INVESTIGATION OF IRREGULAR EFFECTS IN HEIGHT ON CONCRETE STRUCTURES BEHAVIOR COEFFICIENT

Mohammad Nazari,
Department of Structure engineering, Golpayegan Branch, Islamic Azad University, Golpayegan, Isfahan, Iran, mohammad nazar.136565@gmail.com
Aliraza Nikbakht Shahbazi,
Department of Water Science engineering, Ahavaz Branch, Islamic Azad University, Ahavaz, Iran ar-nikbakht@yahoo.com

Abstract. The behavior of structures at the time of the occurrence of large earthquakes enters the nonresponsive range, and their design requires a nonresponsive analysis, but due to the costly nature of this method and its effect to enhance the effect of nonresponsive behavior and energy dissipation due to hysteresis behavior, The damping and the effect of the excessive strength of the structure transform this reactionary force by the coefficient of reduction of resistance or the coefficient of behavior into the design force. Determining the magnitudes of these coefficients in earthquake regulations is mainly based on performance observations of building systems in past earthquakes and based on engineering judgments. One of the cases that has a significant effect on the behavior of structures is irregularity in height, which according to researchers many expressed their concern about the lack of reasonable behavioral coefficients based on research studies and computational backing and emphasized on the correction of these coefficients based on scientific studies. In this study, using finite element software, irregular effects in the defense is studied on the coefficient of behavior of concrete structures studied is. In the present study, 30 flexural concrete frames have been studied regularly and irregularly in structures with 3, 6, 9, 12, 15 floors in elevations with different openings of 4, 6 and 8 meters. The structures were selected for elastic analysis in order to design, model, and load. After this stage, the structures were modeled for non-elastic analysis (nonlinear static analysis with increasing lateral loading) and then the coefficient of structure behavior was calculated. According to the results, in most cases, the coefficient of reduction due to ductility (R_{μ}) in regular concrete structures at altitude is more than that of irregular structures, in other words, in structures with the same number of floors and openings, concrete structures regularly, they have better fitting height than irregular structures at elevation. In particular, it can be said that the coefficient of reduction due to irregular structure ($R\mu$) in irregular structures at elevation is 91% of its value in the structure regularly in height, in this study, with increasing the number of floors from 3 to 6, the resistance coefficient is decreasing further, but from 6 floors to then, in structures 9, 12 and 15, there is no significant change in the resistivity coefficient. Also, the regular or irregularity of the structure did not make any difference in the change in the value of this coefficient. The overall behavior of the structure (R) also affects the regular concrete structures at altitude there is a greater amount than the irregular structures at elevation. The regular structures with the number of floors and the size of the span have a higher coefficient of behavior than the irregular structures at elevation. The results showed that the coefficient of behavior obtained from nonlinear dynamic analysis the linear average is about 15% higher than the values obtained by nonlinear static analysis with making side are increasing and there is little difference between the two methods.

Keywords: Structural behavior coefficient -irregularity at height-concrete structures.

Introduction. The main goal of the seismic design of buildings is based on the belief that the building's behavior against the forces caused by small earthquakes remains intact in the linear range, and in contrast to the forces caused by moderate earthquakes, non-structural damage is acceptable [1]. For this reason, the seismic resistance required by the earthquake design guidelines is generally less and in some cases much less than the lateral resistance needed to maintain the stability of the structure within the reactionary range in a severe earthquake. The behavior of structures occurs during the occurrence of medium and large earthquakes into nonresponsive areas and requires an elastic analysis to design them. Reducing the resistance of the structure to the required elastic resistance is generally done using the resistance coefficients. To this end, the current seismic design guidelines, in this way, provide seismic forces for elastic design of the building from a linear spectrum that depends on the natural period of the building and the soil conditions of the building site, and to enhance the effect of the behavior non-reactive and energy dissipation due to the hysteresis, damping behavior and the effect of the increased strength of the structure, this reactive force is converted by the coefficient of reduction of resistance or coefficient of behavior into the design force [2]. Although the coefficients of behavior defined in the seismic regulations include hysterical behavior, vortexes, excess strength, damping and energy depreciation capacity, the values of these coefficients in the earthquake regulations are mainly based on observations of the performance of various building systems in the strong earthquakes of the past, it is based on engineering judgment [12]. Accordingly, many researchers have expressed concern about the lack of adequate coefficients of behavior based on research studies and computational support in the earthquake regulations, and emphasized on the correction of these coefficients based on scientific studies. Irregular concrete structures at elevation are among these. Due to the fact that irregularity in height is based on Iran's 2800 Regulations, many of today's structures are among the irregular structures that are needed to verify their exact action against earthquakes so that their behavioral coefficient based on the computational support, it is precisely determined for this thesis. Therefore, this paper has been selected for this thesis, and it has been attempted to model the impact of irregularities in height on the coefficient of behavior of concrete structures by modeling and applying applied research.

Research purposes. In the interpretation of most of the regulations in seismic design Regulations in different countries of the world, emphasis has been placed on the empirical character of the coefficient of behavior or the coefficient of reduction of force, and most of them have no specific criteria for calculating this coefficient. In this study, the evaluation of behavioral factors and the relationship between the effective parameters for concrete structures designed according to the regulations are of particular importance. With regard to the above, the most important part in the preparation of seismic design of structures is the availability of appropriate behavior coefficients.

Research questions. Some of the most important questions raised in this research are:

1. What are the factors affecting the structures behavior coefficient?
2. How much is the effect of each factors on the coefficient of behavior?
3. What are the methods for calculating the structural behavior coefficient?
4. What is the irregular effect at height on the behavior of concrete structures?
5. What are the coefficients of recommended behavior in regulation 2800, how much is the actual behavior of these structures?
6. What are the recommendations for accurately calculating the coefficient of behavior of these structures and improving their performance?

