Study the Progressive Destruction of Concrete Buildings Considering the Exit from the Center of Rigidity in Seismic Behavior

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Summary
The progressive destruction is the fraction or destruction of the whole part of the structure due to the incompetency of a part of the structure which is damaged and does not have the capability to distribute overload to maintain the structure's stability. One of the main reasons of destruction of concrete structures is seismic effects and sudden loads, which are regarded as the progressive destruction of buildings. The progressive destruction is not a linear process; therefore, it should be studied nonlinearly; herby, the present research is an applied and descriptive survey. In this paper, a concrete structure of 7 floors in Tehran with high seismicity is analyzed according to the 2800 regulations as well as the concrete regulations of Iran. Moreover, the lateral obstruction system of the structures is located in dual system with a folding frame and a concrete shear wall. The sap2000 software would be used to analyze the procedure. Results demonstrate that the occurrence of a series of breakdowns in the structure, including the destruction of a linear load bearing member like column, increases the imposing effect of load on other columns; consequently, there would be more basic cuttings during the earthquake. Also, shear walls play a pivotal role in counteracting the earthquake side forces in extended concrete structures; the manner of designing, selecting the appropriate openings as well as the construction's architecture is considered highly crucial for the building.
Keywords:
Progressive destruction, seismic behavior, concrete buildings, shear walls, earthquake

1. Introduction

The structure of the building should be capable of withstanding various types of forces, include earthquake and wind forces. Hence, the type and place of hardening in the longitudinal and transverse directions of the building should be designed and embedded in such a way as to withstand the lateral forces applied to the floor level of the floors and ultimately to carry. In order to withstand lateral forces in high buildings, various systems are used i.e. curtain-mounted frames, rigid frames, interlayer frames, shear walls, frame-wall structures and so forth. The most common type of lateral hardening is in the longitudinal structures of the shear wall. In the design of these types of structures, the position of the shear wall in the plan has a significant contribution to the horizontal forces (Gholhaki, 2009).

With lateral effective forces on a structure (wind or earthquake) is confronted in various methods in which the effect of earthquake on the building differs from other impacts. The characteristic of the earthquake effect is that its forces are far more severe and complex than other forces. Resistant elements against the above forces include a folding frame, a shear wall, or a combination of the latter. Using a folding frame as a component of resistance to lateral forces, especially if the lateral forces are exposed to the earthquake's effects, require specific details to provide sufficient frame shape. These details are often intrusive and, if their exact implementation could be ensured, the quality of implementation and supervision in the workshop is very high. In terms of excellence, it can be said that the shear wall is more economical than the frame and the displacements while controlling the frame structures alone cannot be effective in this regard (International Institute of Earthquake, 2002).

In order to reinforce buildings, primary efforts on construction's reaction were defective owing to the lack of adequate analyzing tools and sufficient information about the earthquake. Observing the performance of

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structures during the earthquake as well as analytical studies and laboratory work and gathering data on earthquakes through the recent four decades has provided the possibility of presenting a modern method for designing earthquake resistance structures (Gholhaki, 2009).

During 1950s, the "formable folding frame" raised from the "folding frame" system which was the only resistant system in multi-story concrete and steel floors by the time and continued until late 1970s on account of its appropriate behavior against earthquake. Since then, more efficient and modern systems such as shear walls or trusses have become popular in order to tolerate wind pressure in large buildings and the old method is almost set aside (Sadeghi, 2009).

Both theoretical and empirical researches during 60s, 70s and 80s led to collect detailed information on the reaction of building systems with a shear wall during an earthquake around the world. These studies were emphasized upon the importance of formable folding frame in diminishing the earthquake's load. Considering the fact that more rigid structures would be exposed to more intense forces, while the presence of shear wall would lead to structures' rigidity enhancement, using shear walls are considered inappropriate and more buildings are constructed in folding frame manner. For instance, in some countries, i.e. underdeveloped countries, without complying with the minimum formality requirements, building frames were composed of fragile types and are lacking the competency to withstand severe earthquakes without causing severe damage to the building; as observed during the last four decades, many of its residents were trapped to death. Design based on performance involves design and construction of structures that resist earthquakes through a predictable framework. The approaches involve a selection of suitable parameters including structural rotation time, stiffness and so forth; in order to control the structure's behavior during the earthquake (Sadeghi, 2009).

