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Nota Técnica:
Tabiques de yeso laminado: inspección, caracterización patológica y estudio estadístico mediante un sistema experto

Technical Note:
Gypsum plasterboard walls: inspection, pathological characterization and statistical survey using an expert system

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RESUMEN

Este trabajo presenta un sistema experto de apoyo a la inspección y diagnóstico de tabiques o revestimientos de yeso laminado. Dicho sistema, que permite la clasificación de las anomalías del yeso laminado y sus causas probables, se empleó en un trabajo de campo en el que se estudiaron 121 elementos construidos con este material. El trabajo incluye el análisis estadístico de las anomalías detectadas durante las inspecciones y sus motivos probables. También se analizó en detalle la correlación entre las anomalías y sus causas, evaluándose aquellas en función de la superficie afectada, la urgencia de las reparaciones y el valor estético de la zona implicada.

Las conclusiones del análisis estadístico permitieron la elaboración de un inventario de medidas preventivas que deberían implantarse en las fases de proyecto, ejecución y utilización de estos elementos a fin de erradicar la aparición de anomalías en el yeso laminado o reducir su frecuencia. Dichas medidas contribuirían directamente a la mejora de la calidad de la construcción.

Palabras clave: sistema de inspección, yesos laminados, anomalía, diagnóstico.

SUMMARY

This paper presents an expert system to support the inspection and diagnosis of partition walls or wall coverings mounted using the Drywall (DW) construction method. This system includes a classification of anomalies in DW and their probable causes. This inspection system was used in a field work that included the observation of 121 DWs. This paper includes a statistical analysis of the anomalies observed during these inspections and their probable causes. The correlation between anomalies and causes in the sample is also thoroughly analysed. Anomalies are also evaluated for area affected, size, repair urgency and aesthetic value of the affected area.

The conclusions of the statistical analysis allowed the creation of an inventory of preventive measures to be implemented in the design, execution and use phases in order to lessen the magnitude or eradicate the occurrence of anomalies in DW. These measures could directly help improve the quality of construction.

Keywords: *inspection system, drywall, gypsum plasterboard; anomaly, diagnosis.*

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1. INTRODUCTION

Gypsum-based solutions are the most common interior walls coatings of buildings in Portugal. Gypsum plasters, for instance, can be produced in a factory and sold ready-mixed (only requiring the addition of water), with or without synthetic binders (the former called "synthetic gypsum plasters" with a small market share), or can be made on-site. But there is another gypsum-based solution for wall coatings, which is also used for lining partition walls. This solution is made of gypsum plasterboards, which are panels produced from a layer of gypsum plaster pressed between two thick sheets of paper. This composite structure profits from the compressive strength of the gypsum and from the tensile strength of the paper sheets.

Gypsum plasterboards are already an almost inevitable solution for interior wall coverings and the Drywall (DW) construction method is particularly popular. But its increased use has not been matched by the professional training of the people who design and install it. This has led to the appearance of anomalies in DW in the medium term or just after their application. These problems can be overcome if a significant sample of DW is inspected in detail and pathologically characterized. The inspection reports must include a list of measures to be put into practice in the design, execution and use phases in order to prevent the occurrence of similar anomalies. These measures are a vital information source for everyone involved in the construction sector. However, no works specifically related to inspection systems for DW have been found in referenced journals or in congress proceedings. On the other hand, the technology and pathology characterization of the solution based on "traditional gypsum plasters" and the definition of its most important repair techniques, mainly when applied in ancient buildings, has already been published by the same research team in referenced journals (1-4).

This paper proposes an expert system to support the inspection and diagnosis of DW made with gypsum plasterboards. This system includes a classification of all possible anomalies in DW together with their causes (described in detail in another paper by the authors (5). Using this inspection system, the pathological characterization of 121 DWs was undertaken and is presented in this paper, together with the analysis of the most probable causes of the anomalies. The paper ends with an inventory of the preventive measures to be put into practice to avoid the occurrence of anomalies in DW.

2. PATHOLOGY

The classification system of anomalies and their causes is based on the specialized literature and on the first author's experience of studying many pathological cases, and it was completed prior to the field work. The classification system allowed an inspection system to be created, similar to those already proposed and validated for other materials by the second and third authors of this paper (6-10). This inspection system can be included in a building maintenance strategy which should also include a system to classify diagnosis methods and repair solutions, and the correlation matrices. This paper only describes the classification systems and causes of the anomalies, but the detailed description of all the classification systems and correlation matrices, after validation, can be found in the paper "Inspection and diagnosis of gypsum plasterboard walls" of the same authors (5). Nevertheless, the three anomalies and the two groups of causes that have greater frequency (as described in Chapter 3 of this paper) are described in detail in parts 2.1 and 2.2, respectively.

2.1. Anomaly classification system

The first step in the construction of the inspection system is the identification of DW anomalies. The anomaly classification system proposed in this paper was developed based on the principles of pathology analysis and the knowledge of DW defects by the authors, as no other inspection or classification system of DW anomalies has been found in refereed journals or in conference proceedings.

Despite being absent from scientific literature, DW anomalies are already a concern in many documents of organizations of different countries around the world, like Abragesso (Brazilian Association of Drywall Producers), ATEDY (Spanish Technical and Business Association of Gypsum), the "European federation of national associations of gypsum products manufacturers" and the "Gypsum Association" in USA (11-14). These documents were analyzed and the most important findings were taken into account for the construction of the classification systems, namely for the defects and causes.

The anomalies are classed in two groups (Table 1). Each anomaly has an acronym: an A (for "anomaly") plus a hyphen and the group reference – A for aesthetic and B for functional. A sequential number follows this second letter. The causes of the anomalies (Table 2), the diagnosis methods and the repair techniques adopt the same labelling system.

The three anomalies that have greater frequency (as described in Chapter 3 of this paper), A-A2, A-A3 and A-A7 (see Table 1), are next described in detail.

Anomaly A-A2 – cracking at concave or convex joints, between boards or at the wall/ceiling interface – normally

Table 1
Classification of anomalies (5).

