"Effect of Plain Bars on Hystersis Behavior of R/C Members"

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Introduction

Although, the use of plain bars was prohibited by recently developed Iranian building codes [1], Iranian engineers used to design structures with plain bars till 1980. During the past earthquakes, the bad performance of plain bars was one of the most causes of damages to R/C buildings. Figure 1 shows a typical one story one span R/C building which suffered heavy damages during Iran-Qayen (Ardakul) earthquake of may 10, 1997 [2]. Due to recently killer earthquakes in Iran, the Government pushes for strengthening of existing buildings. In order to strengthening and retrofitting of existing R/C buildings with plain bars, a proper member hystersis model is of essential. Unfortunately there is a lack in such proper member hystersis model that implies the effects of bonding and pinching of plain bars. This can be due to lack in experimental results. Two identical R/C structural members one with plain bars and another with deformed bars were designed and constructed in almost same conditions. The members were subjected to cyclic load to obtain and compare their hystersis diagrams. The test procedures, observations and results are explained in the following sections.

Fig. 1 A typical R/C building (Ardakul) suffered by joint failure and slip out of plain bars

Experiment Procedure

Fig. 2 Test set-up of prototype member

A cantilever member was used to simulate the seismic behavior of a member with moment contra-flexural point at mid-span during earthquake motion (Fig. 2). A 100KN servo hydraulic jack, manufactured by Instron Company, was used to apply cyclic concentrated loads history at a point with a distance of 126cm from top of the stub level. The loading system was controlled by servo hydraulic dynamic actuator systems at the structural laboratory of Tehran University. Data acquisition systems consisted of a static data logger, transducers, and strain gauges, which were obtained from Tokyo Sokki Company. Two half scaled R/C members one with plain bars and another with deformed bars were designed to meet setup capacity of the laboratory. The members were prototypes of a big Hospital in Tehran, which is target for a strengthening project. Lateral steels ratio was adequately large to prevent shear failure. In order to compare the results of the test, the dimensions of specimens, lateral and longitudinal steel ratios, reinforcement detailing, steel types, concrete mixture, and curing conditions were identical for both specimens. Totally 6 strain gauges were used for each specimens, 3 at each sides. The 3 strain gages were mounted on longitudinal bars at a distance of 2, 10 and 18cm from top of the stub. Strain gages on each side were mounted at the same level. Strain gages were calibrated using simply supported steel plates at the laboratory. The information of calibrated strain gages were monitored and registered at each loading step to find out the mechanical behavior of steel at each step. Mechanical properties of longitudinal steel bars are shown in Table 1. Four 15*15 cubic specimens of concrete were casted and subjected to uniaxial compressive test at the date of member test. The average of compression strengths of concrete for specimens with plain and deformed bars were 32.25 and 321 MPa, respectively. Moment-curvature diagram for plain bar member and deformed bar member was drawn and compared in figure 3. Tensile strength of concrete was assumed to be 10 percent of compressive strength. Initial elasticity Young's

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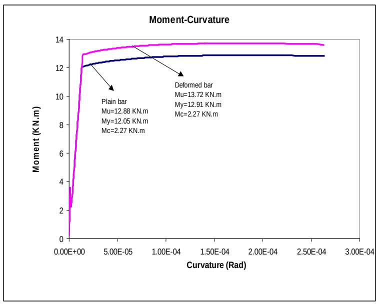
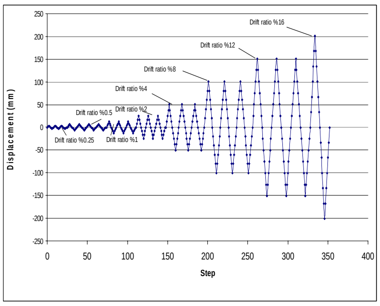
modulus of concrete E_c was 2.92×10^4 MPa based on a secant value recommended by AIJ (Architectural Institute of Japan). A parabolic stress-strain relation was assumed for concrete in compression zone at cross section of members, and moment-curvature relation was calculated for a given constant axial force. It was assumed that cylindrical compression strength f'_c is equal to 0.85 of cubic compression strength. It is evident from figure 3 that flexural capacity of the member with deformed bar is about 7% greater than flexural capacity of the member with plain bar. This disparity must be considered when comparing the hysteresis behavior of two specimens.

