ASSESSING STRUCTURAL DAMAGES OF A HERITAGE BUILDING
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Abstract
This paper presents an intensive structural survey work on an industrial heritage structure. This study identified the decay mechanism and material characteristics of the historic structure, including material homogeneity, material strength, structural failures with crack pattern, and deteriorated surface. The damages in the building include decay in timber and stones, dampness problem and incompatible structural assemblage. The lack of a long-term maintenance is one of the potential causes which aggravate the decay mechanism. The findings permitted to appraise the structural safety and to depict some recommendations for better treatment of the structural cracks to restore this industrial heritage structure. These proposals would be useful in the conservation management plan of the city.

1 INTRODUCTION
During the industrial revolution, a huge number of factories, warehouse, power plants and other industrial structures were built, which are significant due to their architectural, technological and social value (TICCIH, 2003). These structures became the part and parcel of the urban landscape and in the course of time it was converted into the visual landmarks. However, due to the lack of good care and change of the service mode, gradually lead these industrial structures to their extinction (Läuferts & Mavunganiidze, 2009).

Awareness is being built up among people from a remarkable pace of time for restoring and preserving these important industrial historic structures. Protection which includes the adaptation and re-use of these industrial heritage structures is an important issue of the sustainable development (Sýkora et al., 2010 a

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and Pickard, 2009). More specifically, it has been recognized (Sýkora et al., 2010b and Zhang, 2007) that the protection and re-use may positively contribute to the sustainable development.

The way of measurements regarding the restoration practice become more formal after the formation of ICOMOS, 2001, where specific recommendations were proposed for the restoration and the intervention of the historic structure. According to House of Commons, (2004) these monuments can act as an income generation source attracting tourists from around the globe. The tourists will be attracted if the true essence of any city with its monuments is authentically revived along with the state of the art touristic facilities.

In Europe, large investments have been provided for the inspection, non-destructive testing, monitoring and structural analysis of the historical constructions according the guidelines. Eventually these measures will allow for safer, economical and more adequate remedial measures of the affected historical structures (Lourenço, 2004 and Pickard, 2009).

Guimarães city is one of the oldest cities which is renowned for its antiquity and important historical monuments. In 2012, the Council of Ministers of the European Union had awarded this city as the European capital of culture to draw attention to the affluence, diversity and shared features of Europe’s cultures. The Couros district of this city was renowned for its traditional economic activities (tannery and textile industries). In the last quarter of a century these economic activities drop down which eventually increase the unemployment and degrade the living standard. To build up a platform for promoting economic development in the Couros district, a project named CAMPURBIS was proposed to refurbish and revitalize the urban area for attracting the tourist. The Âncora set of buildings was amongst the selected old industries which were considered as industrial heritage structure. Under this scheme restoration is needed for these old structures.

The goal of the present study is to identify and specify the decay mechanism of the historic structure. Combined structural survey and intensive visual evaluation allowed to enabling damage detection and material characteristics, including material homogeneity, material strength, structural failures and crack pattern, and deteriorated surface. The result of the aforementioned methods permitted to appraise the structural safety and depicting recommendations for the restoration of this industrial heritage structure which would undergo for the conservation management plan of the city.

2 MATERIALS AND METHODOLOGY

International Council on Monuments and Sites (ICOMOS) has been working on the principles enshrined in the Venice charter, 1964. On October, 2003 some specific recommendation was approved by ICOMOS for the analysis, conservation and structural restoration of architectural heritage through the formation of the International Scientific Committee for Analysis and Restoration of Structure of Architecture (ISCARSAH).

The main principles of their proposals are general criteria, research and diagnosis and remedial measures and controls. They also fix some specific rules and methodology such as general criteria, acquisition of data on information and investigation, the structural behaviors, diagnosis, safety evaluation and decision on interventions which lead to the explanatory report (Croci, 1998, CUR, 1997 and Giuffre, 1993). Structural behavior and material characteristic are the guiding factors to understand the heritage project. Diagnosis of the problems in structure depends on the qualitative and quantitative information.
The qualitative approach is based on direct observation of the structural damage and material decay as well as historical and archeological research, while the quantitative approach requires material and structural tests, monitoring and structural analysis (Lourenço, 2004).

Contemporary standard based structural calculations or code based design guidelines are not best suited or even inapplicable to the historic structure. Multidisciplinary approach has to be considered in order to reach the optimal solution for conservation and restoration of the monumental heritage (ICOMOS, 2003).

