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A NEW AND EFFICIENT APPROACH FOR REPAIR AND STRENGTHENING OF SHORT COLUMNS

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ABSTRACT

Short column failures are among the major causes of damages in buildings. Especially in many developing countries inadequate control both in the design and the construction levels are the reason for short columns. The failures are due to low concrete strength, poor detailing, and alterations of architectural layouts without consulting to structural engineer. In this paper, an efficient and reliable method to repair and strengthen reinforced concrete short columns in existing and damaged structures is presented. The technique is actually to provide enough confinement of concrete against sudden brittle failure. Two approaches were used. The first is the application of two U-shaped steel laminates to the specimens using epoxy adhesives. Although this approach is found to be satisfactory, it requires skilled and careful workmanship and is expensive. Therefore, the second approach of the application post tensioned metal strips to columns utilizing a strapping tool together with metal clips is adopted. Various types of specimens were tested under bending, shear, and axial compression to simulate the effect of earthquake loading. The experiments were carried out using displacement controlled static alternating hydraulic jacks. The results show that the failure of short columns during earthquakes can be prevented by strengthening with the post tensioned metal strips around columns. The results also show that the technique increases both the strength and ductility of the short column.

KEYWORDS

Reinforced concrete; short columns; repair; strengthening; metal strips; strength; ductility.

INTRODUCTION

A research project is in progress at the Faculty of Civil Engineering of Istanbul Technical University for the last four years to develop the methods of retrofitting techniques for reinforced concrete buildings of prime importance such as schools and hospitals which were built according to former seismic codes. Most reinforced concrete buildings failed and were heavily or lightly damaged during the earthquake of March 13, 1992 in Erzincan, Turkey. Post-earthquake damage assessment of some of these buildings revealed that the damages were due to poorly reinforced structural elements and low concrete strength. Quite a high number of failures were due to short columns. It is observed that most of the short columns are created by the placement of non-structural partition walls, addition of some partitions for window openings at the basement floor. Short columns are defined according to their column height to depth (h/D) ratios. Therefore, a cost-effective technique of strengthening and repairing short columns is needed. Available literature shows that a large number of tests have been performed to study the behavior of concrete beams in shear. There have been some work in the area of the shear design of reinforced concrete members (Aoyama, 1993). There have been also some tests on columns (Jirsa and Umehara, 1982). Shear capacity of columns under combined bending, shear, and axial loading has been investigated with increasing loading (Gercek and Boduroglu, 1994). Repair and strengthening of columns are as important as the shear capacity of columns. There are different temporary and permanent restoration techniques developed such as using steel bar, wirerope, adhesive tape, steel plate which are used to increase the lateral confinement of columns under axial load only (Okada *et al.*, 1987). Strengthening of a column can also be done by covering columns by carbon fibers under lateral load (Katsuma *et al.*, 1987). Another recent method of repair and strengthening reinforced concrete beams and columns is to wrap the member by metal strips (Pilakoutas and Dritsos, 1992; Frangou and Pilakoutas, 1994). This technique is applied experimentally to beams and beam-columns. Taking into account all these techniques, the last approach is adopted for repair and strengthening of short columns. In this study, extremely short column is defined as a column with a clear height to depth ratio equal or less than two.

EXPERIMENTAL SET-UP AND PROGRAM

In the experimental program, twenty four test specimens, representing full scale models of short columns in a medium-rise reinforced concrete building. The column is loaded axially together with shear and end moments to simulate the similar loading conditions during an earthquake. For test set-up, a special reinforced concrete reaction wall is designed to provide lateral support for the specimen and the hydraulic jack. The hydraulic jack is modified into a displacement controlled loading mechanism with special software and mechanical equipment. The axial load in the column is provided by a hydraulic jack. The schematic test set-up is shown in Fig.1. The reinforcement arrangement, dimensions of the specimens and internal force diagrams are shown in Fig.2. In preparing the test specimens different hoop spacings are used to observe the failure type. Considering the practice in uncontrolled construction of placing the hoops with large spacings, certain specimens are prepared without any hoops along the height of the short column. A specimen was subjected to a constant axial load and lateral load reversals maintaining the top and bottom stubs parallel. The loading history consisting of several cycles of increasing lateral displacements is shown in Fig.3. The lateral displacement was measured at column mid height. As a result lateral load vs. displacement response, stiffness and strength degradation and ductility of the specimens were obtained during the application of loading history.

