Challenge Journal of Structural Mechanics

Research Article

Earthquake resistant design of reinforced concrete retaining walls considering the project location change effect

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ABSTRACT

In this paper, the design process of reinforced concrete retaining walls is investigated under the issue of "project location change effect" which becomes a significant requirement to assess the earthquake resistant design depending on the new Turkish Building Earthquake Code-2018 (TBEC-2018). Within this context, in the light of the related code, fourteen different districts which are located in the Anatolian Side of Istanbul Province (Turkey) have been taken into consideration, to search for also the effects of the supported earth fill depth, the unit weight and the shear strength angle of surrounding soil and the external loading conditions. In this way, it has been aimed to focus on the application details of the design code and reflect the outcomes of the analysis in terms of the changes that happened in wall dimensions depending on the locations of project. Besides, with this study, it is aimed to reveal that the definition of type sectional wall will not be possible with the new code. As the result, the influence rates of the investigated project variants have been explained considering site-specific retaining wall design in terms of integrated relations of the design parameters.

ARTICLE INFO

Article history:
Received 7 February 2022
Revised 1 March 2022
Accepted 16 March 2022

Keywords:
Retaining walls
Location effect
Sizing
Turkish Building Earthquake Code

1. Introduction

The earthquake-resistant design of reinforced concrete retaining walls has been the main subject of several studies till now depending on the widespread usage and easily applicable characteristics of the retaining walls.öThe design of retaining walls is based on both the attainment of the geotechnical stability in terms of sliding, overturning and bearing capacity adequateness and the fulfilment of the structural requirements based on the envisaged codes to resist static and dynamic loads. In this context, Ahmadi-Nedushan and Varaee (2009) performed analyses for the optimal design of RWs with the Particle Swarm Optimization method to minimize both cost and weight. Kaveh and Khayatazad (2014) utilized the Ray optimization method to optimize RWs and check the design parameters with the determination of seismic active earth pressure with the pseudo-dynamic method. Uray et al. (2019) used the discrete optimization method with the use of the minimum weight of the wall as the objective function and formed a brief parametric study depending on only static conditions. Konstandakopoulou et al. (2020) conducted analyses for the design of RWs under static and seismic conditions with the satisfaction of all structural and geotechnical necessities according to European Code requirements with optimization algorithms during the decrement process of the ultimate cost. Dagdeviren and Kaymak (2020) derived a new regression model through the use of the Artificial Bee Colony algorithm to ensure the pre-design of RWs that is resting on the soil layer which has a high bearing capacity for static loading conditions. Besides, nowadays, there are various studies considering different methods and codes that are conducted to design RWs under static or/and dynamic conditions. The suggestions presented in the design codes or technical guidelines lead to the determination procedures of the lateral pressures (Kramer 1996). These codes and standards are

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ISSN: 2149-8024 / DOI: https://doi.org/10.20528/cjsmec.2022.01.004

set up by considering earthquakes that have occurred or are likely to occur at relevant locations. Considering the destructive earthquakes that happened in Turkey like Erzincan-1992 (6.6 M_w), Adana-Yüreğir-1998 (6.2 M_w), Düzce-1999 (7.1 M_w), Gölcük-1999 (7.6 M_w), Bingöl-2003 (6.3 M_w), Van-2011 (7.1 M_w), Gökçeada-2014 (6.5 M_w), Elazığ-2020 (6.8 M_w) İzmir-2020 (6.6 M_w) the necessity to improve the existing code arose (AFAD). Therefore, a new Turkish Building Earthquake Code is developed in 2018 (TBEC-2018) depending on the prepared actual Earthquake Hazard Map of Turkey (TDTH 2018; Akkar et al. 2018).

In the context of this study, the consideration of the TBEC-2018 requirements for the design of reinforced concrete retaining walls to determine the earthquake effects have been made depending on the locations of immediate vicinities in the Anatolian side of Istanbul (Turkey). For this purpose, fourteen districts are taken into consideration and, also the effects of the change of excavation depth (supported earth fill depth), the unit weight of the surrounding soil, the shear strength angle of the surrounding soil and, the external loading magnitude has been searched. The coordinates of the city halls have been selected as the mentioned fourteen different locations. For this aim, macro codes are generated via Microsoft Excel software. As a result of the study, the significance degrees of the investigated variants have also been explained in terms of integrated relations of the design parameters in comparison with the mostly used pseudo-static approach.

2. Material and Method

In Fig. 1, the load distribution along a T-shaped retaining wall section generated depending on the earthquake condition has been given. Besides, the abbreviations that are used to describe the parts of the wall system is also given in the figure. B, z, H, d_{p1}, d_{p2}, t_1, t_2 represents the foundation base width, the supported earth fill depth, the total height of the wall, the thickness of the stem at the top, the thickness of the stem at bottom, the width of the wall toe and the width of the wall heel respectively.

In Fig. 1, the weight of the wall stem, the foundation base, the backfill soil is represented with W_w, W_{fb}, W_{sb} respectively and the surcharge is abbreviated by q_a. P_{as} and P_{ps} define the active and passive lateral soil forces respectively. P_{tb} is the base pressure and P_{qa} is generated force depending on the surcharge loading and P_{eqa} represents the active pressure due to the surcharge load for earthquake condition. In addition, the lateral soil pressures including both the active and passive states for earthquake condition are defined by P_{eas} and P_{eps} respectively.

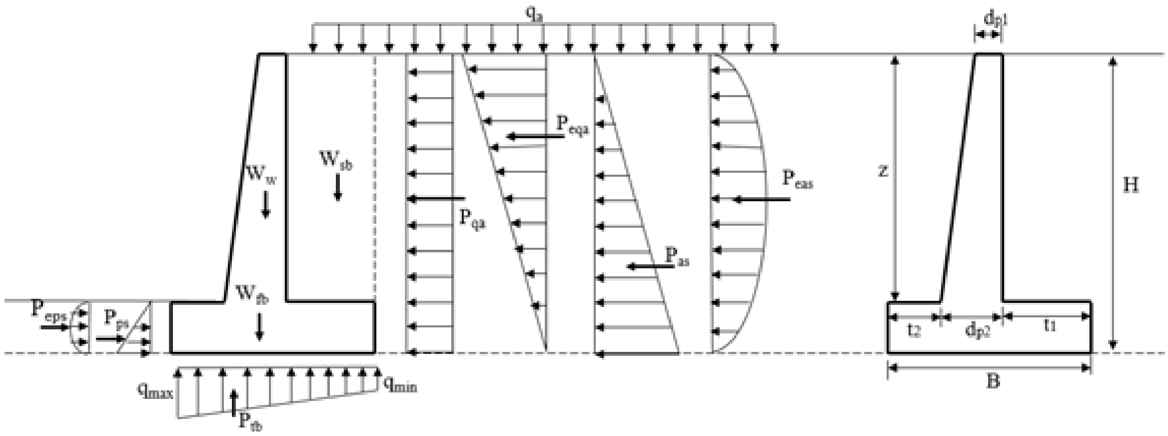

Fig. 1. The load distribution along the T-shaped retaining wall section.

