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# A case study on the updates of Turkish rapid visual screening methods for reinforced-concrete buildings

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ABSTRACT

The changes in rapid seismic assessment methods that can be used to determine the regional earthquake risk distribution of buildings have become inevitable, with the Turkish Building Earthquake Code and Turkish Earthquake Hazard Map which updated in 2018, Within the scope of this study, risk prioritization was made according to the last two regulations for ten different settlements that located in the same earthquake zone in the previous earthquake map. With the current regulation, it has once again emerged that site-specific based analysis and evaluations are necessary. While the building performance scores in the previous regulation were the same for all provinces since they were located in the same earthquake zone, different values were obtained for the provinces with the current regulation. As the PGA value increased, the design spectral acceleration coefficient increased and the building's performance score was lower. This increases the risk in these regions.



## 1. Introduction

Large-scale loss of life and property may occur due to the structural damage after the earthquakes (Harirchian et al., 2020; İnel et al., 2008; Tabrizikahou et al., 2021). The characteristics of the building stock in any region are one of the important factors that will directly affect the losses that may occur (Kaplan et al., 2010; Işık, 2016; Bilgin et al., 2021). In this context, seismic vulnerability assessment is a major concern, especially in regions where earthquakes are common (Harirchian et al., 2021a; Arslan, 2010; Candela et al., 2021). In this context, determining the earthquake safety of buildings before a possible earthquake ensures correct decisions about the existing building stock (Doğan et al., 2021; Sipos and Hadzima-Nyarko, 2017; Yakut, 2004; Bilgin and Uruçi, 2018). However, the increase in the existing building stock with urbanization and increasing population makes it difficult to determine the earthquake safety of buildings in terms of time, qualified personnel and economy (Işık ve Tozlu, 2015; Kapetana and Drsitos, 2007; Ademoviç et al., 2020). At this point, it is not possible to determine the earthquake safety in detail for the entire existing building stock (Işık et.,al 2018; Özmen and İnel, 2017). Thus, buildings with risk priority can be determined by using faster and more practical evaluation methods on the building stock (Sucuoğlu et al. 2007; Kassem et al., 2021; Işık et al., 2020). These methods are generally called rapid visual screening methods (RVS). By using these methods, the number of buildings to be subjected to detailed earthquake safety analysis is greatly reduced (Harirchian and Lahmer, 2019; Biçen et al., 2020; Büyüksaraç et al., 2021; Ayhan et al., 2021). In order to overcome the destructive effects of earthquakes on the structural parameters of the building and human losses, different countries are developing various approaches and methodologies related to these methods (Harirchian et al., 2021b). These methods are one of the important measures to be taken in the pre-disaster structural sense of modern disaster management (Işık et al., 2020a). These studies on the building stock before the earthquake are also important in terms of spatial planning and urban transformation.

Officially in Turkey, these methods were first put on a legal basis with the regulation published by the Ministry of

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Environment and Urbanization in 2013 titled as "The Principles of Determining Risky Buildings" (PDRB, 2013). With this regulation, the evaluation and prioritization of risky structures are expressed in detail. The application of the first stage evaluation method for reinforced-concrete and masonry buildings is detailed under the title of methods that can be used to determine the regional earthquake risk distribution of buildings in this regulation. However, due to the significant changes in Turkey Earthquake Hazard Maps and Turkish Building Regulations in 2018, the change in the first stage evaluation method in the regulation has also become mandatory and it has been updated and started to be used in 2019 (TBEC-2018; PDRB, 2019; https://tdth.afad.gov.tr/, 2020).

Within the scope of this study, information is given about the changes in the first stage evaluation method, which is included in both regulations and recommended for reinforced-concrete structures. In this study, the results obtained for an existing reinforced-concrete building selected as a sample were also compared. Considering the geographical location of the selected building as an example, earthquake parameters were determined with the help of the updated Turkey Earthquake Maps Interactive web application. In addition, the necessary data for this application aid rapid evaluation method were obtained.

