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Using forensic reports to manage the probability of lawsuits being filed in relation to pitched roofs: the case of Madrid

Using forensic reports to manage the probability of lawsuits being filed in relation to pitched roofs: the case of Madrid

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Abstract. Roofs are among the construction units in buildings with the highest number of deficiencies and problems. Given their direct and constant exposure to weather (temperature, wind, rain, snow…), even minor issues can lead to important pathology processes if not addressed early on. This research examines unresolved issues of pitched roofs in the capital of Spain which eventually led to the filing of lawsuits. Different types of deficiencies were detected (humidities, condensations, fissures…) and classified according to their recurrence. The thousands of pages of forensic reports presented to the courts were consulted and analysed to determine the probability/risk of recurrence, based on a number of factors. Among them is the causal origin (according to the properties/characteristics of the materials or to the placement/application conditions) and the respective building typologies (single-family houses or multi-storey buildings). The results that were obtained were calculated through weighted risk matrices of the existing interrelations, before determining the levels of joint severity and the classification categories according to the final operational value.

1. Introduction

Roofs (the upper and horizontal part of building envelopes) are one of the most vulnerable construction areas, given their own characteristics and their significant exposure to the elements [1], such as snow, wind, solar radiation, and variable temperatures [2]. Among roofs, pitched tile roofs are a construction solution that is several centuries old. Despite their antiquity, there are presently a number of issues that require technicians' attention as well as study to understand their underlying causes.

This paper sets out to indicate the most common deficiencies found in pitched tile roofs, based on lawsuits filed by Spanish building owners – specifically, in Madrid. It also proposes a manner to develop a method for the determination of the probability that such lawsuits might be filed.

The knowledge of these complaints serves as a useful snapshot of the current situation in the construction sector and helps better understand the most common deficiencies [3]. Overall, it is intended to help reduce future problems in pitched roofs.

2. Literature Review

The analysis of deficiencies in engineering enables an optimal (quick and effective) means of learning about materials or phrases of the construction process (design, development, control, materials…), also allowing to verify whether there have been any deviations from the expected performance. Most of the literature on pitched roofs consulted for this study focuses on materials and on the interaction with the environment: durability of construction elements [4], the effect of wind on pitched roofs [5], or even calculations of the load bearing down on roofs, trough the quantification of the accumulation of volcanic ash [6]. Few studies can be found to focus on the execution process or on aspects specific to the design stage.

While not all roof deficiencies necessarily turn into pathologies [7], some can be catastrophic. While they may not presently be problematic, a subsequent development may trigger a significant. Thus, small deficiencies in a limited part of the surface can turn into water infiltrations subsequently requiring significant corrective actions [8].

For some authors [4], design deficiencies in roofs are prevalent across many countries, and only a quality improvement in the design planning can lead to a significant reduction of deficiencies in the execution stage and to an increase in these elements' service life.

Improperly maintained buildings [9] and roofs promptly experience a number of problems. As a result, roofs should be one of the first areas to be proactively maintained, in order to prevent infiltrations and humidities [10]. Indeed, an Australian study [11] found that large amounts of money are spent in that country to address repeated construction deficiencies in roofs.

All of the above can lead to negative consequences in other places as well. This is because, in many countries, roof designs to not include specific construction details, nor plans with sufficient definition [4].

3. Methodology

3.1. Data collection

The methodological process in this study used the data of incidents reported to the civil responsibility insurance of Spanish technical architects and engineers [12]. Those cases were selected that had associated lawsuits resulting from construction deficiencies in buildings – and, specifically, in pitched roofs. The research period was from 2010 to 2017 (8 years), with the additional requirement that each lawsuit should have already received a final verdict [13]; in other words, appeals to higher courts were no longer possible.

Lawsuits were filed against various stakeholders of the construction process (designers, construction managers, and construction company), as users attempted to obtain financial compensation from those stakeholders or at least obtain a direct repair of the deficiencies in question.

A considerable amount of data was handled. The review and analysis of the data yielded 95 cases in total. The entirety of the data was obtained from expert reports requested during the lawsuit from architects or engineers specialising in building anomalies. The 95 cases in question correspond to the totality of situations arising in Madrid (Spain) during the abovementioned period. In other words, they do not correspond to a partial sample, but to 100% of the cases appearing in that location (no case was left out). This data collection represents a completely novel contribution to science, as there are no precedents for it in other countries.

