Bitlis Eren Üniversitesi Fen Bilimleri Dergisi
BİTLİS EREN UNIVERSITY JOURNAL OF SCIENCE
ISSN: 2147-3129/e-ISSN: 2147-3188
VOLUME: 12 NO: 1 PAGE: 261-271 YEAR: 2023
DOI:10.17798/bitlisfen.1232889

The Effect of Different Heavy Overhang on Structural Performance in Reinforced Concrete Structures

Ercan IŞIK[1*], Fırat AKAT[1]

[1]*Bitlis Eren University, Faculty of Engineering and Architecture, Department of Civil Engineering, BİTLİS*
(ORCID: 0000-0001-8057-065X) (ORCID: 0000-0002-6645-2363)

Keywords: Earthquake, Overhang, Performance, Reinforced-concrete, Structural analysis.

Abstract
There are many structural factors that affect the earthquake performance of buildings. Heavy overhang is one of these factors which are made to increase the storey area on the storeys above the ground storey. Within the scope of this study, the effect of different heavy overhangs on the earthquake performance of the building was investigated, which are commonly used in reinforced-concrete (RC) structures. A sample RC building with no heavy overhangs was chosen as the reference building model for numerical analysis. The numerical analyses were carried out for a total of 16 structural models designed by adding heavy overhangs of different lengths to different facades of the reference building model. The obtained results were compared with the results of the reference structure model without heavy overhang to reveal the heavy overhang effect. The period, base shear force, displacement, and performance levels were obtained for each structural model. It has been determined that the base shear force, period, and total mass increase with the increase of heavy overhangs, while the earthquake performance decreases. The obtained results clearly revealed that the earthquake performance was negatively affected by the increase in the amount of closed heavy overhang.

1. Introduction

Different damage levels may occur in engineering structures under the influence of earthquakes due to weak structural features and the magnitude of the earthquake. Damage levels are directly related to structural features. In particular, discontinuities and irregularities in the structures can increase the level and the amount of damage. In this context, in order to keep the loss of life and property at a lower level in the event of possible earthquakes in settlements that are very risky in terms of earthquake hazards, it is of great importance to consider earthquake-resistant building design principles both in the design and construction phases. Therefore, it is obvious that many factors that may adversely affect the earthquake performance of buildings should be taken into account, and studies on these issues will make significant contributions in this area [1], [2], [3], [4], [5].

Significant property and life losses occur due to structural damage as a result of destructive earthquakes [6], [7], [8]. It does not seem possible to predict and prevent earthquakes with today's technology [9], [10]. In this context, the design rules of earthquake-resistant engineering structures have become much more important [11], [12], [13], [14]. These rules, which may differ from country to country, are updated over time. It has carried out the necessary renovations and codes on this issue in Türkiye on different dates and has finalized and implemented the earthquake resistant building design principles with the Türkiye Building Earthquake Code (TBEC-2018) in 2018 [15], [16], [17], [18]. Due to this change in the earthquake code, a change in the rapid assessment method used in the country has become inevitable [19].

Irregularity and negativity parameters in the structures have found their place with their details both in the code and in the rapid assessment methods

*Corresponding author: eisik@beu.edu.tr
Received: 12.01.2023, Accepted: 19.03.2023

that will affect the seismic behaviour. Heavy overhang is one of the factors taken into consideration in RC structures. Heavy overhangs are generally formed by increasing the ground floor area of the building on the upper floors. This subject has been studied in detail by different researchers. Sarı (2010) examined the effects of different structural parameters, which may be encountered in practice, on the seismic behaviour of the heavy overhangs. In the study, static pushover analysis was used for 16 different building models, and the obtained results were compared [20]. Doğangün (2004) stated that heavy overhang was one of the reasons for the structural damage that occurred in May 1, 2003, Bingöl earthquake [21]. İnel et al. (2008) investigated the effects of structural parameters commonly encountered in Türkiye's RC building stock on the seismic performance of the building. One of the parameters they examined is soft-storey irregularity with heavy overhangs [22]. Tesfamariam and Liu (2010) performed reinforcement scaling using different statistical methods. The heavy overhang ratio was included in six different parameters that they used in their study [23]. On the other hand, Saatçi and Vecchio (2009) experimentally investigated the overhang effects of beams on eight different RC beams. The values obtained as a result of 20 different experiments were compared, and the results were interpreted [24]. In his master's thesis study, Öz (2019) performed linear and non-linear time history analyses on the structural models he created with a 1.50 m overhang for three different storeys and revealed the effect of closed heavy overhangs on the seismic behaviour of the building [25]. İnel et al. (2009) investigated the closed overhang irregularity created by beam lifting in the RC structures, depending on the amount of overhang. They stated that the seismic behaviour of the structure was significantly affected by the frame discontinuity that occurred with the removal of the beams [26]. In the study conducted by Meral (2019), for a sample RC building with 3 different storeys, non-linear time history analyses were made and the effect of overhangs on the earthquake behaviour of the building was revealed [27]. Meral and İnel (2016) created a total of 144 building models for 3 different storeys such as 2, 4 and 7-storeys, within the scope of their studies. They used static pushover analyses to reveal the effects of different parameters. Heavy overhang was one of the parameters they took into account [28]. Işık and Tozlu (2015) revealed the effects of different variables on the building performance score, such as heavy overhang, which are taken into account in the rapid assessment method [29]. Işık, et al. (2012) examined the heavy overhangs as one of the causes of structural damage in the Adilcevaz district, based on observation after the 2011 Van earthquake [30]. Özmen (2005) compared the seismic performance of the RC structures for different parameters, including heavy overhangs, which are taken into account in rapid evaluation methods within the scope of his thesis [31].

