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# Investigation of the effects of using steel cross and reinforced concrete shears earthquake performance in buildings

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**Abstract**

Most of Türkiye on the seismic belt and it causes serious loss of life and property. To prevent this, quake proof structures should be developed and more research should be studied. While reinforced concrete curtains are common in earthquake resistant buildings in Türkiye, steel usage has not spread. Reinforced concrete structures, which are more known in project design and application used frequently. Steel structures have been used typically world-wide since the old years while different and innovative methods have been developed and new studies are continuing. Within the scope of this study, five different system models were designed including a reinforced concrete system without curtain, a reinforced concrete system with a curtain on the outermost axis, reinforced concrete system with a curtain on the one axis inner, a reinforced concrete system with a steel cross on the outermost axis, and reinforced concrete system with a steel cross on the one axis inside then examined. The analyzes are modeled in the SAP2000 program which is internationally accepted and frequently used in academic studies and it will be designed according to the Turkish Building Earthquake Code (TBDY-2018). Modeled buildings were analyzed using the equivalent earthquake load and time history calculation method.

## Introduction

68% of all earthquakes in the world are located in the Pacific belt, 21% are in the Mediterranean - Himalayan belt and the remaining 11% are located in other continents. Türkiye is located in the Mediterranean-Himalayan belt [1]. It is a fact that we will suffer great loss of life and property due to frequent earthquakes in the future, just as there have been many devastating earthquakes in our country in the past. According to the Türkiye Earthquake Hazard Map, it is known that 92 of our country is in earthquake zones, 98 of our population lives under earthquake risk, and 98 of our large industrial centers and 93 of our dams are located in earthquake zones. In the last 58 years, 58,202 citizens have lost their lives, 122,096 people have been injured, and approximately 411,465 buildings have been destroyed or severely damaged by earthquakes. As a result, it can be said that an average of 1.003 citizens die and 7,094 buildings are destroyed every year due to earthquakes [2].

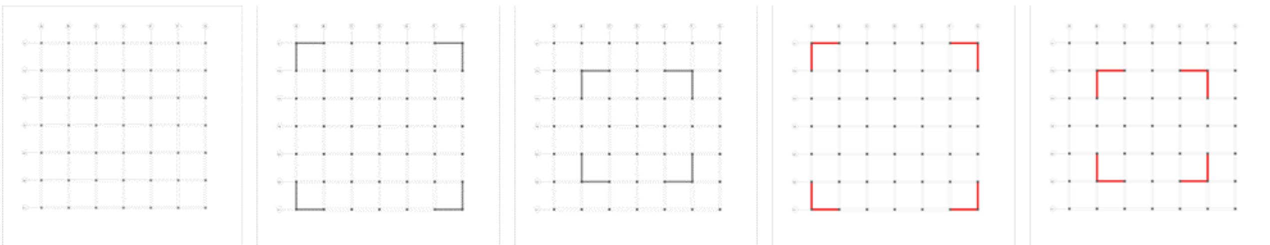
In the buildings built in our country, importance is given to aesthetics and architecture as well as to the economic and robustness of the building. Since our country is in an earthquake zone, one of the most important forces affecting our buildings is earthquake. Earthquake is a reality for our country and we engineers need to do various researches and studies for this. In this study, it is aimed to compare the performances of reinforced concrete (RC) shears used in large areas in our country and steel cross against earthquakes. In addition, it is aimed to expand the scope of the study and to find detailed results for wider data by taking the placement of both reinforced concrete shears and steel braces to be used instead of curtains in different places.

