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# Iran Qajar's Era Architectural Heritage Durability

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**Abstract:** Defects or violations in protection, maintenance, consolidation and restoration of Iranian historic buildings made of brick are as the indicators of performance failure in the preservation of valuable architectural heritage of Iran during structural interventions. The problem is considered as a factor for disintegration in the essential components of this building that is, incompatibility of physical form, concept, function, technology and integrity. Therefore, inefficiency of some damaging and unnecessary interventions will be significant in the rehabilitation process, lack of codified rules, lack of appropriate awareness and lack of efficient patterns in the seismic protection and rehabilitation plan of Iranian historic structures. The present study hunted to discover a pattern consistent with the seismic stability of buildings against earthquake risks specific to the Iranian plateau. For this purpose, the physical geometrical characteristics of sustainable historic buildings made of brick in earthquake-prone areas with average and high relative earthquake acceleration were studied. With the overall evaluation of quantitative and qualitative characteristics of Iranian historical standing buildings made of brick and determination of the origin seismic condition, physical dimensions in width, length, height and the calculation related to the geometric proportions i.e. relative levels relating to the ratio percentage of relative walls, the raw data of research are acquired. In evaluation of the technical engineering standards, Iran (2800) earthquake code, the world valid charters and cods such as; (FEMA, CHBC, ISCARSAH, ICOMOS, ICCOROM) have been considered. The reliability and validity of the data were assessed by (SPSS) software. Survey evaluation and analysis of quantitative data obtained from the measurements was done by factor analysis between the dimensional components of the building and correlation between effective factors. Path analysis, discovering interactive structure and structural equation modeling process (SEM) for seismic stability model was done through (AMOS) software. Explaining the structural equation modeling related to the final effective factor i.e. the important factor of potential for seismic failure as independent variable, vulnerable factor of direct seismic resistance as the dependent variable and mediating factor of indirect seismic resistance as intermediary, the fitness of direct and indirect relationships among these factors was assessed. The seismic stability model of Iranian historical brick heritage with perfect reliability and fitness were determined. This study can be a criterion for developing rules on assessment, seismic design, seismic retrofitting and structural interventions in Iranian monuments made of brick.
**Keywords:** Architectural heritage of Qajar's era, seismic stability model, structural equivalence, rehabilitation or restoration and retrofitting

## 1. INTRODUCTION

Considering the extent and variety of architectural heritage in the world, protection and rehabilitation of all items in a balance and at the same time is impossible, therefore, a logical planning based on adoption of prioritization and recognition of the objective necessities as a decision criterion in the interventions is necessary. This requires active cooperation of senior officials from various countries and pro-environment groups and organizations responsible for the maintenance and preservation of the cultural heritage of nations. Since the early twentieth century, designers and manufacturers were willing to use reinforced concrete and steel to cope with the devastating effects of the earthquake. Because they felt that building structures do not have the tolerance and load capacity of earthquake. Review of the performance of traditional and historical monuments in dealing and bearing the earlier devastating earthquakes and reviewing past pre-concept causes a new trust for us to the structural seismic potential of monuments. It calls codified regulations for new building to challenge new perspective on historical and masonry structures. It is important to note that apparently poor communities should financially feel a greater sense of responsibility and protect to their own cultural treasures than others. Before any action, by identification and introducing these valuable and precious works; save their architectural heritage against amnesia and destruction in the process of the globalization of cultures which are survived from natural factors because of their compatibility with the elements of nature and save them against the real destructive factor of cultural heritage that is negligence, indecisiveness and lack of required support in maintenance, protection and rehabilitation of ancient architectural monuments.

After preparing a prioritized smart list of valuable architectural heritage, including the analysis of materials, structural damage, legal frameworks, indexing and mapping of risk-taking in terms of the amount of damage and serious irreversible collapses, cultural valuing and classification of objective dangers, the possibility of evaluation and planning interventions with respect to financial and operational resources and work capabilities are examined to prepare the comprehensive interventions plan at three levels of emergency actions (in the consolidation of failure process), preventive measures (in conservation and maintenance) and restoration measures (in improving the quality of building performances) to improve the quality of historic buildings. Interventional operations should be carried out in accordance with valid instructions such as ICOMOS. Any failure in this regard may lead to an increased risk of collapse of historic structures sensitive areas (G. CROCI, 2000).

It should be noted that proper design of form and dimensions and proportions of the body and orifices and orientation of historical monuments and matching their color, texture and materials and construction technologies of such buildings integrated in the regulation of environmental conditions within the building than outside are effective. In other words in historical monuments, effects of light, heat, humidity and vibrations are compatible with performances of their implementation. Historic buildings in different climatic conditions during summer and winter have a suitable use for human, but the problem of traditions and culture lying in the way of historic buildings as sustainable building tradition is considered as a learning lesson from pasts and is an active workshop of teaching traditional technology for today's designers to match a positive sense of optimization of communication and performance of architecture framework with environment for correct modeling (Dincyureka, 2003).

On the other hand, given the scarcity of traditional construction knowledge used in the construction of monuments and industrial development in developing countries to signify the cultural richness of the past for future generation and economic struggle of such long-standing plans with modern architecture, true value of the historical monuments need to be considered, compatibility with the environment and operating ease of many old buildings based on experience of hundreds of years to meet the local people's needs should be taken into account, understanding the theoretical and practical principles of design structure and implementation of traditional buildings will be examined. By analyzing the causes for vitality of valuable historical buildings, fundamental methods of design and construction of the sustainable architecture will be detected, methods for restoration and compatibility of key architectural buildings with environmental conditions would be disseminated (Miltiadis TZITZAS, 2004).

