A CAUSE AND EFFECT DIAGRAM FOR FACADE PATHOLOGIES

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ABSTRACT

Besides the aesthetic features and the public safety risk, failure of ceramic tiling systems impacts several sectors. In a general way, defects in facades are consequences of several factors acting together. In the present work, in order to evaluate the major features related to facade pathologies, a Cause and Effect Diagram was built. Once the fishbone diagram was completed, the key causes were identified based on our experience in facade design and inspection and on published literature. Among several causes of failures, the major contribution was found to be associated with poor quality of ceramics, improper specification of mortar, lack of specifications and experience in use of dry-set mortars, and absence of facade project.

1. INTRODUCTION

Besides the aesthetic features and the public safety risk, failure of ceramic tiling systems impacts several sectors. In the last years, around the world, the lack of confidence in ceramic tiles and the mortar industry has increased as may be seen in several papers presented in QUALICER 2004:

DÍAZ, from Spain, in his paper entitled *Ceramic Tiling Pathologies*, pointed out that "recent years have witnessed a significant decrease in the number of new buildings with tiled facades, owing to the insufficient assurances provided by tiling performance". He also said that "alternative solutions to the foregoing are being increasingly used, which are capable of offering comparable visual appeal and equivalent functional performance".

In Singapore, as revealed by WAN (*Tiling Failures – A Chronic Problem Re-visited*), "The use of adhesive bonded ceramic tiles had been discouraged by the Building Control Authorit y for buildings exceeding 4 storeys". He also observed that "for buildings under 4 storeys, ceramic tiles initially continued to be used but they were few and far between. Unfortunately, despite its reduced application, failure of such adhered facade system persisted and received no less attention from the industry and media as compared to its high rise predecessors".

In the same congress, CASS, from Australia published a paper (*Achieving 100% Adhesive Coverage, an Industry Wide Approach*) in which he indicated that "people returning regularly to common public areas such as shopping malls where tiling is deteriorating and needing repair, are likely to consider alternatives to tile when they are in position to make a purchase decision". Besides that he pointed out that "not only is there a potential loss of sales as alternative products are selected, there are the negative effects associated with the cost of repairing cracked and delaminated tiling, and add to that the environmental impact of the wasted energy of production and landfill requirements".

The overall result is a reduction in the industry growth and, indirectly, it has an adverse impact upon all manufacturers, merchants and installers. Based on these features it is crucial to evaluate tiling failure causes.

In a general way, defects in facades are a consequence of several factors acting together and in the present work, in order to evaluate the major features related to facade pathologies, a Cause and Effect Diagram was built.

2. CAUSE AND EFFECT DIAGRAMS

A Cause and Effect Diagram is a tool that helps identify, sort, and display possible causes of a specific problem or quality characteristic. It graphically illustrates the relationship between a given outcome and all the factors that influence the outcome. This type of diagram is sometimes called an "Ishikawa diagram" because it was invented by Kaoru Ishikawa, or a "fishbone diagram" because of the way it looks (Figure 1).

