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Re-examination of damage distribution in Adapazarı: Structural considerations

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Abstract

Adapazarı was the scene of spectacular structural damage as well as widespread foundation displacement that occurred in the city during the devastating earthquake of August 17, 1999. The damage patterns observed in Adapazarı were quite peculiar, so these are re-examined in an effort to answer the question of whether they are indicative of a consistent trend in terms of the building attributes and/or site conditions. For this purpose two databases comprising buildings surveyed in Adapazarı after the earthquake have been re-evaluated. The first data set included buildings that had collapsed fully; hence no complete data on the as-built properties have been assembled. Their examination was necessarily a desk study conducted from the design blueprints of the individual buildings that no longer existed. The second source was a larger database comprising buildings that had experienced various levels of damage and examined using conventional evaluation procedures. All buildings were rated from the viewpoint of conventional seismic performance using accepted parameters to confirm the observed damage. An examination based solely on structural attributes leads us to believe that building collapses observed in Adapazarı are perhaps too involved to reduce to a few simple deficiency attributes. The site effects seem to have played a major role in the observed damage, because conflicting trends of structural attributes and the actual damage were established. A companion paper focuses on the influence of site effects on the observed building damage.

Keywords: Kocaeli earthquake of 1999; Damage assessment; Damage survey; Site effects; Seismic evaluation

1. Introduction

The August 17, 1999 Kocaeli earthquake near Izmit caused significant damage in many urban districts, including the city of Adapazarı that lies 35 km further east (Fig. 1). The widespread foundation displacement and site effects are considered as other major factors in addition to structural parameters that caused significant damage to many buildings. Two modes of damage were identified: (1) damage due to structural inadequacy for resisting strong ground shaking manifested through collapsed or severely damaged buildings and (2) damage resulting from foundation failure apparent in terms of excessive settlement leading to overturning and tilting of the buildings without significant structural distress. In addition to these modes of failures, non-uniform damage patterns were observed in similar buildings located at sites at approximately the same distance from the source.

Immediately after the earthquake, the Adapazarı Municipality conducted a comprehensive damage assessment survey in the city. The results of this survey are provided at district level within the central municipality area. The total number of buildings investigated in the 26 urban districts, covering an area of about 20 km^2, was 23 914. The damaged buildings were classified into two damage grades according to the criterion of whether the building could be feasibly repaired (light or moderate damage) or needed to be demolished and removed (collapse or heavy damage). The corresponding damage statistics are presented in Table 1. In this article this database will be used only for allowing an insight into the distribution of damage within the urban area,

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Fig. 1. Location of Adapazarı.

but its simplified attributes make it unsuited for the type of scrutiny that is permitted by two other surveys that are described next.

Another damage survey was conducted during the summer of 2002, nearly three years after the event. By that time, extensive repairs had been done in surviving buildings, and many others had been demolished and removed. Homeowners were reluctant to permit another round of examinations to be conducted in their property, so the decision was made to include those buildings that had collapsed during the earthquake, and had led to loss of human life. When such is the case, the law requires expert witnesses to prepare a statement that will establish the professionally liable persons. Because of their proximity to the site the Department of Civil Engineering, Sakarya University (SU), had served in this capacity for many buildings on the basis of design blueprints and structural calculations, so the decision was reached to use that information, extracted through a damage assessment form, assuming that the drawings were an accurate replication of the as-built structure. The data template used for this purpose was modified from a post-earthquake damage assessment form developed for engineered buildings in Turkey [1]. A hand-held GPS device, accurate to about 10 m, determined the coordinates of the buildings.

Government compensation schemes that were in effect at the time of the earthquake mandated a more thorough building damage examination. This was conducted in the months following August 17 by General Directorate of Disaster Affairs (GDDA) engineers in the ranks of the Ministry of Public Works and Settlement. Their survey included every building that had been examined in the quick post-event municipality survey. From this, we extracted a reduced and more reliable data set of 2726 reinforced concrete buildings with four or more stories in order to allow a better judgment for the type, height and other structural properties of the overall building stock in the city. Buildings with fewer stories were generally non-engineered masonry. The database contained entries for the mode of damage, i.e. the observations of foundation settlement were also noted. Although the exact measurements of the observed foundation settlements were not made, the cases of buildings with foundation-induced damage were calculated to be around 3% of the buildings in the database. For this reason, the database might be considered to include building damages dominated by structural features. This database was used to carry out regional conventional damage predictions.

The objective of this article is to test tools of current practice in an attempt to question whether, had these buildings been available for examination prior to the occurrence of the earthquake, we would have succeeded in identifying those buildings that collapsed. The evaluation consisted of two phases. Phase 1 focused on the damage mode due to structural attributes including site effects using conventional practice. A complementary study was carried out in Phase 2 dealing with the non-uniform damage patterns and damage due to foundation failures. This paper covers the first phase of the study whereas the second phase is presented in the companion article [2]. Here, we also test the relative efficiency of available approximate procedures used to determine inelastic displacement demands and their influence on the damage prediction. While the data sets comprise fewer buildings, their structural characterization is more accurate than that for the Adapazarı Municipality survey.

2. Building inventory

The building stock included in this study is comprised of two databases created by two separate institutions: Sakarya University (SU) and General Directorate of Disaster Affairs (GDDA). In the SU database of 241 buildings information on the properties of the structural components, architectural features, the layout and location for individual buildings are provided, whereas the GDDA database contains superficial data on a larger number of buildings (2726 buildings) without their exact coordinates but with their addresses given. The buildings assessed by GDDA were further examined to extract information on the number of stories, type of structural system and location. As a result, those buildings were assigned to the 26 districts of Adapazarı that are the limits of the area covered in this study.

2.1. SU database

The buildings reported by SU were situated in the locations in Fig. 2 where the districts in the city have been numbered, and the number of stories of these collapsed buildings coded to allow a rapid assessment of the building heights. The total number of buildings in the data set was 241, all were reinforced concrete frames. Building heights are as much a function of the economics of the corresponding usage as of zoning laws enacted by the city government. In central urban areas in Turkey there is commonly a mixed form of occupation, where small businesses (small grocery shops, barber shops, professional offices, etc.) are dispersed among the residences under the same roof. The ground story is usually made as free of