

STUDY ON THE EFFECT OF HOOK LENGTH IN RC COLUMN SUBJECTED TO CYCLIC LOADING

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ABSTRACT

Reinforced concrete columns have to be designed and detailed adequately to resist both gravity and lateral loads. Transverse reinforcements in columns in the form of hoops, cross-ties, or spirals play an important role in safeguarding the columns, especially when they are subjected to strong earthquakes or accidental lateral loads. They are required in any column-whether they are parts of a moment resistant frame or the gravity system in order for them to deform laterally and provide the required ductility. As per IS:13920-1993, a 135° hook with 10 diameter extension at each end that is embedded in the confined core is recommended in all reinforced concrete structures located in seismic zone III, IV and V which are highly prone to earthquake. The objective of this work is to carry out experimental investigation by reducing the hook length from 10d to 8d and 6d and to study the behaviour of columns. Studies are conducted to determine the load carrying capacity and energy dissipation of the required specimens and results were discussed.

1. INTRODUCTION

Ductility of a structure is its capacity to undergo large inelastic deformations without significant loss of strength or stiffness. It is the capacity to absorb energy by deforming into inelastic range. This capacity of the structures to absorb energy with acceptable deformations and without failure is a desirable characteristic in any earthquake resistant design [5,7]. Thus ductility should be guaranteed for the safety design of any structure subjected to unexpected and/or reversal loads since plastic hinges may develop in columns of reinforced concrete buildings, especially in column-foundation joints.

After the occurrence of Bhuj earthquake in Gujarat, India in 2001, the scope of IS 13920 was extended to include all buildings in zone III, whereas, prior to that, it was applicable for high and very high seismic hazard areas(zone IV and V) and for buildings greater than five storeys in moderate seismic hazard

area(zone III)[3]. The IS 13920 emphasizes the same conditions for seismic detailing of frame members and shear walls regardless of the level of seismic hazard. This needs to be rationalized. It may be possible to simplify some of the ductile detailing in zone III [1, 2, 5]. Ductile detailing requires substantially higher effort in design, construction, and quality control. Hence it is desirable to have the option for zone III to provide lower level of ductility.

IS 13920 recommends a 135° hook with 10d extension (d-diameter of lateral reinforcement) at each end that is embedded in the confined core of R.C. columns.

2.OBJECTIVE

The objectives of the study are to check whether the IS:13920-1993 recommended hook length, for lateral ties of RC columns, of 10d can be optimized to 8d and 6d, by evaluating the performance of these columns subjected to quasi static reverse cyclic loading.

3.EXPERIMENTAL SETUP

The methodology involves analyzing an exterior column in a multi-storeyed building located in seismic zone III and determining the design moments and axial forces[3,4,5], material testing, preparation of mix design and designing the specimens as per IS 456:2000 and IS 13920[4,5]. The mix proportion was 1:1.36:2.7 with water cement ratio of 0.44. Testing of specimens was done in a self-straining testing frame.

Figure 1 and 2 shows the reinforcement cage of the column specimen and specimen after casting respectively. Table 1 shows the specimen designation. The scale down size of column is 150 mmX150 mmX500 mm and stub size is 400 mmX400 mmX150 mm. All the specimens were reinforced with 4 no: of 12 mm bar as main reinforcement and 2 legged 6 mm lateral ties at 12 mm c/c for specimens with ductile detailing and at 100 mm for specimen without ductile detailing.

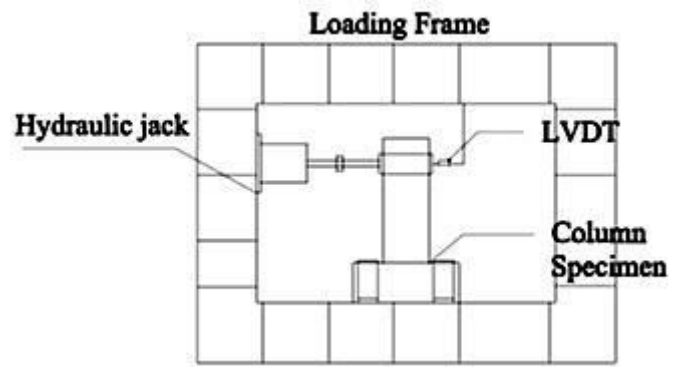


FIGURE 1. REINFORCEMENT DETAILING

Fig 4. During testing, the observations were made for each cycle of loading, first crack and ultimate stage. Fig 5 shows the loading history of cyclic loading [6]. Load at each cycle of deflection controlled loading were observed and recorded. The displacement controlled loading sequence consisted of drift-controlled mode with two increments of 0.125% drift followed by increments of 0.25% up to 2% drift, after which the drift increments were 0.5%. A metallic collar was inserted to the tip of the column through which the loading was given. A base fixer attached to the column footing is fixed at the bottom plate of 2000 kN testing frame. This support condition was chosen to simulate the fixity condition of the column in the field.