On the other hand, indigenous construction template in historical buildings can be considered as a bioclimatic template in architectural design. By translating the indigenous live constructional language as a language for modern construction and promotion of this process in modern architecture as an efficient design strategy, compliance and the necessary reconciliation between modern architecture and the environment will be provided. Stability of modern architecture would be developed. Because these lasting monuments have been formed based on smart trial and error over the past courses and during centuries-old periods of human life and were stable with their environmental strategy to counter the damaging environmental factors. Factors affecting the stability of these structures include: protection against light penetration and solar heat, proper utilization of solar radiation, the use of local natural resources, the form proper for land use compatible with environmental conditions, basic protection against wind, rain, cold, heat and withstanding other destructive factors in the location. So, during different seasons, they had provided user comfort stage in the best manner. Therefore, using traditional methods for enduring historical monuments in the design of new buildings can save energy, materials, internal comfort. Proof of this is clear for stability of historical buildings during past periods (Ignacio Canas, 2004).

Therefore, with adequate assessment of valuable historical monuments and places and enough attention to the risks and structural diversity of these monuments, plans for interventions, planning, safety precautions, protection and maintenance for the preservation of cultural identity of these buildings and promoting the quality of the monuments should be ratified, and easy access and rectification of damage inflicted and prevention of future destructive events should be provided. With attracting timely financial assistance and equipping proper facilities based on supportive policies of the recorded architectural heritage, and with compliance with technical guidelines and building codes; we can improve emergency and immediate, short-term and long-term protective and strengthening measures (Department of Environment Planning Guidelines, 2004). Geometric characteristics, context and connections between elements and components, the physical, chemical and mechanical features of materials, especially composite materials, and the mechanical behavior against static, dynamic and seismic loadings, especially the quantity and quality of masonry mortar used between the basic structure and shear and compressive strength of elements and details of the building, they have a great importance in analyzing the vulnerability of historical structures, and affect the retrofitting projects and improvement of seismic stability of such buildings. Apart from the vulnerability pattern, the damage of such buildings when presenting in urban high-density contexts should be sufficiently considered. We should consider the tolerance of compressibility and seismic of such buildings in terms of speed, acceleration and displacements resulting in structural members and materials used in historic buildings, assessment of creep, consolidation and historical structure subsidence. While examining the effects of retrofitting and rehabilitation treatments in the short term, durability and stability of structural quality promotion should also be interpreted and evaluated so that the compatibility of materials' behavior and applied restoration methods will be controlled by the location conditions (Luigia Binda, 2005).

Thus, the masonry buildings affected by the devastating earthquakes should be considered to learn lessons for the future. In this context, building materials have an important role in determining the behavior of masonry structures against earthquake, and can affect the methods of protection, maintenance, retrofitting and improvement of stability of monuments. Of course, the role of connections and lock of masonry structures in their seismic behavior is very effective. Even observing proper connections in ornamentation and extensions to structural members is effective in improving the seismic response (Richard E. Klingner, 2006).

Research questions

To carry out steps of research and discover the accuracy of assumed items and providing the results necessary for logical reasoning in solving the research problem, the following necessary questions on research should be carried out:

1.What are the physical features and geometric proportions of Iranian historic buildings made of brick?

2.What are the forms and shapes of the seismic stability factor of Iranian historic buildings made of brick?

3.What are the destructive and debilitating factors for seismic stability of Iranian historic buildings made of brick?

4.What are the effective factors in the integration of identity and the preservation of authenticity i.e. factors composing structure or seismic stability model of historical brick-made monuments in Iran?

Hypotheses

According to the research objectives and the relevant topic and issue, in the present study the most important assumptions can be expressed briefly as:

Main hypothesis: In case of discovery of seismic stability model of Iranian historic brick-made buildings and understanding the effective factors and structural relationships and determining the effect among the factors according to the structural equation, seismic stability of the Iranian brick-made historic buildings can be assessed. The need for structural interventions necessary in the structural components and structures of these buildings can be determined. To prove this hypothesis, the main components and categories effective in seismic stability of Iranian brick-made historic buildings can be evaluated and assessed based on the following sub-hypotheses:

1. First hypothesis: geometric proportions of the building body or indirect seismic resistance of Iranian brick-made historic buildings affects the direct seismic resistance of the buildings.

2. Second hypothesis: destructive factor or seismic potential in Iranian brick-made historic buildings affects the direct seismic resistance of the buildings.

3. Third hypothesis: destructive factor or seismic potential in Iranian brick-made historic buildings affects the geometric proportions of the buildings' body or indirect seismic resistance of the buildings

## .2. Methodology

In terms of the methodology, scientific research can be divided into the following major methods:

Historical research in analysis of the causes and the historical events, descriptive research in identifying the effective factors and relations among phenomena, survey in diagnosis of information and purposefulness of structural relationships, content research in a systematic description of social message, field research in testing hypothesis of interactions and relations of social factors, case study in determining all the characteristics and aspects of a study phenomenon, correlation research in determining the effectiveness and correlation of a phenomenon factors, field test research in the search of results of the manipulation in the variables of a studied phenomenon, causal research in the discovery of the cause and effect relationship between two specific variables and causal-comparative research in discovering the cause and effect relationship between dependent and independent variable.

In the same category, items such as statistical population, sampling method and measuring instruments in the study should be clearly stated in the research to clarify the procedure of the research. In this research, according to the circumstances discussed above, the methods of survey and correlation have been used to discover the factors affecting the seismic stability and determining the seismic stability model of the historical brick-made buildings.

Statistical population (field of research):

The statistical population consisted of all members of a real or imagined set of people, events or objects that the researcher wants to generalize his research findings to them (Gal et al., 2003). What is studied in the research is the element or unit of analysis called sample. Analytical data are collected from all individuals who are considered as the unit of analysis, to have a certain deduction from the statistical population (Delavar, 1998). Therefore, according to these definitions, the statistical population of this study includes Iranian valuable historical monuments, which have valid technical documentation, built in Qajar, Safavid and eventually Patriarch historical periods, have the brick-made masonry structure, the number of their stories is a maximum of two floors on earth or a basement and are in the seismic regions of Iranian plateau with relatively high to moderate risk that are able to maintain their seismic stability against earthquake and in terms of body, they have accepted complete technical and physical digital maps and tariffs of Cultural

Heritage Organization with the uniform distribution of location of the monuments across the Iran earthquake-prone plateau have been considered.

