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# Reinforced Concrete Deep Beams Strengthened in Shear

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**Summary**

Results of tests in nine reinforced concrete deep beams, simply supported and submitted to two top point loads (seven strengthened in shear) are shown. The seven strengthened beams were 800 x 150 x 1600 mm with $f_c$ around 50 MPa, designed with insufficient shear reinforcement and loaded previously until service load. The main strengthened variables were the type, position and amount of the reinforcement positioned. The strengthening reinforcement were positioned with special mortar in ducts sawn on the surface of the beam. The results showed that the strengthening technique adopted worked properly without any problem of anchorage of the glued reinforcement. Besides this, the strengthened beams reached considerable higher ultimate loads and behaved very well in comparison with the two reference ones.

**Keywords:** Deep Beams, Reinforced Concrete, Repair, Shear Strengthening.

## 1. Experimental Program

The main objective of the research was to investigate the behaviour of reinforced concrete deep beams strengthened in shear, after being loaded to service load, in comparison to a monolithic beam with the full reinforcement. This work followed experimental investigations done at the University of Brasília in deep beams in 1994 and in strengthened columns in 1996, under two of the main research interests of the Structures Group, *"Experimental Analysis of Structures"* and *"Pathology and Recuperation of Structures"*. The investigation was basically done in four steps: A reference beam with insufficient shear reinforcement was initially tested until rupture (1$^{st}$step). It was adopted after this first test about 70% of the ultimate load was the level that all others beams would be loaded (2$^{nd}$step) before strengthening (3$^{nd}$step). These beams and beam 2M (monolithic) were then tested up to failure (4$^{th}$step). The strengthening reinforcement were positioned with high performance mortar in ducts sawn on the surface of the beam. The behaviour of the beams tested were analysed through the strains of the flexural and shear reinforcement, and of the concrete, by

the horizontal and vertical deflections, by the developing and widths of the cracks, and by the ultimate load and mechanism of rupture. The shear reinforcement of the reference beam (1) and for all the beams to be strengthened was similar, an orthogonal mesh with smooth bars. The strengthening shear reinforcement were also of smooth bars, as horizontal and vertical bars (2/S to 4/S, 6/S and 8/S), and of inclined reinforcement (5/S and 7/S). Figures 1 and 2 present the detailing of the beams 5/S and 7/S respectively. The dotted lines in these figures are the initial reinforcement and the continuous line are the strengthening reinforcement positioned later. Beams 2/S, 3/S, 4/S, 6/S and 8/S were strengthened with the same amount of orthogonal reinforcement, but with different detailing.

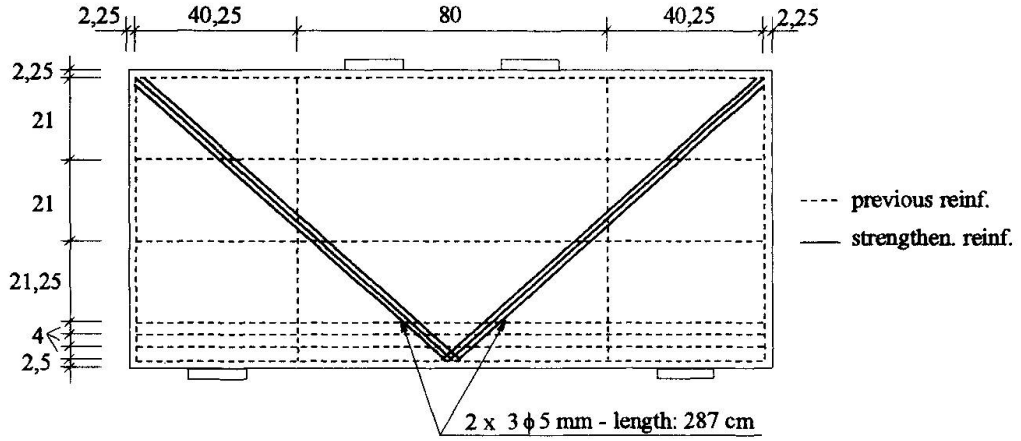


*Fig. 1 – Beam 5/S strengthening reinforcement detail (cm)*

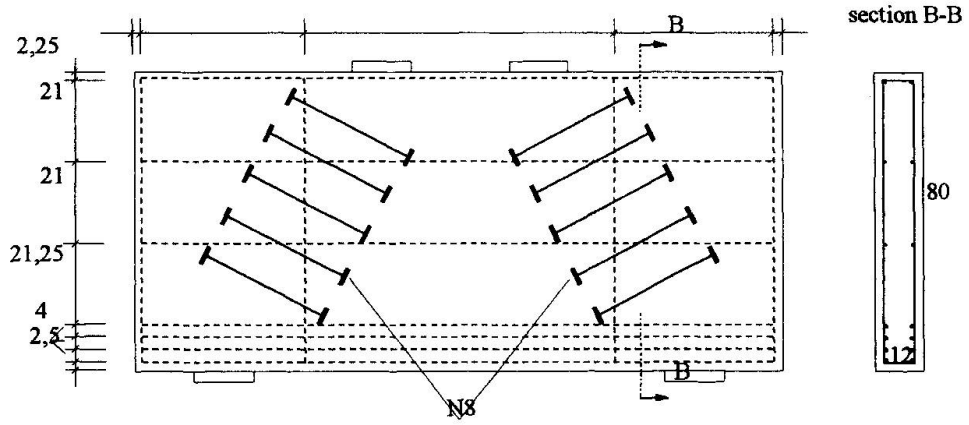


*Fig. 2– Beam 7/S strengthening reinforcement detail*