RESULTS

The column shear vs. displacement curves of a typical short column without hoops is shown in Fig.4. The sudden brittle failure occurs due to a slight increase in the controlled displacement. The failure shear force was compared with the shear force formulas of (JSIM - Japanese Seismic Indexing Method, 1977), (ACI-318, 1989) and (TS500, 1984). This sudden brittle failure was not forecasted by neither of these formulas. The similar column was tested with very small increments in controlled displacement to catch the brittle failure of concrete in shear. The results were presented in Fig.5. The damaged specimen was repaired using steel strips and was retested to failure. It can be seen that the energy dissipation capacity of the repaired specimen is much larger than the previous case. The results of the test of strengthened column specimen is shown in Fig.7.

CONCLUSION

The test results show that wrapping of columns by metal strips can improve the earthquake-resistant capacity of existing and/or damaged reinforced concrete short columns for square cross-sections. The result is also applicable to columns of rectangular and circular cross sections. The metal strips should be protected as usual against corrosion and fire. The technique is easy to apply and very cheap.

ACKNOWLEDGEMENTS

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REFERENCES

ACI 318-89. (1989). Building Code Requirements for Reinforced Concrete and Commentary- ACI 318R-89. American Concrete Institute, Detroit, Michigan.

Aoyama, H. (1993). Design philosophy for shear in earthquake resistance in Japan. In: Earthquake Resistance of Reinforced Concrete Structures (T. Okada, Ed.), pp.407-418. Univ. of Tokyo Press.

Frangou, M. and K. Pilakoutas (1994). Novel technique for the repair and strengthening of RC columns. Proc. of The Fifth U.S. Natl. Con. on Earthq. Engng., pp.637-646.

Gercek, M. and M.H. Boduroglu (1994). An experimental study on shear carrying capacity of columns under combined bending,shear and axial loading. Proc. of The Fifth U.S. Natl. Con. on Earthq. Engng., pp.785-794.

JSIM (1977). Standard for Evaluation of Seismic Capacity of Existing Reinforced Concrete Buildings. Japan Building Disaster Prevention Association, Ministry of Construction, Tokyo.

Katsumata, H., Kobatake and T. Takeda (1987). A study on the strengthening with carbon fiber for earthquake-resistant capacity of existing reinforced columns. Proc. of the workshop on repair and retrofit of existing structures, U.S.-Japan Panel on Wind and Seismic Effects, Tsukuba, Japan, pp. 18.1- 18.23.

Pilakoutas, K. and S. Dritsos (1992). Design of structural repair schemes for RC structures. Proc. of the 10th WCEE, pp.5183-5186.

Okada, T., T. Endo, M. Okubo and M. Yoshimura (1987). Methods of temporary and permanent restoration applied to reinforced concrete buildings damaged by earthquakes. Proc. of the workshop on repair and retrofit of existing structures, U.S.-Japan Panel on Wind and Seismic Effects, Tsukuba, Japan, pp.10.1-10.19.

TS 500 (1984). Building Code Requirements for Reinforced Concrete. Turkish Standards Institute, Ankara.

