

## Contribution of Reinforced Concrete Infills to Seismic Behavior of Structural Systems

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*The object of this paper is to report an experimental investigation on the internal force distribution in reinforced concrete (RC) frames with added RC walls. The paper describes a special test setup and force transducers designed to determine the internal forces. The transducers were designed so that the stiffness change in the column would be minimal. The paper reports the results of a test in which a 1/3-scale, two-story, three-bay RC frame was first subjected to damaging lateral-drift reversals and was then strengthened with the addition of an RC wall to fill the middle bay and subjected again to drift reversals. The frame, built purposely with the deficiencies commonly observed in buildings in Turkey, was displaced to a roof-drift ratio of 1.6%. The frame developed a base shear force of approximately 14 kN. Two RC walls were then cast to fill the middle bay. Tested in that condition to a drift of 1.6%, the modified structure developed a base shear force of approximately 53 kN. The observed hysteresis loops were stable even though slip of the longitudinal bars was observed at the splices in the interior columns.*

**Keywords:** loading; rehabilitation; reinforced concrete; repair; strength.

### INTRODUCTION

The characteristics of typical buildings in Turkey include flexible columns, soft stories, nonseismic detailing, and strong beam-weak column systems. It was also observed that a great majority of these buildings had inadequate lateral stiffness. Therefore, a large number of reinforced concrete (RC) buildings damaged in recent earthquakes required extensive strengthening and repairing. The authors define strengthening as the rehabilitation to upgrade the strength of existing structures. Strengthening made by adding RC infills to the selected bays also increases the lateral stiffness of the structure significantly. Different methods and techniques have been developed and applied in the past three decades to strengthen existing structures (Wyllie 1996; Ersoy 1996; Sugano 1996). These strengthening techniques for framed structures include addition of infill walls, addition of wing walls, concrete jacketing of columns, single and multiple precast panel walls with and without openings, steel bracings, and steel frames (Higashi and Kokusho 1975; Kahn and Hanson 1979; Liauw and Kwan 1985; Jirsa and Kreger 1989; Phan and Lew 1996). In these studies, the loading histories were either monotonic or cyclic (Endo, Adachi, and Nakanishi 1980; Higashi et al. 1980; Sugano and Fujimara 1980; Ohki and Bessho 1980; Hayashi, Niwa, and Fukuhara 1980).

Many different types of connections of the infill wall to the surrounding frame were also studied, such as shear keys, dowels, and chemical anchors (Sugano 1980; Aoyama et al. 1984). Although almost all tests in the literature were performed on one-bay, one-story frames, there are some tests on one-bay, three-story frames (Higashi, Endo, and Shimizu 1982, 1984). Studies showed that the benefit of strengthening nonductile RC

frames might be limited due to the failure of splices in the existing column made above the floor level (Valluvan, Kreger, and Jirsa 1993). Feasibility studies on different methods of seismic upgrading were also performed (Miller and Reaveley 1996; Gregorian and Gregorian 1996). It has been concluded that the simplest and the most effective way of improving the behavior of such buildings, where unsatisfactory seismic behavior is inherent in the structural system, is to provide an adequate number of structural walls. Such walls not only increase the lateral stiffness significantly but also relieve the existing nonductile frames from carrying large lateral forces.

In Turkey, rehabilitation of frames damaged in earthquakes by introducing RC infills was first applied after the 1969 Bartın earthquake. Starting with the 1992 Erzincan earthquake, structural rehabilitation by RC infills has been used extensively. As a result of these rehabilitation projects, there has been a significant increase in research related to rehabilitation. A review related to RC-infilled frames in the literature shows that the first published experimental research in this area is the one reported by Ersoy and Uzsoy in 1971 (Ersoy 1971). The researchers tested nine 1/2-scale, one-story, one-bay frames with RC infills under monotonic loading. It was concluded that the presence of the infill increased the lateral load capacity of the frame and reduced the lateral displacement at failure significantly. Subsequently, several research projects were carried out on one-bay, two-story frames at METU Structural Mechanics Laboratory (Altin, Ersoy, and Tankut 1992; Sonuvar 2001). Some tests were also made at the Bogazici University as a part of this program (Türk 1998).

As stated previously, one of the most efficient methods for decreasing the vulnerability of existing RC frames to earthquake effects is the addition of structural walls. The critical issue in the analysis of the structure with the added walls is the distribution of the shear force to the walls and the frame. There are several issues that need to be taken into account. Among them, the two most significant ones are: a) the wall and the frame members, built at different times, experience different cracking histories; and b) the stiffness of the infilled frame is influenced by the type and effectiveness of the connections made between the infill and the frame members (Altin, Ersoy, and Tankut 1992; Sonuvar 2001). Therefore, determination of the internal force distribution in the structure requires experiments to test some of the fundamental

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