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Comparison of performance evaluation of an existing reinforced concrete structure and post-retrofitting analysis results with linear and non-linear calculation methods

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Abstract

According to AFAD data, a significant part of the country's population is settled in regions with high earthquake risk. For this reason, performance analysis and retrofitting issues are extremely important for the buildings in Türkiye and the building designs should be calculated in the most realistic way under the influence of earthquakes. In this study, a building in İzmir, which was built according to the 2007 Turkish Earthquake Code, was analyzed. Within the scope of the analyzes, performance analyzes were made in the Sta4-CAD 14.1 software using the linear and non-linear calculation methods in TBDY 2018, and it was determined that the structure did not provide the required performance levels. For this reason, the structure was retrofitted with additional reinforced concrete shear walls and the analyzes were repeated. Structural performance of the building and the damage of the structural elements were examined using both calculation methods before and after retrofitting, and attention was drawn to the effect of solutions made with different methods on the analysis results.

Introduction

As a result of the loss of life and property in Turkiye, especially in the earthquake disaster we have experienced in recent years, the need for new approaches has increased both in the design phase of new structures and in assessment of the earthquake performance of existing structures. In TBDY-2018, linear and non-linear calculation methods can be used to determine the performance of buildings under earthquake effects depending on their height and earthquake design classes. In linear calculation methods, it is assumed that the materials are linear elastic and the displacements of the structural system are small. In nonlinear analysis methods, there is an approach that the displacements are larger considering the effects of the nonlinear inelastic behavior of the materials on the system [1-2]. In addition, linear calculation methods are strength-based, non-linear calculation methods are strain-based.

Advances in structural engineering and computer technology help engineers calculate earthquake motion and its effects on structures more realistically and accurately. These developments allow the nonlinear behavior of building systems during earthquakes to be monitored more closely and their safety against collapse to be determined more realistically [3].

In this study, it is aimed to draw attention to the effect of solutions made with different methods on the analysis results.

Material and Method

The building was built in Izmir according to 2007 Turkish Code and consists of 10 floors; It is designed to 10.50 x 15.50 meters dimensions and story heights of 2.72 meters (Figure 1). The total height of the building, including the basement level, is 28.2 meters. The building type is reinforced concrete shear-frame, slab type is beam and slab floor, and the foundation type is continuous foundation arranged with bond beams. Hollow bricks are used for interior and exterior walls. As a result of the stripping and x-ray tools of the structural elements in the existing structure, it was seen that the rebar application was obeyed for the project, and it was understood that the rebar class was S220 from the experiments. According to the concrete core results, the concrete strength was c20. Soil class is Z2 and earthquake design class is DD2. The purpose of use of the building is residential.

With Sta4-CAD 14.1 software and calculation methods specified in TBDY 2018; Performance analyzes were performed using linear (mode combination method) and nonlinear (multi-modal method) calculation methods, respectively. In both calculation methods, collapse conditions were observed according to the current regulation, and then, taking into account the architectural project, retrofitting was made with 3 pieces of 2.50/0.30 m and 1 piece of 3.20/0.30 m reinforced concrete shear walls (Figure 2). In the new shear walls added, the reinforcement class is designed as s420 and the concrete quality as c30. After retrofitting, analyzes were repeated with linear and nonlinear calculation methods and the results were examined.

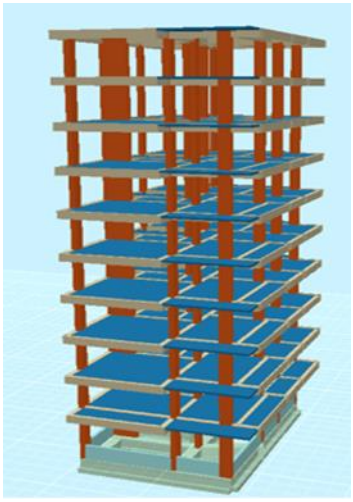

Figure 1. Building 3D View

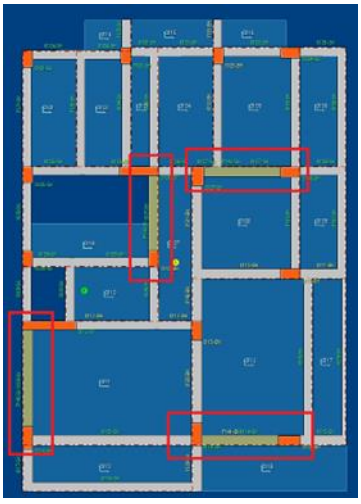

Figure 2. Floor Plan–Reinforcement Curtains

Results

One of the most important stages of the performance-based design method is to determine the damage levels of each of the structural elements [4]. Three damage states and damage limits were defined in TBDY-2018 for ductile sections. These are Limited Damage (IO), Controlled Damage (RC) and Collapse Damage (AR) states and their limit values. These criteria are important to achieve the targeted building performance level of Controlled Damage. The current and post-retrofitting conditions of the building were analyzed linearly and non-linearly, and the damage percentages of the structural elements were presented in the graphic (Figure 3-4). When we evaluate the element damages in the current situation; the linear calculation method showed approximately 2 times more damage value than the nonlinear calculation method. In the post-retrofitted situation, as expected, element damage remained at the targeted damage points, and no difference was observed.

