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Investigation of acceleration on non-structural building elements under earthquake effect

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Abstract
Non-structural elements of a building are often not considered in structural analysis. Therefore, due attention is not paid to them during the design process of the building. However, non-structural elements are exposed to seismic forces and therefore they are exposed to damage and failures that have psychological and economic consequences in some critical and vital structures during seismic events. Depending on the type of building the total cost of non-structural elements and the ratio of the project cost are many times higher than the cost of structural elements. In this study, the equivalent earthquake load was investigated within the scope of the design principles of non-structural building elements under the effect of the earthquake defined in Turkish Building Earthquake Code 2018.

1. Introduction

Earthquakes, which are caused by the shaking of the earth by seismic waves that occur as a result of unexpected energy in the Earth's crust, cause damage to structures according to their magnitude. Plastic deformations or collapses occur in columns, beams, floors and foundations of the building, which cannot bear the energy generated during an earthquake. If the structural elements damaged beyond the target level, the damage of the non-structural elements could cause loss of life, property and function.

The design of non-structural building elements was compulsory by the Turkish Building Earthquake Code 2018 (TBEC 2018) [1]. There is a lack of project controls and implementation supervision in our country about this subject area. Studies conducted on this important issue were continue in our country which is at the earthquake zone [2-3].

Atu [2] has studied about the architectural details damaged by earthquake and precautions to be taken in her master thesis in the year 2000. According to this study; it has concluded that precautions should be taken and that the subject is not sufficiently covered in the codes. Özkaya [4] evaluate the performance targets, measures and the approach of the TBEC 2018 to this issue in order to avoid the losses and negativities that may occur. Girgin [5] has explained the importance of seismic design of secondary systems due to the damage during several earthquakes and studies for dynamic analysis of secondary systems with the effect of dynamic and physical characteristics in his master thesis. Tüzün [6] has presented new approaches in seismic design of buildings and seismic protection methodologies for mechanical installations and emphasized that the earthquake protection of the installations is a multidisciplinary study and requires the interdisciplinary collaborations. İpek et al. [7] investigate the evaluation of non-structural systems in terms of earthquake effects in their study. İpek [8] have made the definition, classification and examination of non-structural elements in terms of dynamic behavior of a structure under the effect of earthquake loads in his study. Mısır et al. [9] studied about the reducing the damages of non-structural elements and performed dynamic tests on non-structural elements using a shaking table. Taş [10] investigate the earthquake

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behavior of non-structural wood interior equipment. Beşir and Dereci [11] investigate the risks and measures that can be taken by non-structural elements in housing indoor during earthquakes.

In this study, the equivalent earthquake load (which is abbreviated as F_{ie}) calculation for the non-structural element or equipment was studied within the scope of the design principles of non-structural building elements under the effect of the earthquake defined in TBEC 2018. By making calculations for some non-structural elements related to the subject, the variation of the equivalent earthquake load acting according to the location of the elements in the structure has been examined and the importance of the subject has been revealed. Even if the non-structural elements are the same element, the manufacturing details may be different, as they may receive different earthquake loads. The objective of this study is to reveal this situation by calculating the earthquake loads acting on non-structural building elements.

2. Material and Method

In TBEC 2018, Design Principles of Non-Structural Building Elements under the Effect of Earthquake are explained under the Section 6 (TBEC 2018).

With the performance-based approach, minimum damage will occur at the targeted performance level in structural and non-structural elements. Damage loss can also be minimized after the earthquake.

According to TBEC 2018; it is compulsory to make an earthquake analysis according to the rules given in Section 6, for;

- all kinds of protrusions (such as balcony, parapet, chimney, console) that connected to the main structural system but self-sustaining and which could harm people or the main structural system or prevent the use of the building in case of damage in an earthquake,
- facade and partition panels,
- architectural elements,
- mechanical and electrical equipment,
- and their connections to the structure.

However, it is not compulsory to make an earthquake analysis for the furniture in the building, the equipment temporarily located in the building and not connected to the building, and the non-structural elements in the buildings with Earthquake Design Class 4 (DTS-4).