Table. 1 Mechanical properties of steel bars

Expression	No. of Spec.	Elasticity Modulus (MPa)	Yield Strength (MPa)	Tensile Strength (MPa)	Yield Strain	Fracture Strain
Plain round bar	2	2.1×10^5	350	493	0.0017	0.215
Deformed bar	2	2.1×10^5	375	526	0.0018	0.205





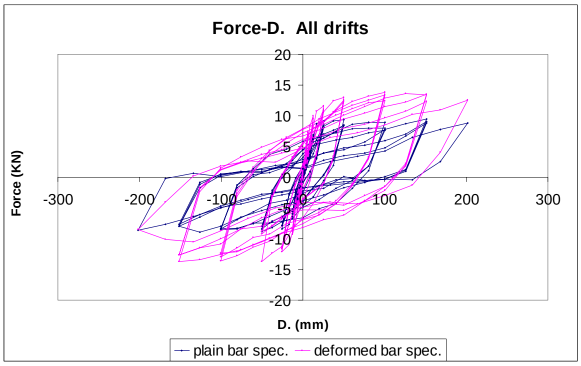


Fig. 3 Moment-curvature, loading steps, and hysterssis diagram

Lateral load was applied to the members based on a displacement control loading steps to a drift ratio of 0.25, 0.5, 1, 2, 4, 8, 12, and 16 percentages. In each drift ratio, 3 cyclic loading set was applied (Fig. 3). We observed detachment of member from the stub for both specimens. This was occurred in the member with plain bars sooner than the member with deformed bar which can be related to bond problem and slipping out of the plain bars. No buckling and steel fracture was observed in member with plain bars. Thought member with deformed bars faced with buckling of longitudinal bars at second load cycle and drift ratio of 12%, and steel fracture of longitudinal bars at first loading cycle and drift ratio of 16%. Cracks were highly concentrated at member end in the member with plain bars. This can be related to slipping of bars in the member with plain bar. In the member with plain bars main cracks development length was about 0.5D from the stub face (D is the depth of the member), while in members with deformed bars this length was about 1.5D. These distances may be representative of plastic hinge length of the members. It is notable that very few cracks on the stub were observed which indicate a rigid behavior of the stub. Hystersis diagrams at all drift ratios are plotted in figure 3. Notable strength decay (more than 40% at around pick strength) of member with plain bars is observed. Although pinching effect was occurred in both specimens, it was more considerable for member with plain bars. Strain gauges revealed that initial yielding of longitudinal steel bars was occurred at a drift ratio of about 0.5 to 1%. And, at a drift ratio of 2% strain gages showed that all bars were yielded. It is notable that loss of force in second and third loading cycle compare with the first cycle obviously occurred which shows the deterioration effect.

Conclusion

Seismic performance of R/C members with plain bars is poor compare with R/C members with deformed bars. Two main improper behaviors were observed. The first improper behavior was considerable loss in strength of R/C member with plain bar compare with the member with deformed bar. Another improper behavior was increasing the pinching effect in hystersis diagram of the member with plain bar. This leads to less dissipation of hysteresis energy under same circumstances of member with deformed bar which can result in much destroyed damages in earthquake.
Cracks were much concentrated at starting end of member with plain bars. Consequently plastic hinge length of member with plain bars was about 0.5D (member depth), while it was about 1.5D for members with deformed bar.
According to the results in this research, the hystersis model of R/C members with plain bars can be obtained by applying a strength reduction factor and some pinching factors to conventional model of R/C members with deformed bars. This model can be used in analyzing R/C structures with plain bars in order to evaluate the seismic performance of existed structures for the purpose of retrofitting and/or strengthening. More experimental work is needed to find out a proper strength reduction factor and pinching parameters of members with plain bars.

References

1. BHRC, “Iranian Code for Seismic Resistant Design of Buildings,” Building and Housing Research Center (BHRC), Ministry of Housing and Urban Development, Iran, 1988.
2. Alaghebandian, R., “Building Damages During The IRAN-Qayen (Ardakul) Earthquake of May. 10, 1997,” Otani & Shiohara Lab., Dept. of Architecture, The Univ. of Tokyo, Japan, Nov. 1997.

Acknowledgment

Author acknowledges supports of Boali Sina University for paper submission and presentation. Helps of my graduate students who passed the course of Nonlinear Earthquake Response Analysis of R/C buildings at Tehran University are appreciated.