INFLUENCE OF INITIAL CRACKS ON LOCATION OF PLASTIC HINGES IN STEEL FRAMES

Yameen Patel[1], Bhairav Thakkar[2]

[1]Under-Graduate Student, [2]Associate Professor, School of Science and Engineering,

Navrachana University, Vadodara

ABSTRACT

Plastic hinges that form near the beam column joints have been found to be playing a vital role in pushover analysis of frames. If the plastic hinges shifts away from the column faces, the seismic capacity of frames must be determined accordingly. Various approaches have been adopted by researchers to describe the formation of plastic hinges under flexure in steel frames. Stress fields near beam column joints are significantly affected by the initiation of imperfections in any form for example a crack. Flexural stiffness and strength of cracked members would also be significantly affected and will show changes in stresses. This paper tries to describe a study conducted on shifting of plastic hinges near beam column joints in a steel frame due to initial cracks. A fracture analysis code FRANC2D has been adopted here to generate a model of a two story steel frame having two cracks in beam column joints on the windward side. Stress distribution in expected plastic hinge generation region has been studied in this paper. Behavior of stress distribution around cracks has also been studied taking in to account the location of crack tip, mode of crack etc.

Keywords: Finite element analysis, Fracture Mechanics, FRANC2D, Plastic hinge, Steel frames.

I. INTRODUCTION

To perform push over analysis or to study the behavior of steel frames under the presence of plastic hinges and initial cracks, it is necessary to obtain the location and depth of cracks[1]. These cracks influence the stress distribution and consequently act as hinges in the frames. The plastic hinges may not form in presence of a deep crack in nearby vicinity. Plastic hinges are usually assumed to form at 0.25L[2]. The location and depth of existing cracks are usually achieved by non-destructive evaluation techniques. While designing members by Fracture Mechanics approach, a crack of small length is usually postulated.

In present study, a steel frame with 10mm cracks in the beam column joints region has been considered. The frame is subjected to horizontal load. An effort to describe the behavior of plastic hinge in such a situation has been made. As the crack propagates, the relocation of plastic hinges is simulated.

A finite element model for simulating propagation of crack as well as effective stress contours in a beam column joint in steel frame has been developed in *FRANC2D*. Two non-cohesive edge cracks of approximately 10mm length have been introduced in the beam column joints to observe the deformation and stresses. Over the increase in total

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applied load, shift in plastic hinge locations is studied as well as the deformed shape is noted. Direction of crack, mode of failure, crack tip locations etc. have been taken into consideration while modeling as well as analyzing.

II. FINITE ELEMENT SIMULATION

A steel frame with 2 stories has been modeled. Each story has been modeled to be having 3500mm centre to centre height. Bay distance between two columns is considered to be 4000mm. All the beams and columns considered to be ISMB450. The frame is considered to be made of mild steel having young's modulus of elasticity = 200000 N/mm^2, poisons ratio = 0.33 and fracture toughness = 220 MPa√m[3] Figure 1 is the schematic of the simulated two story steel frame with two cracks in beam column joints. All dimensions in the figure are in mm.