Code	Anomaly
A-A	AESTHETIC
A-A1	Detachment of the joint tape
A-A2	Cracking at concave or convex joints, between boards or at the wall/ceiling interface
A-A3	Wall uneven or having irregularities
A-A4	Wall not vertical or with warping
A-A5	Damp
A-A6	Mould growth
A-A7	Boards broken or damaged
A-A8	Bulging or detachment of the board covering
A-B	FUNCTIONAL
A-B1	Lack of acoustic and/or thermal insulation
A-B2	Loss of safety

occurs due to lack of joint tape (Figure 1). The joint material does not have enough elasticity to support structural movements without cracking. Convex joints are affected by exterior mechanical actions which can cause their slow or quick deterioration depending on the frequency and intensity of the actions (Figure 2).

Anomaly A-A3 – wall uneven or having irregularities – can result from incorrect storage of the boards that causes bending impossible to correct. Inaccurate alignment of the wall support structure or irregular positioning of metal-metal drywall screws near the baseboard can also cause this anomaly. Inadequate gypsum board finish can be noticed at the joints between boards or in the plaster over the screws at the centre of the boards (Figure 3).

Anomaly A-A7 – boards broken or damaged – is normally observed in places with high-traffic of furniture on-wheels, namely hospitals (Figure 4), due to the frequent impact and slip of these equipments.

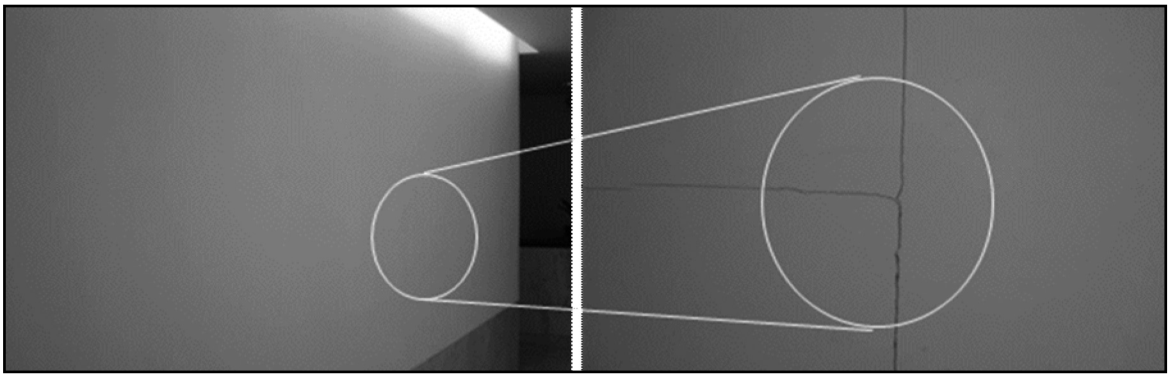

Figure 1. Lack of joint tape between boards (20).

Figure 2. Degradation of tape in a convex corner (20).

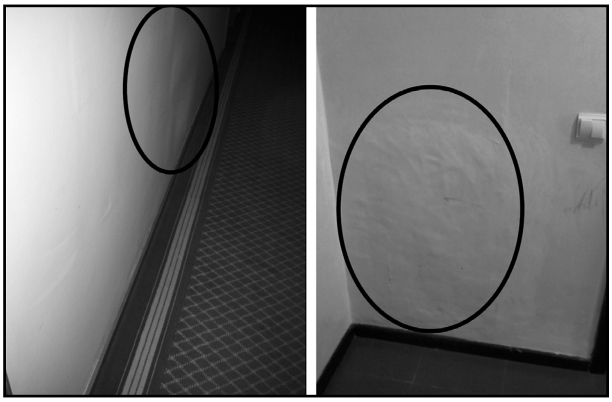

Figure 3. Walls with irregularities due to inadequate gypsum board finish (20).

Figure 4. Damaged wall due to the frequent impact of chairs (20).

2.1.1. Anomaly rating

Every anomaly detected during the inspections is rated in terms of its repair urgency that depends on the severity of the defect in the moment it is inspected: 0 – action required immediately or in the short-term (six months); 1 – action required in the medium-term (18 months); 2 – action required in the long-term (reassessment of the situation at the next routine inspection).

2.2. Classification of probable causes

The probable causes of the anomalies are classified as follows: design errors; execution errors; exterior mechanical action; environmental action, and maintenance errors (Table 2). A detailed and illustrated description of the anomalies and their causes can be found in another paper by the same authors (5). Nevertheless, the two groups of causes that have greater frequency (as described in Chapter 3), C-A and

Table 2
Classification of probable causes (5).

Code	Probable cause
C-A	DESIGN ERRORS
C-A1	Incorrect specification of materials
C-A2	Incomplete system detailing
C-B	EXECUTION ERRORS
C-B1	Incorrect storage
C-B2	Inexperienced or unskilled drywall workers
C-B3	Lack of supervision, quality control and/or correct procedures
C-B4	Inaccurate alignment of the wall support structure
C-B5	Irregular positioning of metal-metal drywall screws near the baseboard
C-B6	Unsatisfactory execution of the drywall gypsum board finish
C-B7	Deficient top to top joints
C-B8	Reinforcement missing, insufficient or badly executed
C-B9	Lack of joint tape
C-B10	Short execution time
C-B11	Disregard of the drywall gypsum board finish drying time
C-B12	Bad execution of the drywall adhesive
C-B13	Bad application of the adhesive of DW coverings
C-B14	Lack of structural joints
C-B15	Inadequate drywall gypsum board finish
C-B16	Excessive weight on each structural element
C-C	EXTERIOR MECHANICAL ACTION
C-C1	Impacts on DW
C-D	ENVIRONMENTAL ACTION
C-D1	High relative humidity and lack of ventilation
C-D2	Rain entering through external openings
C-E	MAINTENANCE ERRORS
C-E1	Burst built-in pipe

C-B (see Table 2) are described in detail in the following paragraphs.

C-A – design errors group of causes normally result from the insufficient knowledge about the characteristics of the DW system on the part of designers. They may involve either the choice of materials of inferior functional quality or the incorrect choice of the construction system itself.

Inadequate or missing acoustic and thermal insulation is one of the commonest design errors. Incomplete system detailing can also occur (e.g. lack of detailing of a sound insulation solution where pipes perforate the gypsum plasterboard). Errors like this only result in DW anomalies if there is lack of supervision, quality control or correct procedures during construction works (5).

C-B – execution errors are common and are mainly due to unskilled labour. Inexperienced or untrained drywall workers are linked with most of the anomalies that can result from incorrect DW installation: walls that are uneven or that have irregularities; walls not vertical or that are warped, lack insulation or have the security plate wrongly fitted alongside the wall. If there is proper supervision and quality control during the work the majority of these problems can be prevented or fixed without affecting the final user (5).

