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STRESS STRAIN BEHAVIOUR OF CONCRETE CONFINED BY FRP

°Shitindi R V, Kato Y, Hattori A, Miyagawa T and Fujii M
Member, Kyoto University

INTRODUCTION

A better understanding of stress- strain ($\sigma-\varepsilon$) behaviour of concrete is important as input to studies of rotation as well as earthquake behaviour of RC beams and colums. This work is part of a research on deformation of FRP-reinforced concrete flexural members. In this experiment the $\sigma-\varepsilon$ relation of concrete is investigated with special attention on the post-peak indicators: ultimate strain (ε_{ult}) and gradient of descending part (E_{des}). Varied parameters were type of confinement material and fiber volume ratio of confinement (ρ_{vf}) (Table 1).

Experiment Outline: Compression tests were conducted on 58 column specimens (29x2 replications) of rectangular section with 400mm height and core section dimensions 80 x 180mm. The confinement ratio (ρ_v) was provided to the central 200mm portion of the specimen. Concrete strength was 40N/mm^2 and 60N/mm^2. Table 2 and Fig 1 show FRP spiral properties and measured items.

Table 1: Test Variables

Series1:Effect of ρ_{vf}, E_f and f_{sf} (f_c=60N/mm^2)

Variable	Levels
Type of confinement material	AFRP(H), AFRP(P), CFRP(H)
Confinement vol. ratio, ρ_{vf} (%)	0.0 - 1.74

* (H) = sheet; (P) = spiral

Series2:Effect of f_{sf}, ρ_{vf}, and E_f (f_c=40N/mm^2)

Variable	Levels
Type of confinement material	CFRP(P), AFRP(P), GFRP(P)
Confinement vol. ratio of fiber, ρ_{vf} (%)	0.0 - 2.1

Table 2: FRP properties

	AFRP	CFRP	GFRP
Diam., mm	6	6	6
f_f, N/mm^2	1600	2570	1390
E_f kN/mm^2	64	152	44

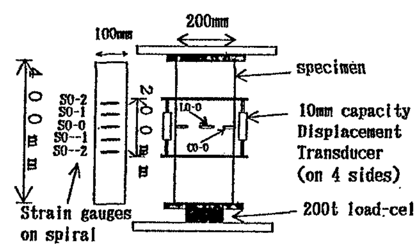

Fig 1: Test arrangement

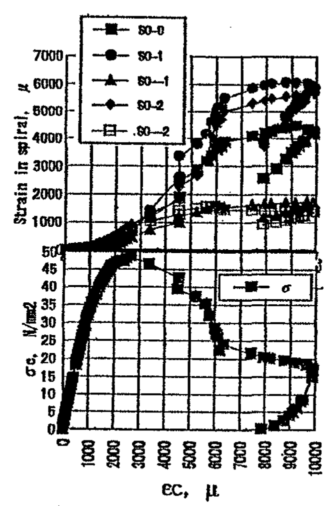

Fig 2: Spiral strains along vertical axis

RESULTS AND DISCUSSIONS

Post- peak Indicators Definitions:

ε_{ult} is strain at onset of failure. This can happen by rupture of spiral or by failure of core concrete. For spiral ρ_{vf} between 0 and 1.74% the later was usually the case whilst for sheet confinement it was the former. There was tendency for the descending curve to reach a residual strength (<30%σ_{max} for spiral; approx. 50%σ_{max} for sheet) which represents the load carried by friction across the cracked shear planes. Fig 2 shows that spiral strains tended to flatten at high ε_c. Among all spiral specimen only 3 had rupture failure. On the other hand, beyond 50%σ_{max} the damage to concrete is substancial and difficult to repair. Thus an arbitrary definition for ε_{ult} is adopted as strain at a point when stress drops to 50% of σ_{max}. E_{des} is slope of falling branch calculated using points ε_0 (strain at σ_{max}) and ε_{ult}. This definition conforms to the following $\sigma-\varepsilon$ model for descending part[1]:

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$$\sigma_c = \sigma_{max} - E_{des}(\varepsilon_c - \varepsilon_0)$$

Strains in confinement material:

Fig 2 and 3 show that after ε_c passes ε_0 there is a sudden general increase in spiral and sheet strains. Furthermore this increase vary greatly for different points around the specimen. This indicates development of strain localisation in concrete and some contribution of bond friction between spiral (or sheet) and concrete.

