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Seismic Evaluation and Retrofit of a RC Frame Structure by Method of Steel Jacketing

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ABSTRACT:

Recent earthquakes in India show that not only non-engineered but also engineered buildings in our country are susceptible even to moderate earthquakes. Indian Standard IS 1893 is revised in 2002. A number of buildings those were designed as per the previous code may not comply with the present code. Therefore evaluating seismic performance of a building and proposing suitable retrofit measure is an important area of study in this context. In the present study an attempt has been made to evaluate an existing building located in Guwahati (seismic zone V) using equivalent static analysis. Indian Standard IS-1893:2002 (Part-1) is followed for the equivalent static analysis procedure. Building is modeled in commercial software STAAD Pro. Seismic force demand for each individual member is calculated for the design base shear as required by IS-1893:2002. Corresponding member capacity is calculated as per Indian Standard IS456:2000. Deficient members are identified through demand-to-capacity ratio. A number of beams and column elements in the first floor of the present building are found to be deficient that needs retrofitting. A local retrofitting strategy is adopted to upgrade the capacity of the deficient members. This study shows that steel jacketing is an efficient way to retrofit RC members to improve flexure as well as shear capacity.

1. GENERAL:

Seismic evaluation and retrofit plan by the Japanese Standard for three existing reinforced concrete buildings (an apartment house, a school and a hospital) of Algiers, the capital of Algeria, were introduced. Algeria is a seismic country, and the Boumerdes earthquake in 2003 caused more than 2,200 deaths and 19,000 building collapse. Seismic evaluation and retrofit of existing buildings are useful measures to mitigate earthquake damages. Approximately 65% of existing buildings are reinforced concrete buildings in Algiers, which has the population of 1.5 million. Many of those are reinforced concrete moment frame structures designed by older seismic design standard (reference 1). Seismic judgment is done by the comparison of Seismic Index of Structure, Is, and Seismic Demand Index of Structure, Iso, which is adjusted based on expected seismic intensity of Algiers. Seismic performance of three buildings was not satisfactory as a result. The vulnerability of three buildings was clarified with respect to structural plan and design through the evaluation of Ductility Index, F, Strength Index, C, and Seismic Index of Structure, Is. The improvement of seismic performance expressed by above Indices, after proposed retrofit, was introduced quantitatively. In addition, the Seismic Index of Structure, Is, of collapsed buildings by the 2003 Boumerdes earthquake was also introduced based on the concrete strength by the core sampling.

2 SEIMIC EVALUAION AND RETROFIT PLAN OF EXISTING BUILDINGS:

2.1 Methodology:

There are three levels of seismic screening procedures in the Japanese Standard of reference 2.

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The first level seismic screening is simple and the result is on the safe side. The second level screening is performed based on column collapse mode. The third level screening is performed including beam collapse mode, but calculation volume increases. Column collapse mode will be dominant for buildings in Algiers as shown in Appendix 3. As a result, the second level seismic screening procedure was applied for the evaluation.

2.1.1 Seismic Evaluation:

Related equations for the seismic evaluation are shown in Appendix 1 for information, and key equations are as
follows.
Seismic Index of Structure, Is,
Is = EoSDT (1)
whrere; Eo : Basic Seismic Index of Structure, SD : Irregularity Index, T : Time Index, Eo is expressed by the product of Strength Index, C, and Ductility Index, F. Seismic Demand Index of Structure, Iso,
Iso=EsZGU (38)
where; Es : Basic Seismic Demand Index of Structure, Z : Zone Index, G: Ground Index, U: Usage Index, The EsZ with the range of 0.5 to 0.6 will be suggested to apply instead of 0.6, which is used in Japan, based on the estimated seismic intensity of Algiers as shown in Appendix 2. The value of 0.5 was used for the judge of three buildings.

2.2. A Five Storey Apartment House

2.2.1. General:

This building is a typical apartment house of reinforced concrete moment frame with cast-in- place concrete, and was designed based on “The Algerian Paraseismic Regulations RPA 88”. Typical column sizes are 35cmx35cm, and 30cmx30cm at the 1st storey. Concrete strength by the core sampling was 27.5 N/mm2. Hoops are φ8mm@100mm. All walls are hollow brick works. The Seismic Index of Structure, Is, was 0.40, and CTSD was 0.18 and were not satisfactory. It is noted that columns were evaluated as flexural columns but the ductility index of columns was low because of the high axial force ratio at the 1st storey.