3.2. Indicators

To carry out the classification, analysis, and evaluation of the cases, different indicators were established to determine each issue's recurrence. The three indicators in question are:

-First Indicator: Type of 'Deficiencies' (D), which groups together these different damages: 'Infiltrations' (D1), 'Detachment' (D2), 'Condensations' (D3) y 'Cracking' (D4).

-Second Indicator: Type of 'Causal origin' (O) of the deficiencies analysed. The following two were considered: 'Conditions of placement and application' (O1) and 'Properties and characteristics of materials' (O2).

-Third Indicator: 'Building typology' (T). The buildings were categorised into: 'Apartment blocks' (T1), 'Houses' (T2), 'Other types of buildings' (T3).

Subsequently, the connection between the three indicators was studied further, so as to analyse and label each case according to the variants of each indicator. The concept of 'interrelation' thus emerged, and it is expressed by the concatenation of three codes (one for each indicator) separated by two dashes: 'Dx'-'Tx'-'Ox'. These codes indicate the type of deficiency (Dx) occurring in a specific building typology (Tx), and which, in turn, results from a specific causal origin (Ox). These interrelations, therefore, allow each case to be uniquely identified.

It should be pointed out to the reader that the specific types referred to by each indicator correspond to those that reached the Spanish courts following complaints by users of buildings. From a conceptual and technical perspective there may be a greater diversity of types, but those that are considered herein are only those that were contained in lawsuits and are a part of the records of the Spanish Justice Administration. It should also be noted that there were no cases resulting from environmental wear or actions, since all buildings had been recently built and the complaints were filed shortly after.

3.3. Calculation Process

Once the results for each type of deficiency are obtained, according to building typology and causal origin, categories are established for the risk of lawsuit. No precedent was found in the international literature for this concept nor for an analogous one. It was necessary, then, to produce an ad hoc procedure to this effect. While the procedure was produced by the authors of this study, it has taken into account some general criteria and concepts referred to in a number of Spanish regulations [14] [15]. This procedure consists of the following 5 stages:

■ <u>Stage 1</u> - 'RANKING ACCORDING TO THE SEVERITY OF THE PROBLEM' composed of the first and second indicators: type of deficiency (Dx) and its causal origin (Ox). To measure and evaluate this severity, an 'interjudge validation' was carried out with the assistance of 12 experts, according to the UNE-EN-31010 regulation [15]. To be a part of this group of persons it was necessary to have a university degree (civil engineer, building engineer or architect), be in frequent contact with the diagnosis and treatment of construction deficiencies, and have at least 15 years of work experience in this field. The design process for 'Ranking according to the severity of the problem', included the following considerations (all within Stage 1):

1A- The group of experts decided to create a scoring system based on which a criterion of relevance of the concepts handled in this research was applied. Thus, the cases were conceptually quantified according to each of the types forming the first indicator (deficiencies: D1, D2, D3 and D4) and the second indicator (causal origin: O1 and O2). To quantify the deficiencies, the experts decided that the scoring should use odd numbers (1, 3, 5 or 7) and it was done according to the degree of inconvenience or perception of dissatisfaction on the part of users due to each deficiency. To quantify causal origin, it was decided that this scoring should use even numbers (2 or 4 points) and be done according to the degree of technical or construction importance they represent.

2A- The concept of 'possibility of occurrence' of a deficiency was extracted from the Spanish regulation UNE-60812 [14]. to apply the first and second indicators of this research. The *degree of inconvenience or perception of dissatisfaction on the part of users due to each deficiency* was thus individually assigned by each of these experts. This was done according to their professional experience and considerations, according to the characteristics of said deficiencies and the resulting problems of use or habitability leading users to file a lawsuit (this process was done with no knowledge of the data collection that was carried out). It should be indicated that the abovementioned regulation acknowledges in its wording that there is no unique and universal definition to assign a 'possibility of occurrence'; it is necessary for those carrying out the analysis (in this case, the experts) to define and accept a common framework for action for each case, according to the specific discipline and sector in which it will be applied *(for this situation: construction of buildings > roofs > pitched roofs > existence of deficiencies > construction risk of appearance of deficiencies > risk evaluation from the perspective of lawsuits)*.