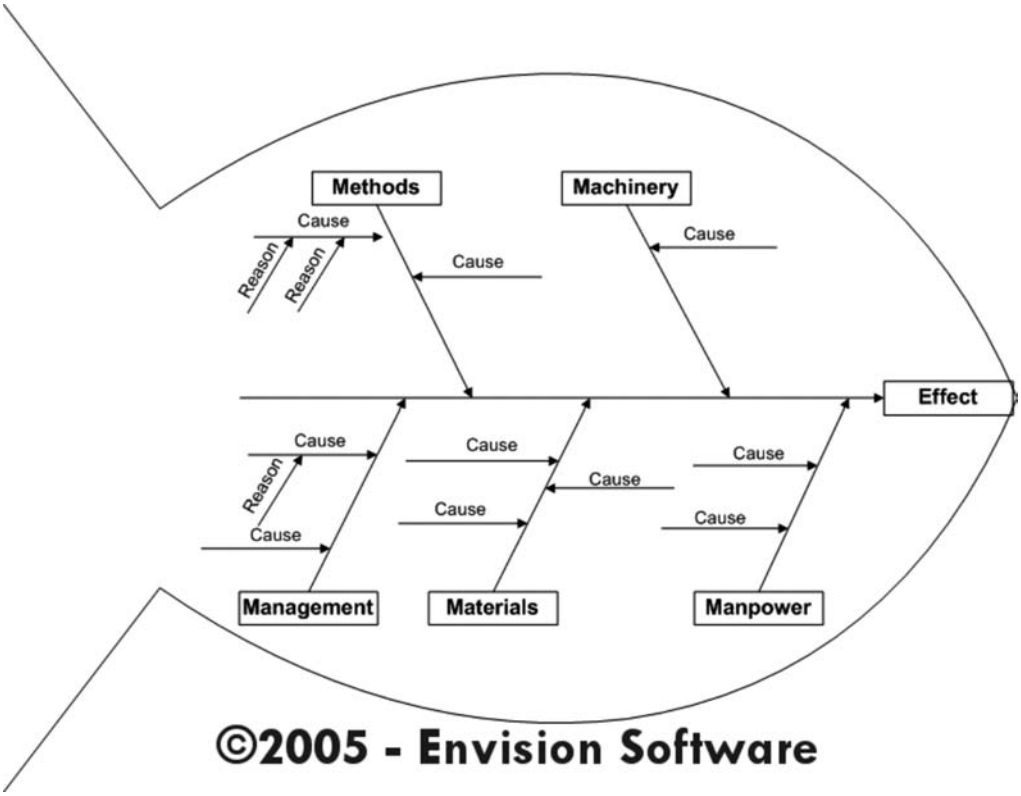

Figure 1, Cause and Effect Diagram Structure.
(adapted from http:// www.envisionsoftware.com/es_imgs/Fishbone_Diagram.gif)

In the present study, cause and effect diagram was used to explore all the potential or real causes that result in the single effect: facade pathologies. Causes were arranged according to their level of importance or detail, resulting in a depiction of relationships and hierarchy of events.

When using a fishbone diagram, several categories of cause can be applied. Some often-used categories are:

- Human resources (manpower), methods, materials, measurements, and equipment (machinery);
- Clients, workers, supplies, environment, and procedures;
- What, how, when, where;
- Environment or Mother Nature, a potentially significant category, etc.

In this case, the diagram was prepared considering the 6Ms categories: Manpower, Materials, Methods, Measurements, Machines and Mother Nature. After that, for each potential cause identified before, new branches were added answering 'why does that happen?' Once the fishbone diagram was completed, the key causes were identified.

3. RESULTS

Potential causes of the problem in each main category were brainstormed, as indicated below and in Figure 2.

- Manpower: improper installation practices, workers without tiling installer formation, unknown of facade project, unknown of materials characteristics, absence of a professional responsible for inspection;
- Materials: poor quality or improper specification of mortar, ceramic tile, grout material and sealant, problems on substrate materials;
- Methods: lack of a facade design which outlines all materials and methods for entire external ceramic cladding system, absence of a schedule which defines the time span between steps, absence of substrate preparation design, improper width of joints between pieces, lack of installation practices, improper location and size of movement and structural joints;
- Measurements: absence of evaluation of adhesive strength, absence of qualitative acoustic tap testing post-installation, insufficient back tile coverage, lack of controlling dry-set mortar open time, lack of evaluation of sealants after joint filling, lack of controlling mortars mix time, wait time before use and pot life, lack of controlling the amount of water added for mortar mixture, absence of controlling of wait time between different steps, absence of controlling of concrete frame deformation, lack of determination of ceramic tile and substrate water absorption;
- Machines: notched trowel with notch depth and configuration not appropriated, use of wood box for mortar mixing and storage, use of steel trowel for grouting, absence of mechanical mortar mixing or adoption of a not suitable mechanical mixer;
- Mother nature/environment: wind, solar exposure, atmospheric pollution, cold temperatures, acid rain, water exposure, ultra-violet radiation, thermal shock, improper access for installation.

