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Application of Diagonal Reinforcement to Reinforced Concrete and Masonry Short Columns

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The paper describes the use of diagonal reinforcement in concrete members to prevent brittle shear failure and to ensure ductile behavior in earthquake resistant structures. The use of diagonal reinforcement was proposed by T. Paulay to provide ductility in coupling beams and has been used in practical buildings. However, past earthquakes have revealed that brittle shear failure takes place more frequently in short columns than in beams, and can lead to overall structural failure. The authors have used the diagonally reinforcing system in short reinforced concrete columns and in wall-columns of reinforced concrete-grouted masonry, and have developed design formulas to predict the maximum load carrying capacity and ductility.

Figure 1 shows the hysteresis loops obtained from the preliminary tests of diagonally reinforced short columns. It can be clearly seen that the behavior of the diagonally reinforced column is far better than that of an ordinary reinforced concrete column, with respect not only to maximum load capacity but also to deformability without load degradation, shape of hysteresis loops, and energy dissipation. The superiority of the diagonal reinforcement has been confirmed by a series of experiments using full scale specimens, as indicated in Figs. 2 - 4. The physical model used to predict the ultimate load carrying capacity consists of two basic resisting mechanisms, a beam mechanism and an arch mechanism. This is shown in Fig. 5. Ultimate load capacity is obtained by the summation of the load capacities of the basic mechanisms according to the generalized addition theorem. Correlation between the experimental and predicted load capacities can be seen in Fig. 6. The proposed diagonal arrangement of main reinforcement for reinforced concrete column has been used in apartment buildings designed by the National Housing Cooperation of Japan, as shown in Figs. 7 and 8. In addition to its use in ordinary short columns, the diagonal system is very effective in the case of columns which are shortened in their clear height by wing wall, as in the school buildings shown in Fig. 9. The system is also applicable to concrete-grouted brick masonry wall. Ductile behavior can be anticipated even in brick masonry structures, as shown in Fig. 10.

The following conclusion can be drawn from the experimental and theoretical work:

(1) The diagonal reinforcement system is very effective in increasing the shear capacity and in improving the earthquake-resistant characteristics, such as ductility and energy dissipation, of reinforced concrete columns and masonry wall-columns.

(2) The maximum shear capacity, ductility and energy dissipation can be controlled by the amount of diagonal reinforcement.

(3) At least sixty percent of the main reinforcement should be arranged diagonally in columns to guarantee ductile performance during earthquakes.

(4) The maximum load carrying capacity of diagonally reinforced members can be predicted with reasonable accuracy by the proposed analytical method.

APPLICATION OF DIAGONAL REINFORCEMENT TO REINFORCED CONCRETE AND MASONRY SHORT COLUMNS

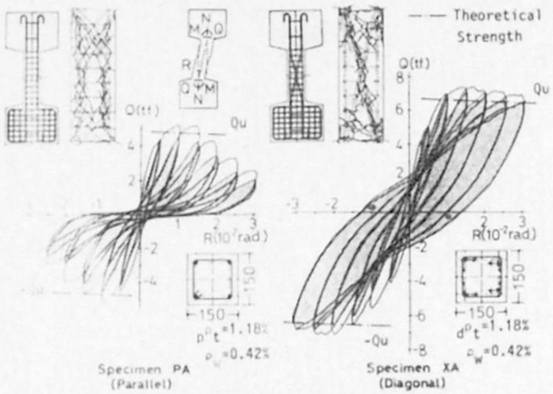

Fig.1 PRELIMINARY TEST

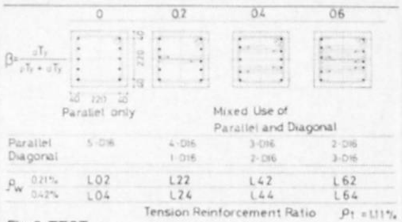

Fig.2 TEST PROGRAM

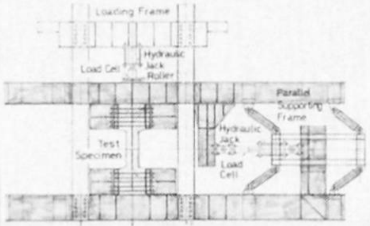

Fig.3 LOADING SET UP

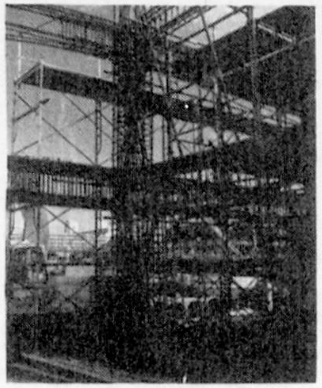

Fig.7 CONSTRUCTION SITE

Fig.8 REINFORCING ARRANGEMENT

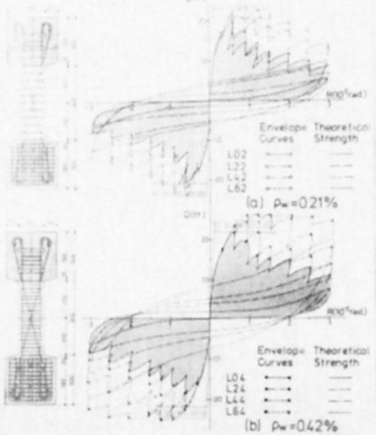

Fig.4 ENVELOPE CURVES

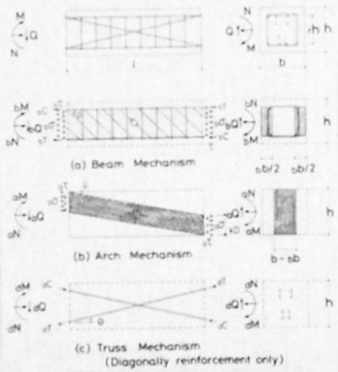

Fig.5 RESISTANT MECHANISM

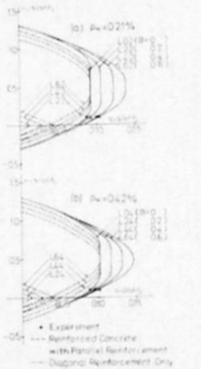

Fig.6 COMPARISON OF TEST AND THEORY

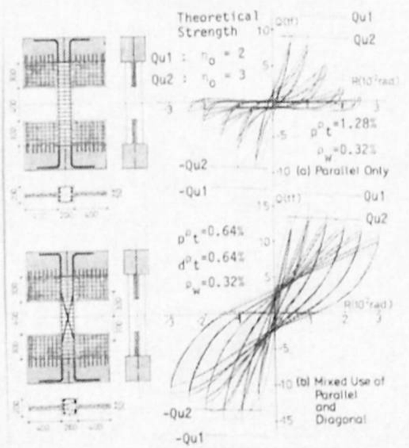

Fig.9 APPLICATION TO SHORT COLUMNS

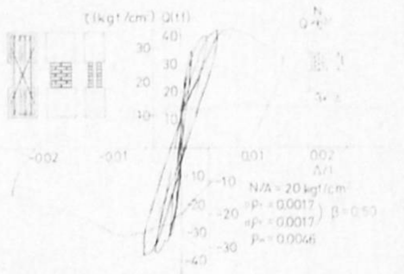

Fig.10 APPLICATION TO A MASONRY COLUMN