Research sampling method

Among the various methods of probability and non-probability sampling, by taking into account categories such as stratified, random or selective, it can be said that the only method in which the obtained results of that method are considered because on a particular group of statistical population classes, are obtained according to the expert judgment and opinion and sampling and preparation of questionnaires related to appropriate observations within the group is quite generalized, the method is non-random sampling or judgmental (Mohammad Reza Hafeznia, 2009). However, to prevent unnecessary waste of time and costs, the statistical population can be downsized and, but at the same time provide it with scientific precise sampling and reducing possible errors, provided that the sampling method has a selection method generalizable to the statistical population, and includes grouping, indices, stratification proportional to the population. In this regard, sampling is done as random, neatly organized, stratified, simple clustering, multi-stage cluster and voluntary. Although each has its specific functional specifications and special results, but it should be noted that the lower the number and size of sampling is, reliability and validity of sampling should be more and measurement errors of statistical data should be reduced (Delavar, 2006). On the other hand, in non-random sampling method, classification of the statistical population is common that by adjusting the sampling size so that by supplying the specialized view of researchers to at least 30 cases in the smallest group sampling is done and ensure that the sample selected based on the characteristics and factors which basis constitutes the classification and judgment, would establish consistency and true representation of the condition of the statistical population (Delavar, 2007).

So considering the objectives and hypotheses in existence and observing technology of seismic stability in monuments of Iran and understanding this technology when used by old designers and creators of ancient monuments and eyewitness of survival and durability of these buildings in dealing with the severe earthquakes, the statistical population samples and analyzing units are defined. Because the selection is done by nature and environment already according to the natural selection and these buildings have survived from the risk of failure of massive earthquakes.

Therefore, among the valuable historical monuments in Iran; seismic stability samples remained in earthquake-prone plateau of Iran which belong to the Qajar, Safavid and Patriarch periods up to 700-years with brick masonry structures and containing very authoritative technical documentation from the cultural heritage organization of country, so that they have various forms with a limit of maximum two storeys above ground and a underground like unarmed brick buildings. The buildings have a variety of applications in various climates and geographical locations. So taking into account the quantitative characteristics of such buildings from physical and geometrical aspects and based on engineering and technical judgment in seismic stability of buildings, sampling has been done through non-random judgmental method. So the set of selected items and their total specifications are presented in Table 1:

