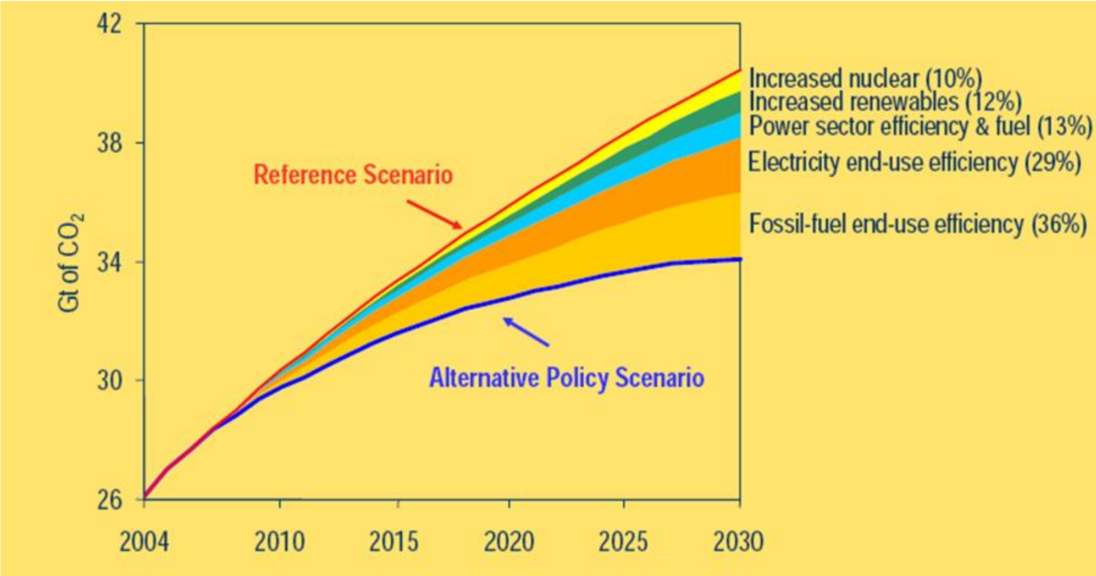


Figure 80 Alternative Policy Scenarios for Reduction of CO_2 Emmission (OECD/IEA, 2006)

4. IMPORTANCE OF COOPERATION

Concepts for Sustainability may be applied with physical / geographical, ecological and jurisdictional arguments. Then, carbon emission growth slows, but more action is needed. More action represents global cooperation. Worldwide cooperation is the most important with the concepts of 6 C's (Credibility, Capability, Continuity, Creativity, Consistency, Commitment). Then, it can be success development on sustainability, sharing with public, strategy & culture, procedures & evaluation together with 6 C's (Figure 11).

Figure 91 Important Factors For Cooperation on Sustainability

In here, an important argument for applicance of the cooperation is in large scale. Therefore, sustainability concept should be applied from micro-scale to macro-scale. Then from individuals and groups to governmental and international institutions.

5. CONCLUSION

Energy has a pivotal role in every society, touching upon all aspects of life and creating, in particular, an accelerated sustainable economic and social development, which in turn enhances the welfare of people and consolidates the country's standing in the world. The new concepts of world energy require a shift of position in mind and strategic orientation.We are at the edge of a new energy revolution, driven by the world's need for affordable energy and by the real threat of climate change.

The coming decades are likely to bring about huge changes in the world's energy system. Future energy policy will be driven by the triple challenge of achieving substantial reductions in emissions of greenhouse gases while ensuring a secure supply of energy, all at reasonable cost to economies. In order to cope with this challenge, it must be changed the way we use energy. Increasing the energy efficiency of the economies is an absolute necessity. Also, all of us must move rapidly towards a more diverse, sustainable set of energy resources. This move depends on the aggressive development and deployment of more sustainable energy sources.

Some actions related with energy for sustainable development should be via;

- Residential actions energy saving actions
- Industrial actions
- Country's actions
- Global actions

6. REFERENCES

Hesta Project, (2012).

Jones, R.H, (2012). Tapping Technology's Potential to Secure a Clean Energy Future, *ETP-2012*, Astana, Kazakhstan

Orr,L., (2010), Changing the World's Energy Systems, Stanford University Global Climate & *Energy Project*, SRI Consulting

Owens, S., (1986), Energy, Planning and Urban Form.

Soriano, M.L., (2012), Energy-Integrated Planning for Low Carbon Development in Cities, *UNDP.*

TREN, (1990), Introduction to Sustainability, *TREN-1F90.*

http://news.uns.purdue.edu/UNS//images/+2007/diffenbaugh-heat2.jpg. accessed on 01.03.2014.

Tugrul, A.B. 2011, "Nuclear Energy in the Energy Expansion of Turkey", *Journal of Energy and Power Engineering*, Vol. 5, No 10, pp. 905-910, Oct.2011,

Tugrul A.B.,Cimen,S., (2013), "Energy Initiatives for Turkey", *"International Conference on Economics and Econometrics - ICEE 2013*", 2-3 Aralık 2013, Dubai-BAE, Proc. pp. 40-44.

World Bank, 2010.

World Commission on Environment and Development (1987): *Our Common Future.*

World Energy Outlook (2006) *OECD/IEA.*

Political Economy of Natural Resources: As a Key for Sustainability and Regeneration of the World's Resources

Egemen Sertyesilisik
email: egemens@alumni.bilkent.edu.tr

Abstract

Political economy deals mainly with privatization to increase effective and efficient use of resources. As water resources are vital for the life in the world, they need to be efficiently utilized (e.g. reducing the waste of water resources, and enabling everyone to have access to water) and protected. This is needed for the sustainability and regeneration of the world's resources. This paper focuses upon the ways to increase efficiency and effectiveness in the usage of the water resources.

Key Words: *Political economy, natural resources, water, privatization*

1. INTRODUCTION

Water resources seem abundant in our world. However, the fresh water resources that can be used by humans are very limited. World's water reserves are about 1.4 million km^3, only 2.5 % of these water resources are fresh water (Kaya, 2009:11). Humans can only use 0.5 % of this water as more than 90% of these fresh water resources locate on poles and in the underground (Kaya, 2009:11). In addition to this, water resources of the world have not been spread evenly on the earth by nature. That's why the resources are consumed by people unfairly, 85% of the water supply of the earth is consumed by 12 % of the world population (Minibaş, 2007: xxiv). This paper focuses upon the ways to increase efficiency and effectiveness in the usage of the water resources.

2. POLITICAL ECONOMY AND PRIVATIZATION

The amount of fresh water of the world remained constant for about 2000 years. However, world's population increased by 33 times during the same period (Kaya, 2009:11). Thorough out this duration, the increase in the population of the world decreases water availability per capita. There is still huge industrial and economic growth in our planet. This growth increases water demand. Additionally, increase on life style in a country also increases water demand in that country (BFC, 2009). Besides, it is estimated that 1.1 billion people worldwide today lack of access to water and by 2025, it is expected that two-thirds of the world's population may face water shortages (Wildlifeorg, 2014). According to UN Medium Population Projections of 1998, more than 2.8 billion people in 48 countries will face water stress, or scarcity conditions by 2025 (UNDP, 2008). So we need to find solution to water scarcity. We must use our water resources in an efficient way and need to prevent them from wasting. One of the important solutions to scarcity is privatization of water resources and water infrastructure.

Privatization of water infrastructure reduces water losses among the water systems. This practice leads us to use of our water supplies more efficient. According to BBC news, “since 2005, the companies ranked in the top five - Severn Trent Water, United Utilities Water, Thames Water, Yorkshire Water and South Staffordshire Water - have reduced leaks by a combined amount of 226.86 million liters a day” (BBC, 2012). The data on Table 1 indicates the loss of huge amount of water. There is huge municipality water loss in many parts of the world.

Table 1. Losses in municipality water (Postel et al, 2004:16)

Country	Water losses in municipality water infrastructure (%)
Albania	75
Canada	38
Check Republic	20-30
Denmark/Kopenhag	3
France	50
Japon/Fukuoka	5
Jordan	48
Singapur	5
S. Africa/Johannesburg	42
Spain	24-34
Taiwan	25
U.S.A	10-30

Taking into consideration the previous information; it appears that these countries can minimize their losses by privatization of water services. By looking at the Table 2 in near future we can observe an increase in privatization of water services is in our world.

Table 2. People served by private water or sewerage services in 2012 and forecast for service in 2025 (Pinsent Masons, 2013:49)

People served by private water or sewerage services in 2012 and forecast for service in 2015 and 2025

Million people		**2012**		**2015**		**2025**
Western Europe	188.6	47%	204.9	50%	226.7	55%
C&E Europe	39.9	12%	57.3	18%	84.0	28%
ME & Africa	86.9	7%	116.7	8%	227.7	13%
South & Central Asia	20.0	1%	28.6	1%	113.4	5%
South East Asia	411.3	20%	469.4	21%	642.0	27%
Oceania	12.5	36%	15.7	42%	18.8	45%
North America	106.7	23%	125.5	26%	201.4	39%
Latin America	102.1	21%	119.5	23%	158.0	29%
World total	**968.0**	**14%**	**1137.6**	16%	**1672.0**	21%

Both developing and developed countries need privatization for different reasons. In the developing countries there is huge population growth. Such growth applies pressure on water infrastructure and many governments do not have enough financial capacity in order to build their water systems (Menard and Peeroo, 2011:9). When they privatize their water systems, their infrastructure will be built by multi national water companies. On the other hand, developed countries have water systems since more than one century so their infrastructures are getting older (Menard ve Peeroo, 2011:9). The developed countries need water privatization in order to renew and upgrade their existing old water infrastructure; doing such maintenance also requires important finance. Through privatization such finance can be provided by multi national companies (Menard ve Peeroo, 2011:9).

Privatization of water services in many developing countries are quilted by multinational companies due to many reasons (IBRD, 2006:5). This is because the infrastructure building costs too much. The companies cannot retrieve their investments back. This situation causes many multinational companies to cancel their agreements with national states (Hall ve Lobina, 2006:7; Yılmaz, 2012:123).

Privatization of the water supply network and utilities can cause an increment in the prices of the water. However, in case this privatization of the water network had not been made in time when the authorities did not have enough finance to invest on water infrastructure, the people are going to face serious water problems in the future. The population growth will decrease water resources per capita (Wardam, 2004:62). Additionally, as expressed, by Hall and Lobina (2006:7) and by Yılmaz (2012:123) the multinational companies can not retrieve their investments back and this fact indicates that they do not make enough profit. Thus, the rise in water prices due to the privatization of the water network isn't against to the interest of the people.

Privatization of water gives many advantages to the poor people. According to Postel and Vickers, the people with high income consume more water with lower price. The people with low income consume less water and pay much higher price (Postel and Vickers, 2001:19). The low income people who don't have access to municipality water infrastructure need to get water from private water sellers and pay higher fee to the water (Postel and Vickers, 2001:19). In Delhi the people who has access to municipality water system pays 1 cent per m^3 and the people who has low income don't have access to municipality water infrastructure need to pay 4.50 $ per m^3 .(They pay 500 times higher price for the same amount of water) (Postel and Vickers, 2001:19).