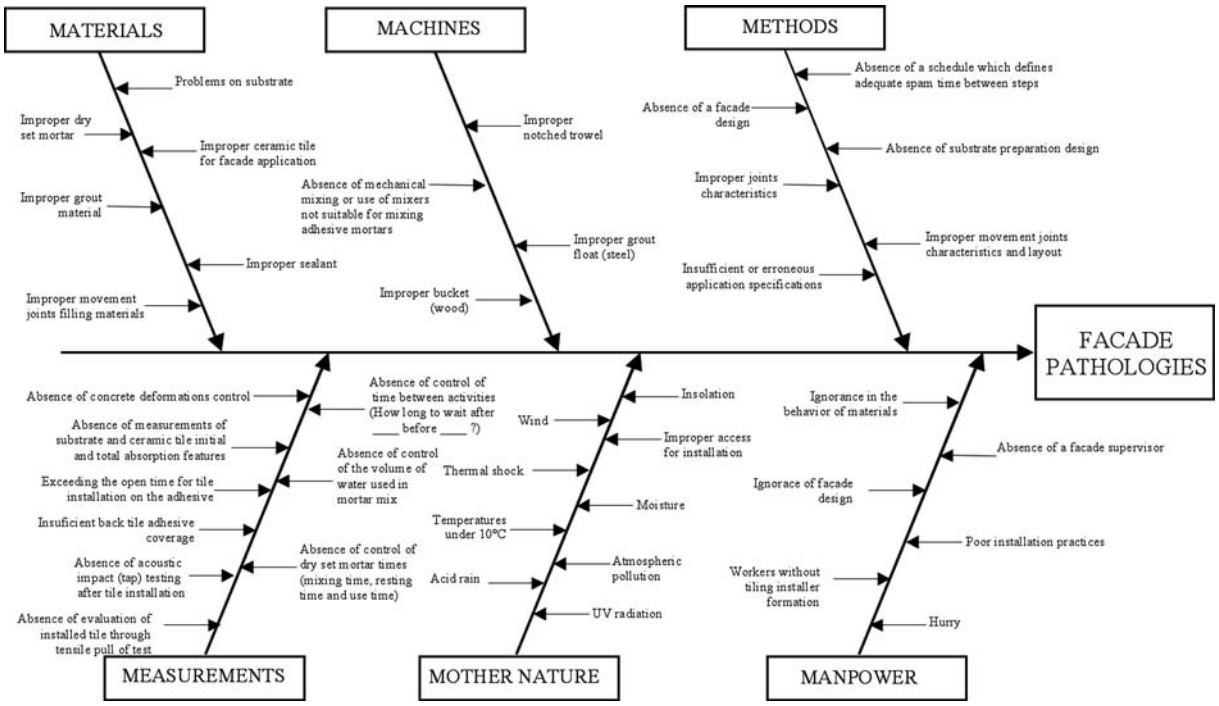

Figure 2. Cause and Effect Diagram for Facade Pathologies.

In the sequence, more detailed levels of causes were added. We did this by asking the why question: "Why does that happen?" Figures 3 to 8 show the obtained answers for each category.

