IJIRSET

ISSN(Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 4, April 2015

Survey on Comparison of Steel and Concrete Composite Beam Column Connections

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ABSTRACT: Composite constructions are nowadays very popular owing to their advantages over conventional Concrete and Steel constructions. Concrete structures are bulky and impart more seismic weight and less deflection whereas Steel structures instruct more deflections and ductility to the structure, which is beneficial in resisting earthquake forces. Composite Construction combines the better properties of both steel and concrete along with lesser cost, speedy construction, fire protection etc.

In present study, literature work of comparison of steel and concrete composite building frame work by different researchers in seismic performance. The composite connections are consider in all four cases, as beam in RCC to column in steel, column in RCC to beam in steel , beam and column both in RCC and also both in Steel. Equivalent static method and Response Spectrum method will be used for analysis. Also same modules compared on SAP 2000 software. Cost effectiveness based on material cost for all types of building frames will be determined. Comparative study concludes that the composite frames will be best suited among all the four types of constructions in terms of material cost benefit added with better seismic behavior.

KEYWORDS: Beam Column Connection and Types, Analysis Design and Cost Effects.

I. INTRODUCTION

As the our country is the fastest growing country across the globe and need of shelter with higher land cost in major cities like Mumbai, Delhi, Ahmadabad where further horizontal expansion is not much possible due to space shortage, we are left with the solution of vertical expansion. High rise buildings are the best suited solution for this problem. Steel – concrete composite construction is a faster technology which saves lot of time in construction which will help the planners to meet the demand with minimum time in real estate market. This technology provides more carpet area than any other type of construction. Composite construction also enhances the life expectancy of the structure.

II. LITERATURE STUDY

Composite construction consists of providing monolithic action between prefabricated units like steel beams or pre-cast reinforced concrete or pre-stressed concrete beams and cast-in-situ concrete, so that the two will act as one unit. Although there is bound to be a certain amount of natural bond between concrete and steel at least at the initial stages, this bond cannot be relied upon as the same is likely to be deteriorate due to use and over load. Mechanical shear connectors are therefore provided to help the steel and concrete element to act in a composite manner ignoring the contribution made by the inherent natural bond towards this effect.

Research Work by Different Researchers As Follows:

Nicholas J. Brooke1 and Jason M. Ingham; Poor seismic performance of RC moment-resisting frames can be expected to occur if the beam-column joints in such structures are not appropriately designed and detailed. This

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expectation is owing to the fact that joint failure can jeopardize the axial load capacity of the column framing into the joint, and can also reduce the stiffness of the structure. Referring specifically to interior RC beam-column joints, two failure modes are typically considered. These two modes are joint shear failure and anchorage (or bond) failure. While there continues to be international disagreement about the design of beam-column joints, it is generally recognized that the consequences of joint shear failure are more severe than the consequences of bond failure in a joint, because shear failure has a brittle nature and is likely to compromise column axial capacity. The main consequences of bond failure in a beam-column joint are that the stiffness and hysteretic energy dissipation of the joint are significantly reduced. A further motivation for designing to avoid bond failure during earthquakes is that damage owing to bond failure is difficult to detect, and if detected it is difficult and costly to repair. It has also shown that severe bond failure can reduce the ductility capacity of the beams adjacent to a joint. Despite the lesser severity of bond failure it is nonetheless important to detail joints so that bond failure is avoided, particularly if the capacity design philosophy is being used to design the structure.
The requirements for the anchorage of beam longitudinal reinforcement at interior beam-column joints in earthquake-resistant

RC moment-resisting frames are reevaluated. An introductory comparison of international design criteria shows that a broad disparity currently exists between these requirements. The suitability of existing criteria was assessed by assembling a database of more than 90 interior beam column joint tests and comparing the assessed test performance with the performance that was predicted by each design criterion. This comparison showed that none of the existing design criteria were adequately able to predict experimental performance. To improve the design of earthquake-resistant RC frame structures, an improved design criterion was developed by parametrically determining the influence of important variables on anchorage performance.

Steven A. Oosterhof and Robert G. Driver; Unexpected events such as accidental blasts, vehicular collisions, terrorist attacks, natural disasters, and human errors can lead to localized damage in a structure. This damage, in turn, can exert a combination of severe strength and ductility demands on structural components. It is often impractical (if not impossible) to design explicitly for unexpected events using statistical approaches applied to the treatment of more conventional loads, yet it is generally considered good engineering practice to mitigate the potential for collapse under extreme loads by incorporating concepts of structural integrity and robustness into design.