I would like give an important example on privatization. Jordan has experienced a privatization of water networks during past decade. Water Authority of Jordan **(**WAJ), that is one of the authorities of the Ministry of Water and Irrigation (MWI), made a four-year management contract with a consortium with a French multinational water company named Suez in the year 1999 (Wardam, 2004:73). According to this agreement all water and wastewater related service management in the Amman Governorate will be given to LEMA company (Wardam, 2004:73). This service area represents 37% of the total population of Jordan, 9% of the total area, and 43% of the total number of subscribers, as well as 37% of the total water consumption in the country (Wardam, 2004:73). Under the terms of the contract, LEMA the private company was responsible for providing water, for customer service, for dealing with complaints, and for maintaining the tertiary network (World Bank, 2007:48). However, LEMA didn't have right to set the water prices. On the other hand, the company is empowered to discontinue its services to the people who are not paying their bills. The company also had right to reduce staff by moving them to the MWI (World Bank, 2007:48). LEMA had succeeded in many areas. The company covered 125 percent of its operations and maintenance costs (World Bank, 2007:48). Water service has improved since. This also brought increase in the customer satisfaction (ibid). Before the contract the inhabitants of Amman was receiving water services up from 32 hours per week after the contract services increased up to 40–45 hours per week in 2003 (ibid). LEMA also reduced unaccounted for water from 55 percent in 1999 to 43 percent in 2004. However the improvements have been slower than expected (World Bank, 2007:48).

3. CONCLUSION

In conclusion, both developing and developed countries need important amount of financial resources in order to keep their water network efficient. Privatization of water networks can be an important solution to solve the financial problems. Privatization is also an important solution that can reduce the water losses. Taking into consideration from the information above; the countries like England and Jordan who privatized their water networks achieved a success to reduce the water losses. Preventing water looses will contribute to reduce waste and pressure on water resources. This will also help us sustainable use of our planet's limited fresh water supplies.

4. REFERENCES

Abingdonreservoir. (2014). "Thames Water's Leakage Performance", http://www.abingdonreservoir.org.uk/popup/tw_leakages.html

Barilla Center for Food & Nurition (BFCN) (2011). "Water Economy", İtaly. http://www.barillacfn.com/en/position-paper/pp-fs-water-economy/

BBC (2012). "How much does your water company leak?", http://www.bbc.com/news/uk-17622837

Hall, D. and Lobina, E. (2006). “Pipe Dreams: The failure of the private sector to invest in water services in the developing countries”, Public Services International Research Unit (PSIRU), London, http://www.psiru.org/reports/2006-03-W-investment.pdf

IBRD (2006). “Approaches to Private Participation in Water Services: A Toolkit”, USA: Washington: IBRD,World Bank, PFIAF-Public-Private Infrastructure Advisory Facility.

Kaya, K. (2009). “Dünya Su Forumları ve Suyun Özelleştirilmesi”, TMMOB Elektrik Mühendisleri Odası (EMO) Dergisi, No.45, Ezgi Matbacılık, Istanbul, May 2009.
http://www.emo.org.tr/yayinlar/dergi_goster.php?kodu=571&dergi=5

Menard, C. and Peeroo, A. (2011). “Liberalization in the Water Sector: Three leading models”, Edward Elgar Publishing, Rolf Kuneke (Ed.), Matthias Finger (Ed.), Handbook of Liberalization. UK, 2011, pp 310-327.
http://halshs.archives-ouvertes.fr/docs/00/62/43/03/PDF/2011--Menard-Peeroo--Liberalization_of_the_Water_Sector.pdf

Minibaş, T. (2007). “Globalizmde Suyun Ekonomi Politiği”, TMMOB Çevre Mühendisleri Odası, 7. Ulusal Çevre Mühendisliği Kongresi Yaşam Çevre Teknoloji, İzmir, 24-27 October 2007.

Postel, S. and Vickers. A. (2004). “Su Verimliliğini Arttırmak”, Ayşe Başçı
Sander (translator.) Dünyanın Durumu 2004, İstanbul: TEMA Vakfı Publishing, 51-75.

Pinsent Masons (2013). “Pinsent Masons Water Yearbook 2012-2013, The essential guide to the water industry from leading infrastructure law firm Pinsent Masons”, 14th Edition, London: Pinsent Masons LLP
http://wateryearbook.pinsentmasons.com/PDF/water_yearbook2012.pdf

UNDP (United Nations Development Programme). “Increased Global Water Stress”, 2008. http://www.unep.org/dewa/vitalwater/article141.html

Wardam, B. (2004). “More politics then water: Water rights in Jordan”, Global issue papers No.11; Water as a Human Right: The understanding of water in the Arab countries of the Middle East, A four country analysis, Heinrich-Böll Foundation, Palestine, 2004.
http://www.boell.de/sites/default/files/assets/boell.de/images/download_de/internationalepolitik/GIP11_Jordan_Batir_Wardam.pdf

Wildlifeorg. (2014) “Overview”,. http://worldwildlife.org/threats/water-scarcity

World Bank (2007). “MENA Development Report on Water, Making the Most of Scarcity: Accountability for Better Water Management in MENA”, World Bank, Washington.
http://siteresources.worldbank.org/INTMENA/Resources/Water_Scarcity_Full.pdf

Yılmaz, G. (2012) “Suyun Metalaşması: Kıtlığın nedeni kıtlığa çare olabilir mi?”, Evrensel Kültür Kitaplığı, İstanbul.

Reducing the Energy Costs of Municipal Wastewater Treatment Plants by Improvement the Control of the Aeration System

Ahmet Nurlu Bruns
University of Applied Sciences Bremen, Ahmet.Bruns@hs-bremen.de

Abstract

The commonly used aeration control system in wastewater treatment plants, based on the dissolved oxygen concentration, has many disadvantages. Therefore a new control system of the aeration based on the ammonium concentration was developed and applied in a biological basin constructed as a multi stage cascade of a wastewater treatment plant with a capacity of 450,000 PE. This control system of the aeration is based on the calculation the required oxygen transfer rate for the ammonium degradation in each cascade stage. The solution equation for the ammonium removal in each stage is calculated with balance equations consisting of transfer terms and transformation terms. The kinetic parameters of the biochemical ammonium removal used in this balance equations were verified by our own investigations. For the calculation of the ammonium removal in each stage the temporal character of the process parameter is taken into consideration. In short intervals the ammonium removal is calculated for the whole biological basin using the solution equation for each stage. And for this ammonium removal a certain oxygen transfer is required, so that the aerators are adjusted to the oxygen transfer rate, required in this current time interval. With this control system a power saving of more than 11 million kWh, 33,7% respectively was achieved in the first four project years. Furthermore in this first four project years also a an additional power production of round 3 million kWh, 12% respectively was found, so that the whole power yield was 14 million kWh, round 37% respectively.

Key Words: *Control the Aeration System, Reducing the Energy Costs, Operation the Wastewater Treatment Plants*

1. INTRODUCTION

Due to the environmental rules, the Wastewater Treatment Plants are to be designed for the maximum load! That means the aeration system must also be designed for the maximum load, so that the limiting values for the effluent of the Treatment Plant given by the environmental rules can be safely maintained. But this maximum load only occurs in one or two days of the year, as the next picture shows:

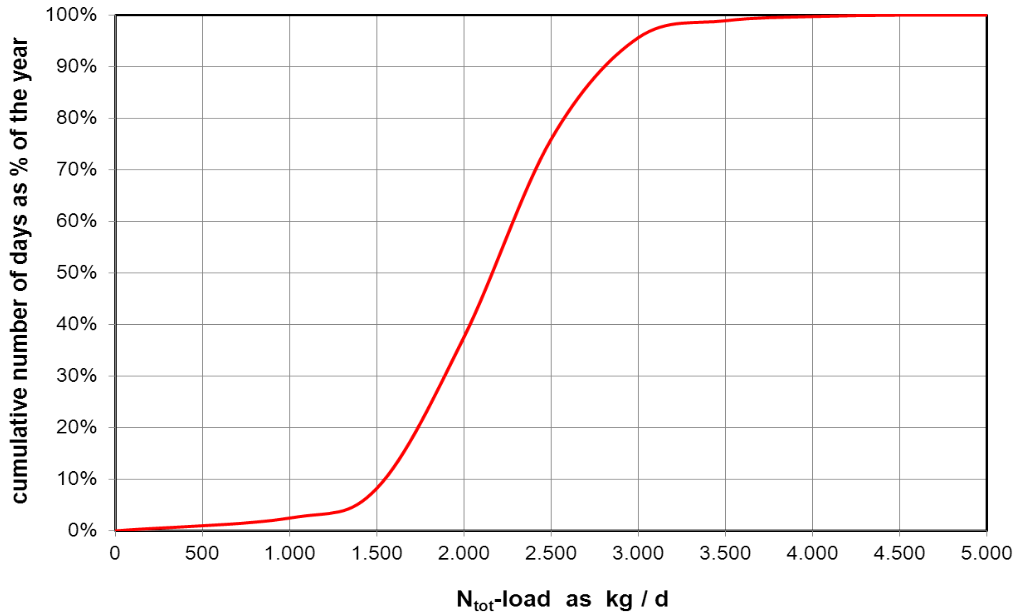


Figure 1: Sum curve of the N_{tot} load in kg N_{tot}/d

In this picture the cumulative numbers of days as percent of year is shown versus the total nitrogen load in the influent of a typical municipal wastewater treatment plant with a capacity of 450,000 PE, 5,000 kg N_{tot}/d respectively. 75% of the year the load of the plant is less than 2,500 kg/d, less than 50% of the maximum load respectively. Furthermore, 95% of the year the load of the plant is less than 3,000 kg/d, less than 60% of the maximum load respectively.

That means that only a small part of installed capacity of the aeration system is required in the majority of the operating time. At this time the remaining capacity could be renounced, if the aeration rate would be adapted to the current load of the wastewater treatment plant. Unfortunately a reasonable control of aeration system is often missing. Almost always, the installed aeration capacity is used on a large scale. The main reason for this is that an aeration control system depending on the current load in the influent is not existing. In most cases the staff of the plant is not able to adjust the aeration rate so that on the one hand the limiting values are never exceeded and on the other hand an unnecessary power consumption can be avoided.

The commonly used aeration control system in almost all wastewater treatment plants, is based on the measurement of the dissolved oxygen concentration. The idea behind this control mechanism is the fact that for an aerobic substrate removal a certain oxygen amount, consumed by the aerobic removal process is needed. The goal is to enter enough oxygen to avoid the oxygen limitation. For this goal it is often assumed to be a concentration of round 2 mg/l. And if a dissolved oxygen concentration of 2 mg/l can be established then enough oxygen, consumed by the process, is already transferred.

But the aerobic removal process is not only one oxygen consumption source. There is also another certain oxygen consumption because of the endogenous respiration of the bacteria. The part of the oxygen consumption because of the endogenous respiration in low loaded wastewater treatment plants is in the same order of the oxygen consumption because of substrate removal. And the control system of the aeration can not decide, how much oxygen is needed only for the substrate removal, so that the aeration system works on a high level, to deliver the oxygen amount, only needed by the endogenous respiration.

Furthermore there are some other reasons, why the control of the aeration system based on the measurement of dissolved oxygen concentration is not the best solution:

a) The measurement of dissolved oxygen concentration is problematic in most cases. Because, the measurement is based on the diffusion of oxygen molecules through the membrane of the electrode. But in activated sludge basin, a biofilm on the surface of the membrane increases quickly. And this biofilm reduces the transportation rate of oxygen to the detector, so that the electrode shows a lower concentration than needed. And the operator turns the blower higher, to keep this limiting oxygen concentration of 2 mg/l without any need.
b) Moreover the dissolved oxygen concentration of 2 mg/l, to avoid the oxygen limitation, is still disputed. It is a fact, that at this concentration the substrate removal occurs without oxygen limitation. But the question is, if the oxygen limitation is also avoided at a lower oxygen concentration, for example at a oxygen concentration of 1,5 mg/l or 1,0 mg/l. Our own investigations suggest, that an oxygen concentration of 1,5 mg/l is enough in many cases. Even an oxygen concentration of 1,0 mg/l is enough in some other cases. Therefore, to choose the correct oxygen concentration is not easy. If you take an oxygen concentration of 1,0 mg/l, the process occurs maybe with oxygen limitation. And if you take an oxygen concentration of 2,0 mg/l your power consumption is unnecessarily too high.