Over the last few decades, shear structures have been less steel-intensive than those were recommended by the current US regulations; however, for decades, it has resisted against earthquake loads. Investigations carried out since 1963 on the performance of these structures during the earthquake have demonstrated that, despite the observation of different cracks, there has not even been a case of destruction or life loss in shear structures. Most of the damages to buildings with a frame system have been due to the torsion of the floors (the shear failure of the columns). However, this is not due to the lack of resistance of framed structures to new methods, against earthquakes, but rather to illustrate the high capacity of shear walls, even in the case of reinforcement with old and non-scientific methods. Observing the buildings' destruction of the recent earthquakes (1972 Nicaragua, 1985 Mexico and 1988 Armenia), emphasize on using shear walls (especially in residential buildings) seems reasonable, showing that the construction of non-wall structures in areas with severe earthquake. Risk is not recommended due to its adverse consequences.

Initially, steel and shear reinforced steel walls were used vertical and horizontal hardening in the United States and Japan, which caused in preventing sheet buckling and increasing the shear strength of steel plate; though, owing to the cost and time highly spent by welding to connect hardeners to the wall, numerous studies and experiments were conducted in the United States and Japan on uneven shear walls. The idea is based upon using non-rigid steel shear walls as well as a diagonal tensile field created after the buckling of the steel plate.

The primary objective of the present paper is to study the progressive destruction due to the weakness of the element in concrete buildings, taking into account the severity of the exit from the center. Its practical objective is to investigate all executive research firms on technical and civil engineering affairs. Its secondary objectives are included study the construction's drift fluctuation and structural base shear oscillation under various earthquake mapping accelerations.

2. Research Literature

In 2015, Yaghoubi et al. studied the progressive destruction in concrete folding frames by using non-linear static analysis. Progressive destruction is the expansion of the initial localized defect from one component to the other, in which eventually the whole structure or a large part of it would collapses. Progressive destruction is currently threatening structures. It usually initiates with the removal of the column and then extends to the destruction of adjacent members; afterwards, the whole structure or a large part of it will finally collapse. For the first time, the matter of progressive destruction was raised since the explosion in the Ronan Point building in 1691, and during recent years, other terrorist incidents, i.e. bombing the Federal Building of Mora in 1661, and the terrorist attacks on the buildings of the World Trade Center in 2001, had led the researches toward a more precise study on this phenomenon.

Yavari et al. (2015) studied the general history of the potential of failure in steel structures. Progressive destruction consists of a set of failures that results in partial or total collapse in a chain structure, which could be occurred due to human factors such as design, construction, fire, explosion, load over the size or natural hazards such as earthquakes, winds and so forth.

In 2015, Karimi et al. studied the progressive destructions of concrete buildings under the influence of explosion. Several incidents include explosions, fires, vehicle collisions, errors in calculations or construction would cause destruction in the structure. The UFC 4-023-03 instruction of the US Department of Defense divides buildings into four categories based on security levels. Progressive breakdown analysis is based on one of the static linear, static, nonlinear, linear, and nonlinear dynamical methods by deleting columns in certain classes. Due to the fact that concrete buildings with a modular framing frame are used in many structures, it is necessary to investigate the progress of failure for these structures.

In 2015, Mahmoudi et al. studied a variety of methods for reinforcing concrete structures against explosions. Although the occurrence of heavy loads like explosions in conventional structures rarely occurs, its impacts can cause a sudden failure of the structure and the disastrous consequences after that. The failure is either a local failure of the members of the instruments or a general or part destruction of the structure as a progressive destruction, which is the main cause of deaths while explosion takes place. The main reason for the demolition of building structures is the destruction of its columns. Hence, exploring the explosive response of the columns will provide useful information.

