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A new approach on the strengthening of primary school buildings in Turkey: An application of external shear wall

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Abstract

Considerable life and property losses have occurred because of the devastation due to the earthquakes happened in Turkey during the last 10 years. Especially, the damages that occurred on the public buildings were more serious and irrevocable when compared with the damages that took place on private buildings. In Turkey, primary school buildings constitute a large portion of the public buildings. Unfortunately, these buildings faced with heavy damages during the last earthquakes. The strengthening of existing primary school buildings in accordance with new contract specifications, thereby reducing losses of life and property to a minimum in case of an earthquake, has become one of the important issues on the agenda of the Turkish government. However, the strengthening of the primary school buildings by using the available methods is so difficult, because the strengthening works take a long time, the user of these buildings are obliged to evacuate the buildings and also there occurs extra costs caused by the additional repairs and renovations within the buildings when these methods are used. In this study, a new strengthening type of reinforced concrete buildings namely "external reinforced concrete shear wall" application method is discussed. For this purpose, three typical projects, which have been built commonly, are mentioned. The structural deficiencies observed in these buildings are given. In the experimental stage of this study, an experimental programme is formed in order to evaluate the performance of the external shear wall application. In the experimental schedule, four reinforced concrete test specimens are produced by using the design and detailing data of the considered school buildings. According to these tests, the strengthening and system improvement performed through adding external reinforced concrete shear wall to the reinforced concrete buildings will add improved behaviour, strength and rigidity to the system with its low cost besides the ease of construction and application. Since these buildings are detached and located in a multi-purpose garden, constructed as typical projects and have special architectural layout, developing this method for the existing primary school buildings will be able to be implemented in most of the primary school buildings without any problems.

Keywords: Primary school buildings; Reinforced concrete; Earthquake; Strengthening; Architectural design; Shear wall

1. Introduction

Considerable losses of life and property have occurred as a result of the devastation caused by the earthquakes that have happened in Turkey during the last 10 years. Especially, the damages that occurred on public buildings are more serious and irrevocable compared to the damage that occurred on private buildings. In Turkey, which has a very young population, primary school buildings constitute a large portion of the public buildings. The damage that occurred to the primary school buildings in the Marmara earthquake of August 17, 1999, Duzce earthquake of November 12, 1999, and Bingöl earthquake of May 1, 2003 [1–3] made it clear that these buildings, which are built mostly of reinforced concrete, need to be examined and strengthened rapidly and effectively if necessary.

The compulsory primary school education in Turkey was extended from 5 to 8 years in 1997. As a consequence

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of this extension, additional floor or floors were built in the existing primary school buildings which could no longer meet the needs. The fundamental reason why most damage occurred in these buildings is that these buildings, which were not detailed sufficiently in respect of seismic detailing, were made riskier through additional floors.

The projects and construction of existing primary schools that were built before 1998 were conducted in accordance with the regulations TBC-1984 [4] and TEC-75 [5], which were in effect at the time. However, the earthquake and construction regulations in Turkey underwent significant changes with revisions made in 1998, 2000 and 2006 [6–8]. The strengthening of existing primary school buildings in accordance with new contract specifications, thereby reducing losses of life and property to a minimum in case of an earthquake, has become one of the important issues on the agenda of the Turkish government [9].

Studies in the literature that are devoted to the strengthening of reinforced concrete buildings usually concentrate on methods of strengthening that will be performed inside existing buildings (by using infill frames) [10–14]. Such work to be done in the building, on the other hand, requires the evacuation of especially the intensively used primary school buildings during the strengthening and renovations that may take months. Moreover, this leads to substantial additional construction work within the building, alters its architecture and increases costs. This often causes the appliers and users to take a lukewarm attitude towards the strengthening of buildings.

Moving from this problem, researchers seek ways to find a more practical and economical method of strengthening especially for primary school buildings. The external reinforced concrete shear wall application, which can be performed on the existing primary school buildings in Turkey, forms the scope of this study.

2. Primary school buildings in Turkey and typical projects

Typical projects developed by the Ministry of Public Works were used in all provinces until the year 1970. After 1980, typical projects prepared by Provincial Directorates of National Education began to be used. Although the typical projects used displayed minor differences from province to province, they were similar architecturally. Commonly used typical projects had three, five and seven classrooms.

A revolutionary step was taken in 1997 when the 5-year compulsory primary education was extended to 8 years after being combined with the 3-year secondary education. The transformation of 5-year primary schools to the 8-year ones in the implementation of 8-year primary education led to the emergence of a need for new spaces. Attempts were made to solve these problems by, for example, adapting the existing primary schools to the 8-year ones through some physical changes or by constructing new school buildings and such efforts still continue. The adaptation of the existing schools to the 8-year programme is implemented as follows:

- Rearrangement of spaces in accordance with the requirements of the new system.
- Construction of extensions and additional floors.

The most frequently preferred method for the adaptation of existing buildings is the addition of floors to them. Through addition of floors, these buildings now have 10, 14, 21 or 24 classroom [15].

The general and common properties of primary school buildings produced in a similar fashion within the framework of typical projects:

- The load-bearing system of these buildings is composed of a reinforced concrete column and beam system.
- The buildings are constructed in accordance with TEC-75 and TBC-1984.
- There is no reinforced concrete shear wall in the load bearing system to resist lateral loads and lend rigidity to the building.
- The column members of structural frame are located in the exterior axes.
- Spaces within the school are created through non-load-bearing brick walls.
- Buildings are detached and located in a multi-purpose garden.

The pictures of three commonly used typical projects produced with these common properties in Turkey are given in Figs. 1–3 [15].

3. Seismic performance of school buildings

TBC-500 and TEC-2006 are used in the preparation of projects for reinforced concrete buildings in Turkey. During the preparation of projects, the live load values of buildings according to their use and their multipliers and building importance factor demonstrate differences. There are no separate regulations for buildings such as schools and hospitals. Different coefficients given in the regulations for schools are shown in Table 1.

Substantial damages have occurred in recent earthquakes, which led to serious doubts as to the seismic performance of school buildings [16,17]. Similar damages were observed in the school buildings in various countries after earthquakes [18,19]. It is no coincidence that these damages concentrate especially on school buildings in Turkey. The damages that occur in school buildings are caused by the following reasons:

- Compression strength of concrete is very low (8–14 MPa).
- Plain and inappropriate reinforcement bars.
- Insufficient stirrup spacing in the column and beam joints.
- The fact that the hooks of stirrups are of 90° in angle.
- Insufficient column sections.
- Stronger beams than columns (in respect of moment capacities).