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Foundation systems of some heritage buildings in Najaf/Iraq case study: Al Shelan Khan

N.K.S. AL-Saoudi
Building and Construction Engineering Department, University of Technology, Baghdad, Iraq

M.Sh. AL-Shakerchy
Civil Engineering Department, University of Kufa, Najaf, Iraq

ABSTRACT: The word "Khan" refers to the place where visitors to Najaf city will rest for few days. Historically visitors with their animals, as the only means of transport, usually come to Najaf city in certain religious occasions, rest and settle down in Al Shelan Khan. The Khan was constructed in 1895 by the governor (Wally) Muhammad Mueen Aga during the last years of the Ottoman Empire. The Khan is distinguished by its architectural design and the configuration of the types of columns and arches. The structure has an overall area of 1500 m^2 consisting of two floors and three basements located at different places in the structure layout. The foundation of the structure is strip type extended approximately 5.5 m below ground level. Bricks of dimensions 22 cm ∗ 10 cm ∗ 4.5 cm are the building units with a mixture of "juss", lime as binding material. The paper focuses on the overall structural skeleton of the Khan and on the analysis of foundation system.

1 INTRODUCTION

Najaf is one of the most important cities in Iraq due to its spiritual and religious reputation. It is located in middle of Iraq and south of Baghdad in the west of the Euphrates River. Locally Najaf extends between 44° 15′ 23″– 44° 25′ 25″ longitude and 31° 54′ 25″–32° 02′ 45″ latitude and lies on the edge of the sedimentary plain of the lower Mesopotamian. Figure 1 demonstrates the location of Najaf city with respect to Iraq.

Najaf city has a remarkable historical background. It is a holy town containing the shrine of Imam Ali Bin Abe Talib, the fourth Caliph and the cousin of Prophet Muhammad. The city is distinguished by its religious reputation which makes it a respectable place for all mausoleums. The city host many archeological monuments and heritage structures, among these is Al Shelan Khan. The Khan was constructed in 1895 by the governor (Wally) Muhammad Mueen Aga during the last years of the Ottoman Empire to serve as a rest house for the visitors of the holy shrine of Imam Ali Bin Abe Talib and sometimes by merchants travelling between different places; as part of the trading activities. After many years, the Ottoman government decided to make the Khan as head quarters of the Ottoman government. (A1-Khalidi 2010)

From 1915 till 1920, the Khan was the centre of the local government under the control of the

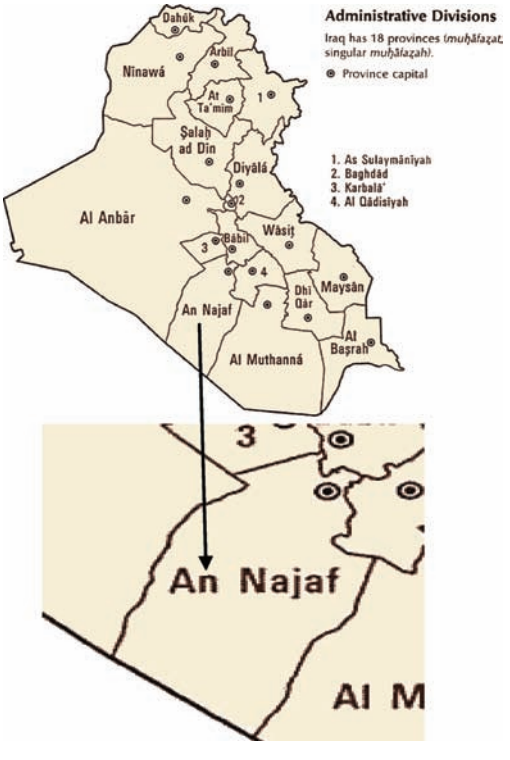

Figure 1. Location of Najaf city in Iraq.

