© INTERNATIONAL JOURNAL FOR RESEARCH PUBLICATION & SEMINAR
ISSN: 2278-6848 | Volume: 11 Issue: 01 | January - March 2020
Paper is available at http://www.jrps.in | Email : info@jrps.in

Effect of using high concrete grade at beam-column junction: A Review

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Abstract

A joint or junction is basically the portion of the beam into the column and is the zone of complex stress concentrations and is prone to failure via crushing of concrete. It is not necessary that failure would only occur because of crushing of concrete at joint but there may also be other structural failures related to reinforcement design and detailing. In this project an attempt has been made to study the behavior of beam-column junction with respect to the behavior of concrete at joint and an attempt has been made to improve the efficiency of joint by adopting measures to prevent crushing of concrete at joint.

ISSN : 2278-6848
© International Journal for Research Publication and Seminar

Keyword: Beam column, concrete,

Introduction

A beam-column joint is a very critical zone in reinforced concrete framed structure where the elements intersect in all three directions. Joints ensure continuity of a structure and transfer forces that are present at the ends of the members. In reinforced concrete structures, failure in a beam often occurs at the beam-column joint making the joint one of the most critical sections of the structure. Sudden change in geometry and complexity of stress distribution at joint are the reasons for their critical behavior .In early days, the design of joints in reinforced concrete structures was generally limited to satisfying anchorage requirements. In succeeding years, the behavior of joints was found to be dependent on a number of factors related with their geometry; amount and detailing of reinforcement, concrete strength and loading pattern.

In developing countries, the increasing reliance of employment on economic and social considerations is one of the reasons that lead to increasing rural-to-urban migration which in turn lead to increased demand on land use in large cities like Addis Ababa. Following this, more high rise structures are being constructed now than in the past. On the other hand, for the developed countries, the engineering challenge where by the two targets of boasting the longest bridge and the highest building have become serious considerations in the conceptual design of landmark projects is another stimulus for construction of high rise buildings. Thus, the need for higher buildings naturally leads to the conclusion that high strength construction materials will be increasingly used in the future. The following three performance criteria lend weight to the argument for the use of high strength concrete (HSC) for such high rise buildings.

Review of literature

(Adam, 2015) studied "Effect of Using Different Concrete Strengths for Columns and Beams on the Behavior of Building Frames" and found that in high-rise buildings and heavy loaded structures where RC columns are subjected to heavy loads, the use of High Strength Concrete (HSC) in columns construction is essential for the purpose of reducing column size and increasing column capacity. However, from the economical standpoint, combination of high and normal strength concrete (NSC) in building construction is becoming common practice, where HSC is used for columns and NSC is used for the surrounding beams/slabs floor system. This creates a situation where concrete strength of the column portion at the beam/slab floor level is lower than concrete strength used for rest of the column. Previous studies indicated that such variation in concrete strength affects the load carrying capacity of the RC columns. This paper presents a theoretical study on the effect of using concrete with different strengths for columns and floor beams on the structural behavior of integrated RC building frames under static, lateral pushover and earthquake loading cases. Four-story frame was analyzed employing a ready package program for the inelastic structural analysis of buildings (IDARC-5). The obtained results indicated that under static loading, variation in the concrete strength of the transition zone has a negligible effect on the behavior of the studied frame. However, under lateral pushover and earthquake loading the behavior of the studied frame is influenced by the ratio of column concrete strength to the transition zone concrete strength. For a ratio of 1.4 or less, no real influence was noted. On exceeding this ratio, the frame response was adversely influenced. This agrees with the recommendations of the ACI 318 Building Code.

