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Research Article

Effects of Material Strength on Structural Performance of Damaged RC Buildings

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Abstract

The first defect was related with concrete for RC buildings that damaged after an earthquake. In this study, effects of concrete class on structural performance of reinforced concrete building have been investigated. Çeltiksuyu School building that has collapsed after 2003 Bingöl earthquake was selected to obtain realistic results. Calculations have been made for each concrete class which was selected as C8, C16, C20, C25 and C30. Pushover analyses were used for both direction of selected building. As a result, structural behaviour of RC buildings with different concrete classes is compared and evaluated according to analysis results in detail. The displacement and internal forces obtained from results of analysis is investigated comparatively. The results show that base shear of building was increased according to increasing concrete strength. The increasing in base shear has increased the amount of peak displacement in the structure. As a result, it cannot be said that the concrete strength is so effective. The main issue here is whether the concrete has been produced according to technical specifications or not. The reason for this is lack of control, workmanship and material defects.

Keywords: Structural performance, conrete class, strength, pushover analysis

1.Introduction

Reinforced concrete (RC) is a structural material commonly used in world that combined by steel and concrete. Concrete has strong compressive strength and steel has strong in tension strength. The idea of compressive stresses was covered by concrete and tensile stresses were covered by steel in the structures was revealed RC materials. Steel and concrete give common response to loads and forces. Any defect in concrete or steel element affects all of the structures. The adherence between these materials improves properties of RC elements. The first defect was related with concrete for RC buildings that damaged after an earthquake because of the weak material is concrete in RC building.

The importance of studies, researches and prevention about earthquake have risen after destructive earthquakes in the world especially in recent years.

Earthquake damages increase according to vulnerability of urban and rural building stocks. The size of earthquakes and the negative structural features will increase damage amount. To know the features affecting the behaviours of structures under seismic loads negatively will lead to more serious approaches to reduce the damage amount due to earthquake. In order to reduce the damages of the earthquakes firstly the performance of buildings needs to be determined. Earthquake safety of existing buildings has gained considerable importance after earthquakes which have occurred in our country especially in the last 30 years. Performance based assessment methods have been widely used for existing reinforced concrete structures.

Some variables cause RC buildings under earthquake influence to be damaged. In this study the variable was concrete class. . Calculations have been made for each concrete class which selected as C8, C16, C20, C25 and C30. Çeltiksuyu School building that has collapsed after 2003 Bingöl earthquake was selected to obtain realistic results.

2- Description of the Building

Approximately 1.2 billion students are enrolled in primary and secondary schools; of these, 875 million school children live in high seismic risk zones all over the world. Although these children spend up to 50% of their waking hours in school facilities, all too often schools are not constructed or maintained to be disaster resilient [1]. The primary school of Çeltiksuyu built in 1990's and heavy damaged during the May 2003 Bingöl earthquake (Figure 1).

Figure 1.Çeltiksuyu Regional primary Education School Building

The blue prints of Çeltiksuyu Regional Primary Education School Building that has the heavy damaged due to earthquake is given in Fig. 2.

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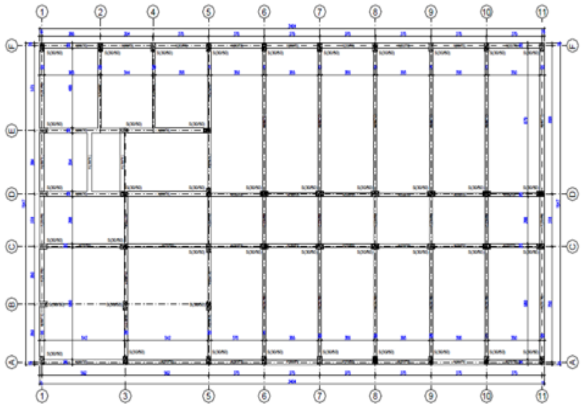

Figure 2. Blue print of Çeltiksuyu (Celep, 2003)

Furthermore, the plan of the Çeltiksuyu had been improved and applied to other schools in the region. Several schools have been built in the area by using the same blue prints. Building is totally three storeys that comprised a ground storey and two normal storeys. The dimensions of the building are 17.17m×33.74m rectangular in the plan. The columns are 0.30x0.50m. Internal beams are 0.20x0.70m and outer beams are 0.30x0.70m dimensions. Height of floor is 0.12m. The structural system has a very smooth axis system in the plan. The ground story of the building has been totally collapsed. The columns in the first story have been significant damage [2].