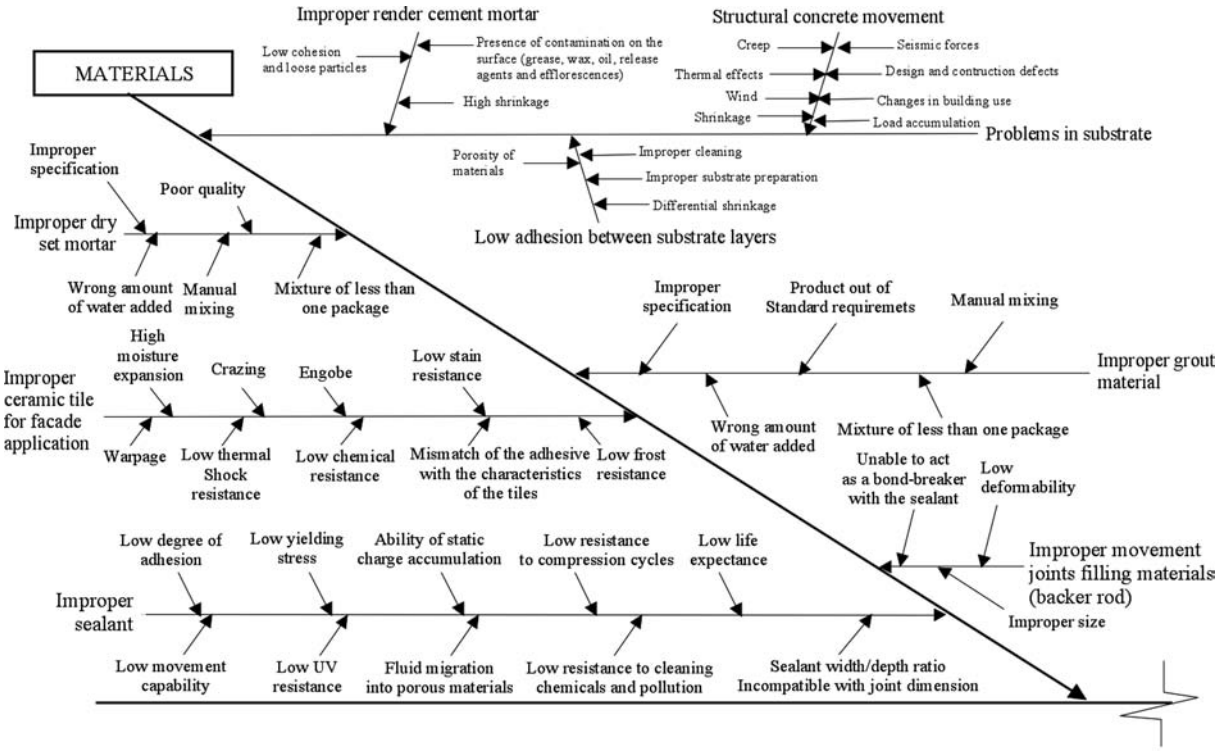

Figure 3. Causes of facades pathologies related to Materials.

