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Research Article

Comparison of equivalent seismic load and response spectrum methods according to TSC 2018 and TSC 2007

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ABSTRACT

In this study, two different analysis methods were compared; the first is a linear static analysis method and the second is a linear dynamic analysis method. First one is the Equivalent Seismic Load Method, which is a linear static method where seismic loads can be obtained by applying a simple calculation. The second method, the Response Spectrum method, is a linear dynamic analysis method which obtains the seismic loads using more complex statistical calculations. For this analysis study, 18 structural models with 3 different building heights were analyzed according to the conditions of Equivalent Seismic Load Method and Response Spectrum Method specified in both TSC 2007 and TSC 2018 and base shear forces obtained as a result of these analyzes were compared. As a result of analysis; compared to the results obtained from TSC 2007, due to the effective stiffness coefficients specified in TSC 2018, it was observed that the base shear forces obtained for both methods were lower and the modal period values were longer in the analyzes applied according to TSC 2018. This means that the structural systems created with the designs according to TSC 2018 are more ductile than the structural systems created with the designs made according to TSC 2007. Base shear forces obtained by 2 different analysis methods applied according to regulations stated in both TSC 2018 and TSC 2007; it was observed that the base shear forces obtained by the Equivalent Seismic Load Method were higher than the results of the Response Spectrum Method.

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1. Introduction

There are various regulations and standards around the world in order to ensure the adequacy of the structures to be constructed under the titles of inspection, usability and safety. In these regulations and standards, there are various solution methods for the design of structures and alternative solutions that can be used in exceptional cases where these solution methods cannot be applied effectively. While some of these calculation and analysis methods are highly complex and developed directly on the goal of predicting the actual performance of the building, some methods provide simpler solutions to ensure adequate security of structures. The reason that these solutions are simple, that is to say less complicated, is that some assumptions are used in the calculations and the use of safety factors. Examples of these safety factors are reducing the material strength, increasing the loads expected to be effected, reducing the effective rigidities of the structural system elements and accepting the ground bearing capacity as low.

Seismic loading is one of the most important topics to consider in the design of structures. When it comes to these effects, it must remembered that our country is located on an active fault map. Today, population density is generally found in the areas close to these fault zones. Throughout history, the result of seismic movements, our country experienced heavy losses of life and property as well as moral damage on the population and the economy. For this reason, it is known that the real behavior of the existing buildings and the buildings to be constructed under seismic effects in our country can be determined

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with the nonlinear analysis. However, it is of utmost importance that the structural strength of the buildings against seismic effects is meticulously and accurately determined even by linear calculations that specified by the regulations.

Considering these situations, an analysis study was conducted to examine the results of Equivalent Seismic Load Analysis and Response Spectrum Analysis, which are used to estimate seismic loads that are predicted to be met by structures as linear analysis methods according to regulations. These analyzes were carried out in accordance with the conditions stated in TSC 2007 and TSC 2018.

In the literature, Yılmaz (2008) applied linear analysis according to TSC 2007, Equivalent Seismic Load Method to form the initial step of the nonlinear analysis to determine the seismic performance of an existing building. Uzun (2014) conducted an analysis study to examine the effect of desired slab type on the seismic performance of a thirty-three-storey building and used the Response Spectrum Method in the initial step of this study as linear analysis. Pakoglu (2009) in his thesis study on a 100 meter high, reinforced concrete (RC) tube walled structural system has preferred and Response Spectrum Method has used to determine the linear seismic loads. Kıran (2010) preferred to use the Equivalent Seismic Load Method in his study in order to examine the behavior of an existing 8-storey building and a newly designed 2-storey building under the effects of seismic effects. Dinçer et al. (2014) carried out the performance analysis of a 4-storey school building with static push over analysis and preferred to make the calculation according to the Response Spectrum Method in the linear analysis section which is the initial step of this analysis study. Köse (2008) designed a 3-storey reinforced concrete structure in her thesis and chose to use the Equivalent Seismic Load Method in his study in order to investigate the behavior of this structure under seismic effects. Arias et al. (2019) ASCE / SEI 7-10 / 2010 in their study according to the seismic effects of multi-degree of freedom systems in their work in order to examine the interaction of the structure of the soil in their study carried out with the method of Response Spectrum Analysis. Kocer et al. (2018) presented a comparative analysis of the design considerations specified in the TSC 2018 and TSC 2007 regulations on the seismic data selected for 4 different provinces in their analytical study in order to compare the linear calculation methods. In the study of Erkan et al. (2019) conducted an analytical study to investigate the effect of the change in the ratio of reinforced concrete walls on seismic performance. In this study, Equivalent Seismic Load Analysis method was preferred. Doğan (2019), in his thesis study, evaluated the building models he prepared to examine seismic performances according to TSC 2007 and TSC 2018 and made a comparison in accordance with the conditions specified for Equivalent Seismic Load Method and Response Spectrum Method specified in these regulations. Arslan et al. (2013) examined the characteristics of the earthquake that occurred in Kütahya in 2011 in their study.

2. Material and Method

2.1. Determination of geometric properties of analysis models

Within the scope of the study, there are 3 different building heights including 4-storey, 7-storey and 10-storey; 1 reference model and 5 RC walled models are designed. For each building height, 6 models were prepared and a total of 18 types were created. The models containing the reinforced concrete walls were prepared by using different amount of RC walls up to the ratio value (the ratio of the sum of the RC wall areas in a floor plan in any direction to the total of the floor plan areas of the structure is equal to or greater than 0.002 (TBDY, 2018), which defines the structures consisting of the reinforced concrete walled structural system specified in TSC 2018. Naming of the prepared building models was made as ‘Model (number of storey).(number of RC wall ratio)’. For example, a building model with a 7-storey and 4th wall ratio is called ‘Model 7.4’, and the model that provides 4-storey and 1st Wall ratio is called ‘Model 4.1’. In Table 1, the RC wall ratios were determined according to the conditions specified in TSC 2018 that are given for different building heights. According to these values, this ratio is calculated as 0 because there is no reinforced concrete wall in the floor plans of the building models with the 1st RC wall ratio for each building height.

According to TSC 2018, the response modification coefficients of these models are taken as R=8 and the over strength factors as D=3. Models with a RC wall ratio number from 2 to 5, the structural system conforms to the definition of structures consisting of both reinforced concrete walls and frames with high ductility according to TSC 2018. The response modification coefficients of these models are taken as R=7 and over strength factors as D=2.5. The structural system of the models with the RC wall ratio number 6 complies with the definition of structures made of reinforced RC walls with high ductility. The response modification coefficients of these models are taken as R = 6 and over strength factors as D=2.5.