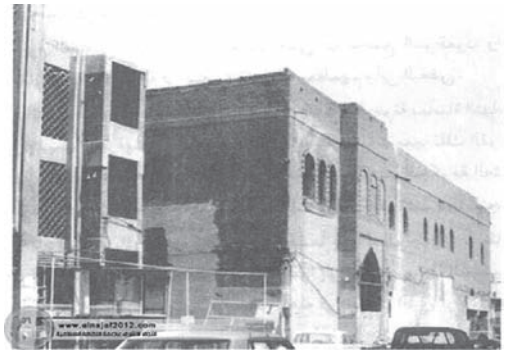

Figure 2. Old photo of Khan Shelan.

Figure 3. Damaged parts of Khan Shelan.

British authority. In 1920 and after the Najaf revolution, the Khan had been used for different purposes. Figure 2 shows one of the oldest photos of the Khan (Al-Arraji 2011).

As many other historical and cultural places the Khan suffers from the lack of rehabilitation and maintenance. During the past decades, it was used by the local people of Najaf in an illegal way. Parts of the ground floor were modified into a number of stores that damaged its architectural presence as a heritage symbol of Najaf city. Parts of the Khan were also subjected to devastation by vandalism actions and many others were damaged due to the long period of different environmental conditions. Figure 3 shows parts of the devastated arches and walls (Shinan 2012).

Currently the local government of Najaf is rehabilitating and redecorating this heritage structure. After the rehabilitation is completed, the Khan is going to be the historical museum housing the panorama of the Najaf revolution in 1920 and many archeological and cultural pieces of the city.

2 GENERAL DESCRIPTION OF THE KHAN

The Khan is an old bearing type structure of plan dimensions 45 m by 46.5 m, consists of two floors with open yard 20 m by 22.66 m in the middle of the structure, figure 4. The total height of the Khan is about 11.5 m above natural ground level. The Khan contains many rooms of different dimensions with two distinguished large rooms on the ground floor of dimensions 9 m ∗ 9 m and double height ceiling, which were probably used as meeting halls.

There are three basements extending in depth to about 5 m below natural ground level, two of dimensions 9.18 m ∗ 10.15 m and the other 9 ∗ 11.5 m. Figure 5 shows the location of the basements.

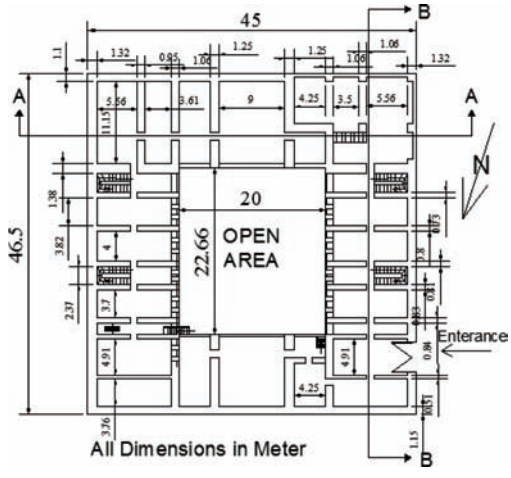

Figure 4. General plan of Khan Shelan.

Figure 5. Location of the three basements.

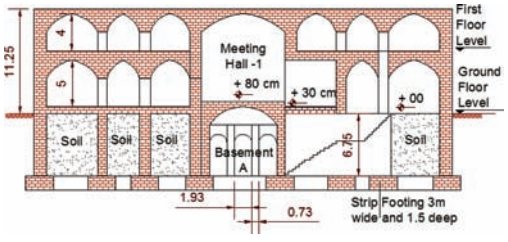

Figure 6. Section A-A in figure 4.

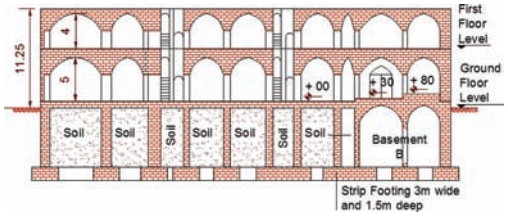

Figure 7. Section B-B in figure 4.

Figures 6 and 7 show the details of the sections A-A and B-B in figure 4. The two sections in figures 6 and 7 clearly demonstrate the different arches used in the Khan and all foundations are placed on the same level.

