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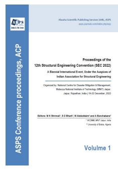

Comparisons of Performance of Building Using Bright New And Old Rusted Rebar

Khwairakpam Sachidananda [1, *]

[1] Department of Civil Engineering, Assistant Professor, National Institute of Technology Manipur, Langol, Manipur, 795 004, India

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Abstract

Reinforced cement concrete structure are the most common structures in India. The strength of structure depends mainly on two components i.e. concrete and steel rebar. One of the main constituent i.e. steel, changes its strength along with the changes in property of steel rebar irrespective of the types of steel, mainly due to rusting of iron i.e. formation of iron oxide by the reaction of iron and oxygen in the presence of water or air moisture. In the present study, experimental investigation has been done as to find the property of steel for the bright new rebar as well as for the old rusted rebar of a particular brand of steel rebar. The experimental result showed that the new bright rebar has ~ 50% higher yielding strength as compared to the old rusted rebar strength. The ductility of new bright rebar is having ~125% higher than the old rusted rebar. The material property of steel extracted from the experiment has been incorporated in Finite Element modelling of a particular building using SAP 2000. The building has been designed under the gravity load as well as uniform lateral load. The performance of building is found out through push over analysis in terms of load vs displacement. The ultimate strength of building using new rebar is around 60% higher than the strength of building with old rebar. The displacement capacity of building also differs significantly i.e. building with new rebar is having ~60% higher than building with old rebar's. Overall, the steel rebars need to be protected from corrosion for the construction of structures.

Keywords: Push-over, Performance, Rebar, SAP 2000

1. Introduction

The development levels of any country largely depend on the construction industries, as it is the backbone of any country economy. The construction industry mainly focussed on two types of structural materials namely RCC (Reinforced Cement Concrete) and Steel. Out of these two types of structures, RCC structures are the most popular choice of construction in India, as the materials are available throughout the country and the methodology of building structures has been descendent from the early period as a patent of William Wilkinson's in 1854 (Stuart, 2003). Generally, RCC structures consist of iron rebar and concrete materials. So, the strength of RCC structures mainly depends on the strength of concrete and rebar steel. The concrete component takes only the compression load while steel rebar takes both the tension and bending component of structures e.g. beams, column etc. For construction purpose, people generally bought steel rebar and keep for long time. People usually neglect the importance of storage of steel in the proper way. The storage of rebar for long period under heat and rain may lead to rusting of iron by formation of iron oxide due to the reaction of iron and water vapour present in the environment. Many researchers i.e. Agarwal and Shrikhande (2006), Cimellaro *et al*., (2014), have studied the procedure and analysis of earthquake resistant design but none have studied the variation of strength of building for bright and old rusted rebar in the building structure.

Since the material property of steel changes along with time, the study on the variation of strength between new and old rusted rebar becomes an inevitable study for the sake of strength of structures. In this paper, an attempt has been made to show the variation of strength of rebars between the new and old rusted steel rebar experimentally. The study has been further extended by finite element modelling of a building using software SAP2000, considering the material properties of steel extracted experimentally for both the new and old rusted steel rebars. The difference in performance of building using the new bright and rusted iron rebars has been studied in details. The safety of the building has been checked by following the Indian Standard codes of IS 456 (2000), IS 13920 (2016), IS 875 part 1 and 2 (1987), IS 1893 part 1 (2016). The performance of the building has been found out by push-over analysis, following ATC 40 (1996). The property of steel is found out by tensile testing of steel by using UTM (Universal Testing Machine) in terms of stress-strain property. The importance of proper storage of iron rebar will be reflected in this study. The elaborated form of study of experimental and finite element analysis of steel rebar has been shown in the following subsequent sections. The finite element analysis of a building has been taken into account for the present study as the experimental

*Corresponding author. Tel: +919957546722; E-mail address: 28sachi19@gmail.com

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study required huge expenditure and the finite element analysis results are also acceptable for consideration.

