A REVIEW PAPER ON SEISMIC EVALUATION OF BUILDING HAVING STEEL CONCRETE COMPOSITE COLUMNS AND RC BEAMS

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***Abstract*- Steel concrete composite structures are gaining popularity due to the advantages they offer over the conventional reinforced concrete and steel structures like the ease and speed of construction. In the light of this, it becomes essential to understand the behaviour of this type of structures when used in buildings. This study mainly focuses on the use of building frame consisting of steel-concrete composite column section with the reinforced concrete beams. To achieve this objective, the seismic analysis of the buildings was chosen for evaluating the performances of the buildings designed and analyzed using Indian standards. The building selected for the study was rectangular in plan and had an elevation of 30 meters with no plan or vertical irregularity present. The gravity loads considered for the building are in compliance with the IS 875 Part 1 and IS 875 Part 2. However, the gravity loads used in case of both buildings were kept to be same as the prime focus of the study was seismic analysis. The materials used for the design of the building with respect to Indian standards are E345 grade of steel and M30 grade of concrete. Various codes of practices including IS 456, IS 11384, IS 1893 and IS 13920 have been used throughout the study in case of the building designed and analysed with respect to Indian standards. The assumptions regarding the seismic characteristics of the buildings are also selected of the same nature for both the buildings. A finite element modelling based software ETABs is used to carry out the design and analysis for the buildings. The buildings were designed with respect to the selected gravity loads and the seismic loads to obtain the section details to be used for seismic analysis. The building with finally obtained section sizes is used for carrying out the nonlinear analysis. This includes both the nonlinear static and nonlinear dynamic analysis as they both have their respective advantages in predicting the behaviour of the structure. For carrying out nonlinear analysis both material as well as geometric nonlinearity is considered. In case of the nonlinear dynamic analysis, the ground motions with respect to the guidelines of FEMA P695 and ASCE 7-16 were selected and scaled to perform the analysis. A total of 11 time histories were considered for NLTHA to have a thorough analysis. Various factors such as the capacity curves, story displacements, base shears and story drifts were considered for evaluation of the seismic performance of both the buildings. The results obtained from the analysis of both the buildings are represented in the form of tables and graphs, and are compared with each other to study the differences observed. It can be concluded that the buildings designed composite columns offers a better ductility and thus is more earthquake resistant.**

Introduction:

Today, the need for fast paced and high strength construction has become a very important aspect of the construction industry. Due to the increase in migration of high number of people from all corners of the country to the cities, the need of office spaces and residences in the city areas is growing at a very rapid pace. To cater to this need of increasing population in cities it becomes important for the construction industry to adopt high rise building systems to accommodate large number of occupants in the limited space available in cities. As stated earlier, the most important perspective in constructing a high rise building is the pace that has to be maintained in the construction, while also maintaining the high strength requirements of the structures. Traditionally, RCC i.e. reinforced cement concrete is used to cater to this need. RCC has its unique set of advantages that it offers and thus has been one of the most sought after method of construction since a long period of time. But with the development of modern machineries and techniques of construction various new concepts for constructing the structures with higher strength and lesser time are being developed.

Concept of Steel-Concrete Composite Structures :

Steel-concrete composite structures are gaining high importance in the construction of bridges and highways, high rise buildings, etc. The sections in steel-concrete composite structures tend to use the compressive strength offered by concrete and the property of high resistance to tension and compression offered by the structural steel. Thus when these properties are combined in a section, the resultant section is a highly efficient and comparatively light weight section which most commonly find its way in the construction of high rise multi-storey buildings and highway bridges. Along with the goodness of strengths from concrete and structural steel, steel concrete

structures offer certain more benefits as well. They offer high resistance to corrosion and thus are highly durable in nature, they are considerably low maintenance structures when compared with RCC or steel structures, which gives it a edge in becoming a preferred economic solution in life cycle of the structure. To have a better idea, it is found that the use weight of composite structures to be

lighter than as much as 25% when compared to rccstructures (Rathore and Gupta 2020). This results in lesser efforts in erection and installation of the structure, thus saving labour and construction cost. These economic savings in construction of steel concrete composite structures can be as high as 10% when compared with the traditional RCC framed structures and around 7% when compared with steel structures (Rathore and Gupta 2020).

