Earthquake-Resistant Strategies in Traditional Architecture of Tabriz

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ABSTRACT: Tabriz, as a city located within a strategic location, northwest of Iran, has confronted many earthquakes throughout its long history. The influences of earthquakes on the old city of Tabriz are distinguished from other cities by two factors: First, it is located in a specific natural container surrounded by mountains and also on the intersection point of the two historical world trade routes; That is, the West to East and the North to South routes. The second factor is the buried wealth existing under the old Bazzar and the active merchandise in the city. These two factors prevented the city from moving to and being reshaped in another place and made people reconstruct the new city over the old one a number of times. The restrictions in the geographical context and the strategic commercial location, have led Tabriz’s traditional architects to develop a number of strategies to confront earthquakes. The in-the-field study of the remaining traditional structures together with the historic printed material on the subject reveal some of these strategies that can be categorized into five main methods. This paper will show in detail how these five methods have been applied to the structures.

Keywords: Constructing Underground, Decreasing Hanging Decoration, Historical Architecture, Lightening Structure, Resistant Strategies.

INTRODUCTION

After each earthquake, which is followed by great destruction and decimation of inhabitants, the communal thought deals with it for a time and these events remain alive in memories by the viewers, travelogue writers, poets and historians. This way, the experiences will transfer to the next generations and will cause the architects to revise and select more proper ways to preserve people’s lives and properties by strengthening the buildings. The use of historic written materials, books and reports on Iran earthquakes and its reflection on the buildings has a long history outside Iran, for example the book The History of Iran Earthquakes by Ambraseys in 1982 in Cambridge. One distinct of such works is the book on Tabriz earthquakes by Yahya Zoka.

Tabriz, as a city located within a strategic location, northwest of Iran, has encountered many earthquakes throughout its long history. The influences of earthquakes on the old city of Tabriz are distinguished from other cities by two factors; First, it is located in a specific natural container surrounded by mountains and also on the intersection point of the two historical world trade routes; That is, the West to East and the North to South routes. The second factor is the buried wealth existing under the old Bazzar and the active merchandise in the city. These two factors prevented the city from moving to and being reshaped in another place and made people reconstruct the new city over the old one a number of times.

Regarding the earthquake risk plan of Iran, the city of Tabriz is located within the high risk region (Fig. 1). The most clear earthquake factor is the young fault north of Tabriz. This region has confronted many earthquakes throughout history, which have ruined the city completely a number of times, but the city has quickly regained its role, on the same place, in its national and international scales\textsuperscript{1}. It is about 240 years since the last earthquake in Tabriz happened. Statistics show that the return period of destructive earthquakes ranges between 260-379 years.

\textsuperscript{1} - In some other cities of Iran like Quchan and Kermanshah, after the destructive earthquakes the cities have moved and been reconstructed in another place.
Due to the reconstruction of the new city over the friable ruins of the older city, the newer houses were built low, one-story and with the use of mainly wood. Even the Palace of Shah (King's Palace) was also built using wooden anchors. In cities like Tabriz, earthquakes have led to the special construction strategies. These influences can be found in the establishment, the shape form, structure and even in architectural decorations (Ambraseys and Melville, 1982).

**Figure 1. Earthquake Risk Plan of Iran**

**Historical View**

Studying the historical texts on Tabriz we are confronted by descriptions about the city, the earthquakes, their impact on the buildings and some information about how traditional architects responded to them. Ali Mazaheri (1993) describes the city as "Trade in the city of Tabriz was of great importance, because the Italian merchants exchanged their own products and other European countries with products from China and India. Other Iranian products like fabric and textiles of Yazd and Kashan were also exchanged here". In the book Mojmal Fasihi, the earthquake of 1272 AD is described as "The earthquake in Tabriz destructed many buildings and caused the minarets to collapse" (Zoka, 1990). In the travelogue of Jubert, Voyage en Armenie et en Perse, we come across "Tabriz is today the second important city of Iran in terms of size and trade; The minarets seen here are much lower that minarets in Turkey" and he continues "Fear from earthquakes has taught the people that they should build the buildings as low as possible" (Jubert, 1968). Charle Auguste Benetepms (1966) describes the city, in his travelogue as "The people build the buildings not so high and the mosques do not have minarets". James Morier, in his first journey to Iran, describes the state of the remaining buildings as: "Most of domed buildings, especially Khan Hammam², which is the biggest in Tabriz, survived" (Morier, 2010).