3.Methodology

In this study, a three story school building collapsed during the Bingöl earthquake on May 1, 2003 is examined by the seismic behavior of the structure defined according to different concrete classes.

In recent years, with the effect of an increasing consciousness on earthquakes, the society has started to think more rationally about the dangers related to earthquakes and they want to learn about the performance of their buildings against a possible earthquake. This consciousness is coming both from individuals and companies. Turkish Earthquake Code 2007 (TEC-07), Section 7 [3] has the characteristics of responding to those needs.

In performance based design and assessment method it is possible to determine in quantities the damage levels that may arise under the design ground motion within the structural system elements. It is checked whether this damage stays under the acceptable damage levels for each related element. Acceptable damage limits are defined in a way to be consistent with the foreseen performance targets at various earthquake levels [4, 5, and 6].

The assessment procedure aims to estimate the earthquake force demand at which the building would sustain the performance objectives. Demand spectrum, which is used in determining the performance of the building's system, shows the maximum response that a building gives against seismic activities during an earthquake [7].

Two fundamental parameters of performance based design and assessment are earthquake demand and capacity [8, 9]. Earthquake demand represents the earthquake ground movement, whereas capacity represents building's reaction under the effect of an earthquake. Structural capacity is represented by static pushover and capacity curve. This curve is derived by drawing the function between base shear force and building's roof displacement. Capacity curve is derived by calculating building system with gravitational loads and proportionately increasing lateral forces up to the target point where structural capacity ends. The actual purpose of the nonlinear static method is to determine the target displacement of a building, then by performing a final pushover analysis by increasing the lateral loads up to the target displacement. As a result, the demand values such as internal forces, rotations, strains and displacements are computed and the performance of the analyzed section is then evaluated by comparing the strains obtained from the total curvature of the section with the upper boundary strains designated for different cross-sectional performance levels.

Concrete is a composite material of using various materials such as aggregate, cement and water. Production of concrete is possible and easy in every way in everywhere in the world. Furthermore, step number of concrete production is very much such as calculation of composition, transportation, concreting, compaction and curing of concrete. The defects of materials that used for concrete affects concrete strength directly. Steel production was made only in factories under control. This make concrete weaker than steel. So the first defect was related with concrete for RC buildings that damaged after an earthquake.

In this study, structural behaviour of RC buildings with different concrete classes is compared and evaluated according to analysis results in detail. The displacement and internal forces obtained from results of analysis is investigated comparatively.

4- Pushover curves for different concrete classes

Based on structural dynamics theory, the modal pushover analysis procedure retains the conceptual simplicity of current procedures with invariant force distribution, now common in structural engineering practice [10]. The POA has been widely used for its conceptual simplicity, computational attractiveness and capability of providing satisfactory predictions of seismic demands for low and medium-rise structures if the inelastic action is distributed over the height of the structures [11]. The pushover should be continued to the largest displacement practicable until degradation of the overall system occurs or limits of structural stability occur. In cases where a target displacement is set as a goal, it is generally worthwhile to push a little further to establish a better confidence level. [12].

S220 steel grade was used for RC building. SAP2000 software was used for calculations. Loads were obtained same for all type concrete classes that selected in the study. Moving loads in the building was adopted as 3.0kN/m2 in normal floor; 5.0 kN/m2 in corridor and stairs. Wall loads was adopted as 6.0kN/m2 and cover load was 1.5kN/m2. The calculations were made separately for each concrete class. Pushover curves of building for X and Y direction were given in Figure 3-7.

