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Examination on the contribution of Turkey's building stock future by the regulation of structural joint problems in reinforced concrete buildings according to 2018 Turkish Building Earthquake Code

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Abstract

Turkey is an earthquake country due to its geological location. Our existing structures are frequently exposed to earthquakes. These exposures cause buildings to become unusable before they reach the end of their useful life and cause great loss of life. Torsional irregularity should be avoided when designing the framed structure. In reinforced concrete buildings, the structural system should be designed in such a way that hyper static behavior can be effective under earthquake effects. When the behavior in question is valid, some structural system members will not be exposed to forces beyond their strength under the effects of earthquakes and loads will be shared by other carrier system members. With the Turkish Building Earthquake Code 2018 article 3A3.2 (a), it is recommended to design framed structure without making structural joints by preventing irregularities. In this study, jointed and jointless analyzes of a 10-storey reinforced concrete building were made. According to the jointed and jointless conditions of the building, its behavior under the effects of earthquakes and its damages were investigated.

Introduction

In static projects created in our country, earthquake joints were required to be placed in buildings exceeding 40 m until the 2018 earthquake regulation was published by the public sector project approval authorities in accordance with TS500 6.3.4 article and it was recommended to design framed structure without making structural joints [1].

This rule was also valid for buildings that were designed very close to the center of gravity and rigidity, where all precautions were taken against torsion, and were adequately designed against dynamic effects. A large part of the building stock consists of residences. The designs of the architectural projects that must be followed while creating the framed structure cannot be changed easily, and they are user-oriented and commercial concerns.

In this study, a 10-storey building which was designed very close to the center of gravity and stiffness, and used for residential purposes was examined. Joint and jointless cases were analyzed separately with Opensees building performance program, which is an extension of STA4CAD static analysis program.

In the study, the benefits of avoiding the separation of buildings with structural joints due to their length in plan in the 2018 regulation will be shown in practice.

Material and Method

The building in question has 10 floors and the floor heights are designed as 3m. The design of the building was made according to the 2007 earthquake code.

While forming the framed structure, the center of gravity and rigidity is designed to be very close. C30 was used as the concrete class and S420 was used as the reinforcement class. The length of the building is 51.90m and the width is 19.65m. According to TBDY 2018 regulation article 4.9.3.2, the joint spacing was created as 11cm. The design showing the center of gravity and stiffness of the building with and without joints is presented in Figures 1 and 2. After the building in question is separated with the joint, the divergence in the centers of gravity and stiffness formed in the blocks can be observed from the plan.

The analyzes were carried out using the nonlinear calculation method in the time history analysis. The nonlinear calculation in the time history corresponds to the step-by-step direct integration of the differential equation set, which expresses the equations of motion of the structural system under the influence of earthquake ground motion, with time increments. During this process, the variation of system stiffness matrix with time due to non-linear behavior is taken into account [2]. In the literature, earthquake acceleration records are obtained in three ways. The first is the use of the real acceleration record of the earthquake that occurred. The second is the use of an artificial acceleration recording, in which the desired response spectrum is obtained by obtaining the spectral density function from the corrected response spectrum. The third is the use of virtual acceleration records produced from seismological source models. Real ground motion recordings are used because of their superiority over other recording types [3].

Earthquake records were selected in accordance with TBDY 2018 section 2.5. Earthquake records 11 earthquake records were selected from the University of California PEER [4] in accordance with the regulation (item 5.7.2.1), and they were selected to include a maximum of 3 sets from the same earthquake. While selecting the earthquake records, earthquake magnitudes, fault distances and local ground conditions compatible with the location of the building and the earthquake ground motion level used in the design were taken into account. In particular, earthquake records with appropriate PGA values were selected. The scaling of earthquake records was also done according to TBDY2018 rules. Earthquake records were scaled with the OPENSEES program and the conditions of TBDY 2018 item 2.5 sub-clauses were complied with. Selected 11 earthquake acceleration record sets were applied to the building in two directions, then the acceleration records were rotated 90 degrees to create a total of 22 analyzes. All earthquake acceleration records were affected on the building in a horizontal direction perpendicular to each other. The displacement and torsion values of the building for both cases are given in Figures 3 and 4.