These cases are part of the questions that have been tried to be addressed in this thesis and are given appropriate answers.

Methods of calculation of behavior coefficient. So far, different researchers have used different methods to calculate the coefficient of behavior. By comparing these methods, they can be categorized into two general categories. [19] One way is the American researchers and the other methods of European researchers.

1. American methods

In this group, two methods are more prominent than other methods. One of these methods, known as the Spectrum Capacity, is the result of extensive research by the distinguished Freeman scholar [23]. The second method, also known as the ductility coefficient, is the results of Uang's research [18], which is described below.

A. The Freeman Frequency Capacity Method

Freeman presented an analytical method for calculating the behavior coefficient influenced by many parameters as follows:

R = Ri.Rj.Rk ... .Rn (1)

Each of the parameters is a substitute for factors such as frame arrangement, structural system, combination of loads, uncertainty degree, damping, nonlinear behavior of structure, properties of materials, structural aspect ratio, failure mechanism and other effective parameters. In this method, two main factors of structure capacity and earthquake damage are considered.

B) The method of Uang ductility coefficient

In Uang method, considering the general behavior of a conventional structure (Fig. 2), the amount of elastic resistance required by the structure, which is defined in terms of the cut-off coefficient of the base, is:

$$C_{eu} = \frac{V_e}{W} \quad (2)$$

The advantage of using this method is that the designer only performs an elastic analysis, and then, using the current regulations, determines the dimensions of the parts and executive parts. This method also has some drawbacks, some of which are:

- The designer will not be able to determine the actual strength of the structure, and if the amount of resistance implied in the earthquake rule is assumed to be in the amount of reduction coefficients (excess resistance), the behavior of the structure in severe earthquakes will not be satisfactory.
- The values of non-elastic displacement cannot be calculated by linear elastic analysis.

2. European methods

In recent years, European researchers have been working with researchers in the United States to investigate the estimation of structural behavior coefficients. Mostly, the methods used by Europeans are divided into two groups [21]: methods based on the theory of coefficient of formability and energy methods are briefly introduced.

A. The form of the theory of ductility

This method, based on the theory of plasticity, was first introduced by Cosenza et al. in 1996, in which the behavioral factor (q) is obtained according to the following form in [3]:

$$q = \frac{\delta_u}{\delta_y} = \alpha_c \left[\frac{\alpha_u}{\alpha_y} - \beta \right] + \beta \qquad (3)$$

Thi... ehavioral model of free-system systems based on the critical elastic coefficient and ... is parameter related to the vibrational time of the structure and is calculated from the following equation:

α β (4)

$$\beta = \beta' \frac{\;}{\alpha_y}$$

Given the above circumstance, we can calculate the value of the coefficient of behavior as follows:

$$q = \frac{\alpha_u}{\alpha_y}\left[(1 - \beta')\alpha_c + \beta'\right]$$

B) Energy method

The energy method is based on the assumption that the maximum kinetic energy generated by a severe earthquake with the maximum energy that a structure is capable of absorbing is equal to the equilibrium energy equation in a structure as follows:

Eku = Wo + Du - E2u (5)

In this regard, Eku is the maximum absorbing kinetic energy in the structure, Wo is the energy stored in the structure during the elastic deformation stage, Du energy stored during structural non-elastic transformations and E2u work performed by the vertical forces in the overall structure deformation trend.

Research background

In this section, some of the studies conducted by other researchers on the assessment of the coefficient of behavior of different types of structures will be mentioned. Some of the most important studies are as follows:

1. Newmark and Hall

Newmark & Hall proposed a relationship in their research, which uses a reduced coefficient of ductility for elasto plastic systems of a degree of freedom as follows [14]. For structures with a period of time less than 0.03 seconds or frequencies above 33 Hz:

$$R_\mu = 1.0 \qquad (6)$$

For structures with a period of time between 0.12 and 0.5 seconds or frequencies between 2 and 8 Hz:

$$R_\mu = \sqrt{2\mu - 1} \qquad (7)$$

Fo... er than 1 second or frequencies smaller than 1 Hz:

$$R_\mu = \mu \qquad (8)$$

Fo... of time between 0.03 and 0.12 and 0.50 to 1 sec, it is also possible to calculate the reduction factor du... ticity by summing up between the values.

2) Dr. Sahebi studied the coefficient of behavior of reinforced concrete bending frames. In order to calculate the coefficient of behavior of nine reinforced concrete frames with three spans of 4 meters and the number of floors 1-2-3-4-5-6-8-10-15 and with a height of each floor was considered 3 meters. The loading of models was done according to the 2800 Regulations and their design was based on the 9th National Building Regulations. [2] Static nonlinear analysis was used to analyze the models. The roughness coefficients of the members according to the period of joint failure in the three modes of Uninterrupted Use (IO) of Life Safety (LS) and Collapse Threshold (CP) defined in terms of seismic recovery instruction [6] and based on the coefficient of shape the overall fidelity of the frames was calculated. These results are presented in the table below. The results showed that changing the height and level of expected performance of the structure would change the behavior factor.