2. Experimental study of steel

The property of steel rebar is mandatory for understanding the quality of steel, as many companies are manufacturing steel and available in market under different brands. The steel rebar played an important role in determining the strength of RCC members. The testing of steel rebar for tensile test is generally done in Universal Testing Machine (UTM). For the study, same grade of steel have been considered for both bright and rusted rebar, as to maintain same type of composition for steel. The rebar of grade Fe500 bars with diameters of 16 mm are taken both for the new and old rusted steel rebar. These rebar are bought from local place i.e. Imphal Bazaar, Manipur, India (a state of Northeastern India). The difference in the physical properties of old and new rebars is shown in Fig. 1, where the new rebar is bright and the old one is quite rusted. The weight of new bright rebar is lighter as compared to the rusted rebar due to the oxide formation of steel. The straight rebar portions are considered for testing. The gauge length 5d (5 times diameter of rebar) are marked within the parallel section portion of the sample as per IS 1608(2005) as shown in Fig. 2. The marking of gauge length will enable to take the extension of the rebar after taking the load. The rebars are fixed into UTM with appropriate grip as shown in Fig. 3. The extensometer is also attached to the specimen to record the change in gauge length.

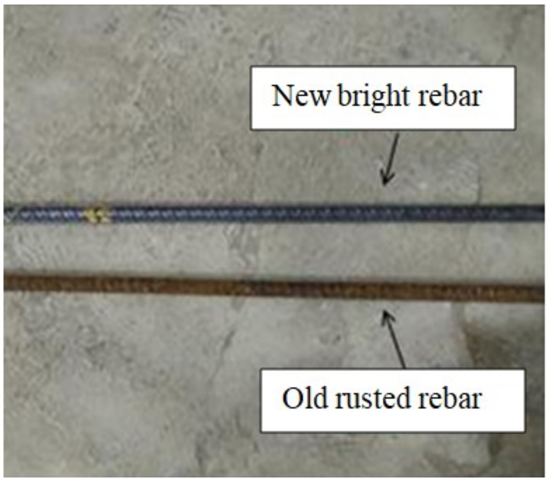

Fig.1. Old rusted and ne

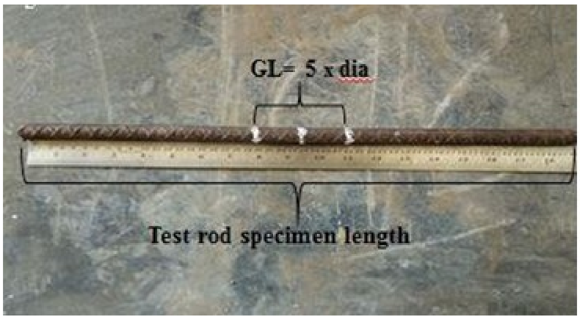

Fig. 2. Marking of gauge length in steel rebar w bright rebars

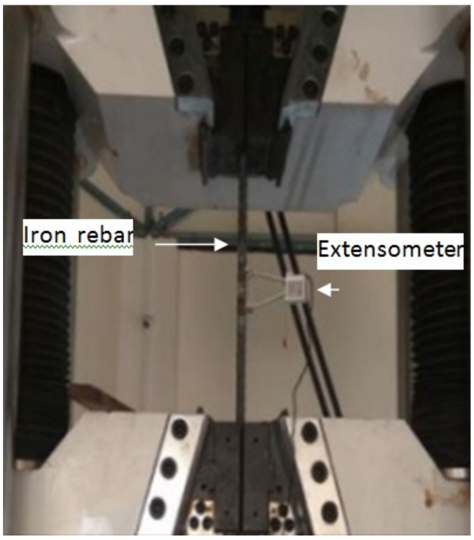

Fig. 3. Tensile testing in UTM

3. Finite element modelling in sap2000

For the present study, a particular building has been considered. The building has been modelled in SAP 2000, which is a well known finite element analysis software that can performed the static or dynamic, linear or nonlinear analysis of structural system. The performance of the building has to be found out by push over analysis.

For modelling, a building plan of 1 storey (G+1) as shown in Fig. 4 is taken, in which the properties of steel rebar in terms of stress-strain curve and material properties values, from experimental study has been incorporated in the model. Reinforced cement concrete (RCC) is made up of steel and concrete portion. To study the importance of steel, the property of concrete for building has been taken constant at M20 while the steel property changes as bright steel changes into rusted iron rebar as shown in Table 1, results obtained from UTM

This study will enable to understand the effect of changes in the properties of new bright and old rusted rebars. The building has been checked for the design of safety against the gravity load as well as for the design seismic weight for the public building as per IS 875 Part 1 and 2 (1987).