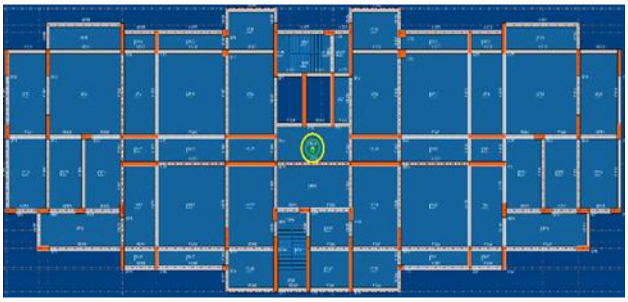

Figure 1. Jointless design

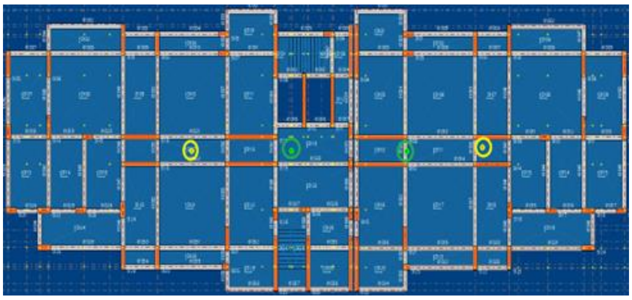

Figure 2. With joint design

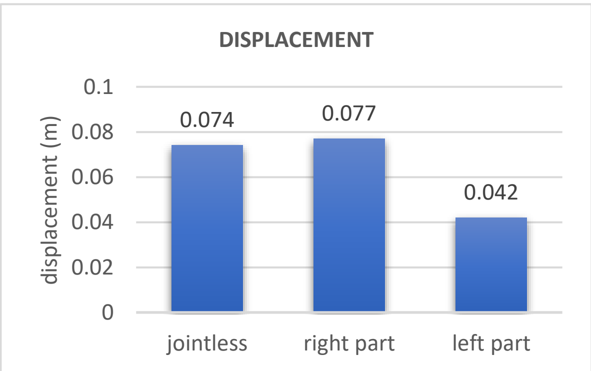

Figure 3. Displacement

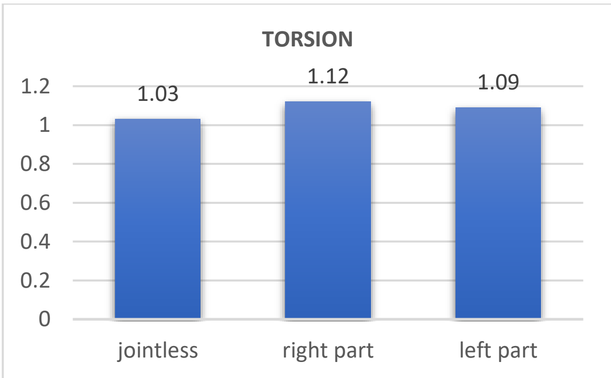

Figure 4. Torsion

Results

The displacements are plotted taking into account the x-direction. The reason why the displacement is less in the left block can be explained by the large curtain wall area perpendicular to the x direction.

The results were obtained by averaging the largest absolute values of the 22 analysis results. As a result of combined and averaged performance calculations, jointless and jointed construction performance has given the failure damage in x and y directions. As a result of the analysis, the amount of damage on the basis of elements in the structure, with and without joints, according to the damage class, is given in Table 1 for the ground floor of the building. While 7% damage occurs in the jointless structure for failure damage in the columns, this rate is 10% in the jointed structure. As a result of the analysis carried out in the time history, the jointless design resulted in failure structure performance in 15 analyses of 22 analysis, and failure performance occurred in 17 analyses of 22 analysis when separated by joint. It has been proven that the building suffers less damage in the jointless condition. It is known that the strengthening of the buildings will be made on the damaged structural system elements or additional curtains will be created.

With the 2018 earthquake code article 3A3.2 (a), wrong designs caused by joints were prevented in our country's building stock. It is understood from the damage results that there will be a decrease in the reinforcement costs after possible earthquakes during the first constructing (While creating the joints, the foundation makes more, the columns, beams and walls are manufactured twice on the same axis, etc. non-production) and life of the building.

Table 1. Element damages on the ground floors

Damage	**Limited**		**Apparent**		**Higher**		**Failure**	
Items	**Beam**	**Column**	**Beam**	**Column**	**Beam**	**Column**	**Beam**	**Column**
Jointless	118/118	40/55	-	9/55	-	2/55	-	4/55
Jointed	119/121	42/60	2/119	9/60	-	3/60	-	6/60

Discussion

The Italian Building Regulations for the Construction to be Made in the Earthquake Zones, taken from Italy, which was first published in our country in 1940, started to be implemented. In the Earthquake Zones Temporary Building Regulation published in the same year, joints were mentioned for the first time under the title of Article 13-Earthquake joints (antiseismic) joints. In the Turkish Earthquake Zones Building Regulation published in 1947, it is stated in Article 14 that adjacent buildings constructed at the same time can be considered as a building without dilatation if they are built at the same height and in the same construction systems. In the 1968 Regulation on the Structures to be Constructed in the Disaster Areas, the joint condition was introduced again in 6.8.1 and it was continued until the 2018 code. The regulation of torsion was first mentioned in Article 22 of the 1953 Regulation on Structures to be Built in Earthquake Zones.

With the innovation brought by the 2018 earthquake regulation, structures that do not have torsion irregularities and provide hyperstatic over-connection behavior that are much more resistant to earthquake effects are prevented from separating with the joint, and the risk of damage to the blocks by colliding in an earthquake is prevented.

In this way, it has been revealed that the new building stock of our country will consist of structures that are more resistant to earthquakes.

Conclusion

While designing the framed structure of the buildings, attention should be paid to the symmetry and the placement of vertical structural elements, especially care should be taken to place the curtain walls equally on the x and y axes. Thus, it should serve to design buildings with close centers of gravity and stiffness and regular in terms of torsion. While designing, it is necessary to provide hyperstatic behavior. During an earthquake, it should be ensured that each element in the system receives a load as much as its capacity and transfers it to other elements.

Structural joints should be avoided as much as possible by anticipating that the structural elements will be damaged by hammering in buildings separated by joints under horizontal loads.

The recommendations under the title of Article 3A.2 Regular and Symmetrical Arrangement of the Carrier System and Article 3A.3 Ensuring the Over-Dependency Feature in the Structural System of the 2018 earthquake code should be followed meticulously.

References

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