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A REVIEW ON EFFECT OF CONFINING REINFORCEMENT ON DUCTILITY OF RC STRUCTURE UNDER DYNAMIC LOADING

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Abstract:
RC structures have been the area of research for a very long time. Engineers are concerned of the vulnerability of public buildings due to lack of dynamic consideration in design procedures. In India usually joint is neglected for specific detailing. This design methodology can work only in absence of dynamic loading. If beam-column joint of any structure is damaged due to poor detailing it becomes difficult to repair as it is inaccessibility. This can jeopardize the stability of whole structure. The focus has been to improve building codes and make it mandatory for all the structures to be designed accordingly. One of the most important parameters that has played crucial role in improving the performance of RC structures under dynamic loading is ductility

Keywords: ***confinement; ductility; dynamic loading; RC structures; lateral reinforcement; pushover analysis***

Introduction:

Ductility is defined as the ability of RC member to undergo considerable deflection prior to failure. This kind of behavior is extremely crucial as it provides the signs of failure and prevents total collapse. The various ways in which the ductility can be improved include making the plan simple and regular; providing greater redundancy to the system of lateral loading resistant; application of strong column-weak beam principle in the design of a structure to prevent column failure or to avoid the formation of plastic hinges in columns; making foundation strong; avoiding undesired brittle failures such as failure due to shear, anchorage, bond and concrete compression failure. Ductility can also be improved by providing lateral confinement at critical locations of columns.

RC structures

RC buildings are made up of concrete and reinforcing steel bars. The advantage of using these materials is that any desired shape can be obtained by molding concrete and bending the steel bars. Various components of RC buildings are:

Horizontal (beams and slabs)
Vertical (columns and walls)
Supporting system (foundation)

RC columns and beams together constitute RC frame which is the main component in resisting Earthquake forces. When the structure is subjected to dynamic loading inertial forces are induced whose magnitude is directly proportional to the mass of the structure. Since the mass is usually concentrated at the floor level, these inertial forces primarily develop at floor level. These forces are then transferred to the foundations through slab-beam and column-walls. As the horizontal forces are developed more towards the base of structure, they are designed to be stronger than the storeys above.

Role of floor Slabs and Masonary walls

Floor slabs are horizontal plate-like elements, which facilitate functional use of buildings. In most cases beams and slabs at each story level are cast together. In residential multi-storey buildings, thickness of slabs is only about 110 to 150mm. These thin slabs bend along with beams and when beams move with columns in horizontal direction, the slab usually forces beams to move together with it. In most buildings, the geometric distortion of the slab is negligible in the horizontal plane; this behavior is known as the rigid diaphragm action. After columns and floors in a RC building are cast and the concrete hardens, vertical spaces between columns and floors are usually filled-in with masonry walls to demarcate a floor area into functional spaces (rooms). The masonry walls/infill walls are not usually connected with RC columns and beams. So, when columns are subjected to horizontal loading at storey level and they try to move in horizontal direction, these infills resist this movement. Due to their heavy weight and thickness, these walls attract rather large horizontal force. Masonry walls being brittle develop cracks when load exceeds their carrying capacity. However, the earthquake performance of masonry walls can be enhanced by using mortars of good strength, proper packing of gaps between RC frame and masonry infill walls.

Behavior of Structure during earthquake

Gravity loading on buildings causes RC frames to bend resulting in stretching and shortening at various locations. Tension is generated at surfaces that stretch and compression at those that shorten. Under gravity loads either sagging or hogging moments are developed. The dynamic forces are responsible for load reversal. Concrete is weak in tension. As such it is essential to provide reinforcement on both faces of beams. For columns the reinforcement is provided on all faces. For safety under dynamic loads, columns are made stronger than beams. Further, connections between beams and columns and columns and foundations should not fail so that beams can safely transfer forces to columns and columns to foundations. If structures are designed as per this criteria damage is likely to occur in beams first. If beams have proper ductile detailing building can resist loads of higher magnitude before failure. In contrast, if columns are made weaker, they suffer severe local damage, at the top and bottom of a particular storey. This localized damage can lead to collapse of a building, although columns at storeys above remain almost undamaged.

LITERATURE REVIEW:

The literature review includes work done in the field of concrete confinement.

Read M Samara studied ductility of confined concrete. He describes in detail the weakness in the procedure of the American Concrete Institute (ACI) Building Code used for detailing columns for ductility. By using idealized moment curvature curves, stress-strain diagrams for steel and confined concrete he calculated the quantity of transverse steel required in confined column for different loads. The approach proposed is more realistic than ACI code. ACI assumes that the function of transverse reinforcement is just to compensate for loss of concrete cover. The procedure developed by M Samara is important in columns which are subjected to shear loads, bending loads and axial loads simultaneously. As per design philosophy plastic hinges should be formed in beams rather than in columns. So, ductility in columns can be enhanced by providing transverse reinforcement but it has less effect on strength. Transverse reinforcement prevents lateral buckling of longitudinal reinforcing steel, exerts passive lateral confining pressure on core concrete [1].

