Development of Raised Access Floor Panel by Optimisation Techniques

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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).

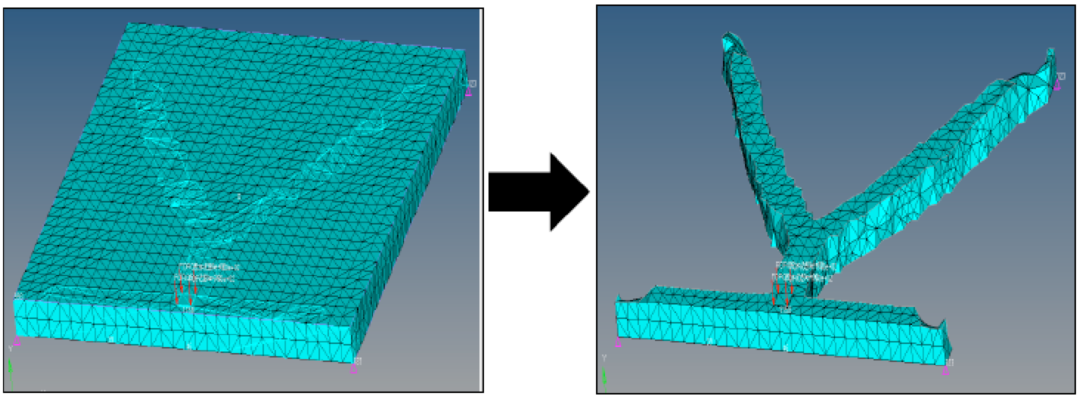
An evolutionary structural optimization (ESO) method was used to find the best way to design an optimised shape for the raised access floor panel. The shape optimisation of raised access floor panels was focused only on the weight of floor panel as an optimisation criterion. The shape optimisation procedure 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.

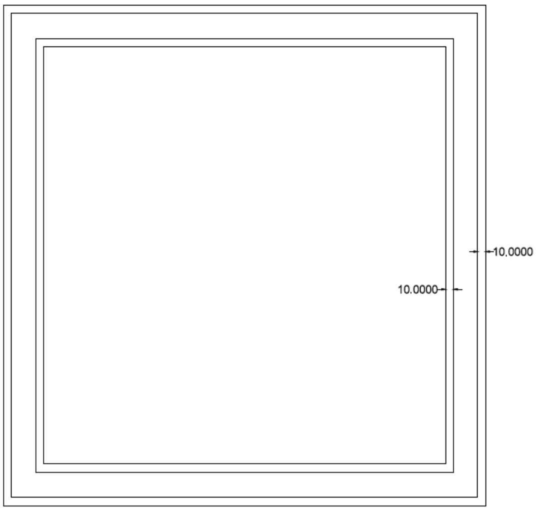


Figure 2: Ideal thickness of the ribbing for optimised panel

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.

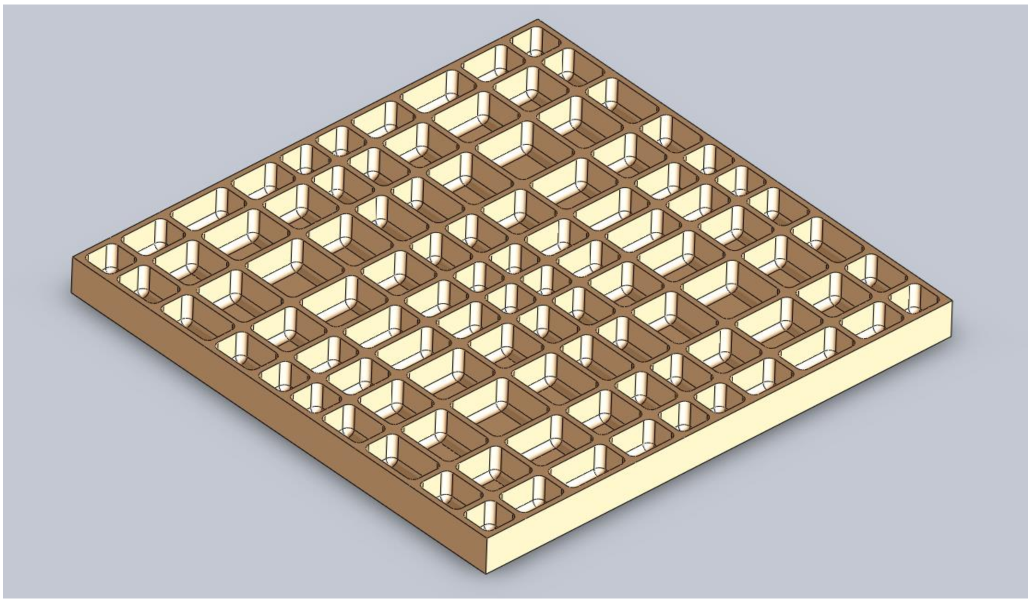


Figure 3: Structure with a rectangular array of cavities

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.

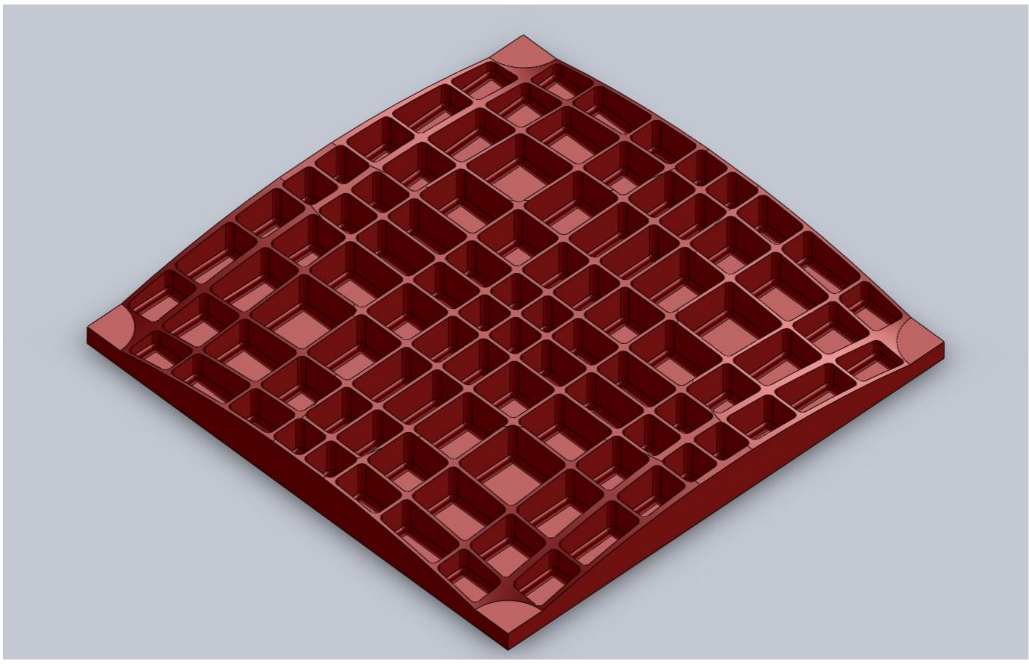


Figure 4: Optimum design of raised floors panel

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.

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