

Post-Processing Tools for Nonlinear fe Analysis of Concrete Structures

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ABSTRACT

Finite element analysis of the cracking process in concrete structures brings new requirements for the post-processing environment. Crack direction and location are important for identification of the failure mode. The problem have been solved in the finite element program SBETA which was developed by the authors for simulation of the failure processes in reinforced concrete structures. The post-processing system creates the graphical images of crack patterns. Graphical sequences for simulation can be generated.

KEYWORDS: post-processing, computer graphics, simulation, cracking

INTRODUCTION

The simulation of concrete cracking was a subject of the paper [2], in which the results of the analysis for two examples were shown with emphasis on the fracture process and its simulation. The present paper describes the graphical tools especially developed for the post-processing of the cracking behavior of concrete structures. The graphical tools are illustrated on an example of the analysis of the reinforced concrete beam treated in [2]. The program system is described in the report [1].

PROGRAM SYSTEM

The core of the program system SBETA is a finite element module (solution), which is surrounded by a pre- and post-processing graphical environment. The modular structure of the program system can be seen from Fig.1. The post-processing has two levels. In the first level (processing) the relevant data from the solution are selected and transformed into graphical data. In the second level (interpreting) the graphical data are plotted on various graphical devices. FE solution, processing and interpreting are relatively independent tasks. They communicate through ASCII data files, which ensure data compatibility in different operating conditions. The program system is written for IBM PC compatible computers under MS DOS and is determined for plane stress analysis.

GRAPHICAL TOOLS

The post-processing uses the standard types of graphical tools typically employed for the FE analysis, such as deformed shapes, stress vectors and isolines and new types of tools for showing crack propagation. For simulation of the failure process the sequences of

images can be produced by animation procedures. In [2] as an example the simulation of shear failure of a reinforced concrete beam was shown. Here we shall discuss the methods, which were used to produce the crack patterns. The finite element model of the beam is shown in Fig.2 and 3. Only one symmetrical half of the beam was analyzed. Two meshes were used in order to investigate the element size effect.

The fracture analysis based on the smeared model produces data about displacement fields, strains, stresses and material states. From these data the failure crack can be identified by several ways. The first and simplest way is the picture of deformed mesh, Fig.4. If displacements are properly magnified the path of the crack can be identified from the deformed mesh. It can be seen, that the fine mesh allows better localization of deformations then the coarse mesh.

The second way of crack representation is drawing of the crack patterns with crack locations and directions. They are calculated according to the crack model (rotated or fixed). An example of this picture is shown in Fig.5, top, for the fixed crack analysis. This picture shows the crack areas including process zone (as defined in Fig.6, ref.[2]), but does not indicate the strain localization. It can be improved if the strain is indicated by the crack line thickness as shown in Fig.5, middle. In addition to this only the open cracks can be plotted. These are the stress free cracks exceeding a given strain limit. The resulting crack pattern is shown in the bottom of Fig.5 (for fine mesh) and in the middle of Fig.4 (coarse mesh). The final crack pattern in the full beam is shown in Fig.6. This procedure, "crack filter", was used to produce the simulation sequence presented in paper [2].

The identification of a failure crack by the standard graphical tools is not so efficient, as can be seen from the examples of stress vectors in Fig.8 and isoareas in Fig.9. However, the isolines, Fig.7, are useful for determination of the compression zone in the failure mode.

The graphical tools described above can also be used for the real-time graphics, which monitors the progress of the FE analysis. An example of the screen image of the program SBETA running in the interactive graphic mode is shown in Fig.10.

CONCLUSIONS

The cracking process and the failure crack resulting from the nonlinear FE analysis of concrete structures based on the smeared approach can be effectively identified using a "crack filter" when postprocessing the crack pattern. This method is also suitable for producing the graphical sequences of failure processes. The crack patterns in combination with the isolines or isoareas for compressive stresses can effectively be used to identify the failure modes in concrete structures.

