THE CITADEL OF ERBIL: STRUCTURAL ASSESSMENT AND
PRESERVATION MEASURES

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Abstract. The Citadel of Erbil (Kurdistan-Iraq), with eight thousands years of inhabitation, is considered one of the oldest continuously inhabited urban settlements in the world. It is built on layers of archaeological ruins that witnessed the rule of many historical nations.

The citadel earthen mound has an altitude of about 32m higher than the surrounding city with hill sides slope in a steep way towards the surrounding valley. Most of the houses inside the settlement are poor one or two stories high, constructed from brick walls and having mud roofs supported on timber joists, however, few luxurious house having architectural values still exist at the southern zone of the citadel. These houses are relatively large in terms of size, having fountains within their courtyards and verandas which carried on columns made of timber or marble. Along the perimeter of the mound, houses were built from adobe bricks to form the citadel external façade. Now, all the houses within the citadel are abounded, with few of those with architectural values utilized as museums, exhibition and cultural centers.

In 2008 a global project was initiated by the UNESCO for revitalization of the citadel of Erbil. This paper summarizes the findings of the structural study that was conducted at that time, with the aims of 1) Assessing the current structural conditions for the citadel buildings and 2) Defining the priorities for intervention and proposing the different intervention schemes. In this regard, this paper discusses in details the different damage patterns observed within such large inventory of historical houses. These damage patterns included deep through cracks within bearing walls, severe deterioration to wooden roofs, decay of wooden columns, spalling of walls plaster layers, separation gaps between perpendicular walls, severe cracking to flat barrel arches and movement for the walls forming external façade along the face the mound slope. Then it explains the proposed retrofitting measures to retrofit such endangered citadel. These measures included, ensuring the stability of the mound slope, stabilizing the external façade walls, repairing disintegrated and decayed wooden roofs, repairing damaged walls and tying walls together strongly.
1 INTRODUCTION

The citadel of Erbil lies in the middle of the city of Erbil (Hewler) which is the capital city of the Kurdish regional government of Iraq. It has an elliptical plan with a long diameter of 430 meters and a short diameter of about 340 meters as can be noted from Fig.1 that shows an aerial photo to the citadel. According to literature, with seven thousand years of inhabitation or more, it is considered the longest inhabited place on the earth by people and unique for not being military structure like the citadels of Cairo, Aleppo, Damascus [1]. The citadel is situated on top of artificial, 32-meters high earthen mound with its sides slope in steep way that reaches at some locations nearly 45 degrees towards the surrounding valley. It has a total of 330 houses out of about 500 that possess important cultural and architectural interest.

Like most of the historic sites, there have been some rebuilding and new additions over the years, nevertheless, the citadel kept its essential physical elements such as its perimeter wall, urban pattern, overall aesthetic and architectural qualities. Many of the citadel houses are traditional courtyard building having one-or-two stories high, constructed from ochre-colored bricks and having mud roofs supported over timber joists. Only few houses are considered luxurious with fountains in their courtyards and open verandas which are carried on columns made of timber or marble. In addition, there are several important public buildings such as 3 mosques, a public bath (Hammam), 7 historic graves, two gates, and several open urban spaces. The residential quarters are reached by a labyrinthine network of narrow pedestrian alleyways which spread out in a tree-like pattern from the main Southern Gate.

In 2008 a global project for revitalization of the citadel of Erbil was launched under the UNESCO and HCECR (High Commission for Erbil Citadel Revitalization) umbrella. The findings listed in this paper are part of the preliminary structural study conducted at that time with the aim of 1) Assessing the current structural conditions for the citadel buildings and 2) Defining the priorities for intervention and proposing the different intervention schemes.
2 STRUCTURAL SYSTEMS AND CONSTRUCTION MATERIALS FOR HOUSES

The houses within the citadel complex are bearing wall type structures that are traditionally built from adobe blocks as shown on Fig.2. The walls consist of multi-leaves with the two outer layers are formed from well-dressed adobe blocks bounding between them a filling layer made of clay/lime and pebbles as can be observed from Fig.3. At certain locations, were new interventions were utilized, cement blocks were used. Roofs were constructed from wooden joists supporting wooden blanks or blanket from palm leaves covered by layers of lime/clay and cement mortar as shown on Fig.4. These joists, in turn, were supported on the bearing walls. For more recent buildings, steel beams with flat arches from adobe blocks were used to construct the roofs as shown in Fig.5. Internal walls were plastered in many cases using new cement based plaster or old plasters made from clay and lime, while external walls were either plastered or covered with marble stones as shown in Fig.6. In other cases, they were left uncovered as shown on Fig.3 [2].
Figure 4: Wooden joists supporting wooden blanks and supported in turn on the houses bearing walls.

Figure 5: Roofs constructed from Steel beams with masonry flat arches in between.

Figure 6: Different cladding types used for external walls
3 CITADEL CURRENT STRUCTURAL CONDITIONS

As previously indicated, the buildings within the complex are categorized into two groups, one group includes luxurious houses that have special architectural features and have great value and another group of ordinary houses having limited architectural value.