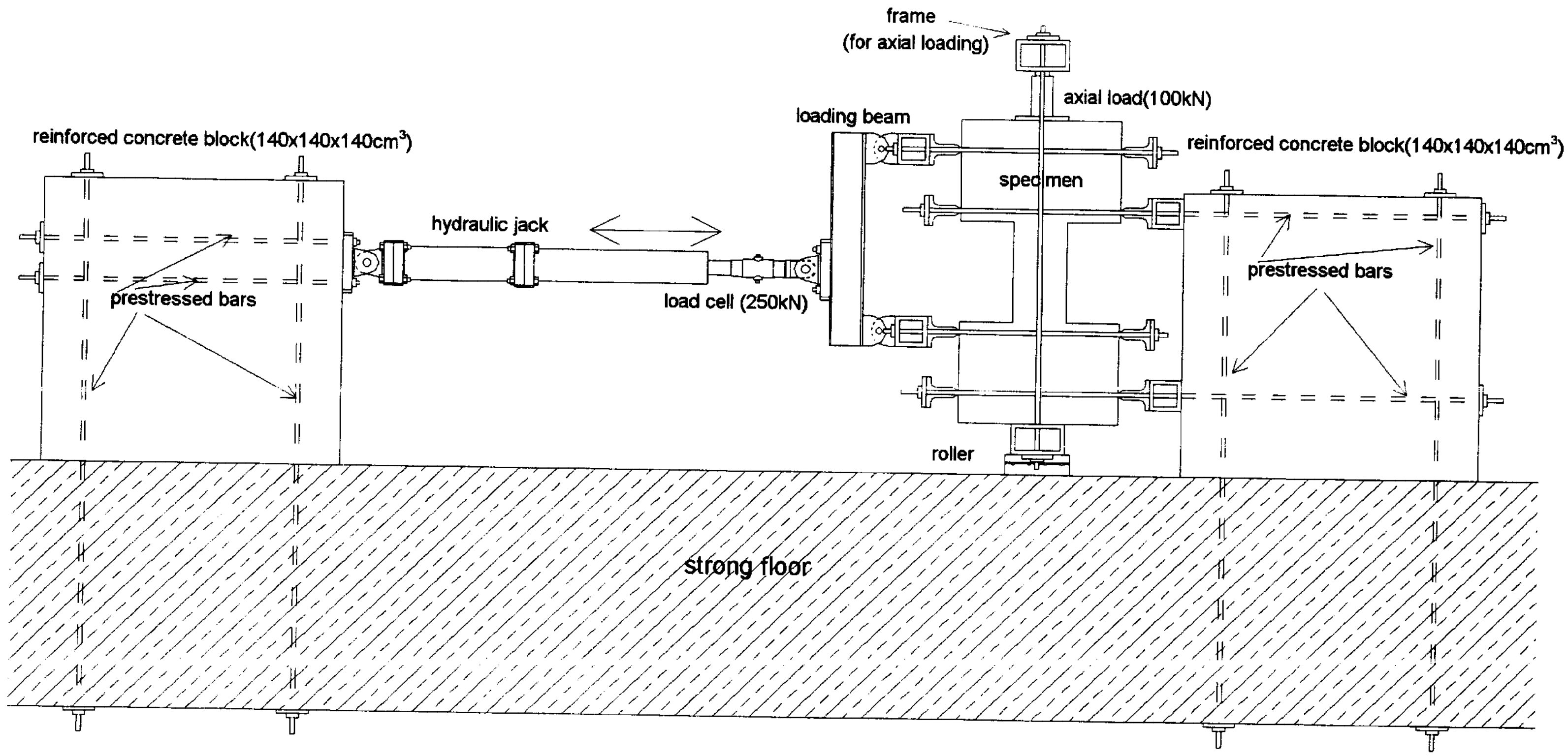

Fig1. Test Setup

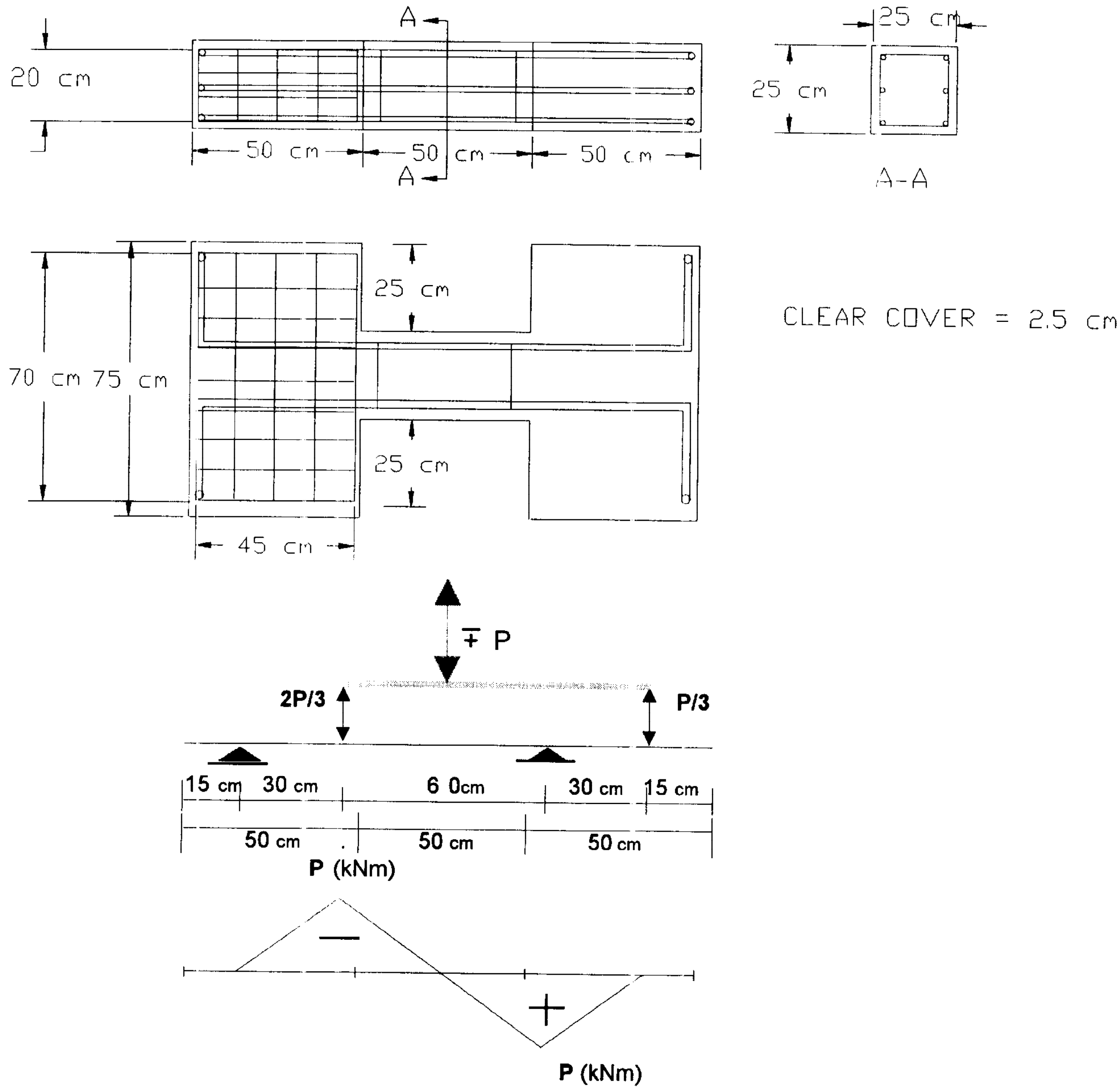