3 THE STRUCTURAL ANALYSIS OF THE KHAN

The whole structure was constructed of bearing walls made of bricks of dimensions 22 cm ∗ 10 cm ∗ 4.5 cm. These dimensions are not the same as the current standard brick dimensions. The mortar between the bricks is a mixture of lime and "juss". The structure is distinguished by its architectural and structural design. The ceilings of the rooms are basically a combination of arches and domes, supported by different sizes of embedded columns in the walls. The different patterns of ceilings are discussed separately according to their existence in the structure.

3.1 *The basements*

A typical section in basement A of dimensions 9 m by 11.15 m is shown in figure 8.There are two types of embedded columns in the walls; the major ones are 1.06 m ∗ 2.20 m and 2.5 m apart along the long sides and the minor ones are 0.52 m ∗ 2.00 m along the short side, 2.45 m apart. Each two opposite columns support a complete arch, and the number of arches forms the ceiling of the basement. Figure 9 shows the merging of two arches from the top of a column.

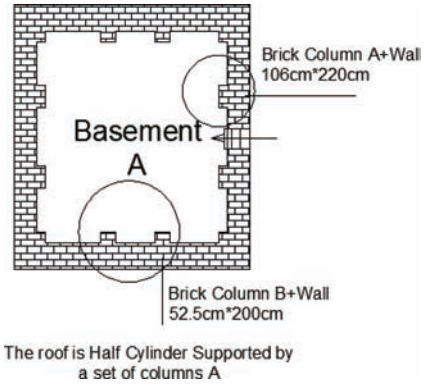

Figure 8. Section through basement A.

Figure 9. Two arches in different directions merging from one column.

Figure 10. Patterns of decorations on the walls of the basments.

Figure 10 demonstrates the different patterns of decoration observed on the walls of the basement and in many other walls of the Khan, with inner circular arches between the columns. All these decorations were made using the same building unit with perfect measurements and stiles.

3.2 *The meeting halls*

The two meeting halls in the ground floor, figure 11, have similar pattern of columns to those

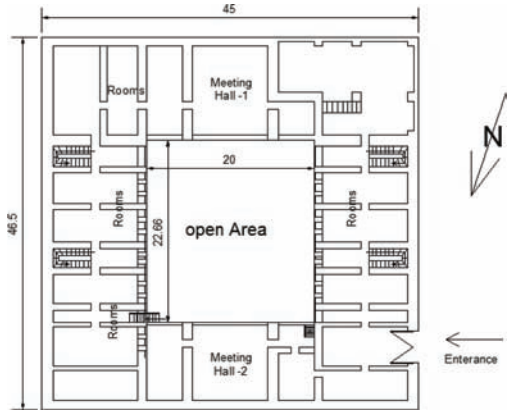

Figure 11. Location of meeting halls.

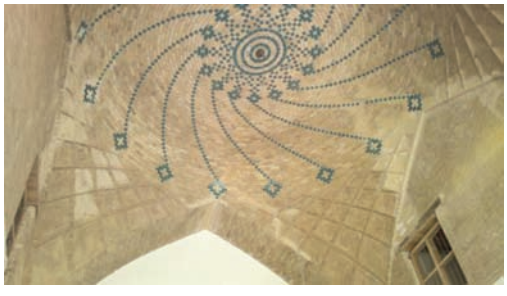

Figure 12. Original decoration of meeting hall 2.

in the basements but the columns are higher since these two halls are designed to have double height ceiling as shown in section A-A of figure 6.

The ceiling of meeting halls has the shape of a dome with real artistic patterns of decorations. The dome of meeting hall 2 remained in its original shape and decoration as shown in figure 12, indicating high quality of artistic proficiency.

Meeting hall 1 was subjected to serious damage and during rehabilitation it was nearly removed and reconstructed using the same size of building units. In spite of the great efforts made by the working crew to get as close as possible, the same decoration of the dome of meeting hall 2, the builders were unable and unsuccessful in achieving the same pattern of decoration as shown in figure 13. The difference in the quality and patterns of decorations can clearly be observed in the two figures.