FIGURE 2. SPECIMEN AFTER CASTING



3. SCHEMATIC DIAGRAM OF EXPERIMENTAL SET UP

TABLE 1. SPECIMEN DESIGNATION

Sl. No.	Specimen name	Details
1	CNDD	Column without ductile detailing
2	CDD10	Specimen with hook length 10d (Control specimen)
3	CDD8	Specimen with hook length 8d
4	CDD6	Specimen with hook length 6d

After 28 days curing, the specimens were tested in the 2000 kN capacity self-straining testing frame. A schematic diagram of experimental setup is shown in Fig.3. Loading was done with push and pull hydraulic jack with the test set up in the Laboratory as shown in



FIGURE 4. EXPERIMENTAL SET UP IN LABORATORY

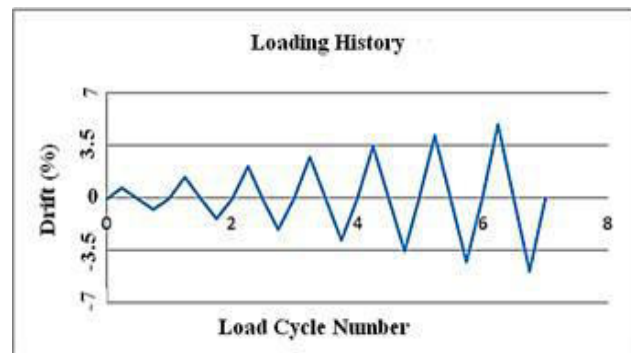


FIGURE 5. LOADING HISTORY OF CYCLIC LOADING

4. RESULTS AND DISCUSSIONS

The test results are presented in the form of load-displacement hysteresis loop, load-deflection envelope, energy dissipation capacity and cracking patterns. The observations made during test are discussed as follows.

Hysteresis Curve

The load-displacement hysteresis loops for the specimens are shown in Figure 6, 7, 8 and 9. Hysteretic loops show the performance of column under cyclic loading. The area under the curve denotes the potential energy stored in the structure at the maximum displacement position. The Hysteretic behaviour of reinforced concrete is characterized by the rounding and pinching of the loops. The wider the loops, the larger will be the energy dissipation capacity and better will be the seismic performance.

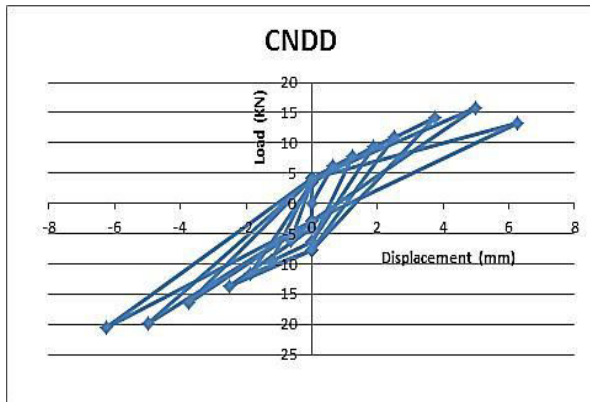


FIGURE 6. HYSTERESIS CURVE FOR CNDD SPECIMEN

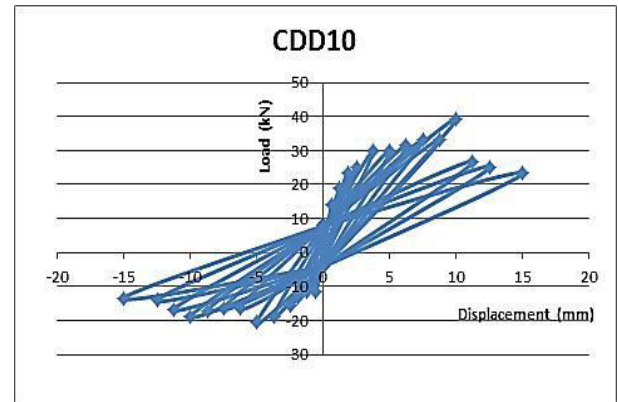


FIGURE 7. HYSTERESIS CURVE FOR CONTROL SPECIMEN (CDD10)