Table 1. Ratio of reinforced concrete walls determined for analysis models.

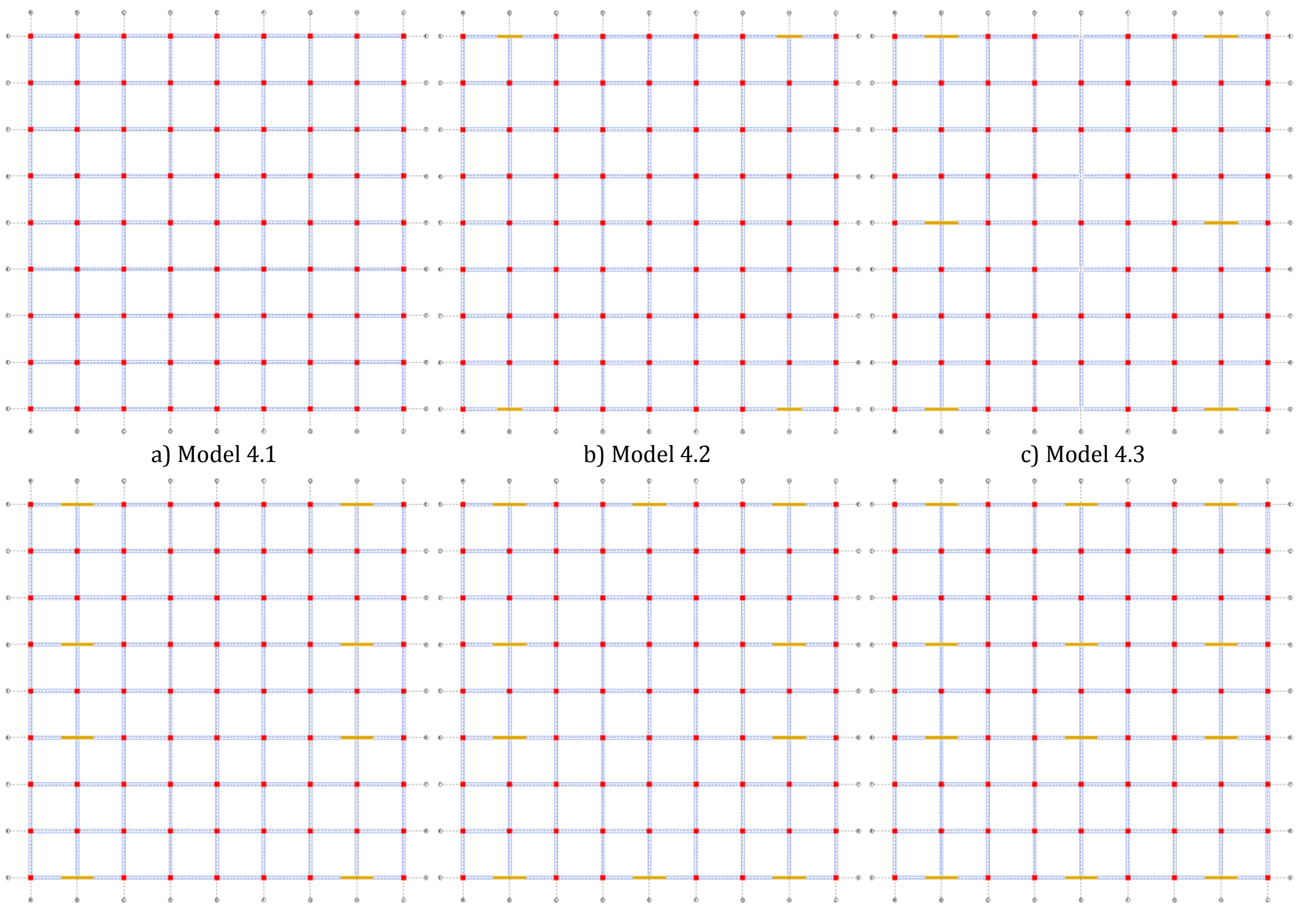
Number of RC wall ratio	4 Storey	7 Storey	10 Storey
1	0	0	0
2	0.512	0.512	0.512
3	1.007	1.011	1.007
4	1.416	1.416	1.416
5	1.700	1.702	1.709
6	2.016	2.023	2.014

The models have 8 bays in X and Y directions and the length of each bay is 4 meters. Rigid diaphragm was adopted and beamed slab type was preferred. The slab thickness used in the buildings was determined as 15 cm. In all models, the columns are 40 x 40 cm and the beams are 25 x 50 cm. The dimensions of reinforced concrete wall elements vary according to the type of construction model designed to meet the selected wall ratio. The dimensions of the RC walls used in the models are given in Table 2.

Table 2. Dimensions of reinforced concrete walls determined for analysis models.

Number of RC wall ratio	4 Storey	7 Storey	10 Storey
1	0	0	0
2	210 x 25 cm	210 x 25 cm	210 x 25 cm
3	275 x 25 cm	290 x 25 cm	275 x 25 cm
4	290 x 25 cm	290 x 25 cm	290 x 25 cm
5	290 x 25 cm	305 x 25 cm	280 x 25 cm
6	295 x 25 cm	290 x 25 cm	275 x 25 cm

In TSC 2018, effective rigidity multipliers are defined on columns, beams and RC wall elements in order to be able to make modeling in accordance with the Design by Strength. There is no such requirement in TSC 2007. The structural elements of the structural system are defined according to the Mander Confined Concrete Theorem from the Section Designer menu on the SAP2000 analyzing software. As the dimensions of the structural system elements except the RC walls are the same in all construction models, the reinforcement is determined to be uniform for all models. The reinforcement determined for each section of wall was calculated separately up to the H_{CR} as well as the height of the building. This table also shows the lengths of the flange and web regions of the RC wall elements. The models designed in this way have been subjected to the analysis procedures with Equivalent Seismic Load Method and Response Spectrum Method according to TSC 2018 and TSC 2007. The analyses performed due to the effective rigidity multipliers defined on the structural system elements were carried out separately for each regulation. Structural plans of the models created in accordance with the given data are shown in Fig. 1.



a) Model 4.1 b) Model 4.2 c) Model 4.3

d) Model 4.4 e) Model 4.5 f) Model 4.6

Fig. 1. (continued)

