Abstract

Stress-resultant models for optimal design of reinforced concrete frames

The standard design procedure of reinforced concrete frame structures starts with linear analysis to obtain the corresponding diagrams of stress resultants (bending moment, shear and axial force), followed by the ultimate analysis of each cross section. The main disadvantage of such a design procedure concerns the (highly) statically indeterminate frames, where the failure of each beam or column would not imply the complete failure of the structure, but would lead to a significant stress resultant redistribution with respect to the result obtained by linear analysis.

For that reason, we propose the performance based design procedure where the behavior until complete failure of beam-column and frames imposes to consider so-called plastic hinges corresponding to the zones where plasticity and/ or damage localizes. Engineering structures are usually statically indeterminate, so that the total failure of one member would affect the global response of the structure but it would not lead to a complete loss of the structural integrity. Moreover, being capable of describing the softening response of the members of one particular structure can provide an estimate of the residual life of a partially damaged structure. Such a procedure can also help to provide a more detailed crack description, which is needed to make decisions about the maintenance and repairs.

Objectives:

The aim of this work is to provide an efficient tool for the optimal design of reinforced concrete frames under severe loading. A multi-scale approach has been adopted. Three levels of refinement are considered: 1- At the global level, a force resultant model has been implemented in a Timoshenko beam element with strong rotation discontinuity; 2- At the semi-global level, a uniaxial model has been implemented in a multi-fiber beam element with strong discontinuities in the fibers; 3- At the local level, a 2D solid modeling of the reinforced concrete is used, including cracking of concrete and bond slip behavior between steel and concrete

Proposed approach:

The non-linear response of the whole structure is computed in two steps:

In the beginning, the moment-curvature behavior of a section of each beam or column of the frame is computed with the multi fiber element (embedded on one end and with an imposed rotation on the other end), and then the parameters of the global Timoshenko beam element are identified. Since there is only one element used for these computations, they are very fast to carry out.

After that, the response of the frame structure can be computed fast by using the three degree of freedom Timoshenko beam elements with a global model. Since these elements are able to represent the softening of the cross sections and the rotation discontinuities due to the cracks, it is possible to compute the force redistributions in a statically indeterminate structure until global failure.

This basic idea needs at least two main improvements:

The influence of the axial force on the bending curvature response must be taken into account, especially in the columns. It has been done while introducing a parameter depending on the rate of axial force in the global model.

When dealing with softening, the size of the elements is of almost importance. Since the global Timoshenko beam elements model both the spread plasticity/damage along the element and the discontinuity due to the cracking concentrated at the middle of the element, the length of an element is guided by the crack spacing in the structure. This crack spacing is very much related to the bond-slip behavior. The local 2D model is used to determine this spacing and identify the length of the softening elements. Moreover, the 2D model is also used to identify the descending branch of the global model with proper value of fracture energy considerations.