3A- Qualification of the classes included in said regulation to define the possibility of occurrence (rare, occasional, probable and frequent), associated to the score mentioned earlier: 1, 3, 5 and 7 points, respectively (association between a conceptual scale and a numerical scale). Thus, the relevant concepts considered in this case are the type of deficiency (D1, D2, D3 and D4) and the scoring scale to be applied (1, 3, 5, 7), which are unique for each of them (bidirectionally assigned), so that a single value is established for each of the types of deficiencies.

4A- As for the previous consideration, this procedure was also carried out in an analogous manner, adapting it to the characteristics of the second indicator (causal origin).

5A- To carry out a weighting of the scores obtained in considerations 3A and 4A, the operations listed below are carried out, during Stages 2 and 3.

■ <u>Stage 2</u> - 'LEVEL OF JOINT SEVERITY, defined as the numerical combination of the ranking defined previously, in Stage 1. The results were obtained through the multiplication of each of the two types of causal origin by each of the four types of deficiencies.

■ <u>Stage 3</u> - According to the level of presence of each of the interrelations, a 'MATRIX OF INTERRELATION AND INTENSITY' was defined, obtaining its data from the values in Table 1. The different possible combinations, resulting from the interrelation between the types of deficiencies, the types of causal origin and building typologies were thus quantified.

■ <u>Stage 4</u> - Multiplying the level of joint severity – obtained in Stage 2 – by the 'matrix of interrelation and intensity – obtained in Stage 3 – the 'MATRIX OF WEIGHTED RISK FOR LAWSUITS' is obtained, composed of different 'risk factors' (RF). The numerical value of RF thus quantifies the likelihood of users filing lawsuits according to the specific problem they are experiencing. This allows to visualise the severity and scope of the problems found in this research.

■ <u>Stage 5</u> - The 'CATEGORIES OF LAWSUIT RISK' of users are established (from lower to higher), according to the values of RF obtained in the previous stage, enabling the visualisation and understanding of the results obtained during the creation of risk rankings. The following categories are established: Very Low (VL), Low (L), Moderate (M), High (H) and Very High (VH).

4. Results

4.1. Results by type of deficiency

The first result obtained was the determination of the most frequent type of deficiencies. As shown in Figure 1, 'Infiltrations' are dominant, with 48 cases, or 50% of the total. "Detachment" comes second, with 20 cases, or 21% of the total.

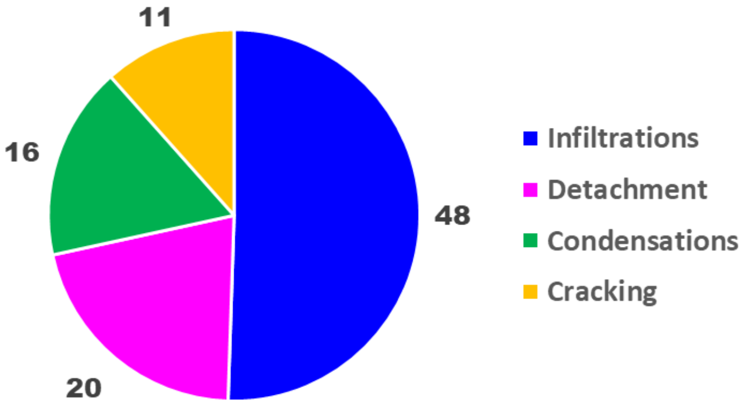

Figure 1. Number of cases by type of deficiency

4.2. Results by type of causal origin

Secondly, the results were determined according to causal origin. Figure 2 shows that the most common origin is ‘Conditions of placement and application’, with 64 cases, representing 2/3 of the total. ‘Properties and characteristics of materials’ thus correspond to 33% of cases.