Both direct and indirect approaches to mitigating the potential for disproportionate collapse following localized damage have been outlined in current design guidelines with various levels of detail and effectiveness. Two extensively developed guidelines that address the issue specifically along with a wide range of recent research on the topic employ an approach known as the alternative path method, wherein a building's robustness is assessed according to its performance under a condition of instantaneous column removal. The application of this methodology to buildings with steel gravity frames requires an understanding of the behavior of shear connections under the high levels of rotation and combined axial and shear forces that are expected to develop following column removal. However, such an understanding is currently limited by a deficiency of physical test data for even the most commonly used beam-to-column shear connections.

Pham XuanDat, Aff. and Kang Hai Tan; This paper presents an experimental program to investigate the progressive collapse resistance of reinforced-concrete (RC) building structures subjected to a loss of a penultimate-external (PE) column that is the exterior one nearest to the building corner. Under this accidental scenario, any mobilization of catenary action in beams and slabs bridging over the column, as an alternative load path, should rely solely on the strength of a half perimeter compressive ring forming within the deflect ted slab area. Three one-third scaled beam-slab substructures were designed, built, and tested by a static loading scheme to examine the overall load capacity and displacement ductility that are two aspects of the progressive collapse resistance of RC building structures. The test variables are (1) additional amounts of beam stirrups, (2) additional beam longitudinal reinforcement, and (3) the aspect ratio of the slab panel. The boundary condition of the specimens is rotationally and vertically restrained, but laterally unrestrained. A 12-point loading system is used to simulate uniformly distributed loads. Based on the test results, a simple but conservative approach to quantify the progressive collapse resistance of RC building structure under a PE column loss scenario is proposed.

Building structures are conventionally designed for two types of limit states, namely, the ultimate limit states and serviceability limit states. Since collapse events such as the Ronan Point building, Murrah building and World Trade Center, design for progressive collapse, which can be considered as the survival limit state, has been introduced in many modern codes of practice. It is stated that under abnormal loading conditions such as explosions, fires, and large earthquakes, structural damage of a primary component such as a supporting column may be allowed to occur, but it should be confined locally so that buildings do not collapse progressively. Currently, sudden column loss is adopted as a principal scenario to assess the progressive collapse resistance of building structures in recent American design documents. The column to be removed can be either inside a building or along its perimeter edges. Following a sudden column loss, bending moments in the beam slab structures bridging over the removed column are severely increased by both the double-span effect and dynamic effect. Since flexural action in the double-span structures is not likely to resist the increased bending moments, catenary action is what is expected to be mobilized at large deformations to redistribute the amplified gravity loads, mitigating progressive collapse. As catenary action resists gravity loads by tension forces developing in longitudinal reinforcing bars in the double-span beams and slabs over the removed column, lateral restraint at the beam ends, together with reinforcement continuity, plays an essential role for the mobilization and load capacity of this secondary mechanism.

*Tauqlr M. Sheikh, Gregory G. Deierlein, Joseph A. Yura, and James O. Jirsa***;** Increasingly, engineers are designing composite and mixed building systems of structural steel and reinforced concrete to produce more efficient structures than realized using either material alone. Recent literature has pointed out a need for greater understanding of the interaction of structural steel and reinforced concrete in such systems. In this paper, the behavior of composite beam-column connections is examined through results of an experimental research program where 15 two-thirds scale joint specimens were tested under monotonic and cyclic loading. Such connections are typically employed in composite framed structures consisting of steel beams and reinforced concrete or composite columns. Significant strength increases were achieved using straightforward details to enhance concrete participation in the joint region. Details considered include the following attachments to the steel beam: vertical stiffener plates, steel columns, welded shear studs, and Dywidag reinforcing bars. The results and discussion presented in this paper provide background for a companion paper that includes a design model for calculating the joint strength.

In the last few decades, mixed steel-concrete structural systems have gained in popularity for the construction of buildings. However, until recently such systems employed only simple shear connections between structural steel and reinforced concrete elements. Thus, there was minimum interaction between the two materials. More recently, mixed structural systems have taken a new direction. In composite framed structures, unprecedented interaction between structural steel and reinforced concrete is being utilized in beam-column moment connections, thereby achieving greater economy in the overall structure. The term "composite frame" is used in this paper for a moment-resisting frame with steel beams and reinforced concrete columns, in which the composite beam-column connection is an integral part. To date, composite frames have been employed as the lateral force system for buildings in the 40-70 story range, with conventional slab/deck/steel-beam floor framing. Typically, such structures are built by first erecting a frame of light steel erection columns and deep spandrel beams. The steel columns are later encased by reinforced concrete columns. In most cases, the steel erection advances roughly ten stories ahead of the concrete column, thus providing for an efficient vertical spread of the construction activity.