3.3 *Rooms*

The same construction approach was used in all rooms. The ceiling of all rooms is made of close arches. The space between two adjacent arches

Figure 13. Decorated ceiling of meeting hall 1 after rehabilitation.

Figure 14. The inside of a typical room after plastering.

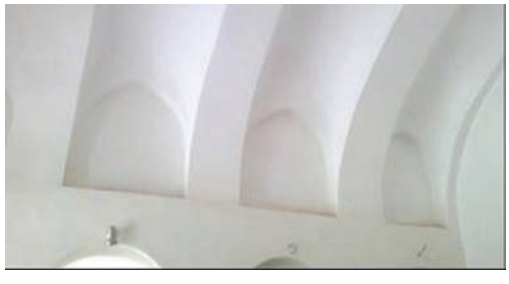

Figure 15. Typical ceiling of room-arches in the form of ribs.

depends on the dimensions of the room. These arches act as ribs and the bricks filled the space between them taking the curvature of the arches. Figures 14 and 15 demonstrate the pattern of arches in a typical room after rehabilitation.

Most of the walls in the rooms were constructed with high artistic decoration similar to those shown in figure 10. The working crew was unable to restore and preserve these original fantastic decorations due to the lack of experience and most of these decorations were covered by a layer of "juss" and lime as shown in figure 14.

4 FOUNDATION SYSTEM OF THE KHAN

All the walls are of bearing type extending approximately to a depth 5 m below natural ground level, resting on a strip footing 3 m wide and 1 to 1.5 m thick. The walls and the footings are all constructed from bricks with "juss" and lime as mortar. It is hard to inspect the durability of the building materials of the footings under such high stress, but since they remained sound for more than 100 years, it is thus expected that both walls and footings had integrated and interacted, in such a way that they formed a rigid pad able to sustain high stress under sever environmental conditions.

There are no geotechnical data reflecting the current geotechnical properties of the soil underneath the Khan as it is impossible to get the drilling facilities inside the building. It was suggested that the soil investigation report of the multistory building close to the khan, shown in figure 2, can be adopted. The report was prepared in the sixties, and revealed the soil stratification shown in figure 16.

Figure 17 demonstrates that the top 5 m has an SPT-N value between 10 and 30, overlaying a strong layer of SPT-N—value >50.

Since the base of all footings of the Khan is located approximately 5.5 m below natural ground surface, then the footings of the whole structure are resting on the strong layer of medium to very dense silty sand mixed with pebbles and gypsum. Previous studies on Najaf soil (Al-Shakerchy 2007), showed that the presence of high gypsum created lumps of cemented material that exhibit high resistance to penetration.

For this particular case where the strip footing 3 m wide, placed at a depth D = 5.5 m, below natural ground level, the allowable bearing capacity based on 25 mm settlement can better be estimated using the equations proposed by Meyerhof 1956, 1974. The proposed equations shown below are based on SPT data corrected to N_{55} or N_{70} as reported by (Bowles 1996).

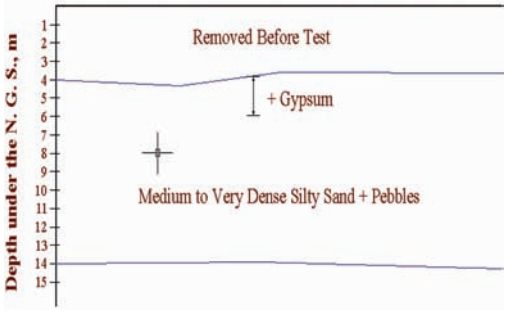

Figure 16. Soil stratification from a nearby site to the Khan.