Table 1: Results of the behavior coefficient of reinforced concrete frames in Sahabi's research [2]

R	**R_s**	**R_μ**	**Performance level**
2.28	**1.80**	**1.26**	**IO**
4.43	**1.93**	**2.29**	**LS**

5.30	**1.93**	**2.74**	**CP**

Research Method. This thesis will be of applied research type and will be used for library studies. Considering that SAP2000 software and PUSH OVER or nonlinear analysis are used to determine the coefficient of behavior of the structures studied in this thesis. Nonlinear analysis methods for determining the coefficient of behavior of structures and in seismic design based on performance, the structure is analyzed for the different levels of expected performance associated with different levels of earthquake hazard. The first method of analyzing the nonlinear time history and the second most used method is static nonlinear analysis (incremental analysis). Incremental analysis has no problems with nonlinear dynamic analysis and by doing this, using the response spectrum as a need curve, an appropriate estimation of the coefficient of structural behavior can be obtained. Also, the method of the analysis of overloads with more precision in response estimation and structural capacity. The push-over method of nonlinear incremental load analysis or failure analysis is a simple and convenient method for predicting seismic response along with nonlinear dynamic analysis. Using incremental load analysis, the succession sequence and succession can be arranged. The shape, the coefficient of formation and the lateral resistance of the structure. In incremental load increment analysis, an incremental load increment is analyzed step by step. In order to validate the research method, two papers have been used. The first paper, entitled "The influence of a certain degree and the type of sections used in the design on the coefficient of behavior of the frame structures of the bending frame with the average shape". This article is the result of the study of Mr. Vaseghi Amiri, Abdullah Zadeh and Bani Hashemi. In this research, a few examples of modular steel folding frame with a number of floors and openings have been analyzed and designed, the designs are based on the AISC-ASD89 regulations, and all the rules related to the design of the folding frame with Modular formability has been evaluated. The structural system chosen for verifying the steel folding frame with modular steel and steel consumption in design and analysis of St37 type [27]. In order to validate the second, a paper is used as follows.

"Response modification factor for steel moment-resisting frames by different pushover analysis methods".

This ISI article was published in the Journal of Structural Steel Research. In this research, several FEMA Steel FAC frame designs have been analyzed and designed, according to the UBC94 regulations, and all the criteria for the design of the folding frame have been evaluated. Assigned sections are quite similar to the SAC project and are standard American sections. After modeling, the samples are analyzed by static non-linear static analysis, and this analysis is carried out to the extent that the corresponding target shift (relative positional control of the class in accordance with the UBC94 code) is carried out and the results of the coefficient of behavior and component. The results of each sample are obtained and finally, the results are compared.

Specifications of concrete structures. In the present study, 30 flexural concrete frames have been studied regularly and irregularly in structures with 3, 6, 9, 12, 15 floors in elevations with different openings of 4, 6 and 8 meters. The structures were selected for elastic analysis in order to design, model, and load. The results of the analyzes carried out in the design were used and the sections of the components were determined for all frames. After this phase, the structures are modeled for non-elastic analysis (static nonlinear analysis with increasing lateral loading). The height of the floors for the frames studied is 3 m and the width of the openings is 4, 6, and 8 m. It is assumed that the selected frames of the frames of the modest buildings are in accordance with Iran's 2800 standard. The ground of the construction site is assumed to be of type II and the loading width of each frame is 3 meters. Also, the frames are very high in the area with a lot of earthquakes. Frames are loaded in accordance with the Sixth National Building Regulations and Standard 2800. The design of the structures is in accordance with the ninth chapter of the national building regulations (design and implementation of concrete structures).

Linear analysis and design of structures using ETABS software and SAP2000 software have been used for nonlinear analysis and structural modal analysis. In the following figure, the structure of the structures and the slab of the 6-story structure are presented.

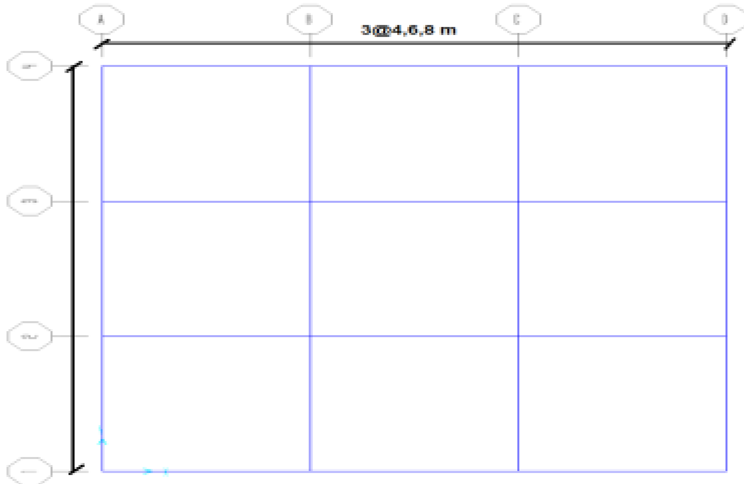


Figure 1. Plans for the studied structures

Figure 2- Shear of structure of 6 studied floors

Structure identifier. To facilitate the identification of the studied structures and to avoid repeated expressions of their specifications, the identification system in which each identifier is composed of one to four letters and four numbers and is used as follows. The common form of identifiers is Ir-nopq, in which Ir denotes irregular structures at elevation, and irregular structures at regular altitudes.

No specifies the number of structural classes, which includes states 03, 06, 09, 12, 15. pq specifies the width of the frame openings, which include the following three modes: 08.06.04, for example, Ir-1208 is a 12-story concrete structure that is irregular in height with a width of 8 meters and a structural structure 0304 Classy and regular at a height of 4 meters. The structures are in accordance with the regulations of the Sixth Section of National and Building Regulations and 2800 Iran Standard and their design has been done according to the rules of the ninth chapter of the national regulations and the building.

Criteria for regularity and irregularity of structures at height. In accordance with the rules of the regulations for regular structures at elevation, there are regular structures that have all of the following features:

- The distribution of mass at the height of the building is approximately uniform, so that the mass of any floor, with the exception of roof and roof rafting, does not change by more than 50% of the mass of the sub floor.
- The side hardness on any floor is less than 70% of the hardness of the floor on its own or less than 80% of the average hardness of the three floors on its own.

- No lateral resistance of any floor is less than 80% of the percentage of the lateral resistance of the floor. The strength of each floor is equal to the total resistance of all resistant components that can withstand the cutting of the desired direction.