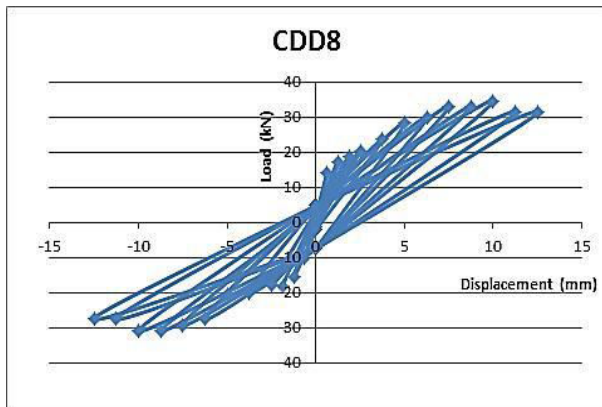


FIGURE 8. HYSTERESIS CURVE FOR CDD8 SPECIMEN

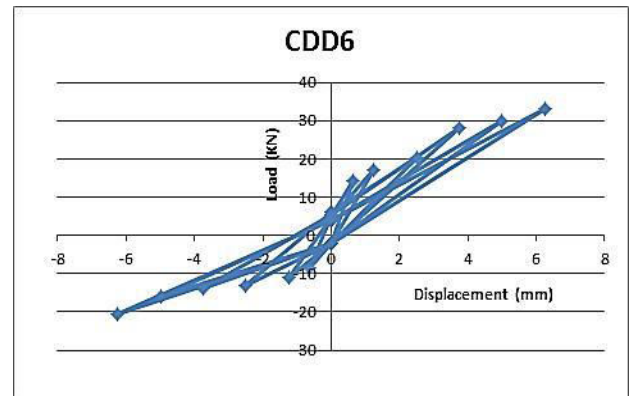


FIGURE 9. HYSTERESIS CURVE FOR CDD6 SPECIMEN

Load-Deflection Envelope

The maximum loads and displacements obtained in each half cycle were used for plotting the load displacement envelopes for the tested specimens as shown in Fig 10. The envelope enables the comparison of relative performance of the different specimens.

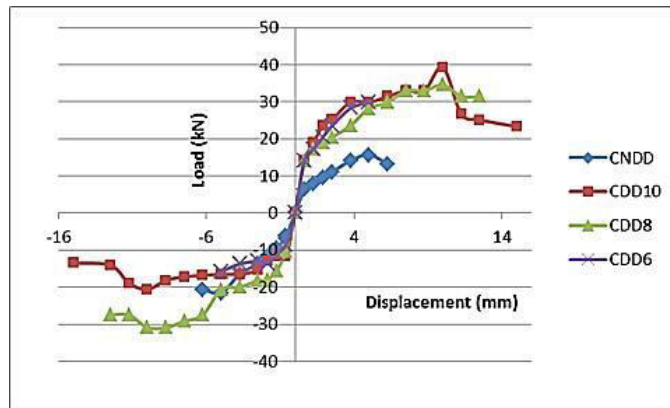


FIGURE 10. LOAD-DEFLECTION ENVELOPES

Energy Dissipation Capacity

As a measure of the dissipated energy of the specimens, the area under the full load displacement envelope was computed and defined as the energy that could be dissipated by the specimens before the system lost its stability. Table 2 summarises the details of energy dissipation capacity of the specimens. Figure 11, 12 and 13 shows comparison of energy dissipation capacity, ultimate deflection and ultimate load carrying capacity of various specimens respectively.

