ABSTRACT

Phuvoravan, Kitjapat, Ph.D., Purdue University, December 2003. A Finite Element for the Nonlinear Analysis of Reinforced Concrete Slabs. Major Professor: Professor E.D. Sotelino.

The nonlinear behavior of reinforced concrete (RC) structural systems is very complex. Depending on the application, both concrete and steel behave nonlinearly. Cracking of concrete is the main source of material nonlinearity, and usually occurs at the low levels of applied load due to the low resistance of concrete to tensile loads. Thus, in order to more accurately simulate these systems, there is a need for the development of efficient sophisticated elements that can be incorporated in a nonlinear finite element framework.

Two techniques exist for modeling RC slabs: discrete and layered modeling. In the discrete modeling, concrete is modeled by three-dimensional solid elements while the reinforcing steel is modeled by truss elements. The drawback of the discrete modeling is that a large number of degrees of freedom are required. This is of particular concern in nonlinear analyses. In the layered modeling, concrete is divided into a set of layers, while the reinforcing steel is smeared into a layer between concrete layers. Layered modeling of RC slabs is simple, but provides an unrealistic representation of the reinforcing steel. Since real reinforcement is discrete, only highly reinforced slabs can be appropriately modeled by the layered approach. Furthermore, the interaction between concrete and reinforcement bars, i.e. bond-slip effect, can not be modeled directly.

This research presents a new finite element for the nonlinear analysis of RC slabs. The element combines a four-node Kirchhoff shell element for concrete with two-node Euler beam elements for the steel reinforcement bars. The connectivity between reinforcement beam elements and concrete shell element is achieved by means of rigid links. By using the transformation method for rigid links, beam nodes are eliminated from the final mesh of the structure. The stiffness and resisting forces from the

reinforcement are implicitly included in the new element. In this manner, this finite element is able to take into account the location of the reinforcement bars. This is in contrast to the smeared method, which is often adopted in the layered modeling. The proposed RC shell element is further extended to include the effect of bond-slip between concrete and reinforcement bars.