This study examines the behaviour of heavy overhangs in RC buildings under earthquake effects, which are widely used. The aim of this study is to reveal at what level the closed heavy overhangs affect the earthquake performance of the building with different variations. For this purpose, a sample RC structural model was created, and structural analyses were carried out considering the current seismic design code in Türkiye. First of all, a regular RC building model was designed that does not contain any heavy overhang. In order to reveal the heavy overhang effect, analyses were carried out considering four different overhang lengths on different facades. Four different overhang lengths were taken into account: 0.80 m, 1.0 m, 1.2 m, and 1.5 m. Structural models are grouped into four different categories: 1 facade, 2 facades, 3 facades, and 4 facades. In this study, it is tried to reveal the effects of both the heavy overhang length and the number of facades on the structural analysis and performance results. In addition, the effect of heavy overhang was tried to be revealed by using the rapid scanning method recommended for Türkiye, which was updated with the seismic design code and seismic hazard map. According to TBEC-2018, this study, which is carried out with the details of performance analysis and heavy overhang irregularities, may contribute to this and similar studies. The comparison of the amount of heavy overhangs both on different facades and at different lengths according to TBEC-2018 is what the study differentiates from other studies. In the study, the comparison and interpretation of the heavy overhang results according to the Turkish rapid assessment method that was updated in 2019 also makes the study different from other studies.

2. Material and Method

Engineering structures are exposed to different levels of damage due to their weak structural features and irregularities, and as a result of the structural damage, life and property losses occur on different scales depending on the magnitude of the earthquake. In general, low-strength concrete, insufficient reinforcement, non-usage of materials in accordance with the standards, and workmanship defects, as well as irregularities and negativities in the structures, directly affect the damage levels in RC structures. These irregularities are included in the seismic design code. The types of irregularities considered in TBEC-2018 are shown in Figure 1.

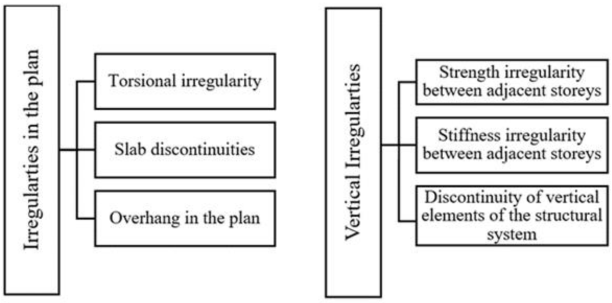

Figure 1. Irregular buildings under earthquake in TBEC-2018

Irregularities in RC structures are also taken into account in the rapid assessment methods, which have been updated with the changes in TBEC-2018 and have been used to determine regional risks in Türkiye since 2019 [32]. The negativity parameters taken into account in this rapid assessment method for the RC buildings are shown in Figure 2.

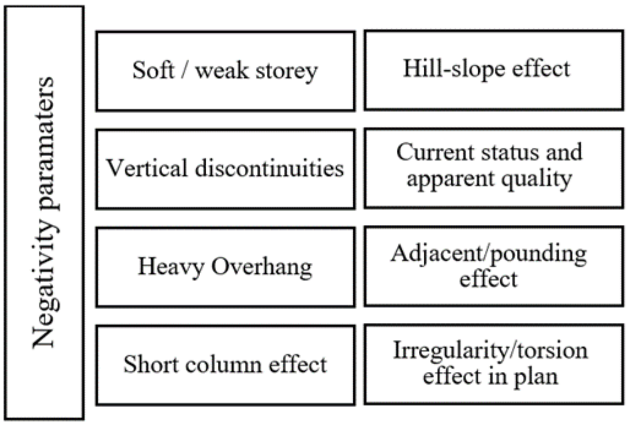

Figure 2. Negativity parameters that specified in Türkiye rapid assessment method

2.1. Heavy Overhang in RC Structures

One of the factors that can affect the earthquake performance of RC structures is the presence of heavy overhangs. This type of heavy overhangs is common in every settlement. In general, such heavy overhang, which are made to increase the building area, are formed by making overhangs on one or more facades of the building. The lower building area, especially on the ground storey, is replaced by larger building areas on the upper storeys. Heavy overhang status is clearly stated within the negativity parameters taken into account in the rapid assessment method [33], [34], [35], [36]. In this method, the presence of heavy overhangs is determined according to Figure 3.

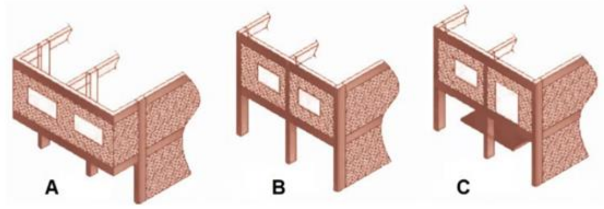

Figure 3. Examples of overhangs (**A**) with overhang, (**B**) no overhangs, and (**C**) balcony with no overhangs.