Therefore we developed a new control system of the aeration based on the ammonium concentration as the main control parameter. With this control system the plant staff is able to adjust the aeration rate to incoming load without exceeding the limiting values in the effluent and without an unnecessary power consumption.

2. THE NEW CONTROL SYSTEM OF THE AERATİON

2.1. The Wastewater Treatment Plant with the new aeration control system

This concept is developed for a multi stage cascade basin of a Wastewater Treatment Plant in Northern Germany with a capacity of 450.000 PE. But it is also applicable without any problems to other reactor system as plug flow reactors and CSTR (Continuous Stirred Tank Reactor) as well. The next picture shows the multi stage cascade basin of this Wastewater Treatment Plant as a scheme.

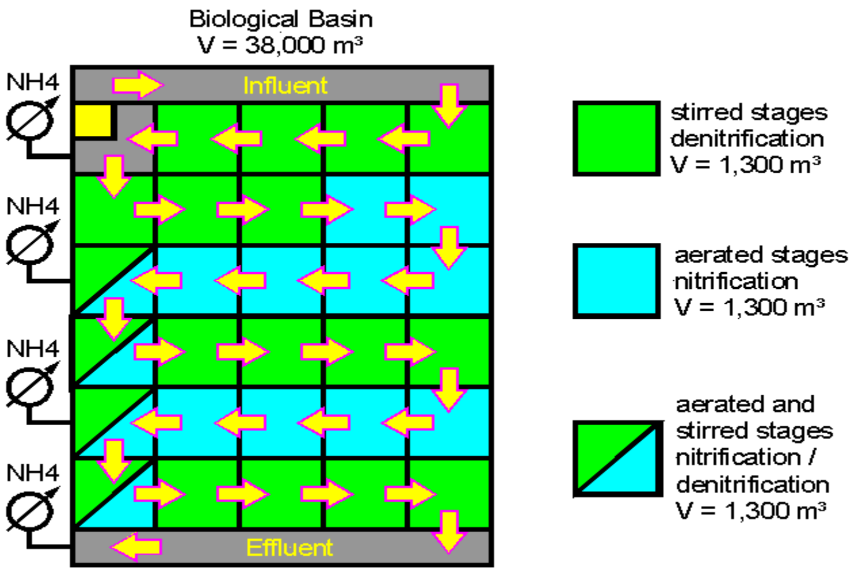


Figure 2: Biological basin as a multi stage cascade with the new aeration control system

The biological basin of this plant consists of 29 cascade stages. The volume of each stage is 1,300 m³, so that the whole volume of the biological basin is round 38,000 m³.

The water flows from one stage to the other. Each stage of the cascade can be considered as a CSTR. From 29 stages 10 stages are pure nitrification basin and equipped with surface aerators for oxygen transfer. The other 15 stages are pure denitrification basins and are equipped only with stirrers. For better denitrification the anoxic stages are placed between the aerobic stages. The other 4 stages are equipped with aerators and stirrers, so that these stages can be used as nitrification or denitrification basin according to the demand of more nitrification process or denitrification process.

2.2. Fundamentals of the dynamic process simulation

The new control system of the aeration that is used here is a dynamic process simulation, based on the calculation the required oxygen transfer rate for the ammonium degradation in each cascade stage. In short intervals the ammonium load is calculated based on the flow rate and the ammonium concentration in influent of the biological basin. These ammonium load decreases due to the biodegradation of cascade stage to cascade stage, and for this ammonium removal a certain oxygen transfer is required. In each time intervals the aerators are adjusted to the oxygen transfer rate, required in this current time interval.

The calculation of ammonium removal in each stage is based on the balance equation consisting of the transfer terms, namely load in and load out, and of the transformation term, that means biochemical ammonium removal term.

$$0 = \left(c_{N,1} - c_{N,2}\right) \dot{V} - \frac{\mu_{max}}{Y_N} \frac{c_{N,2}}{K_N + c_{N,2}} c_B \; V$$

$c_{N,1}$: *Ammonium concentration in the influent*

$c_{N,2}$: *Ammonium concentration in the effluent*

$\dot{V}$: *Flow rate*

V : *Stage volume*

c_B : *concentration of the nitrificants in the stage*

μ_{max} : *specific growth rate of the nitrificants*

Y_N : *Yield constant of the nitrificants*

K_N : *Monod constant of the ammonium removal reaction*

Because of the steady state conditions in the cascade stages the accumulation term is zero. The solution equation for the effluent ammonium concentration out of each stage is calculated with these process and kinetic parameters is shown below:

$$c_{N,2} = \frac{c_{N,1} - K_N - \frac{\mu_{max}}{Y_N}\, t_R\, c_B}{2} \pm \sqrt{\left(\frac{c_{N,1} - K_N - \frac{\mu_{max}}{Y_N}\, t_R\, c_B}{2}\right)^2 + K_N\, c_{N,1}}$$

$$t_R = \frac{V\,(stage\ volume)}{\dot{V}\,(flow\ rate)}$$

t_R : *Retention time in the stage*

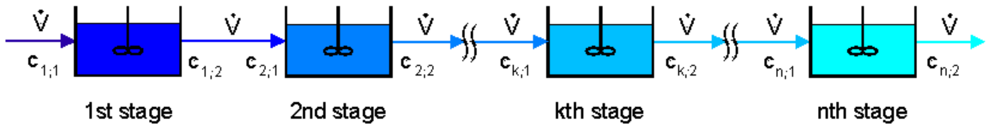
The kinetic parameters of the ammonium degradation process, used in this calculation are listed in the table below:

Table 1: Kinetic parameters used in the calculation

parameter	value	unit
μ_{max}	6.5	1 / d
K_N	0.6	mg NH_4-N / l
Y_N	0.15	g nitrificants / g NH_4-N
c_B	90	mg nitrificants / l

The kinetic parameters used in the calculation are usual values, often cited in the literature. We could confirm these kinetic parameters based on our own investigations. Only the maximum specific growth rate is with a value of 6,5 1/d lower than the literature values of about 9 1/d. But the μ_{max} used in the calculation for the effluent ammonium concentration is backed by several of our own measurements. Perhaps the wastewater of this treatment plant due to the additional industrial part of a fishing industry is a little bit different. The Monod Constant K_N for ammonium degradation with a value of 0,6 mg NH4-N/l as also given in the literature is very low. But because of the low ammonium concentration in the effluent of the nitrification basin and in the nitrification basin as well (because of CSTR conditions) this low Monod Constant may not be neglected. Also the Yield Constant Y_N with a value of 0,15 gram nitrificants per gram ammonium and the concentration of the nitrificants c_B with a value of 90 mg/l are in the same order as the literature values.

First the effluent ammonium concentration out of the first stage is calculated with the measured ammonium concentration and flow rate in the influent of the biological basin. And the calculated effluent ammonium concentration of the first stage is the influent ammonium concentration into the second stage.



But both these parameters are a function of time. Therefore this temporal delay must be taken into consideration. Because of the incompressibility of water the variation of the flow rate in the influent of the basin is present in each stage immediately. But that does not apply to ammonium concentrations! The calculated effluent ammonium concentration of the first stage is the influent ammonium concentration into the second stage. But the influent concentration in the second stage arrives at the second stage only after the retention time of the first stage. Due to the certain retention time in the first stage the new concentration needs exactly the same time to arrive at the second stage. And now with this influent ammonium concentration as a time function the effluent ammonium concentration of the second stage can be easily calculated. And this calculation is carried out for each stage, so that in each stage the ammonium concentration in the effluent is known.

Now you are able to calculate the ammonium mass degraded in the first stage with the ammonium concentrations in the influent and effluent of the first stage and with the flow rate. Namely, the ammonium mass degraded is equal to the product of the difference between the both concentrations and the flow rate. For this ammonium mass the oxygen amount needed for the aerobic removal process can be calculated. Because the ratio between ammonium mass and oxygen amount is constant. Now the aerators or blowers of the first stage can be adjust according to the oxygen amount needed there.

And this calculation is carried out for each single stage, so that in each stage the ammonium removal rate and thus the oxygen transfer rate needed for this current removal in this interval is known. The aerators can be adjusted to this required oxygen transfer rate anytime and the ammonium removal process occurs outside the oxygen limitation and without any unnecessary oxygen consumption.

2.3. Application the Dynamic Process Simulation

This dynamic process simulation has been carried out in this wastewater treatment plant very successfully for many years.

The goal of controlling the aerators using the dynamic process simulation is to keep a concentration of 5 mg/l in the effluent of the biological basin anytime. For a usual ammonium load only six or seven aerobic stages of all in all fourteen aerobic stages are enough. And if for example the ammonium load is increasing, the running aerators are turned higher, to transfer the higher amount of oxygen needed by the new situation. If the oxygen transfer rate is still not enough in this case some additional stages must be taken into operation. After a while the ammonium load is decreasing, now some stages are taken out of operation. The goal of the calculation and thus the goal of taking stages in operation or out of operation is always to keep an ammonium concentration of 5 mg/l in the effluent of the biological basin. And the ammonium concentrations are always monitored by the online ammonium measuring instruments.

3. THE RESULTS OF THE DYNAMIC PROCESS SIMULATION

This project was escorted by us in the first four years. The results in this time are shown in the table 2.

Table 2: Results for Power Saving in the first 4 years

	power consumption before project start	current power consumption	power saving	
1. project year	9,5 Mio. kWh	7,6 Mio. kWh	1,9 Mio. kWh	20,0%
2. project year	9,5 Mio. kWh	6,3 Mio. kWh	3,2 Mio. kWh	33,7%
3. project year	9,5 Mio. kWh	6,2 Mio. kWh	3,3 Mio. kWh	34,7%
4. project year	9,5 Mio. kWh	6,7 Mio. kWh	2,8 Mio. kWh	29,5%
Sum	**38,0 Mio. kWh**	**26,8 Mio. kWh**	**11,2 Mio. kWh**	**29,5%**

The power consumption of biological basin before project start was as an average value of the last three years round 9,5 million kWh. Using this dynamic process simulation the power consumption in the first project year was 7.6 million kWh. That means a power saving of 1,9 million kWh, 20% respectively. Already in the second project year the power consumption decreased to 6,3 million kWh. In this case the power saving was 3,2 million kWh, 33,7% respectively. In the next years similar values were achieved, so that the whole power saving in the four years using our concept of dynamic process simulation was more than 11 million kWh. That means a power saving of round 30% .

Beyond this power saving a more biogas production in the digesters was found out, as shown in the next picture.

