Optimization of seismic behavior of steel frames with semi-rigid connection using genetic algorithm

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Keywords: optimization, genetic algorithm, semi-rigid connection, non-linear analysis, plastic hinge

In analysis and design of steel frame, beam-column connection has a significant role. The researches have shown that the moment–rotation (M-θ) relationships for some of the connections are nonlinear, and the assumption of a constant value for stiffness of connection is not real because it changed by increasing load levels. Laboratory test results have shown that the beam to column connection is neither complete articulated nor complete restraint, rather it is in the form of semi-rigid (semi-restraint). Therefore, for accurate response of the structural behaviour, it is necessary considering the structure connections in the form of semi-rigid with nonlinear behaviour.

Since inelastic behaviour is intended in most structures subjected to infrequent earthquake loading, the use of nonlinear analyses is essential to capture behaviour of structures under seismic effects.

This paper presents a genetic algorithm based on optimum design method for reducing the weight of steel frames and obtains the rigidity of connection in a state where the structure has been reached its least weight. The results in 4 states of rigid connection with static linear analysis, semi-rigid connection with static linear analysis, rigid connection with non-linear analysis and semi-rigid connection with non-linear analysis are compared.

The following constrains have been used in the frame design and optimum procedure with genetic algorithm:

The first constraint is control of interactive stresses in the elements (bending stresses + axial stresses). The combinations of axial and bending stresses of the members are calculated. For members subjected to both axial compression and bending stresses.

The second constraint is control of relative displacement of the stories (Drift). The story drift is defined as the difference of maximum lateral displacements of any two adjacent floors. Some limiting requirements are needed for the interstory and top deflections of buildings in the earthquake regulations. The maximum interstory drift and top deflection of building is restricted to earthquake resistant codes. And the last constraint is number of plastic connections created in the elements. Plastic hinge formation is a tool that is used in seismic analysis for determining the inelastic capacity of structural members. The ultimate performance of structure depends on location, number, capacity and behaviour of plastic hinges. In this paper lumped plastic hinge which idealized by FEMA356 were used.

The fitness factor of plastic hinge depends on the ratio of beam and column elements. Thus, hinge number to whole beam and column element could be defined. In this paper, for each element, two plastic hinges are defined and location of hinge is approximately 0.5 times the element depth.
SAP2000 (Ver. 11.07) traditional engineering software has been used for modelling the frames, and coding in MATLAB software has been used for optimization procedure. For verifying the method of semi rigid connection modeling with rotational spring in SAP Ver. 11.07 program, a beam is exposed to uniform loading \( w \), with connection characteristic parameters and initial stiffness \( K_i \), and definite section and load analyzed, then, the results (ultimate moment, \( Mu \)) have been compared with the results in same studies.

The sizes of population, possibility of mutation, and maximum number of generations have been assumed to be equal to 30, 0.005 and 100, respectively. The initial generation critically affected the convergence, the performance and the ability of the GA. If the size of design space is small, these properties of the GA may not be influenced.

Considering the presented explanations and examples, it is observed that the application of genetic algorithm on analysis and design programs can change the procedure of analysis and design in the manner that there will be no need for the initial estimation of sections and control of stresses by the designers. Of course, the current initial estimation may reduce time of analysis. The analysis, design and selection of optimum sections will be performed by the program and the final design will be performed considering the proposed sections by the program and special executive issues of that project which will not take too much the time of the designer too much.

Considering the obtained results, the proposed results are presented as follows:

- Considering the shear force, the average stiffens of connection in semi-rigid frames increase in each story downwardly until it has become close to the restraint border.
- In the frames analyzed with semi-rigid connection, the optimum stiffness of connection in linear analysis state is more than non-linear state.
- In the frame being studied is that the weight of structure in non-linear analysis method is generally less than the linear analysis method.
- Non-linear analysis method is more accurate than linear analysis method and in fact more percentage of elements capacity is used leading to decrease of consumed materials.

References

ABDUL-RASSAK SULTAN, S. Performance-Based Optimal Design of Semi-Rigid Connected Steel Frame under Seismic Loading, PhD dissertation, Department of Civil and Engineering, The Hong Kong Polytechnic University, 2007


FEDERAL EMERGENCY MANAGEMENT AGANCY (FEMA-356), 2000. Pre standard and commentary for seismic rehabilitation of buildings. Washington (DC);


UNIFORM BUILDING CODE, UBC. (1997), International Conference of Building Officials, Whittier, CA

