Integrated Optimization of Reinforced Concrete Frames and Iterative Solution

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A symbiosis of integrated optimization of reinforced concrete frames is combined with iterative methods of solving systems of linear equations. This technique was devised to alleviate the lack of convergence when the frames presented nonlinear material behavior. The strategy used to optimize the design was based on the generalized reduced gradient method. The design variables considered were the dimensions of the element sections and the reinforcing steel areas.

The optimization algorithm was devised for planar reinforced concrete frames submitted to static loading. The flexural performance of the elements was evaluated as a function of the actual stress-strain curve of concrete and of the elasto-plastic behavior of the reinforcing steel. Formation of rotational hinges with strain hardening were allowed. The reinforced concrete element was modeled as a linear elastic beam with nonlinear rotational springs at the ends.

Global displacements were considered as design variables implying the addition of the equilibrium equations to the set of constraints. The constraints included behavioral requirements as well as safety conditions. The adequacy of the frames was guaranteed by limiting the element reliability indices and the global displacements. The system probability of failure, evaluated at the mechanism level at the end of each optimization cycle, assured the global safety of the frame.

In large frames, with several design variables, convergence was hard to achieve when the material presented nonlinear behavior. An intermediate phase was created to improve convergence based on iterative methods for the solution of systems of equations. This approach used the conjugate gradient method combined the non zero terms and element by element storage techniques. This mixed method performed well with a faster convergence and more accuracy than the method uniquely based on the optimization algorithm.

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