For the luxurious houses observed damage included; 1) Deep through cracks within the bearing walls (Fig.7); 2) Severe deterioration to wooden roofs and columns supporting them due to aging process, environmental conditions, infiltration of water from the roof and infection by insects (Fig.8); 3) Movement of the building walls facing the mound slope due to possible soil settlement or erosion of the mound slope (Fig.9); 4) Damage to buildings steel cantilever balconies due to severe rust of the steel sections and deterioration of flat arched masonry between the steel beams as shown on Fig.10; 5) Spalling of plaster layers covering the walls due to high dampness in the walls as shown on Fig.11; 6) Complete separation between perpendicular walls and initiation of deep through cracks at walls intersections, especially the walls located along the mound steep slope. Those cracks were initiated mainly from settlement of soil underneath these walls accompanied by lack of physical connection between these walls and walls perpendicular to them (Fig.12) and 7) Severe cracking to basement roofs that have the form of flat barrel arches as shown in Fig.13.

For the ordinary houses damages patterns included, in addition to those observed for luxurious ones the; 1) Collapse and shearing to arches as shown on Fig.14 and 2) Severe deterioration and bulging of walls due to high dampness coming both from roofs and ground as shown on Fig.15. Such dampness caused the filling layer to expand pushing the external adobe layer.
Figure 8: Deterioration of wooden roof joists, roofing layers and wooden columns

Figure 9: Movement of external façade for one of the buildings

Figure 10: Deterioration of cantilever Balconies
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Figure 11: Spalling of plaster layers

Figure 12: Deep through cracks between perpendicular walls

Figure 13: Cracks through the basement roof
As previously indicated, this citadel has no traditional fence, but the external walls (external façade) of the houses located near by the slope of the mound formed together with the mound steep slope a protective fence against attackers. Examining the houses located along the mound slope and the slope itself indicated that they experienced severe damages. These damage patterns included: 1) Failure to external wall brick layer due to dampness as shown on Fig.16; 2) Total collapse to façade walls at certain locations as shown on Fig.17; 3) Exposing façade wall foundation at several locations (Fig.16); 4) sliding of the mound soil and its movement due to instability of the slope under the action of running ground water that seep from the mound to out-side. This was evident from the cavities and holes noted within the
slope and shown in Fig.18 and the dampness noted in the walls at foundation level; 5) Erosion to the slope with time at many locations, which added to soil movement and exposed the façade foundation leading to lose of the required foundation embedment as shown on Fig.19; and 6) Lack of physical connections between perpendicular walls which allow building walls to behave separately and allow for wall cracking especially at corner connections.

Figure 16: Damage to façade walls due to dampness

Figure 17: Collapse to façade walls and failure to external wall brick layer
PRIORITIES FOR INTERVENTION AND PROPOSED DIFFERENT INTERVENTION SCHEMES

Based on examining the current structural conditions for the citadel houses, priorities for interventions were decided. These priorities we arranged as follows; 1) immediate interven-
tation with the external façade. This is important to avoid failure of any part of this façade which is considered loss to architectural heritage and to ensure safety of people living nearby the mound. In this regard, priority maps similar to that shown on Fig.20 and utilizing color coding to indicate the level of dangerous associated damage of façade were produced. In these maps red indicated endangered sections that need immediate intervention, yellow for less endangered sections, and green for safe sections; then, 2) intervention with building having architectural values; and finally 3) intervention with buildings having less importance.

Figure 20: Map showing the priorities for intervention with external façade

Following identifying the priorities, different retrofitting schemes were proposed for structural restoration of the citadel houses. They include; 1) Stabilizing the side slope of the mound using micro-piling to avoid possibility of slope sliding especially during earthquakes. This technique was previously used at several locations for stabilizing earth slopes [3]; 2) Creating deep foundation to the façade walls, since open pits excavated adjacent to these walls indicated that they are directly founded on top of the mound. In doing that, a scheme consists of executing plastic concrete piles parallel to these walls from both sides followed by grouting between them to create the required deep foundation underneath façade walls was proposed as shown on Fig.21; 3) Connecting the walls of each house together at foundation level by RC strip footings that cast adjacent to these walls and connected to them by steel ties to form a closed frame; 4) tying the external walls to internal walls perpendicular to them at several levels using steel ties similar to that shown on Fig.22 to ensure that external walls will join strongly the internal walls and close any existing gaps between these walls; 5) replacing the damaged wooden roofs by new ones that are rigidly connecting to walls to form a rigid diaphragm at roof level; 6) Lowering the ground water table inside the citadel by preventing any leakage from water supply system and installing drainage system to discharge the water outside the citadel and keep the ground water table low as possible; 7) demolishing and reconstructing all sheared arches, bulged and severely deteriorated walls; 8) Stitching all deep cracks within the walls by using timber stitches or carbon fiber bars; and 9) removing all new intervention using cement and re-plastering all walls using original materials.
5 CONCLUSIONS

This paper presents the findings for the preliminary structural study that was conducted to assess the structural conditions for the houses of Erbil citadel with the aim of defining the priorities for intervention and proposing different intervention schemes. The paper described in details the different damage patterns observed within citadel houses, the priorities for intervention and in general form the different proposed schemes for intervention.

REFERENCES