Talaat et al. investigated the model of progressive destruction in concrete buildings using the direct element omission in 2009. They achieved a novel formula, based on dynamic stability, to analyze element omission algorithm which caused a transitory alteration in cinematic system. In this method, an acceleration of the imposition was used instead of external forces within a node in which an element had only one connection. This algorithm has been implemented for a limited source element of finite element. Moreover, counting experiments have been performed using a criterion structure system with simplified element elimination criteria, and has been able to record the uncertainty effect on the capacity of that member. Two plans were implemented using structural RC frame armed with URM designed walls. The first one was considered to be a single-unit model, a total of 14 earth movements, during an earthquake event, to a collection of 14 land-based land-registrations of similar neighboring neighbors that occurred during a zealous. This study produced an empirical probability function for partial and complete conditional collapse at different levels of risk, and concluded that intra-event diversity was a major source of effective uncertainty resulting from the progressive collapse simulation. The second plan was a definite sensitivity study of the gradual decay response in a five-factor structural model for uncertainty in available load, rigidity, low fluctuation, and seismic hazard level, subjects studied to capture a ground motion. Time analysis in early collapse is considered as an appropriate measure of sensitivity and uncertainty in the intensity of ground motion as the most important cases, followed by the hardness of the URM wall.

Wittel et al. (2010) studied the progressive destruction mechanism of breaking as well as shatterproof structures' frame. They studied the progressive collapse of three-dimensional frame construction made of reinforced concrete, which was created after the sudden loss of a pillar. The structure was shown by Euler-Bernoulli Elasto beams with increasing threshold deflection of rotational length. The simulation was performed using discrete element method with respect to non-elastic collision between structural elements. Results indicated the beginnings of the collapse as well as the mechanism of propagation of the axis in the structures with different geometric and mechanical properties are activated. In other words, in addition to the final decay rate and distribution of the size of the segment, and their relationship with αα, ββ, they also studied decay mechanism. Mason et al. (2008) studied progressive destruction of the main shock in Christchurch, New Zealand. The aftershock could have devastating effects on the environment, for example, in New Zealand during 2010 and 2011. In this research, aftershocks and a numerical model of soil structure have been introduced. Numerical models are provided on the basis of a 9-story building with a tensile diverting bracing, steel, embedded in a broad foundation. The interaction of the Earth Foundation was explicitly considered using nonlinear Winkler springs, the model was created in the time of the earthquake and two larger aftershocks occurred on February 22, 2011 in Christchurch; progressive seismic damage was detected. Therefore, results delivered that the seismic damage caused by aftershocks comparing to the main shocks is negligible for this type of structure.

During 2016, Kurdbagh et al. investigated the effect of vibrational surface and building's altitude on resistance against the progressive destruction of steel frames. They studied the effect of building height and seismicity on the resistance to gradual collapse of the building is investigated in this paper. The heights were for buildings, 4 floors, 8 floors and 12 floors with folding steel for frames. The results express that larger buildings are safer than advanced collapse. In order to investigate the effect of seismic surface, different surface structures of special flexural frame system were designed for different levels of seismicity, namely, very high, high, medium and low. Structures were evaluated using a nonlinear dynamic method and two main code scenarios, including the sudden removal of one corner and a middle column on the first floor. Several charts for progressive decay resistance are presented. It was shown that the structure designed for larger seismic gaps is more resistant to progressive collapse.