Some heavy overhangs encountered in practice in RC structures are shown in Figure 4.

Figure 4. Heavy overhangs observed in existing RC structures

In heavy overhangs, the presence of beams negatively affects the aesthetic appearance, and due to architectural needs, beams are often not built in areas with closed overhangs, resulting in a lack of connection between column and beam. Since beam deficiencies cause frame discontinuity, the load transfer mechanism between column and beam is adversely affected [26], [37]. It has been stated by the researchers that especially the closed overhangs made on one side increase the distance between the centre of gravity and stiffness of the structure, and that the increase in weight affects the earthquake behaviour of the structure [21]. It has been understood that buildings with heavy closed overhangs are more damaged during earthquakes than buildings that are regular along the height [38], [39]. In buildings with heavy overhangs, these parts are damaged after earthquakes. Some of the damages caused by heavy overhangs in different earthquakes are shown in Figure 5.

2.2. Structural Models

In this study, a sample RC building was made with no heavy overhangs so that the effects of heavy overhangs could be looked at. The blueprint of the reference building model is shown in Figure 6.

Figure 5. Damages observed in heavy overhangs after different earthquakes in Türkiye

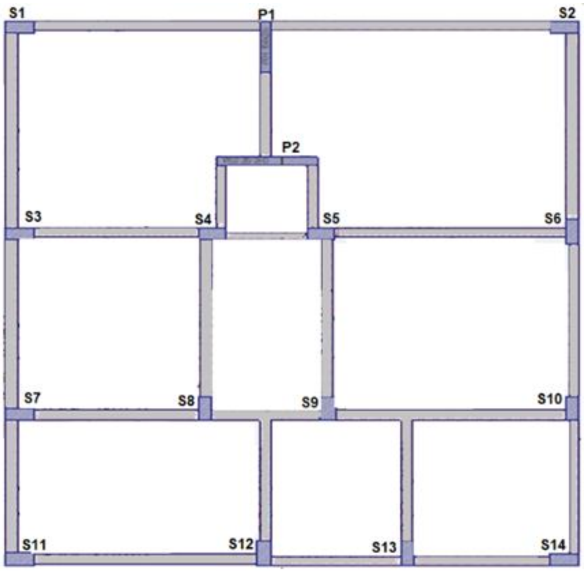

Figure 6. The plan of the reference RC building

Earthquake parameters for the sample RC building were obtained using the Türkiye Earthquake Hazards Map Interactive Web Application (TEHMIWA). The values obtained through this application, depending on the location of the building, are shown in Table 1.

Table 1. Earthquake parameters considered for the reference building

Parameter	Value
Local soil class	ZD
Earthquake ground motion level	DD-2
Spectrum characteristic periods (T_A /T_B)	0.13/0.65
Short period map spectral acceleration coefficient (S_s)	0.274
Map spectral acceleration coefficient for a 1.0 s period (S_1)	0.12
Short period design spectral acceleration coefficient (S_{DS})	0.433
Design spectral acceleration coefficient for a 1.0 s period (S_{D1})	0.283
Peak ground acceleration (g) (PGA) (g)	0.122
Peak ground velocity (PGV) (m/s)	9.31

The structural parameters considered for the sample RC building are shown in Table 2.

Table 2. Structural features for the reference building

Number of storeys	7
Total height of the building (m)	21.90
Maximum storey height (m)	3.40
Building importance coefficient (I)	1
Building usage class (BKS)	3
Ductility level	High
Earthquake design class (DTS)	3
Building height class (BYS)	6
Normal performance target	Controlled Damage
Evaluation / design approach	Design by strength
Material	C25-B420C

In this study, four different structural group models were created to examine the heavy overhang effect. Structural models are grouped into four different categories: only 1 facade, 2 facades, 3 facades, and four facades. The models considered for each group while constructing the structural models are shown in Figure 7.

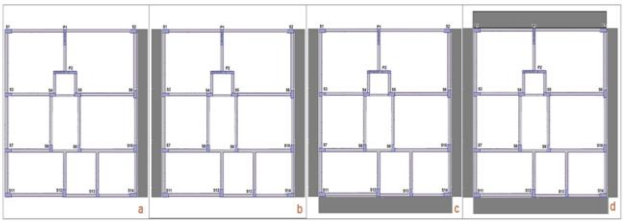

Figure 7. Structural models with heavy overhangs added to their facades a) one facade, b) two facades, c) three facades, d) four facades

Four different overhangs were taken into account in each structural model group, such as 0.80 m, 1.0 m, 1.2 m, and 1.5 m. The groups and the length of overhang of the structural models are shown in Table 3.

Table 3. Structural models considered in the study

Group	Group I	Group II	Group III	Group IV
Length of overhang (m)	0.8	1.0	1.20	1.50
1 facade	Model 1	Model 5	Model 9	Model 13
2 facade	Model 2	Model 6	Model 10	Model 14
3 facade	Model 3	Model 7	Model 11	Model 15
4 facade	Model 4	Model 8	Model 12	Model 16

The values to be obtained for the 16 structural models were compared both with the reference building model without heavy overhangs and within the structural group. The mode superposition method was used in all structural analyses.

3. Results and Discussion

In this study, a total of 17 RC structural models were designed, and one of which is a reference building. Structural analyses were performed with IDECAD software [48] for four different heavy overhang cases for four different structural model groups. The total mass, period, and modal base shear forces obtained for all structural models are shown in Table 4. The percentages of change obtained for structural models with different heavy overhangs compared to the reference building are also given in Table 4.