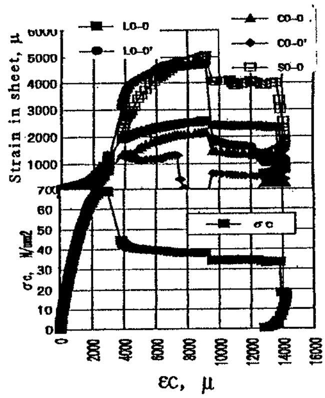

Fig 3: Spiral strains around cross-section

Effect of E_f and f_f: Since FRP has no yield point, f_f can be considered to have no influence on σ–ε behaviour when rupture of spiral does not occur. The development of lateral confining passive pressure in concrete depends on the ability of the confinement material to restrain the lateral expansion of the core concrete. This in turn depends on deformation stiffness of the spiral material, E_fA_f (A_f is section area of FRP). Fig. 4 shows that in the range considered increase in E_f can bring over 30% improvement in E_{des} for both spiral and sheet specimen. A similar influence was observed on ε_{ult} for the case sheet confined specimen. This improvement is more significant for the sheet confined specimen because it is generally more difficult to improve ductility in concrete of higher strength.

Effect of ρ_{vf}: Improvements in ε_{ult} and E_{des} due to the increase in ρ_{vf} were up to 60% and 150% respectively. Since ρ_{vf} is directly proportional to A_f it was expected to give similar degree of influence as E_f. However, particularly in spiral confined specimen, ρ_{vf} appeared to have a greater influence than E_f (approx. twice). For spiral, reduced spacing associated with increasing ρ_{vf} also contribute to the observed influence. This shows that at low ρ_{vf} spacing is a critical factor in confinement performance as it affects the ability of spiral to suport the concrete (Fig. 5) and also as it affects the effective load-carrying section area. When sheet ρ_{vf} was increased further, benefits increased at much reduced rate.

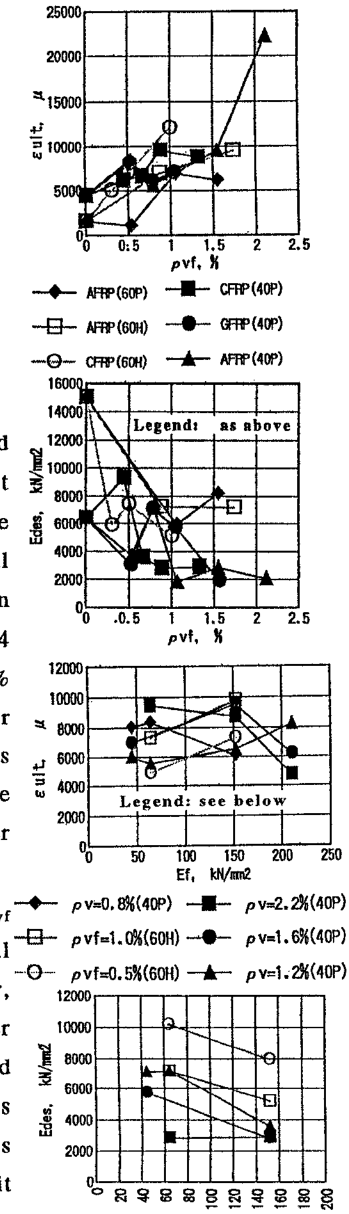

Fig 4: effect of ρ_{vf} and E_f on E_{des} and ε_{ult}

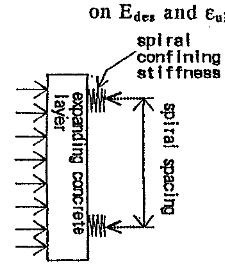

Fig 5: Effect of spacing

CONCLUSION

1. Confinement by FRP spiral or sheet ($\rho_{vf} \leqq 1.7\%$) can cause a 150% improvement in ε_{ult} and 60% in E_{des}.
2. For $\rho_{vf} < 1.7\%$ and $E_f > 40kN/mm^2$ ρ_{vf} has greater (≅twice) influence on ε_{ult} and E_{des} than E_f.

REFERENCE (1) Hoshikuma J, Kawashima K, Nagaya K "A STRESS-STRAIN MODEL FOR RC COLUMNS CONFINED BY LATERAL REINFT" Conct. Library of JSCE No 27, June 1996, pp165-176