Hayes et al. studied the probability of optimizing the building's maintenance against the earthquake, explosion, and progressive destruction during 2005. Some engineers suggested that the present seismic instructions could optimize the new building's resistance against the explosion load as well as the gradual collapse. Meanwhile, efforts were put in order to determine the quantity. In order to begin analyses, the probable relationship between seismic explosion and resisting against the progressive destruction caused providing a study on behalf of the ministry of indoor security. The first building, which was located in an earthquake prone region, had examined. Afterward, three reinforcement plans were designed to assess the longitudinal vulnerability; a spring spandrel system and a new concrete frame, both for the ground floor (street or alley) where the building is located, and a set of internal shear walls. Furthermore, by reinforcing the designs, the main concrete frame is accurate on the ground (street or alley) of the building to comply with the current building code, without any side loading analysis. Three reinforcement plans and a detailed frame were subsequently reviewed to respond to an explosion that occurred in 1995. The explosion analysis occurred and the gradual collapse indicated that the spandrel beam and the special bending frame of the design, as well as the precise main system, reduced the damage caused by the direct explosion and gradually collapsed afterwards, in comparison with the main building behavior. However, the internal shear wall, in some cases, is not effective in reducing explosion and progressive decay damage. One of the key findings of this study was that strengthening the elements of the environment, using the existing seismic details, improves the survival of the building, while the reinforcement of the internal elements of the building's coating does not have a significant effect on the reduction of damage.

3. Methodology

The research is practical owing to t their influences on Ministry of Roads and Urban Development. Applied researches, are those which are provided by using the results of fundamental research in order to improve the behaviors, methods, tools, devices, products, structures and patterns used by human societies. Also, this research is descriptive-survey.

In order to analyze research objectives, we used non-linear dynamic analysis of sap2000 software. Beside checking the drift and the basic cutting in this software, finding the most suitable cutting plan for the shear walls is one of the parameters to be considered. In this research, a concrete structure of 7 concrete floors in Tehran is high with seismicity, which is analyzed according to the 2800 regulations and the concrete regulations of Iran. The cluster is type 2 while the floors are rigid. The structures' lateral obstruction system is in one direction a dual system with a framing frame with a concrete shear wall; in another direction, it is arranged in a horizontal direction of the bending frame.

4. Findings

The method: Includes model's general characteristics, consumable characteristics of concrete and steel in construction, and calculating earthquake factor to introduce earthquake loads. Construction's characteristics: In this section, the project specification includes the type of materials used, i.e. concrete and reinforcements, sections used for linear issues (beams and columns), sections of the sections of the roof panel and the walls are introduced in the software.

Introducing linear threads: In this project, for the columns of the first three floors from below, a 50 * 50 cm square pillar is used. For floors 4.5, 4.6, the building has a square column of 45 * 45 cm and for the 7th floor a square column of 40 * 40 cm is utilized. Introduction of surface threads: The ceiling of the floors is considered a two-sided slab with a thickness of 15 cm, and the special weight of the staircase height is considered equally zero.

Introduction of earthquakes entered into the model: Three earthquakes of Kobe, Manjil, and Tabas are used within the model. Introduction of the gravity load and earthquake loads pattern: The software would recognize the gravity loads as well as the applied earthquakes.

Calculation of the effective seismic mass of the building: For this purpose, we must take into account the standard 2800% of the live weight in order to calculate the structure mass during an earthquake. The percentage of live traffic participation for a residential property in Tehran is 20%.

Mass Source = Dead + Mass + Leq + 0.2 (liveR + LiveNR + Snow)

Three-dimensional modeling of the building: The most important steps in working with the SAP software are the manner of modeling the structure in terms of pivoting, molding as well as modeling the ceiling. Building's modeling is determined according to its architectural plan; started by drawing the columns.

To draw the surface elements of Draw and Draw poly area, we draw the ceilings and choose the type of roof from the section menu.

Editing setting in the model: Includes assigning rigid areas and creating rigid diaphragms in the floors.

Construction's loading and allocating loads: During the project, the floors and roofs load are assigned to building's member, and analyze it regarding to these loads. Then we assign the defined loads for surface elements.

Structure analysis: In order to investigate the progressive destruction in this project, we initially examine the behavior of the model without considering the progressive destruction under the cited earthquakes.

