CHAPTER 4

THE NEURAL NETWORK APPROACH IN PLASTICITY AND FRACTURE MECHANICS

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ABSTRACT
The Sections devoted to the applications of neural networks in plasticity and fracture mechanics cover three topics. The first one is associated with the implementation of hybrid programs in which neural procedures are used for the analysis of elastoplastic constitutive equations by means of back-propagation neural networks. The first program corresponds to the bending analysis of elastoplastic beams. The second program deals with the analysis of elastoplastic plane stress problem. The second topic is related to the so-called Panagiotopoulos approach. The approach depends on the formulation of the Quadratic Programming Problems and then analyzing them by the Hopfield-Tank network. This approach was used successfully for the analysis of unconstrained and constrained QPPs associated with the classical crack problem and the analysis of elastoplastic structures. The third topic corresponds to the parameter identification problem. This problem is analyzed by means of two neural networks. The supervised learning of a simple backpropagation neural network interacts with the analysis of subsidiary equations by means of the Hopfield-Tank network.
4.1. HYBRID NEURAL-NETWORK/COMPUTATIONAL ANALYSIS OF ELASTOPLASTIC STRUCTURES

4.1.1. Neural networks and neural procedures

The backpropagation neural network can be used as a quick simulator to map input to output data for complex relations between them. Such a network is trained off-line and as a neural procedure it can then be incorporated into a computer program instead of the corresponding numerical procedure. This leads to hybrid, neural-network/computational strategies and programs [1,2].

Neural procedures associated with BP neural networks can be applied to the analysis of constitutive equations. The BPNNs were earlier used to formulate the stress-strain relations in concrete [3]. The moment-curvature relation was established on the base of experimental data [4] or analytical formulae [5]. The inversion of uniaxial Ramberg-Osgood relation was performed in [6].

The idea of implementation of neural procedures in the finite difference or finite element programs was led in [5,7]. The elastoplastic plane problem and bending of elastoplastic plates were analyzed by hybrid NN/FEM programs in [8,9].

In the following Section two from the above mentioned problems are discussed. The problems concern the applications of neural procedures to the analysis of elastoplastic structures, especially the bending of beams and plane stress problem.

4.1.2. Bending of elastoplastic beams

4.1.2.1. Basic equations

Linear geometric and equilibrium equations are assumed:

\[ \nu' = \phi(x), \quad \phi' = -\kappa(x), \quad T' = -p(x), \quad M' = T(x), \]

where \( (\cdot)' = d(\cdot)/dx \) and other variables are shown in Figs.4.1a,b.

\[ (4.1) \]

\[ Fig.4.1: \text{a) Generalised displacements, b) Load and cross-sectional forces, c) Finite difference nodes along the beam axis} \]

Eqs (4.1) have to be completed by physical relationship:

\[ \kappa = \begin{cases} \frac{M}{EI} & \text{for elastic deformation}, \\ f(M) & \text{for elastoplastic deformation}. \end{cases} \]

\[ (4.2) \]