References

- [1] ČERVENKA, V., ELIGEHAUSEN, R., PUKL, R. - SBETA Computer Program For Nonlinear Finite Element Analysis of Concrete Structures, Institut für Werkstoffe im Bauwesen, Universität Stuttgart, 1989.
- [2] ČERVENKA, V., ELIGEHAUSEN, R., PUKL, R. - Simulation Of Cracking And Failure Of Concrete Structures, STRUCENG & FEMCAD, Grenoble, 17-18.October, 1990.

SBETA Program system

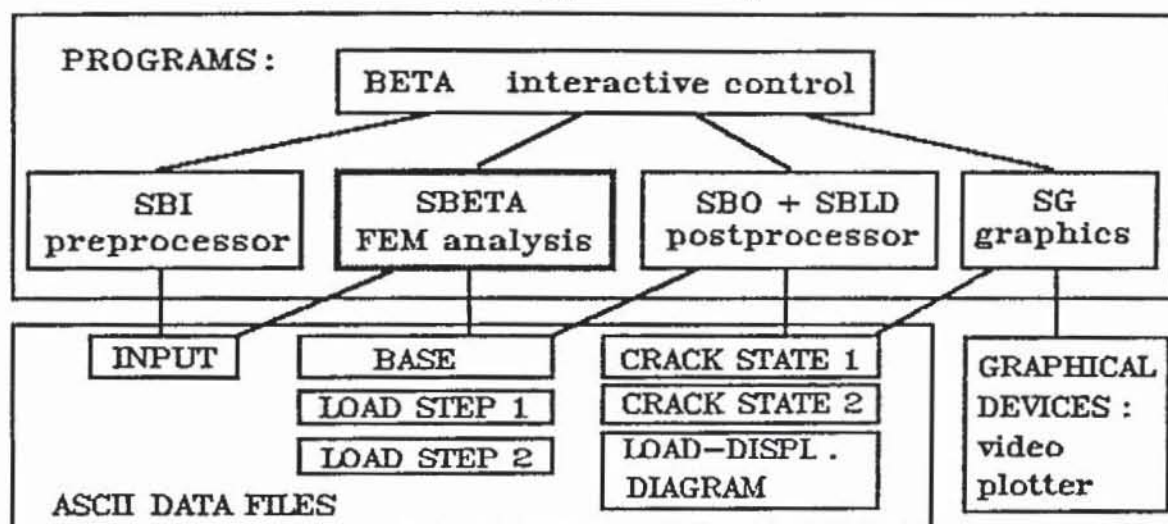


Fig.1 Structure of the program system SBETA.

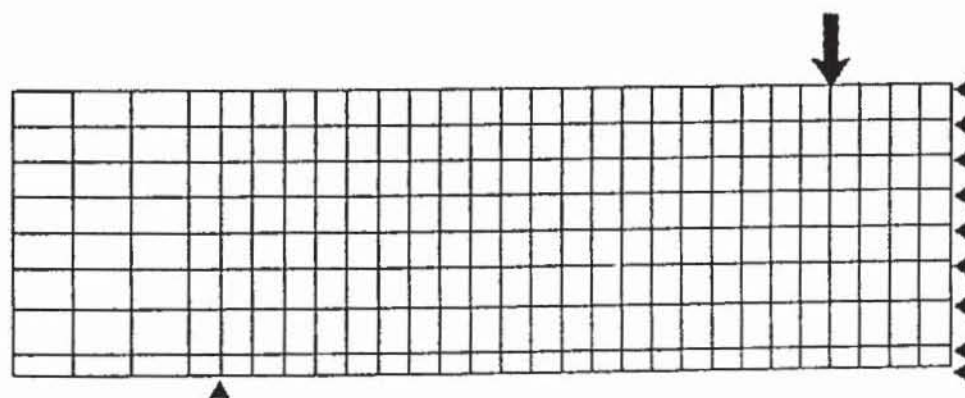


Fig.2 Finite element model of the beam. Coarse mesh with 224 elements.