Fig.2 Test Speciment

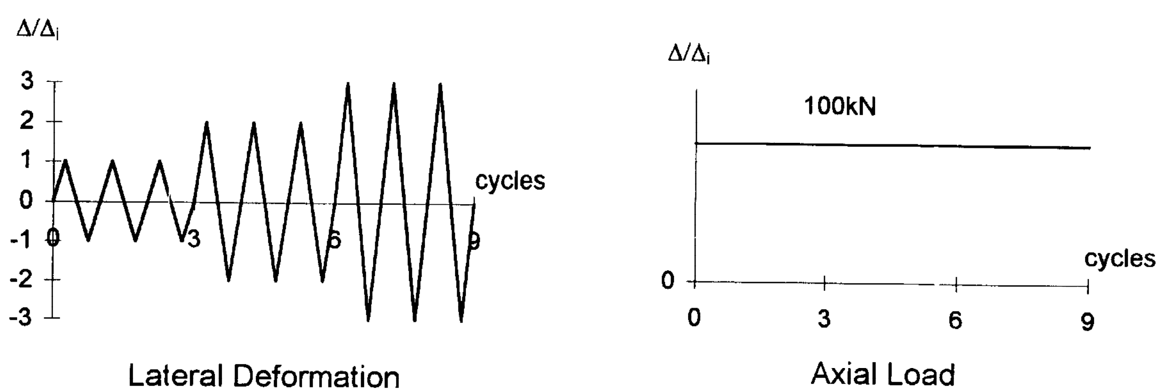

Fig.3 Loading History