Table 4. Comparison of total mass, period and shear forces for the structural models

Group No	Model	Total mass (t)	%	Period (s)	%	Modal base shear (tf)	%
Reference	Reference	1525.96	0.00	1.172	0.00	44.62	0.00
Group I	Model 1	1660.22	0.09	1.251	0.07	48.554	0.09
	Model 2	1794.48	0.18	1.299	0.11	48.613	0.09
	Model 3	1910.14	0.25	1.316	0.12	49.987	0.12
	Model 4	2023.64	0.33	1.38	0.18	49.987	0.12
Group II	Model 5	1675.35	0.10	1.264	0.08	48.613	0.09
	Model 6	1824.74	0.20	1.313	0.12	48.748	0.09
	Model 7	1953.86	0.28	1.332	0.14	50.296	0.13
	Model 8	2079.86	0.36	1.406	0.20	52.298	0.17
Group III	Model 9	1690.53	0.11	1.277	0.09	48.425	0.09
	Model 10	1855.05	0.22	1.327	0.13	48.911	0.10
	Model 11	1997.64	0.31	1.349	0.15	50.612	0.13
	Model 12	2136.04	0.40	1.434	0.22	53.236	0.19
Group IV	Model 13	1713.17	0.12	1.298	0.11	47.807	0.07
	Model 14	1900.39	0.25	1.348	0.15	49.117	0.10
	Model 15	2063.17	0.35	1.382	0.18	51.106	0.15
	Model 16	2220.31	0.46	1.478	0.26	54.841	0.23

Figure 8 shows a comparison of the total mass values that were found for all of the structural models that were looked at as part of the study.

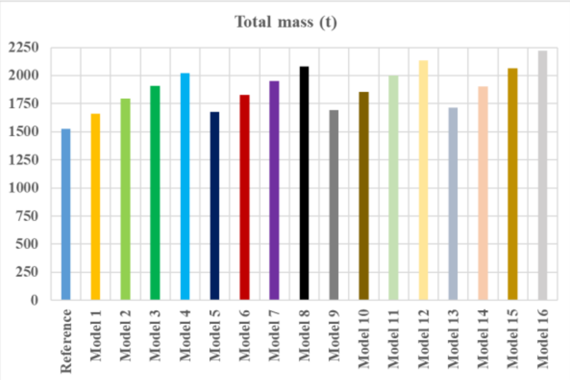

Figure 8. Total mass values obtained for structural models

The comparison of the total masses obtained for Group I (heavy overhang on one side) is shown in Figure 9 as an example.

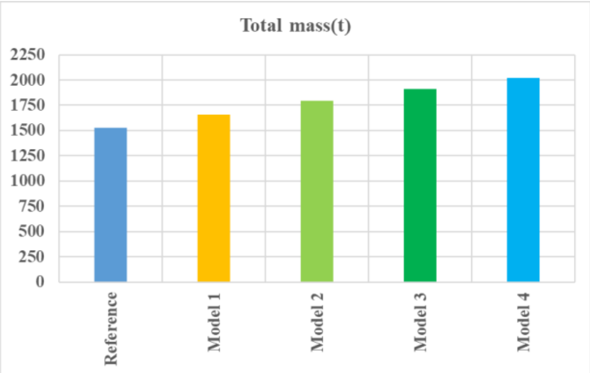

Figure 9. Comparison of total masses for Group I

In order to have the heavy overhang length of 1.50 m, one structural model was selected from each structural group in order to compare the heavy overhangs on different numbers of facades. The total mass values obtained for reference for a single facade (Model 4), two facades (Model 8), three facades (Model 12), and four facades (Model 16) when the heavy overhang is 1.50 m are shown in Figure 10.

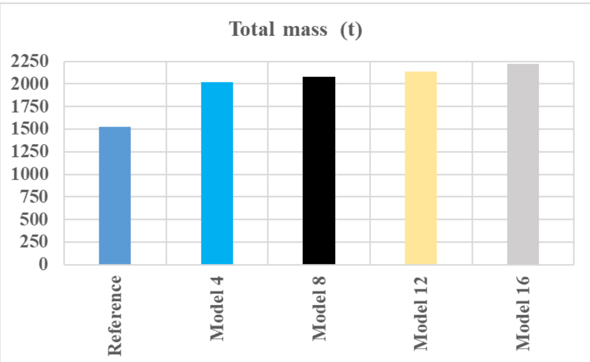

Figure 10. The effect of heavy overhangs on the total mass on different number of facades

The comparison of the period values for selected structural models are shown in Figure 11.

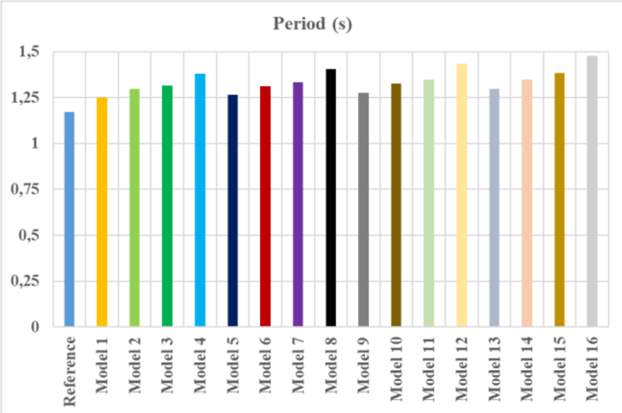

Figure 11. Comparison of the period values for all structural models

The period values obtained for reference for a single facade (Model 4), two facades (Model 8), three facades (Model 12), and four facades (Model 16) when the heavy overhang is 1.50 m are shown in Figure 12.