Regarding element-based calculations also states that non-structural elements and equipment must be fixedly attached to the structure and the fasteners must have the capacity to meet the equivalent earthquake loads and displacements given in Section 6 of TBEC 2018. Additional capacity due to friction will not be taken into account in the calculation of the connection elements (weld, bolt, dowel, rivet, etc.) that connect the equipment to the structure under earthquake effect. Connection elements must have the strength that ensure the load transfer from equipment to the structure continuously.

The non-structural element or equipment should be considered as part of the building carrier system according to TBEC 2018 when the total weight is greater than 10% of the floor that locates. In this case, the mass of the non-structural element or equipment and the rigidity properties of its connection to the building will be considered in the earthquake analysis of the building carrier system.

The calculation of equivalent earthquake load acting horizontally to the center of gravity of the non-structural element or equipment and acting on the non-structural element or equipment with the use of Equation 6.1 of TBEC 2018 is as follows:

$$F_{ie}^{Eq6.1} = \left(m_e\ A_{ie}\ B_e\right) / R_e \qquad (1)$$

In this equation m_e is the working mass of the non-structural element or equipment, A_{ie} is the maximum total acceleration affecting the area where the non-structural element or equipment on the floor i is connected to the floor under DD 2 earthquake ground motion level, B_e is the magnification factor applied to the non-structural element or equipment, Re is the behavior coefficient defined for the non-structural element or equipment. According to TBEC 2018, A_{ie} acceleration should be calculated separately using equivalent earthquake load, modal analysis and time history analysis methods and the maximum one should be used in the calculations.

The inequality about earthquake load acting on non-structural elements according to the Equation 6.5 of TBEC 2018 is as follows:

$$F_{ie} \geq F_{ie}^{Eq6.5} = 0.3\, m_e\ I\ S_{DS}\ g \qquad (2)$$

According to TBEC 2018, equivalent earthquake load acting on non-structural elements calculated with the Equation 6.1 cannot be less than given with the Equation 6.5 of the TBEC-2018.

$$F_{ie}^{Eq6.1} \geq F_{ie}^{Eq6.5} \qquad (3)$$

The flow chart of equivalent earthquake load calculation for the non-structural element or equipment is shown in Fig. 1.

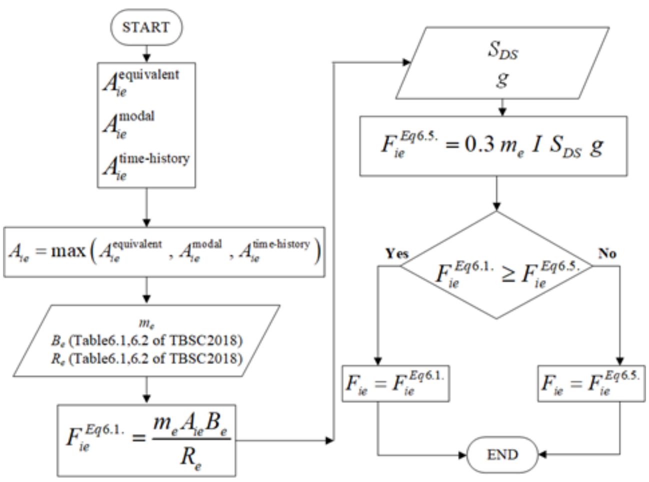


Figure 1. Flow chart of equivalent earthquake load calculation

3. Numerical study

In this numerical example; equivalent earthquake loads on various non-structural elements of nine-story building is investigated. There is a 1m^3 volume of water tank, chimney and a 1m height parapet in the roof floor. Main stairs continue from the first floor to the ninth floor. In the intervening floors, there are railings at the stairs, combi boilers in the kitchen, panel radiators in the rooms, suspended ceilings on the ceilings and facade coatings up to the first floor.