Gregory G. Deierlein, Tauqir M. Sheikh, Joseph A. Yura and James Q. Jirsa; This is the second of two companion papers addressing the behavior and design of moment connections between structural steel beams and reinforced concrete or composite columns. Due to the traditional separation of steel and concrete design, there is currently a need for guidelines to design such connections.

In this paper, a design model and recommendations are presented for detailing and calculating the nominal strength for composite beam-column joints. The design model is based on two limiting modes of failure: panel shear and bearing of the steel flanges against the concrete. Panel shear strength reflects enhancement achieved through

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mobilization of the reinforced concrete panel using vertical stiffener (bearing) plates and steel erection columns attached to the steel beam. Bearing strength can be increased by vertical joint reinforcement attached to the steel beam. In the recommendations, detailing considerations for the structural steel and reinforcing bars are included. Finally, calculated results based on the proposed design model are compared with recent tests of composite connections.

This paper is the second of two papers addressing the behavior and design of beam-to-column connections for composite-framed structures. The first paper (Sheikh et al. 1989) provides a description of the composite frame, including typical applications and its benefits over pure steel or concrete systems. Recent experimental research on composite connections which served in the development of design guidelines is also summarized in the companion paper. As reported here, experimental tests have demonstrated that relatively simple joint detailing can result in significant enhancement to the strength of composite beam-column joints.

*Michel Bruneau and David Walker;*This paper reports on the following: (1) Simple experimental investigations of pultrudedfiber-reinforced plastic (PFRP) material behavior and tests of simple epoxies joints to verify and enhance the reported database; (2) cyclic tests of an attempted PFRP rigid beam-column connections; and (3) preliminary observations regarding the seismic-resistance worthiness of PFRP structures.

These are simple design issues that must be addressed if PFRP structural shapes are to gain broad acceptance by the design community. It is found that epoxies connections alone cannot fully exploit the high-strength potential of this material, and that delaminating of components is more problematic than the inherent brittleness of the material. The cyclic flexural test of an attempted rigid beam-column connection has revealed the particular delaminating weakness of the flange-to-web core of PFRP structural shapes. The construction of rigid beam-column connections using commonly used steel details is found to be ineffective. To this day, the use of pultrudedfiber-reinforced plastic (PFRP) in structural engineering has been rather limited compared to the use of steel and concrete, and it is still mostly confined to specialty applications where resistance to highly corrosive environments, electromagnetic transparency, or a low weight-to-strength ratio is required. However, this industry is growing very rapidly, and the need for conventional design guidelines is already being felt. Yet, many technical/practical detail-oriented questions remain unanswered. This effectively delays the broad acceptance of PFRP structural shapes by the design community.

*Gustavo Parra-Montesinos and James K. Wight;*A model to predict the shear strength versus shear distortion response of hybrid connections between reinforced concrete columns and steel (RCS) beams is presented.

Based on a preestablished maximum attainable joint shear deformation, design equations were developed for use in both interior and exterior RCS connections in buildings located in high seismic risk zones. The proposed model is based on the definition of the state of plane strain in the joint through the development of a ratio between the principal tensile and compression strains. The strength of the joints is given by contributions from the steel web panel and concrete diagonal struts. The joint model is capable of predicting the shear force, and stirrup and concrete strains at any level of joint shear distortion for exterior joints. In addition, the use of the proposed design equations led to excellent agreement between predicted and measured shear strength for both interior and exterior RCS joints.

*Sing-Ping Chiew, Seng-Tjhen Lie and Chao-Wei Dai;*This paper focused on investigating the moment resistance of steel I-beam to concrete-filled tube (CFT) column uniplanar connections under monotonic static loading. The composite connection can be stiffened or unstiffened. An empirical formula was derived based on >100 numerical parametric analysis results. The key parameters were studied numerically by finite-element method and the relevant ones that affect moment resistance were captured in the proposed formula. To verify the empirical formula and understand clearly the static behavior of the composite connections, eight specimens were designed and tested to failure, of which four specimens were semirigid beam-to-column connections and others were rigid connections with different types of stiffening details. The comparison between the predictions and test results showed that the empirical formula could be used to predict the moment resistance. The proposed rebar stiffener was found to be very effective in improving the static behavior of the composite connections.