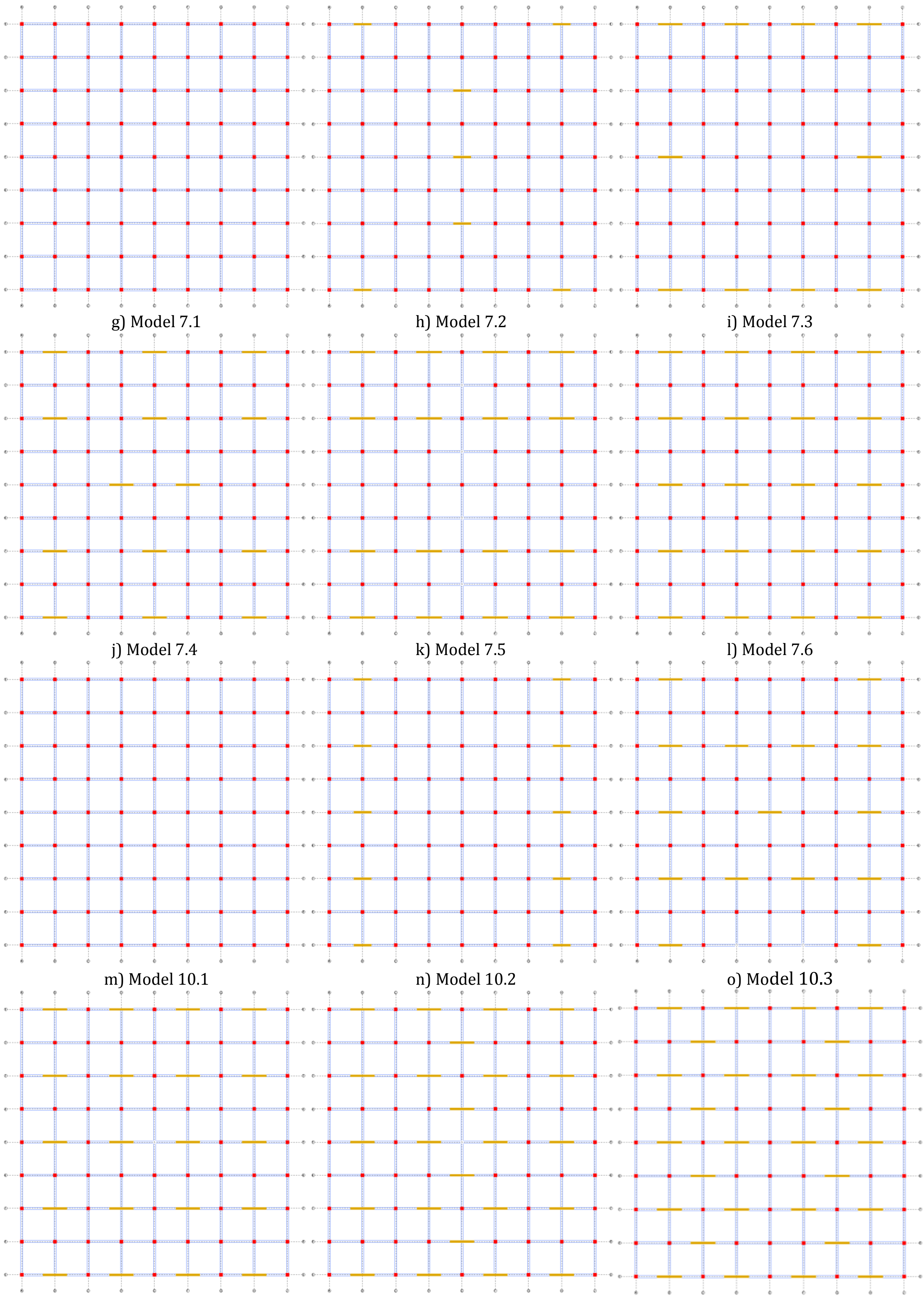


Fig. 1. Structural plans of models used in the study.

2.2. Load analysis

In the 18 types of analysis model prepared for this study, gravitational loads specified in TS498 are used. In order to determine the lateral loads, linear elastic analysis was performed by considering seismic loads calculated by Equivalent Seismic Load and Response Spectrum methods. The 15 cm thick slabs were not defined in the SAP2000 models and like the self weights of the slabs, the dead and live loads on the slabs were allocated to the beams as a line load which the slabs were connected. The columns and RC walls of the base story are fixed into the ground in the SAP2000 models. TS498 was used to determine the gravitational loads in order to design in accordance with the conditions specified by the regulations. In these analyzes, the gravitational loads applied to the models were calculated according to TS498 as follows:

- Slab self weight : 0.375 t/m^2
- Area dead load : 0.200 t/m^2
- Brick walls on beams : 0.500 t/m
- Area live load : 0.350 t/m^2
  - $\sum G_{\text{slab}}$ = 0.575 t/m^2
  - $\sum G_{\text{brick}}$ = 0.500 t/m
  - $\sum Q_{\text{slab}}$ = 0.350 t/m^2

Since the slabs are not modeled in the SAP2000 program, the loads transferred from these elements to the beams with the share of area are applied as triangular line load. The peak value of the triangular line loading condition is calculated as shown in Fig. 2.

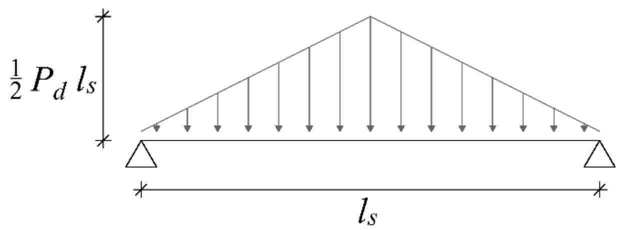


Fig. 2. Triangular line load distribution.

Triangular distributed load values calculated according to this diagram:

G = [4 m x 0.575 t/m^2] / 2 = 1.15 t/m

Q = [4 m x 0.35 t/m^2] / 2 = 0.7 t/m

However, these values are the load values to be loaded on the outer beams. Because loads from only one slab are transferred to the outer beams, load transfers from the two slabs are to the inner beams. Therefore, the values obtained were multiplied by two and the following loads were obtained and loaded on the inner beams:

G = 1.15 t/m x 2 = 2.3 t/m

Q = 0.7 t/m x 2 = 1.4 t/m

The load value of 0.5 t/m, which is determined as the brick wall load, is applied on the inner and outer beams as dead load. Rigid diaphragms have been defined for each story level as the solution will be made with the acceptance of rigid diaphragm.

According to this acceptance, story shear loads affect to center of the diaphragm.