Table 3: Results for Additional Power Production in the first 4 years

	power production before project start	current power production	additional power production	
1. project year	6,0 Mio. kWh	6,3 Mio. kWh	0,3 Mio. kWh	5,0%
2. project year	6,0 Mio. kWh	7,2 Mio. kWh	1,2 Mio. kWh	19,8%
3. project year	6,0 Mio. kWh	6,9 Mio. kWh	0,9 Mio. kWh	14,9%
4. project year	6,0 Mio. kWh	6,4 Mio. kWh	0,4 Mio. kWh	6,6%
Sum	**24,0 Mio. kWh**	**26,8 Mio. kWh**	**2,8 Mio. kWh**	**11,7%**

The electrical power production from biogas produced in digesters before project start was as an average value for the last three years about 6,0 million kWh. Using this dynamic process simulation the electrical power production in the first project year was 6,3 million kWh. That means an additional power production of 0,3 million kWh, 5% respectively. Already in the second project year the electrical power production increased to 7,2 million kWh. In this case the additional power production was 1,2 million kWh, round 20% respectively. In the next years similar values were achieved, so that the whole additional power production in the four years using our concept of dynamic process simulation was 2,8 million kWh. That means an additional power production of round 12%.

The next picture shows the addition of both tables:

Table 4: Results for Total Power Yield in the first 4 years

	power saving		**additional power production**		**total power yield**	
1. project year	1,9 Mio. kWh	20,0%	0,3 Mio. kWh	3,2%	2,2 Mio. kWh	23,2%
2. project year	3,2 Mio. kWh	33,7%	1,2 Mio. kWh	12,6%	4,4 Mio. kWh	46,3%
3. project year	3,3 Mio. kWh	34,7%	0,9 Mio. kWh	9,5%	4,2 Mio. kWh	44,2%
4. project year	2,8 Mio. kWh	29,8%	0,4 Mio. kWh	3,7%	3,2 Mio. kWh	33,5%
Sum	**11,2 Mio. kWh**	**29,6%**	**2,8 Mio. kWh**	**7,2%**	**14,0 Mio. kWh**	**36,8%**

The total power yield as the sum of power savings and additional power production in the four years using our concept of dynamic process simulation was 14 million kWh. That means a total power yield of round 37%. In the middle two years the total power yield was even round 45%. That means a total power yield more than 4 million kWh per year. A power saving of this level is also quite possible in other treatment plants, if this dynamic process simulation is applied there. Another advantage of this concept is that these cost savings are achieved without any investment for building or equipment.

Gathering Methods, Quantification and Management of the Waste Materials in a Construction Site: A Case Study in Istanbul

Gamze Tatlici
Istanbul Technical University, gamzetatlici@hotmail.com

Begum Sertyesilisik
Istanbul Technical University, begum_sertyesilisik@hotmail.com

Abstract

This paper presents an investigation on the application of gathering methods, quantification and management of the waste materials in a construction site of a residential project in Istanbul. Increasing awareness of environmental impacts of construction wastes has led to the development of waste management as an important function of construction project management. Various theories and approaches for managing construction wastes have been developed in the literature and practices. Based on the literature review and case study, this paper provides a framework for construction waste management from the view of fields, methods and measures in existing researches, and then it indicates several directions for further study.

Key Words: *Construction waste, waste management, waste classification, site waste materials.*

1. INTRODUCTION

Construction waste is one of the common problems in construction sites. In Istanbul, municipality started to promote the firms to collect their wastes and settle landfill areas to transport them. Construction sector in Turkey especially in Istanbul can be regarded as the main engine of the economic activities. In the last decades, the role of construction sector in the Turkish economy has been increased especially due to the migration, new housing and infrastructure investments. In Istanbul, after May 2002, excavation, construction and demolition debris are disposed to an area having 10 million m^3 capacities in Kemerburgaz. By April 2005, 10% of this area was used. Daily generated waste amount was 2200 tons and constituted of 70% of excavation waste and 30% of construction and demolition debris in that year. Today, 6000 trucks transport a huge amount of excavation debris, which is almost equal to a small mountain, through 15000 journeys per day. The purpose of this study is to present a case study on on the application of gathering methods, quantification and management of the waste materials in a construction site of a residential project in Istanbul.

2. CONSTRUCTION WASTE METHODOLOGIES

2.1 Construction Wastes Classification by Source and Type

In order to quantify adequately the construction waste, it is useful to have a classification of wastes by their source and type. There are multiple sources of waste generation on a construction site. Waste is usually defined as the difference between the ordered materials and the actually applied ones in a construction site. Construction waste thus comprises of waste caused by breakage in transportation from the retailer to the construction site, by the handling of material and storage on the site, by the handling up to the application point, and last but not least, the waste generated during the actual application or usage. The overall quality of the site management, equipment used and manpower are among the determining factors in waste generation. Hence, wastes generated on the construction site can be classified in the following three classes according to their origin:

• Building waste, generated during the construction process due to defects, damages, breakage or simply due to excess.
• Packaging waste, generated from packaging of materials and products delivered to construction site.
• Wastes produced by workers, similar to municipal waste such as paper, glass, cans, etc.

According to EPA's classification, the main types of waste emerging from construction activities are as follows: masonry and CMU; all untreated wood, including lumber and finish materials; wood sheet materials; wood trim; metals; roofing; insulation; carpet and pad; gypsum board; unused paint; piping; electrical conduit; packaging (paper, cardboard, boxes, plastic sheet and film, polystyrene packaging, wood crates, plastic pails); as well as beverage and packaged food containers.

2.2 Gathering Waste Method

Quantification of wastes by their types is essential for the management and organization of a construction site. The quantification of wastes is the fundamental task of the site manager. This task has to take place before the actual construction activities begin, and it must continue during the construction phase. Prior to the start of actual construction activities, it is essential to carry out a thorough analysis of the project, construction processes and materials that will be used. Waste materials can be collected in 3 main methods, namely: gathering wastes by their material type (wood, metal, gypsum board, etc.); gathering wastes according to work item or subcontractors; and gathering wastes according to recyclable or non-recyclable materials. Waste can be gathered by providing separate bins for all recyclables, and by trainning all site personnel to use these bins as well as by out-sourcing from the recycling companies so that waste is separated and recycled. While storing the waste, it is important that the waste is separated properly. This can be facilated with the help of labelling the bins or allocating different colours to the bins with respect to the material type to be stored (i.e. red for the bricks; blue for the steel). Assigning a site waste manager can enhance the quality of the waste gathering process. The site waste manager needs to be able to recognize and handle recyclables correctly. Furthermore, he needs to instruct the workers and subcontractors on site to do so.

2.3 Waste Management Approaches

There are two main approaches suggested for waste management, namely the Global index and the Component index. Global Index Approach is based on the global data from similar construction types that provide the amount of waste per square meter of construction. The global data is gathered from previous construction works and registered on data files that are used as a global index for a given construction. It is noted that this index can be used also for quantification of waste from a region or even from the whole country. Component Index Approach, on the other hand, provides the amount of waste generated from each construction component that composes the project. It is noted that both of these methods are acceptable and their applicability depends on the accuracy of the data available rather than the method itself.

2.4 Waste Assessment Calculations

According to Winkler (2010), assessment of new construction waste is, in some ways, more difficult than assessment of the quantity of demolition waste. This is mainly due to the difficulty encountered in the assessment of the amount of packaging for products entering the jobsite as well as due to difficulty in determining the expected amount of waste that will result from new construction operations. Skilled subcontractors usually estimate fairly closely the amount of material they will need for new construction. The U.S Environmental Protection Agency (EPA) collected construction and demolition waste data for a 2003 study examining volumes of waste generated from new construction. They found that the amount of waste generated varied widely with respect to the region of the country, size and type of the project as well as type of construction. For residential construction, the EPA collected data and provided average values for waste.

3. CASE STUDY IN ISTANBUL

The case project located in Bakirkoy region in Istanbul. It is a middle scale residence project consisting of 3 blocks, each having 107 flats. The gross area of the construction is 72000m^2. The structure of the buildings is reinforced concrete. Four different types of survey techniques have been used to gather data. These are: direct observations; interviews (face-to-face); mail surveys; and telephone surveys. The data have been collected from the construction site day by day via telephone surveys and interviews. The data have been gathered with respect to the amount of waste by material type, the way and time period waste is generated. There are approximately 30 different construction components in the construction project which is taken as a case study. The construction components have been detailed in terms of materials used and the type of waste generated in their production. In the case study, the waste generated in the four mostly used material types (metal, wood, concrete and masonry) have been investigated. The Component Index approach has been used for calculations.

The amount of the waste generated and its classification based on their type have been provided in Table 1. The site manager revealed that in the excavation process 150000 m^3 sand (10000 trucks) have been transferred to the landfill areas. In total, 534 kg of metal, 123 kg of wood, 347 kg of concrete and 244 kg of masonry waste has been generated. 1248 kg waste has been deposited in one month. The main factors that caused waste have been observed to be the lack of professionalism and failures in the execution. On the other hand, it results in loss of money.

Table 1. Construction waste management - montly project progress

Nr.	Date	Total Kg	Metal	Wood	Concrete	Masonry(Brick)	Total Diverted Kg	% (Recyled/Diverted)
November-December Totals								
1	20 Nov.	30	30				30	100%
2	21 Nov.	12		12			12	100%
3	23 Nov.	10	10				10	100%
4	24 Nov.	23				23	0	0%
5	25 Nov.	25		7	18		7	28%
6	26 Nov.	44	44				44	100%
7	27 Nov.	14				14	0	0%
8	28 Nov.	138	113	25			138	100%
9	1 Dec.	65		9		56	9	14%
10	2 Dec.	64			64		0	0%
11	3 Dec.	62	30		32		30	48%
12	4 Dec.	12		12			12	100%
13	5 Dec.	20	20				20	100%
14	8 Dec.	17				17	0	0%
15	9 Dec.	29		6	23		6	21%
16	10 Dec.	48	48				48	100%
17	11 Dec.	26				26	0	0%
18	12 Dec.	49	49				49	100%
19	15 Dec.	28		28			28	100%
20	16 Dec.	132			82	50	0	0%
21	17 Dec.	156	156				156	100%
22	18 Dec.	82		24		58	24	29%
23	19 Dec.	162	34		128		34	21%

Total Loss of Money:
Wastes can cause an economical loss for the project and the employer. The average unit prices in sector have been used to calculate the average loss of money for the mostly wasted four material types. The calculations are as follows:

i. Metal
Unit price: 2770TL/ton
Total loss payment of metal = 2770 x 0,534 = 1480TL

ii. Wood
Unit price: 250TL
Total loss payment of metal = 250 x 12,3 = 3075TL

iii. Concrete
Unit price: 102TL/m^3
Total loss payment of metal = 102 x 347 = 35394TL

iv. Masonry
Unit price: 16TL/m^2
Total loss payment of metal = 16 x 244 = 3904TL

The project had lossed an average of 43853 TL for wastes within the month investigated.

Based on the American waste standards, the expected total amount of waste (for residential new construction) has been calculated as follows:

- Project Land Area: 20000 m²
- Project Total (Gross) Construction Close Area: 72000 m²
- Total New Construction Waste (NCW)= The gross building area x 2.0 = Total New Construction Waste in kilograms= 72000 x 2.0 = 144000kg (144 tones)
- Total New Construction Waste Weight
  - Dimensional lumber and wood products: 144000 x 42% = 60480kg
  - Masonry/tile: 144000 x 11% = 15840kg

- Metal: 144000 x 2% = 2880kg

These calculations can be used for estimating the estimated average waste amount according to the material type and for analyzing the container type which will be needed on the construction site. As a result of these calculations, it is expected that the whole construction process of the case study will have 144 tons of waste. Wood works will have 60480kg of waste, masonry works will have 15840kg of waste and metal will have 2880kg of waste by the end of the construction.