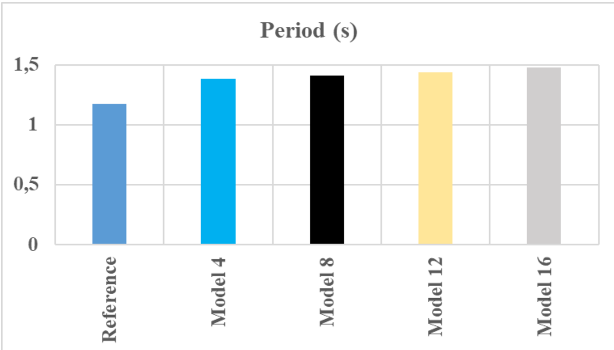

Figure 12. Comparison of periods for different number of facades

The comparison of the period values obtained for Group IV (heavy overhang on all four facades) is shown in Figure 13, as an example.

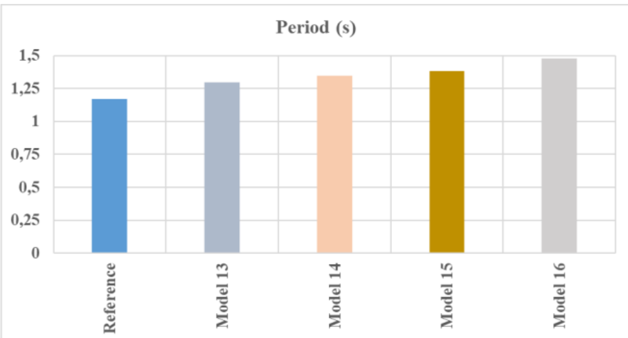

Figure 13. Comparison of periods for group IV

Column plastic rotations and section unit deformation demands for models where the heavy overhang length is constant (1.50 m) but the number of heavy overhangs increases sequentially for each facade are shown in Table 5. As an example, the S7 column on the ground floor was taken as an example.

Table 5. Column plastic rotations and section strain demands

Group No	Model No	ε^{C} (10^{-3})	ε^{s}(10^{-3})	θ^{p}(rad)
Reference	Reference	2.290	5.242	0.00213
Group I	Model 4	3.266	6.370	0.00310
Group II	Model 8	3.422	6.535	0.00322
Group III	Model 12	3.582	6.702	0.00329
Group IV	Model 16	3.782	6.834	0.00345

The displacement values obtained in the X and Y directions for heavy overhangs on equal but different numbers of facades are shown in Table 6.

Table 6. Comparison of displacements

Model	Displacement (mm)	
	X	Y
Reference Model	97.95	93.32
Model 4	110.02	105.18
Model 8	111.69	107.24
Model 12	113.13	109.1
Model 16	115.11	111.59

The earthquake performance results of the models in which the heavy overhang length is constant (1.5 m) and the number of heavy overhangs increases sequentially for each facade are shown in Table 7.

Table 7. Comparison of earthquake performances of some structural models

Criteria	Reference	Model 4	Model 8	Model 12	Model 16
Up to 35% of beams on any storey can pass into the forward Damage Zone	0.00	0.00%	0.00%	0.00%	7.10%
Contribution of vertical elements to the shear force in the Advanced Damage Zone should be less than 20%	0.00	16.10%	16.20%	16.30%	16.40%
The contribution of the vertical elements in the Advanced Damage Zone to the shear force on the top storey should be less than 40%	0.00	0.00%	0.00%	0.00%	0.00%
The ratio of shear force carried by vertical members whose Significant Damage Limit has been exceeded should not exceed 30%.	0.00	0.00%	0.00%	0.00%	8.60%
All other structural elements must be in the Limited or Significant Damage Zone	✓	X	X	X	X
Building performance	Controlled damage	Collapse	Collapse	Collapse	Collapse

In the Turkish Rapid Assessment Method, which was updated in 2019, the effect of heavy overhang was also looked at as part of this study. According to this method, the negativity parameter scores recommended for a heavy overhang in RC structures depending on the number of stories are given in Table 8.

Table 8. Negativity parameter score for overhang

Number of storeys	Heavy overhang
1,2	-10
3	-20
4	-30
5	-30
6,7	-30

In this method that used to determine the regional risk priorities in RC structures, the heavy overhang changes only according to the number of storeys. It has not been taken into account the amount of heavy overhang, its length, or how many facades there are. Within the scope of this study, structural performance scores were calculated for a sample building selected as an example in cases of no heavy overhangs and heavy overhangs for all storeys in the rapid evaluation method. All parameters are taken into account equally for the building with and without heavy overhangs. As a variable, only the presence of a heavy overhang was taken into account. For the selected RC building, the danger zone is selected as I. While selecting the base point, the values were chosen with the assumption that the sample RC structure consisted of only the frame. A comparison of the obtained results is made in Table 9.