2.3. Determination of earthquake parameters

18 analysis models have been created in 3 different building heights with the same floor areas. The story heights of the models are 3 m and the total building height is 12 meters for 4-storey models, 21 meters for 7-storey models and 30 meters for 10-storey models. The site class to be analyzed for these buildings is determined as ZC and the seismic level considered is DD-2. The building usage class is BKS-3 and the building importance coefficient is taken as I=1. For buildings with S_{DS}=1.327 and BKS-3, the seismic design class specified in TSC 2018 is DTS=1. DTS=1 and total building height values were taken into consideration and the building height class was found as BYS=6 for 4-storey models, BYS=5 for 7-storey models, and BYS=4 for 10-storey models.

The location determined for obtaining the parameters to be used in the calculation of seismic loads in accordance with TSC 2018 is the central Yakutiye district of Erzurum province. Fig. 3 shows the coordinates selected on Turkey Seismic Map arranged by MTA. (39.90601500°, 41.27772700°). (Disaster and Emergency Management Presidency, 2018).

Seismic parameters of this region with site class ZC and the earthquake level considered DD-2 are given:

PGA = 0.464 g	PGV = 28.055 cm/sn
S_S = 1.106	S_1 = 0.288
S_{DS} = 1.327	S_{D1} = 0.432
T_A = 0.065 sn	T_B = 0.325 sn

Seismic parameters determined for linear analysis in accordance with TSC 2007; the 1st seismic zone and site class as Z3 (2007).

3. Analysis and Results

3.1. Equivalent seismic load method

Since the intended use of the designed buildings is determined as housing, the live load participation coefficients are taken as n=0.3 for both TSC 2007 and TSC 2018. The building masses are defined as G + 0.3Q. The determined earthquake parameters are defined for 18 types of models and two different regulations on SAP2000 program.

The response modification coefficient of the models with 1st RC wall ratio (frame structural system) is R=8, the response modification coefficient of the RC wall ratio number 2 to 5 (wall-frame structural system) is R=7, for the buildings that have the RC wall ratio number 6 (RC wall structural system) response modification coefficient was selected as R=6. It should be noted that the Equivalent Seismic Load Method is not applicable for both regulations on 10-storey models used in this study. However, 10-storey models were also analyzed with this method in order to examine the results. Table 3 shows the percentage increase in the shear forces due to the shear ratio as compared to the reference models.

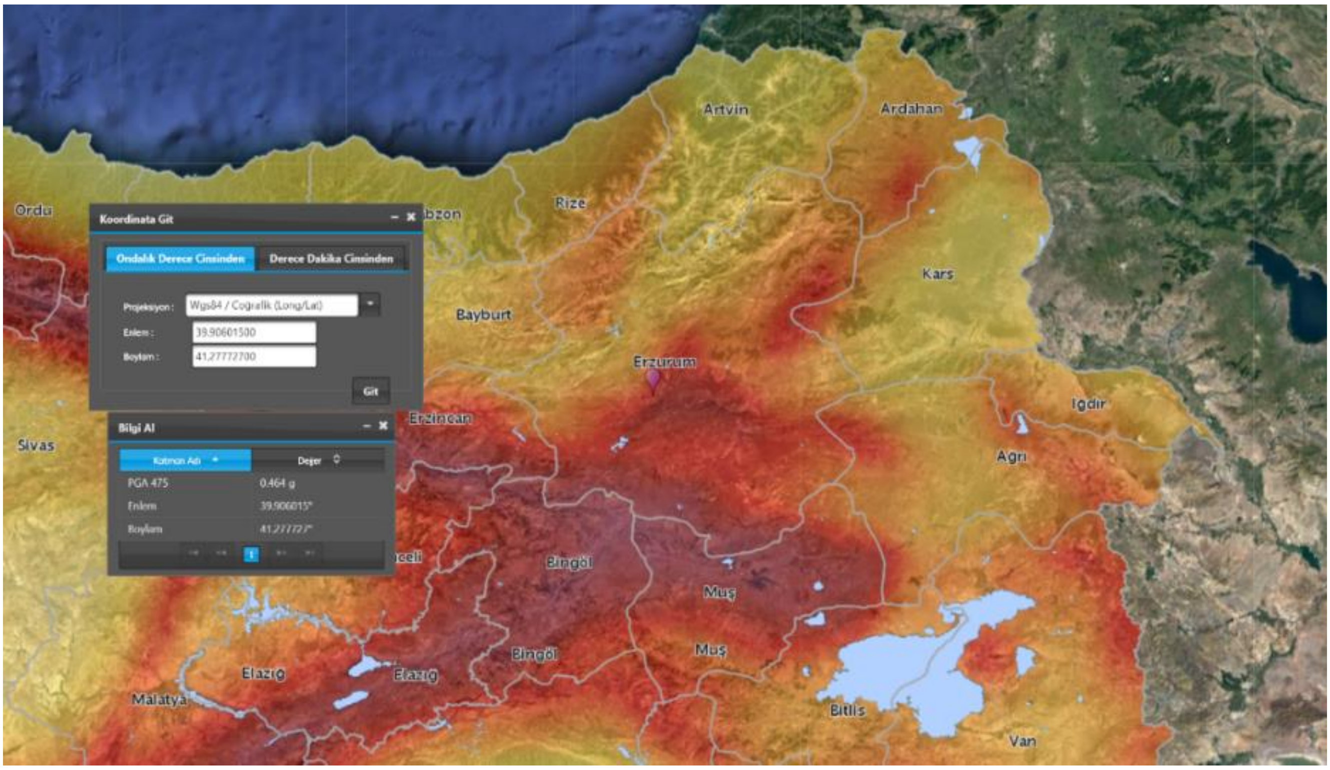


Fig. 3. Coordinates of the specified location.

Table 3. Percentage increase in the shear forces due to the shear wall ratio as compared to the reference models for equivalent seismic load method.

RC Wall Ratio (‰)	0	0.5	1	1.4	1.7	2
4 Story	0	21.76	50.00	68.71	76.29	115.50
7 Story	0	15.93	41.69	60.73	67.08	110.34
10 Story	0	2.10	5.12	21.99	30.68	64.62

3.2. Response spectrum method

This method does not have any restriction according to the geometric properties of the structures to be applied such as Equivalent Seismic Load Method. However, this method requires a more complex calculation. For this reason, analytical project design offices often use this method to determine seismic loads used in structural design. The response modification coefficients used for the models to be subjected to this analysis are the same as those used in the Equivalent Seismic Load Method. Spectrum curves were generated by using the functions given in the regulations and defined on the SAP2000 with the acceleration values corresponding to the period values used. For both regulations, only the base shear forces obtained from the results of the analyzed methods were compared. This method is defined in accordance with TSC 2018 and TSC 2007. Table 4 shows the percentage increase in the shear forces due to the shear ratio as compared to the reference models.