Reinforced concrete curtain wall structures are used very frequently in our country and in the world. In addition, different studies have been carried out on reinforced concrete. Steel plate structures have been widely used in the United States, Canada and Japan since the 1970s, and these structures have not suffered serious damage as a result of earthquakes [3]. Common strengthening methods are based on two basic approaches. The first of these is to strengthen the structure by adding steel diagonal elements or shear walls, and the other is to increase the strength of structural elements such as column beams in reinforced concrete structures or to increase the performance of the structure by strengthening the column-beam junctions [4]. In similar studies, it has been observed that the reinforcement area decreases in reinforced concrete sections when steel braces are used. In addition, when calculating the approximate costs of the structures, he concluded that the cost is 3.09% more economical if steel braces are used [5].

## Material and Method

In order to ensure that the reinforced concrete buildings, which are used extensively in our country, are reliably strong, some regulations are used while static calculations are made. TBDY-2018 is the regulation that should be taken as a basis in order to determine earthquake forces and to build resistant structures in Türkiye [6]. Earthquake forces can be determined by dynamic analysis, taking into account ground accelerations and the mass, stiffness and damping properties of the structure [7]. Earthquake forces cannot be taken as a constant load for every structure and situation because they are not a constant force. Many approaches and methods have been developed on this subject.

Two of the three most commonly used methods were used in this study. The methods used are the equivalent earthquake load method and the calculation method in the time history. The equivalent earthquake load method is based on the first mode of the building and it is assumed that the earthquake forces acting on the floors are proportional to the floor mass and the height of the floor from the foundation. Since the mass of the building is taken into account in the calculation of the vibration period and the distribution of the earthquake load, this method can be considered as a dynamic method based on the first degree of freedom of the building [8]. The purpose of the calculation method in the time history is to integrate the equation of motion of the system step by step, taking into account the nonlinear behavior of the carrier system. During the analysis, the displacement, plastic deformation and internal forces occurring in the system at each time increment and the maximum values of these magnitudes corresponding to the earthquake demand are calculated [9]. In this method, according to (TBDY-2018), at least 11 earthquake records should be used and the two horizontal components of these acceleration records should be acted simultaneously in the direction of the X and Y principal axes of the carrier system. In addition, maximum three acceleration records from the same earthquake should be used [6-10]. The structure was modeled in the Sap2000 program with earthquake records from the Pacific Earthquake Engineering Research Center (PEER) ground motion database [11–12]. Column sections of the modeled building are 50x50cm, beam dimensions are 50x30cm, slab thickness is 15cm and braces are HE120A steel profile.



(a) Model 1 (b) Model 2 (c) Model 3 (d) Model 4 (e) Model 5

**Figure 1.** Bearer system plans of the building (a) RC system without curtain (b) RC system with a curtain on the outermost axis (c) RC system with a curtain on the one axis inner (d) RC system with a steel cross on the outermost axis (e) RC system with a steel cross on the one axis inside

## Results

The mode values obtained as a result of the analysis of our structure are shown in "Fig. 2" is shown. Since the first two modes of our structure are symmetrical, the first modes are equal in the x and y directions, and the third mode is torsion.