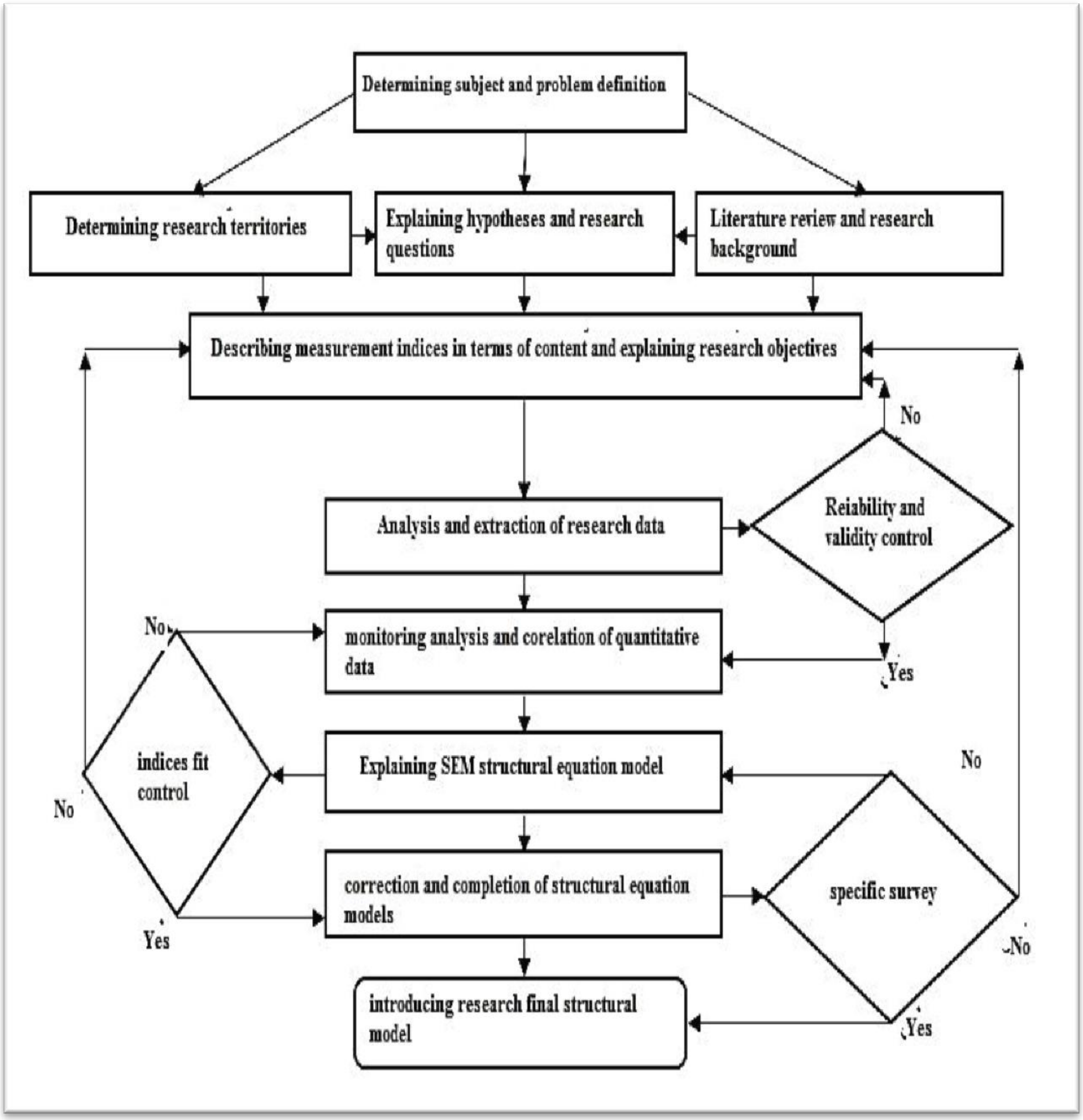
| Row | Name of monument | Location | Usage | Relative risk of Earthquake | Number of Roof | Estimated Age(Year) |
|---|---|---|---|---|---|---|
| 1 | Blue Mosque | Tabriz | Religious | Severe | One roof | 1465 |
| 2 | Sheikh Safi al-Din Khānegāh and Shrine | Ardabil | Shrine | Severe | One roof | 1334 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | Arabi House | Esfahan | Residential | Average | Three roofs | 1878 |
| 4 | Zehtab House | Esfahan | Residential | Average | Two roofs | 1227 |
| 5 | Tousi zadeh House | Esfahan | Residential | Average | Three roofs | 1201 |
| 6 | Jalalieh School | Esfahan | Educational | Average | One roof | 1703 |
| 7 | Majd Khajoo School | Esfahan | Educational | Average | One roof | 1710 |
| 8 | Safa Mosque | Esfahan | Religious | Average | One roof | 1611 |
| 9 | Khozan mosque | Khomeini Shahr | Religious | Average | One roof | 1071 |
| 10 | Kolah Farangi edifice | Fin Kashan | Recreational | Severe | Two roofs | 1644 |
| 11 | Fin Garden Bathroom | Fin Kashan | Hygienic | Severe | One roof | 1644 |
| 12 | Tomb of Khwaja Taj al-Din | Kashan | Shrine | Severe | One roof | 1717 |
| 13 | Gozar No Bathroom | Kashan | Hygienic | Severe | One roof | 1558 |
| 14 | Borujerdis House | Kashan | Residential | Severe | Three roofs | 1875 |
| 15 | Great Mosque | Kashan | Religious | Severe | Two roofs | 1558 |
| 16 | Aqa-Bozorg School and MMosque | Kashan | Educational | Severe | Three roofs | 1840 |
| 17 | Imam Jom’e House | Tehran | Residential | Severe | Two roofs | 1861 |
| 18 | Vosouq-al-Dawleh House | Tehran | Residential | Severe | Three roofs | 1832 |
| 19 | Negarestan Mansion | Tehran | Recreational | Severe | Two roofs | 1815 |
| 20 | Moayer al-Mamalek Mosque | Tehran | Religious | Severe | One roof | 1814 |
| 21 | Tomb of Sheikh Ahmad Jam | Torbat Jaam | Shrine | Severe | One roof | 1235 |
| 22 | Qotb-al-Din Heidar Tomb | Torbat Heidarieh | Shrine | Severe | One roof | 1500 |
| 23 | Mosalla | Sabzevar | Religious | Severe | Two roofs | 1799 |
| 24 | Khorshid Kalat Naderi palace | Khorasan | Government al | Severe | Two roofs | 1747 |
| 25 | Balasar School | Mashhad | Educational | Severe | Two roofs | 1812 |
| 26 | Parizad School | Mashhad | Educational | Severe | Two roofs | 1420 |
| 27 | Shah Mosque, 72 bodies | Mashhad | Religious | Severe | One roof | 1414 |
| 28 | Bell tower Church | Qazvin | Religious | Severe | One roof | 1876 |
| 29 | Amir Kabir School | Qazvin | Educational | Severe | Two roofs | 1878 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 30 | Jahangir Khan School | Qom | Educational | Severe | One roof | 1861 |
| 31 | Ganj Ali Khan complex | Kerman | Cultural | Severe | Two roofs | 1619 |
| 32 | Biroun Mosque | Yazd | Religious | Average | One roof | 1417 |
| 33 | Abarkuh Mosque | Yazd his | Religious | Average | One roof | 1576 |
| 34 | Shirazis' House | Yazd | Residential | Average | Two roofs | 1813 |
| 35 | Golshan House | Yazd | Residential in | Average | Three roofs | 1813 |
| 36 | Jame Mosque of Yazd | Yazd | Religious | Average | One roof | 1375 |

Process and structure of the study:

The research measures are presented as systematic as figure (1):




Sampling size in the study

In determining the size of sampling and the number of analyzed units based on the study goals, methodology, funding, time facilities, statistical data analysis, statistical population size and diversity, monitoring and evaluation of variables, the impact of the dependent variables from the independent variables, the percentage of fallibility of results or permissible error, heterogeneity and homogeneity of variables, factors effective in the study of statistical population, and especially the reliability and validity of the sampling variables and the results of previous tests done in the same statistical population and relevant estimation and calculation methods can be taken. So, the adequacy of interpretation and judgment of the samples is established (Gholam Reza Khaki, 1999). Therefore, to determine the size or number of justifiable samples during the sampling, the results from the same research and assessment of the statistical properties can be used to predict the number of required samples according to the following equation; if S2 is the variance of the research, Z is the type II error of distribution of standard population and D is sample mean difference compared to the mean statistical population in the total study. According to the following equation N is used to determine the number of samples (Delavar, 2006):

$$N= (Z2 \times S2) \div D2$$

During the evaluation carried out, taking into account the distribution of data extracted from the research, for values obtained i.e.: S2 = 58860.88 at 95% confidence level and type II error is Z = 1.96. Differences in mean samples obtained compared to the mean total population is D = 79.25. Therefore, the number or size of required sampling in this study is 36 samples; it will be as the following calculation:

$$N= (58860.\ 88 \times (1.96)2) \div (79.25)2 = 36$$

After at least 36 cases of sampling, the study may have sufficient volume of judgment. However, in a study with correlation method, the number of subjects is at least 30 and for each subgroup of study through survey, 20 to 50 subjects would be sampled (Ahmad Reza Nasr, 2007). On the other hand, it can be said that in estimating sampling size based on statistical documentation methods and estimation and personal judgment between 10% to 50% of the size of the entire population for valid and reasonable correlation study, at least 30 sampling should be performed (Mohammad Reza Hafeznia, 2005). In addition, with regard to the necessity of using standard distribution and establishing of generality of the distribution of statistical data in the present study convergence with distribution and similar to standard statistical characteristics i.e. Z, the minimum samples from the same population should be 30 (Saleh Sedghpoor, 2009). Therefore, according to all the criteria outlined and evaluations and calculations, in categorizing the two-storey brick monuments dating back to more than 700 years provided the seismic stability and survival of these buildings in seismic regions with high and moderate intensity, 36 samples of historic building eligible for the study and comparison of results and the findings obtained in survey – correlational research are considered.