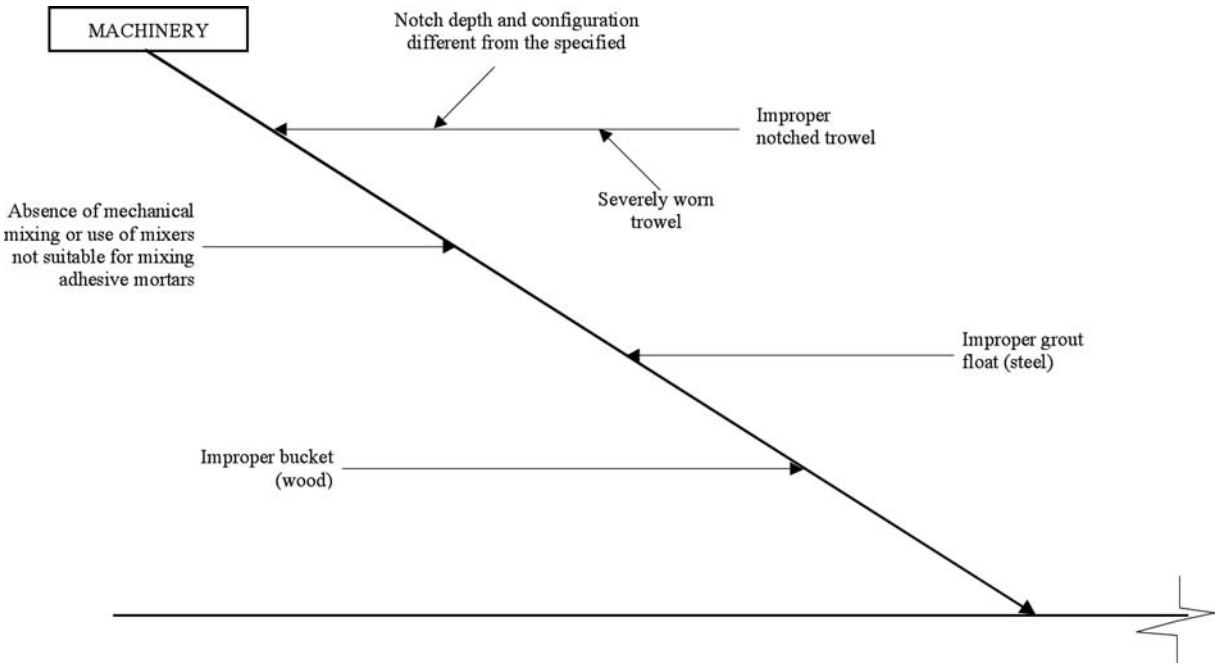

Figure 4. Causes of facades pathologies related to Machinery.

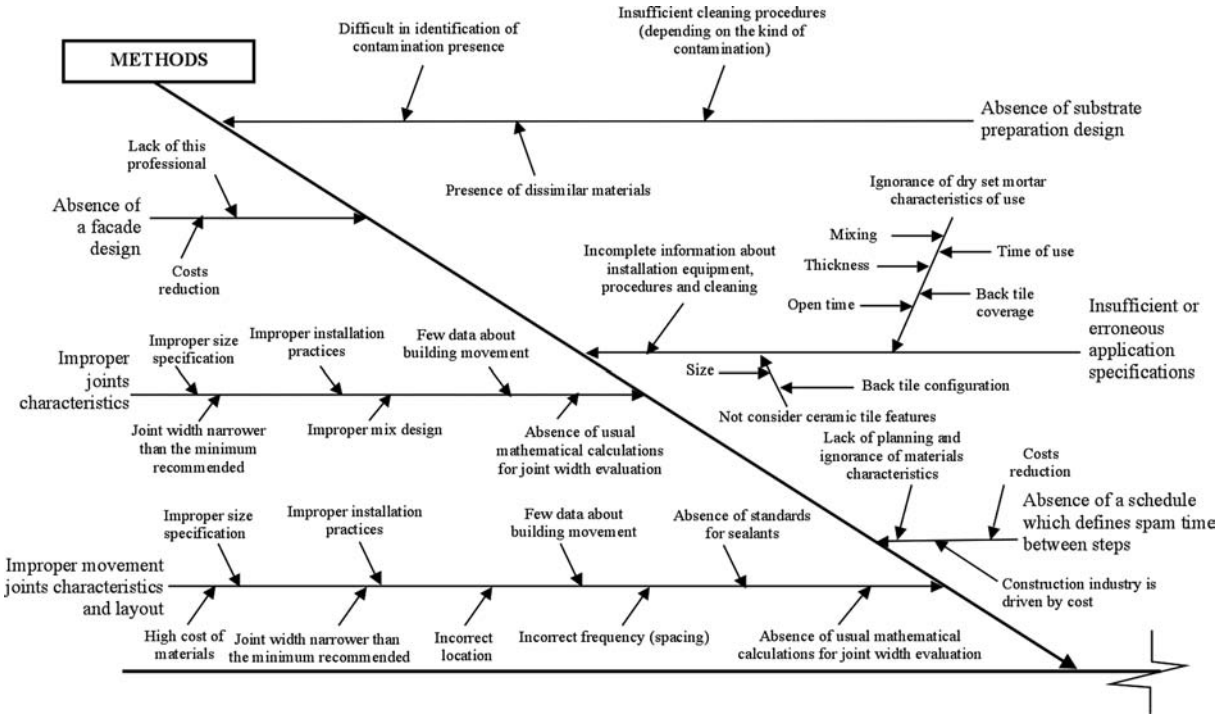

Figure 5. Causes of facades pathologies associated with Methods.