In Fig. 2, the application details of TBEC-2018 are given to design RWs considering the remarkable effect of project location in terms of the geotechnical parameter determination process considering the dynamic response. The application process of TBEC-2018 begins with the identification of the class of the soil formation dominated in the project field. The code requires to obtain the accurate representative parameters of soil formation and in addition, necessitates to use the existing coordinates of the project field. The development of the new earthquake hazard map leads to discontinuing the concept of earthquake zone, and in the new map, unlike the previous map, instead of the earthquake zones, the peak ground acceleration (PGA) values are given. With the consideration of the earthquake active faults, it started to be entered into calculations as separate spectrum values and acceleration values for each location. In the context of this study, the seismic hazard maps in terms of peak ground acceleration, peak ground velocity, 5%-damped pseudo-spectral accelerations at 0.2 sec and 1.0 sec periods for return periods of 43, 72, 475 and 2475 years have been produced. In addition, the determination of the lateral earth coefficients is depended on the short period design spectral acceleration coefficient (S_{DS}) value. S_{DS} value varies according to each location on the map and soil classes that are defined in TBEC-2018. Besides, S_{DS} value can take five different values depending on the soil classes and these values can be acquired interactively from the earthquake hazard map. Therefore, lateral earth coefficient values vary according to each soil class defined in TBEC-2018. Within this context, Gürsoy (2013) articulated the necessity of the consideration of the soil parameters in the response spectrums for the safer designs with the discussion of the previous earthquake design code of Turkey and Eurocode -8. Considering the requirements arising from the new earthquake code, Öztürk (2018) compared the last two codes used in Turkey in terms of the designs that are modelled for different locations within the same province. Keskin and Bozdoğan (2018) investigated the application details of the new code with the evaluation of another province, Kırklareli. Elçi and Göker (2018) discussed the last two design codes in terms of the design of reinforced concrete columns. Kayhan and Demir (2018) used a method based on the differential development algorithm technique in the design of reinforced concrete cantilever retaining walls at minimum cost. Özberk and Kahyaoğlu (2018) conducted the comparative analysis to see the effects of the change in wall height depending on the last two codes. Aksoylu et al. (2020) conducted a comparative analysis considering the design requirements of reinforced concrete buildings depending on the last two codes. Atmaca et al. (2019) were also compared to the last two codes considering a school project constructed in Gaziantep with the use of SAP2000 software. Yüksel and Akbaş (2020) determined the lateral soil pressures that are affecting a cantilever retaining wall depending on the last two earthquake design codes and investigated the surcharge loading effect on the dimensions.

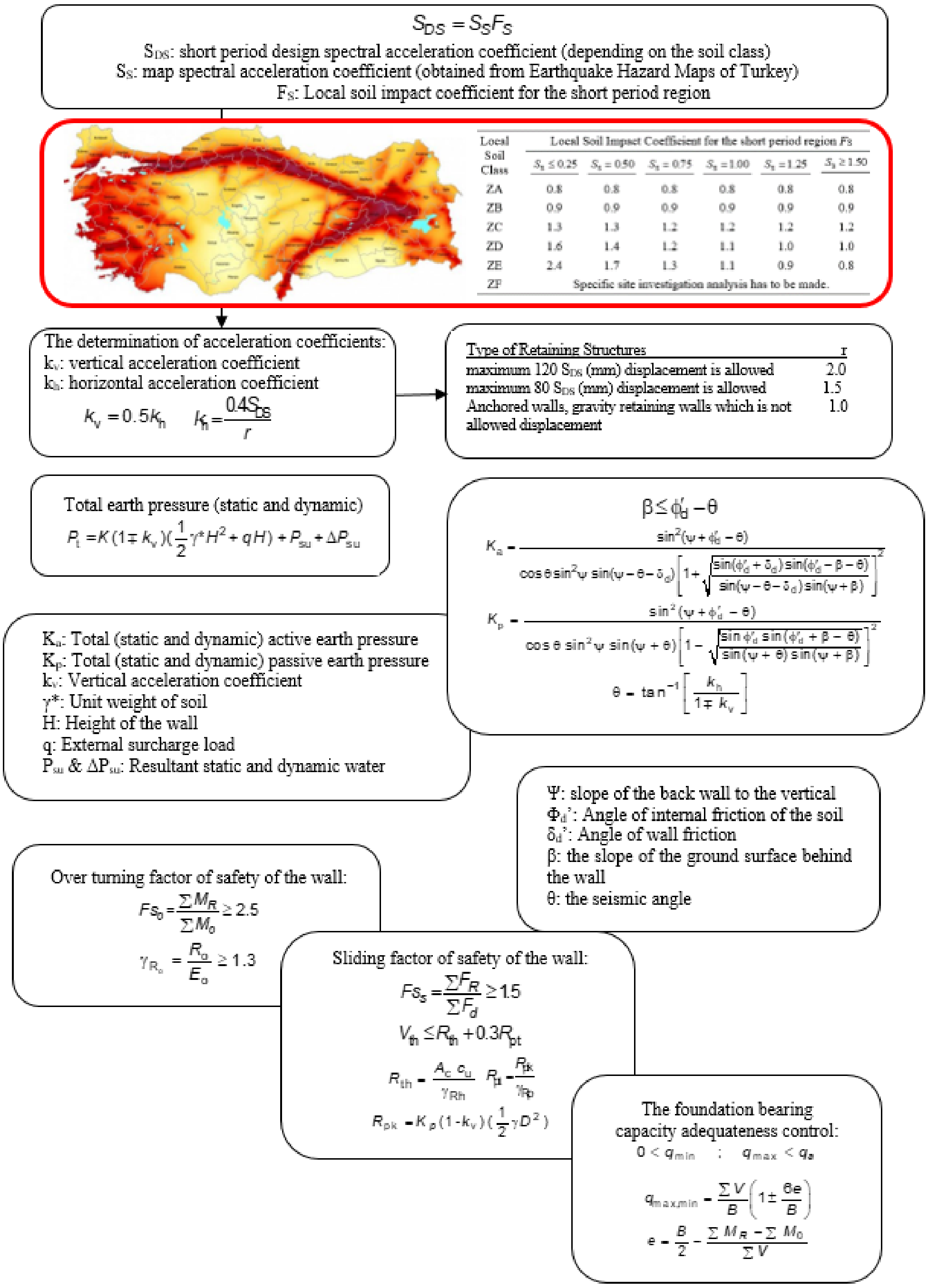

Fig. 2. The flowchart for designing RWs according to TBEC-2018.