## Theoretical principles and criteria

Before any protective and restoration measure of architectural valuable heritage, enough information about dimensions and historical, value and subjective components should be acquired and have enough familiarity with the definition and delimitation of outer space using shape or establishment and realization of artistic phenomena in the field of visual arts. In other words, by understanding the relationship of form and context corresponding to the relationship of architecture body and its development environment, we facilitate the evaluation of qualities and quantities of the effect of architecture. Considering the three validating aspects as meaning, function and shape in space through presenting semantic truth of life affected by the causality of cultural functional performances in the form of gathering world as a body in something as a shape or form, presence of meaning as the center of the functional aspect or interaction of internal and external functions as event distinguishes shape from the rest. So, international valuation of works and architectural history can reduce the problems of developing countries to protect their architectural treasures. In this regard, valid methods can be used formally in coordination with international accredited organizations in the fields of conservation and restoration and even reconstruction of valuable historic architectural works.

Traditional and ancient architecture is considered as the best storytellers of cultural values in the future; so it guarantees comprehension and holistic, compatibility, universality and cultural world view, purposefulness in serving, considering the flexibility and conformity with the text of the stability environment. Therefore, to introduce the principles, Figure 2 will be worthy of attention as follows (Rehabi Med, 2005):

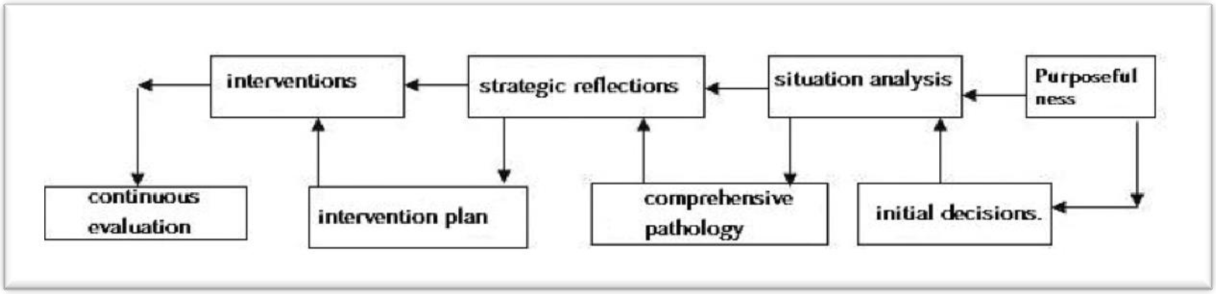



Figure 2: principles and standards of protection, conservation and improvement of seismic heritage stability

In maintaining the integrity and continuity of the historical area, identity, authenticity, operation and rehabilitation of historic building should be considered. Therefore, sufficient understanding of the structure of historical structures, determining the gravity load, identification of structural defects, defect trend analysis, evaluation of seismic adequacy and determining weaknesses in of restoration and rehabilitation of historic structure, using non-destructive methods to determine the existing condition of structure and damage in the material strength, structural stiffness and stability based on valid regulations for a logical, precise and applied plan is necessary (Michele M. Holland, 2005).

Given the similarity between engineers and physicians, if we assume monuments as patients deserving treatment, with a comprehensive review of monuments' characteristics, we see as if historical buildings report their sickness, now using qualitative evaluation method and direct observations determining the safety level, structural reliability and quantitative assessment method with analysis, behavior modeling and assessing damage and decay, along with experimental methods in place, with the help of comprehensive limited destructive and non-destructive tests, we diagnose the damage to historic structures. We plan so that maintenance is considered as preventive measure and all interventions are provider of integration of historical structures (STEPHEN J. KELLEY, 2005).

In most historical buildings, arch ceilings are made of brick and stone masonry materials. The importance of integration of the arch at the top of the fountain and harmony and compatibility of the historical arc are specified by the walls of the Patagh junction, that in the traditional methods, it is done by strengthening the retaining wall and utilization to strengthen as groin in the arches' walls and increasing lateral difficulty of rehabilitation for roofing in the past; but the originality of the architectural heritage is partially and locally impaired; a proper strength, stiffness and functioning of the aspects of earthquake tolerance for architecture heritage was provided, but today, new inconsistent materials are used (GUBANA, A. ARENGHI, 2000).

About the liability of protection engineering and observing architectural heritage conservation principles to achieve the best results, we can say that the architect in charge of the conservation and restoration of monuments, must be committed to preserve the authenticity and integrity of the historic building to properly do the diagnostic pathology and recommend proper solutions to the environmental conditions and protection purposes. So, interdisciplinary field of conservation and restoration of historical monuments is identified, compassion and commitment of artist specializing in decision making is essential for improvement interventions. In other words, based on the Charter of India's architectural heritage conservation, in the principle step we should know what, why and based on what moral principles we should protect and in the guidelines, observing neutrality in conservation, documentation of decisions and interventions should be done. The codes for the implementation regulation in practical measures for the preservation, management, training, studies and preparation of the necessary technical knowledge must be met (Koenraad Van Balen, 2003).