3. INSPECTION PROGRAMME

An inspection plan for buildings with DW was designed to simultaneously validate the classification systems and correlation matrices and calibrate the procedure adopted (15). The scope and size of this inspection campaign was different from others previously conducted on DW worldwide. One example is the survey made on 74 buildings in Singapore to find the most important design-related failure causes. For internal walls, the data available concerned the most important anomalies and corresponding causes but did not include their division by type of material. Nevertheless, some of the walls are made from gypsum plasterboards (16). Another study includes a review of the methods for investigating sick buildings, with a particular focus on toxic moulds, including the characterization of anomalies and identification of causes. This study refers a black mould that grows on moisture-saturated building materials with high cellulose content, such as gypsum plasterboards, and which is a cause of different diseases. However, the study does not refer any inspection campaign that has been made to verify the importance of this anomaly in a significant sample of DW (17). The World Health Organisation (WHO) "Guidelines for indoor air quality: dampness and mould" is also devoted to this subject and refers that this problem can be avoided by controlling moisture and dampness, and providing adequate ventilation. This document also refers that the brand, composition and liner and core materials of plasterboards affect the development of different types of mould (18).

The inspection plan covered 121 DWs applied in 21 buildings in the Lisbon area in Portugal: gypsum plasterboard walls applied in three shopping centres, four stores, a school, three offices, a gymnasium, two condominiums, a hospital, four hotels and two restaurants. The standard inspections consisted solely of a visual observation of the DW (no in situ or laboratory tests were performed) and were documented in standard inspection and validation files. 123 anomalies (only one anomaly of each type was recorded for each DW) were identified in the sample, which gave an average of 1.02 anomaly types per DW. The average number of probable causes associated with each anomaly was 2.98, half direct/near causes and half indirect/remote causes, on average.

3.1. Inspection files

The aim of the inspection files is to characterize the buildings with the DWs, and to identify all the DW characteristics. The inspection files thus contain the following fields, adapted from (6, 7):

- Heading, with the file number, the inspection date, the inspector's name and job, and the inspection aim.
- For each building: the address, the construction year, the main use (housing, stores or offices), contacts made with the people involved in the construction process, with the inhabitants or with the person in charge of maintenance.
- For each DW inspected: the installation date, location, designation and constructive characterization, wall finish (plasterboard, ceramic tiling, wallpaper, etc.), other characteristics of the DWs surroundings (moisture, heat, rain, suspended loads) and the live loads that could affect the wall (people, moving equipment and chairs).
- Characterization of the maintenance work undertaken during the DW service life that has been recorded.

3.2. Validation files

Validation files enable the main characteristics of the DW anomalies to be identified and recorded in order to verify the comprehensiveness of the inspection system and to validate the relationships cause-pathology. The direct and indirect probable causes are among these characteristics, along with:

- Location, size and orientation of detachments and cracks; percentage of DW area affected; conditions that allow the anomaly to progress; moisture, isolated loads, structure affected, degradation of the adhesive or lack of thermal or acoustic insulation.
- Repair urgency and aesthetic value of the affected area.
- Assessment methods to be used in the diagnosis and the most suitable techniques to repair the anomalies and/or eliminate their causes.

The statistical organization of the data collected in the validation files allowed the analysis which follows.

3.3. Anomaly frequency and characterization

The statistical analysis of the data collected from the inspection of the DWs begins with the relative frequency of occurrence of anomalies (Figure 5). The chart in Figure 5 shows that the commonest anomaly is A-A2 – cracking at concave or convex joints, between boards or at the wall/ceiling interface. Since this anomaly is not easy to identify even for daily users, especially if it occurs out of sight under normal conditions, the repair is normally less urgent than for other anomalies. Notwithstanding the single observation (1%) of anomaly A-B2 – loss of safety, it is retained in the classification system because of its severity. The A-A (aesthetic) group of anomalies accounts for most occurrences, with group A-B (functional) coming second. But the latter are serious and difficult to repair.

(Figure 6) gives the percentage of DW area affected by the anomalies. The values were divided into six groups: 1%, 5%, 10%, 20%, 50% or 100% of the wall area affected. Most anomalies (74%) affect only up to 5% of the wall area. Figures 7 and 8 present the percentage of DW area affected, for each anomaly. It becomes obvious that anomalies from the A-B group (functional) affect larger wall areas, despite occurring less often. Anomaly A-B2 – loss of safety affected the whole wall area the only time it occurred. Anomalies A-A1 – detachment of the joint tape, A-A2 – cracking at concave or convex joints, between boards or at the wall/ceiling interface, and A-A8 – bulging or detachment of the board covering always affected small areas (up to 10%) of the DW.

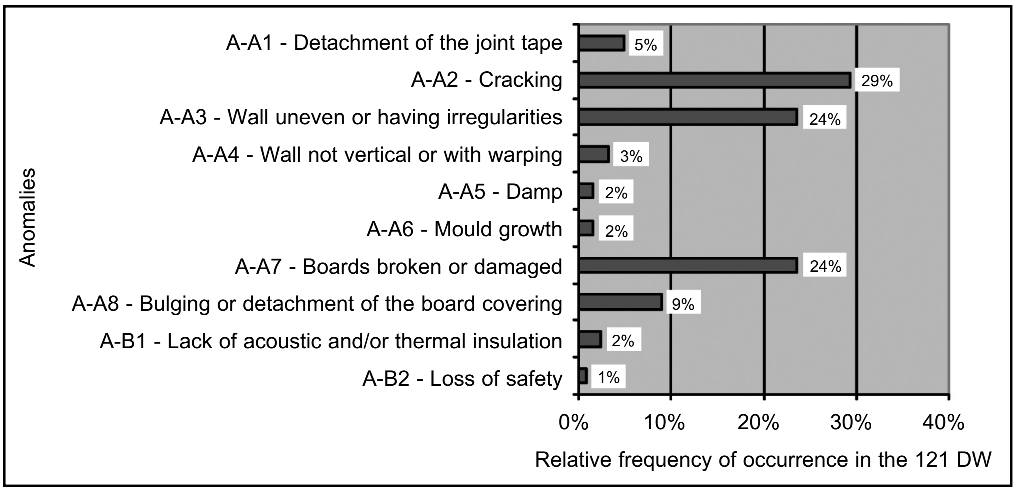

Figure 5. Relative frequency of occurrence of anomalies in the 121 DWs inspected.