And according to the criteria, irregular structures are considered to be in height, which lack one or more characteristics of the above criteria. In order to create irregularity in height in irregular structures at elevation, we considered the height of the first floor to be 6 meters and then, in accordance with the table, to model the lateral difficulty of each floor, the model was modeled individually and one horizontal we have added 10 tons to that class. Then, we obtained the displacement corresponding to the load loaded and, by comparing the displacements, we examined the above criteria to determine the orderly and irregularity of the structure at the height.

Table 2: Review of the regular results or the irregularity of the studied structures at elevation

Is structure considered irregular ?	The side hardness of the first floor is less than 80% of the average moderate toughness of the upper 3rd floor?	The side hardness of the first floor is less than 70% of the hardness of the second floor?	Movement corresponding to the severity of the fourth floor (mm)	The displacement corresponds to the stiffness of the second floor and the other (mm)	The displacement corresponds to the hardness of the first floor (mm)	Structure identifier
Yes	-	Yes	-	0.966	2.035	Ir-0304
Yes	Yes	Yes	0.775	0.592	1.235	Ir-0604
Yes	Yes	Yes	0.587	0.485	1.059	Ir-0904
Yes	Yes	Yes	0.483	0.409	0.902	Ir-1204
Yes	Yes	Yes	0.408	0.350	0.626	Ir-1504
Yes	-	Yes	-	0.794	1.135	Ir-0306
Yes	Yes	Yes	0.629	0.518	0.741	Ir-0606
Yes	Yes	Yes	0.438	0.434	0.653	Ir-0906
Yes	Yes	Yes	0.373	0.323	0.512	Ir-1206
Yes	Yes	Yes	0.323	0.277	0.377	Ir-1506
Yes	-	Yes	-	0.523	0.749	Ir-0308
Yes	Yes	Yes	0.509	0.378	0.541	Ir-0608
Yes	Yes	Yes	0.376	0.322	0.472	Ir-0908
Yes	Yes	Yes	0.322	0.285	0.409	Ir-1208
Yes	Yes	Yes	0.285	0.249	0.369	Ir-1508

Static analysis of nonlinear structures

In order to use this method in the present study, all structures under constant vertical load and lateral loads are used with a flexible distribution model with modus. For this purpose, the number of vibrational modes has been selected to contribute at least 90% of the mass of the structure to the analysis. Before this, it is first necessary to draw a link between the basic cut and the relative displacement of the roof for different structures, which are presented in the following forms.

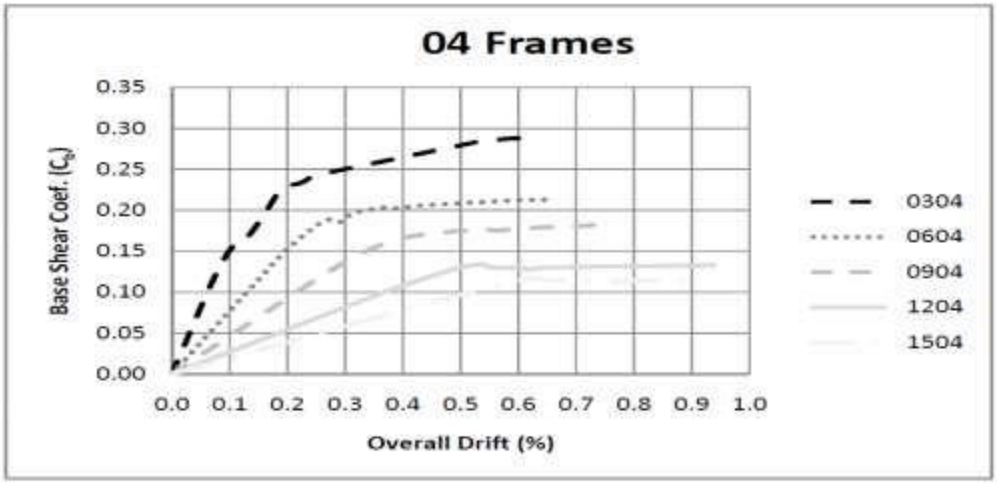


Figure 3. Relationship of the base cut with relative displacement of the roof for various regular structures at a height of 4 meters

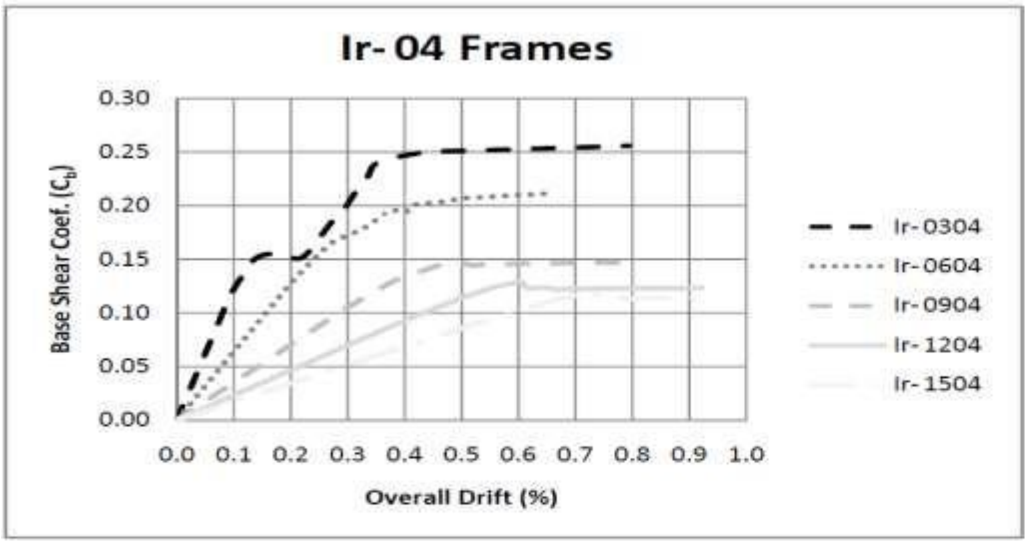


Fig. 4: Relationship of the base cut with relative displacement of the roof for irregular structures with a 4-meter span