3. Parametrical Analysis

Parametrical analyses were conducted according to the change of design parameters such as the supported earth fill depth, the unit weight and, the shear strength angle of the surrounding soil, the external loading conditions and, the location of the project site. In this context, the supported earth fill depth was assumed to be 3, 6, 9 m, the unit weight of the soil was selected as 17, 19, 21 kN/m^3, the shear strength angle of surrounding soil was 30, 31, 32, 33, 34°, the external load was 0 and 15 kPa. The soil class was assumed to be ZB for all the considered cases. Besides, the location effect was taken into consideration depending on the selected 14 different places in Istanbul Province from the Anatolian side. The location of European and Anatolian sides of Istanbul Province is shown in Fig. 3a and the selected districts are exhibited in Fig. 3b. These districts are Adalar, Ataşehir, Beykoz, Çekmeköy, Kadıköy, Kartal, Maltepe, Pendik, Sancaktepe, Şile, Sultanbeyli, Tuzla, Ümraniye, Üsküdar respectively.

The obtained values of S_S and S_{DS} from the Earthquake Hazard Map of Turkey depending on the locations of the districts are given in Table 1. The details of the attainment process of the PGA values that are used to determine the S_{DS} values can be ensured by the interactive web application of Earthquake Hazard Map of Turkey that is given in Fig. 4.

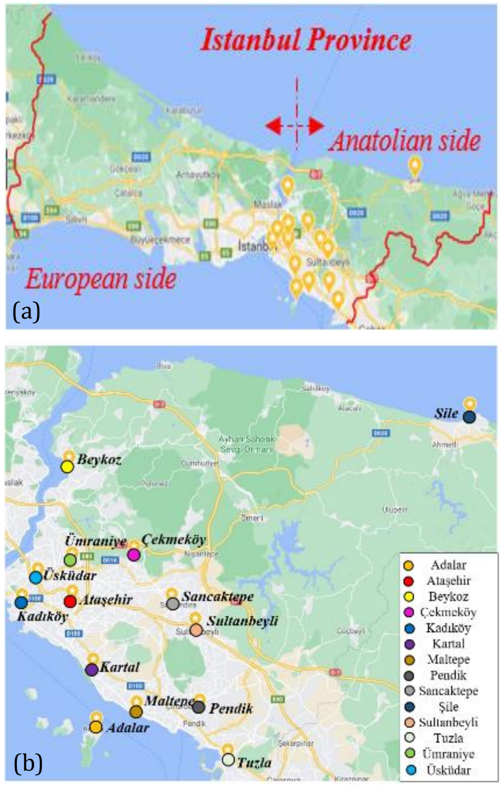

Fig. 3. (a) Map of Istanbul Province; (b) Location of investigation location.

Table 1. The obtained values of S_S and S_{DS} from the Earthquake Hazard Map of Turkey depending on the coordinates of the districts.

No	District	X	Y	PGA (g)	SS	SDS
1	Adalar	40.87438701	29.13267396	0.523	1.276	1.148
2	Ataşehir	40.98375666	29.11600874	0.379	0.890	0.801
3	Beykoz	41.12695186	29.09775237	0.278	0.665	0.599
4	Çekmeköy	41.03323219	29.16828953	0.323	0.762	0.686
5	Kadıköy	40.99326509	29.03723949	0.392	0.958	0.862
6	Kartal	40.89009159	29.18387493	0.458	1.116	1.004
7	Maltepe	40.93144641	29.12791484	0.441	1.069	0.962
8	Pendik	40.87663041	29.23256815	0.447	1.034	0.931
9	Sancaktepe	40.99412562	29.23041597	0.340	0.816	0.734
10	Şile	41.17749167	29.61098592	0.245	0.583	0.525
11	Sultanbeyli	40.97081508	29.25938800	0.352	0.845	0.761
12	Tuzla	40.84360330	29.30085842	0.477	1.174	1.057
13	Ümraniye	41.02992824	29.09882910	0.339	0.821	0.739
14	Üsküdar	41.02066768	29.01974777	0.367	0.894	0.805

According to Table 1, if the achieved S_{DS} values are arranged in descending order, $S_{DS(\text{Adalar})} > S_{DS(\text{Tuzla})} > S_{DS(\text{Kartal})} > S_{DS(\text{Maltepe})} > S_{DS(\text{Pendik})} > S_{DS(\text{Kadıköy})} > S_{DS(\text{Üsküdar})} > S_{DS(\text{Ataşehir})} > S_{DS(\text{Sultanbeyli})} > S_{DS(\text{Ümraniye})} > S_{DS(\text{Sancaktepe})} > S_{DS(\text{Çekmeköy})} > S_{DS(\text{Beykoz})} > S_{DS(\text{Şile})}$ is obtained. Totally 1260 design analyses were performed with the use of TBEC-2018 to search for the effect of the location effect on the design in relation with other variants of the analyses.

4. Results and Discussion

In Fig. 5, the change of the wall foundation base width against shear strength angle is given depending on different districts. The unit weight of the surrounding soil is assumed to be 21 kN/m^3 to evaluate only the effects of shear strength angle change. In addition, Fig. 5a-c concerns the change of the excavation depth. The comparison of Fig. 5a-c shows that the increase of the excavation depth leads the design to enlarge the base. The triple increase of the excavation depth causes to enlarge *B* approximately as triple times the value that is determined for 3-meter excavation depth. The main theme of this study is to investigate the location effect of the project site. Therefore, the individual evaluation of the figures gives the average approximations for design dimensioning depending on the change of the location. For 3-meter excavation depth at Φ=30°, the dimensions of the wall system were not affected by the change of the coordinate.