Table 9. The effect of heavy overhang in the rapid assessment method

Number of storeys	Base score	Heavy overhang negativity parameter score	Reference	Heavy overhang
1,2	90	-10	90	80
3	80	-20	80	60
4	70	-30	70	40
5	60	-30	60	30
6,7	50	-30	50	20

As the number of storeys increases, the performance score of the heavy overhang decreases for the building. In the rapid assessment method, the average effect of heavy overhang is 38%. As can be understood from this value, it is an important factor even in the simplified methods used in determining the risk priorities. While heavy overhangs are taken into account in the rapid evaluation method, the number of facades with heavy overhangs and the lengths of heavy overhangs are not taken into account. The result values obtained in this study revealed that the number and amount of facades with heavy overhangs directly affect the structural performance results.

4. Conclusion and Suggestions

Within the scope of this study, the behaviour of heavy overhangs in RC buildings, which are widely used, under earthquake effects was investigated. In future studies, different analyses, including the time-history analysis, will be able to analyse more structural models in different software programs. The data obtained from this study can be a source for such studies.

The results were based on two main situations that show how heavy overhangs on RC buildings can have different effects on the structure. The first of these two main cases is the case where the length of the heavy overhang is kept constant and the heavy overhang is added to all facades, while the second case is the case where the number of heavy overhangs is kept constant and their lengths are applied in variable lengths. As a result of the analyses performed for all structural models within the scope of the study, the following results were obtained;

- With the increase in the number of facades with heavy overhangs, it has been observed that the structural elements have difficulty performing compared to the reference model. Furthermore, the building performance of heavy overhangs on 1, 2, and 3 facades, while controlled damage occurred as in the reference model, was obtained as the collapse state in the model with heavy overhangs on 4 facades.
- The period value increased as the length of the heavy overhang and the number of facades with heavy overhangs increased. The high period value is related to the rigidity of the structure. Therefore, the rigidity of structures with heavy overhangs will be lower than that of structures without heavy overhangs.
- As more heavy overhangs were added to the facades of the sample RC building, the building's weight naturally went up.
- It has been found that the value of the base shear force goes up as more heavy overhangs are added to the facades.
- When compared to the reference model, the number of heavy overhangs added to the facades of the Group IV models caused both the concrete section unit shortening and the reinforcing steel unit strain to go up.
- Plastic rotation has increased compared to the reference model due to the increase in the number of added heavy overhangs.
- It was seen that the length of the heavy overhang made the building less stable during an earthquake.
- Models with heavy overhangs on one side and variable lengths (0.8 m-1m-1.2 m-1.5 m) had the same performance compared to the reference model, and the building performance of 5 models was found to be controlled damage.
- The performance of all models with heavy overhangs on all four facades and variable lengths has been found to collapse. In all models with heavy overhang, the contribution of vertical elements in the forward damage zone to the shear force increased, respectively. In addition, the forward damage zone penetration of the beams in the 16th model increased by percentage.

As a result, it is necessary to avoid, as much as possible, the parameters that will negatively affect the behaviour of structures under the effects of earthquakes. In cases of necessity, it is obligatory to take the necessary preventive measures. This study was carried out by analysing the regular RC structure.

These results can be compared with future studies for irregular buildings.

It can also be suggested that the number of facades with heavy overhangs be integrated into the scoring in the rapid assessment method.

Acknowledgment

This research was produced from master thesis of second author of the article.

Contributions of the authors

All authors contributed equally to the study.

Conflict of Interest Statement

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The study is complied with research and publication ethics

References

[1] A. Tabrizikahou, M. Hadzima-Nyarko, M. Kuczma, S. Lozančić, Application of shape memory alloys in retrofitting of masonry and heritage structures based on their vulnerability revealed in the Bam 2003 earthquake. *Materials*, vol.14 (16), 4480, 2021.

[2] G. Dogan, A.S. Ecemis, S.Z. Korkmaz, M.H. Arslan, H.H. Korkmaz HH, Buildings damages after Elazığ, Turkey earthquake on January 24, 2020. *Natural Hazards*, vol.109 (1), pp.161-200, 2021.

[3] O.F. Nemutlu, B. Balun, A. Sari, A. Damage assessment of buildings after 24 January 2020 Elazığ-Sivrice earthquake. *Earthquakes and Structures*, vol. 20(3), pp.325-335, 2021.

[4] E. Çelebi, M. Aktas, N. Çağlar, A. Özocak, M. Kutanis, N. Mert, Z. Özcan, 2013. October 23, 2011 Turkey/Van Ercis earthquake: structural damagesin the residential buildings. Natural Hazards, vol. 65(3), pp.2287-2310, 2013.

[5] R. Pekgökgöz, A. Gürel, F. Avcil, GAP YENEV Binasının Kısmi Göçmesinin İncelenmesi ve Güçlendirme Çalışmaları. *Dicle Üniversitesi Mühendislik Fakültesi Mühendislik Dergisi*, 12(2), pp.389-399, 2021.

[6] M.H. Arslan, H.H. Korkmaz, What is to be learned from damage and failure of reinforced concrete structures during recent earthquakes in Turkey?. *Engineering Failure Analysis*, vol. 14(1), pp.1-22, 2007.