The slab depth has been assumed as 200 mm. The gravity load as well as lateral loads are taken into account for the design of building, considering IS 456 (2000) and IS 1893 part 1 (2016).

Table 1. Properties of steel rebar from UTM

	New steel bright	Old rusted steel
Elastic modulus, E (GPa)	5	3
Yield stress, f_y (kN/m^2)	726642	427729
Ultimate yield stress, f_u (kN/m^2)	732610	497857
Expected yield stress, f_e (kN/m^2)	799306	470502

Table 2:Load considered for analysis (IS 875-1 & 2)

Types of loads	Values taken
Live load	4 kN/m^2 – typical floor
	1.5 kN/m^2-terrace
Floor finish	1 kN/m^2
Water proofing	2 kN/m^2

In order to differentiate the strength of building for old rusted and new rebar, the performance of building needs to be found out. Many methods like time history method (non-liner dynamic), push over analysis methods (non-linear static) etc are available for finding the performance of buildings. But for the current analysis, the push over analysis has been considered as it is a static analysis and require less time in analysis. The finite element software SAP 2000 has been used for design of building. The performances of building are plotted in terms of load vs displacement. For the analysis, the buildings are first designed to be safe using the properties of bright iron rebar. In the next step, the same buildings are again checked to be safe using the old rusted rebar.

The dimension of the building for the analysis is taken as length x breadth i.e., 4 m x 4 m , with one storey. The foundation of building is considered as fixed. The slab of the building has been model as a diaphragm, which holds the vertical structures together. The non-structural member like brick wall has not been modelled, even though the brick loads have been considered. The plan and elevation of the considered building are shown in Figs. 4 and 5. The building height has been maintained constant at 3.2 m and the plinth height has been taken as 2 m. The loads that have been considered for design are shown in Table 2.

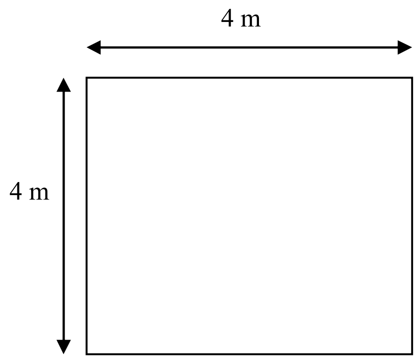

Fig. 4. Plan of the building

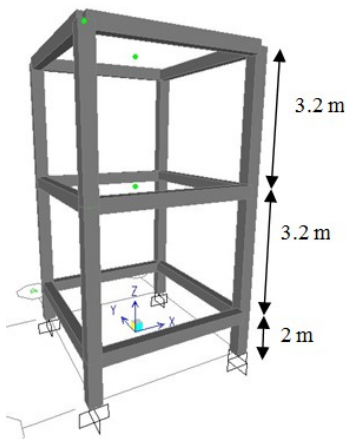

Fig. 5. Elevation of building (G+1) in SAP 2000

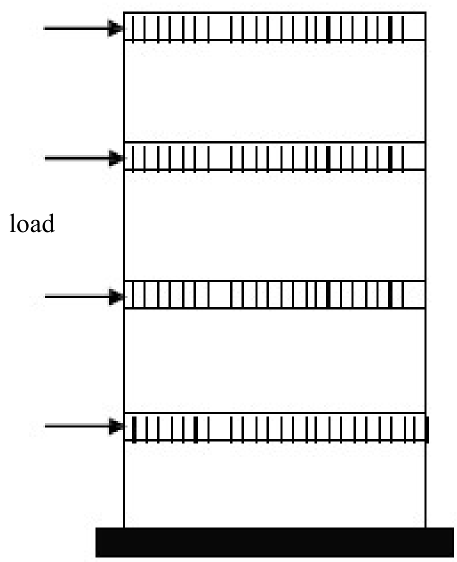

Fig. 6. Typical building frame with lateral load

3.1 Non liner static (Push over) analysis

The push over analysis is a nonlinear static analysis method. In this method, the analysis is performed by applying monotonically increasing pattern of lateral load to the structure, representing the lateral forces generating from the shaking of the earthquake. As the load increases incrementally, the structure started yielding sequentially. Using this method, the characteristic nonlinear force displacement relationship can be determined.