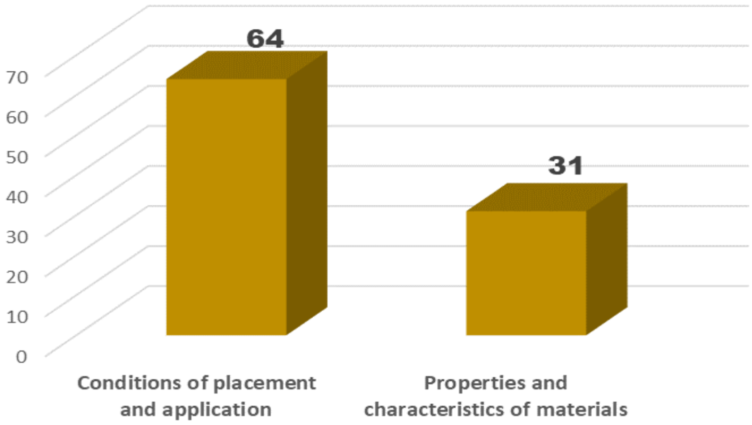

Figure 2. Number of cases by type of causal origin

4.3. Results by building typology

Lastly, a classification was established by building typology. As shown in Figure 3, ‘apartment blocks’ clearly have the most cases (52 cases), representing 55% of the total. The building typology with the highest number of cases is ‘houses’.

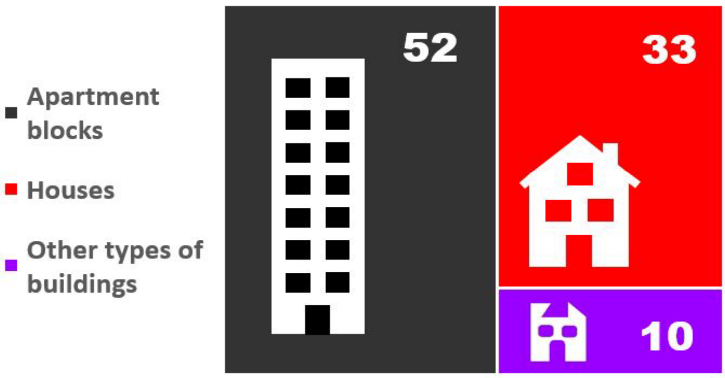

Figure 3. Number of cases by building typology

4.4. Breakdown of results according to the three indicators

To have more specific details, a complete and individual breakdown of each case was carried out, so as to characterise it based on the interrelation between the three indicators. Table 1 shows these results, expressed in percentages.

Table 1. Percentage of cases according to the three indicators, out of the total set of this research

T	D1			D2			D3			D4		
	O1	**O2**	**ST**	**O1**	**O2**	**ST**	**O1**	**O2**	**ST**	**O1**	**O2**	**ST**
T1	8	20	28	4	6	10	3	5	8	2	4	6
T2	5	11	16	3	4	7	2	4	6	1	3	4
T3	1	3	4	1	2	3	1	1	2	0	1	1

Abbreviations:
T: Building typology
D1: Infiltrations
D2: Detachment
D3: Condensations
D4: Cracking
O1: Conditions of placement and application
O2: Properties and characteristics of materials
ST: Subtotal
T1: Apartment blocks
T2: Houses
T3: Other types of buildings

It can be noted that the highest value (20%) occurs in D1-T1-O2, followed by D1-T2-O2 (11%), which confirms that 'cracking' is frequent in all buildings (whether apartment blocks or houses), especially – and with greater intensity – in those issues related to 'properties and characteristics of materials'.

4.5. Determination of lawsuit risk categories

From these three indicators, a systematic calculation procedure was carried out in 5 stages, allowing to measure the frequency and importance of the existing 'interrelations'. As shown in Table 2, the values were calculated for each of the 5 stages, to obtain the 'lawsuit risk categories', defined as the probability that construction deficiencies turn into legal complaints, according to the recurrence and nature of the interrelations between these indicators.

Stage 1 is explained in the first row of the table, Stage 2 in the second, and Stage 3 in the third row (and according to the general percentages indicated in Table 1). In turn, Stage 4 is explained in the fourth row, it being noticeable that the situations of high RF (risk factor) are precisely due to the types of deficiencies that are at once most frequent and have been assigned the most points by the group of experts in terms of their assessment of importance or technical repercussion.