[7] H. Bilgin, N., Shkodrani, M. Hysenlliu, H.B. Ozmen, E. Isik, E. Harirchian, Damage and performance evaluation of masonry buildings constructed in 1970s during the 2019 Albania earthquakes. *Engineering Failure Analysis*, vol.131, 105824, 2022.

[8] N., Ademović, M. Hadzima-Nyarko, N. Zagora, Seismic vulnerability assessment of masonry buildings in Banja Luka and Sarajevo (Bosnia and Herzegovina) using the macroseismic model. *Bulletin of Earthquake Engineering*, vol.18(8), pp.3897-3933, 2020.

[9] B. Özmen, H. Can, Ankara için deterministik deprem tehlike analizi. *Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi*, vol.31(1), pp.9-18, 2016.

[10] E. Işık, Ç. Sağır, Z. Tozlu, Ü.S. Ustaoğlu, Determination of urban earthquake risk for Kırşehir, Turkey. *Earth Sciences Research Journal*, vol.23(3), pp.237-247, 2019.

[11] A. Yakut, Preliminary seismic performance assessment procedure for existing rc buildings. *Engineering Structures*, vol.26(10), pp.1447-1461, 2004.

[12] E. Işık, Comparative investigation of seismic and structural parameters of earthquakes (M≥ 6) after 1900 in Turkey. *Arabian Journal of Geosciences*, vol.15(10), pp.1-21, 2022.

[13] H. Bilgin, M. Hadzima-Nyarko, E. Isik, H.B. Ozmen, E. Harirchian, (2022). A comparative study on the seismic provisions of different codes for RC buildings. *Structural Engineering and Mechanics*, vol.83(2), pp.195-206, 2022.

[14] B. Yön, O. Onat, M.E. Öncü, A. Karaşin, Failures of masonry dwelling triggered by East Anatolian Fault earthquakes in Turkey. *Soil Dynamics and Earthquake Engineering*, vol.133, 106126, 2020.

[15] M.F. Işık, E. Işık, E. Harirchian, Application of IOS/Android rapid evaluation of post-earthquake damages in masonry buildings. *Gazi Mühendislik Bilimleri Dergisi*, vol.7(1), pp.36-50, 2021.

[16] C. Aksoylu, A. Mobark, M.H. Arslan, İ.H. Erkan, 2020. A comparative study on ASCE 7-16, TBEC-2018 and TEC-2007 for reinforced concrete buildings. *Revista de la Construcción*, vol.19(2), pp.282-305, 2020.

[17] H. Ulutaş H, DBYBHY (2007) ve TBDY (2018) Deprem yönetmeliklerinin kesit hasar sınırları açısından kıyaslanması. *Avrupa Bilim ve Teknoloji Dergisi*, vol.17, pp. 351-359, 2019.

[18] Ö.F. Nemutlu, B. Balun, A. Benli, A. Sarı, Bingöl ve Elazığ illeri özelinde 2007 ve 2018 Türk deprem yönetmeliklerine göre ivme spektrumlarının değişiminin incelenmesi. *Dicle Üniversitesi Mühendislik Fakültesi Mühendislik Dergisi*, vol.11(3), pp.1341-1356, 2020.

[19] E. Işık, A.E. Ulu, M.C. Aydın, A case study on the updates of Turkish rapid visual screening methods for reinforced-concrete buildings. *Bitlis Eren University Journal of Science & Technology*, vol.11(2), pp.97-103, 2021.

[20] H. Sarı, *Mevcut Betonarme Yapılardaki Tasarım Olumsuzluklarının Yapı Performansına Etkisi.* Yüksek Lisans Tezi, Sakarya Üniversitesi, Sakarya, 2010.

[21] A. Doğangün, 2004. Performance of reinforced concrete buildings during the May 1, 2003 Bingöl earthquake in Turkey. *Engineering Structures*, vol.26(6), 841-856, 2004.

[22] M. İnel, H.B. Ozmen, H. Bilgin, Re-evaluation of building damage during recent earthquakes in Turkey. *Engineering Structures*, vol.30(2), 412-427, 2008.

[23] S. Tesfamariam, Z. Liu, Earthquake induced damage classification for reinforced concrete buildings. *Structural Safety*, vol.32(2), pp.154-164, 2010.

[24] S. Saatci, F.J. Vecchio, Effects of shear mechanisms on ımpact behaviorof reinforced concrete beams. *ACI Structural Journal*, vol.106-109, pp. 78-86, 2009.

[25] S.B. Öz, *Kapalı Çıkma Düzensizliğinin Betonarme Yapıların Sismik Davranışına Etkilerinin Doğrusal Elastik Olmayan Analizle Belirlenmesi*. Yüksek Lisans Tezi, Osmaniye Korkut Ata Üniversitesi, Osmaniye, 2019.

[26] M. İnel, M. Bucaklı, H.B. Özmen, Betonarme binalarda çerçeve süreksizliğinin yapı performansı üzerindeki etkileri. *Uluslararası Sakarya Deprem Sempozyumu*; 1-2 Ekim 2009, Sakarya, Türkiye, 2009.

[27] E. Meral, Kapalı çıkmalı betonarme binaların deprem davranışının değerlendirilmesi. *Fırat Üniversitesi Mühendislik Bilimleri Dergisi*, vol.31(2), pp. 309-318, 2019.

[28] E. Meral, M. İnel, Düşük ve orta yükseklikteki betonarme binaların yapısal parametre özelliklerinin değerlendirilmesi. *Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi*, vol. 22(6), pp.468-477, 2016.

