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Member Endochronic Model for Nonlinear Analysis of Frame Structures*

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ABSTRACT

Beam-column models are widely used in the nonlinear analysis of structures concerned with earthquake ground motions. Many researches have proposed their models for different members in engineering structures [1-7]. The Member Endochronic Model (MEM) is a kind of new model. It is established on the combined idea of section endochronic description and the member model of finite element method [8]. The section endochronic description has a similar idea with the Endochronic Theory of Plasticity [9], while it is based on the definition of section intrinsic time rather than on the definition of material point. MEM has been put into the use of simple frames and the results showed that it can be used in the simulation of the elastic-plastic procedure of the structure under horizontal forces [10].

As the P-Δ effect is very significant for frames with multi-stories, the establishment of MEM should contain the geometric nonlinear effect. Three aspects should be taken into account in that works. The first one is the establishment procedure of MEM, so that some basic equations of the model are obtained. Secondly, the compound characteristic of the column sections under axial and bending condition should be given correctly. Then some numerical methods should be given so that the nonlinear analysis of the structure could under go effectively. This paper gives a detail of the establishment of MEM and then discusses the other two problems by some examples.

According to the finite element method, the relationship between the nodal forces and section forces are obtained as $\{\Delta R^e\} = \int_0^L [B]^T \{\Delta F\} dx + [K_F^e]\{\Delta\delta^e\}$, where $[K_F^e]$ is called as the original force matrix and could reflect the P-Δ effect of the column. For the description based on the Section Endochronic Model (SEM), there are two forms to describe the section characteriscs: $\{\Delta F\} = [D]\{\Delta e\} + \{\Delta F^p\}$, $\{\Delta F\} = [\overline{D}]\{\Delta e\}$. Putting these equations to the equation of $\{\Delta R^e\}$, we obtain:

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$$\{\Delta R^e\} = ([K_0^e] + [K_L^e] + [K_F^e])\{\Delta\delta^e\} + \int_0^L [B_0]^T\{\Delta F^p\}dx + \int_0^L [B_L]^T\{\Delta F^p\}dx\,,$$

or, $\{\Delta R^e\} = [\overline{K}^e]\{\Delta\delta^e\} = ([\overline{K}_0^e] + [\overline{K}_L^e] + [K_F^e])\{\Delta\delta^e\}$.

All the matrices with subscript "0" relate to the linear part and the matrices with subscript "L" and "F"relate to the nonlinear part coming from the large deformation and the section-order effect of the member.

Based on above equations, several numerical methods could be given to undergo the nonlinear analysis of the structure step by step, during which the nodel force $\{\Delta R\}$ is known and the nodel displacement $\{\Delta\delta\}$ is the goal of calculation. The task of SEM is to establish the relationship between $\{\Delta F\}$ and $\{\Delta e\}$ so that one could be obtained when another is known in the procedure. For a definite structure, the relationship between $\{\Delta F\}$ and $\{\Delta e\}$ could be obtain by the material character and geometry of the member section, where the definition of the section intrinsic time, dz , is the key point.

For the plane frame examples in the paper, a reasonable method of the definition of dz is discussed and some of the results are given. Examples show that the MEM establised in this paper could consider the P-Δ effect of the structure successfully and could be used to estimate the nonlinear behavior of frames under horizontal earthquakes.

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