Extraction of diagram of main effective factors

Using (SPSS) in factor analysis , research data were prepared and presented in the form of a graph of factor gradation or scree plot. In this graph, looking at the ease of the load factor, coarse and influential factors can be found. In this regard, F1 is the first key factor called earthquake damage factor, and resulting from the impact of geometrical dimensions, dimensional ratios, earthquake proportions, and percentages of relative transverse walls of ground floor and relative longitudinal wall of the first floor of historical monuments and F2 is second essential factor called direct seismic factor resulting from the effect of percent of relative transverse and longitudinal walls of the basement floor, ground longitudinal and transverse walls of first floor of the historic buildings and F3 is the third major factor called indirect seismic factor resulting from the indirect effect of transverse aspect and aspect ratio of height to width of brick-made monuments. According to the present graphical views as shown in Figure (3), we see below how the above-mentioned original three factors rule the relationships among data:

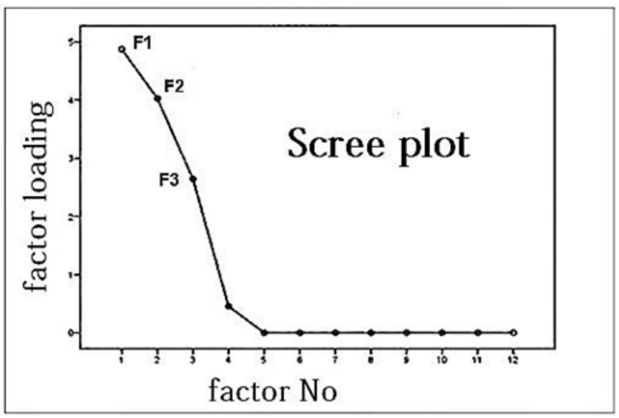



Figure 3: Scree plot to determine the gradation of the main effective factors

Extraction of correlation of effective factors

After factor analysis of research data and discovering the significant relationship and fruitful and effective factors, it is necessary to obtain the correlation among these factors to conduct research arrangements and basic research modeling. This is done in correlation information table among the main analyzed factors in the summarizing method and detecting variances i.e., Varimax method in the Kaiser Normalization method in four rotational steps to improve the values. The results are presented in Table (2):

Table 2: Matrix of main factors after rotation and determining correlation of factors

| Factor Name | Variable name | Initial variables for factor analysis | Main latent factors after rotation | | |
|---|---|---|---|---|---|
| | | | F1 | F2 | F3 |
| First main factor | F11 | Percent of relative longitudinal wall on the first floor of monuments in Iran | -0.992 | - --- | - --- |
| | F12 | Coefficient of earthquake acceleration in response spectrum (A) | 0.893 | - --- | - --- |
| | F13 | Percent of relative transverse wall on the ground | -0.875 | - --- | - --- |

| | | | | | |
|---|---|---|---|---|---|
| | | floor of monuments in Iran | | | |
| | F14 | Height aspect of historic buildings in Iran | 0.830 | - - - | ---- |
| | F15 | Longitudinal aspect of historic buildings in Iran | 0.778 | - --- | - - - |
| | F16 | Length to width ratio of monuments in Iran | 0.720 | - - - | - --- |
| Second main factor | F21 | Percent of relative transverse wall on the first floor of monuments in Iran | - - - | -0.996 | - --- |
| | F22 | Percent of relative longitudinal wall on the ground floor of monuments in Iran | - - - | 0.960 | - --- |
| | F23 | Percent of relative transverse wall in the basement floor of monuments in Iran | - - - | 0.942 | - --- |
| | F24 | Percent of relative longitudinal wall in the basement floor of monuments in Iran | - - - | 0.842 | - --- |
| Third main factor | F31 | Ratio of height to width of monuments in Iran | - - - | - - - | 0.970 |
| | F32 | Transverse aspect of monument in Iran | - - - | - - - | -0.947 |

Description of analyzed factors

In this evaluation, three main factors have been obtained. First factor is the same effective factor or the independent category, as a potential for damage or seismic. Increasing amount of it, seismic damage to buildings will rise. Second factor is the impressionable factor or dependent category, which is considered as direct resistance factor against earthquakes. With the development of the factor, seismic stability of historical buildings increases. Third factor is the mediating factor or intermediary category, as the indirect resistance factor and is considered a dimensional proportional factor. By increasing the factor, the seismic stability of historical buildings increases.

Design and description of primary experimental model

In the experimental model, three main components, i.e. the potential for damage in the earthquake are considered as independent and effective variable, the affordability of seismic resistance as the criterion or impressionable dependent variable and finally affordability of indirect earthquake resistance of historic buildings in Iran as a mediator or intermediary variable, as noted in Chapter III.

Our base model in this study is a prototype or assumed model in which researchers design an initial model given the theoretical studies and logical analysis of studied statistical population and then using experimental data and through path analysis, the model will be corrected to have a good fit. In the second chapter, the concepts and theoretical bases on factors affecting the seismic stability of historical buildings and measures of improvement of seismic stability of such buildings were obtained and we preliminary achieved an idea to develop a testable theoretical model, i.e. Figure (4):