**The Earthquake Resistant Strategies**

The study of the remaining traditional structures by the authors together with the historic printed material on the subject reveal some of these strategies taken by the traditional architects in Tabriz. These methods are as the following:

**Eliminating damaging elements**

Among the remaining traditional buildings in the city of Tabriz, the ones having distinct prominent elements such as high loggias, minarets and isolated two-layer domes are rarely seen. Of the high buildings of the city in the eras of Ilkhani and Teymourian, when Tabriz was the capital of Iran, unfortunately almost nothing has remained. Buildings with high loggias and mausoleums from Ilkhanid era which are generally seen in other old cities of Iran, can not be seen now in Tabriz, except for Arg-e-Alishah which its roof had collapsed even before earthquakes. The minarets which are the highest and the most distinct elements of Iranian Islamic architecture are not found or take a different shape in Tabriz; because of high destruction risks and also ruining the neighboring buildings. One

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² - Communal Bath House
of the major characteristics of Azari Style\textsuperscript{3} is the attached minarets to the building from the ground which attaches the two sides of the entrance loggia and are not much higher than the loggia itself.

But as eliminating these elements, would mean the elimination one of the main urban landmarks, the builders would substitute Mils\textsuperscript{4}. From the viewpoint of a citizen, mils and minarets have almost the same formal characteristics. But the minarets are usually more complicated in structure and form than mils; In fact, a mil is the simplest form of the minaret. The mils have their main structure made of wood which are integrated as a part to the whole structure of the building. In other historical texts such as the travelogue of Pieere Amedee Jubert and Charle Auguste Benetemps the reference to the low buildings and minarets can be found (Fig. 2) and also that the mosques do not have minarets (Jubert, 1968) and (Benetems, 1966).

![Figure 2. Mill Lee mosque in Tabriz](image)

Generally, the minarets, especially minarets of less structural homogeneity, are subject to more destruction during earthquakes. Besides their own structure, they might also cause destruction to other neighboring structures. Devising methods and endeavoring to strengthen the structures against earthquakes has also affected the forms of the domes. In Tabriz, lofty Isfahani-style\textsuperscript{5} domes are almost not found and in order to consolidate the domes against earthquakes, they are constructed in connected two-layer structures. There are examples of this type of dome such as Soltaniah dome, Kabood mosque dome and the only isolated two-layer dome is the dome of Haj-Safar-Ali mosque (Tehrani et al., 2001).

3-2. eliminating and decreasing the hanging decorations
The relation of decorative finishing and the structure might be divided into three categories:
- Decoration as a part of the structure itself
- Decoration attached to the structure after completion of the structure
- Decoration hanging from the structure

The destruction and collapse of hanging decorations, regardless of its direct injuries, would also change the form of the space. In Tabriz, the hanging decorations such as muqarnas are hardly used; also, instead of decorations like Yazdi-Bandi\textsuperscript{6}, structural Kar-Bandi decorations are used.

Most of the decorations used, are part of the structure. The most common decoration used is a 3-millimeter gypsum plaster on which the geometrical lines of the brickwork are carved off. That is, the extra layer on the bricks is cut off and the pointing would be protruding lines on the surfaces; the decorative pointing might follow the

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\textsuperscript{3} - The "Azari style" is a style of architecture when categorizing Iranian architecture development in history mostly found in Azerbaijan-Iran. Examples of this style are Soltaniyeh, Arg-i Alishah, Mosque of Varamin, Goharshad Mosque, Bibi Khanum mosque in Samarqand, tomb of Abdas-Samad, Gur-e Amir, Jame mosque of Yazd.

\textsuperscript{4} - A Mil is A persian word referring to a category of tall minaret-like structures that are used as landmarks within the cities or in the roads.

\textsuperscript{5} - The "Esfahani style" is a style of architecture (after Azari style) when categorizing Iranian architecture development in history mostly found in Isfahan. Examples of this style are Chehelsotoon, Ali Qapu, Agha Bozorg Mosque, Kashan, the Shah Mosque, and the Sheikh Lotf Allah Mosque. The Safavid dynasty were chiefly instrumental in the emergence of this style of architecture, which soon spread to India in what became known as Mughal architecture.

\textsuperscript{6} - Yazdi-Bandi is the non-structural kind of Kar-Bandi.
brickwork pattern or may create a different pattern. At the end of the process, the final brick pattern created will be painted (Fig. 3).

![Image](image_url)

**Figure 3. Brickworks with Protruding Pointing Patterns**

**Constructing partially underground**

When studying historical texts about earthquakes, we come across numerous cases in which people living in underground spaces have survived; a number of these earthquakes are 1779, 1787 and 1914 earthquakes (Zoka, 1990). The only building belonging to the time before ninth century earthquake, which has survived up to the present time, is a building under Bani-Hashem mosque which was not discovered until 1992 by the cultural heritage organization. The highest part of the building is about one meter lower than the new Bani-Hashem mosque floor (Fig. 4). The building, seeming to belong to Teymourian era, has been possibly the springhouse of an office house which has been used during six centuries (Tehrani et al., 1995). The location of the building underground, together with its shell roof and masonry materials, has made possible the resistance against thrust of the roof by the soil around it and this has let the architect use roofs of lower height. In comparison between the intersected high-rise vaults, the low rising non-intersectional shells have much better performance against the horizontal forces from the earthquake and reduce the probability of damage.
Construction underground will cause different problems such as the spatial connection of underground space to outside space, especially from the viewpoint of access and natural lighting. This problem becomes more complicated in underground spaces having stories above which block natural light from roof (Tehrani et al. (a), 1999). As construction underground has many advantages regarding earthquakes, contriving to install windows and doors between load-bearing mullions, requires special details for the openings in order to construct as low as possible (Fig. 5).
lightening of the upper parts and bringing lower the center point

Due to lack of wood resources in Iran plateau, wood technology is less developed than masonry construction technologies; besides that, the architectural decorations on wooden basis, are more restricted than those of masonry construction. The following table compares some of the structural features of the traditional materials used in construction (Table 1).

