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THE SIDE-EFFECTS OF RETROFITTING RC FRAMES WITH STEEL X-BRACES

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For different reasons, such as changes in seismic code, change in application or low quality of operation, it may become necessary to upgrade or retrofit an existing RC building. Steel bracing, as a global method of retrofitting, is a very suitable technique to decrease the global displacement, reduce displacement ductility demand and increase the capacity of an RC building.

The technique of attaching bracing system directly to the RC frame, in a similar manner to attach bracing to a steel frame using gusset plates, was first proposed by Maheri and Sahebi (1997). Their test results showed that the bracing system is able to substantially increase the shear strength of RC frames. Since this early work, numerous other experimental and numerical works (Abou-Elfath & Ghobarah, 2000; Maheri, 2005; Maheri & Ghaffarzadeh, 2008; Rahimi & Maheri, 2018) have been carried out on this technique. They have reported on the beneficial effects of this method of bracing to increase the in-plane shear capacity and to reduce the drift of the retrofitted RC frames. They also showed that the technique is not only suitable as a retrofitting measure for existing buildings, but also is suitable as a method to increase lateral capacity at design level for buildings to be constructed (Maheri, 2005). Other studies concentrated on evaluating the behaviour factor of RC frame-brace assemblage, evaluating the overstrength due to brace connections to the frame, proposing different methods of connecting the steel brace system to the RC frame and providing design guidelines for these connections (Maheri, 2005), as well as providing design guidelines for the whole frame-brace system (Maheri & Ghaffarzadeh, 2008).

In all the works reported on different aspects of this retrofitting scheme, the researchers have highlighted the positive effects and aspects of the technique on improving the global strength and performance of RC frames. However, addition of any new systems which may result in a change in the load path through the frame may have some side-effects on the performance of local elements of that frame (Rahimi & Maheri, 2018). These elemental side-effects are generally in the form of increased demand or reduced capacity.

In the proposed paper, the side-effects of retrofitting an existing RC frame with X-braces on the global performance of the retrofitted frames and their main elements, including columns, beams and beam-column joints are investigated by using extensive nonlinear time history analyses of the frame-brace system. For this purpose, 20 representing earthquake records have been utilised and applied to three different frame-brace systems, representing low-rise, medium-rise and high-rise frames. The main side-effects of X-brace retrofitting on the elements of an RC frame are summarized as follows:

1. Steel brace retrofitting has an adverse effect on the shear demand on columns. As the height of the frame increases, the adverse effect on the shear in columns attached to the bracing system increases. The same pattern is also noted for shear in other columns, but with less intensity.

2. After retrofitting, the axial compression force in the columns attached to the bracing system increases significantly and as the height of the frame increases, this effect is intensified.

3. Ductility demand on beams not attached to the bracing system may increase in the top storeys of the taller frames. This means that retrofitting may have an adverse effect on the performance of some beams and that these beams may require local strengthening prior to steel brace retrofitting.

4. Although, as a result of retrofitting, the shear demands on the joints are generally reduced, the shear capacity of the joints may also reduce. This requires a careful examination to assure that the required performance is achieved.

5. As a general conclusion, it can be stated that: retrofitting low-rise RC frames with steel X bracing is beneficial to

the frame in almost every aspect; however, for mid to high-rise frames, the adverse effects of retrofitting, particularly on columns attached to the bracing system, are noticeable and should be taken into consideration.

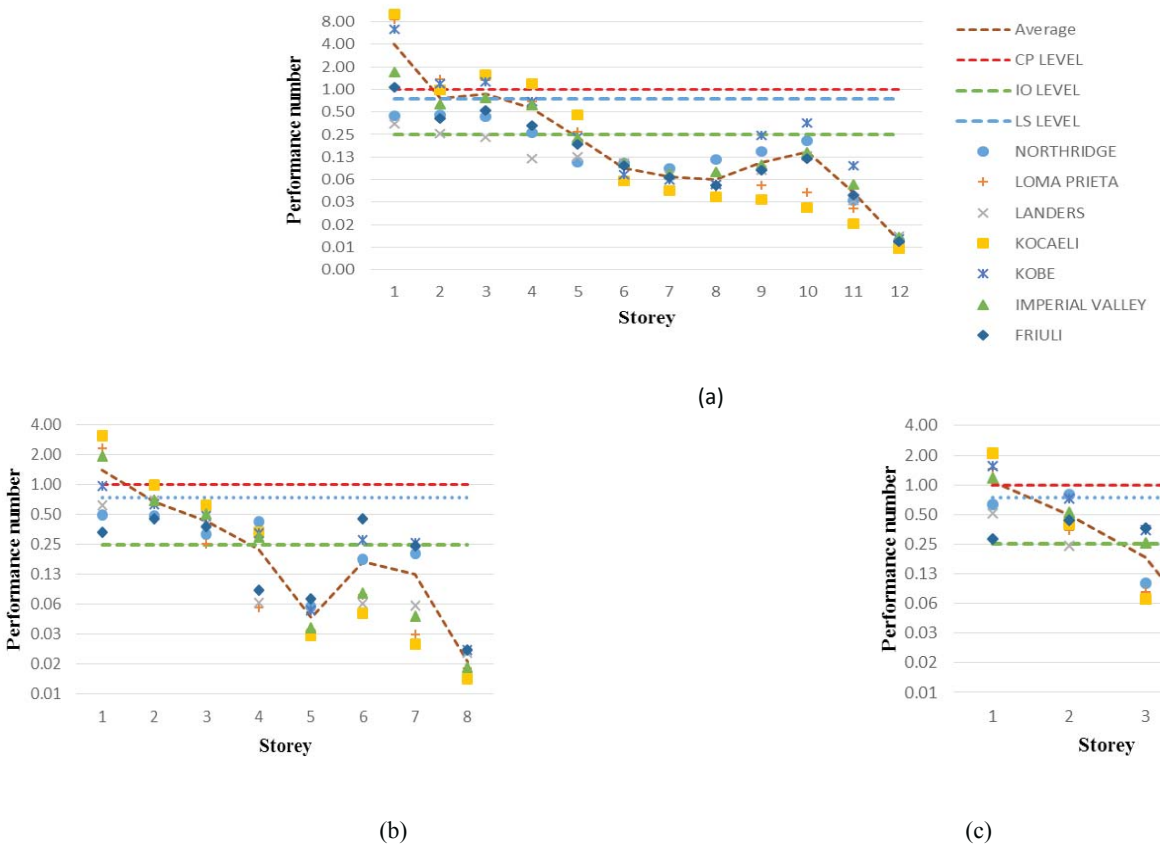

Figure 1. Performance of columns attached to steel brace system: (a) 12-storey, (b) 8-storey and (c) 4-storey frame.

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