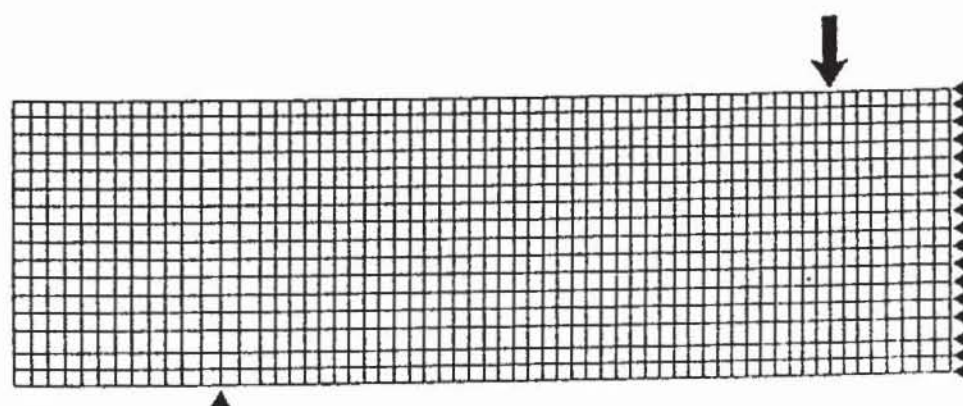
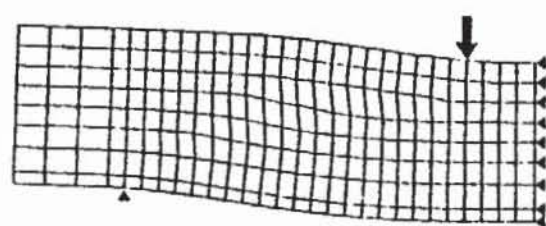
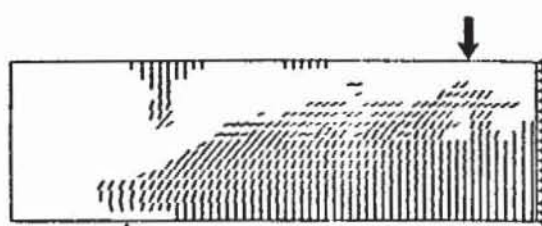


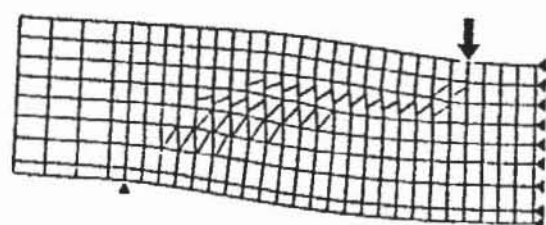
Fig.3 Finite element model of the beam. Fine mesh with 976 elements.



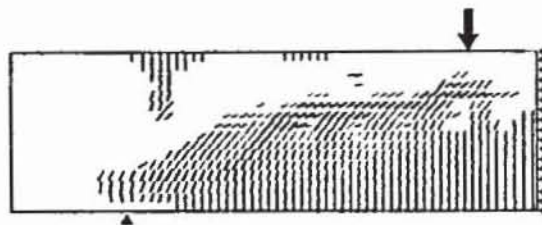
coarse mesh



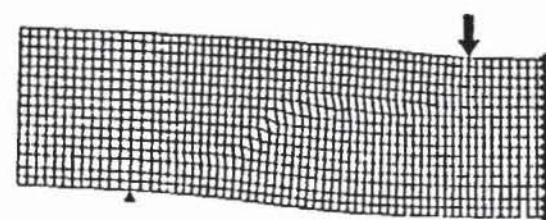
cracked area



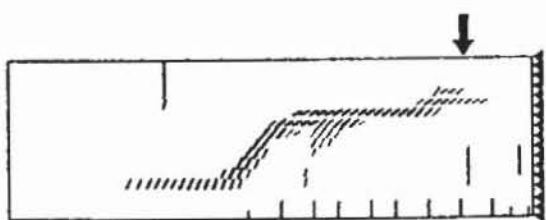
coarse mesh with cracked elements



indication of crack widths



fine mesh



localized cracks

Fig.4 Deformed mesh shapes.