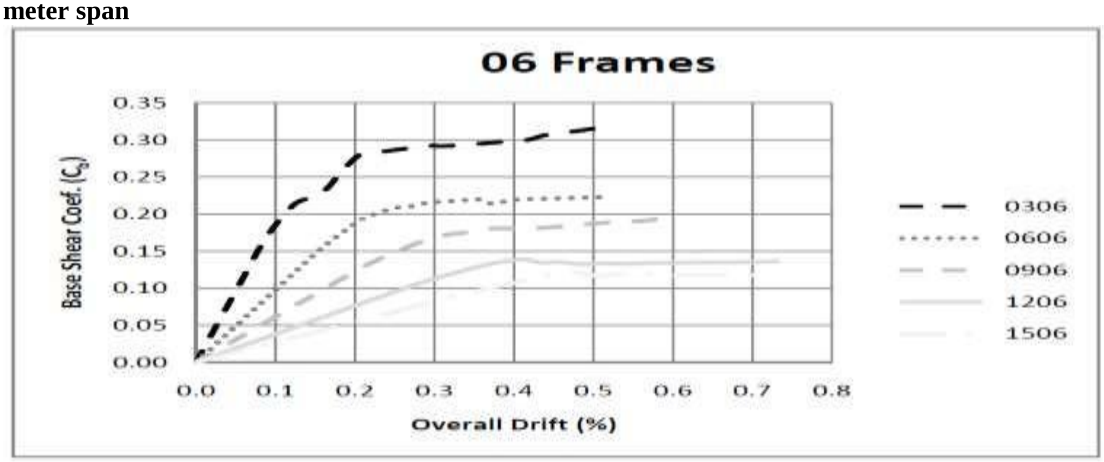


Fig. 5: Relationship of the base cut with relative displacement of the roof for regular structures at a height of 6 meters

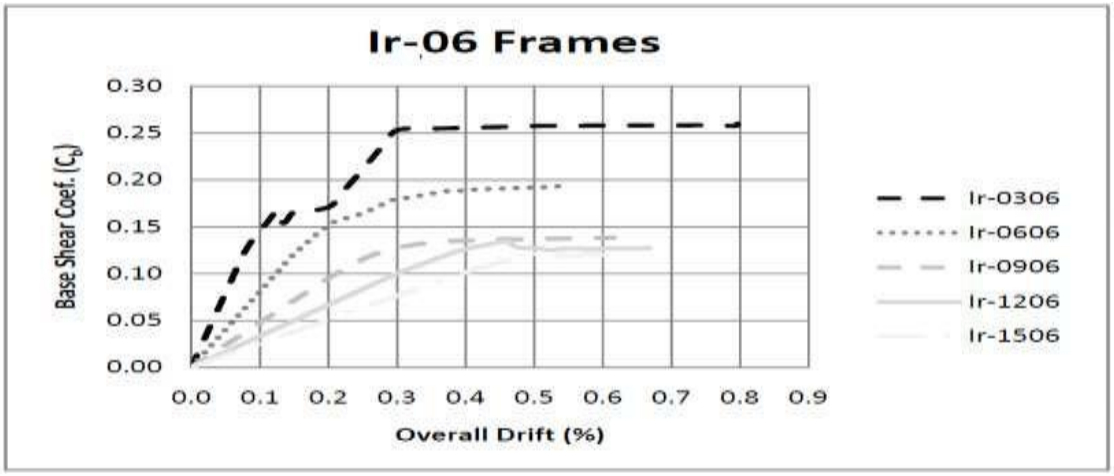


Fig. 6: Relationship of the base cut with relative displacement of the roof for irregular structures at an altitude of 6 meters

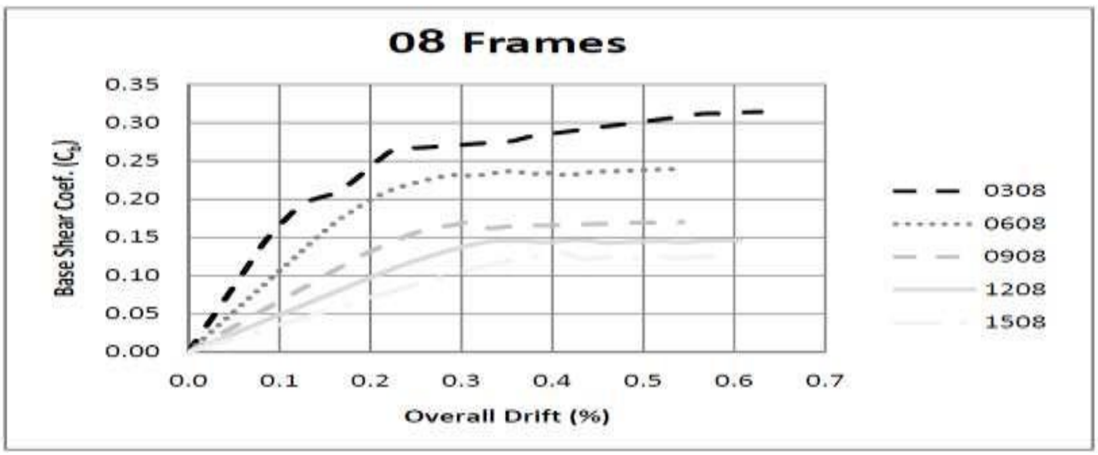


Figure 7. Relation of the base cut with relative displacement of the roof for regular structures at an altitude of 8 meters