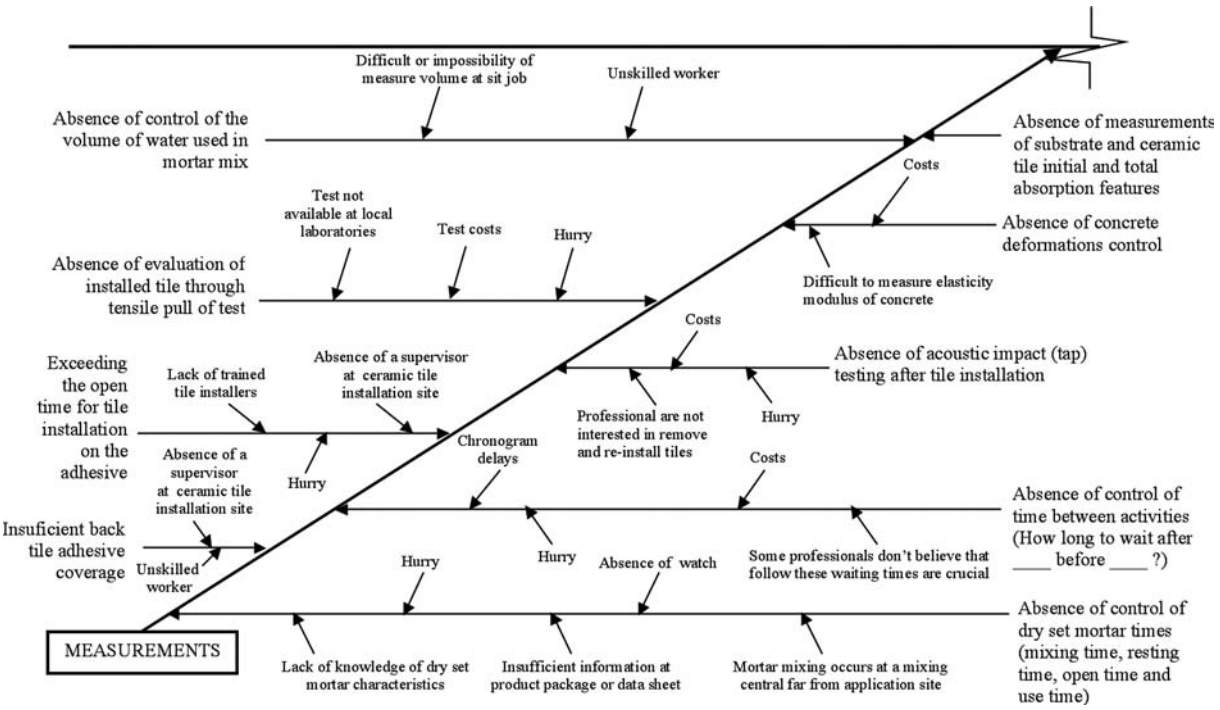

Figure 6. Causes of facades pathologies associated with Measurements.