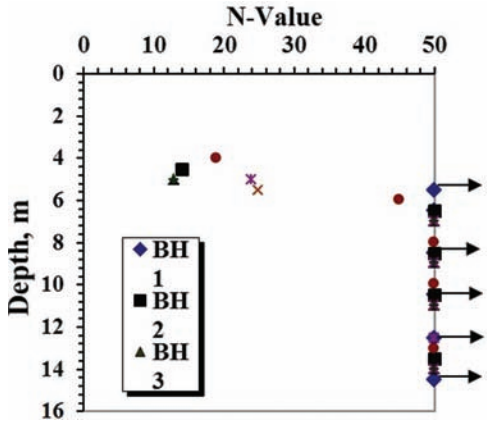

Figure 17. SPT versus depth.

$$q_a = (N/F_1) * K_d \ldots \quad \text{for} \quad B \le F_4 \tag{1}$$

$$q_a = (N/F_2) * ((B + F_3)/B)) * K_d \ldots \quad \text{for} \quad B > F_4 \tag{2}$$

where q_a = allowable bearing capacity in kPa for settle ment 25 mm.

$$K_d = 1 + 0.3\,(D/B) \le 1.33 \tag{3}$$

Since the geotechnical report was written in the late sixties, it is more reliable to consider the F factors corresponding to N_{55} rather than $N_{70.}$ The quoted values are $F_1 = 0.05$, $F_2 = 0.08$, $F_3 = 0.3$ and $F_4 = 1.2$ (Bowles 1996).

Substituting for D = 5.5 m, B = 3 m and N = 50 in equations 2 and 3, the obtained allowable bearing capacity is 1006 kPa.

According to the measured dimensions of the structure shown in figures 4, 5, and 6, an estimate was made of the average total applied stress generated from live and dead loads of the different structural elements. The outcomes of the analysis revealed a total stress of 775 kPa on a strip footing 3 m wide. Since the depth of the footing is 5.5 m below natural ground level and the submerged unit weight of the soil approximately equal to 10 kN/m^3, the net applied stress at base level is determined as

$$q_{applied} = q_{total} - (\gamma)(D)$$

$$q_{applied} = 775 - (10)(5.5) = 720\ \text{kN/m}^2 \tag{4}$$

The settlement corresponding to this net applied stress will be

$$S = (720/1006) * (25) = 18\ \text{mm}$$

Meyerhof 1965 proposed another approach for estimating the compressibility of cohesionless soil.

The proposed equation, shown below, was applied for the current foundation keeping N = 50.

$$S = (2q/N_{60})(B/(B+0.3))^2 \quad \text{for} \quad B > 1.22\,\text{m}$$
$$S = (2 * 720/50)(3/3.3)^2 = 24\,\text{mm} \qquad (5)$$

In terms of settlement calculations the two values can be averaged to 21 mm. In case this settlement had occurred during the life time of the structure, nearly 100 year, its influence is inconsiderable in causing any serious structural damage to the skeleton of the structure. Close inspection of the whole structure from the inside and outside, did not show any significant cracks or signs of excessive settlement or tilting.

The ground floor level experienced some heaving, in the open areas, due to the lack of proper drainage system. Some deterioration of the walls was also observed due to capillary rise. It can be stated that the Khan was damaged by environmental conditions and by local people taking parts of it as small shops and changing its original architectural appearance. Rehabilitation process is in the final stages and figure 18 shows the new appearance of the Khan from the interior open yard.

Figure 18. View of the Khan from the inside yard.

5 CONCLUSIONS

All nations must be proud of their ancient history as it represents the period where man began to set up the paths of the civilized life. Conservation of cultural and historical sites must be well preserved and passed to the new generations. The paper presents a review of the rehabilitation process taking place in Khan Al-Shelan, one of the heritage structures in Najaf city in Iraq. The paper sheds the light on the quality of the structural elements, types of arches, the difference in the quality and proficiency of the workmanship in terms of architectural decorations.

In terms of structural analysis, the net applied stress on the base of the strip footing was calculated and found to be 720 kPa. This value is less than the calculated allowable bearing capacity, 1006 kPa. The compressibility was also calculated by two methods revealing an average settlement of 21 mm. This value is fairly small and caused no significant impact on the structure. The major source of damage was by the environmental agents.

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