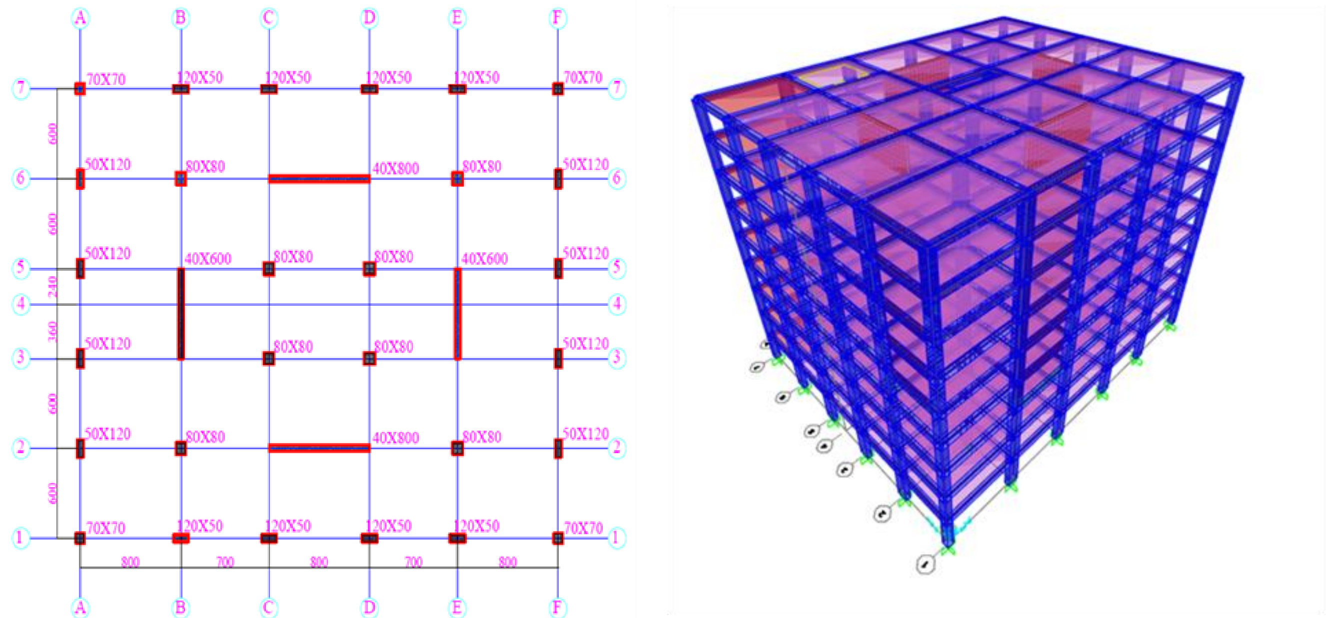


Figure 2. Column and shear wall plan and 3d view of the building

The column and shear wall plan and three-dimensional view of the sample building analyzed by using SAP 2000 v21 are shown in Fig. 2.

Parameters used in the numerical example is shown in Table 1.

Table 1. Parameters used in the analysis

Parameter	Value
Behavior coefficient of carrier system (R)	7
Coefficient of building importance (I)	1
Height of the building as meters	31.5
Building height class (BYS)	4
Building usage class (BKS)	3
Earthquake design class (DTS)	1

In all elements of the example the same material properties is defined. Concrete class is C30/37, E_c=32 GPa, F_{ck}=30 MPa and the reinforcement class is B420C, E_y=200 Gpa, F_{yk}=420 MPa.

The local soil class was taken as ZD and the earthquake ground motion level as DD-2 from the AFAD (Disaster and Emergency Management Presidency) earthquake map belonging to the coordinates of the ground values (Latitude: 39.344763° Longitude 29.26084°) on which the example model will be constructed. Ground data are shown in Table 2.

Table 2. Ground data

Parameter	Value
S_S	0.850
S_1	0.201
S_{DS}	0.986
S_{D1}	0.442
PGA (g)	0.352
PGV (cm/sn)	19.618