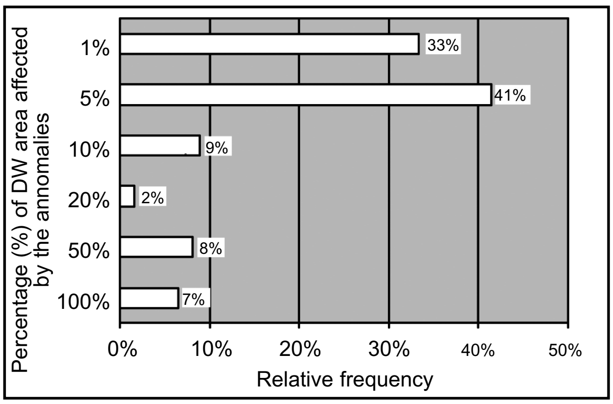

Figure 6. Relative frequency of percentage of DW area affected by the anomalies.

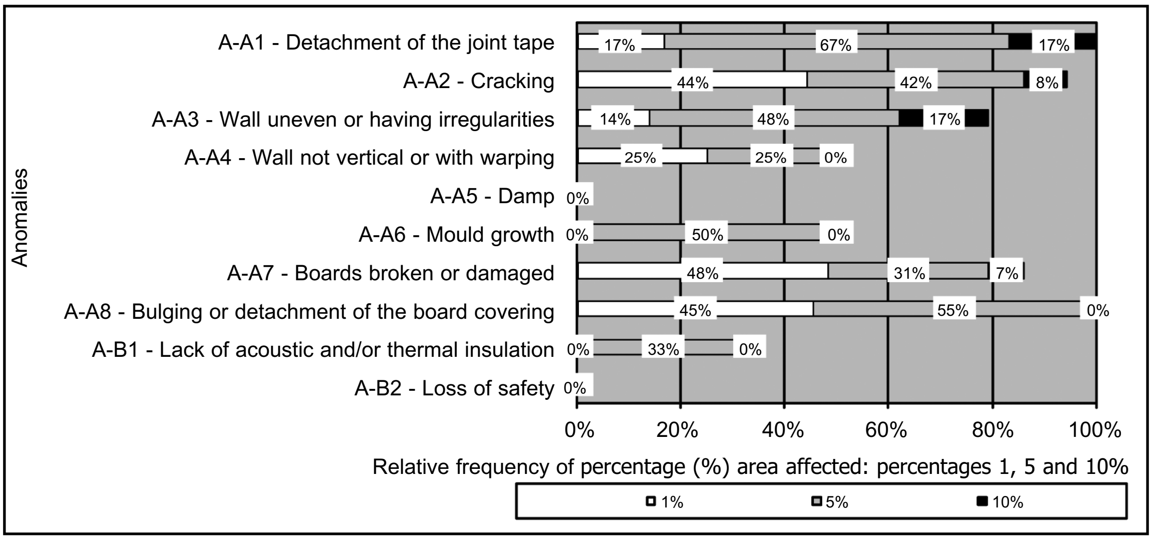

Figure 7. Relative frequency of percentage of DW area affected by each anomaly: 1 to 10%.

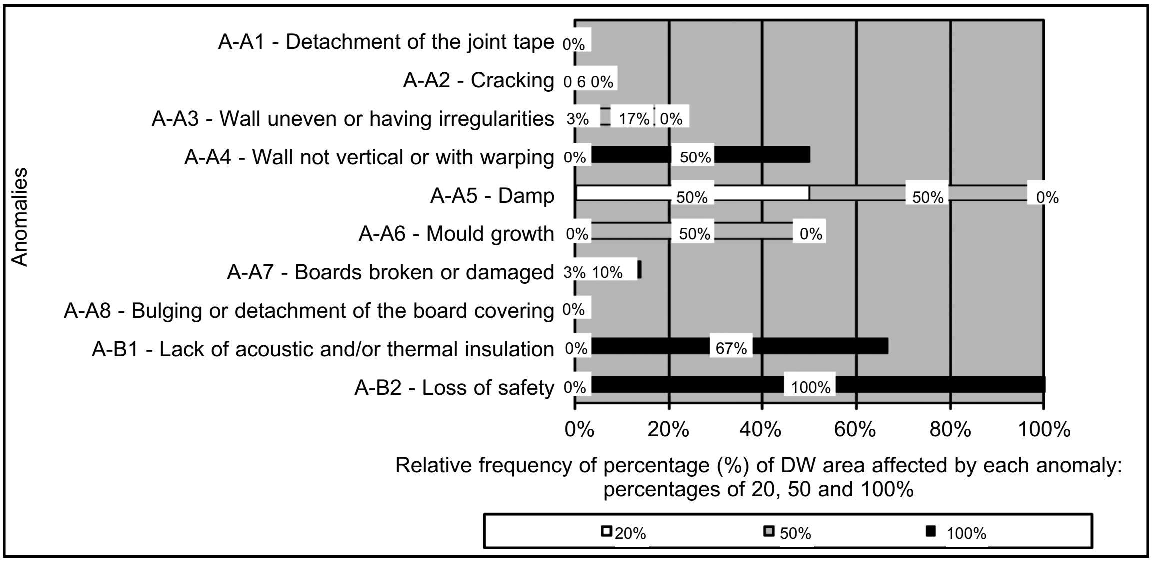

Figure 8. Relative frequency of percentage of DW area affected by each anomaly: 20 to 100%.

The anomalies were divided into three levels depending on their size: 10 % of the anomalies are small (< 1 cm); 1% is medium (1 cm < M < 3 cm) and 88% are large (more than 3 cm long at their longest direction). For the same characteristic, by anomaly type (Figure 9), only anomalies A-A4 – wall not vertical or with warping, A-A8 – bulging or detachment of the board covering, and B-B1 – lack of acoustic and/or thermal insulation are small (1 cm or less) in more than 20% of the occurrences.

The aesthetic value of the area affected by the anomalies was classified into three levels: high (large wall directly seen by users), comprising 77% of the anomalies; 9% of the anomalies occur in areas with medium aesthetic value (wall out of direct sight of users but visible from some places); 14% of the anomalies occur in areas with low aesthetic value (wall out of sight of users at least 3 meters away from them; wall hidden by doors or other elements and hard to reach). The need of fast interventions is also highlighted when the levels of repair urgency are analysed: 78% of the anomalies are classed as requiring immediate repair and only 22% in the medium-term.