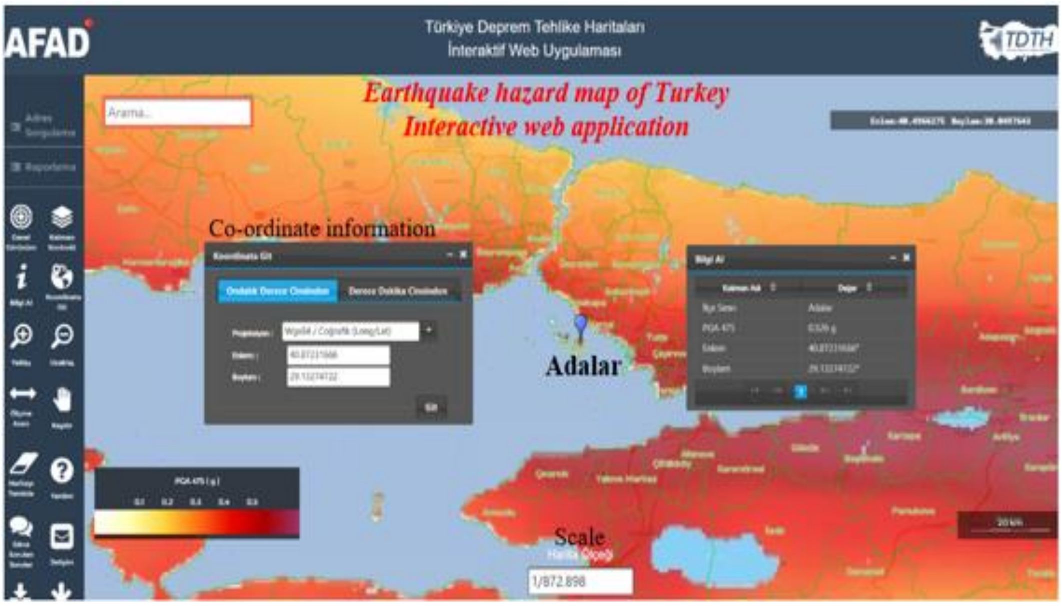

Fig. 4. The interactive web application of Turkey earthquake hazard map.

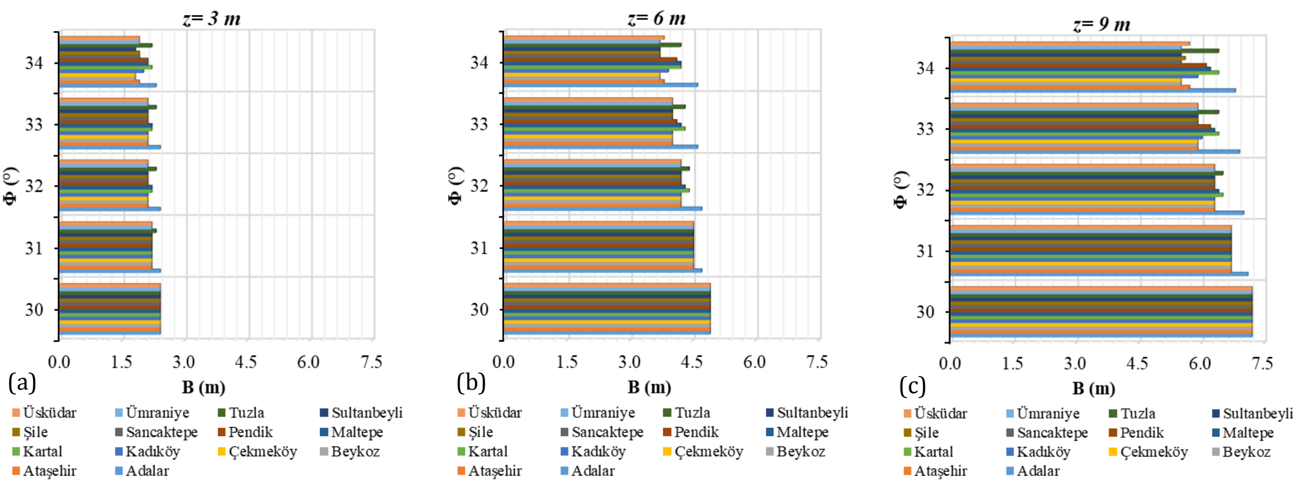

Fig. 5. The change of *B* against the shear strength angle:
(a) for z=3m situation; (b) for z=6m situation; (c) for z=9m situation.

This situation may be arisen because of the attainment of the limit design sizing due to the smallness of the soil strength. In other words, in such a case, the design may access the maximum dimension limits envisaged by the code depending on the suggested safety factors at earthquake condition. The increase of the friction angle ensures the surrounding soil to support the additional loads. Therefore, it is expected the designer to reduce the sizing of RW when the increase of the shear strength angle is possible. For all the foreseen excavation depths studied in the context of this study, the maximum dimensions were obtained for the case that minimum shear characteristics were used. Besides, B value possesses the biggest amount in Adalar district for all the defined different shear strength properties compared to other districts. Adalar district has the biggest value of S_{DS} (1.148) that is increasing the affected active total earth pressure value. It shows that the width *B* is directly proportional with the change of S_{DS} value. If a comparison is conducted between the determined maximum and minimum *B* values at different districts, at z=3 m, it is found that 28% increase of the width is necessary to support the same earth fill at 34° shear strength angle. This situation remarks that it is not possible to use a standard type section proposed in the projecting of retaining walls. In such a case, the construction of the same wall section for every district leads to problematic constructions in terms of earthquake safety. Additively, the maximum change of the *B* width is happened in Çekmeköy, Beykoz and Sultanbeyli districts depending on the increase of the shear strength angle to 34° from 30°. In such a case the width is necessitated to decrease by approximately 33%. The minimum change of the *B* width is happened in the Adalar district depending on the increase of the shear strength angle to 34° from 30°. In such a case the width is necessitated to decrease by approximately 4.5%. The increase of the excavation depth to 6-meters leads to enlarging the base and the relative difference of the *B* that is happened between the envisaged maximum and minimum shear characteristics remains approximately 33%. At 6-meter excavation depth, the minimum change of the B has again happened in Adalar district but the decrease of the *B* is reached to 6% ratio depending on the increase of the shear strength angle to 34° from 30°.