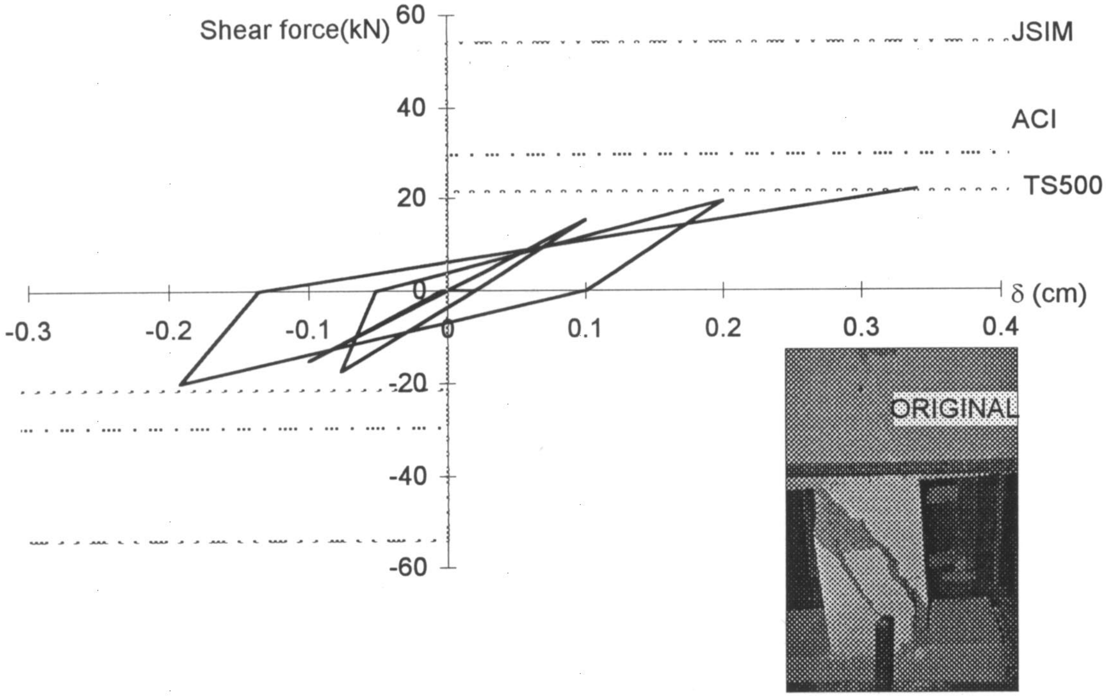

Fig4. Brittle Failure of Original Column

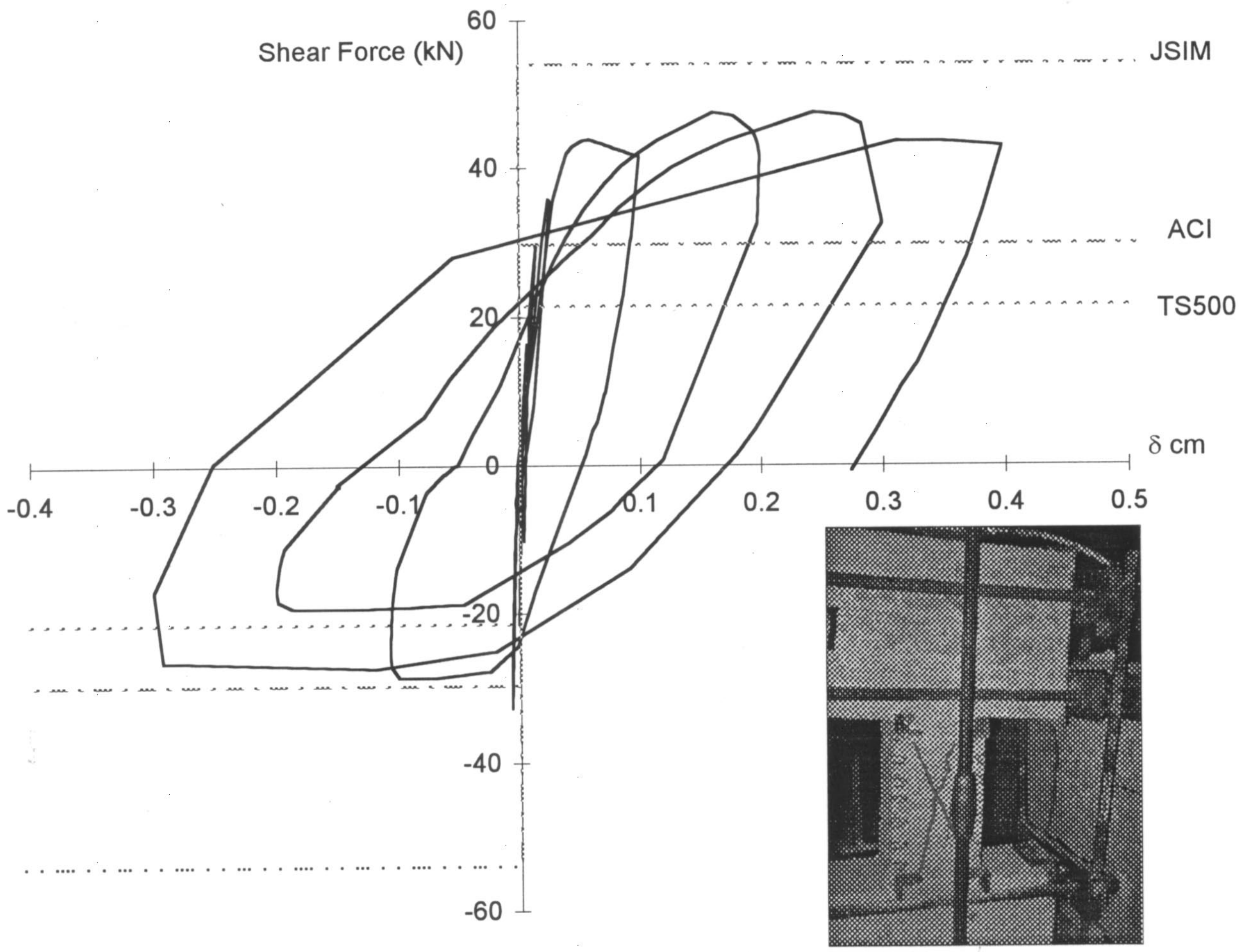