Fig.5 Crack patterns.

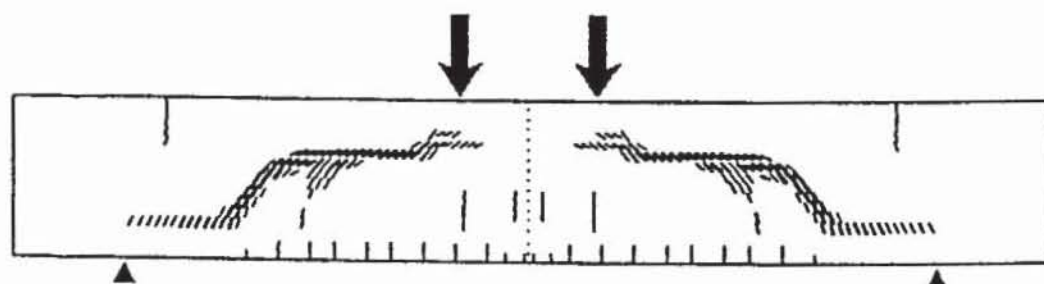
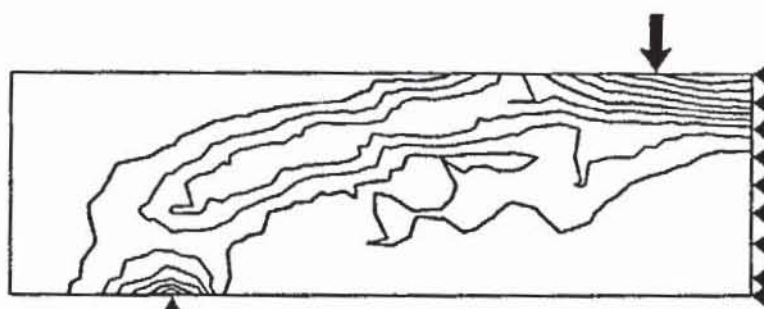


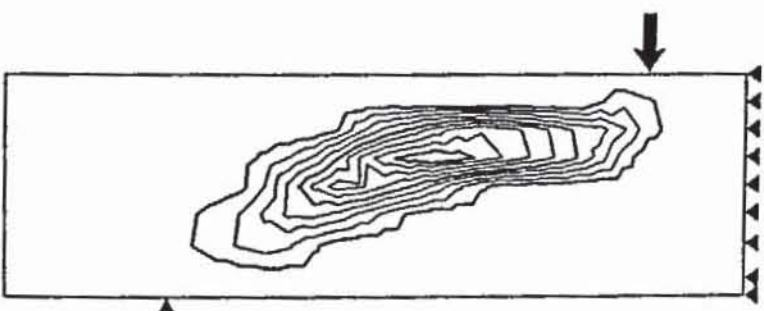
Fig.6 Failure crack patterns in full beam.



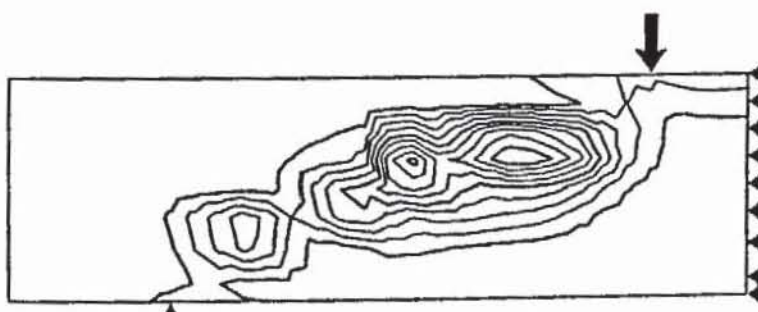
(a) Principal tensile stress.



(b) Principal compressive stress.



(c) Principal tensile strain.



(d) Principal compressive strain.

Fig.7 Isolines for principal stresses and strains.