In this paper, moment resistance was defined as the moment at the state where the structure shows yielding. In the moment rotation curves, moment resistance was defined as the value at the point where the tangential modulus of the curve varies obviously. Ultimate moment resistance was defined as the maximum moment in the moment-rotation curve. The rotation of the connection was defined as the in-plane rotation of the beam from its original axis. It can be obtained from the readings on the inclinometers or by measuring the column indentation at the upper and lower flange locations.

Scott L. Jones, Gary T. Fry and Michael D. Engelhard; this paper describes an experimental study on radius cut reduced beam section RBS moment connections for use in seismic resistant steel moment frames. The effects of panel zone strength, composite behavior with a concrete slab, and the beam web-to-column flange connection were specifically addressed in these tests. In total, eight double-sided specimens were designed, fabricated, and tested in this study, providing data for sixteen individual RBS connections. Each specimen was subjected to a standard quasi-static cyclic load pattern.

Overall, the specimens performed well with seven of the eight achieving total elastic plus plastic story drift ratios of at least 0.04 radians in magnitude before experiencing 20% strength degradation. The other test was stopped due to out-of-plane instability after being loaded to 0.03 radians of total story drift. Comparison of the response of specimens with strong panel zones, balanced panel zones, and weak panel zones relative to beam strength led to the conclusion that weak panel zones allow for the most stable hysteretic response at large drift levels. Inclusion of a composite slab in these tests appeared to stabilize the beams against lateral torsional buckling with no consistently detectable increase in the strains in the bottom beam flange. Welding the beam web to the column flange seemed to decrease the likelihood of weld fracture in these specimens.

Z. H. Qian, K. H. Tan and I. W. Burgess; Although beam-to-column joints are a critical part of steel and composite framed structures, very few tests have been conducted under fire conditions. Of the tests conducted, only a limited range of joint types has been studied. The main reason for this is the high cost associated with elevated-temperature tests. This paper presents the results of an experimental investigation of typical steel extended end-plate beam-to-column joints at elevated temperatures. Six beam-to- column joints were tested. These included three tests conducted at 400, 550, and 700°C, and another three tests on specimens at 700°C with different axial compression forces applied to the beams to simulate restraint effects. Moment-rotation-temperature characteristics are summarized in order to investigate the degradation of this type of steel joint at elevated temperatures.

JianguoNie, Yu Bai and C. S. Cai; A new connection system for a concrete filled steel tube composite column and reinforced concrete beams is proposed. In this Connection, the steel tube is interrupted while the reinforced concrete beams are continuous in the joint zone. Multiple lateral hoops that constitute the stiffening ring are used to confine the core concrete in the connection zone. The transfer of moment at the beam ends can be ensured by continuous rebars; the weakening of the axial load bearing capacity due to the interruption of the steel tube can be compensated by the confinement of the stiffening ring. Using these configurations, concrete casting and tube lifting can be made more convenient since welding and whole drilling in situ can be avoided. Axial compression experiments on six specimens and reversed cyclic loading tests on three interior column specimens and three corner column specimens were conducted to evaluate this new beam-column system; load-deflection performance, typical failure modes, stress and strain distributions, and the energy dissipation capacity were obtained. The experimental results showed that the effective confinement can be achieved by the stiffening ring, and an excellent axial bearing capacity can be obtained, as well as a superior ductility and energy dissipation capacity. As a new connection system for the concrete filled steel tube composite column with reinforced concrete beams, it can also be applied to other types of confined concrete columns.

Kien Le-Trung, Kihak Lee, Jaehong Lee, Do Hyung Lee, SungwooWooc; This paper presents an experimental study to strengthen the shear capacity of non-seismic joints using Carbon Fiber Reinforced Plastic (CFRP) materials. Eight exterior RC beam–column joint specimens including a non-seismic specimen, a seismic specimen and six retrofitted specimens with different configurations of CFRP sheets were developed and tested to find out an effective way to improve the seismic performance of the joints in terms of the lateral strength and ductility. The different configurations of CFRP sheets considered were the T-shape, L-shape, X-shape and strip combinations. The research focused on the effect of using CFRP sheets for enhancing strength and increasing ductility of the non-seismic beam–column joints. The test results showed that appropriately adding CFRP composites to the non-seismic specimen significantly improved the lateral strength as well ductility of the test specimens. Especially, the X-shaped

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configuration of wrapping, the strips on the column and two layers of the CFRP sheets resulted in a better performance in terms of ductility and strength.

