3D FINITE ELEMENT MODELING OF REINFORCED CONCRETE STRUCTURES

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1 INTRODUCTION

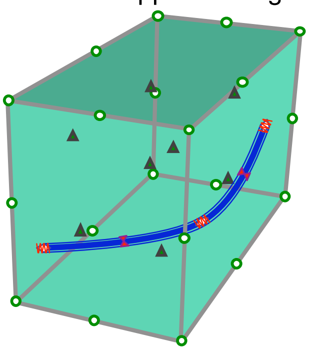
A nonlinear finite element tool for reinforced and prestressed concrete structures is presented. The program is designed as a lucid analysis tool for engineers. The user has to be still experienced and cautious but he does not have to be an expert who is dealing with nonlinear finite element analyses every day. This is realized by following two key ideas: First, model the geometry of the structure as it is given in physical reality and second, employ only such material parameters which are easily accessible and understandable to an engineer.

2 REPRESENTATION OF THE REINFORCEMENT

The first idea requires that the concrete geometry is discretized correctly. Favorably, a mesh with a high regularity should be employed. The same principle applies for the reinforcement. The reinforcement should enter the model exactly at that location where it is present in nature without any restriction. Modifications of the concrete mesh or the reinforcement layout should not cause time consuming challenges. These requirements can be fulfilled employing the embedded approach, presented by Elwi [1]. Anchorage loss or even bond slip along the entire rebar can be formulated in different ways, Elwi [1], Hartl [2, 3].

2.1 Embedded formulation allowing slip

This new developed form of the embedded approach allows the rebar to slip within the parent concrete element. Fig. 1 presents a brick element with parabolic shape functions and one embedded rebar. In this special case the size of the element stiffness matrix is increased for the slip degrees of freedom from 60 to 63. The first form of this approach is presented in Elwi [1]. A new easy to follow derivation of this approach is given in Hartl [3].



Legend:

- Node point of parent element
  (DOF, appears in the vector of nodal element displacements)
- Rebar point
  (DOF, appears in the vector of nodal element displacements)
- Integration point of the parent element
  (local coordinates of the Gauss points are known)
- Integration point for the rebar
  (local coordinates and rebar orientation have to be determined)

Fig. 1 Embedded reinforcement bar allowing slip

3 CONCRETE MODELING

Concrete failure is incorporated in terms of plasticity for its simplicity in concept. Engineers are used to this approach and to the associated parameters. Concrete crushing is modeled by the Ottosen model and concrete cracking is implemented by a rotating fictitious crack model based on Hillerborg's theory. Creep and shrinkage is a very important phenomenon in concrete. It is incorporated along the recommendations given in fib bulletin No 1, with storing the entire stress history.

4 EXAMPLES

4.1 Beam with one post tensioned bonded and one post tensioned unbonded tendon

The example shown in this section is supposed to illustrate the performance of the supplementary slip model. The analyzed beam is shown in Fig. 2. The concrete is assumed to behave solely linear elastic and no creep and shrinkage is considered at all. Additional mild reinforcement is not taken into account as well. Hence, only the capability of the supplementary slip model is pointed out here.

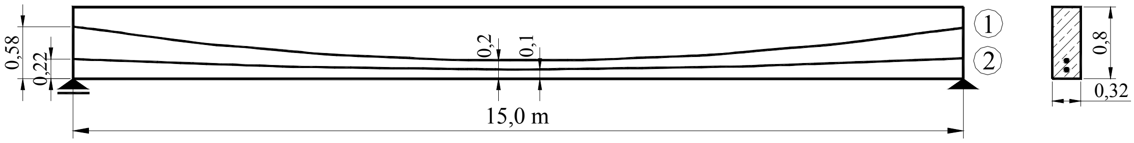
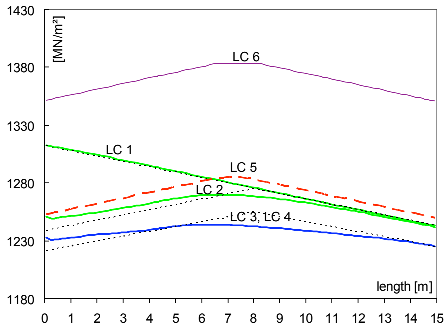


Fig. 2 Analyzed beam

Following load cases get applied to the beam

- Load case 1: Apply a prestress force of 0.785MN to tendon ① + 50% of dead load
- Load case 2: Apply a wedge-pull-in of 1.50mm to the live anchor (left side) of tendon ①
- Load case 3: Apply a prestress force of 0.779MN to tendon ② + 50% of dead load
- Load case 4: Apply a wedge-pull-in of 1.50mm to the live anchor (left side) of tendon ②
- Load case 5: Grout the duct of tendon ② and apply a boundary load q=32.20kN/m
- Load case 6: Apply an additional boundary load q=128.0kN/m

The stress resulting from the loads applied are shown in Fig. 3a and get discussed in the full-length paper.



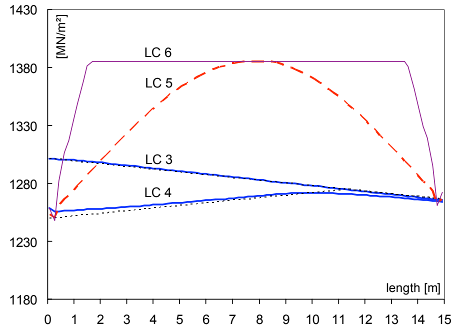


Fig. 3 a)Stresses in unbonded tendon ①   b) Stresses in bonded tendon ②

5 CONCLUSION

A finite element tool taylored for reinforced and prestressed concrete structures is developed as an extension to an existing finite element program BEFE [4]. Today's standard computers are on the edge to allow such programs to become a lucid office tool for engineers. The material models are comparable simple in concept. The parameters can be obtained easily. Nevertheless, the results until now are very promising. The program is employed in teaching and for expert studies in industry with success.

6 REFERENCES

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