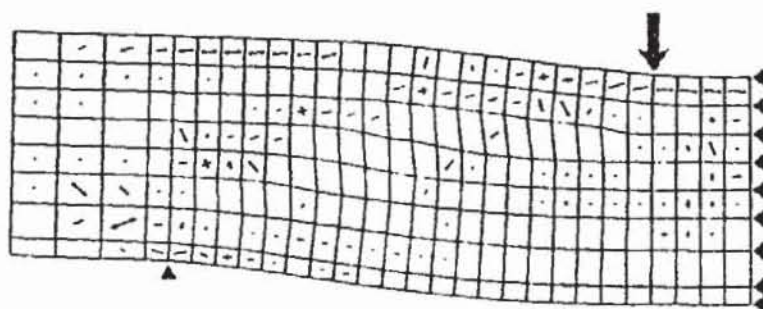


Fig.8 Vector representation of principal stresses.

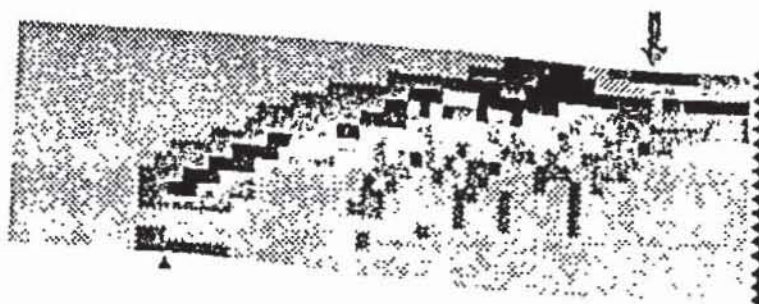


Fig.9 Isoareas of the principal compressive stresses.

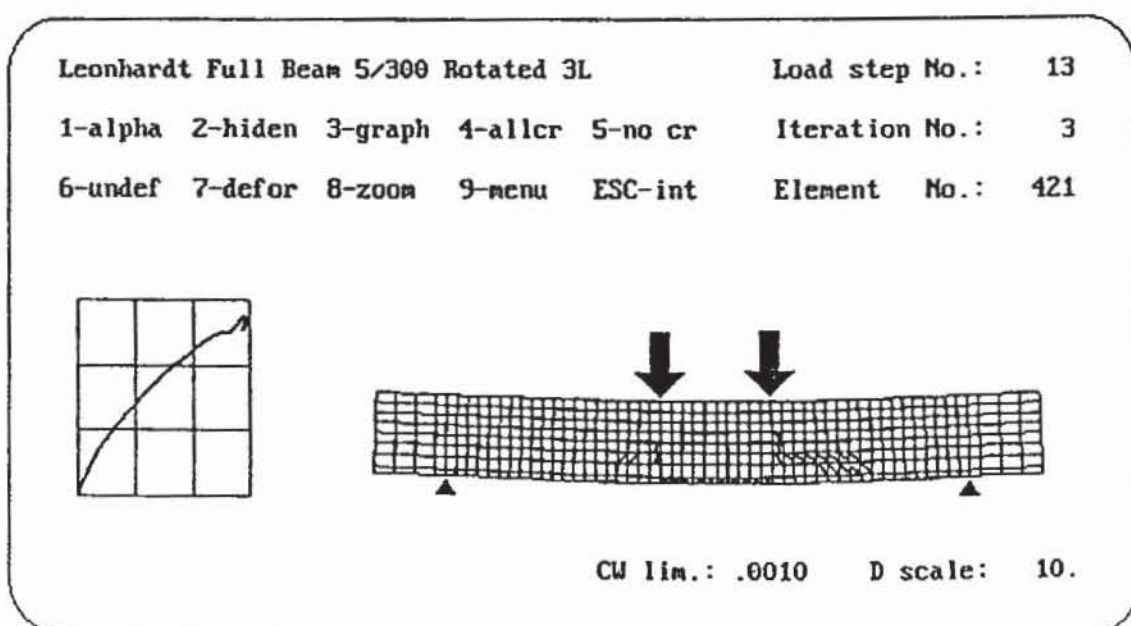


Fig.10 Screen view of the real-time interactive graphics.