The amount of basic shear and drift is demonstrated as followed:

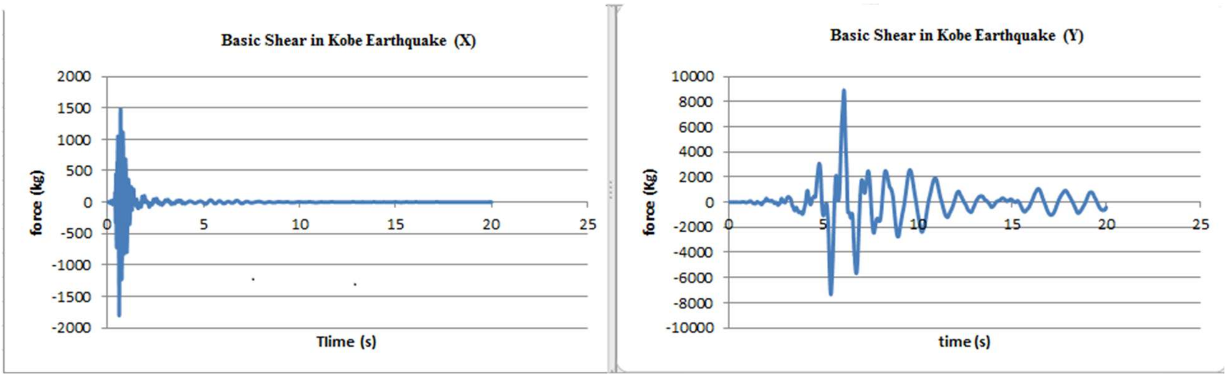

Fig. 1: The amounts of basic shear in Kobe earthquake (push 1)

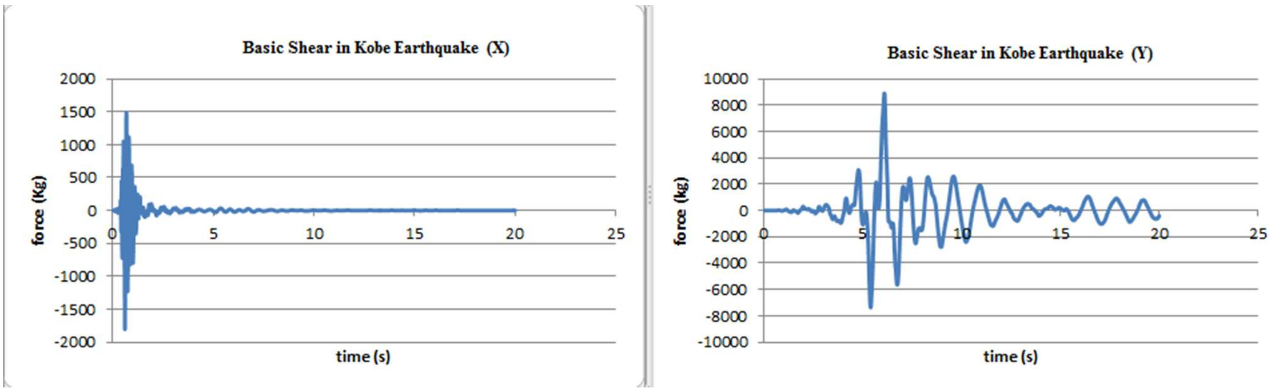

Fig. 2: The amounts of basic shear in Kobe earthquake (push 2)