Table 3. Earthquake records

Number	Acceleration Records	Stations	Latitude	Longitude	Depth	Type	magnitude
1	20070920061911_4302_ap_Acc_E	4302	39.2147	29.3885	16.90	MW	4.4
2	20130609141856_4305_ap_Acc_E	4305	39.1392	29.0220	15.61	ML	4.1
3	20200125174947_4310_ap_Acc_E	4310	39.0293	27.8430	7.84	MW	4.1
4	20201030115124_4304_mp_Acc_E	4304	37.8790	26.7030	14.90	MW	6.6
5	20201211143749_4306_mp_Acc_E	4306	39.9901	28.1961	7.00	MW	4.1
6	20201211143749_4314_mp_Acc_E	4314	39.9901	28.1961	7.00	MW	4.1
7	20210209155154_4307_mp_Acc_E	4307	38.5965	31.6318	7.01	MW	4.7
8	20210209155154_4312_mp_Acc_E	4312	38.5965	31.6318	7.01	MW	4.7
9	20210209155154_4313_mp_Acc_E	4313	38.5965	31.6318	7.01	MW	4.7
10	20210214210815_4311_mp_Acc_E	4311	38.1878	30.0456	6.05	MW	3.9
11	20210630030010_4301_mp_Acc_E	4301	39.0295	29.6541	7.01	MW	3.8

A total of 11 earthquake acceleration records were taken from stations 4302-4305-4310-4304-4306-4314-4307-4312-4313-4311 and 4301 for analysis according to the Mode Addition Method in the Time History Domain. The earthquake acceleration records given in Table 3 are arranged by scaling.

According to TBEC 2018, the maximum total acceleration acting on the element or equipment will be defined as the maximum one among the accelerations calculated according to the Equivalent Earthquake Load Method, Modal Analysis and Time History Analysis.

The natural periods for the first ten modes of the presented example are shown in Table 4.

The accelerations were calculated separately by using different methods of TBEC-2018. The accelerations to be used in the earthquake calculation of non-structural elements in X direction are tabulated in Table 5.

Table 4. Natural periods (sec)

Mode Number	Natural Periods
1	1.55188
2	1.30825
3	1.30219
4	0.37947
5	0.32502
6	0.29713
7	0.16634
8	0.14508
9	0.13159
10	0.11882

The calculated accelerations for Y direction, to be used in the earthquake simulations of non-structural elements are summarized in Table 6.

Table 5. The A_{ie} accelerations in X direction to be used in the analysis of non-structural elements (m/sn^2)

Story	Equivalent Earthquake Load	Modal Analysis	Time History Analysis	Selected Acceleration
1	0.29	0.26	-0.18	0.29
2	0.96	0.50	-0.10	0.96
3	1.86	0.57	-0.22	1.86
4	2.93	0.51	-0.30	2.93
5	4.10	0.37	0.05	4.10
6	5.32	0.30	-0.01	5.32
7	6.56	0.41	0.05	6.56
8	7.78	0.81	0.13	7.78
9	8.95	1.80	0.69	8.95

Table 6. The A_{ie} accelerations in Y direction to be used in the analysis of non-structural elements (m/sn^2)

Story	Equivalent Earthquake Load	Modal Analysis	Time History Analysis	Selected Acceleration
1	0.25	0.25	-0.21	0.25
2	0.82	0.49	-0.25	0.82
3	1.59	0.53	0.14	1.59
4	2.48	0.53	0.09	2.48
5	3.44	0.27	-0.09	3.44
6	4.42	0.19	-0.06	4.42
7	5.37	0.30	0.01	5.37
8	6.28	0.71	0.12	6.28
9	7.14	1.71	0.59	7.14

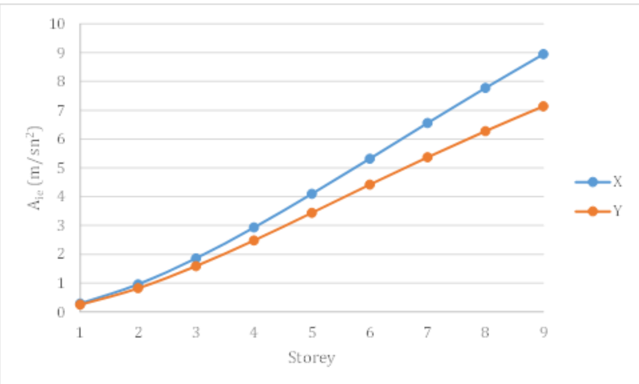


Figure 3. Selected A_{ie} accelerations

As seen from the Fig. 3, selected acceleration is greater in the X direction. Calculations for non-structural building elements were made separately for both the x-direction and the y-direction.

With the Equation 6.5 of TBEC 2018 as expressed in Eq. 2, it has been explained that restrictions on non-structural building elements is imposed.

