ANALYSIS OF ANCHOR BOLTS IN CONCRETE WITH FRACTURE AND AGGREGATE INTERLOCK

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An incremental iterative procedure for the nonlinear finite element analysis of rein forced concrete structures is adopted. So lid concrete is modeled as hypoelastic ma terial, whilst cracked concrete (including fracture and aggregate interlock) is mode led with crack bands, according to the sme ared crack approach. After a brief discus sion on the numerical problems regarding accurancy of the solution, this approach is applied to the principle case of plane stress analysis proposed by RILEM TC 90 FMA regarding pull out test of anchor bol ts in concrete.

INTRODUCTION

Tensile cracking is identified using failure surfaces fixed at the onset of the cracking. The smeared crack concept for fracture and aggregate interlock is adopted since it brings several advantages, the main advantage regarding the adjustement of the compliance (or stiffness) coefficients, which do not require continuous topological changes in element connectivity. Perhaps the most compelling reason for using a smeared approach within the crack band concept is that one can easily consider crack of any direction and pay no penalty when the crack direction is unknown (1). As regard fracture, it is easier to adjust compliance matrix (3,4). Instead, for aggregate interlock (2) it is easier to adjust the coefficients of the stiffness matrix which becomes nonsymmetric and does not yield coincident principal axes for stress and strain increments.

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The material properties are as follows:

E =30000N/mm² initial tangent modulus;
ν = 0.2 Poisson's ratio;
σ_t = 3. N/mm² uniaxial tensile strength;
σ_c =-40.N/mm² uniaxial maximum compressive strength;
σ_u =-36.N/mm² uniaxial ultimate compressive strength;
ε_c =-.0022 uniaxial crushing strain;
ε_u =-.0031 uniaxial ultimate strain;
β = 0.6 stress ratio for failure surface input;
γ = 1.0 strain scaling factor for multiaxiality;
k = 0.6 control for iso/orthotropic material law;
α = .01 control for loading/unloading criterion;
d_a = 3.5mm maximum aggregate size;
$G_F = (2.72+3.10\,\sigma_t)\,\sigma_t^2 d_a/E = 0.1$N/mm fracture energy (1).

The finite element mesh of half structure is shown in Figs.1 and 2.
The load is applied at point A of Fig.1.
For the unit width b=1.mm, the load displacement curve of the full slab is shown in Fig.3 and has the maximum value P_u =440.N/mm with δ_u=0.116mm.
The typical deformations for P=0.8 P_u are represented in Fig.4.
Some of the features of the solution process are:

- both material and geometrical nonlinearities are considered;
- only prescribed displacements are used;
- the strain softening in tension is linear;
- the stiffness matrix is updated at each step;
- the equilibrium iterations are performed at each step.

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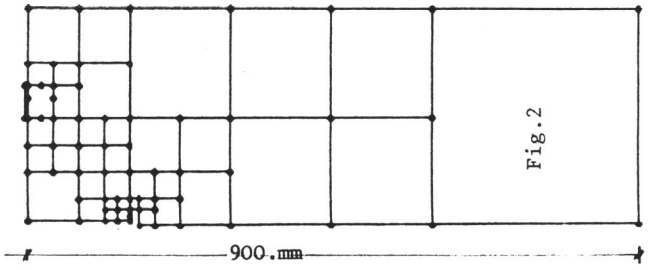