Table 4. Percentage increase in the shear forces due to the shear wall ratio as compared to the reference models for response spectrum method.

RC Wall Ratio (‰)	0	31.60	68.67	87.57	93.53	133.78
4 Story	0	43.58	76.76	98.47	102.34	151.76
7 Story	0	47.59	88.31	111.66	124.76	180.19
10 Story	0	31.60	68.67	87.57	93.53	133.78

3.3. Analysis results

18 types of building models are defined for 3 different building heights and 6 different RC wall ratios for each building height. These models were analyzed in accordance with the requirements of Equivalent Seismic Load Method and Response Spectrum Method specified in TSC 2018 and TSC 2007. These structures are designed regularly in the floor plan and the reinforced concrete RC wall elements are placed in the X direction in order to facilitate the comparison process and only the results in the X direction are considered for these two analysis methods.

The effects of the designs made according to both regulations on the mode periods were observed with the increase of the RC wall ratio. In Table 5, the comparison of the modal periods obtained with the designs made according to the two regulations as well as the base shear forces in the X direction obtained by the Equivalent Seismic Load Method and Response Spectrum Method applied according to TSC 2018 and TSC 2007 belonging to all models were made. Fig. 4 shows the graphs comparing the floor displacements prepared according to TSC 2018 and Fig. 5 according to TSC 2007.

When interpreting the values given in Table 5, it should be noted that 10-fold models among the models subjected to analysis are not suitable for the analysis according to the Equivalent Seismic Load method. Although this situation is known, the reason why the analyses have been applied on these models is to see what results will be encountered compared other suitable models. When interpreting Figs. 4 and 5, it should be noted that the seismic loads expected to be exposed to the structures are different in the analyses made using two different methods.

When the graphs given in Figs. 4 and 5 are examined, floor displacements of the reference models and the models with ‰ 0.5 RC wall ratio have received very large values for each building height. Against these values, the floor displacement values of the models with RC wall ratio ‰1 and more have decreased significantly, compared to the reference model. As a result of the analyzes made with two different calculation methods applied according to two different seismic codes, it is seen that the floor displacements do not decrease in accordance with the increase in the RC wall ratio when this ratio value exceeds ‰ 1. This result was obtained by examining detailed values that are in the tables given in the appendices (Table 6 to Table 17). In these tables, the obtained floor displacements of the buildings designed at three different building heights are given. According to the analysis results obtained for each building height subjected in this study, it can be suggested that the use of RC walls with a ratio of ‰ 1 is sufficient unless there is a demand for more base shear force.

4. Conclusions

In the analyzes carried out by the Equivalent Seismic Load Method, the base shear forces that will affect the structures have increased due to the increase of the RC wall ratio. In addition, the effect of response modification coefficients (R) is very important in this situation. However, it is not correct to say the same for story drifts. With the increase in the height of the building, the increased shear forces can be carried to a certain limit by the RC wall elements in the structural systems of the buildings. When the bending moments caused by the effect of lateral loads on the joints considered to be supported on the foundation of the structural system elements will increase as the building height increases. Increased story drifts caused by the shear forces that increased with building height, can be limited to a certain level by the RC wall elements placed in the structural systems of the buildings. These displacement values showed a linear increase up to the models with RC wall ratio ‰ 1, whereas the models with RC wall ratio greater than ‰ 1 showed a decreasing increase.

For all models and for both TSC 2007 and TSC 2018, the shear forces obtained by the Response Spectrum Method are lower than those obtained by the Equivalent Seismic Load Method. The reason for this is that the calculations made with the Equivalent Seismic Load Method are mainly based on the period values and story drifts of the 1st modes of the structures as well as the values obtained from the acceleration spectrum, conditional formulas and certain earthquake parameters according to the region where the structures will be built. On the other hand, Response Spectrum Method results are obtained by statistically combining the acceleration and period values obtained from the response spectrum for the region where the structures will be built.

It was found that the results of the base shear force obtained by the Equivalent Seismic Load Method increased with lower rates because the structures were dependent on the floor displacements and periods, but the total loads were larger. It can be concluded that the shear force results obtained by the Response Spectrum Method are lower than the Equivalent Seismic Load Method in total but Response Spectrum Method is more sensitive to the increasing stiffness of the structures. This sensitivity was observed with the percentage change of base shear force values which increased with the increase of RC wall ratio compared to the reference models.

The comments that can be made for the displacement values obtained as a result of the Response Spectrum Method may also be similar to the comments on the displacement values obtained as a result of the Equivalent Seismic Load Method. Because even if the different lateral loads affect the structure, the structural system will generate displacements depending on the amount of the loads applied.

Table 5. Comparison of analysis results according to TSC 2007 and TSC 2018.

MODEL	RC Wall Ratio	EDY 2018 (ton)	EDY 2007 (ton)	MBY 2018 (ton)	MBY 2007 (ton)	MODAL 2018	MODAL 2007
Model 4.1	0	420.285	497.182	332.143	436.33	0.735 X 0.735 Y 0.680 T	0.535 Y 0.535 X 0.496 T
Model 4.2	0.512	511.745	678.089	437.108	495.3544	0.734 Y 0.609 X 0.550 T	0.535 Y 0.432 X 0.390 T
Model 4.3	1.007	630.487	728.965	560.216	583.8927	0.731 Y 0.499 X 0.488 T	0.534 Y 0.353 X 0.347 T
Model 4.4	1.416	709.057	734.148	623.020	585.641	0.729 Y 0.468 T 0.447 X	0.533 Y 0.332 T 0.316 X
Model 4.5	1.709	740.923	737.509	642.820	587.539	0.729 Y 0.434 T 0.429 X	0.533 Y 0.307 T 0.303 X
Model 4.6	2.014	905.738	864.575	776.503	685.264	0.727 Y 0.437 T 0.412 X	0.532 Y 0.309 T 0.290 X
Model 7.1	0	485.442	564.012	329.646	487.672	1.287 Y 1.287 X 1.189 T	0.924 Y 0.924 X 0.856 T
Model 7.2	0.512	562.778	791.11	473.305	645.054	1.287 Y 1.035 X 0.996 T	0.926 Y 0.728 X 0.703 T
Model 7.3	1.011	687.850	972.85	582.700	760.125	1.287 Y 0.816 X 0.766 T	0.924 Y 0.574 X 0.536 T
Model 7.4	1.416	780.206	1071.408	654.261	822.472	1.282 Y 0.785 T 0.730 X	0.921 Y 0.556 T 0.519 X
Model 7.5	1.702	811.069	1149.535	667.017	884.414	1.363 Y 0.722 T 0.707 X	0.921 Y 0.488 T 0.479 X
Model 7.6	2.023	1021.058	1392.137	829.939	1070.8627	1.281 Y 0.722 T 0.661 X	0.921 Y 0.505 T 0.462 X
Model 10.1	0	669.943	606.914	334.535	539.841	1.844 Y 1.844 T 1.701 B	1.320 X 1.320 Y 1.218 T
Model 10.2	0.512	684.017	867.682	493.757	713.708	1.854 Y 1.450 X 1.449 T	1.322 Y 1.0241 T 1.024 X
Model 10.3	1.007	704.289	1064.429	629.952	842.132	1.841 Y 1.280 T 1.156 X	1.316 Y 0.906 T 0.817 X
Model 10.4	1.416	817.291	1211.478	708.092	939.018	1.843 Y 1.095 T 1.014 X	1.315 Y 0.765 T 0.711 X
Model 10.5	1.699	875.468	1282.720	751.899	989.961	1.841 Y 1.061 T 0.959 X	1.313 Y 0.742 T 0.672 X
Model 10.6	2.016	1102.871	1591.964	937.341	1220.435	1.839 Y 1.022 T 0.900 X	1.311 Y 0.716 T 0.633 X