Fig5. Slightly Damaged Original Column

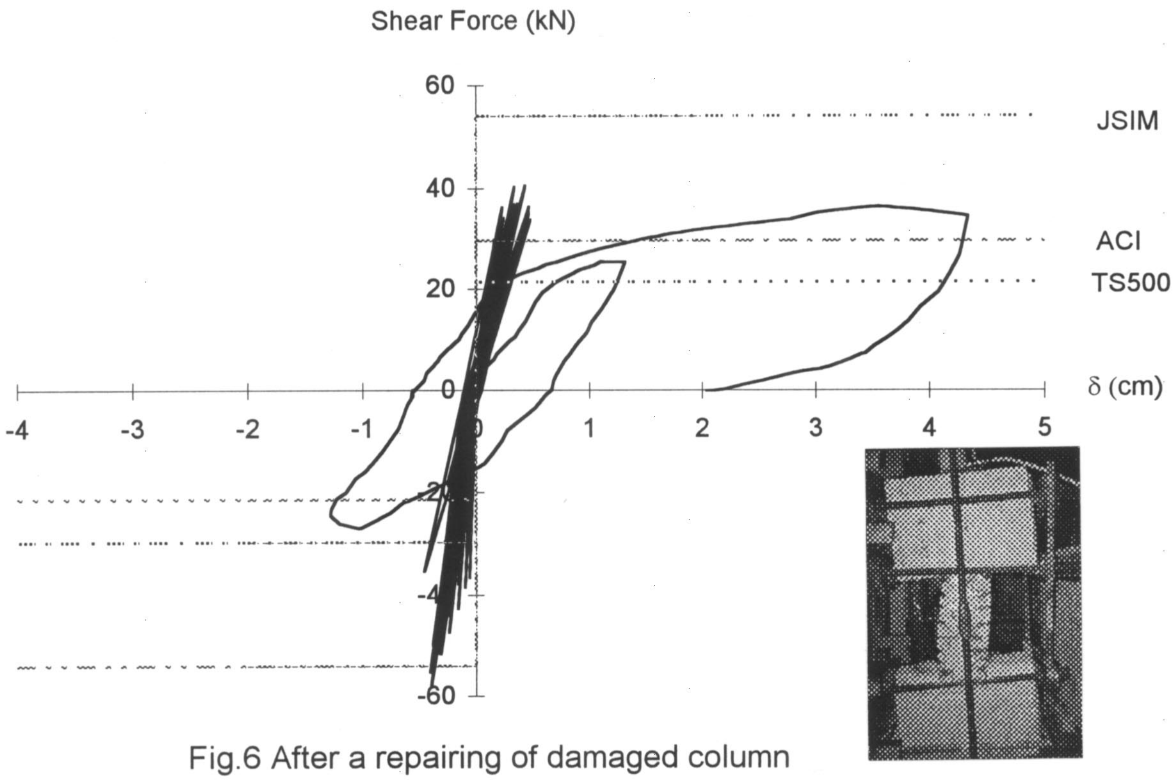

Fig.6 After a