3.Local retrofitting methods:

From the results obtained above for this building, it is clear that the members will fail under the applied load combinations as per IS 1893:2002 (part 1) and we have to provide retrofitting in the building. The scope of my study is limited to local retrofitting measures.

Retrofit methods of columns include:

- Concrete jacketing
- Steel jacketing
- Fibre reinforced polymer wrapping The columns in this structure can be retrofitted by concrete jacketing, which is the most popular method of seismic retrofit in columns. There are two main purposes of jacketing of columns:
- It increases the shear capacity of columns
- It improves the flexural strength of columns by the longitudinal steel of the jacket made continuous through the slab system and anchored with the foundation.

It is achieved by passing the new longitudinal reinforcement through holes drilled in the slab and by placing new concrete in the beam column joints. The method is straightforward and increases both strength and ductility. But the composite deformation of the existing and the new concrete requires adequate dowelling to the existing column. The mix design of the new concrete, surface preparation of the existing column and the choice of bonding material are also important.

The disadvantages of concrete jacketing are:

- Drilling of holes
- Increase in size of the column
- Placement of ties at the beam-column joint

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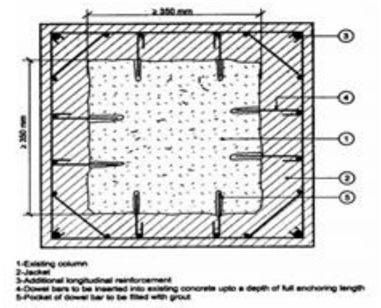

Figure 1: Concrete jacketing

In this structure we can use concrete jacketing as well as steel plating. The scope of my study is limited to retrofitting of beams by steel plating. In steel plating, steel plates are glued to beams to improve their flexural and shear capacities. It increases the strength and stiffness of the beams and reduces the crack width[10].

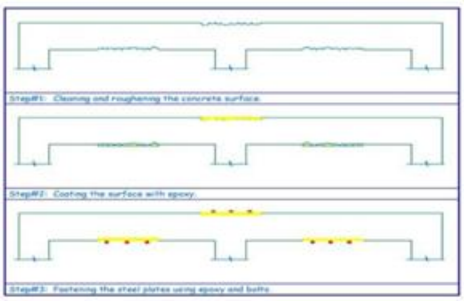

Figure 2: Showing steps of steel plating

Table 13: beams of first floor on which steel plating can be done eligible for steel plating

beams	dcr
21124	1.06
21203	-1.07
21204	1.52
21302	1.17
21303	-1.02
21311	1.15
21312	1.54
21315	1.51
21316	1.13
21503	1.42
21504	1.57
21505	1.55
21506	1.57
21507	1.55
21508	1.41
22142	1.18
22172	-1.26
22182	-1.11
22204	-1.11
22232	1.34
22303	1.39
22332	1.36
22404	-1.68
2241	1.14

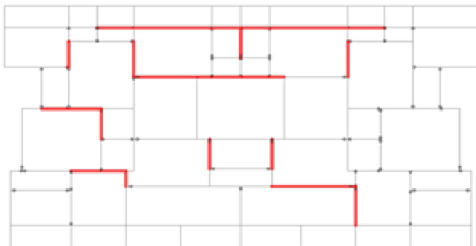

Figure 3: showing beams of 1st floor eligible for steel plating

5.1 Summary:

The purpose of this project was to assess the seismic vulnerability of an existing RC structure and to provide for retrofit in case the members fail. The building under study in this project was an existing multi-storeyed residential building in Guwahati. The plan and reinforcement details of the building were provided. I modeled the building in STAAD Pro software and applied seismic load combinations to it. Equivalent static procedure as per Indian Standard IS 1893:2002 (Part 1) was used to compute the seismic forces. The members' adequacy was assessed by computation of their dcr (demand to capacity ratio) values. The demand of individual members was obtained after analysis from STAAD Pro software and the capacity for the corresponding members was calculated, the ratio of the two gave the dcr values. The simple concept that if the dcr of any member is greater than one would result in the failure of that member under the applied loads was used to find out the status of the members under flexure and shear.

Conclusion:

The results for first floor beams and a large sample of columns showed that a number of beams and all the foundation columns checked were found to be deficient under the applied seismic load combinations. Number of beams failing under flexure was more than the number of beams failing under shear. The dcr of columns under biaxial bending gradually decreased with height, although it was greater than one in most of the cases. For providing retrofit measures for the deficient members, concrete jacketing was found to be a suitable method for retrofitting of columns. It was also concluded that steel plating would be an efficient method of retrofitting of a number of deficient beams.

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