Modelling of plastic hinges in seismic structural analysis using LUSAS

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ABSTRACT

Damage can develop in engineering structures under earthquake loading. Besides steel, non-metallic materials like concrete, timber and composites are widely used in engineering. Furthermore, damage may not only occur in materials, but also in local structures like the voluntary connecting joints. Such damage can result in complicated hysteresis behaviours not typical in cyclic plasticity of metals.

Proper modelling of damage is fundamental for the safety of structures, and required by the performance based design via the so-called pushover analysis\textsuperscript{[1]}. However, it is difficult to model with standard damage models together with normal continuum or structure (beam, plate or shell) elements; instead, engineers use special plastic hinge models. Except for the kinematic hardening model, numerous empirical models have been developed since Clough\textsuperscript{[2]} first introduced the degrading stiffness hysteresis model for reinforced concrete members. Sophisticated models have been introduced by Saiidi and Sozen\textsuperscript{[3]} for describing the stiffness degradation of reinforced concrete members in flexure accounting for the pinching effect due to interface shear sliding and bond deterioration, and by Stewart\textsuperscript{[4]} for timber framed structural walls sheathed in plywood nailed to the framework, allowing for initial slackness as well as subsequent degradation of the stiffness as the nails enlarged the holes and withdrew themselves from the framework.

LUSAS has generalised and implemented a family of plastic hinge models in recent years to enhance seismic analysis, including general anisotropic and kinematic hardening models, and sophisticated empirical models. These models have the following features:

- The primary loading curve can be any arbitrary piece-wise linear curve;
- The origin of the curve does not necessarily have zero displacement and force;
- Tensile and compressive behaviour can be different (or anisotropic);
- Unloading can follow the initial stiffness as well as a stiffness dependent on the deformation;
- Dependence of shearing and bending on the axial force and coupling of bending in two directions can be considered;
- Simple models can be combined to form compound models with more complicated hysteresis behaviours;
- The fibre hinge model can use a proper combination of fibres together with relatively simple fibre properties to describe hysteresis behaviour for engineering structures.

This paper will give an overview of the plastic hinge models that can be used for modelling damage as well as earth-retaining soil-structure interaction and seismic isolation systems; numerical results will be presented to illustrate the hysteresis behaviour of the models.

REFERENCES