Calculation of the equivalent earthquake loads in every floor for non-structural building elements as suspended ceiling, chimney, facade coating, combi boiler, railing, panel radiator, parapet and water tank for x direction and y direction is shown in Tables 7 and 8 respectively.

Table 7. Equivalent earthquake loads on various non-structural building elements in the X direction

Story	Element	m_e	B_e	R_e	A_{ie} (m/sn²)	F_{ie} $^{Eq\ 6.1}$(N)	F_{ie} $^{Eq\ 6.5}$(N)	F_{ie} ^{FINAL}(N)
9th FLOOR	RAILING	7	2,5	2,5	8,95	62,65	20,31	62,65
	WATER TANK	1000	2,5	6	8,95	3729,17	2901,80	3729,17
	CHIMNEY	300	2,5	2,5	8,95	2685,00	870,54	2685,00
	PARAPET	550	2,5	2,5	8,95	4922,50	1595,99	4922,50
8th FLOOR	RAILING	7	2,5	2,5	7,78	54,46	20,31	54,46
	COMBI BOILER	33	1	2,5	7,78	102,70	95,76	102,70
	PANEL RADIATOR	25	2,5	6	7,78	81,04	72,54	81,04
	SUSPENDED	27	1	2,5	7,78	84,02	78,35	84,02
	FACADE COATING	11	1	1,5	7,78	57,05	31,92	57,05
7th FLOOR	RAILING	7	2,5	2,5	6,56	45,92	20,31	45,92
	COMBI BOILER	33	1	2,5	6,56	86,59	95,76	95,76
	PANEL RADIATOR	25	2,5	6	6,56	68,33	72,54	72,54
	SUSPENDED	27	1	2,5	6,56	70,85	78,35	78,35
	FACADE COATING	11	1	1,5	6,56	48,11	31,92	48,11
6th FLOOR	RAILING	7	2,5	2,5	5,32	37,24	20,31	37,24
	COMBI BOILER	33	1	2,5	5,32	70,22	95,76	95,76
	PANEL RADIATOR	25	2,5	6	5,32	55,42	72,54	72,54
	SUSPENDED	27	1	2,5	5,32	57,46	78,35	78,35
	FACADE COATING	11	1	1,5	5,32	39,01	31,92	39,01
5th FLOOR	RAILING	7	2,5	2,5	4,1	28,70	20,31	28,70
	COMBI BOILER	33	1	2,5	4,1	54,12	95,76	95,76
	PANEL RADIATOR	25	2,5	6	4,1	42,71	72,54	72,54
	SUSPENDED	27	1	2,5	4,1	44,28	78,35	78,35
	FACADE COATING	11	1	1,5	4,1	30,07	31,92	31,92
4th FLOOR	RAILING	7	2,5	2,5	2,93	20,51	20,31	20,51
	COMBI BOILER	33	1	2,5	2,93	38,68	95,76	95,76
	PANEL RADIATOR	25	2,5	6	2,93	30,52	72,54	72,54
	SUSPENDED	27	1	2,5	2,93	31,64	78,35	78,35
	FACADE COATING	11	1	1,5	2,93	21,49	31,92	31,92
3rd FLOOR	RAILING	7	2,5	2,5	1,86	13,02	20,31	20,31
	COMBI BOILER	33	1	2,5	1,86	24,55	95,76	95,76
	PANEL RADIATOR	25	2,5	6	1,86	19,38	72,54	72,54
	SUSPENDED	27	1	2,5	1,86	20,09	78,35	78,35
	FACADE COATING	11	1	1,5	1,86	13,64	31,92	31,92
2nd FLOOR	RAILING	7	2,5	2,5	0,96	6,72	20,31	20,31
	COMBI BOILER	33	1	2,5	0,96	12,67	95,76	95,76
	PANEL RADIATOR	25	2,5	6	0,96	10,00	72,54	72,54
	SUSPENDED	27	1	2,5	0,96	10,37	78,35	78,35
	FACADE COATING	11	1	1,5	0,96	7,04	31,92	31,92
1st FLOOR	RAILING	7	2,5	2,5	0,29	2,03	20,31	20,31
	COMBI BOILER	33	1	2,5	0,29	3,83	95,76	95,76
	PANEL RADIATOR	25	2,5	6	0,29	3,02	72,54	72,54
	SUSPENDED	27	1	2,5	0,29	3,13	78,35	78,35
	FACADE COATING	11	1	1,5	0,29	2,13	31,92	31,92