The analysis of the aesthetic value of the areas affected and of the repair urgency of each anomaly (Figures 10 and 11) reveal that only the anomalies A-A2 – cracking at concave or convex joints, between boards or at the wall/ceiling interface, A-A3 – wall uneven or having irregularities, A-A7 – boards broken or damaged, and B-B1 – lack of acoustic and/or thermal insulation are identified in more than 20% of the situations in walls with low or medium aesthetic value. It is also possible to confirm that this group of anomalies also justifies lower repair urgency, corresponding to a repair in the medium-term in more than 20% of situations.

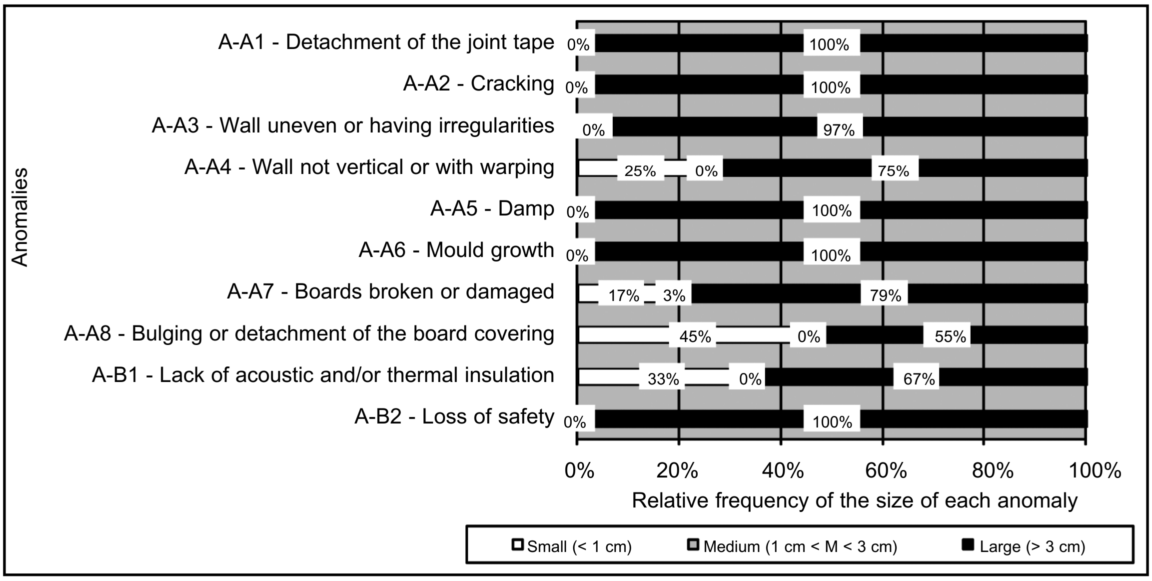

Figure 9. Relative frequency of the size of each anomaly.

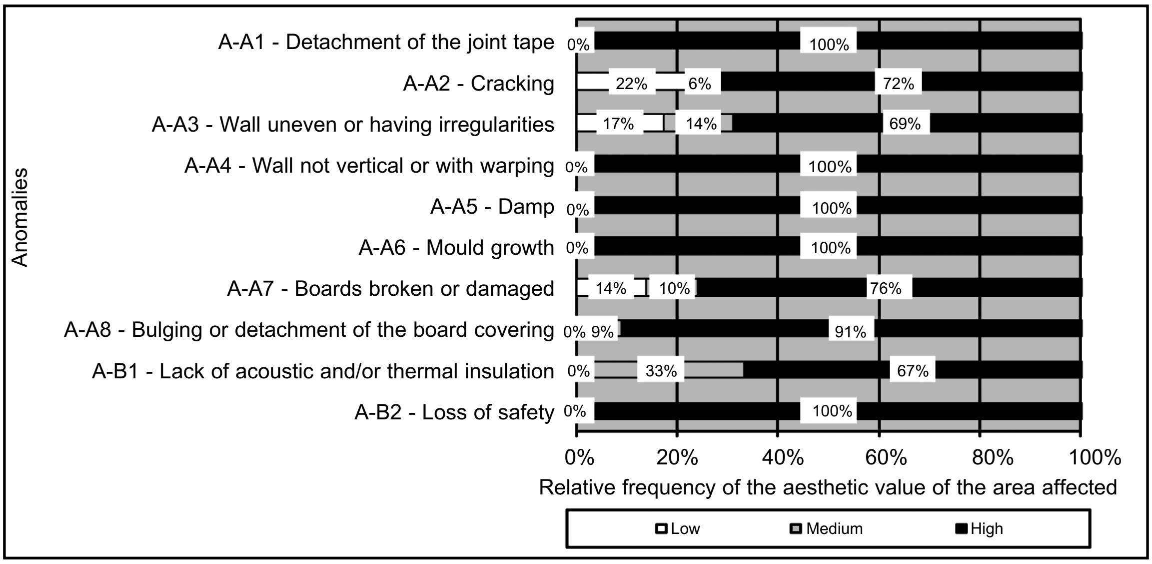

Figure 10. Relative frequency of the aesthetic value of the area affected by each anomaly.

