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Numerical Prediction on Shear Strength of RC Beams without Shear Reinforcement

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1. Introduction

The shear behavior of reinforced concrete members is an important topic of structural engineering research as the shear failure of concrete structures occurs suddenly, and lead to catastrophic failure. In order to capture the shear performance, this paper presents a finite element analysis on shear strength of reinforced concrete beams without shear reinforcement. The shear strength of this kind of RC beam is not only a function of reinforcement ratio and concrete strength, but also significantly influenced by the size of the beam. That is, the size effect on shear strength of a reinforced concrete beam without shear reinforcement. Based on the understanding that tensile stress transfer through bond mechanism, strain-softening in tension and shear associated with fracture energy law of concrete are the main points which affect shear strength of RC beam, a spatially averaged continuum constitutive model which covers the reinforcement-confined concrete and plain concrete is proposed for simulating the unstable propagation of diagonal shear cracking.

2. Proposed Model for Concrete in RC Zone and Plain Concrete Zone

In dealing with RC beam with shear reinforcement as shown in **Fig.1**, the spatially averaged mechanical property of concrete near or far away from the reinforcement is supposed totally different as the concrete confined by steel bars will show stable stress release owing to the bond effecting either tension or shear. The concrete outside the bond effecting zone is supposed the same as plain concrete, showing sharp strain-softening character as the tensile stress is transferred only through the bridging action at the crack surface. These different properties should be simulated in the concrete cracking model for FEM computation as these characters decide the unstable propagation of diagonal shear cracks, which cause the sudden shear failure.

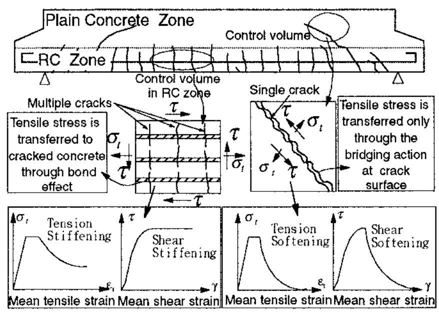


Fig.1 RC zone and plain concrete zone

The smeared crack model for concrete confined by reinforcement has been constructed by combining the constitutive law for concrete and that for reinforcing bars[1]. The constitutive law adopted for the RC zone consists the tension stiffening model and the shear transfer model. Either tension or shear model shows strain stiffening after cracking(Fig.2).

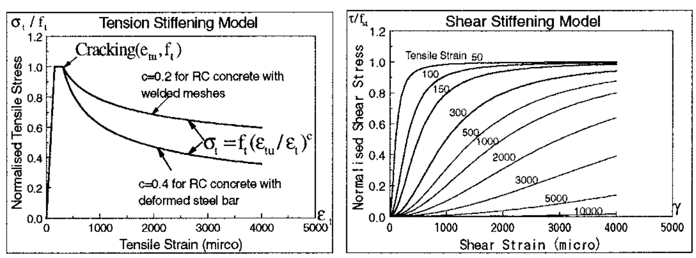
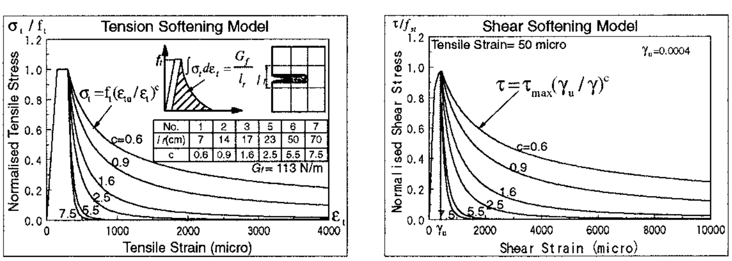


Fig.2 Tension and shear stiffening model for concrete in RC zone[1]



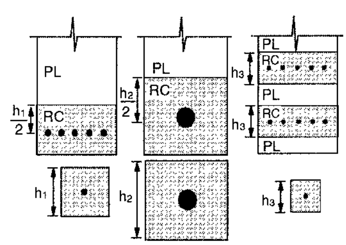


Fig.3 Tension and shear strain softening model for concrete in PL zone Fig. 4 RC zone definition in computation

For cracked plain concrete(PL) outside the RC zone, it shows strain-softening characteristic in tension and shear comparing with the concrete confined by reinforcing bars. The stress-strain curve is decided by adjusting the coefficient c with the element size by getting the constant fracture energy G_f [2]. Fig.3 gives two series of tensile and shear stress-strain curves used for simulating one shear experiment including 6 beams with depth varying from 10cm to 300cm[3].