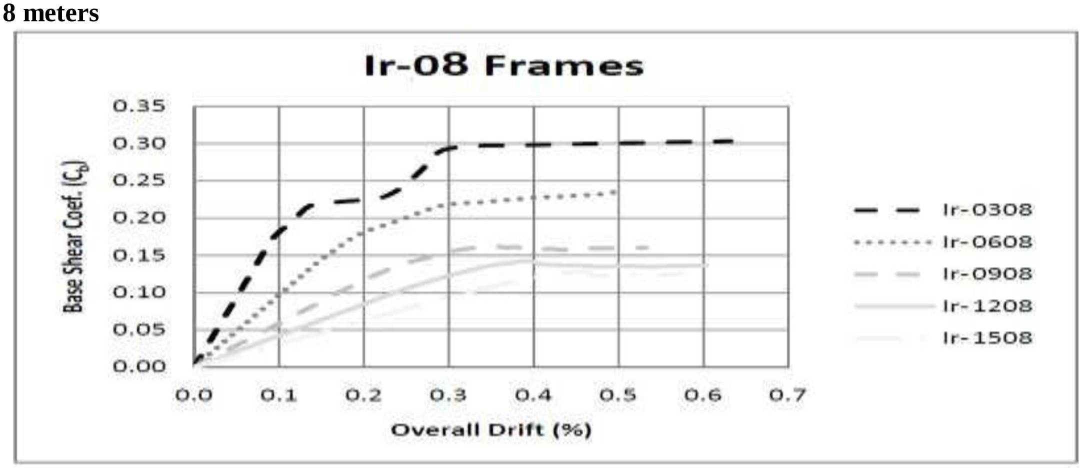


Figure 8. Relationship of the base cut with relative displacement of the roof for irregular structures with a span of 8 meters

Calculate the coefficient of structure behavior based on the plasticity factor

Since the factors affecting the coefficient of behavior of the all-formability, the structural and non-structural resistance, reduces the level of elastic forces to the design forces, they must be reflected in the overall behavior curve of the structural system. In the following two forms, the coefficients of reduction the effect of ductility (R_{μ})

versus the number of structural classes for different sizes of openings is shown for regular and irregular structures at elevation.

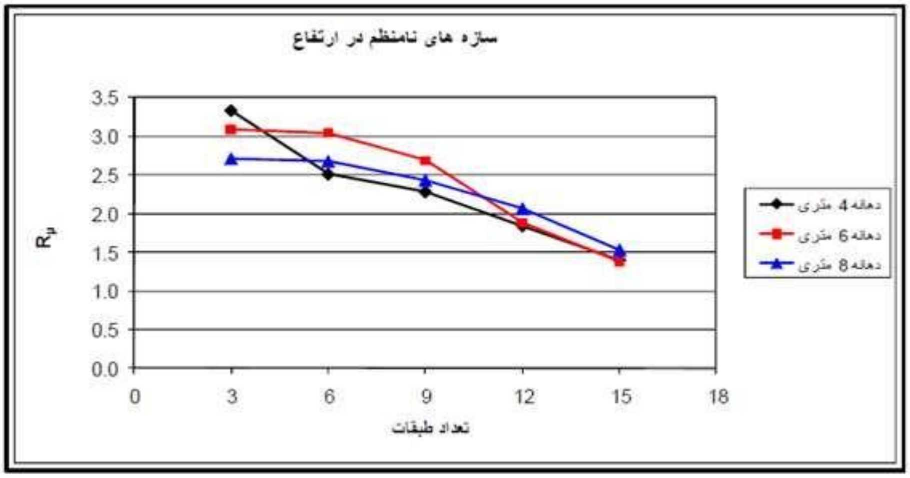


Figure 9- Reducing coefficients on the formability versus the number of classes for regular structures at elevation

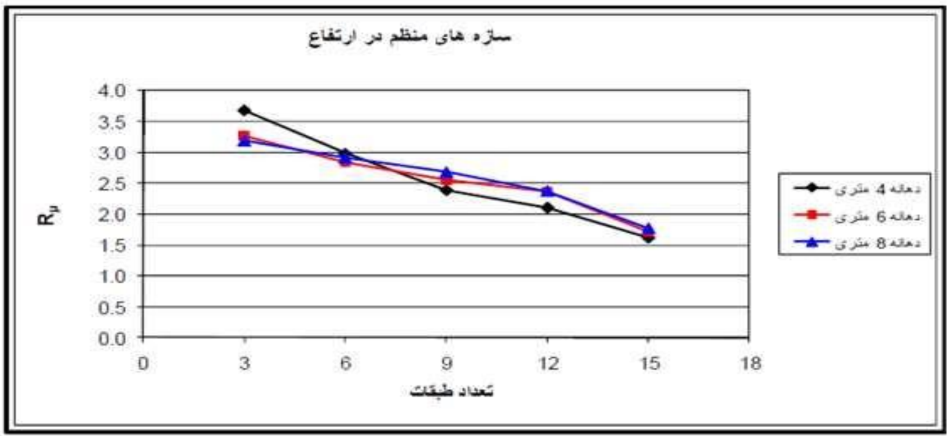


Figure 10. Decreasing coefficients on the degree of flexibility versus the number of floors for irregular structures at elevation

According to the above diagrams, it can be seen that with increasing number of classes, the coefficient of reduction decreases due to dampening (Rμ).

Calculate the coefficient of behavior of structures based on the increased resistance factor

Structural design is performed after determining the cut-off value of the design by seismic loading instructions. In the design process, the designer is required to observe the provisions of the materials and design regulations and their constraints. Also, in order to avoid the widespread variety of dimensions and details of the members of the instruments, it is necessary to classify them into a fewtypes.

