The elasto-plastic response of coupled shear walls under cyclic reversed loading

The Elasto-Plastic Response of Coupled Shear Walls under Cyclic Reversed Loading

Comportement élasto-plastique de parois de cisaillement sous charge cyclique alternée

Elasto-plastisches Verhalten von Schubwänden unter zyklischer Wechselbelastung

T. PAULAY
Reader in Civil Engineering
University of Canterbury
New Zealand

Shear walls provide one of the most effective means to resist lateral loads in earthquake resistant multistorey buildings. In the majority of cases it is neither possible nor economical to design shear walls so as to resist the siesmic forces, generated during a very large earthquake, within the elastic range of behaviour. In the use of shear walls too reliance must be placed on energy absorbtion in the plastic range. Because of the geometry of such structures and the damage encountered in some nominally reinforced concrete shear walls some scepticism exists with regards ductility. It is for this reason that in a continuing research program various aspects of the seismic behaviour of shear walls is being studied at the University of Canterbury.

One recent project examined the behaviour of coupled shear walls under simulated cyclic loading. The critical members of such a structure, models of which are shown in Fig. 1, are the coupling beams. These are usually rather short and often relatively deep. With only a moderate flexural steel content high shearing forces can be generated when the yield capacity of the flexural reinforcement is being utilised. These shear forces, causing diagonal cracking over the whole extent of the coupling beams, dominate their behaviour. During reversed cyclic loading the diagonal cracks, formed in one direction, must close before diagonal compression, necessary for the effective working of stirrup shear reinforcement, can develop. This usually results in large displacements at low loads. Progressive yielding in the top and bottom flexural reinforcement leads to a relatively large continuous crack at the junction of the beams with the coupled walls. The high shear force cannot be transferred across this crack, where grinding of the concrete occurs. After only a few load cycles a sliding shear failure occurs. Only limited ductility can be achieved in such beams.[1,2.]

Further studies showed that if, instead of the conventional flexural and shear reinforcement, only diagonal bars are used in coupling beams, the whole of the shear force can be effectively transferred from one wall to another one with very little assistance from the surrounding concrete. Stable hysteresis loops and large ductility were obtained for such coupling beams.[2,3.] The diagonal bars are assembled in a cage with ample spiral binding or ties so that instability failure during compression loading does not occur.

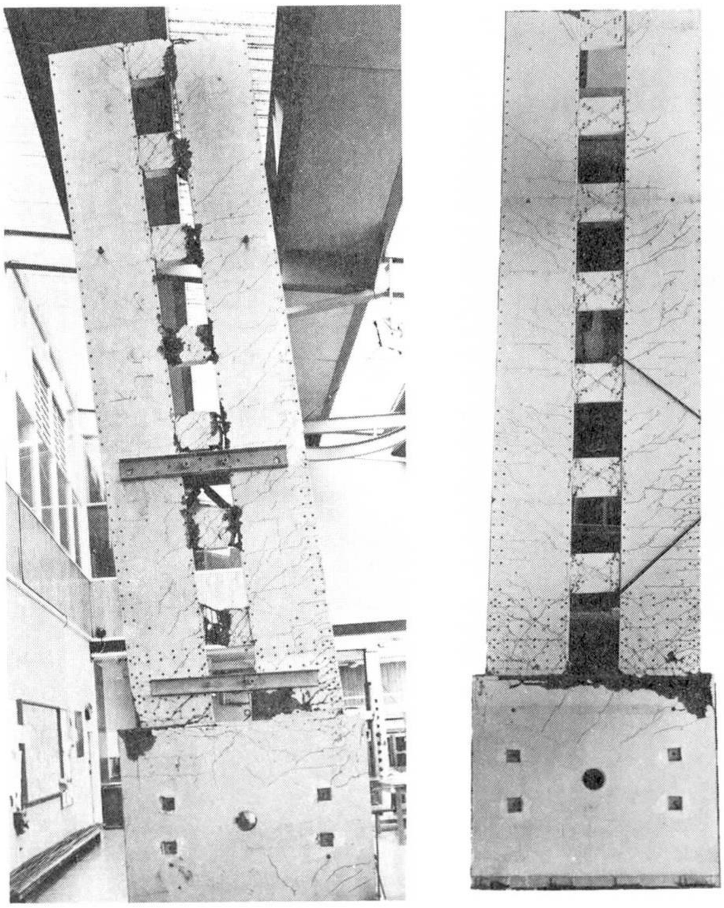

Fig. 1. One quarter full size reinforced concrete coupled shear wall models with conventional (on the left) and diagonal (on the right) reinforcement in the coupling beams.