The collected waste within one month and the expected total waste by the end of the construction can be seen in Table 2. The amount of wasted wood and masonry materials are in the tendency of not exceeding the expected total waste for these material types whereas the amount of wasted metal is in the tendency of exceeding the expected total waste by the end of the construction. If there was a site waste manager on site, the manager could take necessary precautions accordingly.

Table 2. Comparison of the collected waste and total expected waste

	Collected Waste (one month)	Expected Total Waste by the end of the construction
Wood Products	123 kg	60480 kg
Masonry	244 kg	15840 kg
Metal	534 kg	2880 kg

4. RESULTS AND CONCLUSION

This research emphasized the importance of the quantification of waste generation by their types for effective management of waste in the construction. Quantification of wastes supports planning of the construction site, sustainable site management as well as environmental and economic gains. Quantification of waste provides the necessary information not only on the amount but also on the type of actual as well as expected waste generations. The site managers are recommended to keep record of the amount and types waste generated on sites so that the data can be used in similar projects for benchmarking and for improving efficiency as well as sustainability performance of the construction site.

5. REFERENCES

Alarcon L., (1997). *Lean Construction*, A.A. Balkema, pp.78.

Altındağ S., (2011) İstanbul'da Hafriyat Toprağı, İnşaat ve Yıkıntı Atıklarının Tersine Lojistik Yöntemiyle Alternatif Yönetim Planı. Master of Science. Istanbul Technical University, Graduate School of Natural and Applied Sciences.

Arslan H., Coşgun N., Salgın B. (2012) Construction and Demolition Waste Management in Turkey, Chapter 1, available http://www.intechopen.com/books/waste-management-an-integrated-vision/construction and-demolition-waste-management-in-turkey., accessed on october 2014

Coşgun N., Güler T., Doğan B., (2009) The role of designer in reducing/preventing the construction waste. Chamber of Architects Publications. Volume 348: 75-78.

EcoSys, website, www.ecosys.net/solutions/project-cost-management., accessed on october 2014

EPA, (2007) Construction Waste Management, Section: 01 74 19.

Grigoli, A.S. (2000). Management in the Production and Utilization Of The Waste Material In The Construction Site, CIB Symposium on Construction and Environment, Sao Paolo, Brazil.

İSTAÇ A.Ş., www.istac.com.tr., accessed on october 2014.

Istanbul Metropolitan Municipality, (2012), Excavation soil, construction and demolition waste data, Istanbul.

Jalali, S. (2006). Quantification of Construction Waste Amount.

Kanat, G. 2010 '*Municipal solid-waste management in İstanbul'*, Waste Management, 30 (2010) 1737-1745.

McGrath C (2001), *Waste Minimisation in Practice. Resources, Conservation and Recycling* 32 (2001): 227–238.

Türkiye İnşaat Malzemeleri Sektör Görünüm Raporu (2011) Türkiye Odalar ve Borsalar Birliği. (In English: Report of Turkey Construction Material Sector Outlook, The Union of Chambers and Commodity Exchanges of Turkey) Available:

TOBB.,http://www.tobb.org.tr/Documents/yayinlar/Türkiye%20İnşaat%20Malzemeleri%20Sektör%20Görünüm%20Raporu.pdf., accessed on november 2014

Netregs, http://www.netregs.org.uk/pdf/SWMP_simple_guide.pdf , accessed on october 2014

UKSS, http://www.ukswedensustainability.org/downloads/SWMP_Final.pdf , accessed on october 2014

TUIK., http://tuikapp.tuik.gov.tr/Bolgesel/kentArastirmasiSorgula.do#., accessed on November 2014

Intes, http://www.intes.org.tr/content/MArt-2014.pdf ., accessed on october 2014

SMGOV Website accessed on october 2014

Winkler G. (2010) *Recycling Construction and Demolition Waste: a Leed Based Toolkit*. New York : McGraw-Hill Professional, pp.39-46.

TUIK, http://www.tuik.gov.tr/PreHaberBultenleri.do?id=16085., accessed on december 2014

Intechopen, http://www.intechopen.com/source/html/40493/media/image5.jpeg., accessed on october 2014.

Industrial Growth and Political Economy of Water Resources

Egemen Sertyesilisik
email: egemens@alumni.bilkent.edu.tr

Abstract

Political economy deals mainly with privatization to enhance effective and efficient use of resources. As water resources are vital for the life in the world, they need to be efficiently utilized (e.g. reducing the waste of water resources, and enabling everyone to have access to water) and protected. This is needed for the sustainability and regeneration of the world's resources. This paper focuses upon the ways of increasing efficiency and effectiveness in the usage of the water resources. Furthermore, this paper emphasizes that industrial growth depends on the availability of water and on the polical economy of water.

Key Words: *Political economy, natural resources, water, industrial growth*

1. INTRODUCTION

Increase in population as well as in welfare of people increase the demad of water (Yerebakan, 1999; Ayar, 2007). Economic growth in a country enhances living conditions of that country and increases water consumption level as there is direct proportion between economic welfare and water consumption (BFNC 2009). In addition to an increase in water demand, human beings also loosing their fresh water resources due to environmental pollution. Water resources are politicaly and economicaly important as the amount of water in our world is limited and as it is impossible to produce water (Yerebakan, 1999; Ayar, 2007). Water is a renewable resource if we consume less water than its renewability rate. This means that we can keep our water resources safe. *"Although water is a renewable resource, the rate of water use and demand growth is increasingly threatening to outpace the rate of water renewal. Ground water stores and river basins can become depleted and polluted through intensive use, urbanisation and mismanagement."* (Fidelity, 2014). According to the UN, humans need 20-50 liters of freshwater per capita per day, so that they can fulfill their basic needs for nutrition and hygiene (BFCN, 2009). Depleting water resources means depleting life in our world. We need to use our water resources efficiently.

2. WATER'S ROLE IN PRODUCTION

We can't imagine manufacturing without water as water is consummed during production process of the products (i.e. in order to produce a single sheet of paper 3 gallons of water is needed; for one pair of shoes 2,257 gallons, one chocolate bar 454 gallons, one piece of beef 4,000 gallons of water, one slice of cheese 40 gallons, one apple 22 gallons, for one cup of coffee 35 gallons of water is needed to produce) (Garber, 2012). Taking these informations into consideration if we do not protect the water resources in our planet, we will not be able to continue our lives. Everything that we eat and everthing that we wear need water resources for their production. Water resources are not just needed to produce goods or food. They are also needed for production of energy (Jones 2008). Companies need water for two main reasons: first they need energy to continue running their facility and second they need water to produce goods.

Politicians need to consider the political economy of water and the GDP composition in their country while allocating the resources of their country. GDP composition with respect to agricultural, industrial and service sectors differenciates according to the income level of countries as in low income countries agriculture conributes to 25% of the GDP, industrial sector contributes to 38% and services sector contributes to 35% of the GDP, whereas in the middle income countries agriculture contributes to 11% of the GDP, industrial sector contributes to 35% and services sector contributes to 52% of the GDP (Soubbotina and Sheram, 2000). In the high income countries, on the other hand, agricultural sector contributes to 2%, industrial sector contributes to 32% and services sector contributes to 66% of the GDP (Soubbotina and Sheram, 2000). As in high income countries, water consumption in agricultural sector does not play an important role in the GDP composition, in case of water scarcity in a high income country, the politicians can reallocate water resources among the sectors accordingly.

The allocation of water resources among sectors must be taken into consideration, while politicians are reallocating water among sectors. For example, in our world agricultural sector consumes approcimataly 70% of the freshwater, whereas industrial sector consumes 22% of the freshwater and 8% of fresh water is consumed for domestic purposes (BFNC, 2009).

In the light of these explanations, if we imagine, for example, a middle income country having water scarcity where 11% of its GDP is made by agricultural sector which consumes 70% of fresh water, the politicians of that country needs to reallocate water consumption among the sectors and shift agricultural sector's water consumption to the industrial and services sectors. If they can achive such goal the country can have a higher income with less water consumption.

3. CONCLUSION

In our planet there is limited level of fresh water resources. We need water resources to continue our lives. The clothes we wear, the notebooks we write, the food we eat all needs water during production processes. Even water is needed to produce energy. Water has renewablity capacity. If we consume or pollute our water resoruces beyond this capacity than we won't have enough water in future. This can both give harm to our environment and result in low production rate and in economic shrinkage in our world. The politicians can play role as change agents at this stage. They can play role in reallocating water resources among sectors in their country. Through this way, they can support protection of water resources by limiting the consumption of water below its renewable rate, at the same time they can provide economic growth.

References

Ayar, Z. (2007). “Su kaynaklarının ekonomi politiği (Türkiye örneği)”, Marmara University Master Thesis, Istanbul, 2007.

Barilla Center for Food & Nurition (BFCN) (2011). “Water Economy”, Italy, 2011.

http://www.barillacfn.com/wp-content/uploads/2012/07/watereconomy_bcfn2011.pdf (5 Ocak 2014).

Fidelity (Worldwide Investment) (2014). "Water: structural demand growth creates investing opportunities", January, 2014. http://www.fidelityilf.com/market_news/21Century/pdf/investing-in-water.pdf

Gaber, M. (2012). "It takes more than 3 gallons of water to make single sheet of paper…and more mind-boggling stats that hint at a Waterworld future", Theatlantic, 2012. http://www.theatlantic.com/technology/archive/2012/06/it-takes-more-than-3-gallons-of-water-to-make-a-single-sheet-of-paper/258838/

Jones, Willie D. (2008). "How much water does it take to make electricity? Natural gas requires the least water to produce energy, biofuels the most, according to a new study" IEEE Spectrum. http://spectrum.ieee.org/energy/environment/how-much-water-does-it-take-to-make-electricity

http://www.unido.org//fileadmin/user_media/Services/Research_and_Statistics/statistics/publication/QuartProd/STA_Report_on_Quarterly_production_2012Q4.pdf

Soubbotina, Tatyana.P., Sheram, Katherine.A. (2000). "Beyond Economic Growth, Meeting the Challanges of Global Development", USA, Washington: World Bank Press, 2000. http://www.worldbank.org/depweb/beyond/beyondco/beg_all.pdf (18 Ekim 2013).

Yerebakan, M. (1999). "Türkiye'de İçme Suyu Sektörü, Sorunları ve Çözüm Önerileri", İstanbul: İstanbul Ticaret OdasıYayınları.

Innovation in the Construction Industry and Sustainability

Christian Brockmann
University of Applied Sciences Bremen, christian.brockmann@hs-bremen.de

Abstract

Often the construction industry is criticized for a lack of innovation. The same industry designs and builds the largest projects of the world, megaprojects such as bridges, tunnels, dams, harbours, airports and industrial plants. This begs the question how the construction industry can contribute to welfare. There is a large amount of literature on innovation in construction but an economic perspective is seldom given. Therefore it seems necessary to describe the basic economic ideas on innovation and to develop a framework to understand economic sustainability

Key words: Construction innovation, economics, production function, technology, economic growth model.

1. PRODUCTION FUNCTION AND TECHNOLOGY

Many years ago, in 1798, Malthus published “An Essay on the Principle of Population”. Using the idea of diminishing returns in production of agricultural goods (Figure 1), he proved that with time equilibrium will prevail where the population of a country is sustained at the edge of starvation. In consequence, economics was dubbed as the “dismal science” (Figure 2).