The effective size of RC zone is an important factor for computation. Different size of RC zone in an analysis domain will have effect on the stiffness of member after cracking, also the computed failure mode varies from shear to bending as the size of RC zone increases. In two dimensional FEM computation(Fig.4), a formula (Eq.1) is given to decided the height h of RC zone according to the diameter of the steel bar d_b; the yielding strength of the steel f_y and the tension strength of the concrete f_t, as,

$$h=\frac{\sqrt{\pi}}{2}\bullet d_b\bullet\sqrt{\frac{f_y}{f_t}} \qquad (1)$$

3. Verification with Experimental Results and JSCE Shear Design Equation

By using the FEM code **WCOMR**, the computation results for experiment[3] are shown in Fig.5. The shear strength value from JSCE design equation [4] is also drawn in Fig.5. It can be seen that the proposed model can predict the shear strength with size effect tendency, and has good agreement with the JSCE shear design code. The crack pattern in Fig.5 also shows the computation can simulate the crack development and failure mode correctly. In order to verify the shear strength prediction with different reinforcement ratio ρ and concrete strength f_c', the computational results for beam with changing ρ and f_c' are plotted in Fig.6. The predicted shear strength is proportional to $\rho^{1/3}$ and $f_c'^{\ 1/3}$, has good agreement with JSCE equation.

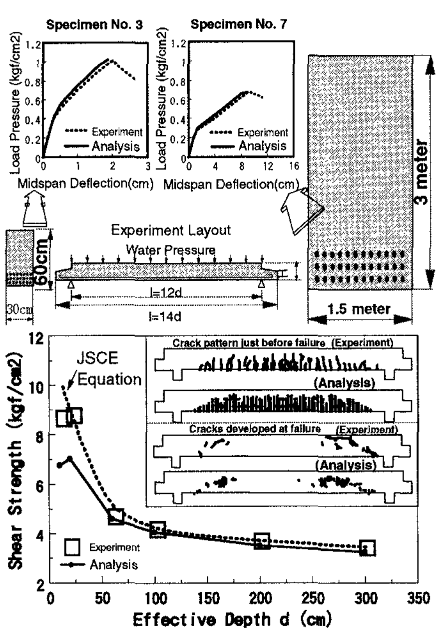


Fig.5 Computational results for experiment

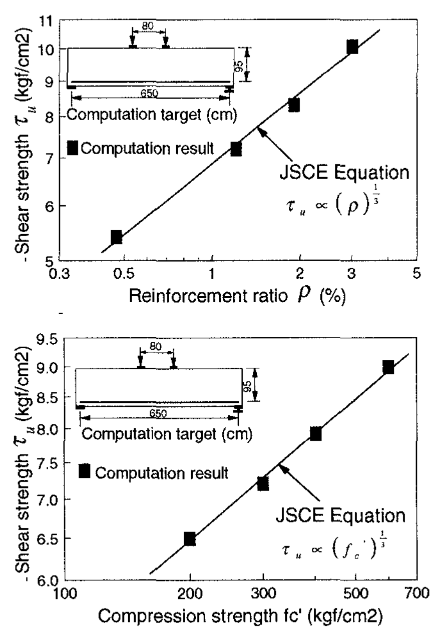


Fig.6 Effect of reinforcement rtio and concrete strength on shear strength

4. Conclusion

In this paper, the model which combines the constitutive laws for cracked concrete in RC zone and Plain concrete zone was proposed and be adopted in to FEM program. The computation for shear tests shows that the proposed model can simulate the shear behavior of RC beam without shear reinforcement.

Reference

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