The multidisciplinary approach involves four main activities:

- Historical investigation;
- Inspection;
- Monitoring;
- Structural modeling and structural analysis.

Figure 1 shows the general methodology for evaluation and diagnosis of any historic structures.

![Fig. 1 Overall flowchart of assessment and diagnosis of heritage structure (CIB, 2010)](image)

In this study, a qualitative approach has been taken into account for the structural survey of this historic commercial structure which is recommended by ICOMOS. Data were collected by visual inspection, photographic survey and the several interviews with the local people and the concerned authority of the municipality. Further inspections and tests have been proposed to assess the damage more precisely.
3 HISTORY OF PROJECT
The Âncora set of buildings was built in the second half of the 19th Century and belonged to the leather plant of Cristovão de Silva. They are placed in the historical center of Guimarães, in an area of leather works tradition since the 14th Century, next to the Couros River (Figure 2). For instance, there were more tanneries there than in Lisbon, Oporto or Braga together. Cristovão de Silva was the most important producer, being awarded at the Industrial Exhibition of London, Oporto and Braga. His mansion was built adjacent to the plant and other similar buildings were built in that area. Therefore, this set of buildings and the surroundings have an important historical and cultural value for the city.

Fig. 2 Âncora set of buildings in the Couros area (GTL, 2002)

Fig. 3 Spatial and plan view of Âncora set of buildings (GTL, 2002)

4 BUILDING MATERIALS
This ancient factory consists of three buildings of 1 or 2 storied (Figure 3), made of stone masonry and timber trusses. In every building the load bearing walls at ground floor were constructed by stone masonry (30 cm width) with lime mortar. Flooring material at 1st floor was a wooden plank supported by wooden beams and joists. At roof wooden trusses were used with roof tiles. Louvered and equally spaced wooden battens were used at 1st floor level for good aeration which helps to tan the animal skin.

5 STRUCTURAL SURVEY
The vital findings from the structural surveys are the identification of damage scenario and their behavior of the generation and propagation.
6 Damage in building 1

The location of building 1 in the study area is shown in Figure 3. After careful observation, the detected damages are shown in Figure 4. These different types of damages or problems are described below.

![Fig. 4 Damage map of Building 1](image)

6.1 Cracks in Wall

A Series of diagonal cracks were observed at the front façade starting from corner of doors and windows. Average widths of the cracks were 20 mm. From the observation it was seen that these cracks were repaired by cement mortar before. These cracks are seemed to be still active and widened its crack opening with spall down the repaired mortar. These cracks give an expression caused by differential settlement of the structure (Figures 5 and 6).

![Fig. 5 Cracks on the front façade of Building 1](image)

6.2 Column related problems

Stone columns were found to be quite slender. In various locations, these stone columns were replaced by timber which has lower strength and stiffness in comparison to the stone (Figure 7). The iron dowels which were placed between the stone column and ground beam had been corroded (Figure 7.a).
6.3 Deterioration of Roof Tiles

From the survey it was found that tiles on roof were broken and even disappeared. This allows rain water intrusion which eventually worsens the inner structure (Figure 8). Lack of maintenance was the reason behind it.

6.4 Balcony Supporting Members

Some of the struts that support the balcony had no stable support condition which may slip at any time (Figure 9). Depending on the case, the base needs rearrangement or substitution the strut by other suitable means to ensure the stability of the balcony.
6.5 Recommendation for Quantitative Analysis

Among all problems, wall crack must be further studied. The crack monitoring instrument should be installed to measure the rate of increase the cracks. In addition, an inspection of the foundations and a characterization of the soil could help to confirm the collapse mechanism. Structural analysis should be carried out for better understanding of this behavior. In order to do the structural modeling, non-destructive tests may be carried for the characterization of the materials. The basic mechanism of the other problems was visually identified and suitable intervention technique can be drawn without further quantitative analysis.

7 CONCLUSION

The present study comes together with structural survey along with intensive visual evaluation of the historical Ankara set of building components. The total procedure was a qualitative and quantitative approach where the damage patterns and major problems were chalked out for the future restoration and preservation works. The results revealed that the major problems are due to structural cracks and deflection of the stone masonry wall, deterioration of wooden structure, improper load distribution by column and struts and disintegration of the stone.

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