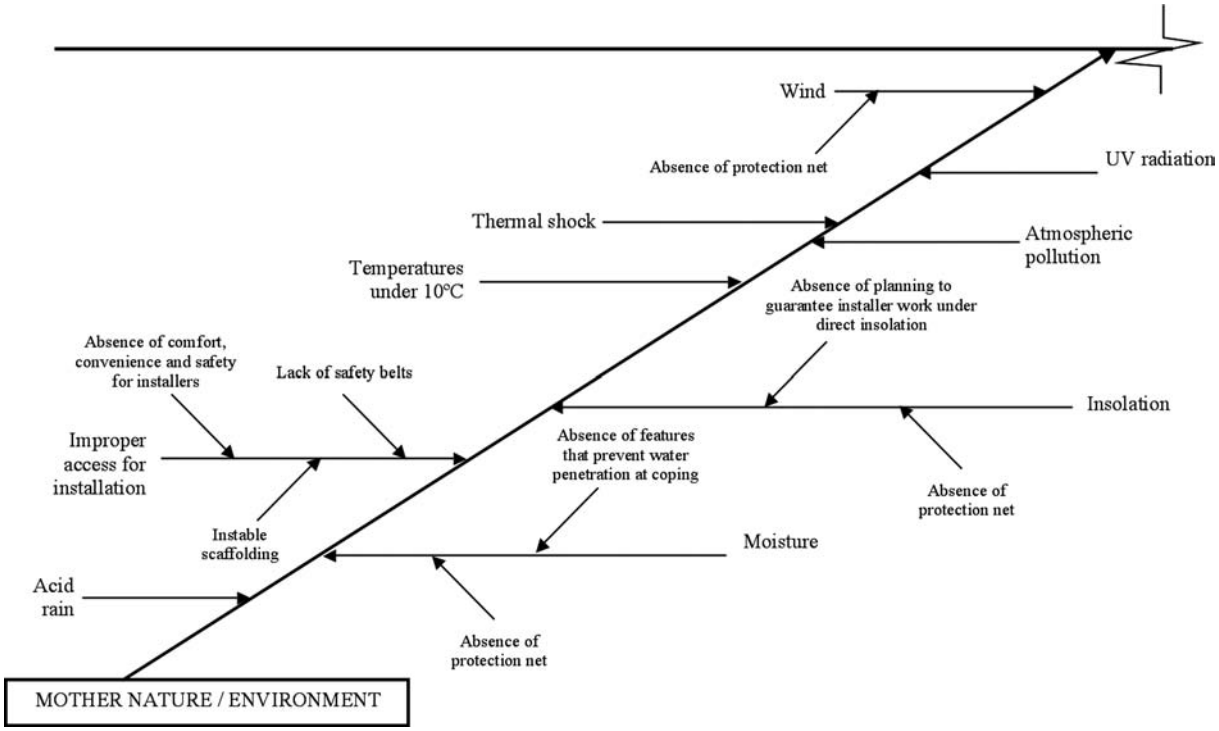

Figure 7. Causes of facades pathologies related to Mother Nature/Environment.

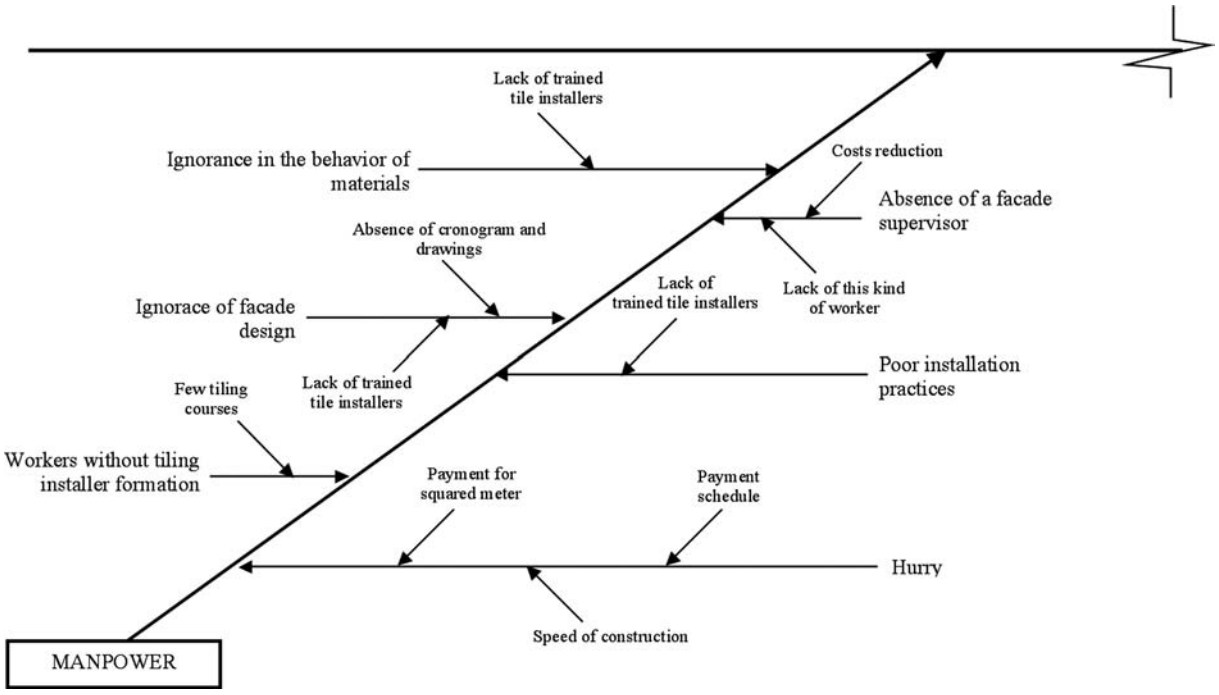

Figure 8. Causes of facades pathologies associated with Manpower.