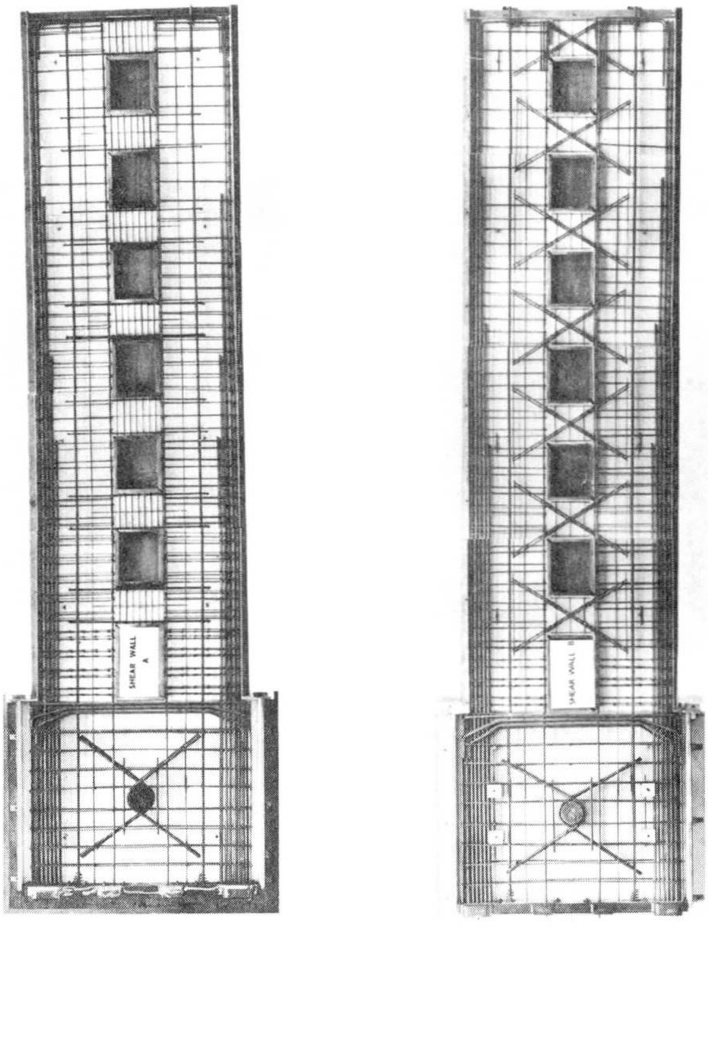

Fig. 2. The arrangement of the beam reinforcement in two otherwise identical coupled shear wall models.

In two one quarter full size seven storey reinforced concrete coupled shear wall models the various effects of the differently reinforced coupling beams upon overall behaviour were studied. The identical wall reinforcement for the two models with the different coupling beam steel are shown in Fig. 2. Lateral point loads of equal intensity were applied at the 3rd, 5th and 7th floors in alternate directions. Fig. 1 shows that, as expected, in Wall A all coupling beams failed by sliding shear. In spite of this considerable ductility was observed with only moderate loss of strength during progressive reversed loading into the plastic range. The damage appears to be much less in the case of Wall B shown in Fig. 1. The full capacity of the beams were maintained in this second test till the end, when the base of the wall failed.

The load-displacement (at the 7th floor) relationship for both specimens is presented in Fig. 3. This clearly shows the excellent histeretic properties of the shear wall with diagonally reinforced coupling beams. The full strength of the structure could be attained four times in each direction when roof level displacement, corresponding with ductility factors of 4 to 12, were imposed.

The tests have shown that carefully designed and detailed coupled shear walls can possess all the qualities required to give the highest degree of protection against damage in moderate earthquakes and to ensure survival during catastrophic ground shaking. Walls with this type of reinforcing are now being constructed in New Zealand.

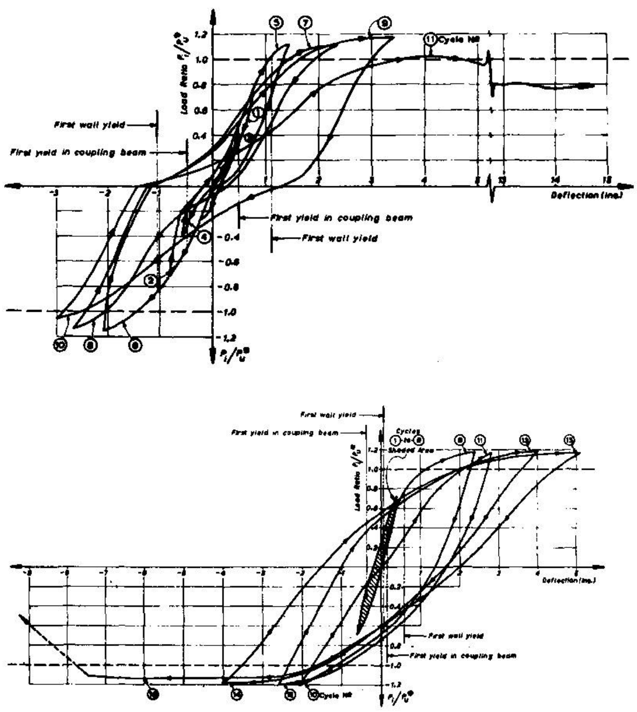

Fig. 3 Load - roof displacement relationship for walls with conventionally reinforced beams (above) and diagonally reinforced coupling beams (below)
(P_i = applied load)
(P_u^* = theoretical ultimate load)

References

1. Paulay, T., "Coupling Beams of Reinforced Concrete Shear Walls", Journal of the Structural Division, American Society of Civil Engineers, Vol. 97, No. ST3, March 1971, pp. 843-862.
2. Paulay, T., "Simulated Seismic Loading of Spandrel Beams", Journal of the Structural Division, American Society of Civil Engineers, to be published in September 1971.
3. Paulay, T., "Some Seismic Aspects of Coupled Shear Walls", Proceedings 5th World Conference of Earthquake Engineering, Rome, 1973, Vol. 2. Paper 245, p. 4.

Leere Seite
Blank page
Page vide