Equivalent earthquake loads for all non-structural elements are calculated for each floor in the relevant rows in Tables 7 and 8. Again, in the column F_{ie} calculated in the aforementioned tables, if the condition of Equation 6.5 of TBEC-2018 is not satisfied, the minimum value that satisfies the condition of the equation is specified in the next column. The appropriate values for the equivalent earthquake loads calculated from Equation 6.5 of TBEC-2018 are shown in red in the last column. While calculations were made for standard five non-structural elements on the eight floors, on the ninth floor, which is the roof floor, calculations were made for three elements other than these elements, such as the parapet, chimney and water tank.

Table 8. Equivalent earthquake loads on various non-structural building elements in the Y direction

Story	Element	m_e (kg)	B_e	R_e	A_{ie} (m/sn²)	F_{ie} $^{Eq\ 6.1}$(N)	F_{ie} $^{Eq\ 6.5}$(N)	F_{ie} ^{FINAL}(N)
9th FLOOR	RAILING	7	2,5	2,5	7,14	49,98	20,31	49,98
	WATER TANK	1000	2,5	6	7,14	2975,00	2901,80	2975,00
	CHIMNEY	300	2,5	2,5	7,14	2142,00	870,54	2142,00
	PARAPET	550	2,5	2,5	7,14	3927,00	1595,99	3927,00
8th FLOOR	RAILING	7	2,5	2,5	6,28	43,96	20,31	43,96
	COMBI BOILER	33	1	2,5	6,28	82,90	95,76	95,76
	PANEL RADIATOR	25	2,5	6	6,28	65,42	72,54	72,54
	SUSPENDED CEILING	27	1	2,5	6,28	67,82	78,35	78,35
	FACADE COATING	11	1	1,5	6,28	46,05	31,92	46,05
7th FLOOR	RAILING	7	2,5	2,5	5,37	37,59	20,31	37,59
	COMBI BOILER	33	1	2,5	5,37	70,88	95,76	95,76
	PANEL RADIATOR	25	2,5	6	5,37	55,94	72,54	72,54
	SUSPENDED CEILING	27	1	2,5	5,37	58,00	78,35	78,35
	FACADE COATING	11	1	1,5	5,37	39,38	31,92	39,38
6th FLOOR	RAILING	7	2,5	2,5	4,42	30,94	20,31	30,94
	COMBI BOILER	33	1	2,5	4,42	58,34	95,76	95,76
	PANEL RADIATOR	25	2,5	6	4,42	46,04	72,54	72,54
	SUSPENDED CEILING	27	1	2,5	4,42	47,74	78,35	78,35
	FACADE COATING	11	1	1,5	4,42	32,41	31,92	32,41
5th FLOOR	RAILING	7	2,5	2,5	3,44	24,08	20,31	24,08
	COMBI BOILER	33	1	2,5	3,44	45,41	95,76	95,76
	PANEL RADIATOR	25	2,5	6	3,44	35,83	72,54	72,54
	SUSPENDED CEILING	27	1	2,5	3,44	37,15	78,35	78,35
	FACADE COATING	11	1	1,5	3,44	25,23	31,92	31,92
4rd FLOOR	RAILING	7	2,5	2,5	2,48	17,36	20,31	20,31
	COMBI BOILER	33	1	2,5	2,48	32,74	95,76	95,76
	PANEL RADIATOR	25	2,5	6	2,48	25,83	72,54	72,54
	SUSPENDED CEILING	27	1	2,5	2,48	26,78	78,35	78,35
	FACADE COATING	11	1	1,5	2,48	18,19	31,92	31,92
3rd FLOOR	RAILING	7	2,5	2,5	1,59	11,13	20,31	20,31
	COMBI BOILER	33	1	2,5	1,59	20,99	95,76	95,76
	PANEL RADIATOR	25	2,5	6	1,59	16,56	72,54	72,54
	SUSPENDED CEILING	27	1	2,5	1,59	17,17	78,35	78,35
	FACADE COATING	11	1	1,5	1,59	11,66	31,92	31,92
2nd FLOOR	RAILING	7	2,5	2,5	0,82	5,74	20,31	20,31
	COMBI BOILER	33	1	2,5	0,82	10,82	95,76	95,76
	PANEL RADIATOR	25	2,5	6	0,82	8,54	72,54	72,54
	SUSPENDED CEILING	27	1	2,5	0,82	8,86	78,35	78,35
	FACADE COATING	11	1	1,5	0,82	6,01	31,92	31,92
1st FLOOR	RAILING	7	2,5	2,5	0,25	1,75	20,31	20,31
	COMBI BOILER	33	1	2,5	0,25	3,30	95,76	95,76
	PANEL RADIATOR	25	2,5	6	0,25	2,60	72,54	72,54
	SUSPENDED CEILING	27	1	2,5	0,25	2,70	78,35	78,35
	FACADE COATING	11	1	1,5	0,25	1,83	31,92	31,92