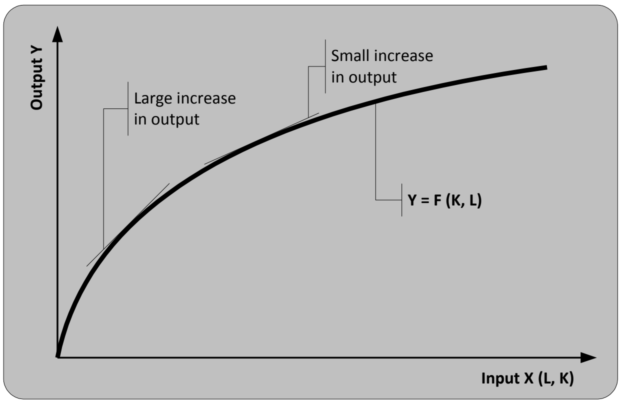


Figure 32: Law of diminishing returns

Malthus used a production function where the output (Y) is based on labour (L) and capital (K), Y = F (L, K).

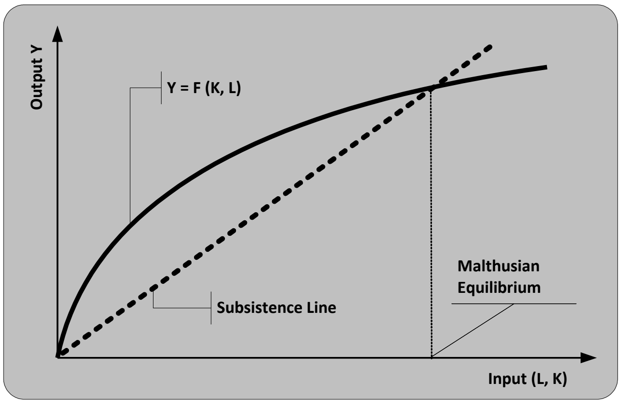


Figure 33: Dismal science

However, starvation is not the standard in many countries and this is due to a factor that Malthus did not consider: technology (T). Technology was then included in the production function, Y = F (L, K, T). Taylor (1995: 773) defines technology in economics "*… as anything that raises the amount of real GDP that can be produced with a given amount of labor and capital*." For technology advance (and survival) we rely on new knowledge brought into application, i.e. we rely on innovation. The construction industry as the largest sector in most countries must contribute to this end (Figure 3).

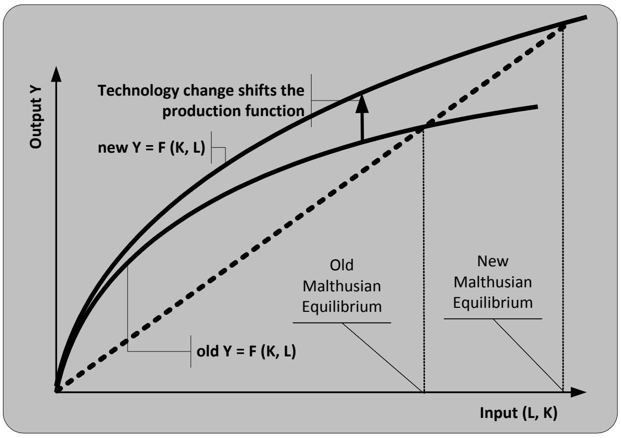


Figure 34: Technology advance

In a more confined sense than it is usual in economics, Tatum (1988: 344) describes construction technology "…*as the combination of resources, processes and conditions that produce a constructed product*." However, the goal of technology for the construction industry remains also in this context the same, i.e. to provide more output with a fixed input; this is called the economic maximum principle.

If we consider the case of two goods, e.g. constructed products and a bundle of all other goods we can find a definition of the technology space. It is the area which supports all possible combinations of goods that can be produced. Only on the production possibility frontier is production efficient, i.e. without any waste. All combinations below this frontier allow for a higher production with the same inputs. Thus, the production possibility frontier also defines cutting-edge technology (fig. 4).

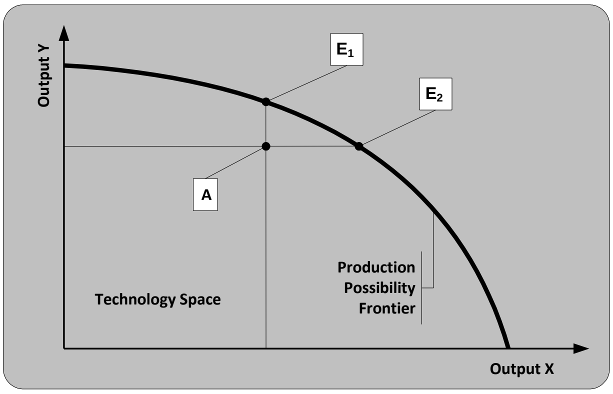


Figure 35: Technology space and production possibility frontier

Innovation is required to push the technology space outwards (Figure 5).

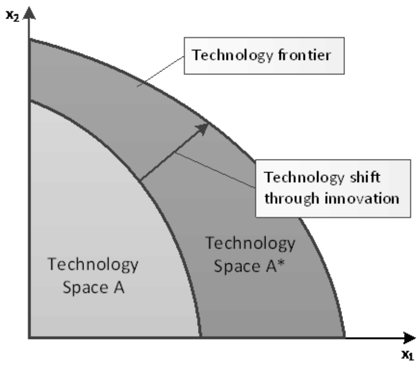


Figure 36: Technology shift through innovation

Trott (2005) provides a useful definition of innovation as the sum of theoretical conception plus technical invention plus commercial exploitation. The conception of new ideas is the first step, transforming the ideas into something tangible means to implement a technical innovation as second step and for the third and final step many people work hard to convert the invention into products that improve company performance. While Trott focuses in his definition on a process, Freeman and Soete (1997) look at the outcome when defining as innovation the actual use of a nontrivial change and improvement in a process, product, or system that is novel to the institution developing the change. For our purposes and summarizing the discussion, the following nominal definition will be applied:

Innovation in construction = (def.) Changes leading to an improved input/output relationship for products, processes or organizations that can be evaluated monetarily. These changes can have different levels of impact and they can be new to a company, the construction sector or the world.

Based on the work of Henderson and Clark (1990), Slaughter (1998) introduced five models of innovation: incremental, modular, architectural, system and radical innovations. The smallest impact is made by incremental changes which are inherent in all design and construction processes and can also stem from basic research. This could be a reduction in rebar weight relative to concrete volume (kg/m³) due to more appropriate computational assumptions. Modular changes exert a broader influence but are still confined in their impact. An improved formwork system to erect bridge columns may serve as an example. Architectural changes affect other parts of the structure, because of existing interrelations between components. Bridge bearings transfer forces from the superstructure to the columns. Any improvements in the design of the bearings will have effects on both the superstructure and the entire substructure (not only on the columns). System changes cause impacts to the overall system. All construction methods belong to this group. The design of the structure, its cost, quality and time of construction are affected. Radical changes occur seldom and change the overall approach to particular problems. The segmental bridge construction technique was such an innovation several decades ago.

2. A MODEL OF ECONOMIC GROWTH

Growth can be modelled as the interplay between supply and demand while assuming profit maximization on the base of a production function for the firms. Including considerations about natural and regenerative resources this production function is extended to $Y = f(K, N, R, Z)$. Here N is used to denominate labour because L will denominate leisure. The production will make use of the environment and pollute it.

Consumers maximize utility based on a utility function $U = f(C, L, E)$. The utility is modelled as consumption C of what firms produce, leisure time L and the environment E. Consumers make a decision on how much they are willing to work and therefore determine together with population growth how much of the resource labour is available. They also request a clean environment. The interdependencies are shown in Figure 6

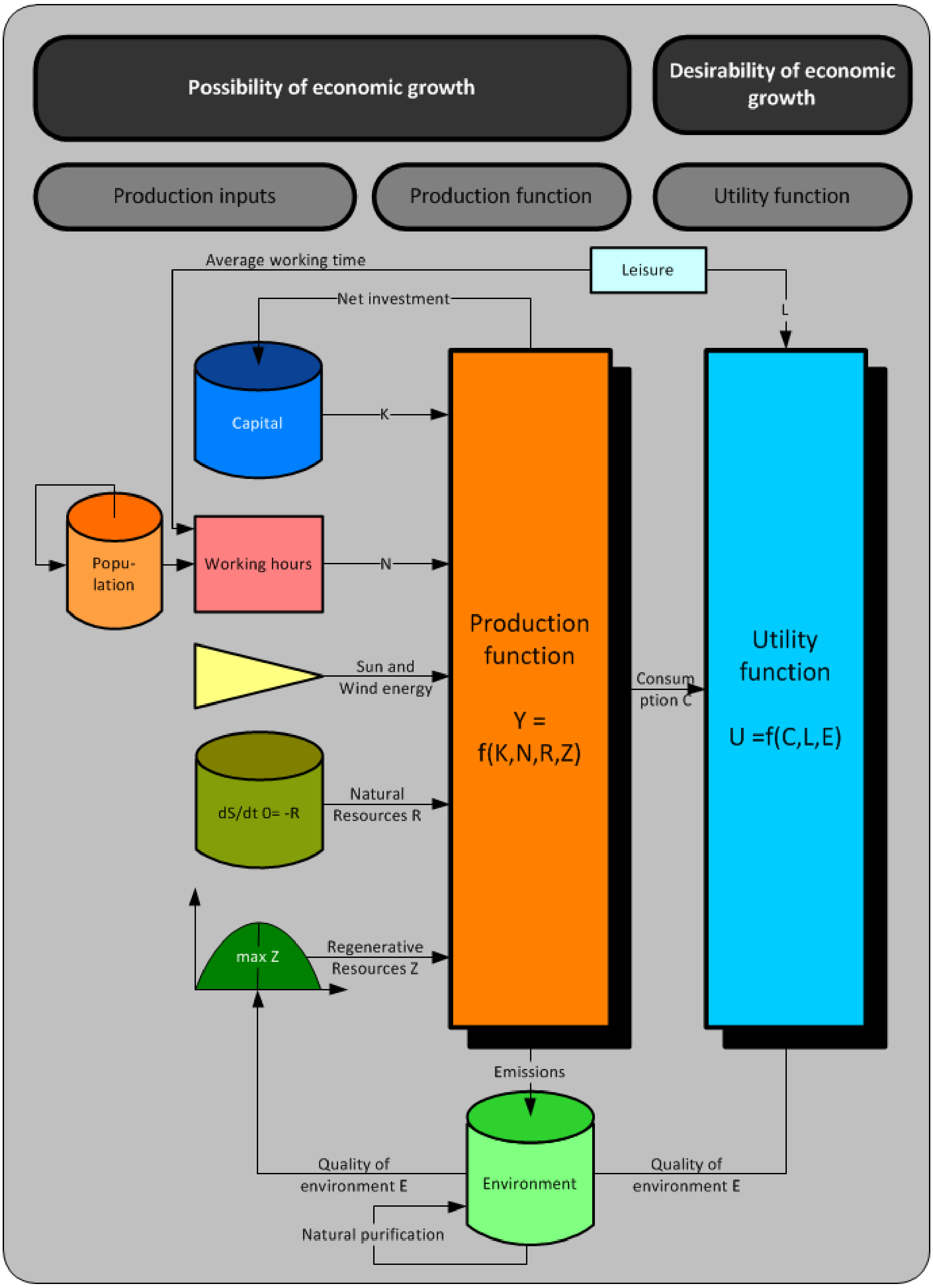


Figure 37: Sustainable economic growth model

3. REFERENCES

Freeman C, Soete L (1997) *The Economics of Industrial Innovation*, 3rd ed., London, Continuum.