X: represents the mode in X direction, Y: represents the mode in Y direction,
T: represents the mode in torsion.

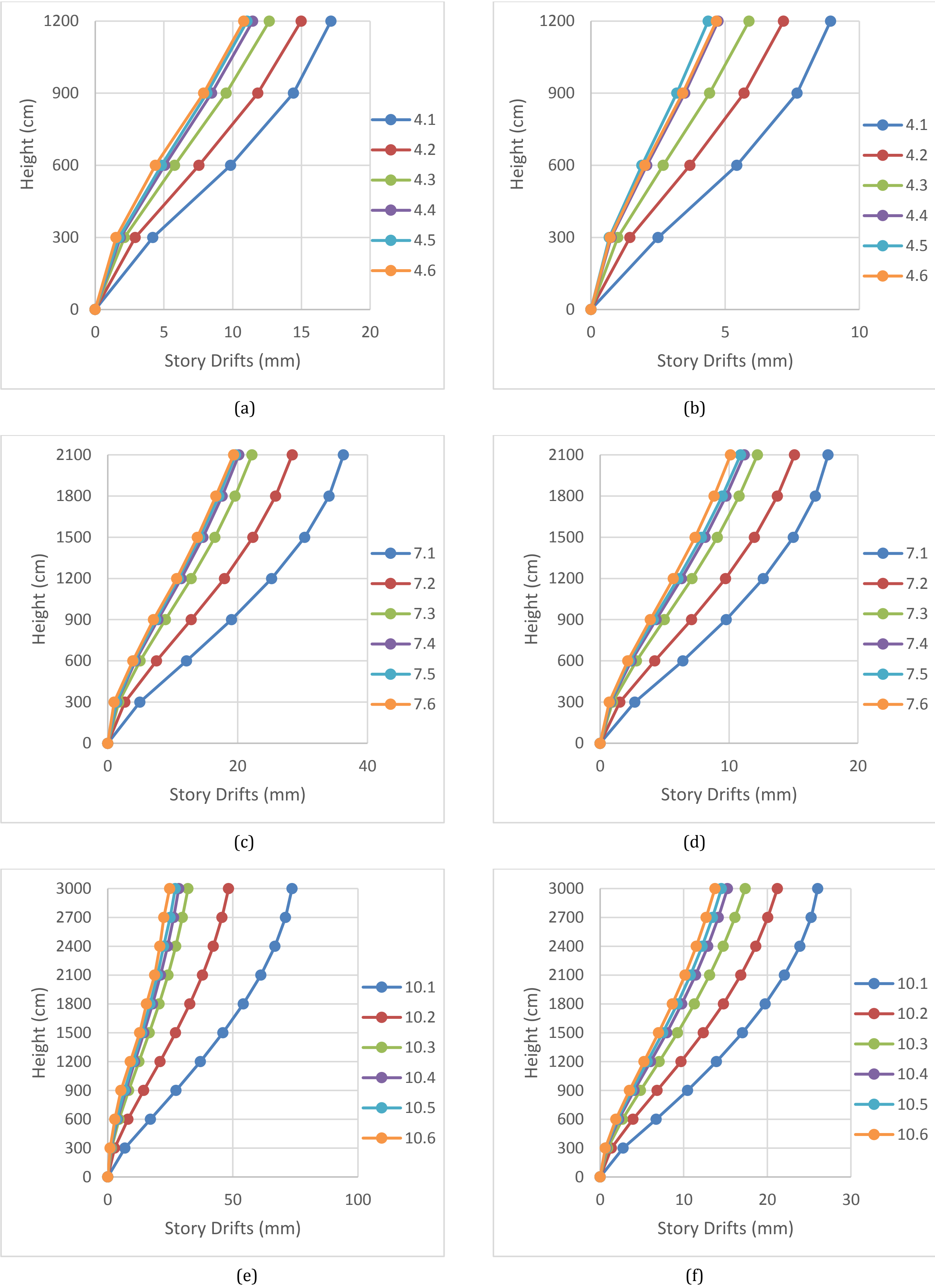


Fig. 4. Building height – story drifts curves for 4-storey, 7-storey and 10-storey models according to TSC 2018: a-c-e) Equivalent seismic load method; b-d-f) Response spectrum method.