The main focus of the present research is that finding out an effective way of applying CFRP sheets to improve the seismic performance of the tested specimens. Eight 1/3 scale RC exterior beam–column joints were designed, built and tested to study the behavior of the joints. There were two baseline specimens, one was designed without seismic details, and the other one was designed with seismic details. The remaining specimens were reinforced by applying the CFRP sheets with different configurations. The different configurations of CFRP sheets considered were the T-shape, L-shape, X-shape and strip combinations. The study focused on the lateral load–displacement behavior and joint shear behavior before and after strengthened using CFRP sheets. Such characteristics as lateral strengths and ductility as well failure modes of the joints were measured and hereby presented.

*W.T. Lee, Y.J. Chiou, M. H. Shih;*An effective rehabilitation strategy is proposed to enhance the strength and stiffness of the beam–column joint in this study. An analytical model is proposed to predict the column shear of the joints strengthened with carbon fiber reinforced polymer (CFRP). Three full scale interior beam–column joints, including two specimens strengthened with CFRP and one prototype specimen, are tested in this study. The specimens are designed to represent the pre-seismic code design construction in which there is no transverse reinforcement. A new optical non-contact technique, digital image correlation (DIC), which can measure the full strain field of specimen, is used to measure and observe the full strain field of the joint. The experimental results show that the beam–column joints strengthened with CFRP can increase their structural stiffness, strength, and energy dissipation capacity. The rehabilitation strategy is effective to increase the ductility of the joint and transform the failure mode to beam or delay the shear failure mode. By observing the measured results, it is found that the mechanical anchorages can prevent the deboning of CFRP.

Comparing the analytical and experimental results, the proposed model can accurately predict the column shear and shear strength of the joints strengthened with CFRP.

*Kien Le-Trung, Kihak Lee, Myoungsu Shin, Jaehong Lee;*This paper presents an analytical study on the modeling of exterior reinforced concrete (RC) beam-column connections strengthened using carbon fiber reinforced polymer (CFRP) composites subjected to lateral loading. To simulate the overall connection behavior reasonably well, the developed analytical model takes into account joint shear behavior, bond slip of longitudinal beam reinforcement, and effects of various configurations of CFRP sheets. In particular, effects of anchorage at the ends of the attached CFRP sheets, which have never been modeled in previous analytical studies to date, were incorporated into the developed model. The results from analytical and experimental studies for seven beam-column connection specimens tested by the authors were compared in terms of initial stiffness, maximum strength, stiffness degradation, strength degradation, and energy dissipation.

The comparison indicates that the analytical results showed a good agreement with the experimental results. Therefore, the developed connection model, which is a macro-scale model with a few elements, can be used for performance assessments of RC structures having CFRP-strengthened beam-column connections with an adequate accuracy and simplicity.

III. CONCLUSION SUMMARY

From the above study it might be concluding that very little work has been completed on all four type section of composite beam and column. In this study of literature work on performance of composite beam column connections. The section will be used in all four cases, as RC beam to steel column, steel beam to RC column, Beam and column in RCC and also in Steel. Comparison of result will be done by experimentally as well as theoretically analysis, and also similarly compare with SAP 2000 software. Cost effectiveness based on material cost for all types of building frames will be determined. Comparative study concludes that the composite frames are best suited among all the four types of constructions in terms of material cost benefit added with better seismic behavior.

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IV. OBJECTIVES OF PRESENT WORKS

1. Mechanical properties and behavior of the various sections.
2. Check Modeling of composite section by using SAP 2000.
3. Behavior of the building under condition in composite with respect to R.C.C., Steel and channel sections.
4. Behavior of composite sections under seismic.
5. Quality assurance of the steel material.
6. Study reductions in overall weight of structure and thereby reduction in costs.

V. PROJECT EXPECTED OUTCOME

1. As the results might be show the Steel option will be better than R.C.C. But the Composite option for high rise building is best suited out of four options.
2. The dead weight will be reducing in the Steel framed structure with respect to R.C.C. frame Structure.
3. As the sizes of the steel members from steel option to the composite option will be reduces in main beams and in secondary beams.
4. Shear forces in main and secondary beams would be increased in steel structure and would be reduced in composite structure as compared to R.C.C. framed structure.
5. Bending moments in main and secondary beams will be increased in steel structure and might be reduced in composite structure as compared to R.C.C. framed structure.
6. Axial forces in column might be reducing in steel structure and will be reduced in Composite framed structure as compared to R.C.C. framed structure.
7. In all the options the values of story displacements might be within the permissible limits as per code limits.
8. Steel and composite structure will be give more ductility to the structure as compared to the R.C.C. which will be best suited under the effect of different loading condition.
9. Steel and R.C.C. structure will be more costly structure as compared to the composite structure which will be best option suited under the effect cost condition.

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