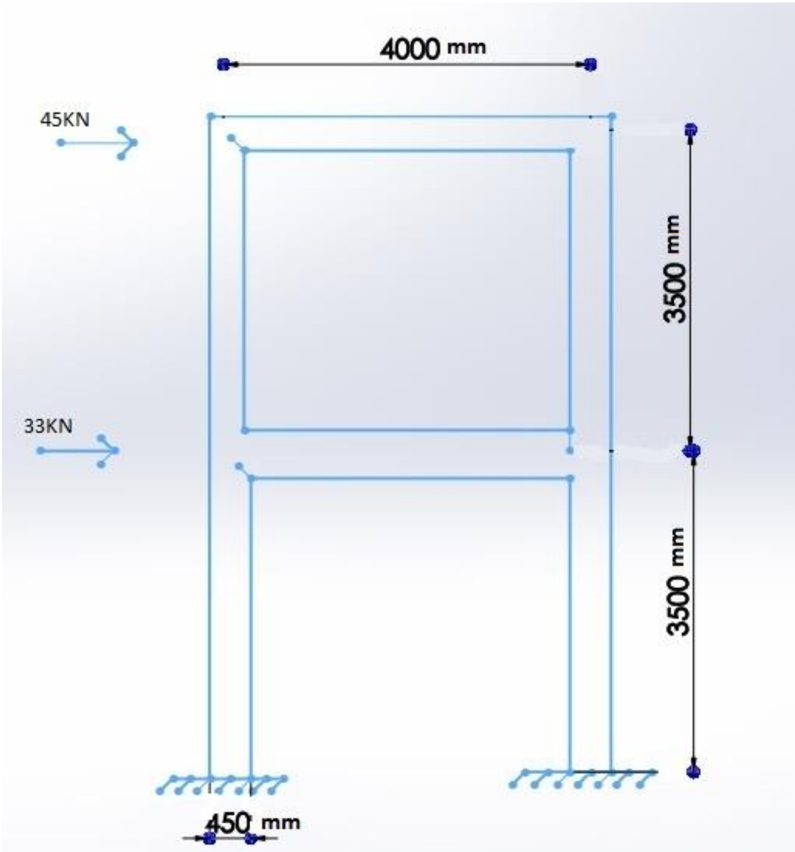

Fig.1 Schematic of steel frame

The bottom two edges of the steel frame have been restrained against deformation in x and y directions [4]. Two horizontal point loads of 45KN and 33KN were applied on both beam column joints. Upper joint was subjected to 45KN load and lower joint was subjected to 33KN load. With these loads, the frame was simulated to be under seismic loading.[5] Two non-cohesive, traction-free edge cracks of approximately 10mm length each were generated on inner corners of both beam-column joints on windward side such that the crack makes a 45^o angle with longitudinal direction of the beam. The crack was gradually propagated and the corresponding change in stress fields near the expected plastic hinge region was observed[6]. Deformed shape of the frame, stress fields near crack tips, crack tip locations etc. were also monitored.

III. RESULTS AND DISCUSSION

A finite element mash showing steel frame and 10 mm cracks is shown in the figure 2(a) and a finite element mash showing steel frame with propagated cracks is shown in figure 2(b).

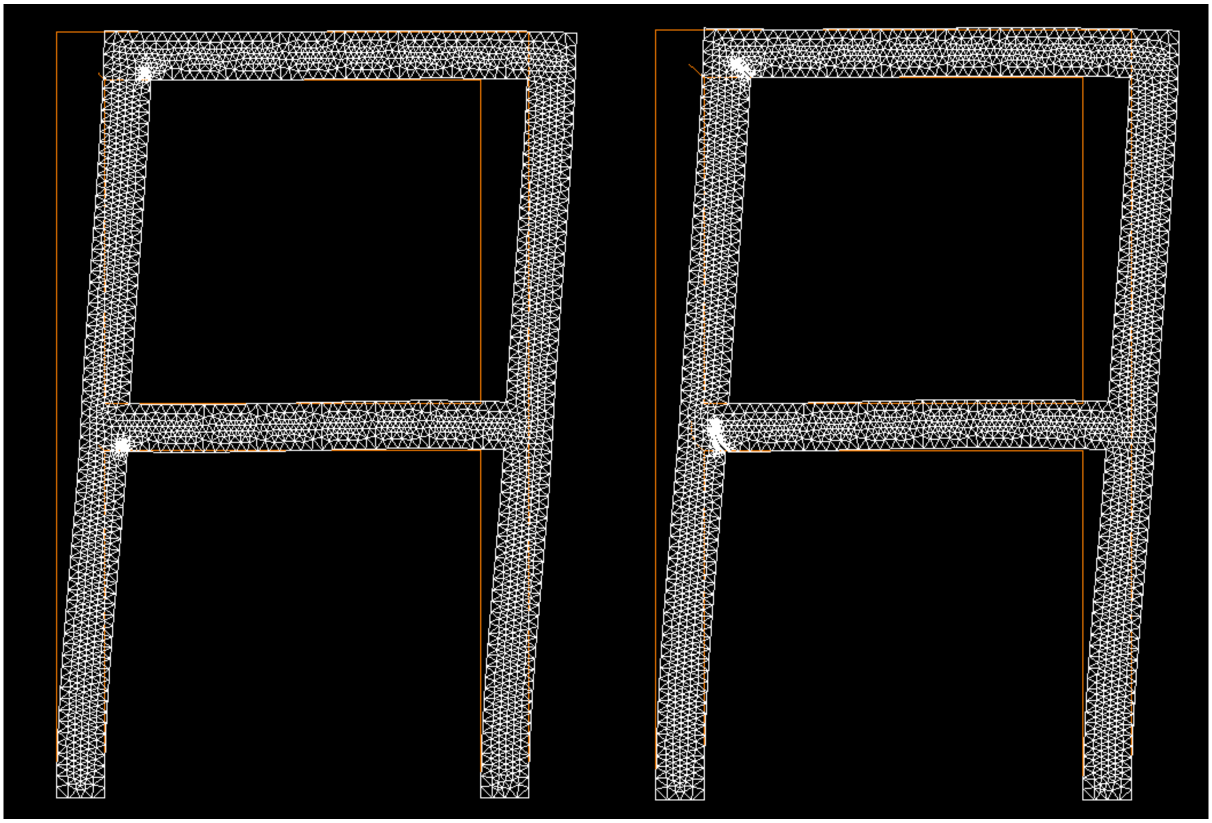

Fig. 1(a): Finite Element Mesh with initial cracks

Fig. 2(b): Finite Element Mesh with propagated cracks

Fig. 2 : Finite element model of two story steel frame

Figure 3(a) shows effective stress contours before generation of cracks and figure 3(b) shows effective stress contours after propagation of cracks.