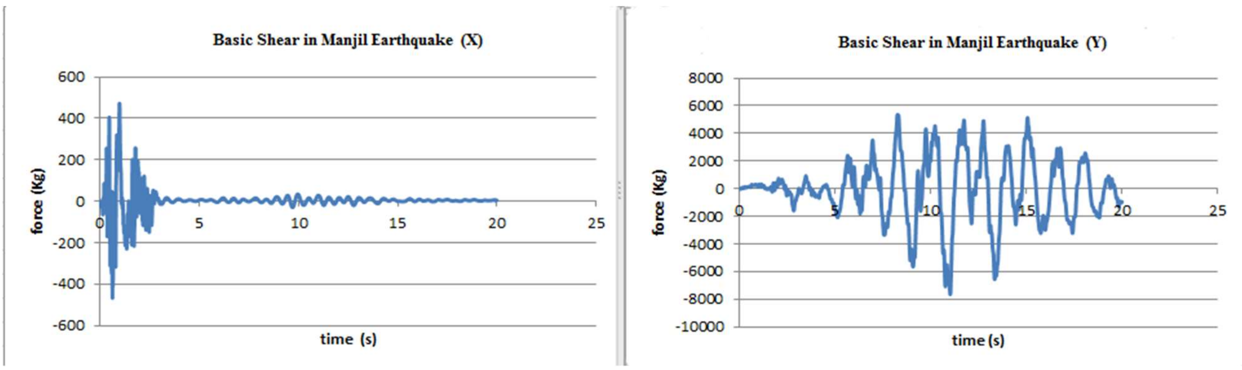

Fig. 3: The amounts of basic shear in Manjil earthquake (push 1)

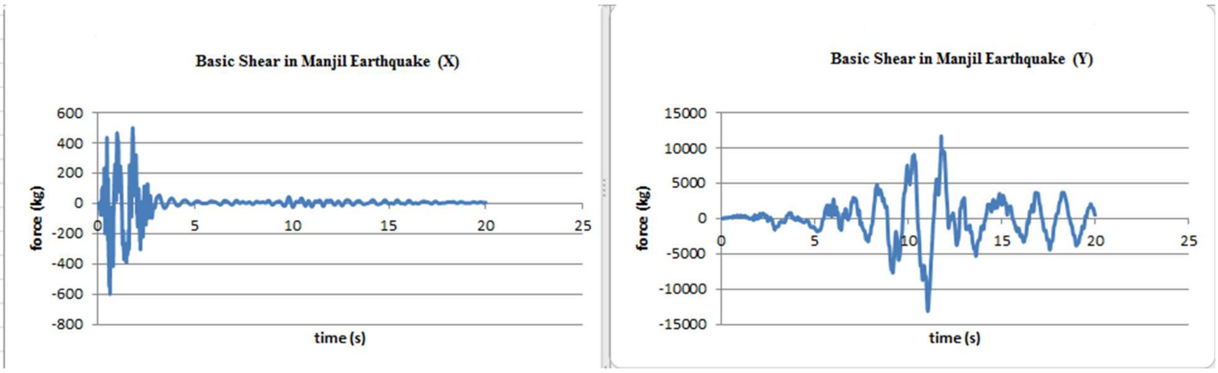

Fig. 4: The amounts of basic shear in Manjil earthquake (push 2)

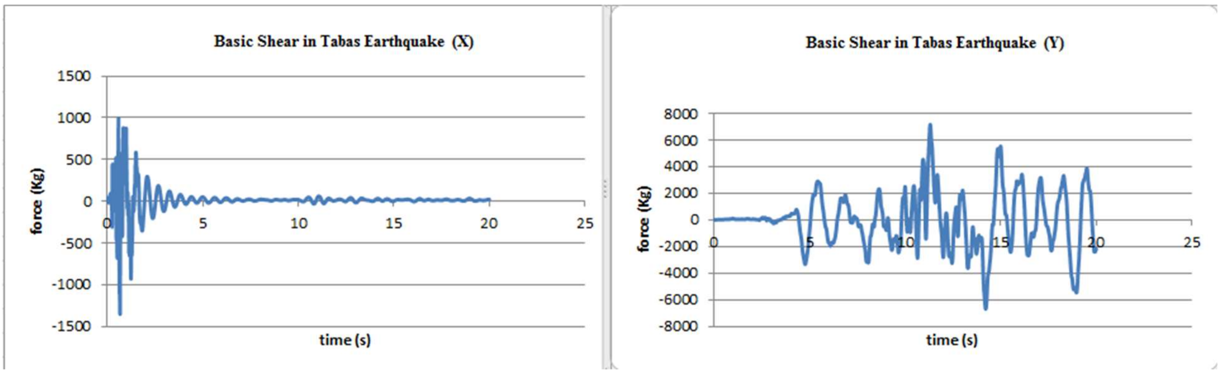

Fig. 5: The amounts of basic shear in Tabas earthquake (push 1)