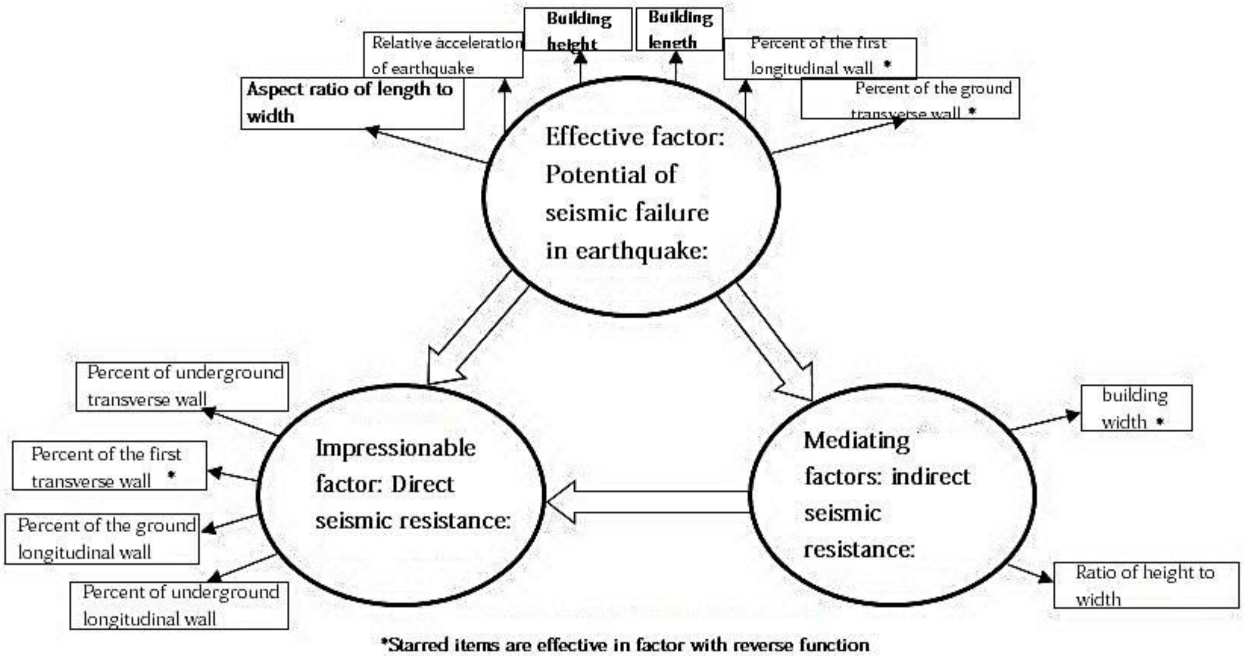



Figure 4: Testable structural model of effective factors in seismic stability of monuments in Iran

Correction, completion and description of the final experimental model

Running the analysis software, modeling, assessing and providing fitness of model, model paths, new correlation values were proposed. Also, according to credible error value index (P-value) and the significance of the correlation coefficients, wrong paths was removed to assess the fitness of the approved model. In other words, as in the evaluation of the correlation between the factors, the aspect ratio of length to width of historic buildings had no significant correlation. Instead, according to the experiences of experts, the devastating effects of earthquakes in buildings will be increased, as the height of existing buildings increases.

Therefore, aspect ratio of height to width of the building in seismic affordability of monuments should be noticed. On the other hand, because the building horizontal proportions are effective only in the orientation of the devastating effects of the earthquake, therefore, it was decided to remove the length to width ratio of building from independent factors i.e. the seismic and effective potential. So, analysis of the correlation of experimental models was done again, and good results were obtained at the end and on the basis of the results, the final experimental model was established. However, given that due to the strong correlation calculated between its components, the model is able to show a high comparatively potential in expressing the seismic performance of historic buildings; and it is considered as the final model and its structural form is presented in Figure (5):

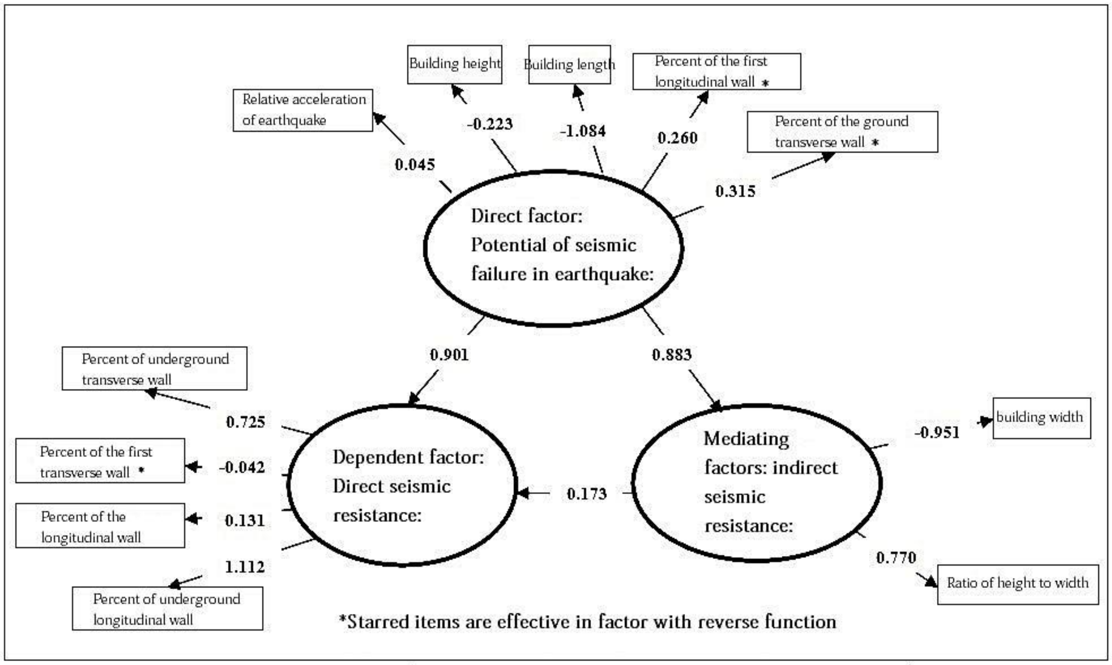



Figure 5: Diagram of direct correlation between the components of the final evaluated experimental model

Describing key factors and explaining final research model

Through the results of the analysis of the final empirical model, the significant level and correctness of fitness of the relationships and correlation of three main factors; the final structural model is provided based on summary of summarized values in the fourth section of the research in Figure (6):