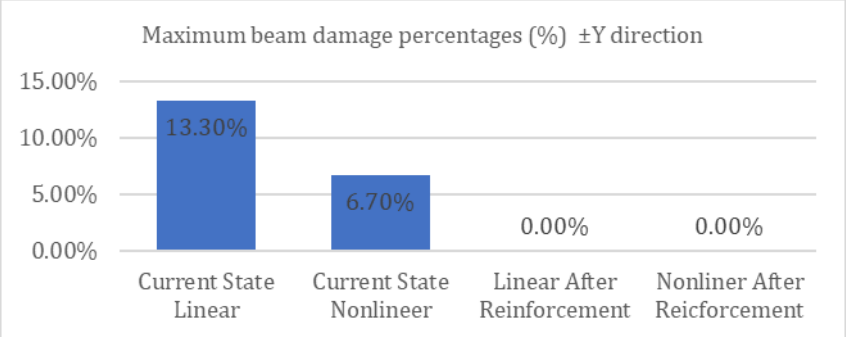

Figure 3. Damage Percentage of Beams in the Failure Zone

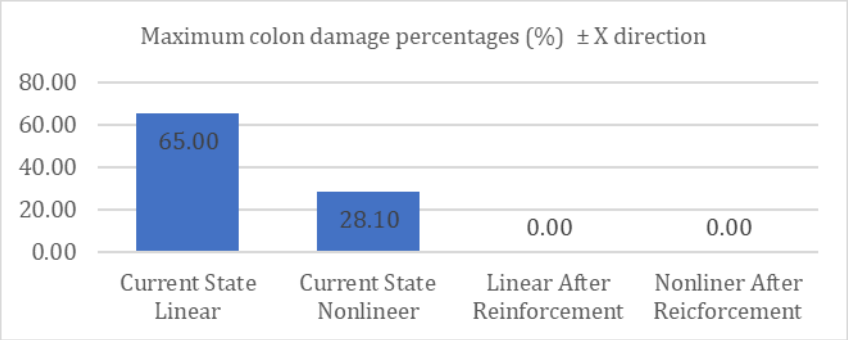

Figure 4. Damage Percentage of Columns in the Failure Region

When we look at the peak story drift values in the x and y directions, it is seen that the drift values decrease after retrofitting as expected in both calculation methods. In addition, the fact that the drift values are higher in the nonlinear analysis than the linear analysis shows that the nonlinear analysis calculates the structure behavior more realistically (Figure 5).

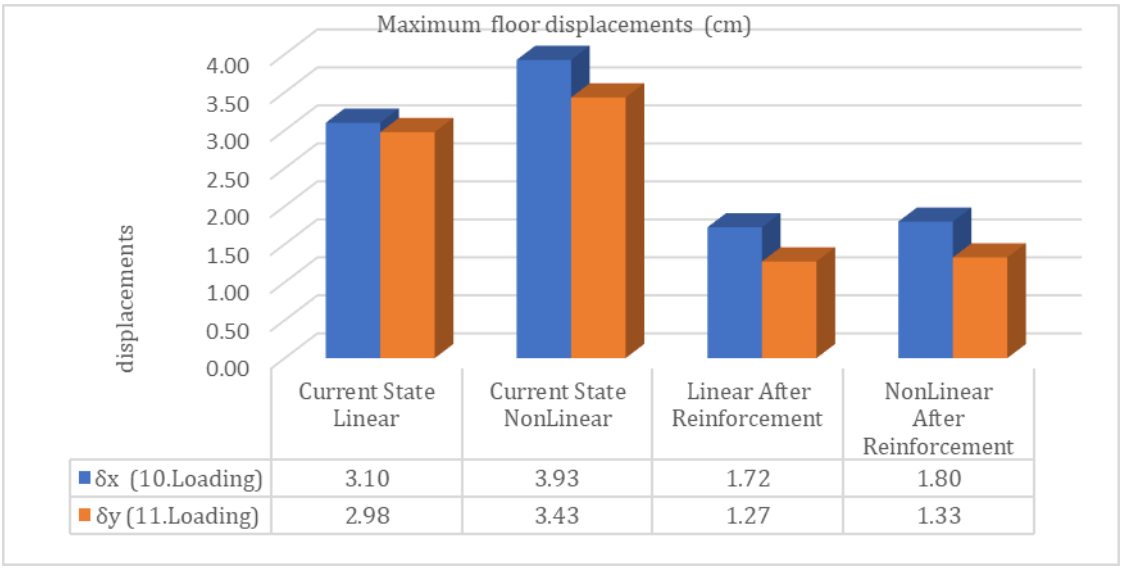

Figure 5. Maximum floor displacements in X and Y directions

Discussion

It is also seen in the literature research that non-linear methods, which are among the calculation methods in the standards, give more realistic economic and safe results. For this reason, it is of great importance that the structures are calculated in the most realistic way against earthquakes during the design and that the designs are made according to this principle. Generally, at the projects, linear calculation methods are predominantly preferred due to obtaining fast solutions.

Conclusion

In the performance analysis of existing buildings and in the design of new buildings, separate analyzes should be made in the calculation methods in TBDY 2018 and control should be ensured.

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