Fig.2

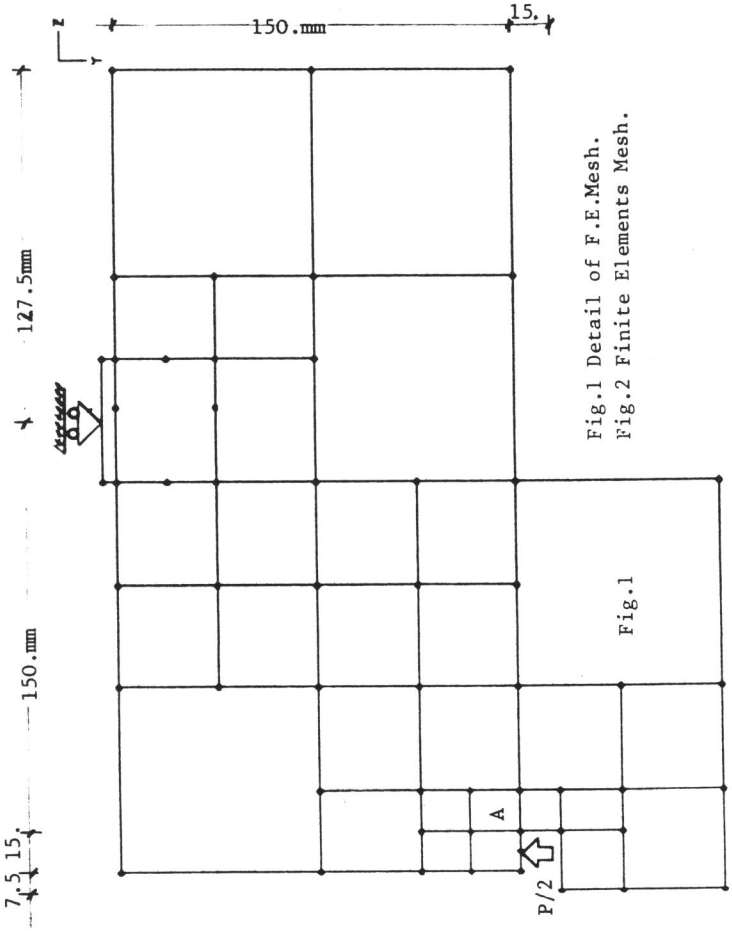

Fig.1

Fig.1 Detail of F.E.Mesh.
Fig.2 Finite Elements Mesh.

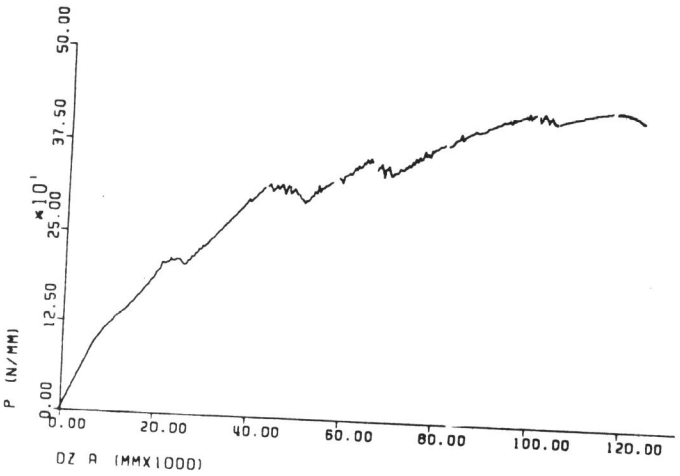

Fig.3 Load Displacement Curve.

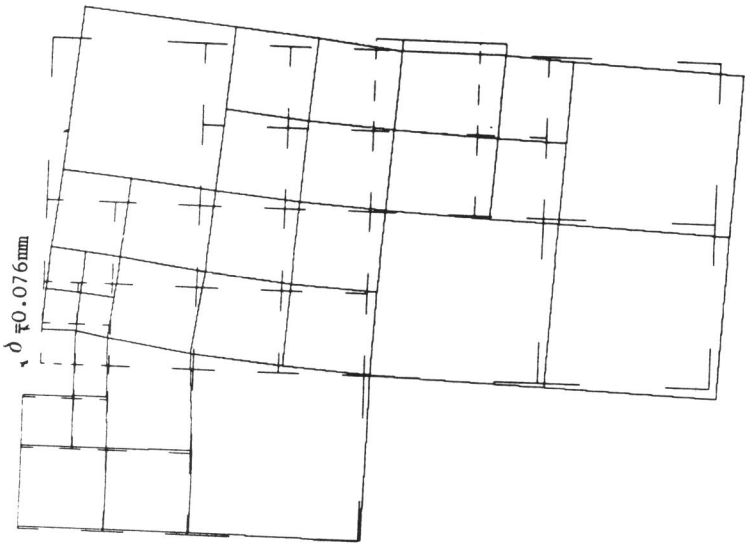

Fig.4 Displacements for $P=0.8P_u$.