(Rasool, Bashir, & Kaur, 2016) studied "Beam-column junction based on variations in concrete grade at junction" and found that a beam-column joint has to transfer the shear forces, bending moments and other related structural response parameters efficiently. The present paper aims at studying the behavior of beam-column junction based on variations in concrete grade at junction. Analysis: To increase the load carrying capacity of a joint, a higher grade of concrete is used at a joint and also up to 1.5D in the direction of beam from face of column, to shift or relocate the plastic hinge from the interface towards the beam. The different specimens were prepared in a T-shaped mould by changing the grade of concrete at beam-column joint and these samples were tested after 7 and 28 days. Findings: Study reveals that use of M20 or M25 grade of concrete at joint and up to 1.5D (D is the depth of beam) of length of beam (M15 grade of concrete in rest of mould) increases the load carrying capacity approximately to about 20% when compared with M20 or M25 grade of concrete at junction and M15 grade in the remaining mould. The most important finding is that the use of higher grade of concrete at a joint and up to 1.5D of length of beam, shifts the failure away from the beam-column interface Thus, a beam hinging mechanism is achieved which is a ductile type of failure compared to beam-column brittle interface failure and there is approximately 15-30% increase in load carrying capacity, in comparison with higher concrete grade only at a joint core. This is a simple and efficient method of preventing the beam-column joint failure. Improvement/Applications: Based on the test results there is remarkable increase in the load carrying capacity of beam-column joint which enhances the rigidity of beam column joint in terms of strength and stiffness.

(Aly M.Said, 2004) studied “Behaviour of Beam-Column Joints Cast Using Self- Consolidating Concrete Under Reversed Cyclic Loading” and found that multi-storey reinforced concrete structural frames are among the most congested structural elements. Placing and consolidating concrete in such structural frames imposes substantial technical challenges. This offers a unique area of application for self-consolidating concrete because of its inherent ability to flow under its own weight and fill congested sections, complicated formwork and hard to reach areas. However, research is needed to demonstrate the ability of SCC structural frames to adequately resist vertical and lateral loads. In the present study, full-scale 3-m high beam-column joints reinforced as per the Canadian Standard CSA A23.3-94 [1] and ACI-352R-02 [2] were made with ordinary concrete and self-consolidating concrete. They were tested under reversed cyclic loading applied at the beam tip and at a constant axial load applied on the column. The beam-column joint specimens were instrumented with linear variable displacement transducers and strain gauges to determine load-displacement traces, cumulative dissipated energy and secant stiffness. This paper compares the performance of reinforced normal concrete and self-consolidating concrete structural frames and discusses the potential use of SCC in such structural elements.

(Ramudu et al., 2014) Studied “Effect of Using High Strength Concrete Columns on the Structural Behaviors of Building Frame” and found that strength, durability and stability are the main criteria for material selection and design in the construction industry. Consequently, development and enhancement of construction materials is always an active and attractive field for engineers and researchers. Elevated temperature (fire) is a potential threat for any structural buildings that can cause a major damage. Response of construction materials exposed to elevated temperature or fire requires a full study and analysis with lessons learned from previous cases. High strength concrete (HSC) has been used in the lower story columns of high rise buildings owing to its qualities over normal strength concrete (NSC) in many countries. But, the full structural qualities of the HSC were unable to be used because of insufficient information regarding the structural behaviour of the material and its properties. Columns moment- curvature curves were developed and maximum inter story drifts were obtained for the different frame models with variation in columns concrete strength. The study shows that frames with HSC columns have got lower stiffness and performed well in satisfying ductility demand. The maximum inter storey drifts are slightly higher for frames with HSC columns, but the contribution of the concrete strength in resisting the lateral deformations was significant. Economic comparisons were also made and it was found that the most economical frame corresponds to frame with the highest columns concrete strength.

(Sohoni & Shiyekar, 2012) studied “Effect of Change in Grade of Concrete on the Composite Members of a Framed Structure” and found that the past few decades have seen outstanding advances in the use of composite materials in structural application. Composite members are widely used in structural systems to achieve additional rigidity. R.C.C.members with conventional Torsteel reinforcement may now be replaced by composite members with rolled steel sections like angle sections, galvanized iron pipe sections.Experimentally as well as analytically these members prove to be a better alternative to conventional members and are more advantageous especially at the beam-column junction and in high rise earthquake-resistant structures.The present paper aims at studying the effect of change in grade of concrete on the behavior of composite members.Beams and columns using rolled steel sections as reinforcement were cast using varying grades of concrete and tested. Results of failure loads and deformations in flexure and axial compression show that use of rolled steel sections as reinforcement proves to be advantageous even for variations in grades of concrete.