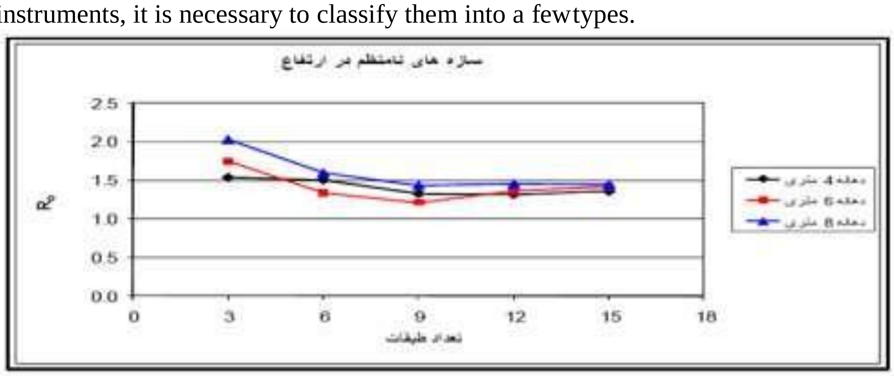


Figure 11: Incremental resistance coefficients versus the number of floors in irregular structures

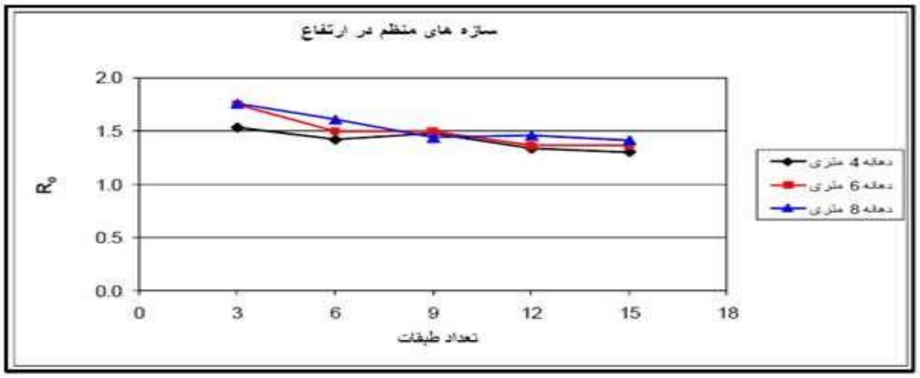


Figure 12 - Incremental resistance coefficients versus the number of floors in regular structures

Calculation of overall behavior coefficient (linear static analysis)