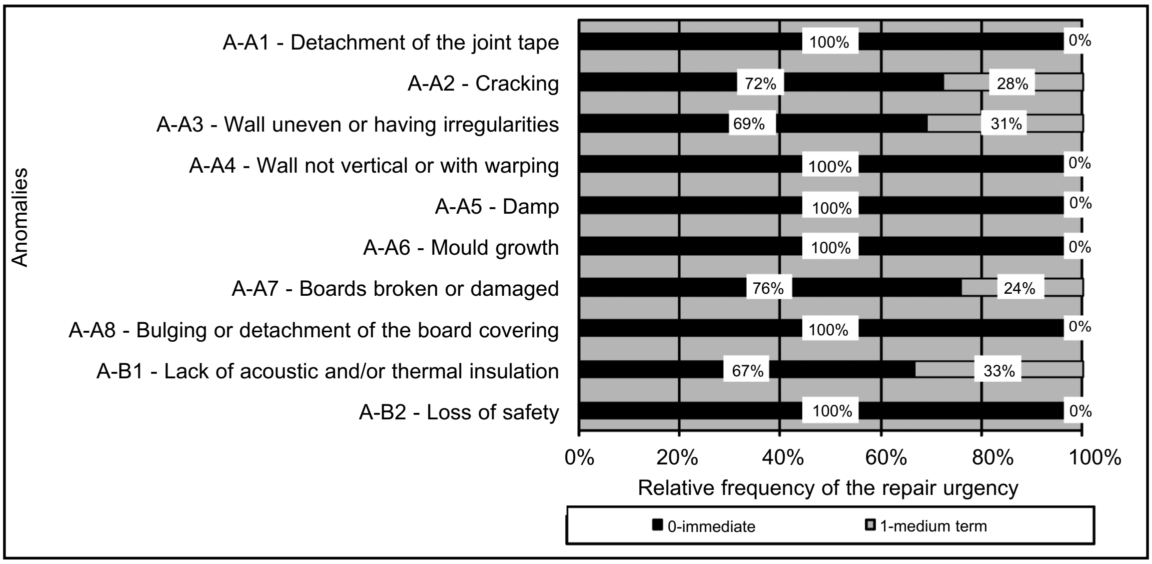

Figure 11. Relative frequency of the repair urgency of each anomaly.

3.4. Frequency of probable causes

The statistical analysis of the causes associated with the occurrence of each anomaly made it possible to create and examine charts detailing their relative frequency. Figure 12 shows the relative frequency of the groups of probable causes of the anomalies observed. It is evident that causes from group C-B – execution errors (74%) make the greatest contribution to the pathological situations. The next group is C-A – design errors (17%). The groups with the least involvement are C-D – environmental actions, and C-E – maintenance errors. It is concluded that problems related to damp and water are insignificant in the sample.

Figures 13 and 14 show the relative frequency of association of causes with the anomalies. The first chart concerns situations where the anomaly-cause correlation was considered indirect (related to design factors or to

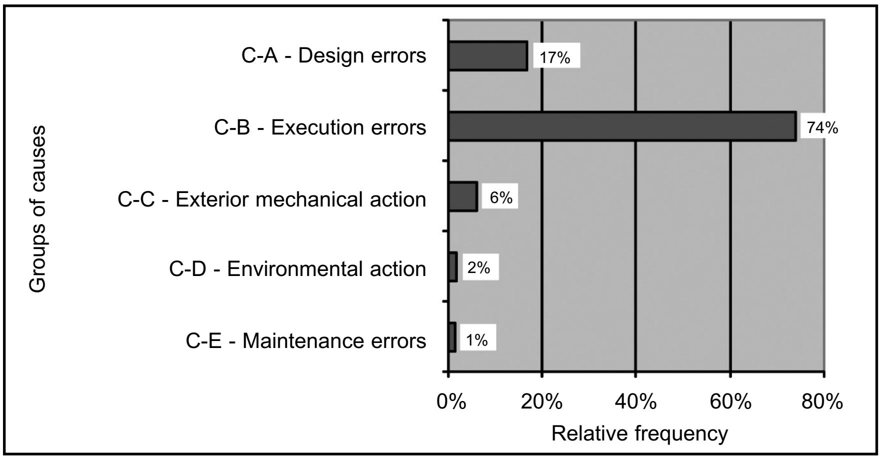

Figure 12. Relative frequency of occurrence of the causes of the anomalies.

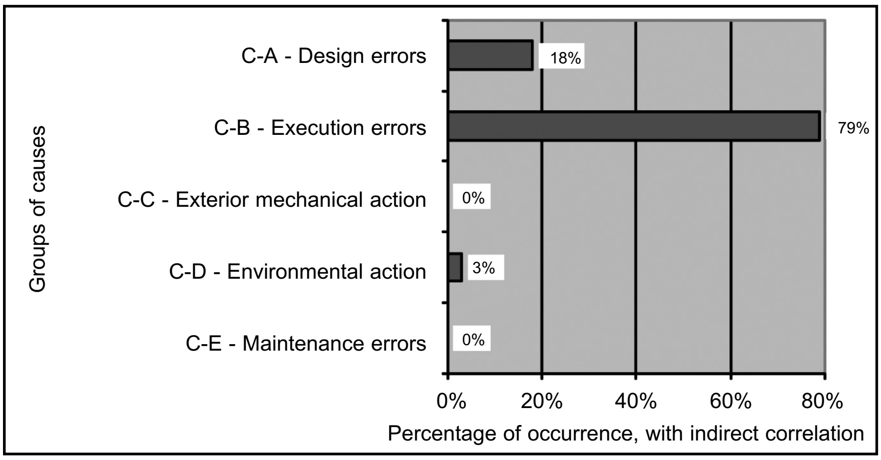

Figure 13. Percentage of occurrence, with indirect correlation, of the groups of causes.

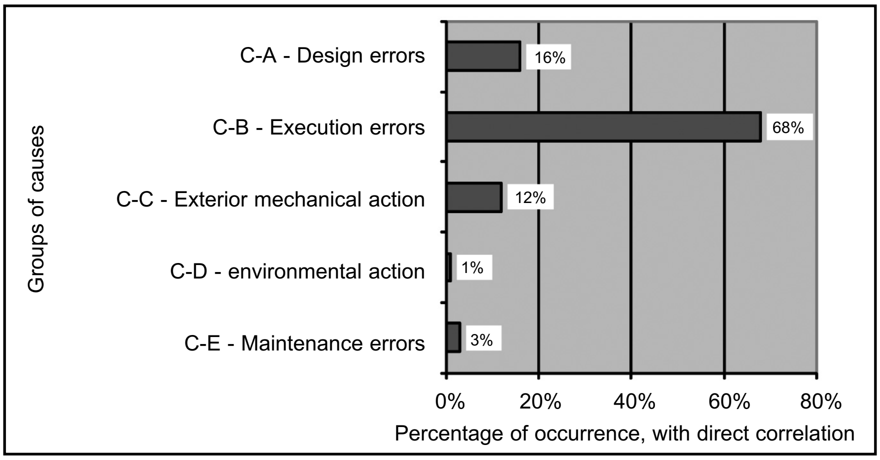

Figure 14. Percentage of occurrence, with direct correlation, of the groups of causes.

circumstances of execution or use, but requiring a direct cause to instigate the anomaly). The second chart shows the situations where causes were considered to be direct (they come into play immediately before the anomaly occurs and can be eliminated). Causes from the C-B – execution errors group made the main contribution as both indirect (79%) and direct (68%) causes. The next most significant group of causes was C-A – design errors, accounting for 18% of indirect causes and 16% of direct causes. These charts also illustrate the small part played by groups C-C – exterior mechanical actions, and C-E – maintenance errors as indirect causes of an anomaly. This is due to the weak relationship between anomalies and these causes, within the sample, and because of their direct nature. Nevertheless, the causes from both groups provoke immediate problems in any DW. The contribution of the C-D – environmental actions group of causes – is small. It should nonetheless remain in the classification system because in some specific situations it can be identified as the probable cause of anomalies in DW.