The performance of building can be found out in terms of IO (Immediate Occupancy), LS (Life safety) and CP (Collapse Prevention). The typical lateral load on the building for analysis is shown in Fig. 6.

4. Results

The results of the current study have been presented in two steps i.e. Experimental and finite element results.

4.1 Experimental

The tensile testing result of new bright rebar and old rusted rebar in terms of load vs displacement is shown in Fig. 7. The experimental result showed that the new bright rebar has ~ 50% higher yielding strength as compared to the old rusted rebar strength. The reason may be rusting of iron as well as the lowering of bonding strength. The ductility of new bright rebar is having ~125% higher than the old rusted rebar. So, the new rebar has higher strength as well as ductility which are very good properties for the building reinforcement from the earthquake and structural point of view. The typical broken rebars of old and new rebars are shown in Fig. 8, in which the outer core of rusted bar showed dull rusted portion while new rebar showed only bright iron core.

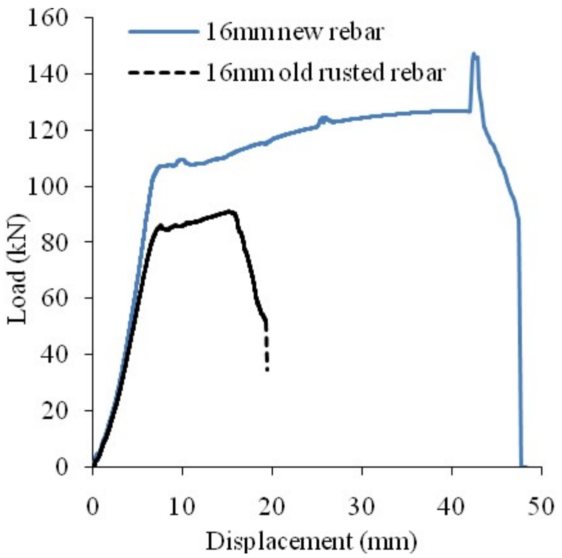

Fig. 7. Tensile testing of rebars of 16 mm

Fig. 8. Typical broken rebars after tensile test

4.2 SAP 2000 (FE software)

The building has been designed as per IS 456 (2000). From the design, the column, beam reinforcement and its sizes have been determined. The column size have been determined as 350x350 mm and beam as 300 x 250 mm. The modeling of building has been designed by providing 8 numbers of 16mm diameters rebar in columns (350mm x 350mm) and 6 numbers of 16mm diameters rebar in beams (300mm x 250mm) with the provision of the properties of new steel and old steel. After the design has been done as per IS456:2000, it has been found that the building with **old rebars failed in design with 8 numbers of 16mm diameter rebars** (abbreviated as ORFDN8D16) with 8 members i.e. for ground and first floor (columns only) as shown in Fig. 9 but the building with new rebars passed in design with 8 numbers of 16 mm diameter rebars (abbreviated as NRPDN8D16) shown in Fig. 10.