## 2. First Stage Evaluation (2013)

The parameters considered in this method, which can be used for existing reinforced concrete buildings with 1-7 floors, are given below:

- Type of structural system
- Number of storey
- Current status and apparent quality
- Soft storey/weak storey
- Vertical irregularity
- Heavy overhangs
- Irregularity/torsion effect in plan
- Short column effect
- Adjacent/pounding effect
- Hill/slope effect
- Earthquake hazard and local soil class

Two different structural system types are expressed as reinforced-concrete frame (RCF) and reinforced concrete frame + shear wall (RCFW). The number of stories on the foundation is taken into account as the number of storey. In gradual structures, the part with the highest number of stories is taken into account. The importance given to the quality of materials and workmanship and the maintenance of the building is determined by the current condition and apparent quality and is classified as good, medium and bad. In addition to the differences in stiffness and strength between stories, the variation of stories height within the building is taken into account in the soft story/weak story parameter. The parameter taken into account in order to reflect the effect of the frame and changing story areas that do not continue vertically is the vertical irregularity. Differences in storey areas are indicated as heavy overhangs. Irregularities that will cause torsion in the zoning plan are taken into account in the plan irregularity/torsion effect parameter. In this method, the presence of short columns in the building examined, the fact that the building was built with a pronounced hill-slope effect, and the relationship of the building with the neighboring structures are also taken into account in this method. Earthquake hazard and class are directly taken from the Regulation on Buildings to be Constructed in Seismic Zones (TSDC-2007; PDRB, 2013). The structural system type is taken into account as a positive basis point. No additional score is given for buildings with RCF system, but a positive base score (Op) is given for buildings with other structural system (RCFW). Structural system and baseline scores are shown in Table 1.

**Table 1.** Base and structural system scores

| Total number of floors | Base score | | | | Structural system score (YSP) | |
|---|---|---|---|---|---|---|
| | | | | | Structural system | |
| | Danger zone | | | | RCF | RCFW |
| | I | II | III | IV | | |
| 1 and 2 | 90 | 120 | 160 | 195 | 0 | 100 |
| 3 | 80 | 100 | 140 | 170 | 0 | 85 |
| 4 | 70 | 90 | 130 | 160 | 0 | 75 |
| 5 | 60 | 80 | 110 | 135 | 0 | 65 |
| 6 and 7 | 50 | 65 | 90 | 110 | 0 | 55 |

While determining the danger zone for the examined building, the local soil classes and seismic zone recommended in the previous earthquake code (TSDC-2007) are taken into account, and the selection is made according to Table 2.

**Table 2.** Earthquake zones determined according to TSDC-2007

| Danger zone | Seismic zone according to TSDC-2007 | Soil class according to TSDC-2007 |
|---|---|---|
| I | 1 | Z3/Z4 |
| II | 1 | Z1/Z2 |
| | 2 | Z3/Z4 |
| III | 2 | Z1/Z2 |
| | 3 | Z3/Z4 |
| IV | 3 | Z1/Z2 |
| | 4 | All soil types |

For all negative parameters, except the apparent quality, determinations will be made as "yes" or "no". Negative parameter values ($O_i$) corresponding to these determinations will be taken as 1 and 0 for "yes" and "no" states, respectively. If the apparent quality rating is "good", the negativity parameter value ($O_i$) will be taken as 0, if it is "moderate" 1, if it is "poor", 2 will be taken. The negative coefficients corresponding to each parameter are shown in Table 3

**Table 3**. Negative parameter values (Oi)

| Negativity parameter | Case 1 | | Case 2 | |
|---|---|---|---|---|
| | Parameter detection | Parameter value | Parameter detection | Parameter value |
| Soft storey | None | 0 | Available | 1 |
| Heavy overhangs | None | 0 | Available | 1 |
| Apparent quality | Good | 0 | Moderate (bad) | 1 (2) |
| Short column | None | 0 | Available | 1 |
| Hill/slope effect | None | 0 | Available | 1 |
| Irregularity in plan | None | 0 | Available | 1 |

The suggested point values for each parameter are shown in Table 4, and the selection is made according to the number of floors.