Figure 15 presents the relative frequency of the association of the individual causes of the two most important groups (C-A – design errors, and C-B – execution errors) with the anomalies in the sample. Causes C-B2 – inexperienced or unskilled drywall workers and C-B3 – lack of supervision, quality control and/or correct procedures are both related to more than 60% of the anomalies. This confirms the impact of the workers' execution of DW on preventing the occurrence of anomalies. Cause C-A2 – incomplete system detailing – is associated with almost 40% of the anomalies. This means that most of DW construction work goes ahead without a proper detailing of the construction system to be built.

The individual contribution of each cause to the anomalies can be established from the relative frequency of the causes with an occurrence frequency of more than 10% and which were associated with the most frequent anomalies (A-A2, A-A3, A-A7 and A-A8 as shown in Figure 5). Anomaly A-A2 – cracking at concave or convex joints, between boards or at the wall/ceiling interface could have various causes, but it is mostly (81%) due to causes C-B2 – inexperienced or unskilled drywall workers, and C-B3 – lack of supervision, quality control and/or correct procedures (Figure 16). In third place there is a cause (C-A2 – incomplete system detailing) also related to lack of professional training, in this case of the designer, that leads to the occurrence of anomalies. The remaining causes (in order of decreasing significance) are C-B14, C-B8, C-B9 and C-B10, all from the C-B – execution errors group, demonstrating the high contribution of execution errors to the occurrence of this anomaly.

The chart in Figure 17 shows the relative frequency of causes related to the 29 instances of anomaly A-A3 – wall uneven or having irregularities. The cause correlated with almost all (97%) these occurrences is C-B2 – inexperienced or unskilled drywall workers, followed by C-B3 – lack of supervision, quality control and/or correct procedures. Once again workers and work supervisors are responsible for the occurrence of anomalies and most of the remaining causes belong to the group C-B – execution errors.

Figure 18 presents the relative frequency of the causes related to the 29 instances of anomaly A-A7 – boards broken or damaged. Both C-A2 – incomplete system detailing – and C-B3 – lack of supervision, quality control and/or correct procedures are strongly related to the

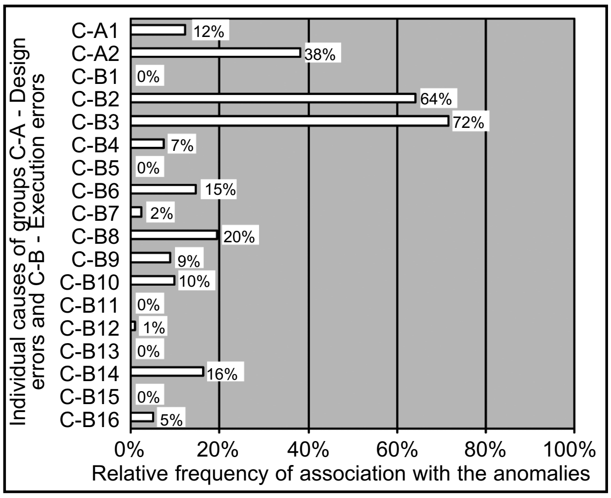

Figure 15. Relative frequency of association of individual causes of groups C-A- design errors and C-B – execution errors with the anomalies.

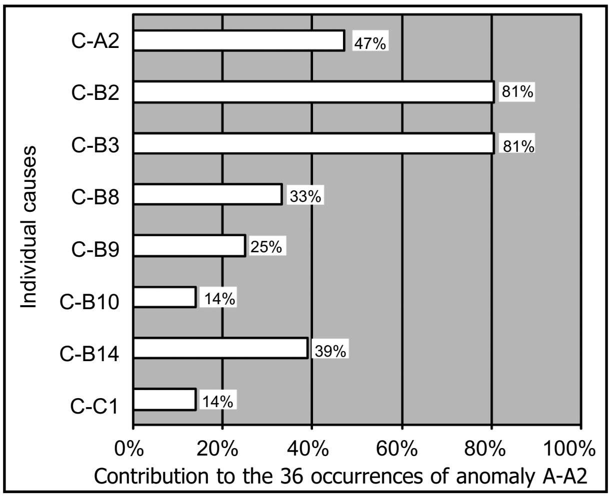

Figure 16. Contribution of the causes to the 36 occurrences of anomaly A-A2 – cracking at concave or convex joints, between boards or at the wall/ceiling interface.

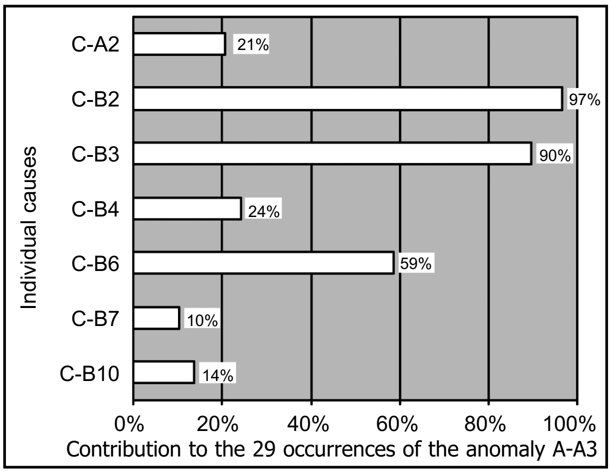

Figure 17. Contribution of the causes to the 29 occurrences of anomaly A-A3 – wall uneven or having irregularities.