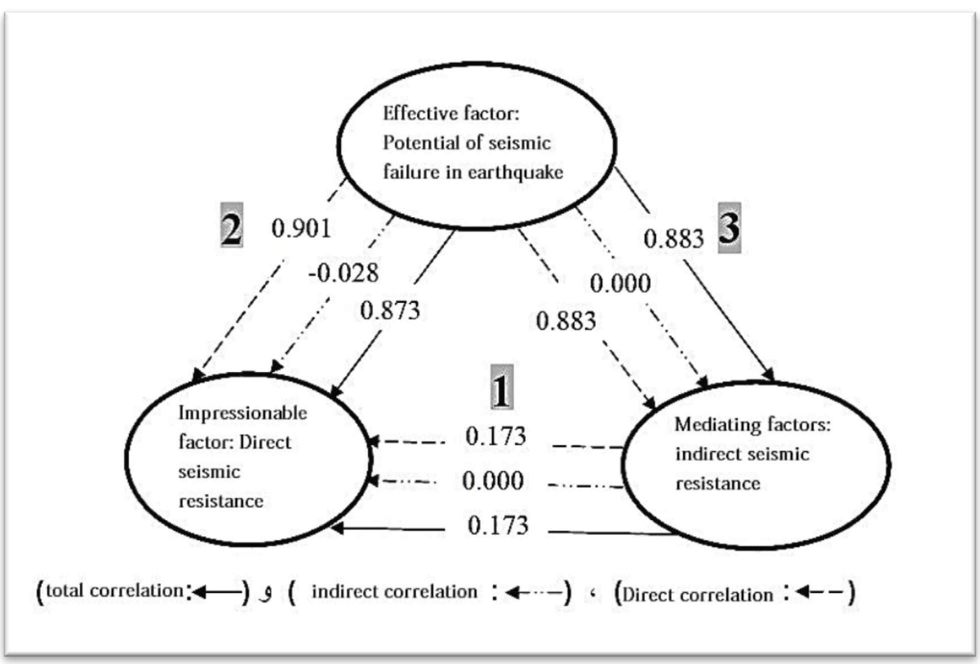


Figure 6: A summary of correlation of main factors in final model of relational structure

In describing the relation and effect of the independent factor on the dependent factor, we can say that there is a significant relationship between damage potential and seismic and dependent factor i.e. the seismic resistance of historical monuments. In describing the relation and effect of independent factor on the mediator and also on the dependent factor through mediator, we can say that damage factor and seismic potential could have a significant effect on the mediator and indirect seismic resistance with the help of transverse dimensions and dimensional proportions of height to width of historical buildings.

Summary of the research results and innovations

According to the first view point, results of communications and tested correlations in terms of significance based on raised assumptions as the final approved graphs only in two directions; direct between two independent – dependent factors and indirect path between three factors of dependent – mediator - independent as Figure (5) provided in chapter five are placed in the interpretation and exploitation sections in this context.

According to the second view point, we can say that the results will be confirmed in terms of consistency with the objective facts. Because the devastating effects of earthquakes of the Iranian plateau will be effective on the seismic resistance of historical monuments and percentage of shear walls, also indirectly affects the aspect ratio of height to width of structures and increasing resistance to the devastating earthquakes.

According to the third view point, the cause of this phenomenon can be sought in the focus of mass and weight of ceiling of historical buildings in height positions. Because the devastating effects of earthquakes is emerged in the mass of floors' ceiling. So, the high effects of altitude of historic buildings on seismic induction or dealing with earthquake are evident and provable. The less the ratio of height to width is, center of seismic mass in earthquake is led to lower points and the reversal factor i.e. the overturning moment of the earthquake will be less effective.

According to the fourth view point, the necessity of comparing the results with similar studies (because the study is conducted for the first time), potential for verification of measures in terms of California Historical Buildings Codes (CHBC) and (2800) earthquake regulation in Iran may be announced. By this research results, the regulation item would be explored. The results show the engineering nature of structure structural situation of Iranian brick-made monuments, good capability and sufficient potential of Iranian brick-made architectural heritage in the face of earthquakes for earthquake-prone plateau of Iran, in accordance with the seismic stability has long been visible. So the techniques and technical knowledge of ancients in the field of design and construction of brick-made seismic buildings can be considered a criteria for development of the design codes in line with modern evaluation techniques in providing stability of Iranian brick-made monuments as a simple, cheap and available method for construction and implementation of safe places to counter the devastating effects of the earthquake in Iran plateau.

## 5. Conclusion

Considering the features, limitations and actions taken, results and achievements gained in this study, following items can be considered to improve and continue the study path, as the underlying ground for meeting scientific and research needs of countries in the maintenance, protection, consolidation, seismic retrofitting and rehabilitation of monuments of Iran. In other words, due to the lack of accurate scientific information about the technical engineering specifications of materials and members and lack of sufficient awareness of the seismic behavior of historic buildings and given the importance of issue, the development of research process seems necessary. In this regard, the development of a comprehensive planned research project with due consideration of all the necessary aspects such as financing, time opportunity, equipment facilities, materials needed along with a multidisciplinary group of professionals with scientific and practical skills appropriate to the following items are suggested:

A.Plan of identification and explanation of the theoretical principles and technical knowledge of the ancestors of historical monuments builders to understand the technical engineering culture of the past in the field of seismic stability of all the monuments of Iran in the specialized field of encrypted sciences in architectural heritage of Iran from structural analysis, strength of materials, design, technology of construction of monuments to identify and classify the applied knowledge and techniques suitable for use in the manufacture of all the monuments resistance to destructive earthquakes in Iranian plateau.

B.Comprehensive understanding of the technical engineering specifications of historic buildings of Iran in terms of geometric, physical, chemical, mechanical and biological aspects related to environmental conditions through contactless accurate non-destructive ways and explaining structure of effective structural members of historical monuments sustainable against the effects of destructive earthquakes in Iran for modeling in developing principles and codes of design, construction, evaluation, pathology, seismic retrofitting and rehabilitation of historic buildings specific to Iranian earthquake-prone plateau.

C.Research initiatives in developing the technical standards and guidelines related to techniques of building and assessment of seismic stability of Iran historical monuments according to the history and technical background of historical buildings made of brick in line with modern global techniques including the Applied Sciences in modern physics energies, such as nuclear energy, the use of nanotechnology in modern methods and materials manufacturing technology, modern methods and equipment of assessment, pathology, consolidation, seismic retrofitting and rehabilitation of monuments in Iran.

D.Extending research project with change in goals, subjects, types of hypotheses, type of tools, documentation, methodology, sampling, the sample size, research territory in the new situation to improve and extend the results of this study, improve the quality and accuracy of metrics acquired and developing complementary models of the research to enhance compliance of structural equation in new models of seismic stability considering the issues and objective concepts of such models and structural equations to make the model measurable in all the monuments in Iran.

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