As an example, for the calculation of equivalent earthquake load for a railing in x direction in first floor with the use of Equation 6.1 of TBEC 2018 is as follows:

$$F_{ie}^{Eq6.1} = (7 \times 0.29 \times 2.5)/2.5 = 2.03 \text{ N} \tag{4}$$

The equivalent earthquake load acting on non-structural elements according to the Equation 6.5 of TBEC 2018 is as follows:

$$F_{ie}^{Eq6.5} \geq 0.3 \times 7 \times 1 \times 0.986 \times 9.81 = 20.31 \text{ N} \tag{5}$$

According to TBEC 2018, equivalent earthquake load acting on non-structural elements calculated with the Equation 6.1 of TBEC-2018 cannot be less than the Equation 6.5 of TBEC-2018.

$$F_{ie}^{Eq6.5} = 20.31 \text{ N} \geq F_{ie}^{Eq6.1} = 2.03 \text{ N} \tag{6}$$

From such value, 20.31 N is selected as an equivalent earthquake load for a railing (a non-structural building element) for the first floor.

As another example on calculation of equivalent earthquake load in y direction for a facade coating on the seventh floor with the use of Equation 6.1 of TBEC 2018 is as follows:

$$F_{ie}^{Eq6.1} = (11 \times 5.37 \times 1)/1.5 = 39.38 \text{ N} \tag{7}$$

The equivalent earthquake load acting on non-structural elements according to the Equation 6.5 of TBEC 2018 is as follows:

$$F_{ie}^{Eq6.5} \geq 0.3 \times 11 \times 1 \times 0.986 \times 9.81 = 31.92 \text{ N} \quad (8)$$

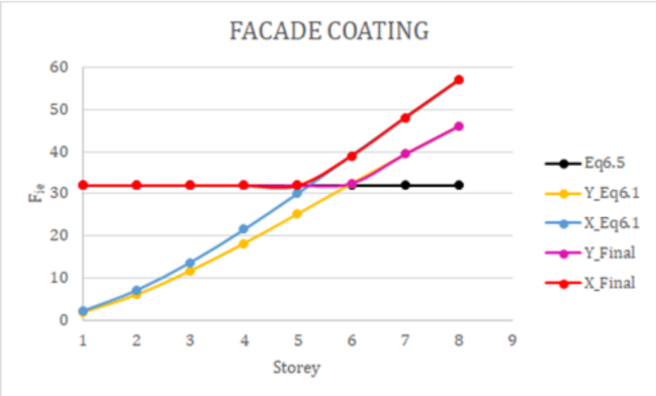
According to TBEC 2018, equivalent earthquake load acting on non-structural elements calculated with the Equation 6.1 cannot be less than the value obtained from the Equation 6.5 of TBEC-2018.

$$F_{ie}^{Eq6.5} = 31.92 \text{ N} < F_{ie}^{Eq6.1} = 39.38 \text{ N} \quad (9)$$

As a result, 39.38 N is selected as an equivalent earthquake load of a facade coating (a non-structural building element) in the seventh floor.

In Tables 7 and 8, if $F_{ie}^{Eq\,6.5} \geq F_{ie}^{Eq\,6.1}$, loads in red indicate the selected equivalent earthquake load.