Malthus T (1798) *An Essay on the Principle of Population*, London, Penguin, 1985.

Slaughter S (1998) "Models for Construction Innovation", *Journal of Construction Engineering and Management*, 124: 226-231.

Tatum C (1988) "Classification System for Construction Technology", *Journal of Construction Engineering and Management*, 114: 344-363.

Taylor J (1995) *Economics*, Boston, Houghton Mifflin.

Trott P (2005) *Innovation Management and New Product Development,* 3rd ed., Harlow, Pearson Education.

AgiLean Innovation Process – Innovating through Collaboration and Knowledge

Selim Tugra Demir
University of Applied Sciences Stuttgart, Selim.Tugra.Demir@gmail.com

Abstract

Construction is perceived as a conservative industry which is resistant to change. This characteristic causes the limited applicability of innovation management approaches. The industry prefers to have incremental innovations on the project level, i.e. small improvements. Radical innovations are more related to business management issues. To this point, however, there have been little propositions, which focus on implementing innovation management on the business management level. An organisational system which wants to manage innovations in construction businesses needs to consider this conservative character of the construction industry. The aim of this paper is to propose such an organisational system. The proposed system consists on the two components. Namely, on the one hand on an organic system, which is agile and a network-like structure. The agile system is composed only by volunteers. On the other hand it consists on the traditional mechanistic system that is rigid and on place already. The organic system runs in the background and does not disturb the mechanistic one, which is responsible for the daily work. Hence the volunteers of the organic system will excite other areas of the company, if they are successful with their innovations. This in turn will create a companywide movement. Hence the combination of an organic agile and a mechanistic lean organisational system, results in a new business organisation which is mechanistic “AgiLean”, i.e. agile and lean at the same time. The AgiLean organisational structure follows three principles, which are collaboration, innovation and the accumulation of knowledge. These three principles on place will result in a learning company.

Key Words: *Business Management, Innovation, Innovation Management, Organisation.*

1. INTRODUCTION

Meanwhile the construction industry is characterised by extreme competitiveness and low profit margins (Polat and Donmez, 2010). Each construction project is unique in its circumstances. This causes additional pressure as knowledge and experience cannot be directly transferred to other projects (Winch, 1989; Pender, 2001). The result is that the construction industry follows a different logic when compared with other industries. Construction has its own culture, which prefers to benefit out of experience rather than radical innovation. Hence Pries and Doree (2005) argue that the construction industry favour more incremental innovations rather than radical as the focus of the construction companies is to improve their own technology and related processes. Dulaimi et al. (2005) elaborate in turn that innovation, regardless of whether incremental or radical, is driven by problems in the construction project. Miozzo and Dewick (2002, p. 991) state that „[…] *innovation requires a sustained effort, the outcome of which is uncertain*“. Hence given that the project team has only one chance to manage a construction project successfully as it is a unique endeavour, the result is that project participants might not want to undertake uncertain actions. Therefore when compared with other industries, the circumstances which construction projects are exposed to, created an image which is best described through buzz words such as "conservative", "backward" and "low technology industry".

On the flipside of the same coin innovation or being innovative is a synonym for competitive advantage (Sexton and Barrett, 2003a; Dulaimi et al., 2005; Gambatese et al., 2011; Cernea et al., 2013). Sexton and Barett (2003b, p. 626) define successful innovation "[…] *as the effective generation and implementation of a new idea, which enhances overall organizational performance"*.

Hence practitioners of the construction industry perceive the need for being innovative (Gambatese et al., 2011). Cernea et al. (2013) argue that the innovation management strategy should be more related to business management and should be placed on the business organisation level. To this point, however, there are little innovation management strategies, which focus on construction companies. The aim of this study is to propose a conceptual approach for promoting and managing innovations systematically in huge construction companies[4]. To achieve this aim, the proposed approach is based on the two systems methodology of Kotter (2012). Hence, in the next two sections, the paper will conceptualise this approach to an innovation management context for construction companies. Finally conclusions will be drawn and areas for further investigation will be recommended[5].

2. THE ORGANISATIONAL STRUCTURE

Kotter (2012) made a distinction between two organisational systems. The first organisational system is the traditional group hierarchy, which is shown in the following diagram.

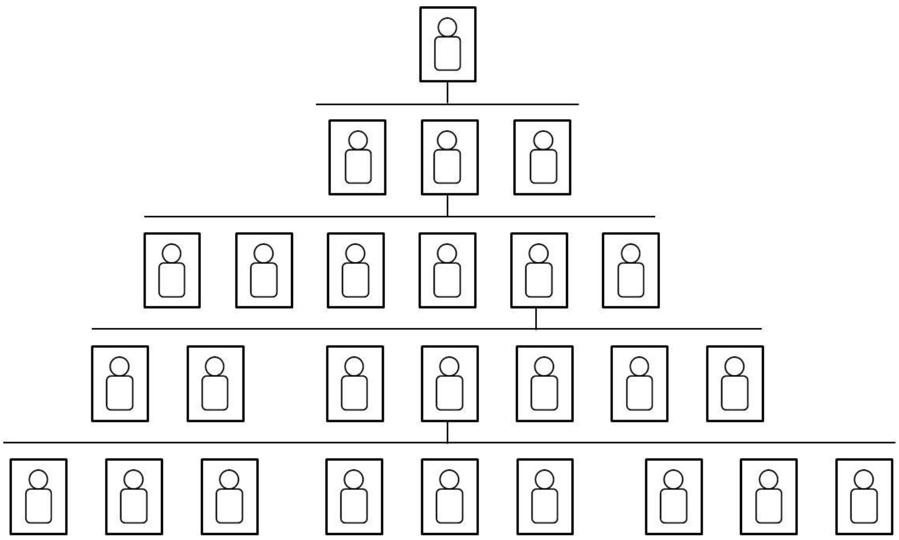


Figure 1. Traditional group hierarchy (adapted from Kotter (2012))

[4] Within the context of this paper are huge construction companies defined with more than 10 billion Euros turnover.

[5] The author wants to emphasise that the content of this paper is purely theoretical, i.e. the presented approach(es) within this paper are not related to any construction company.

The above shown hierarchical organisational structure suits quite well to manage the daily operative work. This organisational system, however, is also at the same time too conservative and rigid to be used for managing changes.

Same applies for managing innovations. Similar to quality management, innovation management is not a standalone activity. It needs to be lived from both, top-down and bottom-up directions. Hence implementing a culture, which makes out of ideas successful innovations, is also a change management process. Womack and Jones (2003) elaborate that for managing the change management it is useful to work with so called „light houses“. These light houses are small units where the implementation of the change (in this case innovation management approach) has been successful. These small units will create successul results. These results in turn will cause a group wide movement.

Innovation management requires also a cultural change. Hence it makes sense to start with a small group of volunteers. These volunteers support the overall process, create initiatives and find new supportive members. These volunteers will be the light houses, who will be used to excite other divisions of the group for managing innovations. This can be illustrated with the following figure.

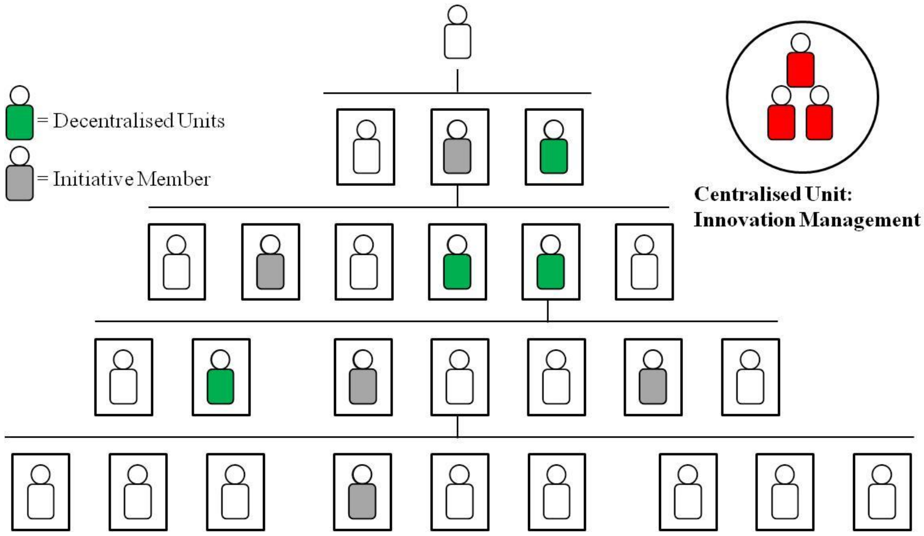


Figure 2. the lighthouses of the traditional organisation (based on Kotter(2012))

The above figure proposes a way of implementing innovations management in the group organisation. Hence a centralised staff unit can be implemented in the first instance. This centralised unit has a more administrative and managerial role. This centralised unit will then identify decentralised units. These decentralised units will initiate innovation projects that are relevant to their organisational unit. This consequently will result in new members, who want to participate into these projects.

3. BECOMING A SELF ORGANISED ORGANISM

Kotter (2012) argues that a second organisational system will be added to the existing organisational structure. It is important that this system shall not disturb the traditional group organisational system in its daily tasks. The second system needs to run in the background. The centralised unit needs to put decentralised units with similar interests together into groups. These groups will deal with certain technologies. Then initiatives can be caused, where people of their units will be integrated into teams for managing innovation projects. Through this process:

- the internal collaboration will be increased
- interfaces will be eliminated
- the core capabilities of the group will be strengthened

The secondary system is illustrated in the following figure.

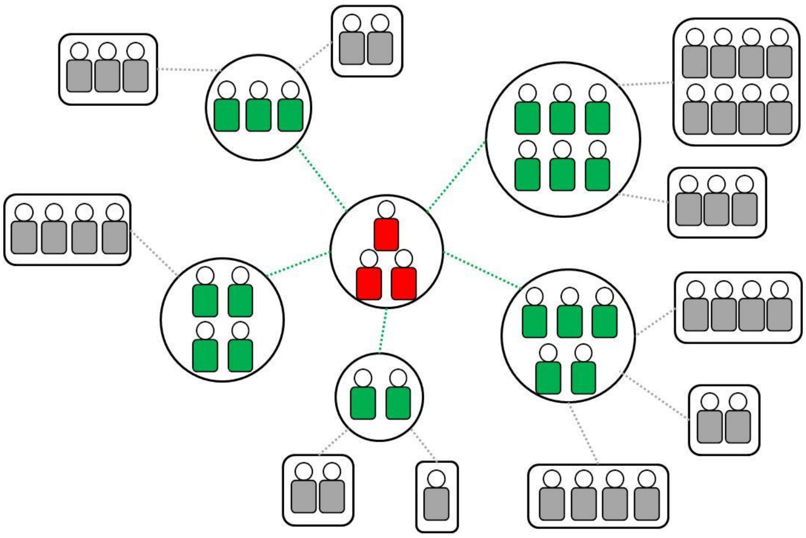


Figure 3. Secondary organisational system (adapted from Kotter (2012)

The above figure shows that the secondary organisational system has flexible network-like structures. Those are very agile. Once the groups are in place, the secondary organisational system becomes a self organised organism, which:

- grows continuously
- has its own processes and mechanisms
- and which works with volunteers from the whole group.

The centralised unit will just report the results.

4. CONCLUSION

Construction projects face meanwhile new problems, which are more complex. Paradoxically these problems are still managed with management methods and technologies which are not up to date anymore. A reason why the industry might be conservative with the adoption of new technologies and methods can be related to the uniqueness of each construction project, which consequently results in that there is only one chance for managing the project successfully. Hence the desire to innovate and develop new approaches is mainly on incremental improvements rather than on radical innovations.