(S. S. Patil, 2013) studied “R. C. C. Beam Column Junction Subjected To QuasiStatic (Monotonic) loading” and found that Beam and column where intersects is called as joint or junction. The different types of joints are classified as corner joint, exterior joint, interior joint etc. on beam column joint applying quasi-static loading on cantilever end of the beam. and study of various parameters as to be find out on corner and exterior beam column joint i.e. maximum stress, minimum stress, displacement and variation in stiffness of beam column joint can be analyzed in Ansys software (Non-Linear FEM Software) Significant experimental research has been conducted over the past three decades on hysteretic behavior of beam-column joints of RC frames under cyclic displacement loading. The various research studies focused on corner and exterior beam column joints and their behavior, support conditions of beam-column joints. Some recent experimental studies, however, addressed beam-column joints of substandard RC frames with weak columns, poor anchorage of longitudinal beam bars and insufficient transverse reinforcement. the behavior of exterior beam column joint is different than the corner beam column joint.

(Jawaharlal & Kala, 2017) studied “Strengthening of beam-column junction for negative moment due to elimination of a column in the frame” and found that during the life span of a structure, the structural system as a whole or part loses its design strength and the design intent of the structure becomes unfulfilled. Also due to the need in the structural configuration under different circumstances such as demand for vertical expansion, change in use of space, the structure undergoes the process of retrofitting and rehabilitation. In retrofitting and rehabilitation the structure is altered in such a way that the revised functional intent is fulfilled and the structure as a whole is brought to service condition for its designed span of life. Different approaches are adopted in practice with different techniques and materials. Different structural member warrants different methods and materials which depend on adoptability, feasibility, durability. But in the case of beam-column junction, the behaviour is very complex and the method available is limited. This paper describes and discusses the different methods followed in practice and suggests few methods in strengthening of beam-column junction especially in negative moment region in a particular case of elimination of a column between floor to floor which results in increased moment of resistance at mid span of column and negative moment region at the column-beam junction.

Experimental procedure

In order to study the behavior of beam-column joint, the specimens were prepared in a T shaped beam. The dimensions of beam were set as per IS specifications. The length of beam is 50 cm including thickness of column. The length of column is 50 cm. The height and width of T beam is kept 10 cm each. The following figures illustrate the dimensions of T beam:

Figure: T Beam used in the project [50cm×10cm×10cm]

Procedure

The different specimens were prepared by changing the grade (mix) of concrete at beam-column joint. These different specimens were tested after 7 days and 28 days. Each specimen is provided with 4 nuts and bolts for the purpose of fixity. A suitable arrangement is made at the time of testing for achieving the fixity condition as illustrated below:

Figure: Nut-bolt assembly and end conditions

Different grades of concrete were used at the joint like M25, M20, M15 etc. The testing of specimens after 7 days and 28 days were conducted on UTM.

The following are the details of tests carried on specimens:

Table 1:-showing details of specimens

S.NO	SAMPLE	DETAILS OF SAMPLE

1	SAMPLE 1	M15 USED UNIFORMLY
2	SAMPLE 2	M15 AND M25@JOINT

RESULTS AND INTERPRETATION

Sample 1

M15 grade used uniformly throughout the beam with no variation of concrete grade at joint. The specimen was tested after 7 days and 28 days using UTM with suitable arrangement for fixity. The load-displacement and stress-strain curves for the sample 1 are given below:

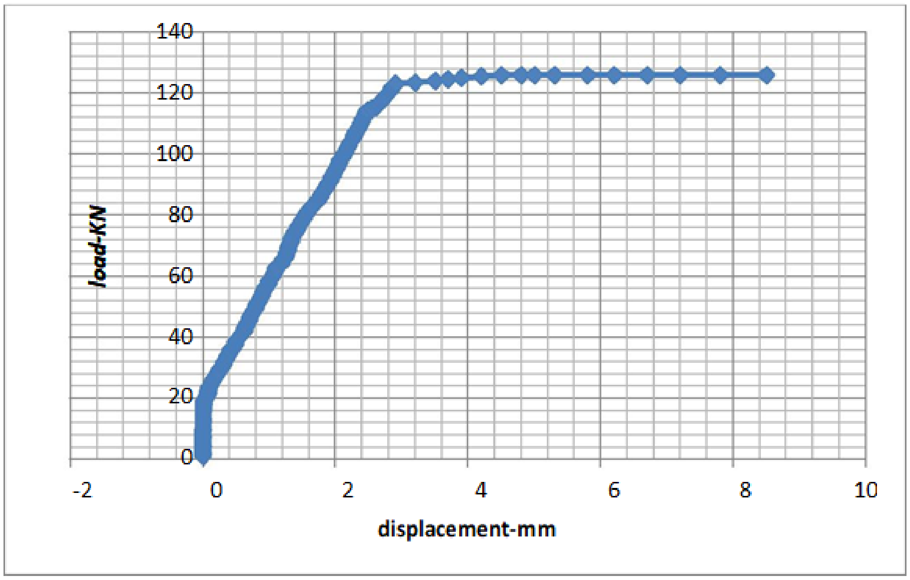

Figure: Load-displacement curve (sample 1)

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ISSN: 2278-6848 | Volume: 11 Issue: 01 | January - March 2020
Paper is available at http://www.jrps.in | Email : info@jrps.in

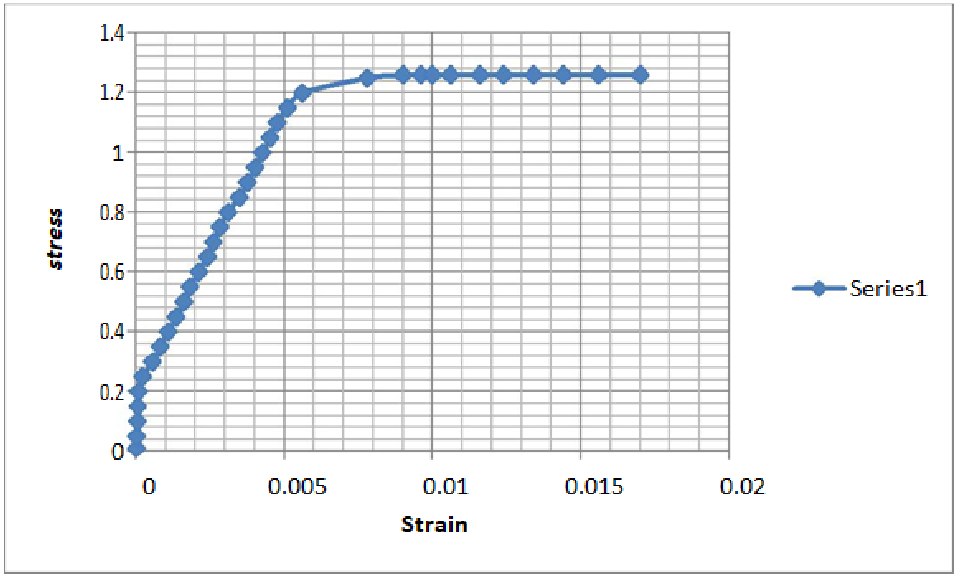

Figure: Stress-strain curve (sample 1)

Conclusion

In high-rise buildings and heavy loaded structures such as stores, warehouses and garages where the columns are subjected to heavy loads, the use of HSC in RC columns construction is becoming more essential for the purpose of having slender columns, which is recommended from the architectural point of view. While, from the economical standpoint, a combination of high and normal strength concrete (NSC) is becoming common practice in building construction. Use of higher concrete grade at beam-column junction saves the junction from failure and hence in the present day construction this technique will surely add to the structural efficiency and at the same time this technique is relatively economic and this may surely add to its implication This modified beam column-junction is economically as well as practically feasible and at site, this technique can be applied with ease without much complexities

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