Calculated equivalent earthquake loads for every floor of facade coatings and railings as non-structural element are shown in Fig. 4.



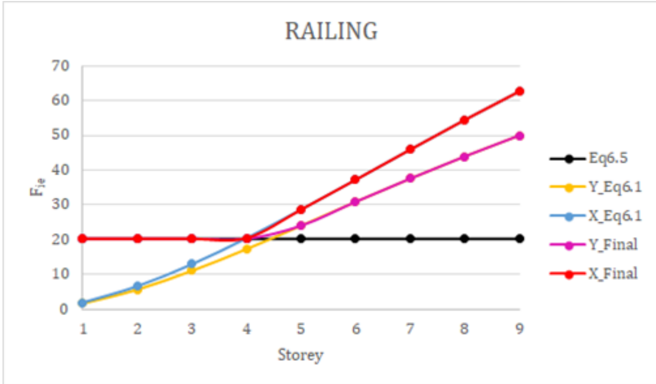


Figure 4. F_{ie} loads for facade coatings and railings for every floor

4. Discussion

The coefficient A_{ie} is directly proportional to the acceleration and displacement that acting on non-structural elements. The equivalent earthquake load acting on non-structural elements is also directly proportional to the coefficient A_{ie}, namely acceleration. In this case, since the displacements acting on the floors are different, even if the same non-structural element is the same, different accelerations and earthquake loads will be affected due to different displacements.

It can be seen from the Table 7 that equivalent earthquake load of the railing (a non-structural building element) does not satisfy the limits of the Equation 6.5 of TBEC 2018 for the first, second and third floors of the building. However, for the other floors of the building it can be seen that the limits are satisfied.

As seen from this example, especially in buildings with a high number of stories the earthquake load that affects to non-structural elements will increase.

For nonstructural element facade coating, from the Fig. 4 it can be seen while the equivalent earthquake forces in y direction were those calculated from Equation 6.5 of TBEC-2018 up to sixth floor, for the stories above the sixth floor Equation 6.1 of TBEC-2018 is preferred. Equivalent earthquake forces in the x direction, like y direction, they were calculated from Equation 6.5 of TBEC-2018 for the stories up to the fifth floor and for the above Equation 6.1 of TBEC-2018 is adopted.

5. Conclusion

Equivalent earthquake loads must be determined for the design of non-structural elements. Even if the non-structural elements are the same, on different locations on building the earthquake loads acting on them may be different. These loads used in the analysis of non-structural elements are calculated using the accelerations.

According to TBEC 2018, these accelerations should be calculated with three different methods and the maximum one should be used in the design. These three methods are Equivalent Earthquake Load Method, Modal Analysis and Time History Analysis respectively.

In this study, a nine-story building with different types of non-structural elements is considered as an example. The maximum total acceleration affecting the area where the non-structural element or equipment on the floor i is connected to the floor under DD 2 earthquake ground motion level is calculated with three methods. Equivalent earthquake load is determined by using the maximum of these accelerations.

Equivalent earthquake load was found to be conservative but governing case in determination of designing the non-structural elements in buildings.

The results of this study also demonstrated that the attention should be paid for the connection, fixing or assembly details. Because of the equivalent earthquake loads acting on them, they could be different during the projecting and manufacturing phase.

The cost of buildings today is quite high. The ratio of the project cost of non-structural elements to the project cost of structural elements is significantly high. The total cost of non-structural elements depending on the type of building (hospital, commercial building, residence, industry, etc.), mechanical-electrical installations, architectural elements, and other items and equipment are many times higher than the cost of structural elements. The cost of non-structural elements damaged during the earthquake is high.

Damages occurring in non-structural elements of manufacturing buildings such as factories after an earthquake may also cause the interruption of working activities. This situation will adversely affect the development of the production and service sectors as well as the society and the psychosocial life of individuals.

Author contributions

Mustafa Halûk Saraçoğlu: Conceptualization, Methodology, Writing-Original draft preparation, Investigation, Writing-Reviewing and Editing. **Ahmet Özkaya:** Methodology, Software Data curation, Software, Validation. Visualization, Investigation

Conflicts of interest

The authors declare no conflicts of interest.

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