The last evaluated excavation depth is 9-meters. In this situation, the maximum change of the *B* has happened with a decreasing tendency of approximately 33% again between the maximum and minimum shear characteristics. It means that, for example, retaining wall construction is fictionalized in the Beykoz district, if the surrounding soil shear properties of the wall is selected 30°, the width of the base will be 7.2-meters. But if the surrounding soil is preferred to be used more strengthen (Φ=34°) the width of the base will reduce to be 5.5-meters. Besides, the decrease of the *B* is determined 6% if the shear strength angle rises to 34° from 30° in Adalar.

Fig. 6 is given to emphasize the significant effect of the change in the supported earth fill depth. In this case, the unit weight of the surrounding soil is assumed to be 21 kN/m³ and the shear strength angle is selected to be 34° depending on the obtained maximum change in *B* considering the districts. It can be clearly seen that considering the same soil conditions for surrounding soil the *B* value can be changed between 1.8 to 2.3 meters for 3 m depth, 3.7 to 4.6 for 6 m depth and 5.5 to 6.8 for 9 m depth of earth fill to support. This is the meaning that the *B* value can be differentiated approximately 25% (the value of the differentiation which is calculated as the mean value for all the considered earth fill depths) depending on the location independent from the soil conditions.

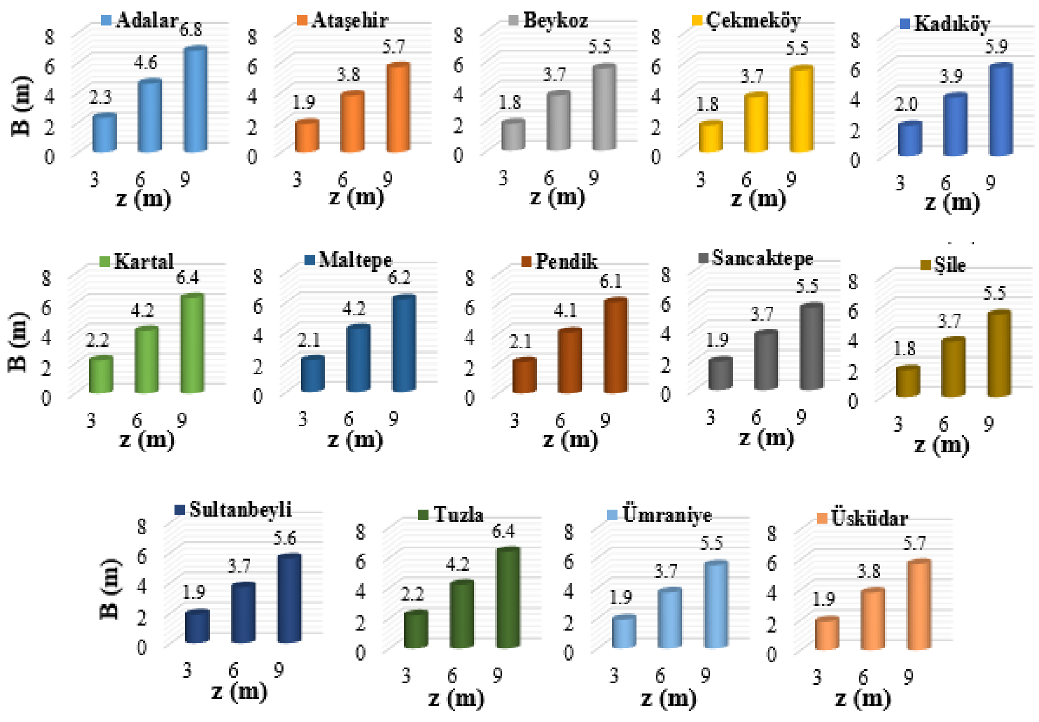

Fig. 6. The change of *B* against the excavation depth depending on the districts.

In addition, Fig. 7 is drawn to show the influence of the change of the soil unit weight depending on the supported earth fill depth which was assumed to be *z*=3m (Fig. 7a), *z*=6 m (Fig. 7b) and *z*=9 m (Fig. 7c) respectively. In this context, the unit weight of the surrounding soil was assumed to be 17 kN/m³, 19 kN/m³ and 21 kN/m³ respectively. The shear strength angle of the surrounding soil was proposed to be constant at 32° to obtain only the effect of the change of soil unit weight. In Fig. 6, it is obviously clear that the effect of the change of soil unit weight has to be evaluated individually for the districts. In Fig. 6a, for *z*=3 m situation, the increase of soil unit weight has no effect on the *B* within Adalar district. For Tuzla, B increases nearly at the ratio of 4.3% if the soil unit weight is increased to 19 kN/m³ from 17 kN/m³, in addition, the increase of the soil unit weight to 21 kN/m³ from 17 kN/m³ increases the *B* width approximately 4.5%. The change of the *B* follows the same trend for Kartal, Maltepe and Pendik districts.

B is calculated 2.10 m, 2.20 m and 2.20 m for 17 kN/m^3, 19 kN/m^3, and 21 kN/m^3 respectively. This means that the use of a relatively dense material as the backfill, can be affect the B nearly 4.6%. Besides, *B* calculated for the designs in other districts have similar change characteristics. There happens an increase for the *B* approximately at the degree of 5% between the loosest and densest states of the surrounding soil strata.

In Fig. 7b, for *z*=6 m situation, *B* is determined 4.60, 4.65 and 4.70 m for 17 kN/m^3, 19 kN/m^3 and 21 kN/m^3 respectively in Adalar district. Differently from *z*=3 m situation, the deepen the excavation depth or the increase of the supported earth fill thickness has an integrated effect with the change of soil unit weight on dimensioning of the wall. The wall design considering the *B* change in Tuzla and Kartal districts exhibit the same path while the change of soil unit weight. In such a case, the *B* value is determined 4.30, 4.35 and 4.40 m respectively for 17 kN/m^3, 19 kN/m^3, 21 kN/m^3 respectively. For Maltepe district *B* is 4.20, 4.25 and 4.30 m and for Pendik district *B* is 4.10, 4.20 and 4.20 m in addition, the other districts have 4.00, 4.10 and 4.20 m of *B*, for the envisaged cases respectively. The acquired widths for *B* determination shows the increase rate of the effect of soil unit weight rises with the decrease of S_{DS} value.