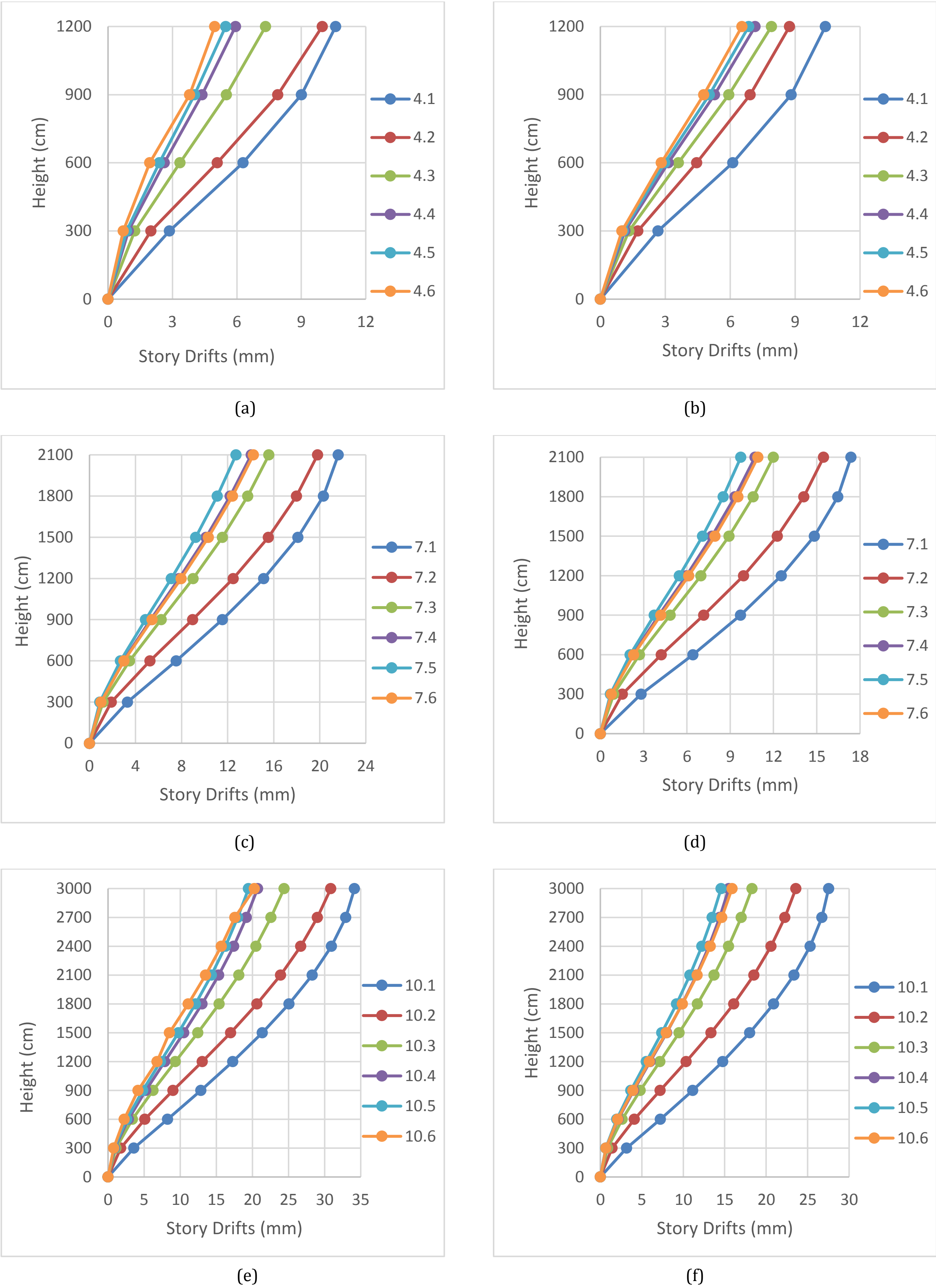


Fig. 5. Building height – story drifts curves for 4-storey, 7-storey and 10-storey models according to TSC 2007: a-c-e) Equivalent seismic load method; b-d-f) Response spectrum method.

The most ergonomic solution recommended to limit the displacements caused by lateral loads is that the optimum RC wall ratio to be determined is placed as symmetrical as possible and close to the outer edges of the building in the floor plan. In this way, the moment of inertia of the building to be obtained by multiplying the RC wall cross-sectional areas by the square of the distance between the element center of gravity and the structural systems center of gravity will increase and thus the bending stiffness of the structure will be increased and the structure will become more resistant to horizontal effects.

In the analyzes carried out by Equivalent Seismic Load Method and Response Spectrum Method specified in TSC 2018 and TSC 2007, the shear force values obtained in the calculations made according to TSC 2018 are lower than the results of the analyzes made according to TSC 2007 for both methods, and floor displacement values are higher in TSC 2018 models compared to TSC 2007 results. The main reason for this is the use of effective stiffness multipliers that must be defined on the structural system elements of the buildings to be modeled according to principles of Design by Strength.

Appendix

Table 6. Displacement values of 4-storey models for equivalent seismic load method according to TSC 2007.

Story Heights (cm)	Displacement Values (cm)					
	Model 4.1	Model 4.2	Model 4.3	Model 4.4	Model 4.5	Model 4.6
300	2.8635	1.9992	1.2471	0.9557	0.8643	0.711
600	6.2889	5.0839	3.3566	2.6222	2.3959	1.9459
900	9.0072	7.9016	5.511	4.3829	4.0269	3.7997
1200	10.599	9.9733	7.3361	5.9341	5.4758	4.9701

Table 7. Displacement values of 4-storey models for response spectrum method according to TSC 2007.

Story Heights (cm)	Displacement Values (cm)					
	Model 4.1	Model 4.2	Model 4.3	Model 4.4	Model 4.5	Model 4.6
300	2.661	1.729	1.3268	1.1359	1.0651	0.9972
600	6.1213	4.4479	3.6042	3.1455	2.9828	2.8164
900	8.8222	6.9272	5.9386	5.2801	5.0377	4.7826
1200	10.398	8.7428	7.9073	7.1538	6.8594	6.5416

Table 8. Displacement values of 7-storey models for equivalent seismic load method according to TSC 2007.

Story Heights (cm)	Displacement Values (cm)					
	Model 7.1	Model 7.2	Model 7.3	Model 7.4	Model 7.5	Model 7.6
300	3.2951	1.8891	1.1926	0.9787	0.901	0.9963
600	7.5339	5.2603	3.4909	2.9283	2.6875	2.9941
900	11.557	8.9704	6.2273	5.3115	4.8666	5.4353
1200	15.138	12.491	8.9933	7.7838	7.1164	7.9561
1500	18.111	15.542	11.539	10.126	9.232	10.325
1800	20.318	17.978	13.738	12.221	11.105	12.421
2100	21.614	19.813	15.588	14.054	12.727	14.235

Table 9. Displacement values of 7-storey models for response spectrum method according to TSC 2007.

Story Heights (cm)	Displacement Values (cm)					
	Model 7.1	Model 7.2	Model 7.3	Model 7.4	Model 7.5	Model 7.6
300	2.8364	1.5263	0.9276	0.7489	0.6921	0.7661
600	6.4168	4.2311	2.7148	2.2428	2.067	2.306
900	9.7117	7.1725	4.8358	4.0676	3.7434	4.1878
1200	12.55	9.924	6.9682	5.9568	5.4702	6.127
1500	14.834	12.271	8.9184	7.742	7.0878	7.9428
1800	16.468	14.112	10.591	9.3328	8.5127	9.5406
2100	17.373	15.476	11.988	10.72	9.7401	10.916

Table 10. Displacement values of 10-storey models for equivalent seismic load method according to TSC 2007.