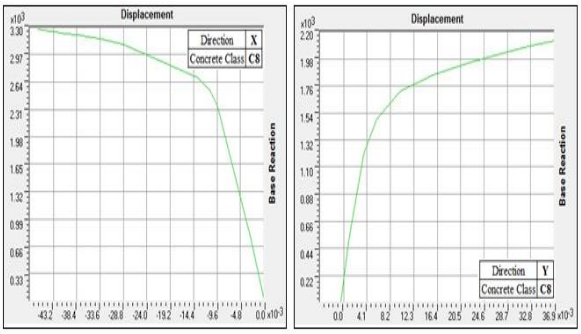

Figure 3. Pushover curves of building for X and Y direction for C8 class

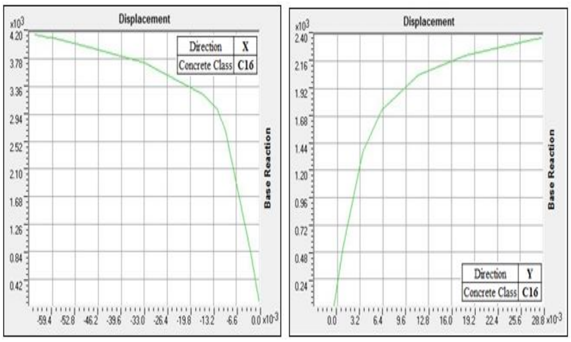

Figure 4. Pushover curves of building for X and Y direction for C16 class

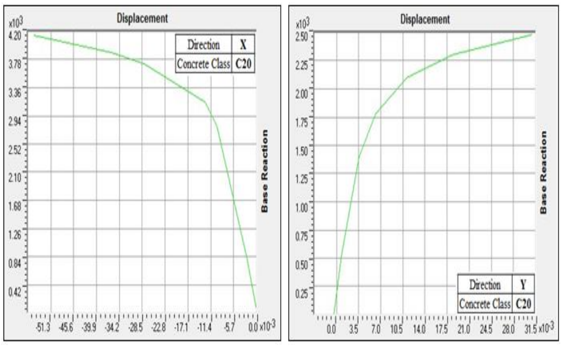

Figure 5. Pushover curves of building for X and Y direction for C20 class

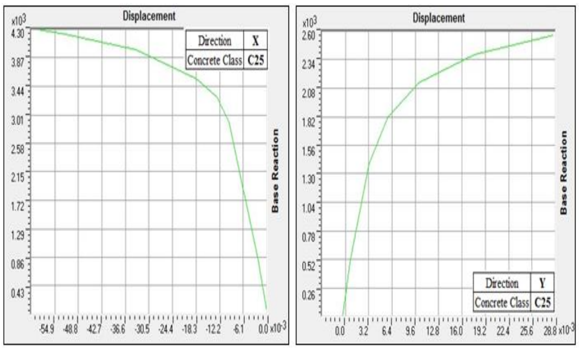

Figure 6. Pushover curves of building for X and Y direction for C25 class

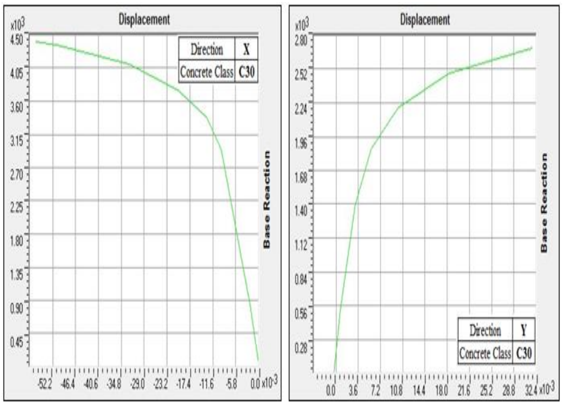

Figure 7. Pushover curves of building for X and Y direction for C30 class

5. Conclusions

The performance based earthquake engineering has overcome the deficiencies of civil engineering. With the performance based planning and evaluation, it is possible to determine the material losses and possible life losses and to calculate quantitatively what level of performance a building or building stock can have. In order to prevent earthquake damages, performance based method is used to enable decision makers to receive information on numerical data and calculations considering building performance.
The displacement and internal forces obtained from results were given in Table 1.

Table1. The results of pushover curves for different concrete classes

Pushover Analysis	X Direction					Y Direction				
	C8	C16	C20	C25	C30	C8	C16	C20	C25	C30
Base shear (kN)	3300	4100	4200	4300	4500	2200	2400	2500	2600	2800
Displacement (m)	0.043	0.051	0.052	0.054	0.059	0.028	0.030	0.031	0.032	0.036

The results show that base shear of building was increased according to increasing concrete strength. The increasing in base shear has been increased the amount of peak displacement in the structure. As a result, it can say that concrete strength was not too defective. The main issue is manufacturing of concrete has not been made under proper conditions. The reason for this is lack of control, workmanship and material defects.
The importance of studies, researches and prevention about earthquake have risen after destructive earthquakes in the world especially in recent years. Earthquake damages will increase according to vulnerability of urban building stocks. The negative structural features will increase the size of hazard. One of the important negative features is material strength.
The concrete properties primarily take place in the issue of the resistance of the reinforced concrete structures to earthquake. Concrete quality is one of the most important factors in the generally damaged reinforced concrete structures.
The concrete is not efficient all alone for the reinforced concrete structures damaged due to the earthquake. Poor

quality of the concrete is one of the elements increasing the damage in the reinforced concrete structures.

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