Ingo Brachmann, Joann Browning and Adolf presented experimental work for the evaluation of relationships between drift and confinement in reinforced concrete columns under cyclic loading. Cyclic load tests were performed on 184 specimens to study effect of axial load and transverse reinforcement on drift limit of rectangular RC columns. The span to depth ratio was kept more than 2.5 so that shear resistance is due to truss action and deformation due to shear is negligible as compared to that of flexure. A simple design equation is proposed to calculate the amount of confining reinforcement required to achieve a limiting drift ratio for reinforced concrete columns in regions of moderate and high seismicity. It was observed that the limiting drift ratio was primarily a function of yield strength of the hoops, compressive strength of concrete and amount of transverse reinforcement. Trends observed in the data indicate that the effect of confinement decreased as the amount of confinement and compressive strength of concrete [2].

P. Paultra and F. Legeron researched in the area of confinement reinforcement design considerations for reinforced concrete column. They proposed new equations for the design of confinement reinforcement for ductile earthquake-resistant rectangular and circular columns based on performance measured in terms of curvature demand. These equations are developed from a study of a large number of columns to reach a certain level of sectional ductility and account for the influence of concrete strength, transverse reinforcement yield strength, axial load level, and transverse confinement reinforcement spatial distribution. The new confinement requirements are superior to those in the current ACI Code or CSA-94 Standard [3].

Oguzhan Bayrak and Shamim A. Sheikh presented results from a research program that aims to study confinement of concrete by lateral reinforcement. They studied the experimental behavior of high-strength concrete (HSC) and ultrahigh-strength concrete (UHSC) column behavior. Realistically sized columns (305x 305 x 1,473 mm) with heavy stubs (508 x 762 x 813 mm) were tested under moderate to high axial load levels and reversed cyclic displacement excursions. The behavior of UHSC and HSC columns was studied and comparison was made with normal strength concrete column behavior. The parameters taken into consideration include steel configuration, concrete strength, amount of lateral steel. A performance-based design procedure for the design of confinement reinforcement in HSC and UHSC columns was presented and compared with current American Construction Institute (United States) and New Zealand. It was observed that an increase in axial load reduces the column’s deformability and ductility and accelerates strength and stiffness degradation with every load cycle. To compensate for this effect a larger amount of lateral reinforcement is required. An examination of member and section ductility parameters for comparable specimens indicates that the higher strength concrete specimens have lower deformability and energy absorption and dissipation capacities initially, but during the latter part of the displacement excursions, these properties improve rapidly and the total values are comparable to those of lower strength concrete specimen [4].

Abbie B. Liel, Curt B. Haselton, and Gregory G. Deierlein applied nonlinear dynamic analyses to assess the risk of collapse of RC special moment-frame (SMF) buildings to quantify the seismic safety implied by modern building codes. Thirty archetypical RC SMF buildings, ranging in height from 1 to 20 stories, were designed according to ASCE 7-02 and ACI 318-05 for a high-seismic region. The results of performance-based seismic assessments show that, on average these buildings have an 11% probability of collapse under ground motion intensities with a 2% probability of exceeding in 50 years [5].

Akira Yasojima and Toshiyuki Kanakubo studied the effect of lateral confinement in bond splitting behavior of RC members. For this purpose, pull-out bond test was carried out with lateral confinement force varied according to the slippage of main reinforcement. Test results show maximum bond stress increase with increase in compressive strength. The slippage at maximum bond stress is influenced largely by shape of reinforcement. [6]

Sudhir K. Jain, R.K. Ingle and Goutam Mondal proposed Codal provisions for design and detailing of beam -column joints in seismic regions. The paper brings forth the fact that traditionally the focus while designing is on individual connected elements (beams and columns) rather than on joint. The study on Beam -Column joint started after 1970s. The 1993 version of IS 13920:1993 incorporated some provisions on the design of beam-column joints. However, these provisions are inadequate to prevent shear and bond failure of beam-column joints in severe seismic shaking. As such there is need to upgrade these provisions with focus on shear design and anchorage requirements. This article proposes provisions for shear design of beam-column joint and anchorage requirements of tension beam bars in the joint area. It also suggests provisions for the confinement of wide beam and column connections [7].

D.N. Shinde, Nair Veena V, Pudale Yojana M conducted the pushover analysis of multistory building. In this study, a building frame is designed as per Indian standard i.e. IS 456:2000 and IS 1893:2002. The main aim is to study the behavior of building designs as per Indian Standards. They carried pushover analysis of building frame using SAP 2000. The analysis involves applying horizontal loads incrementally i.e. pushing the structure and plotting the total applied shear force and associate lateral displacement at each increment, until the structure or collapse condition. The sequence of cracks, yielding, plastic hinge formation, and failure of various structural components is recorded [8]

Ravikumara, Supriya R Kulkarni, K S Babu Narayan studied plastic hinge formation in RC structure. They made an attempt to understand the order of hinge formation for ground formation in SAP2000 and thereby tried to enhance the accuracy of pushover analysis. They observed that the location of plastic hinge can vary as per geometrical properties. The deformation characteristics of structure is controlled by order of sequence of hinge formation [9].

SUMMARY:

Confinement of concrete not only imparts ductility to RC structure but also improves its strength. Proper detailing of RC structures gives enough warning before failure due to formation of plastic hinges. Confinement not only increases the tensile strength but also improves compressive strength. The ductility of HSC columns can be improved by providing additional confinement.

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