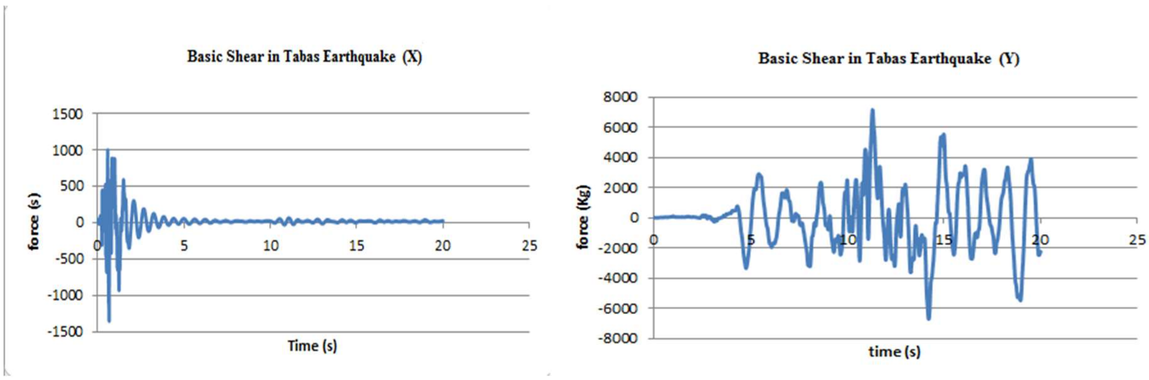

Fig. 6: The amounts of basic shear in Tabas earthquake (push 2)

5. The Displacement Values in a non-degraded Model in Manjil Earthquake

According to 2800 standard, the permissible drift amount is equal 0.02 for those structures with 0.7 < x periodicity which is regarded sufficient in Kobe's earthquake model. The height of the building floors is 300 cm due to the thickness of the flooring. Since within the x direction there is a shear wall in the grooves of the building that limits the displacement values in this direction, the displacement values of the structure in the mass centers of the classes in the X direction are highly constraints. In the direction of the Y axis, the maximum displacement is 0.13 cm.

Considering the displacement amounts in levels of Kobe earthquake push 2, the structure's transposition is more limited through X direction rather Y. Therefore, drift would be calculated in Y direction.

The drift amounts for the Tabas earthquake (push 2) are also approximately equal to the value above. Therefore, the drift values in both directions for the non-destructive model are less than the maximum number of regulations, and the structure provides an appropriate response to these earthquakes in both directions.

5.1 Progressive Destruction in the Structure

In order to act upon the progressive destruction scenario, we examine the structures response through omitting a column of the first floor; then, we calculate the software's outputs.

Results reveal that the basic sheer amounts are increased considering the progressive destruction. Most of these developments were accomplished in Y (with no shear walls) direction.

5.2 The Displacement Amounts in the Structure's Floors under the Accelerated Mappings

According to results, the structure's drift amount is critical in Kobe push1, 2 as well as the Tabas earthquake. However, the drift value in Manjil earthquake is not acute.

5.3 Determine the Proper Location of the Shear Wall

The reason for using a shear wall in structures is to increase the stiffness of the structure, especially for high-rise buildings. This means that the designer engineer will use the shear walls due to the limitation of the lateral displacement of the structure under lateral loads in accordance with the rules of the regulations. Accordingly, in this project, we placed the shear wall as illustrated in both Figures 7 and 8; the result indicates that the shear wall mode in Figure 8 meets the requirements of the standard 2800.

