ENERGY ASPECT OF COUPLED SHEAR WALLS BEHAVIOUR IN AN EARTHQUAKE

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SUMMARY

Experimental results of four coupled shear walls specimens (three stories, 1:3 scale) tested under simulated seismic load are reviewed. Varying parameters are the depth of coupling beams and details in wall and beam reinforcement. Appearance and development of cracks, stiffness degradation and failures mechanism are analyzed. Hysteretic behaviour is analyzed through the relations P - Δ, P - ε, M - θ and Q - γ. The results presented in the paper include the relationships following: dissipation energy – displacement, non-dimensional energy – plastic excursion index, absorption of energy – displacement, ductility coefficient – displacement, and ductility coefficient – – energy absorption factor. The specimen with stiffer coupling beams, diagonally reinforced and symmetrically reinforced walls, has showed the most favourable behaviour. According to the experimental results and the analysis presented, it has been concluded that the proper detailing of coupling beams and walls is important for the behaviour of coupled shear walls under seismic load.

INTRODUCTION

Shear walls with openings (coupled shear walls) are relatively economic and efficient structural element to resist lateral forces in medium tall and tall building structures. Observations of the performance of buildings during recent earthquakes have indicated that adequately designed coupled shear walls limit both structural and nonstructural damage. Reinforced concrete shear walls without openings and their behaviour to earthquake induced loading have been studied more often than coupled shear walls. As the latter offer more flexible designing of tall buildings, their investigation in earthquake conditions arises current interest.

A special structural system which shows great potential to accept earthquake induced loading and offers a satisfactory response in the sense of current design philosophy is the shear walls with openings. This paper presents investigation results which show the influence of coupling beams and vertical walls relationship upon behaviour under earthquake conditions. The purpose of these investigations was to obtain favourable stiffness and strength relations between coupling beams and vertical walls by providing mechanisms for energy dissipation, i.e., by forming plastic hinges first in the coupling beams and then in the walls.

SPECIMEN DESCRIPTION AND INVESTIGATION METHODOLOGY

Four coupled shear wall specimens were constructed and tested in the laboratory of the Institute for Earthquake Engineering and Engineering Seismology in Skopje, Macedonia. The selected specimens represent the behaviour of medium high buildings. According to the prototype dimensions and available equipment, the scale 1:3 has been adopted for specimens. Tests were carried out in laboratory conditions and certain simplifications of specimens were necessary, related to reinforcement splices and the reinforcing of wall ends.

Numerous analytical and experimental investigations of coupled shear walls (Paulay & Binney 1974, Paulay 1981, Saatcioglu at al. 1980, Folic & Zoric 1990) indicate that the ends of coupling beams and wall bases are critical zones in which nonlinear deformations develop. Models with three lower stories of the structure were

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adopted. Nevertheless, the influence of upper, omitted model structure was carefully analyzed and simulated. Previous investigations (Paulay 1981, Saatcioglu at al. 1980, Valenas at al. 1979) show that plastic hinges develop nearly at the same time in coupling beams of the second story and in beams of other upper stories with similar responses. Therefore, it can be said that the model formed in such a way can be used as a specimen with representative prototype behaviour in critical zones. This is done for the purpose of the failure mechanism investigation.

Two series of members each represented by two specimens were designed. Members within each of these series have the same geometrical characteristics. The varying parameters are coupling beams depth and detailing of walls and coupling beam reinforcement. The geometric characteristics and reinforcement detailing in beams and walls of the tested specimens are given in Figure 1.

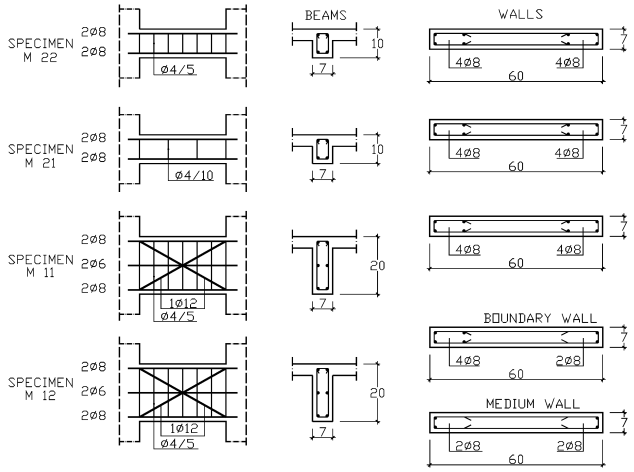

Figure 1. Beams and walls reinforcement of tested specimens.

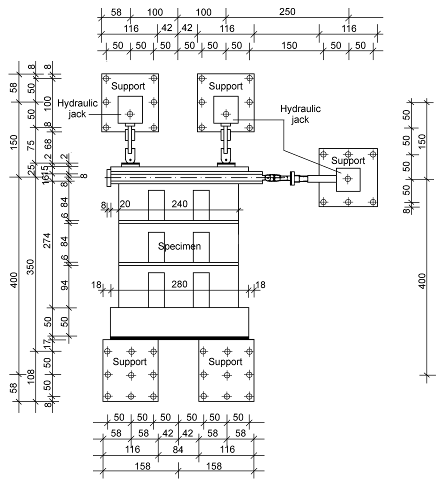

Figure 2. Specimen and testing equipment.

The basic difference between the specimens concerns the depth of coupling beams. Specimens M11 and M12 have diagonally reinforced coupling beams with dimensions of 20/7 cm, while specimens M21 and M22 have conventionally reinforced ones of the size 10/7 cm. For the first group of specimens, the shear parameter (span−to−depth ratio) is 0.75, while for the second one it is 1.50. This parameter represents the relation $M / Q\, d = a / d$, i.e. the relationship between one half of the span and the coupling beam depth. These relations are also usual for real structures.

Figure 2 shows the position of the tested wall specimens and the arrangement of equipment. Vertical load was applied to the specimens by means of two hydraulic jacks positioned on top and horizontal load by means of the third jack positioned on the level of the third floor.

The specimens have were subjected to a cyclic horizontal displacement in accordance to the programme presented in Figure 3, and previously loaded by permanent gravitational loading on their top. Horizontal loading was applied by a hydraulic jack on the third storey. The jack was connected with specimen equipment consisting of steel parts and a load measuring device.

The application of certain loading phases was determined on the basis of the results of a simulated failure mechanism with designed material properties. During tests, vertical loading was constant, and the specimen's top was exposed to forces simulating the influence of upper stories coupling beams on walls.