The aim of this paper was to propose one way for managing innovations, either incremental or radical. To do this the two systems approach of Kotter (2012) has been adapted to an innovation management context for huge construction organisations. The system shows that next to the normal company or group organisation, a secondary system will be placed, which will run in the background without disturbing the daily work. To achieve this, first, a centralised innovation staff unit will be placed. This centralised staff unit will identify volunteers. These volunteers will be formed to decentralised units. These decentralised units will be put together to groups with same interests. These groups will find new members and do innovation projects. The result is a self-organised organic system which runs hand in hand with the traditional mechanistic one. Hence the outcome is a so called “mechaorganic” management organisation, which has been labelled as “AgiLean”. Where Agile describes the organic structure (secondary organisation) and Lean describes the mechanistic structure (primary organisation).

This mechaorganic system is based on collaboration. Collaboration will lead to innovation and further development. This in turn will lead to the accumulation of knowledge. Hence the company will become a learning organisation!

The findings of this paper are purely theoretical. Hence further empirical studies are required to prove the practicality and the implementation of this organisational system.

5. REFERENCES

Černea, M., Jakliča, M. & Škerlavaj, M., 2013. Decoupling management and technological innovations: Resolving the individualism–collectivism controversy. *Journal of International Management,* 19(2), pp. 103-117.

Dulaimi, M. F., Nepal, M. P. & Park, M., 2005. A hierarchical structural model of assessing innovation and project performance. *Construction Management and Economics,* 23(6), pp. 565-577.

Gambatese, A., J. & Hallowell, M., 2011. Enabling and measuring innovation in the construction industry. *Construction Management and Economics,* 29(6), pp. 553-567.

Kotter, J. P., 2012. Die Kraft der zwei Systeme. *Harvard Business Manager: Strategies Change Management ,* 36(12), pp. 22-37.

Miozzo, M. & Dewick, P., 2002. Building competitive advantage: innovation and corporate governance in European construction. *Research Policy,* 31(6), p. 989–1008.

Pender, S., 2001. Managing incomplete knowledge: Why risk management is not sufficient. *International Journal of Project Management,* 19(2), pp. 79-87.

Polat, G. & Donmez, U., 2010. Marketing management functions of construction companies: Evidence from Turkish contractors. *Journal of Civil Engineering and Management,* 16(2), pp. 267-277.

Pries, F. & Dorée, A., 2005. A century of innovation in the Dutch construction industry. *Construction Management and Economics,* 23(6), pp. 561-564.

Sexton, M. & Barrett, P., 2003a. A literature synthesis of innovation in small construction firms: insights, ambiguities and questions. *Construction Management and Economics,* 21(6), pp. 613-622.

Sexton, M. & Barrett, P., 2003b. Appropriate innovation in small construction firms. *Construction Management and Economics,* 21(6), pp. 623-633.

Winch, G., 1989. The construction firm and the construction project: a transaction cost approach. *Construction Management and Economics,* 7(4), pp. 331-345.

Womack, J. P. & Jones, D. T., 2003. *Lean Thinking- Banish Waste and create Wealth in Your Corporation.* 2nd Hrsg. London: Simon & Schuster.

Bican Tugberk Architects: Case Studies

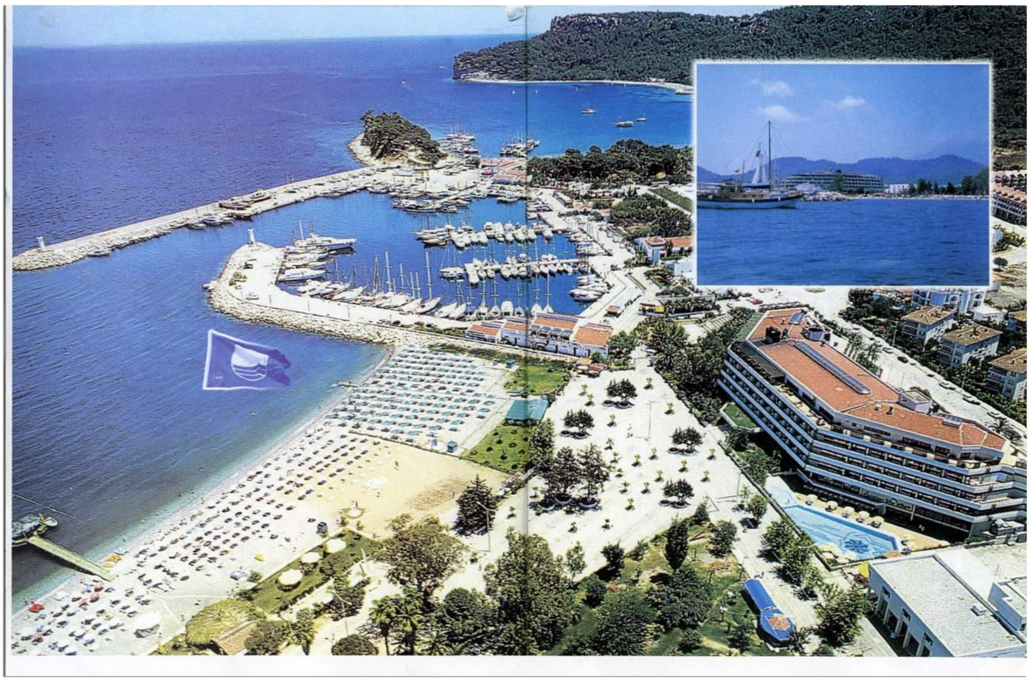
Ahmet Bican Tugberk
Bican Tugberk Architects and Istanbul Technical University, bican@tugberk.com

Abstract

As the research projects includes implementation phases, this proceeding provides information on the projects accomplished by the Architect A. Bican Tuğberk who is the founder of the company practicing for over 30 years. His company, Bican Tugberk Architects, can be a potential partner for research projects' implementation phase. He started his Ph,D with Prof. Sina Berköz in İstanbul Technical University. He received a scholarship from Italian Government and studied continuing his PhD with Prof. Guido Nardi in Milan Politecnic in Italy. He also worked in Gino Valle Milan Office living in Italy for four years. He left for Turkey, founding his Architectural practice in 1984, in Istanbul. The office aims to design, projects very much of the integration with the physical environment and energy saving solutions. His designs are very much concerned with aesthetic aspects and environmental harmony of the building.

Key words: environmental friendly architecture, implementation phases of research projects

KEMER TURKİZ HOTEL - ANTALYA



The five star hotel was designed for SPA clients of 300 beds. Rooms were distributed around an atrium of 4 stories enabling the natural air ventilation of the hotel entering from the landscape refreshing the atrium inside. This cool environment is gained, with the exhaust chimneys in the roof in the atrium.

In 2000 Spa areas are added and some spaces are redecorated according to the changing need of the management requests, successfully creating sustainable spaces.

- Kemer Türkiz Oteli Dekorasyonu (*****345 Yatak) Antalya Uygulama 2000

HOTEL (Ankara) INTERCONTINENTAL ALMATY KAZAKHSTAN

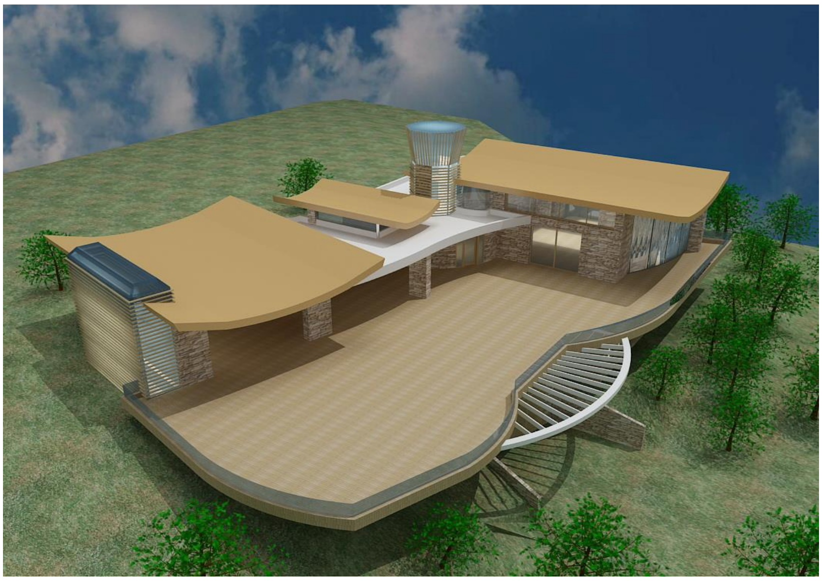
The hotel is designed for cold climate of Kazakhistan's city Almaty, as a Pioneer Hotel with five stars luxury. The mild climates of spring and Autumn is very much appreciated with natural landscape and mild air breezes of the area coming from the mountains of Tienshan – Altay.

Taking into consideration this rural air circulation reality, Restaurant and Bars are designed in ground floor to let natural air ventilation giving fresh air to the public spaces environment.

The big atrium in the center is a meeting point of the clients in the region, which was very much appreciated with the regional Kazakh people. Air ventilation is exhausted with fans in the roof, refreshing the natural air circulation from the ground floor.

This physical natural comfort created a big request of the clients with great satisfaction to visit the hotel frequently.

ŞARKÖY " CHATEAU KALPAK " WINE YARD and PRODUCTION
BOUTIQUE HOTEL CHATEAU KALPAK - TEKİRDAĞ



The wineyard is designed to create a special atmosphere for degustation and accommodation for VIP visitors in wine tourism sector. The aim was to create a special design unique, to take place within the exclusive examples created internationally. Also the quality of wine was another aim to receive a wellknown label to receive fame between the competitors.

Basement is production area hidden in the ground. Ground Floor is designed to respond to the needs of the Chateau, for its sustainable future requests and developements.

The big chimney in the center has various functions. It is a ventilation tower air entering from basement doors and windows, leting air floor to leave from the roof.
It is also the stairs, connecting basement with the ground floor. Basement entrance door and windows let the air flow, according to the wind direction which is very active on top of the vineyard hill.

The ground floor will be designed as a restaurant and degustation terrace, referring to the frequent visits of the guests, increasingly expecting high quality vines.

SARIKAMIŞ SKIHOUSE REFURBISHMENT

The design is a renovation with adding new functions to the existing old building. Light weight construction is designed for this project adding new functions and a Spa area, meeting rooms and some more bedrooms to the existing building.

Glass roof was especially designed to receive the maximum sun rays, to transfer its energy storing the heat to use it for Daily heating of the building.

The general concept of natural air ventilation is again to receive all the air movement from all directions especially rolling from the snow hill of Sarıkamış. Receiving the great amount of energy, will be used in heating the building during night and day.

During the entrance flow of guests, to the building, maximum energy saving entrances are designed for the loss of heat from the building. During sun reflection, absorbing heat from the glasses are transfered to the heat tanks which are used in this building.

BOLU MOUNTAIN RESIDENCE

The building is designed as a residence with 12 room in Bolu hill near Abant in middle Anatolia. Design is created in a way to be able, to divert it to a VIP Hotel in the future. This two storey building has all rooms with chimneys for natural ventilation. Heating pumps are used for ground heat receving it from the 80m deep wells reserving 10°C warmth for the cold climates of the area. In winter, outside is normally -20°C. Roof construction and roof tiles are completely wood, aiming to fit to the enviroment with natural materials, also with better insulation.

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