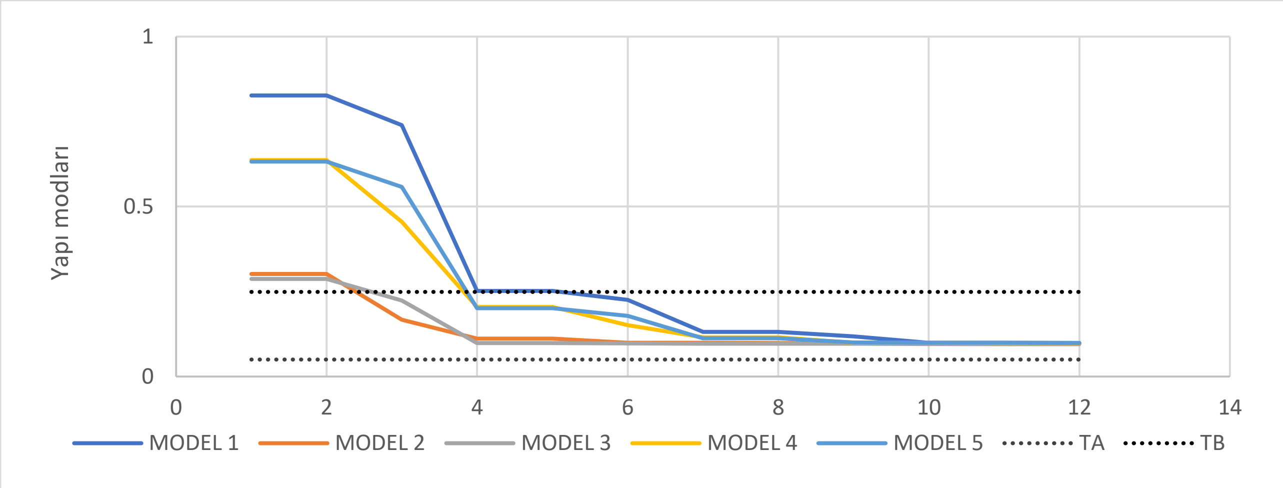



**Figure 2.** Modes of analyzed systems

Base shear forces determined as a result of 11 different earthquake records of the building are given in Table 1. Decreases in the base shear forces are observed in the models in which cross steel elements are used instead of reinforced concrete curtains.

**Table 1.** Base shear forces determined as a result of 11 different earthquake records of the building

| Models | Fx + (kN) | Fx - (kN) | Fy + (kN) | Fy - (kN) |
|---|---|---|---|---|
| Model 1 | 734.98 | 703.56 | 1030.9 | 1263.65 |
| Model 2 | 4164.33 | 4153.07 | 4397.34 | 4520.31 |
| Model 3 | 2649.73 | 2663.61 | 2672.68 | 2747.18 |
| Model 4 | 1724.63 | 1802.44 | 1826.72 | 1930.43 |
| Model 5 | 1211.8 | 1277.58 | 1353 | 1266.2 |

As a result of 11 different earthquake recordings of the building, the section effects affecting the corner arm at the ground level are given in Table 2.

**Table 2.** Section effects of the building determined as a result of 11 different earthquake records

| Models | P + (kN) | P – (kN) | V2 + (kN) | V2 - (kN) | V3 + (kN) | V3 - (kN) | M2 + (kNm) | M2 - (kNm) | M3 + (kNm) | M3 - (kNm) |
|---|---|---|---|---|---|---|---|---|---|---|
| Model 1 | 937.49 | 937.49 | 15.82 | 16.62 | 28.06 | 22.48 | 62.02 | 49.93 | 32.23 | 33.20 |
| Model 2 | 937.50 | 937.51 | 14.69 | 14.99 | 15.23 | 15.12 | 31.98 | 31.81 | 30.64 | 31.21 |
| Model 3 | 938.10 | 938.10 | 5.84 | 5.79 | 5.98 | 5.84 | 13.80 | 13.49 | 13.46 | 13.33 |
| Model 4 | 937.50 | 937.50 | 29.52 | 27.98 | 31.60 | 29.39 | 64.48 | 60.76 | 61.98 | 57.68 |
| Model 5 | 937.49 | 937.49 | 21.78 | 20.04 | 21.11 | 22.22 | 41.75 | 44.26 | 43.16 | 40.31 |

## Conclusion and Discussion

As a result of the limited research and analysis, the reinforced concrete system model without curtain, the system model with reinforced concrete curtain wall and the system models in which steel cross are used instead of curtains in reinforced concrete structures have been examined. The analyzes made give us many parameters and provide data that can lead to many researches. As a result of the data obtained from the analyzes, it is seen that there are situations where steel can better meet the earthquake effects in structures in systems where steel cross is used instead of curtains in reinforced concrete buildings. By developing these models and similar models, the structures can be strengthened against earthquakes by using steel elements in reinforced concrete structures. As a result, more earthquake resistant buildings can be constructed.

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