**Table 4:** Negativity parameter score ($OP_i$) table

| Total number of floors | Negativity Parameter Scores (OP) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Soft storey | Apparent quality | Heavy overhangs | Storey level/ Building status | | | | Vertical irregularity | Irregularity/torsion effect in plan | Short Column | Hill/slope effect |
| | | | | Same | Same | Different | Different | | | | |
| | | | | Middle | Corner | Corner | Middle | | | | |
| 1,2 | -10 | -10 | -10 | 0 | -10 | -5 | -15 | -5 | -5 | -5 | -3 |
| 3 | -20 | -10 | -20 | 0 | -10 | -5 | -15 | -10 | -10 | -5 | -3 |
| 4 | -30 | -15 | -30 | 0 | -10 | -5 | -15 | -15 | -10 | -5 | -3 |
| 5 | -30 | -25 | -30 | 0 | -10 | -5 | -15 | -15 | -10 | -5 | -3 |
| 6,7 | -30 | -30 | -30 | 0 | -10 | -5 | -15 | -15 | -10 | -5 | -3 |

Building performance score (PP) is calculated according to Equation 2.1 after the total negativity score is determined by multiplying the negativity parameter values given in Table 3 with the negativity parameter points given in Table 4.

$$PP = TP + \sum_{i=1}^{n} O_i * OP_i + YSP \qquad (2.1)$$

Here, TP is the base score; YSP indicates the structural system score.

## 3. First Stage Evaluation (2019)

Along with the Turkish Building Earthquake Regulation (TBEC-2018) and the Turkey Earthquake Hazard Map, which were updated in 2018 and entered into force in 2019, many parameters in the previous regulation remained the same in the method specified under the simple methods that can be used to determine the regional earthquake risk distribution of buildings. One of the important changes in the current earthquake code has been the use of site-specific design spectra. The values obtained on a regional basis in the previous regulation have been converted to site-specific with the current regulation. At the same time, another change occurred in local soil classes. Local soil classes, which were expressed with soil group and soil classes in the previous regulation, were combined and specified as only local soil class. These changes have also found their way into simplified methods. These changes have changed the designation of danger zones. The factors taken into account to determine the danger zone of the building to be examined according to the current regulation are shown in Table 5.

In the method, the DD-2 earthquake ground motion level, which has a 50% probability of exceeding in 50 years, will be used as the ground motion level, and the short period design spectral acceleration coefficient (SDS) will be taken from the current Turkey Earthquake Hazard Map. The earthquake hazard zone will be determined by using the relationship between the SDS value and the local soil class.

Negative parameter values are the same as in the previous regulation and the values given in Table 3 are used. Likewise, there is no change in the negativity parameter score table, and the values in Table 4 will be used. The building performance score calculation will be made according to Equation 2.1, there is no change here either.

**Table 5**. Seismic danger zone (PDRB,2019)

| Danger zone | $S_{DS}$ | Soil class |
|---|---|---|
| I | $S_{DS}$≥1.00 | ZC/ZD/ZE |
| II | $S_{DS}$≥1.00 | ZA/ZB |
| | 1.00≥ $S_{DS}$≥0.75 | ZC/ZD/ZE |
| III | 1.00≥ $S_{DS}$≥0.75 | ZA/ZB |
| | 0.75≥ $S_{DS}$≥0.50 | ZC/ZD/ZE |
| IV | 0.75≥ $S_{DS}$≥0.50 | ZA/ZB |
| | 0.50≥ $S_{DS}$ | All soil types |

After the earthquake danger zone is obtained, the determination of the base score for the building to be examined is made according to Table 6.

**Table 6**. Base and structural score table (PDRB, 2019)

| Total number of floors | Base score (TP) | | | | Structural system score (YSP) | |
|---|---|---|---|---|---|---|
| | | | | | Structural system | |
| | Danger zone | | | | RCF | RCFW |
| | I | II | III | IV | | |
| 1 and 2 | 90 | 120 | 160 | 195 | 0 | 100 |
| 3 | 80 | 100 | 140 | 170 | 0 | 85 |
| 4 | 70 | 90 | 130 | 160 | 0 | 75 |
| 5 | 60 | 80 | 110 | 135 | 0 | 65 |
| 6 and 7 | 50 | 65 | 90 | 110 | 0 | 55 |

Information is also given about the parameters taken into account when determining the risk priority of any RC building. Having RC shear walls in the structural system increases the earthquake resistance of the building. Therefore, an additional structural system score is added in RCFWs. The types of structural system types considered in RC structures are shown in Figure 1. If the presence of RC shear walls cannot be determined, it would be appropriate to consider them as RCF.

