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Evaluation of building retrofitting alternatives from sustainability perspective

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Abstract

Buildings primarily provide shelter and acceptable comfort for its intended occupiers and they should also provide adequate protection in case of hazards. Unfortunately, in case of seismic events it is observed that in many cases earthquakes caused considerable damage to residential and commercial buildings, public facilities and infrastructures with substantial casualties due to inadequate engineering and faulty in construction practices. In this study, a reinforced concrete residential building that collapsed in 1999 Kocaeli Turkey Earthquake (MW 7.4) is focused and investigated using current seismic code. Afterwards, building is virtually retrofitted considering architectural plan and using common retrofitting methods for satisfying current seismic code requirements. These retrofit alternatives are then evaluated from structural, cost and environmental aspects and outcomes are discussed. Since structural components that are used in retrofitting the building consumes natural resources and responsible for energy consumption, sustainability criteria should be directly included in the retrofitting requirements. Consequently, structural engineers are able to use natural resources efficiently and reduce the environmental impacts in retrofitting.

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Keywords: Retrofitting; seismic codes; energy consumption; cost calculation

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1. Introduction

RC buildings in the existing building stocks are under the risk of poor earthquake performance because several of these buildings were built before the advent of the seismic codes. Most of these RC buildings were designed under forces equal to small ratio of the weight with non-ductile detailing. Some of these buildings may perform well in possible future earthquakes, but others may not have the ability to survive without severe damage and possible collapse as a result of insufficient seismic performance.

Under these circumstances, there is a significant need to perform adequate performance assessment of RC buildings and to investigate possible retrofitting schemes prior to future seismic events. Strengthening elongates the service life of the building and consequently it contributes to the sustainability. In this study, a building that was collapsed in 1999 Kocaeli Turkey Earthquake (MW 7.4) is focused and possible strengthening alternatives for achieving the current seismic code performance levels are presented. These alternatives are considered to contribute to sustainability since they increase the service life of the building and help to reach the target economic life. Moreover, phases regarding strengthening alternatives are investigated from base shear capacity, cost, energy consumption and toxic gas production perspectives and outcomes are presented for comparison.

2. Determining performance of the building

After catastrophic earthquakes occurred in last 30 years and parallel to the developments in computing technology, improving seismic safety of existing RC buildings against earthquakes have gained attention among researchers [1,2]. In order to evaluate the structural performance of RC buildings, several methodologies are established and many guidelines are presented such as SEAOC Vision 2000 (1995) [3], ATC-40 (1996) [4], FEMA-356 (2000) [5] and FEMA 440 (2005) [6]. Furthermore, some countries like Turkey, these methodologies become a part of the seismic design codes for evaluating the seismic performance of RC buildings [7].

In the current study, Turkish Earthquake Code [7] is accounted for evaluating the seismic performance of buildings. Prior to defining seismic performance levels, adequate data should be taken from building regarding examination, data collection, assessment and material sample collections. Building properties such as; size, detail, type, geometry and material characteristics of the structural members are required for analysis. These data can be obtained from the projects and reports of such buildings, from observations and measurements to be carried out on the building, and from the tests performed on the material samples taken from the building. Information levels are classified as limited, medium, and comprehensive, respectively [7]. Subsequently, these levels are used for the calculations of capacities of supporting elements.

There are three limit conditions defined for ductile elements and these are minimum damage limit, safety limit and collapsing limit [7]. Minimum damage limit defines the beginning of the behavior beyond elasticity, safety limit defines the limit of the behavior beyond elasticity that the section is capable of safely ensuring the strength, and collapsing limit defines the limit of the behavior before collapsing.

The seismic performance of the buildings are related to the condition of the damages that are expected to come out under the effect of the earthquakes and it is defined taking four different damage levels as basis. These are; ready to use, life safety, pre-collapse and collapse performance levels. Details of these performance levels and criteria related to the analysis are presented in TEC (2007) in details [7]. Earthquakes levels that the seismic performances of existing residential buildings are evaluated considering the minimum performance targets as life safety and the probability of the earthquake to be exceeded is given as 10 % in 50 years.

3. Strengthening of the building

Strengthening of the buildings covers applications such as eliminating the defects that will lead to seismic damages, adding new components that will contribute to the enhancement of earthquake safety, improving the seismic behavior of existing components, maintaining the continuity of force distribution and decreasing the mass.

Strengthening applications are evaluated under two different topics, at component level and building system level. Applications used for improving the strength and deformation capacities of the seismic load-bearing building components as beam, column and frame are defined as component strengthening. On the other hand, applications with the aims of improving the strength and deformation capacity of the building and ensuring the continuity of the