<table>
<thead>
<tr>
<th>Material</th>
<th>Density</th>
<th>Compression Resistance</th>
<th>Tension Resistance</th>
<th>Quality of Joints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone</td>
<td>Very High</td>
<td>Mid</td>
<td>Lacking</td>
<td>Much weak</td>
</tr>
<tr>
<td>Brick</td>
<td>High</td>
<td>Mid- Proper</td>
<td>Very low</td>
<td>Weak</td>
</tr>
<tr>
<td>Modular Mud</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Weak</td>
</tr>
<tr>
<td>Wood</td>
<td>Low</td>
<td>Proper</td>
<td>Proper</td>
<td>Proper</td>
</tr>
</tbody>
</table>

In this regard, the ground-floor story consists of lighter brick masonry walls than the underground structure. In the upper story, the amount of wood as vertical structural elements and lateral bracing increases (Fig. 6a&amp;b). In a number of cases, leaving spatial gaps in structure has also been applied in order to lighten the structure. Due to specific climatic features of Tabriz, nightlife on the roof, as it is common in central Iran plateau, is not a common tradition and all the requirements are eliminated from the roof structure (Tehrani et al., 1998). The thatch plaster is the only insulation used for the roofs, which might be damaged, by high amount of precipitation in the region. For this reason, the slope of the roof has been increased up to 8% in order to decrease plaster damage and water absorption by the roof. The other approach is to construct two-layer roofs to lighten the roof structure. Later, this kind of roof structure evolves to wooden space trusses with one-sided or two-sided slopes (Fig. 6c)
Injecting horizontal and vertical wooden framing to the structure in order to add to its integrity; the use of kalaaf

The kalaaves are connected wooden elements which make up a part of the structure and make homogenous the distribution of compression and tension forces on the structure and prevent the structure and its elements from collapsing. It should be noted that in traditional buildings of Tabriz, these wooden substructures are usually hidden under the finishing and when this is not possible, the architects has tried to make them subtle to distinguish by changing its color to the color of the bricks. These elements may be divided into the following categories:

**The Horizontal Kalaaves**

The XY planes make up the horizontal floors of the structure; thus, the kalaaves are found numerous in these parts and usually with square or circular profiles with half-half joints. These reinforcements may occur in rows with a unifying row in the outer level. When the materials used are not homogenous, like stone and mortar, these kalaaves are repeated in rows to homogenize the structural behavior. This kind of reinforcement is found almost in all brick columns (Fig. 8).

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7 - Pl. of kalaaf, a Persian word meaning a wooden or other material integrative structure added to a masonry structure to homogenize forces on the main structure.
The Vertical Kalaaves and the Diagonal wooden bracing

In a number of traditional houses in Tabriz, mostly related to Qajar era, a loggia with a width of about two meters covers the whole main facade of the building and shelters the entrance doors against rain and snow (Tehrani et al., 1999). The structure of these loggias is completely of wood that is covered with a thin layer of gypsum plaster to represent a masonry colonnade looking (Fig. 9). The wooden columns of these loggias are not directly connected to the earth; they are placed within stone pedestals having a hole for the column to stand in (Fig. 10). A continuous wooden beam holds these columns together; when the length of this beam goes beyond the usual lengths, it is connected to another beam through miter joints. When the columns are too tall, they are connected in the middle by secondary brace beams.

-When the diameter of the column is small they look thin, adding wooden pieces to add to its diameter while keeping it light, and then it is plastered to compensate it.
The diagonal bracing is composed of tilted beams installed between columns forming structures similar to two-dimensional trusses (Fig. 11). The places where windows and doors are situated are critical structural point; due to this, some the openings form wooden structural frames. The use of proper wooden and nail joints together, leads to a better structural behavior than the nail-only joints.
Studying the remaining structures of Tabriz’s traditional architecture, despite the wrong perception of low structural resistance, lead us to the conclusion that traditional building methods have been completely earthquake-conscious. The restrictions in the geographical context and the strategic commercial location, have led Tabriz’s traditional architects to develop a number of strategies to confront earthquakes. The field study of the remaining traditional structures together with the historic printed material on the subject reveal some of these strategies which can be listed as: eliminating damaging elements, eliminating and decreasing the hanging decorations, constructing partially underground, lightening of the upper parts and bringing lower the center point and finally injecting horizontal and vertical wooden framing to the structure in order to add to its homogeneity. The research to find more probable methods is still continued by the authors.

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