Once the fishbone diagram was completed, the key causes were identified based on our experience in facades design and inspection and on literature. Among several causes of failures, the major contribution was attributed to poor quality of ceramics, improper specification of mortar, lack of specifications and experience in use of dry-set mortars, and absence of facade design (Figure 9).

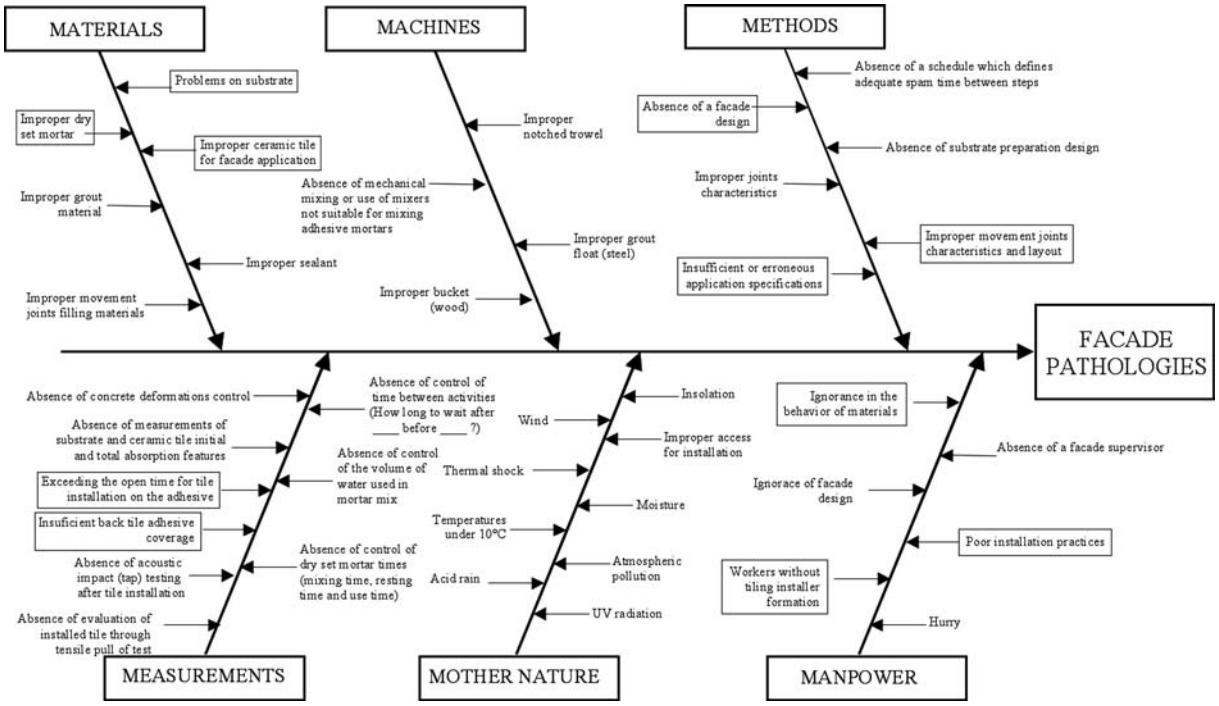

Figure 9. Cause and effect diagram for facades pathologies with major causes of defects highlighted.

4. CONCLUSIONS

In the present work, Cause and Effect Diagram was found to be an important tool to evaluate the major causes of pathologies in ceramic tile system and helped in the definition of the most important actions towards reducing these defects.

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