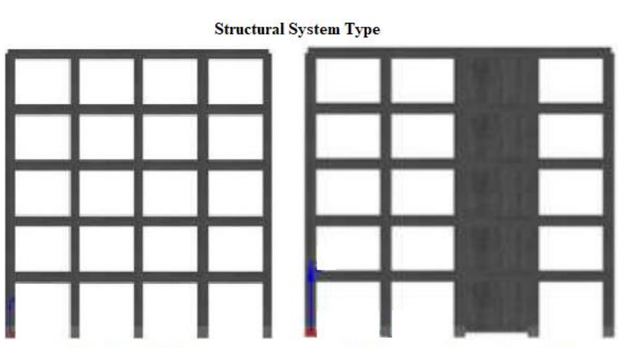


**Figure 1.** Structural system types

The number of stories is one of the factors affecting the earthquake behavior of the structures. The number of free stories ($n_{sk}$) will be determined by considering Figure 2.

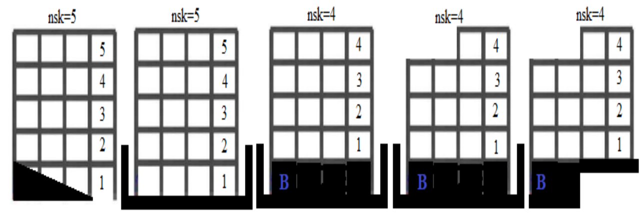


**Figure 2.** Determining the number of stories

The discontinuities in the vertical structural elements negatively affect the seismic behavior of the structure and are taken into account in this method. Some cases of vertical irregularity are shown in Figure 3.

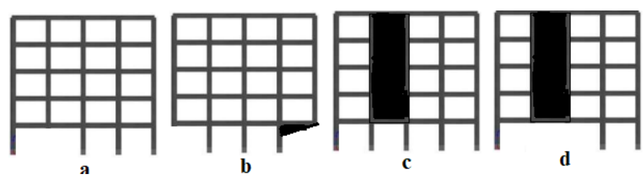


**Figure 3.** Some vertical irregularity, a) Non-continuing column in vertical, b) column at the console end, c) discontinuity on the shear wall, d) discontinuity on the shear wall

The difference between the storey area sitting on the ground and the storey area above the ground will be determined with overhang parameter. The example for overhang is shown Figure 4.


**Figure 4.** Sample for overhangs (available/none/none)

The other parameter is short column and only externally observed short columns are taken into account in the evaluation. The sample for short column is shown in Figure 5.

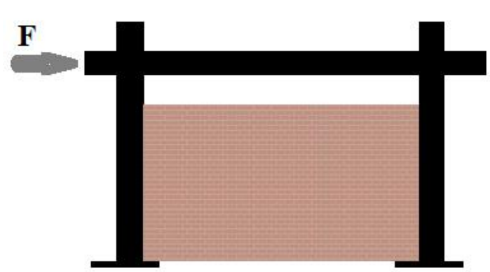


**Figure 5.** Short column sample

One of the parameters that negatively affect the earthquake behaviour is the irregularities in the plan of the building. Some regular and irregular samples were shown in Figure 6.

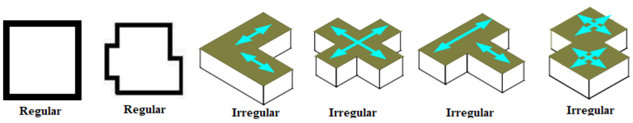


**Figure 6.** Samples for regular and irregular buildings plan

Another parameter is the state of the building with neighbouring buildings. This situation is shown in Figure 6.