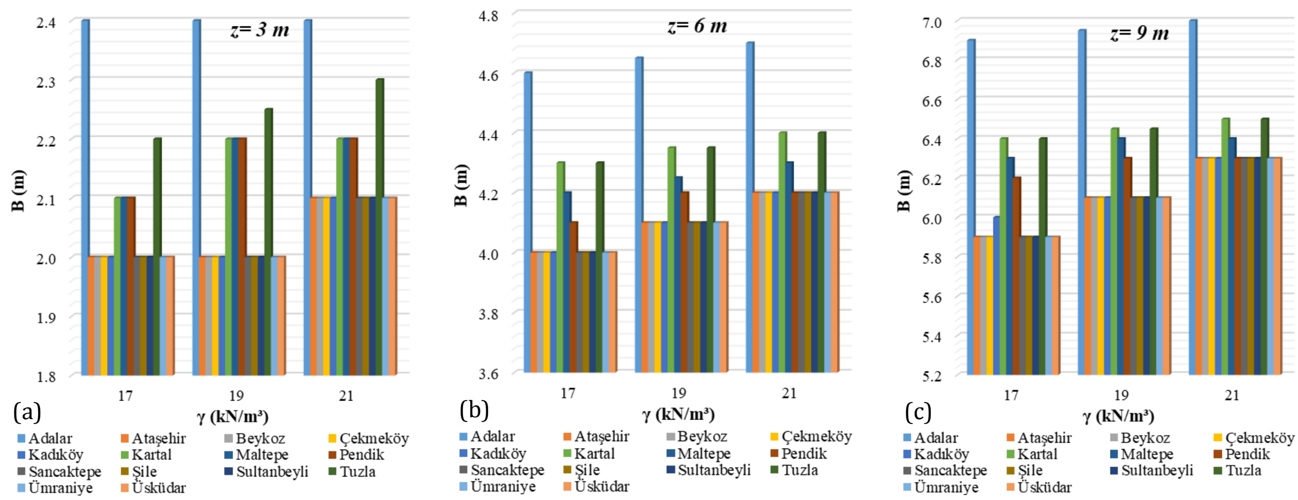

Fig. 7. The change of *B* against the unit weight of surrounding soil: (a) *z*=3 m; (b) *z*=6 m; (c) *z*=9 m.

In Fig. 7c, for *z*=9 m situation, the largest foundation bases were determined for Adalar district and 6.90, 6.95, 7.00 m lengths were obtained for the change of soil unit weight to 17 kN/m^3, 19 kN/m^3, 21 kN/m^3 respectively. In addition, the value of *B* during the change of soil unit weight to 17 kN/m^3, 19 kN/m^3, 21 kN/m^3 respectively, were determined for Kartal and Tuzla districts were 6.40, 6.45, 6.50 m; for Maltepe district 6.30, 6.40, 6.40 m; for Pendik district 6.20, 6.30, 6.30 m; for Kadıköy district 6.00, 6.10, 6.30 m and for all of the other districts 5.90, 6.10 and 6.30 m. As a result of the change in soil unit weight, the biggest rate of design change is determined at *z*=9 m situation which is accessing to 7%. The mentioned dimensions calculated for different districts under the effect of the soil unit weight change remarks that the increase of the excavation depth brings out the considerable influence of the soil unit weight. Furthermore, it is a noticeable result that the effect of the increase of S_{DS} value has an inversely proportional rate with the increase of soil unit weight values. This means that the remarkable change of the *B* width can be obtained for the districts that have relatively smaller S_{DS} values.

In Fig. 8, the effect of the surcharge loading is investigated according to the change of location and depending on the differentiation of *B*/*H* ratio. Accordingly, the effects of the absence of the surcharge loading and the increase of the loading magnitude to 15 kPa was both investigated. Within the context of the analyses conducted in this part of the study, the unit weight (19 kN/m^3) and the shear strength angle (32°) of the surrounding soil was assumed to be constant. The ratio of *B*/*H* has an importance in terms of design practice because traditionally, the beginning step of the design process of the retaining walls consists of the selection of some of the sizes in relation with the empirical approaches (Azizi 2000; Bowles 1979). This process can be named as proportioning and allows the designer to apply an iterative process to take place whereby the dimensions are adjusted at the end of the calculations. In this context, depending on the traditional proportioning process in the literature the width of the foundation base is suggested to be between 0.5-0.7 times the total length of the wall. Considering this situation in Fig. 8, the *B*/*H* ratios were planned to be compared to each other depending on the change of location and the surcharge loading condition. The increase of the surcharge loading amount, has increased the determined ratios of *B*/*H* as expected. The wall designs that were obtained in Adalar district for both *q*=0 and *q*=15 kPa situations give *B*/*H* ratios bigger than 0.7 value which is suggested to be the upper limit for the proportioning of the base width of the wall. The other districts exhibit similar rates with each other in terms of *B*/*H* ratio and the designs are almost remained between the envisaged proportioning limits in the literature. Besides, the consideration of relatively smaller excavation depths leads the design to be enlarged depending on the increase of the surcharge magnitude.

This means that if the excavation depth is 3 m, the width of the base can exceed the foreseen dimensions when the surcharge amount is raised. In addition to all these, the biggest change in the *B/H* ratio depending on the increase of the surcharge amount is obtained for *z*=3 m for all districts except Adalar and Tuzla. From a different viewpoint, the effects of the increase of the surcharge magnitude on the wall design process was also investigated in terms of the base width change in Fig. 9.