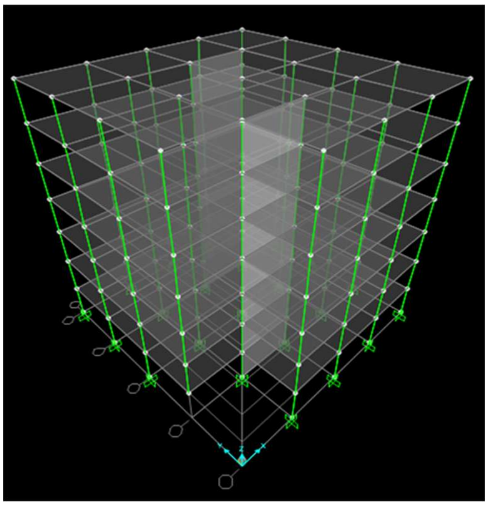

Fig. 7: Shear wall location

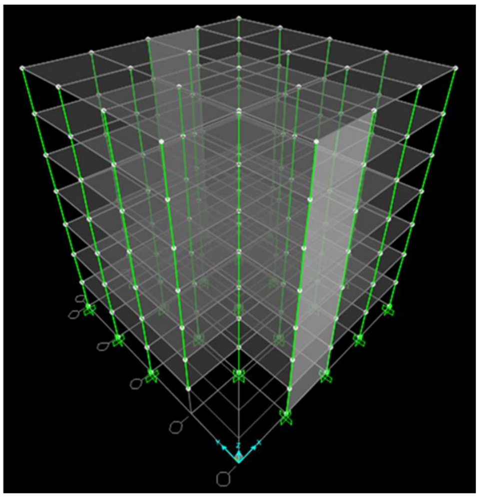

Fig. 8: Shear wall optimized location

6. Conclusion and Future Research

- Progressive destructions are playing a crucial role in destruction of the concrete structures as well as destroying the characteristics of its members include columns.
- In case of selecting appropriate holes for shear walls, the amounts of basic shear and structures drift would be notably decreased.
- The occurrence of a series of failures in the structure, such as the destruction of a linear load member, such as the column, increases the amount of load imposed on other constructed columns, and during the earthquake, the amount of further cutting is applied to these columns, which is in the quake of the earthquake in time An earthquake occurrence will result in significant downtime or total failure of the structure.
- The drift amounts have increased due to the type of destruction that is highly notable.
- The shear walls are playing a pivotal role against the earthquake lateral forces. Hence, the matter of their design as well as choosing a proper opening which make it possible to act its structural role and consider the structure's architecture is crucial.

Structural engineering has striven to predict those occurrence in which had a remarkable impact on structure's efficiency, function and resistance. These factors should be considered by design engineer during designing structure in order to secure the structure's stability. The progressive destruction is caused by lack of the prediction during designing the structure which unfortunately could initiate serious harms and catastrophes. Studying the history of the collapse of large buildings depicts that the cause of the collapse of these structures lays in the destruction of a part of the building, which, due to being subjected to either internal or external forces, continues its destruction throughout the structure, leading to the collapse of the entire structure due to neglecting external forces in designing the structure. This has led researchers to predict all of the forces involved in the building as much as possible. Progressive destruction could be defined as the expansion of rupture from one component to another, which eventually leads to the collapse of the whole or a large part of the structure. Regarding to this condition, structure's longevity will be increased; however, accordingly, the resulted damages by the technology development should be considered.

- It is suggested that the behavior of the structure be investigated by spectral analysis methods.
- It is suggested to model the structure with a bending frame in two directions and compare the results with this model.
- Construct behavior is considered once, regardless of the exit from the center, and examined with the results of this model.
- Exit the center of the structure with a variety of exits from the center of rigidity, such as irregularity at elevation.
- Analyze the model in other structural analysis software and compare the results with the outcomes of this model.

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