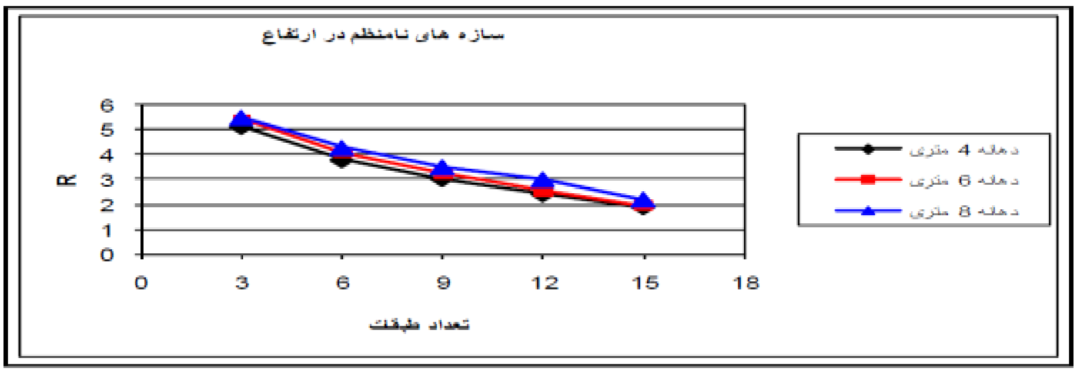


Figure 13 - The value of the overall behavior factor for irregular structures

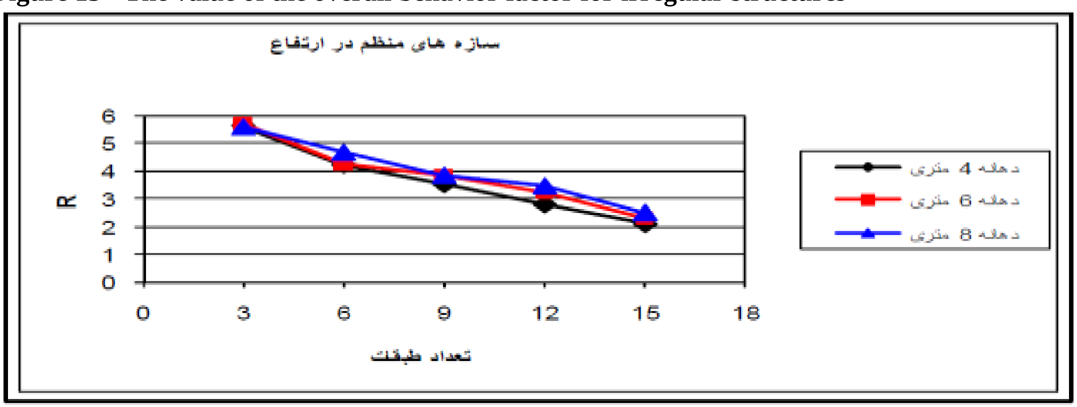


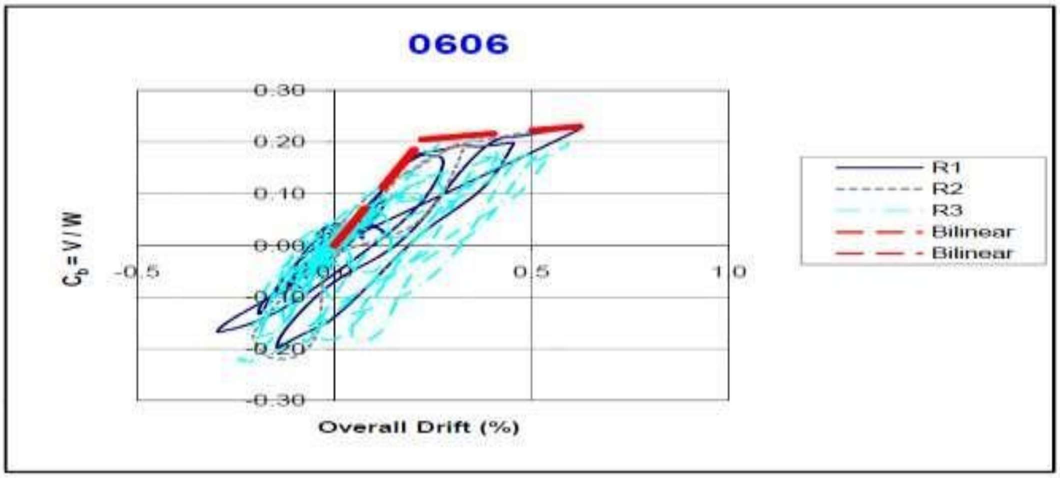
Figure 14. The value of the overall behavior of the overall structures of the regular structures

Irregular structures at height			**Regular structures at height**			
VAR(%)	SD	Mean	VAR(%)	SD	Mean	Floors
0.28	0.05	5.65	3.65	0.19	5.35	3
6.59	0.26	4.39	6.31	0.25	4.05	6
3.19	0.18	3.73	5.58	0.24	3.26	9
10.98	0.33	3.17	9.25	0.30	2.66	12

3.85	0.20	2.31	2.67	0.16	2.03	15

Table 2. Statistical calculations of the behavior of the regular and basic structures

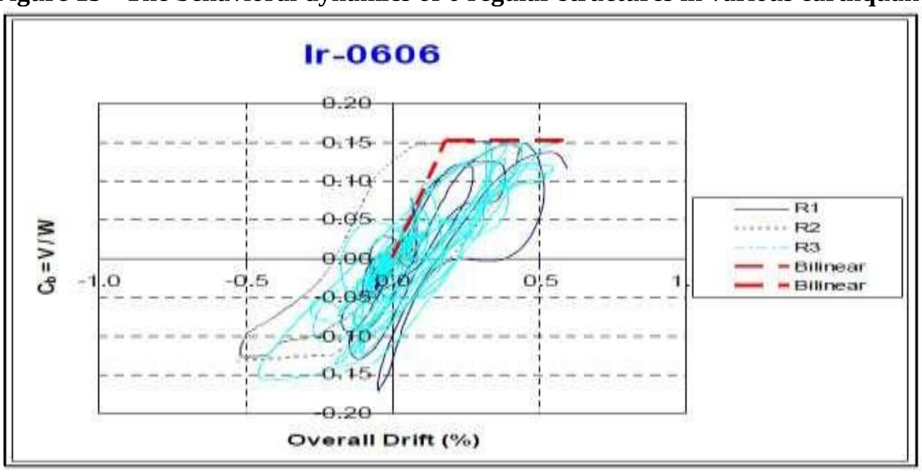
Calculation of Behavioral Coefficient (Nonlinear Dynamic Analysis)
In order to study the results of static nonlinear analysis with increasing lateral loading, we construct 6-story structures under non-linear dynamic analysis and investigate their behavior.



Structure name	0606		
T(sec)	0.7329	Cd	0.127
Δy	0.2240	Cy	0.205
Δmax	0.6210	Cmax	0.230

μ	2.772
Rμ	3.151
R□	1.610
R	5.074

Figure 15 - The behavioral dynamics of 6 regular structures in various earthquakes



Structure name	Ir-0606		
T(sec)	0.8338	Cd	0.1273
Δy	0.1810	Cy	0.1520
Δmax	0.5953	Cmax	0.1520

μ	3.2891
Rμ	3.9376
R□	1.1940
R	4.7016

Figure 16: Dynamic behavior of six-story irregular structure in various earthquakes
We observe accurately the values of the coefficient of behavior obtained from nonlinear dynamic analysis, which is an average of about 15% more than the values obtained by nonlinear static analysis with increasing lateral loading, and there is no significant difference. .

Summary of results. In the present study, 30 flexural concrete frames have been studied regularly and irregularly in structures with 3, 6, 9, 12, 15 floors in elevations with different openings of 4, 6 and 8 meters. The structures were selected for elastic analysis in order to design, model, and load. The results of the analyzes carried out in the design were used and the sections of the components were determined for all frames. After this stage, the structures were modeled for nonlinear analysis (static nonlinear analysis with increasing lateral loading), and then the structural behavior coefficient was analyzed using nonlinear static analysis with increasing lateral loading and some results were obtained with the results of dynamic analysis non-linear comparison. The most important results of this research can be summarized as follows:

1. According to the results, in most cases, the coefficient of reduction due to the formation of ($R\mu$) in regular concrete structures at heights is more than that of irregular structures, in other words, in structures with the number of floors and the size of the span with structures Regular concrete has a more suitable formability than irregular structures at elevation. In this study, it can be said that the coefficient of reduction in the shape of ($R\mu$) in irregular structures at elevation averages 91% of its value in Regular structures are at altitude.

2. In this study, increasing the number of floors from 3 to 6 floors, the coefficient of resistance decreases, but from 6 upwards, ie, in structures 9, 12 and 15 there is no significant change in the resistivity coefficient. Also, the regular or irregularity of the structure did not make any difference in the amount of this coefficient.

3. Structural behavior coefficient (R) in regular concrete structures at altitude is more than the irregular structures at elevation. The regular structures with the number of floors and the size of the spans have a higher coefficient of behavior than the irregular structures at elevation. .

4. The results showed that the nonlinear dynamic analysis obtained from the nonlinear dynamic analysis is on average 15% more than the values obtained by nonlinear static analysis with increasing lateral loading and there is no significant difference between the two methods.

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