Story Heights (cm)	Displacement Values (cm)					
	Model 10.1	Model 10.2	Model 10.3	Model 10.4	Model 10.5	Model 10.6
300	3.5638	1.7505	1.112	0.9157	0.8362	0.7855
600	8.241	5.0848	3.3853	2.8123	2.5838	2.2499
900	12.865	9.0095	6.2443	5.2247	4.8208	4.1528
1200	17.276	13.058	9.3374	7.8534	7.2714	6.8018
1500	21.378	16.982	12.438	10.499	9.7499	8.4967
1800	25.08	20.628	15.396	13.026	12.128	11.098
2100	28.295	23.887	18.106	15.342	14.319	13.51
2400	30.935	26.684	20.507	17.394	16.272	15.677
2700	32.913	28.988	22.584	19.164	17.975	17.584
3000	34.143	30.859	24.387	20.715	19.468	20.272

Table 11. Displacement values of 10-storey models for response spectrum method according to TSC 2007.

Story Heights (cm)	Displacement Values (cm)					
	Model 10.1	Model 10.2	Model 10.3	Model 10.4	Model 10.5	Model 10.6
300	3.1568	1.42	0.866	0.7046	0.6412	0.675
600	7.2314	4.0988	2.6249	2.1608	1.9791	2.0948
900	11.144	7.206	4.8191	4.0051	3.6859	3.92
1200	14.759	10.355	7.1707	6.0018	5.5454	5.9232
1500	18.024	13.355	9.506	7.9954	7.413	7.9492
1800	20.899	16.101	11.712	9.8826	9.1909	9.8916
2100	23.341	18.524	13.717	11.597	10.815	11.68
2400	25.3	20.577	15.477	13.1	12.25	13.272
2700	26.711	22.245	16.985	14.387	13.487	14.66
3000	27.529	23.581	18.283	15.496	14.563	15.88

Table 12. Displacement values of 4-storey models for equivalent seismic load method according to TSC 2018.

Story Heights (cm)	Displacement Values (cm)					
	Model 4.1	Model 4.2	Model 4.3	Model 4.4	Model 4.5	Model 4.6
300	4.1957	2.9025	2.1243	1.8297	1.7296	1.5085
600	9.8451	7.5462	5.7799	5.059	4.8292	4.3691
900	14.422	11.838	9.5255	8.4761	8.1358	7.8898
1200	17.151	14.984	12.673	11.463	11.054	10.804

Table 13. Displacement values of 4-storey models for response spectrum method according to TSC 2018.

Story Heights (cm)	Displacement Values (cm)					
	Model 4.1	Model 4.2	Model 4.3	Model 4.4	Model 4.5	Model 4.6
300	2.5019	1.4522	0.9967	0.7583	0.6843	0.7189
600	5.4385	3.687	2.6902	2.0863	1.902	2.0162
900	7.6823	5.71	4.4229	3.4949	3.2044	3.4153
1200	8.9265	7.1775	5.8917	4.741	4.3672	4.6745

Table 14. Displacement values of 7-storey models for equivalent seismic load method according to TSC 2018.

Story Heights (cm)	Displacement Values (cm)					
	Model 7.1	Model 7.2	Model 7.3	Model 7.4	Model 7.5	Model 7.6
300	4.9549	2.6544	1.6861	1.4224	1.3405	0.9794
600	12.127	7.5051	4.9715	4.2684	4.0503	3.8724
900	19.066	12.879	8.8927	7.7382	7.3925	7.0425
1200	25.241	17.978	12.855	11.317	10.873	10.638
1500	30.346	22.373	16.493	14.676	14.171	13.806
1800	34.107	25.849	19.62	17.643	17.117	16.66
2100	36.311	28.407	22.221	20.192	19.691	19.38

Table 15. Displacement values of 7-storey models for response spectrum method according to TSC 2018.

Story Heights (cm)	Displacement Values (cm)					
	Model 7.1	Model 7.2	Model 7.3	Model 7.4	Model 7.5	Model 7.6
300	2.6939	1.5296	0.9728	0.8158	0.7619	0.7171
600	6.416	4.2329	2.8249	2.4202	2.284	2.1549
900	9.7979	7.1039	4.9864	4.3463	4.1382	3.8996
1200	12.667	9.736	7.1349	6.3114	6.0499	5.6878
1500	14.99	11.973	9.0951	8.1498	7.8559	7.3621
1800	16.699	13.755	10.788	9.7788	9.4746	8.8442
2100	17.694	15.092	12.21	11.188	10.897	10.127

Table 16. Displacement values of 10-storey models for equivalent seismic load method according to TSC 2018.

Story Heights (cm)	Displacement Values (cm)					
	Model 10.1	Model 10.2	Model 10.3	Model 10.4	Model 10.5	Model 10.6
300	6.884	2.7543	1.4781	1.2504	1.1565	0.9814
600	17.039	8.0889	4.5223	3.8613	3.5911	2.8698
900	27.264	14.387	8.3527	7.1907	6.7141	5.2618
1200	37.01	20.866	12.487	10.82	10.136	8.9981
1500	46.039	27.105	16.613	14.469	13.591	12.79
1800	54.154	32.845	20.521	17.943	16.896	15.435
2100	61.16	37.911	24.072	21.115	19.927	18.798
2400	66.867	42.182	27.181	23.908	22.314	20.797
2700	71.084	45.616	29.833	26.31	24.941	22.416
3000	73.65	48.297	32.09	28.38	26.962	24.711

Table 17. Displacement values of 10-storey models for response spectrum method according to TSC 2018.

Story Heights (cm)	Displacement Values (cm)					
	Model 10.1	Model 10.2	Model 10.3	Model 10.4	Model 10.5	Model 10.6
300	2.7667	1.3628	0.8883	0.7318	0.6728	0.6145
600	6.71	3.926	2.664	2.223	2.0588	1.8909
900	10.48	6.8313	4.8235	4.0747	3.7958	3.5052
1200	13.927	9.6916	7.073	6.0386	5.6537	5.247
1500	17.03	12.35	9.2525	7.9672	7.4919	6.9841
1800	19.755	14.745	11.281	9.7765	9.2271	8.6348
2100	22.063	16.845	13.116	11.42	10.811	10.15
2400	23.911	18.625	14.738	12.873	12.217	11.503
2700	25.249	20.073	16.144	14.135	13.444	12.689
3000	26.029	21.216	17.359	15.233	14.519	13.736

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