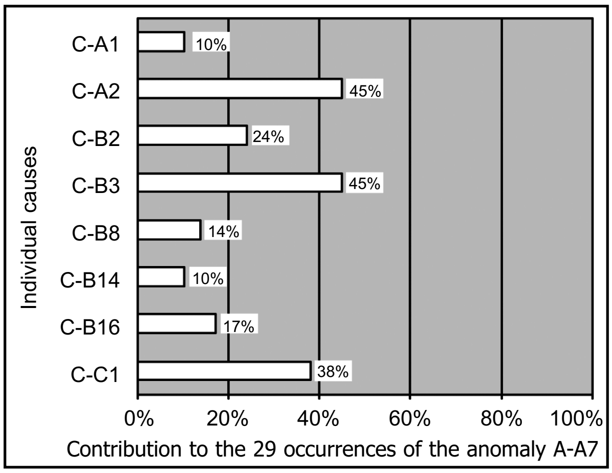

Figure 18. Contribution of the causes to the 29 occurrences of anomaly A-A7 – boards broken or damaged.

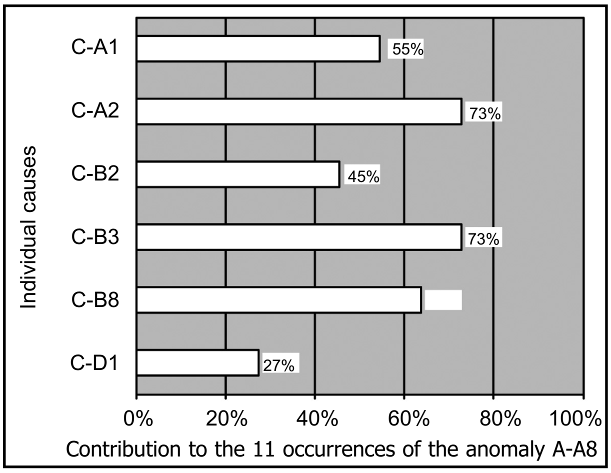

Figure 19. Contribution of the causes to the 11 occurrences of anomaly A-A8 – bulging or detachment of the board covering.

occurrence of this anomaly (45%). The other causes are from different groups, but cause C-C1 – impacts on DW – is also important (38%).

Figure 19 proves that both C-A2 – incomplete system detailing— and C-B3 – lack of supervision, quality control and/or correct procedures make an important contribution to the 11 cases where anomaly A-A8 – bulging or detachment of the board covering was identified (73%). The other causes belong to these two groups and to C-D – environmental actions. This means that this anomaly can stem from the action of a single cause or from several causes in different groups.

4. PREVENTION OF ANOMALIES IN DW

The statistical analysis described above was the result of an inspection campaign that included 121 DWs fitted in 21 buildings. The analysis of the anomalies identified and of their relation with the probable causes allowed the most important degradation mechanisms in DW to be identified. These result from the most frequent correlations between anomalies and causes in the sample. To deal with this problem, recurrent indirect causes must be eliminated. Measures should also be put into practice in the design phase in order to reduce or eliminate the most important direct causes. This part of the paper lists the preventive measures that should be put into practice in the design, execution and use phases in order to lessen the likelihood of anomalies occurring in DW.

The contribution of the C-A – design errors group of causes (18% of indirect and 16% of direct causes) to the occurrence of anomalies – is significant. DW producers must invest in organizing training courses for building designers in order to increase their technical knowledge. Only this kind of initiative can guarantee that the DW project will be properly developed to avoid choosing materials whose functional characteristics fall short of minimum requirements or opting for the wrong construction method. It also ensures that the DW solution prescribed provides adequate acoustic and thermal insulation characteristics all over the wall. Lack of detailing of the interface between DW and other construction elements is also a great problem. This leads to design changes during construction works, without the intervention of the designer, in order to make the DW solution compatible with the adjacent lining solutions.

The incidence of the C-B – execution errors group of causes – as an indirect (79%) and direct (68%) cause is high. An inspection campaign made in Singapore in order to assess the difference between anomalies identified in the construction and in the occupancy stages confirmed these results and the contribution of the design errors. The anomalies from the construction stage of 74 buildings were obtained from the defects database of the public agency in Singapore that manages construction quality and the ones from the occupancy stages were collected from property managers. The anomalies were grouped according to the corresponding building element (e.g. internal wall) and probable causes, but no information is provided concerning the materials of the components (19). Nevertheless it is possible to confirm that execution errors are responsible for 67% of the anomalies in internal walls and design errors for 22%.

Drywall workers are frequently responsible for the occurrence of anomalies due to lack of training in this specific construction method. Once more, training courses must be organized to teach the relevant actors in the construction chain (drywall workers, construction firms) the theoretical knowledge about detailing and assembling this solution that is already available from different organizations around the world (11-14). These all-inclusive actions will definitely help to decrease the incidence of pathologies in DW. The significance of cause C-B3 – lack of supervision, quality control and/or correct procedures – shows the need to raise the importance of supervision in the construction phase. When planning construction works, all those responsible for the activities that interact with the DW (e.g. electrical works, plumbing, air-conditioning, masonry works and wall painting) must be appropriately informed in order to optimize the scheduling of activities.

When in use the DW is permanently exposed to impacts that could result in different kinds of anomalies depending on the location, strength or size of the contact area. A study in Singapore that included the inspection of 74 buildings concluded that 25% of the anomalies in internal walls related with poor design decisions result from impacts of occupants and loads (16). When the building is being designed, solutions to protect the convex corners of the DW and the fitting of reinforcements and chair impact guards must be considered so as to reduce the consequences of these impacts in the most vulnerable areas.

Any maintenance work on a DW (to repair it or to fix built-in equipment) should be followed by restoration to the initial state. These works must guarantee the aesthetic uniformity and evenness of the area repaired and the remaining wall area.

Putting these measures into practice will directly help to improve the quality of DW applied in buildings.

5. CONCLUSIONS

Different expert systems for the evaluation of damage of building materials and elements already exist but no research work similar to this has been found in the specialized literature in terms of scope and aim. Therefore, the expert system proposed in this paper is considered to be at once innovative, robust, and reliable, and supported by statistically significant validation work, as the following statements demonstrate:

- The innovative systematic approach used in the construction of the inspection system proposed in this paper can help the in-situ inspector in making his activities more objective and, at the same time, standardizing his procedures.
- The inspection programme that included 121 DW with anomalies was essential to validate the inspection procedure and confirm the quality of the initial theoretical presuppositions.
- The statistical analysis of the collected data also revealed its unquestionable utility for the professionals that design or assemble DW.
- Continuing to collect pathological situations in DW will enable degradation models to be constructed when the size of the sample is big enough.

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