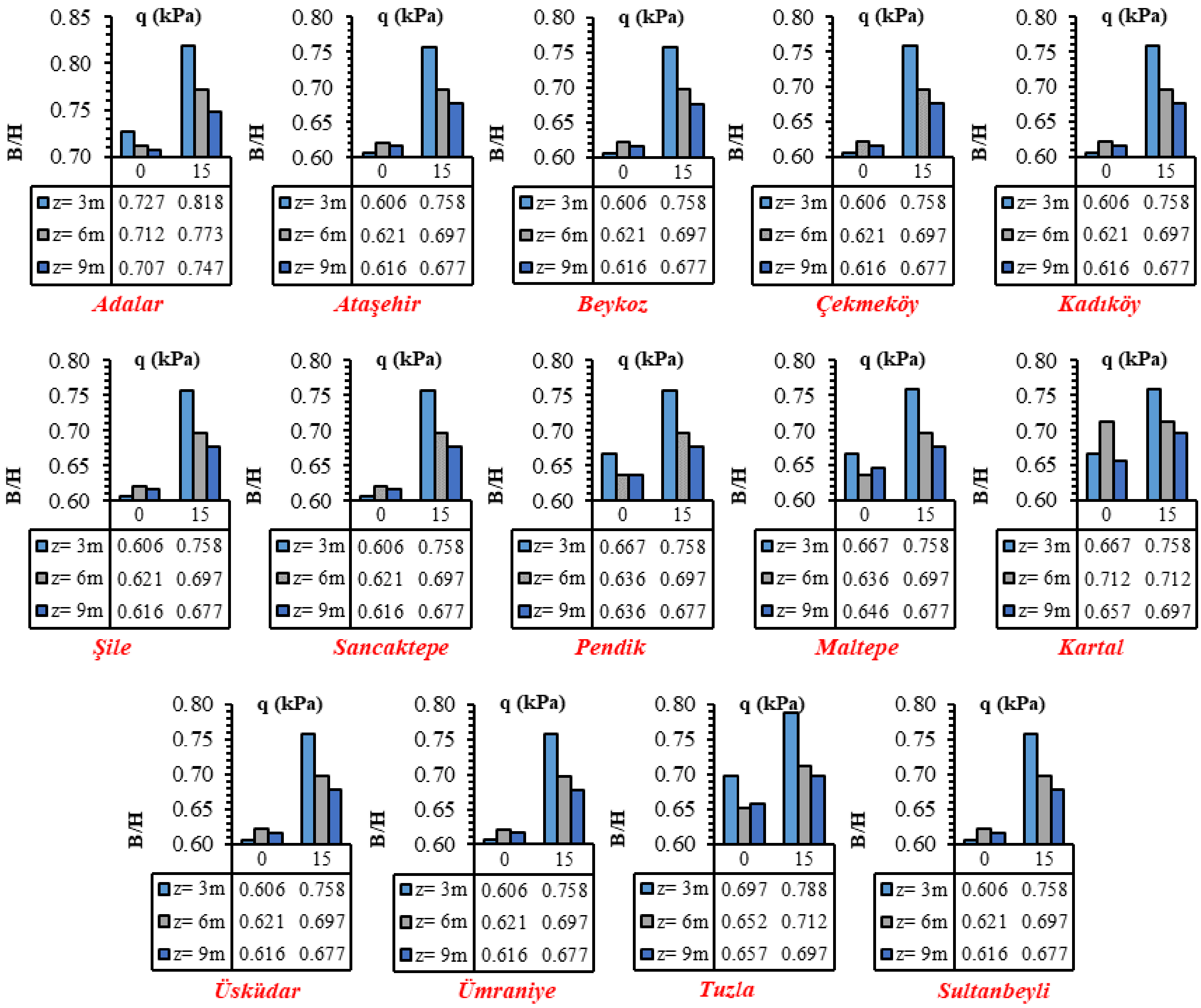

Fig. 8. The change of *B*/*H* ratio against the surcharge loading depending on the districts.

In addition, hand calculations have been also performed to reflect the location effect that is newly considered within the application details of TBEC-2018. The hand calculations were performed depending on the simplified pseudo-static approach of Mononobe-Okabe theory (Okabe 1924; Mononobe and Matsuo 1929). All the analyses were conducted with the use of constant values for the unit weight (19 kN/m^3) and the shear strength angle (32°) of the surrounding soil. The pseudo-static analyses for *q*=0 situation resulted with the determination of the necessitated average *B* values for 3 m, 6 m and 9 m excavation depths as 2.1 m, 4.6 m and 6.5 m respectively. The increase of the surcharge loading magnitude to 15 kPa increases the average *B* width to 3.2 m, 5.4 m and 7.0 m for 3 m, 6 m, 9 m excavation depths respectively. From Fig. 9, the evaluation of the analyses results show that the upper and lower amounts of the *B* widths were determined 2.4 m and 2.0 m (for *q*=0, *z*=3 m), 2.7 m and 2.5 m (for *q*=15 kPa, *z*=3 m), 4.7 m and 4.1 m (for *q*=0 kPa, *z*=6 m), 5.1 m and 4.6 m (for *q*=15 kPa, *z*=6 m), 7.0 m and 6.1 m (for *q*=0 kPa, *z*=9 m), 7.4 m and 6.7 m (for *q*=15 kPa, *z*=9 m) respectively.

The comparison of the pseudo-static approach and the application of TBEC-2018 shows that the pseudo-static approach gives reasonable average values for B which are remaining between the upper and lower limits determined by the use of TBEC-2018 for the absence of surcharge loading condition. On the other hand, the increase of the surcharge loading magnitude leads the pseudo-static approach solutions to be unacceptable in comparison with the solutions of TBEC-2018. This result demonstrates that depending on the crucial hazard of earthquakes in Turkey especially Istanbul, the usage of the location effect has an important necessity to ensure safety.