TABLE 2. ENERGY DISSIPATION CAPACITY OF TESTED SPECIMENS

Specimen	Energy dissipation capacity (kNmm)	Variation in energy dissipation capacity (%)
CDD10	198.297	-
CDD8	180.026	90.786
CDD6	168.85	85.15
CNDD	115.51	58.25

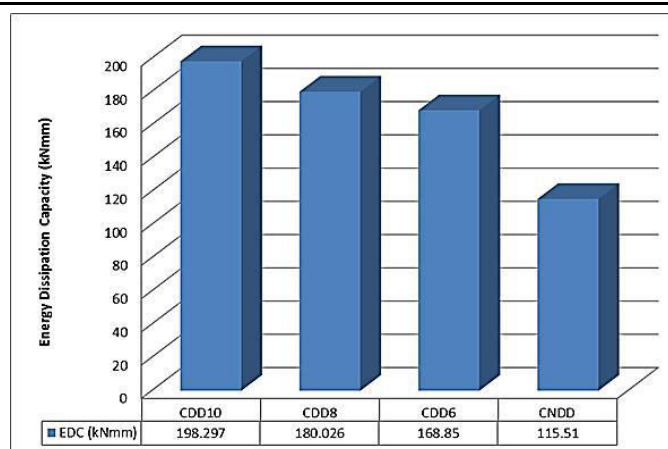


FIGURE 11. COMPARISON OF ENERGY DISSIPATION CAPACITY OF SPECIMENS

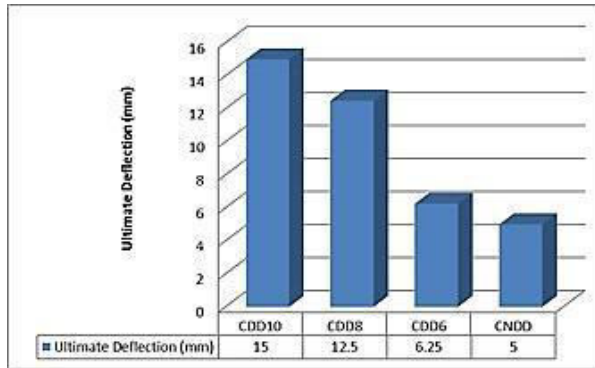


FIGURE 12. COMPARISON OF ULTIMATE DEFLECTION OF SPECIMENS

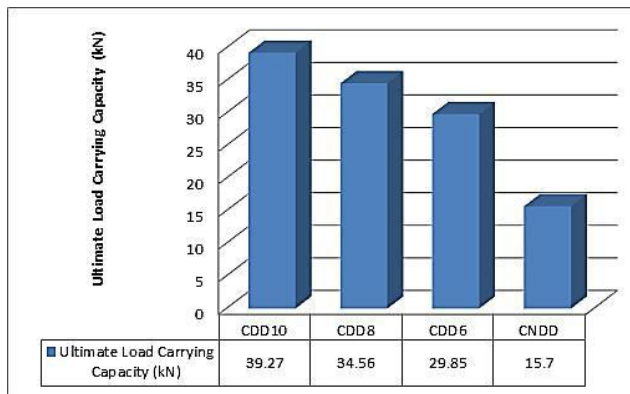


FIGURE 13. COMPARISON OF ULTIMATE LOAD CARRYING CAPACITY OF SPECIMENS

Cracking Patterns

The cracking patterns of the test specimens are shown in Fig.14, 15, 16 and 17.

For the control specimen CDD10 and specimen CDD8 first crack was observed during seventh cycle of loading. The first crack for specimen with hook length 6d was found to develop during fifth cycle of loading, while the specimen with non-ductile detailing CNDD first crack was developed during fourth cycle of loading. Both the control specimen and specimen with reduced hook length of 8d showed similar crack pattern.



FIGURE 14. FAILURE PATTERN OF CDD10



FIGURE 15. FAILURE PATTERN OF CDD8



FIGURE 16. FAILURE PATTERN OF CDD6



FIGURE 17. FAILURE PATTERN OF CNDD

5. CONCLUSIONS

After testing the specimens under reverse cyclic loading and comparing the performance of the specimens, the following conclusions are drawn. The performance of specimen with hook length 8d was similar to that of specimen with hook length 10d (control specimen). The energy dissipation of specimen with 8d hook length was 90.786% that of specimen with 10d hook length, whereas for specimen with 6d hook length and without ductile detailing it were 85.15% and 58.25%, respectively than that of control specimen. The ultimate deflection of specimen with 8d hook length was also similar to that of control specimen. Hence, it can be concluded that the ductility was improved and hook length can be reduced from 10d to 8d in regions of moderate seismicity.

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