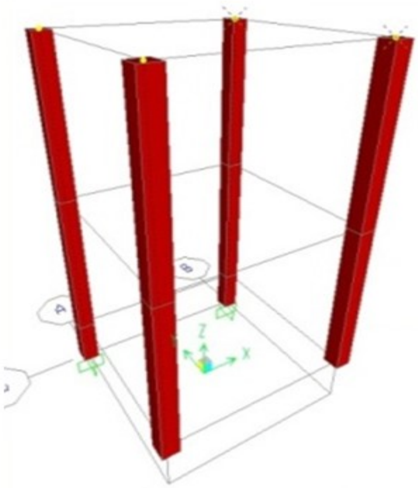

Fig. 9. ORFDN8D16 –8 members (columns) failed

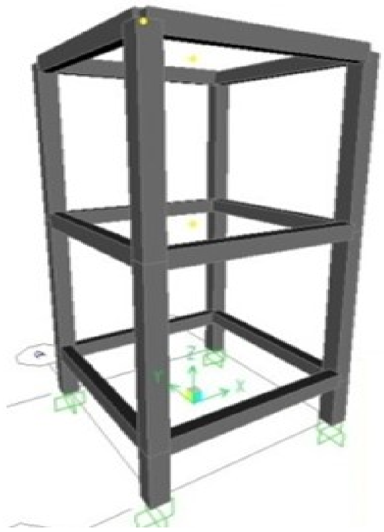

Fig. 10. NRPDN8D16 – all members passed

The pushover analysis are performed in both the buildings. The push over analysis showed that the failed building i.e, ORFDN8D16 has lower strength than the building with new rebars i.e, RPDN8D16 as shown in Fig. 11. The push over analysis showed that the failed building with old rusted rebars i.e, ORFDN8D16 could not get the performance point as the building failed in design but the building with new rebars i.e, NRPDN8D16 could get the performance point of building within the IO (Immediate Occupancy) level. The ultimate strength of building using new rebar is around 60% higher than the strength of building with old rebar. Moreover, the displacement capacity of building also differs significantly i.e. building with new rebar is having ~60% higher than building with old rebars. The typical deformation of the building is shown in Fig. 12. The deformation showed the formation of hinges in the beam as well as on column.

The deformation at different stages of loading can be captured, thereby showing the performance level of building.

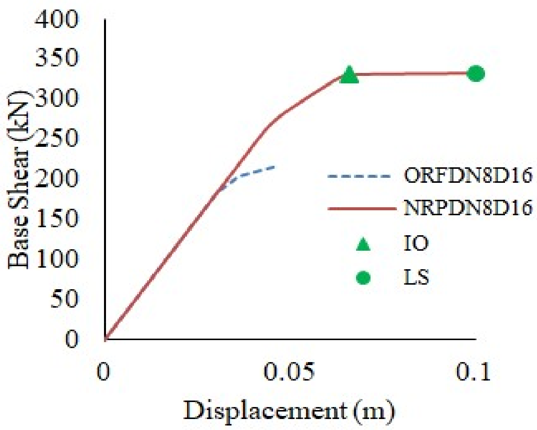

Fig. 11. Load vs Displacement (Pushover analysis)

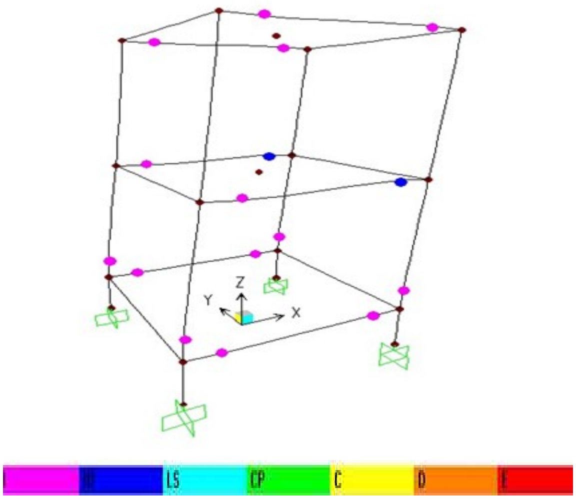

Fig. 12. Deformed shaped of NRPDN8D16 at step 11

5. Conclusion

Experimental as well as FE studies have been conducted on both new bright and old rusted rebars. Based on the studies conducted both on experimental and numerical method using SAP 2000, the following conclusions have been derived as follows:

a) The experiment showed that the new rebar has higher strength as compared to the old rebar. The experimental result showed that the new bright rebar has ~ 50% higher yielding strength as compared to the old rusted rebar strength. The reason may be rusting of iron as well as the lowering of bonding strength.

b) The experiment result showed that ductility of new bright rebar is having ~125% higher than the old rusted rebar.

c) The ultimate strength of building using new rebar is around 60% higher than the strength of building with old rebar.

d) The displacement capacity of building also differs significantly i.e. building with new rebar is having ~60% higher than building with old rebars.

e) For the same building using same amount of reinforcement, the building with new rebar passed the design load while the building with old rebar could not passed the design as the strength of old rebar is less than new rebar

6. Suggestions

As far as possible the steel rebar material should be kept in shed area protected from rain and water. In case there is no way of covering or protected from rain water, than the steel rebar may be covered with cement or material whichever is repellent to rain water or vapour.

Disclosures

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7. Acknowledgements

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