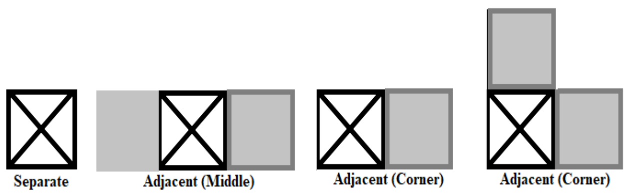


**Figure 7.** Samples for adjacent/pounding effect

In cases where there is a pounding effect, attention is paid to the floor levels in neighbouring buildings. The sample for this situation is shown in Figure 8.

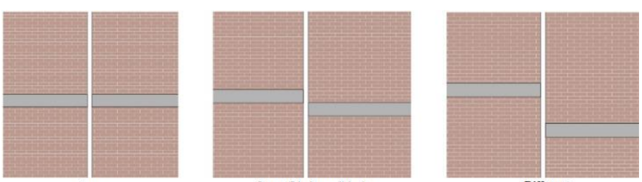


**Figure 8.** Floor level status in adjacent buildings

## 4. Determination of Structural System Score for Example RC Building

The selected sample RC building is evaluated as an existing structure. Although it does not contain any structural irregularities, it is assumed that the building has 5 stories and consists of a RCF. In order to be able to prioritize risk, ten different provinces located in the same earthquake zone were taken into account in the previous earthquake zone map. Within the scope of this study, random geographical locations from Amasya, Balıkesir, Burdur, Bilecik, Aydın, Hakkari, Hatay, Kastamonu, Kırşehir and Muğla provincial centers were taken into account. All of these provincial centers are located in the 1st degree earthquake zone in the previous earthquake zone map. It is assumed that the RC building, which is considered as an example, is located in these locations.

In the simplified method in 2013, the local soil class was accepted as Z3. Since all the provinces subject to the study are located in the same earthquake zone, the same danger zone was obtained and this region became the I. danger zone. Since the selected RC structure consists of only frames, no structural system points are added. Since the structure examined does not contain any negativity, the total negativity score was taken as zero. The provincial values of the building performance scores obtained by using the values prescribed in the previous regulation are shown in Table 7.

**Table 7.** Building performance scores for 2013

| Province | Danger zone | Base score | Structural system score (YSP) | Negativity Score Total | Building Performance Score |
|---|---|---|---|---|---|
| Aydın | I | 60 | 0 | 0 | 60 |
| Hatay | I | 60 | 0 | 0 | 60 |
| Amasya | I | 60 | 0 | 0 | 60 |
| Burdur | I | 60 | 0 | 0 | 60 |
| Balıkesir | I | 60 | 0 | 0 | 60 |
| Muğla | I | 60 | 0 | 0 | 60 |
| Hakkâri | I | 60 | 0 | 0 | 60 |
| Kastamonu | I | 60 | 0 | 0 | 60 |
| Bilecik | I | 60 | 0 | 0 | 60 |
| Kırşehir | I | 60 | 0 | 0 | 60 |

In order to use the simplified method proposed for the determination of regional risk in 2019, design spectral acceleration coefficients are needed. These values were obtained by using Turkey Earthquake Hazard Maps Interactive Web Earthquake Application. ZC was chosen as the local soil class in order to make comparisons. Since there is no regional calculation with the new hazard map, spectral acceleration coefficients were obtained separately for each province. The peak ground acceleration (PGA) and design spectral acceleration coefficients obtained for the geographical locations in the provinces considered in the study, which have a 10% probability of being exceeded in 50 years (recurrence period 475 years), are shown in Table 8.