Based on the classification in the 5 categories previously mentioned (and according to the entire numerical process carried out in the previous stage), it can be seen that, in most cases, the interrelations fall under the 'Low' (10 interrelations) and 'Very Low' (7 interrelations) categories, as they have low level of presence and they do not have high impact.

Nevertheless, the category grouping the highest level of presence (the most risk, VH: $RF \geq 200$) applies to only two types of interrelations, as is the case with the category of second highest risk (V: $100 \leq RF < 200$). It should be highlighted that these four interrelations all occur in houses and are caused by water infiltrations. It is thus to these that technicians should pay greater attention when developing their designs and when carrying out inspection visits to their construction sites.

Table 2. Determination, in 5 stages, of the levels of risk of lawsuit by users

STAGE	CONCEPT			VALUES			
STAGE 1: 'Ranking according to the degree of the problem'	Type of scoring			Value according to each indicator			
	Scoring according to inconvenience to users			D1	D2	D3	D4
				7	5	3	1
	Scoring according to technical importance			O1	O2		
				4	2		
STAGE 2: 'Level of joint severity' between deficiency and causal origin	Combined score for each interrelation			Type of Deficiency			
				D1	D2	D3	D4
	Causal origin		O2	14	10	6	2
			O1	28	20	12	4
STAGE 3: 'Matrix of interrelation and intensity' between deficiencies, Building typology and causal origin	Presence of each interrelation (according to Table 1)			Type of Deficiency			
				D1	D2	D3	D4
	Building typology and causal origin	T1	O2	20	6	5	4
			O1	8	4	3	2
		T2	O2	11	4	4	3
			O1	5	3	2	1
		T3	O2	3	2	1	1
			O1	1	1	1	0
STAGE 4: 'Weighted risk matrix for lawsuits' to determine the risk factor (RF)	Weighted interrelations			Type of Deficiency			
				D1	D2	D3	D4
	Building typology and causal origin	T1	O2	280	60	30	8
			O1	224	80	36	8
		T2	O2	154	40	24	6
			O1	140	60	24	4
		T3	O2	42	20	6	2
			O1	28	20	12	0

STAGE 5: 'Risk categories for lawsuits' by users	Determination according to the risk factor values				
	Category	Code	Condition	No. of interrelations	RF= Risk factor for lawsuits according to Stage 4
	Very Low	VL	RF < 10	7 interrelations	
	Low	L	10 ≤ RF< 50	10 interrelations	
	Moderate	M	50 ≤ RF< 100	3 interrelations	
	High	H	100 ≤ RF< 200	2 interrelations	
	Very High	VH	RF ≥ 200	2 interrelations	

5. Discussion

The limits of this research have to do with the situations that are objectively outside the scope defined in the methodology chapter. In other words, any existing deficiencies that are not the target of lawsuits are not analysed. Indeed, in some Anglo-Saxon countries there is a common practice of resorting to means of Alternative Dispute Resolution (ADR). However, this is not very common in Latin and Mediterranean countries, for which reason it is presumed that the number of such cases would be quite low.

6. Conclusions

The most relevant contribution of this research lies in the development of a specific procedure for forensic engineering, focused on pitched roofs. This procedure is novel (given both the type of data source and the difficulty in obtaining such a data source) and also because adds significant knowledge to the subject of the interrelations between the three indicators analysed. It can thus be stated that the ad hoc scoring-valuation method used, and the ranking of cases according to their recurrence, has no precedents in engineering literature. The method, then, constitutes a new procedural framework that can be used in other building construction units: structures, installations, etc.

By simply acting on 4 of the 20 existing interrelations, technicians could minimise the existence of anomalies in this type of roofs, thus reducing maintenance costs. Moreover, users and building owners would not be as inconvenienced, and their dissatisfaction with property acquisition would be minimised.

As stated, the most recurring deficiencies are 'Infiltrations' and the 4 interrelations with the worst score (and thus with the greatest risk of lawsuits) are: 'D1-T1-O2', 'D1-T1-O1', 'D1-T2-O2' and 'D1-T2-O1'. Their scores are, respectively, 280, 224, 154 and 140 (VL and V categories).

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