repairing of damaged column

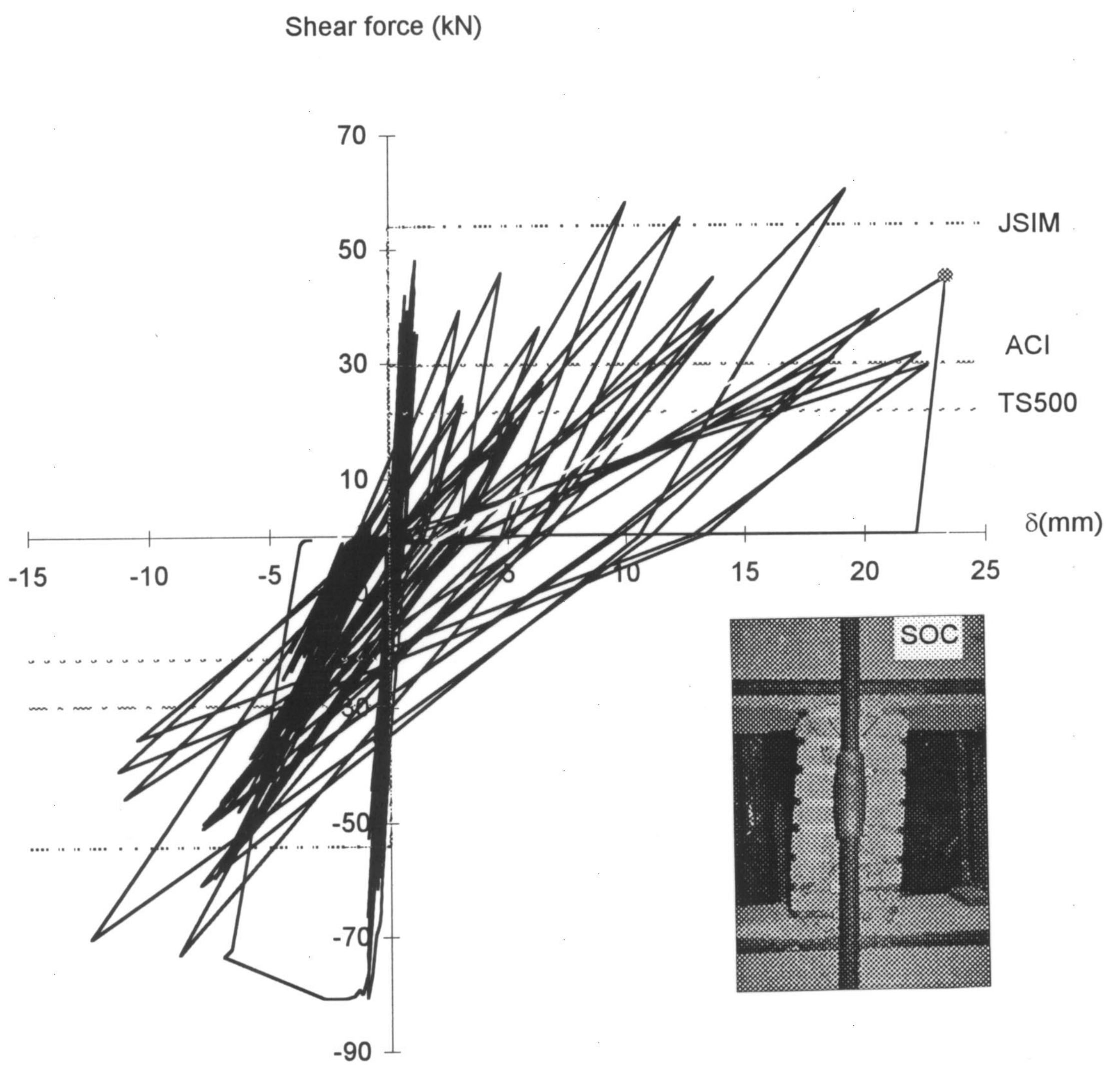

Fig.7 Strenghtened Original Column