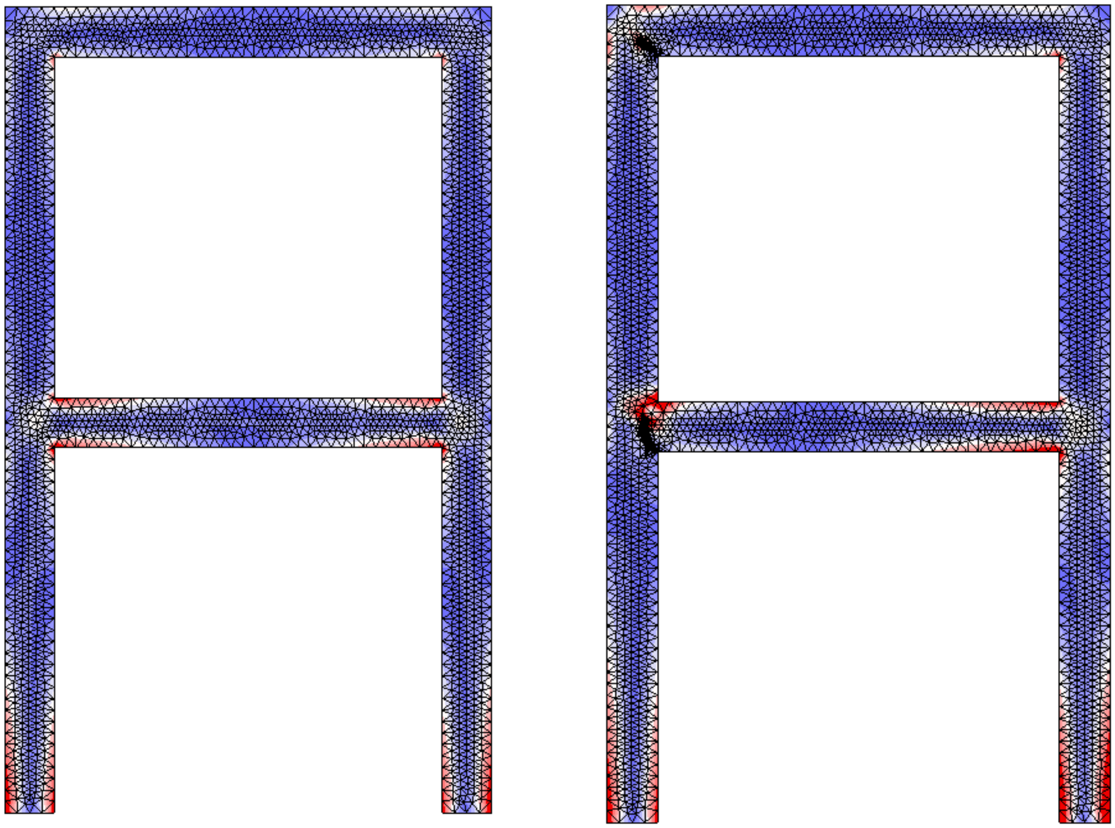

Fig. 2(a): Effective stress counters before generation of cracks

Fig. 3(b): Effective stress counters after propagation of cracks

Fig. 3: effective stress contours in two story steel frame.

Due to presence in cracks, the plastic hinges in beams were observed to shift to 0.22 L and in columns, the plastic hinges were observed to shift to 0.20 L approximately[1]-[7]. Plastic hinges near the cracks were observed to be disappearing.

IV. CONCLUSION

A detailed study on relocation of plastic hinges in a steel frame under seismic loads has been carried out using FRANC2D. It is observed that due to the initial imperfections the plastic hinges near the cracks tend to disappear while those on the farther sides of the cracks shifts a little near to the joints. The capacity of such frames is expected to be significantly deviating from frames without initial imperfections. The value of increment in stress causes a rapid change in plastic zone of the frame due to the initiation and propagation of cracks. This would mean that the initial imperfections must be considered while performing pushover or seismic analysis of frames.

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