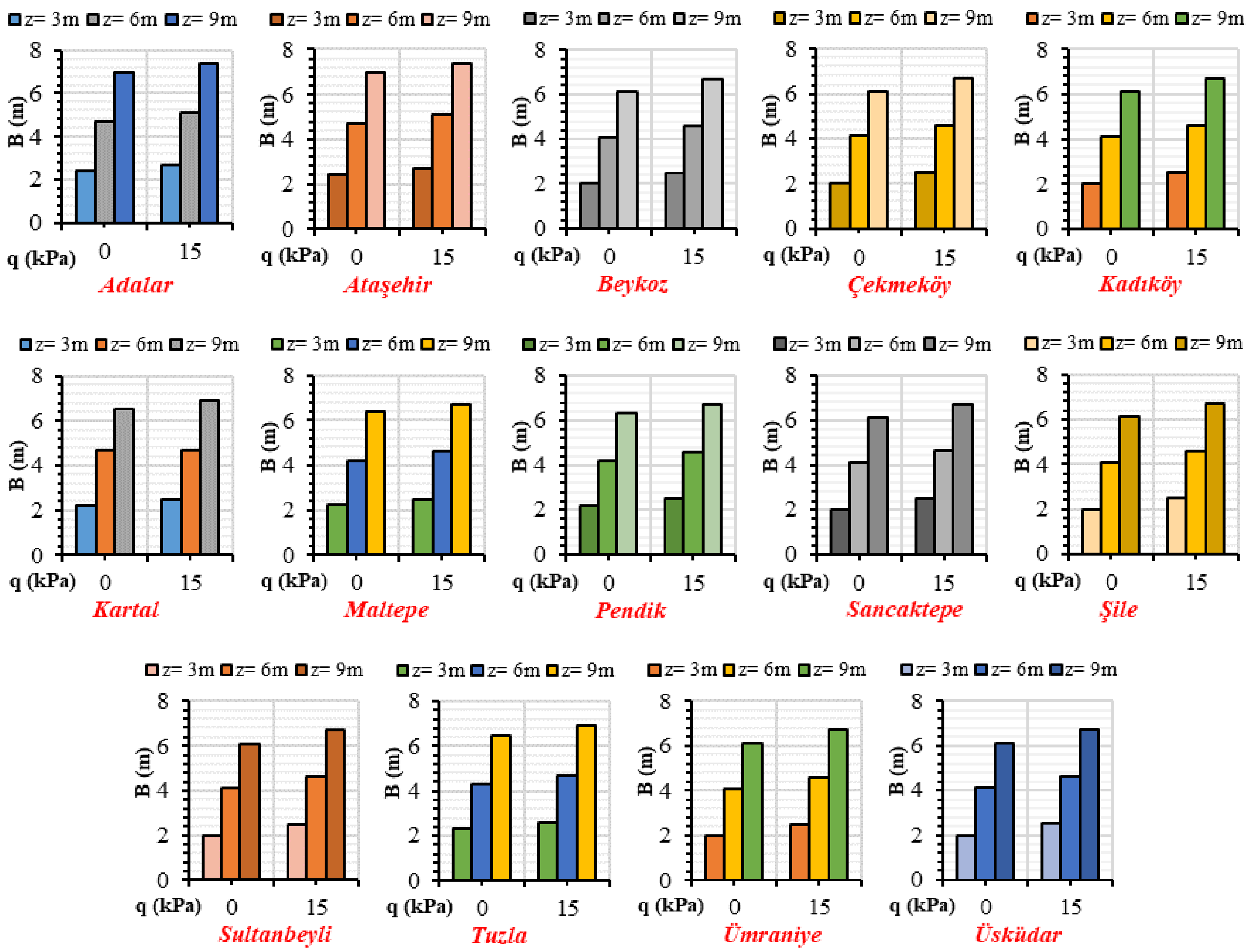

Fig. 9. The change of the B against the surcharge loading depending on the districts.

5. Conclusions

This study is prepared depending on the new design methodology suggested by TBEC-2018 for the design of reinforced concrete RWs under the action of both static and seismic loading conditions. A set of analyses have been planned according to the change of peak ground acceleration values which were obtained depending on the coordinates of the project site from the Earthquake hazard map of Turkey. The coordinates of the project sites were arranged for the districts of Istanbul Province Anatolian side to control the differentiation rate of the dimensioning of the wall system in terms of the foundation base width. In this context, based upon the assumption of same soil class usage, 14 different districts were selected and also the effects of the supported earth fill depth, the unit weight and shear strength angle values of surrounding soil strata, the surcharge load magnitude on the design of retaining walls have been investigated. In total 1260 design analyses were conducted within the scope of the location effect evaluation on the dynamic response of RWs. A comparative interpretation process was applied to the outcomes of the analyses and the following conclusions were obtained:

- The increase of the excavation depth leads the design to enlarge the base of the wall foundation.
- The wall designs are not affected by the change of the coordinate of the project site if relatively smaller depths (smaller than 6 m) are excavated within the soils which has smaller shear strength angle values. This may be because of the attainment of the limit design sizing due to the smallness of the soil strength.
- The increase of the shear strength angle ensures the surrounding soil to support the additional loads such as the earthquake loads. Therefore, it is expected to reduce the sizing of retaining wall if the increase of the shear strength angle of the surrounding soil medium is possible.
- For all the foreseen excavation depths studied in the context of this study, the maximum dimensions were obtained for the case that minimum shear characteristics were used. In addition, the width of the foundation value possesses the biggest amount for the biggest value of S_{DS} that is increasing the affected active total earth pressure value. This trend shows that the foundation width is directly proportional with the change of S_{DS} value. This situation remarks that it is not possible to use a standard type section proposed in the projecting of retaining walls.
- For relatively smaller excavation depths, the increase of soil unit weight has no effect on the width of the foundation base. However, for deeper excavations,

there happens an increase for the width of the foundation base approximately at the degree of 5% between the loosest and densest states of the surrounding soil strata.

- The deepen the excavation depth or the increase of the supported earth fill thickness has an integrated effect with the change of soil unit weight on dimensioning of the wall. The acquired widths for B determination shows the increase rate of the effect of soil unit weight rises with the decrease of S_{DS} value.
- It is a noticeable result that the effect of the increase of S_{DS} value has an inversely proportional rate with the increase of soil unit weight values. This means that the remarkable change of the B width can be obtained for the districts that have relatively smaller S_{DS} values.
- The increase of the surcharge loading amount, has increased the determined ratios of B/H as expected.
- The consideration of relatively smaller excavation depths leads the design to be enlarged depending on the increase of the surcharge magnitude. In addition to all these, the biggest change in the B/H ratio depending on the increase of the surcharge amount is obtained for the shallow depth for all districts except Adalar and Tuzla.
- The comparison of the pseudo-static approach and the application of TBEC-2018 shows that the pseudo-static approach gives reasonable average values for B width which are remaining between the upper and lower limits determined by the use of TBEC-2018 for the absence of surcharge loading condition.
- On the other hand, the increase of the surcharge loading magnitude leads the pseudo-static approach solutions to be unacceptable in comparison with the solutions of TBEC-2018.

All of these outcomes demonstrates that depending on the crucial risk of earthquake hazard of Turkey, the usage of the location effect has an important necessity to ensure safety. Consequently, the consideration of the location effect throughout the design process of reinforced concrete retaining walls has remarkable influence in terms of dimensioning and also cost.

Acknowledgements

None declared.

Funding

The authors received no financial support for the research, authorship, and/or publication of this manuscript.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this manuscript.

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