A PROPOSAL FOR PLASTIC HINGES MODIFICATION FACTORS FOR DAMAGED STEEL MOMENT FRAME

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A Structure subjected to earthquake may be subjected to one or more aftershocks. Strong aftershocks have the potential to increase the damage state of the structure due to the damage accumulates. Damaged structures by the main shocks in these types of events usually cannot be repaired before the subsequent aftershocks due to the short intervals of time. (ATC-35)

The professional engineers inspect structures in a post-earthquake investigation with the purpose of assessing buildings safety. Engineers have no direct knowledge to evaluate damaged structures. Therefore, they should use their previous experiences that were gained by designing and evaluating other structures.

A few guidelines are available such as ATC-20, and FEMA 352 that present procedures for post-earthquake evaluation of buildings. In these guidelines post-earthquake decisions perch exclusively on engineering judgment exercised by expert engineer that visually inspect the facility in the consequence of the damaging event.

Generally, the Damage effects on behavior of individual components are different. Some elements exhibit ductile modes of post-elastic behavior, sustaining strength even with large displacements. Others are brittle and lose strength suddenly after small inelastic displacements. The components behaviors govern the overall displacement and its seismic performance of the building. The quantitative evaluation of the effects of repetition earthquake damage on the structure requires selecting a measurement parameter. Consequently, it seems that the evaluation of the damage effects on seismic performance of the structure can concentrate on how component properties change as a result of damage (ASCE 41-06, FEMA 306).

Numerous investigations were conducted in order to evaluate steel moment frame behavior due to a simulated main shock-aftershock sequence, imitating seismic sequence excitation (Li and Ellingwood, 2007; Lee and Foutch, 2004). However, many questions have been raised about the performance of these types of structures with regard to the components damage severity and residual capacity in post-earthquake. The quantitative measure of the implied degradation in steel structure components was ambiguous. The general moment-rotation relations of the structural elements during the sequence of main shock-aftershock were constant. This assumption seems doubtful.

The main assumption of this paper relies on the principle that an exhaustive list of possible damage states that a special steel moment frame may be experience after the main shock.

This paper presents a methodology and results of an analytical approach for evaluating the effect of initial damage in special steel moment frame component on beam and column moment–rotation plastic hinges depending on damage state. These expressions can be used to assess the performance loss of a building that has been damaged by a sequence of seismic events characterized by a principal earthquake with medium-to-high intensity, followed by aftershocks with comparable intensity. For this purpose, the analytical based procedure has been proposed for modifying the steel beam and column moment– rotation plastic hinges that have entered the plastic range in several damage states. The Finite element analysis employing 3D shell elements is implemented to model a W-section steel beam and a box column element. Firstly, various damage states as a function of element's drift level induce these sections subjected to cyclic loading protocols. Then, the moment- rotation plastic hinges of damaged beam and column have been determined. Moreover, this paper has suggested a suitable expression of modifying factors for stiffness, strength and displacement capacity as a function of the element drifts.

The moment-rotations of the W-section beam without initial damage and 3% initial damage are illustrated in Figure 1. The moment-rotation of damaged beam element for 3% initial damage state exhibits unsymmetrical behavior on the first and the third quadrant of hysteresis curve.

Consequently, it was anticipation that the energy dissipation of damaged beam behavior has been decreased with increasing the initial damage. These variations in seismic behaviors of damaged elements were faced engineers with some problems. It is ambiguous that the designed structures with current designing codes can be stable under mainshock-aftershock sequence or not.

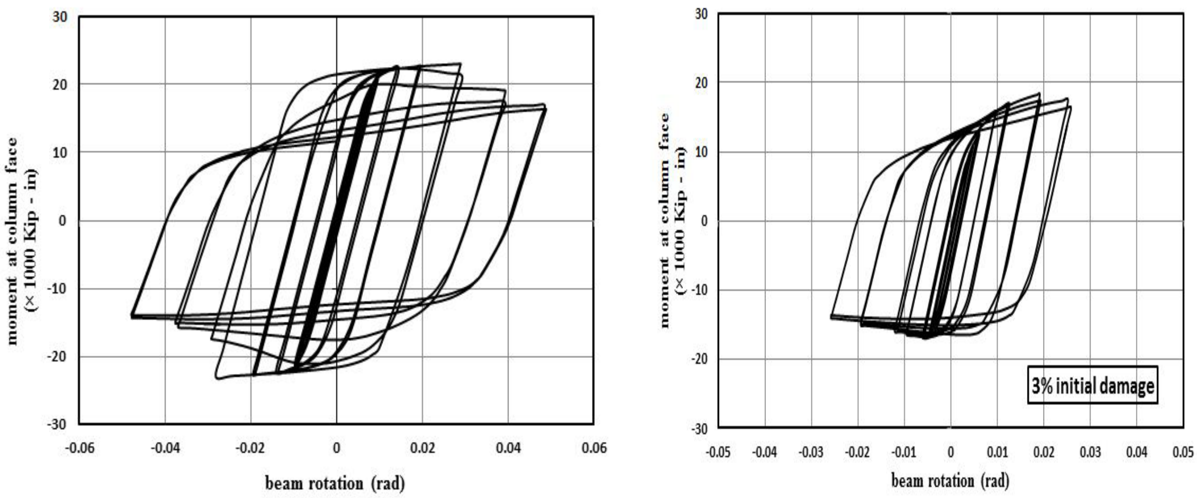

Figure1. The damaged beam hysteresis curve with and without initial damage

REFERENCES

ASCE SEI 41-06 (2007) Seismic rehabilitation of existing buildings, ASCE standard, published by the American Society of Civil Engineers, Reston, Virginia

ATC 35 (1999) Earthquake aftershocks-entering damaged building, Applied Technology Council, Redwood City, California, Technical brief 2

ATC 20 (1989) Procedures for post-earthquake safety evaluation of buildings, Applied Technology Council, Redwood City, California

FEMA 352 (2000) Recommended Post-earthquake Evaluation and Repair Criteria for Welded Steel Moment-Frame Buildings, SAC Joint Venture, Sacramento, California

FEMA 306 (1998) Evaluation of earthquake damaged concrete and masonry wall buildings– basic procedures manual, Federal Emergency Management Agency, Washington, DC

Lee K and Foutch DA (2004) Performance evaluation of damaged steel frame buildings subjected to seismic loads, *Journal of Struct, Eng.,* 130:588–99

Li Q and Ellingwood BR (2007) Performance evaluation and damage assessment of steel frame buildings under main shock–aftershock sequences, *Journal of Earthq Eng Struct Dyn,* 36:405–27