**Table 8.** Earthquake parameter values for selected locations

| Province | PGA (g) | $S_{DS}$ |
|---|---|---|
| Aydın | 0.592 | 1.742 |
| Hatay | 0.453 | 1.289 |
| Amasya | 0.447 | 1.279 |
| Burdur | 0.409 | 1.156 |
| Balıkesir | 0.372 | 1.057 |
| Muğla | 0.370 | 1.036 |
| Hakkari | 0.319 | 0.904 |
| Kastamonu | 0.289 | 0.839 |
| Bilecik | 0.237 | 0.718 |
| Kırşehir | 0.088 | 0.261 |

In order to make comparisons with the previous simplified method, the same RC building was evaluated as the existing building. This building has the same structural features and only the location of the building has changed. As in the previous regulation, no structural system score has been added since the selected RC structure consists only of frames (RCF). Since the structure examined does not contain any negativity, the total negativity score was taken as zero. The provincial values of the building performance scores obtained by using the values predicted for RC buildings in the simplified method in the current regulation are shown in Table 9.

**Table 9.** Building performance scores for 2019

| Province | Danger zone | Base score | Structural system score (YSP) | Negativity Score Total | Building Performance Score |
|---|---|---|---|---|---|
| Aydın | I | 60 | 0 | 0 | 60 |
| Hatay | I | 60 | 0 | 0 | 60 |
| Amasya | I | 60 | 0 | 0 | 60 |
| Burdur | I | 60 | 0 | 0 | 60 |
| Balıkesir | I | 60 | 0 | 0 | 60 |
| Muğla | I | 60 | 0 | 0 | 60 |
| Hakkâri | II | 80 | 0 | 0 | 80 |
| Kastamonu | II | 80 | 0 | 0 | 80 |
| Bilecik | III | 110 | 0 | 0 | 110 |
| Kırşehir | IV | 135 | 0 | 0 | 135 |

## 5. Results and Conclusions

With the increase in population and increasing urbanization due to this increase, our building stock is increasing day by day. Whether the increased building stock is built in accordance with earthquake resistant building design principles and whether it receives engineering services will directly affect the losses in a possible earthquake. One of the processes in the pre-disaster preparation phase of modern disaster management is to decide whether the earthquake performance of the building stock in the region to be affected by the earthquake is sufficient. In the light of this information to be obtained, it is necessary to determine the buildings with insufficient earthquake performance and to decide on demolition and reinforcement when necessary. The large number of building stocks does not make such detailed structural analyzes possible. These methods specified simplified methods in order to minimize the amount of building stock to be examined. For the first time in Turkey, risk prioritization among buildings was legally stated under PDRB-2013. Finally, mandatory changes were inevitable in the proposed simplified methods along with the earthquake regulation and earthquake hazard maps updated in 2018. This study examined the differences of the simplified methods in the last two regulations for reinforced concrete structures. While examining, ten different provinces located in the same earthquake zone were selected in the previous earthquake zone map. The 2013 regulation was based on a methodology on a regional basis, just like the earthquake zone map and earthquake regulation used at that time. As the provinces selected within the scope of this study are located in the same earthquake zone, the same building performance score was obtained for all provinces. Therefore, it was not possible to determine any risk priority among these provinces.

Obtaining site-specific earthquake parameters from a regional basis is one of the important changes and gains in both earthquake hazard maps and seismic design code. The results obtained in this study are a clear indication of this. The design spectral acceleration coefficients and peak ground acceleration values obtained for the provinces with the current map have been obtained differently for all provinces considered in the study. However, the same values were used for these provinces in the previous map and regulation. With the increase of PGA value, spectral acceleration values also increased. It has been determined that the risk of structures in accommodation units where PGA and SDS are large is greater. With the increase in the $S_{DS}$ value, the building performance score was evaluated as riskier by taking lower values. The danger zone and building performance scores obtained for randomly selected geographical locations in Aydın, Hatay, Amasya, Burdur, Balıkesir and Muğla provinces have the same values as the previous regulation. However, different earthquake hazard zone and building performance scores were obtained for Hakkari, Kastamonu, Bilecik and Kırşehir. While there was only one danger zone in the previous regulation, four different danger zones have been obtained in the new regulation. The lowest risk priority was obtained for the province of Kırşehir, which has the lowest $S_{DS}$ value. By using other earthquake parameters obtained with the help of site-specific methodology in the current regulation, risk priority can be decided among buildings with the same building performance score. The current simplified method has been made more practical than the previous one. The visuals on how to obtain the negativity parameters used in the method through the structure prevent users from making incomplete or wrong.

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