[29] E. Işık, Z. Tozlu, Farklı değişkenler kullanılarak yapı performans puanının hesaplanması. *Bitlis Eren Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, vol.4(2), pp.161-172, 2015.

[30] E. Işık, M.H. Özlük, E. Demir, H. Bilici, 23.10. 2011 Van depreminin Adilcevaz ilçesindeki etkilerinin gözleme dayalı incelenmesi. *Bitlis Eren Üniversitesi Fen Bilimleri Dergisi*, vol.*1*(1), pp.1-10, 2012.

[31] H.B. Özmen, 2005. *Hızlı Değerlendirme Yöntemlerinde Kullanılan Parametrelerin Yapı Performansı Üzerindeki Etkilerinin İncelenmesi*, Yüksek Lisans Tezi, Pamukkale Üniversitesi, Denizli, 2005.

[32] PDRB, 2019. *The Principles of Determining Risky Buildings, Turkey Ministry of Environment and Urbanization* Ankara, Turkey

[33] Ö.F. Nemutlu, Ö.F. *2018 Türk Deprem Yönetmeliklerinin ve Amerikan Deprem Yönetmeliğinin Deprem Hesapları Açısından Karşılaştırılmas*ı. Yüksek Lisans Tezi, İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, Türkiye, 2019.

[34] M.A., Bülbül, E. Harirchian, M.F. Işık, S.E. Aghakouchaki Hosseini, E. Işık, A hybrid ANN-GA model for an automated rapid vulnerability assessment of existing RC buildings. *Applied Sciences*, 12(10), 5138, 2022.

[35] Ö.F. Nemutlu, A. Sarı, Comparison of Turkish Earthquake Code in 2007 with Turkish Earthquake Code in 2018. In *International Engineering and Natural Sciences Conference (IENSC 2018), Diyarbakır* (Vol. 568, p. 76), 2018.

[36] Ö.F. Nemutlu, A. Sarı, 2018 Yeni Türk Deprem Yönetmeliği ile Amerikan Deprem Yönetmeliklerinin deprem hesapları açısından karşılaştırılması. *5. Uluslararası Deprem Mühendisliği ve Sismoloji Konferansı,* 8-11 Ekim 2019, Ankara, Türkiye, 2019.

[37] H.B. Özmen, M. İnel, B.T. Çaycı, 2011. Kapalı çıkma düzensizliğinin betonarme yapıların sismik davranışına etkilerinin değerlendirilmesi. *Yedinci Ulusal Deprem Mühendisliği Konferansı;* 30 Mayıs-3 Haziran 2011, İstanbul, Türkiye, 2011.

[38] G. Özcebe, 2004. *Deprem Güvenliğinin Saptanması için Yöntemler Geliştirilmesi*. TÜBİTAK İÇTAG YMAÜ İ574-Araştırma Projesi Sonuç Raporu, Ankara, 2004.

[39] H. Sucuoglu, U. Yazgan, Simple survey procedures for seismic risk assessment in urban building stocks. *Seismic Assessment and Rehabilitation of Existing Buildings*, vol.29, pp:97-118, 2003.

[40] H.B. Özmen, M. İnel, B.T. Çaycı, *23 Ekim ve 9 Kasım 2011 Van Depremleri Yapısal Hasar Değerlendirme Raporu.* Pamukkale Üniversitesi, Mühendislik Fakültesi, İnşaat Mühendisliği, Denizli, 2012.

[41] M, Inel, H.B. Ozmen, E. Akyol E, Observations on the building damages after 19 May 2011 Simav (Turkey) earthquake. *Bulletin of Earthquake Engineering*, vol.11, pp.255-283, 2013.

[42] M. Dogan, E. Unluoglu, H. Ozbasaran, Earthquake failures of cantilever projections buildings. *Engineering Failure Analysis*, vol.14, pp.1458-1465, 2007.

[43] A. Yakut, H. Sucuoğlu, B. Binici, E. Canbay, C. Donmez, A. İlki, B.Ö. Ay, Performance of structures in İzmir after the Samos Island earthquake. *Bulletin of Earthquake Engineering*, vol.*20*, pp.7793-7818, 2022.

[44] M. İnel, H.B. Özmen, B.T. Çaycı, Simav ve Van Depremleri (2011) yapı hasar nedenlerinin değerlendirilmesi. *Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi*, vol.19, pp.256-265, 2013.

[45] E. Isik, M.C. Aydin, A. Buyuksarac, 24 January 2020 Sivrice (Elazığ) earthquake damage sand determination of earth quake parameters in the region. *Earthquakes and Structures,* vol.19, pp.145-156, 2020.

[46] Ö. Yurdakul, B. Duran, O. Tunaboyu, Ö. Avşar Ö, Field reconnaissance on seismic performance of rc building safter the January 24, 2020 Elazığ-Sivrice Earthquake. *Natural Hazards*, vol.105, pp.859-887, 2021.

[47] E. Işık, The effects of 23.10.2011 Van earthquake on near-fieldand damaged on structures. *International Anatolia Academic Online Journal Scientific Science*, vol.2, pp.10-25, 2014.

[48] IdeCAD, 2022, ideYAPI Ltd. www.idestatik.com. Erişim tarihi:15.11.2021.