Literature review:

Chung and Lawson (2000)

In this research, an important aspect of steel concrete composite design i.e. the design of steel concrete composite beams with large web opening is discussed in detail. It is elaborated that how the proper positioning and sizing of openings in a steel concrete composite beam can affect on its favour ability towards bending as well as shear resistance. Here, various tests have also been performed to justify the analytical results obtained through the research. Also in this paper the effect of openings on the deflections is explained with the help of juvenile factor which is basically dependent on the location as well as the size of the openings. The results of the study are presented with the help of typical design tables. This paper is thus basically a design guide to Eurocode which is a detailed code of practise for analysis and design of steel and concrete composite structures for construction in European countries. Various tables are provided in order to facilitate the engineer to design those beam sections comfortably and suitably as per the requirement of the openings in the beam sections.

Spacone and Sherif (2004)

In this research paper, the present state of the art non-linear analysis in steel concrete
composite structures. It focuses on how frame elements can be computationally more faster as compared to continuum finite element models. Some of the systems that were used for the analysis purpose have used a great number of elements and degrees of freedoms which was not even thinkable to analyse a few years ago. In this research mostly the analysis has been carried out on the structural walls used in building construction. Here the models that are lumped and have a distributed inelasticity as well as the models that a perfect and partial connections are also covered In this research paper, the present state of the art non-linear analysis in steel concrete composite structures. It focuses on how frame elements can be computationally more faster as compared to continuum finite element models. Some of the systems that were used for the analysis purpose have used a great number of elements and degrees of freedoms which was not even thinkable to analyse a few years ago. In this research mostly the analysis has been carried out on the structural walls used in building construction. Here the models that are lumped and have a distributed inelasticity as well as the models that a perfect and partial connections are also covered.

Wang (2005)

In this research paper, the focus of study is directed towards the performance of composite structures in fire and the design of fire resistant composite structures. The main components of a composite structure i.e. floor systems, joints and the slab are considered in this study. Various experiments including the experiments on the joints provided in fire, simulation using finite element software, the component method, the performance of different types of joints under the action of elevated temperatures and also the effect of behaviour of joint on overall steel concrete composite structure. Also, the effects of the structural behaviours as a whole are discussed. With the help of this paper we have understood the recent advancements in structural behaviour under the conditions of fire. Thus it has shed light on most recent studies in the design and execution of composite floors, composite column and beam column joints in steel-concrete composite structures.

Bouazaoui and Perrenot (2006)

In this paper the mechanical behaviour of a steel and concrete composite structures using experimental analysis is discussed. Here the steel and concrete i.e. the steel girder and the concrete slab are assembled with the help of adhesives. Hence the effect of the natures of the adhesive used and the irregularity generated using the adhesives are studied and its effects on parameters such as ultimate load and mechanical performance is studied. Two different adhesives are used in this experiment and they are epoxy adhesives and polyurethane. Also their thicknesses in longitudinal and transverse directions are varied for studying the results. And it can be concluded based on this research that a steel concrete composite structure can
be enhanced using adhesives. It is observed that the failure of such sections is due to the crack in concrete slab and yield of the steel girder used. In such a situation there is no problem with the adhesive whatsoever used. Another failure pattern observed particularly in case of polyurethane adhesive is that crack of the concrete slab and vertical displacement of steel girder. But in conclusion, the composite structures constructed using the adhesives give better performance in all types of composite structures application including that of a bridge structure.

Maiorana et al. (2008)

In this paper, in order to increase the flexural strength of a steel concrete composite structure technique using the Fibre Reinforced polymer is used and discussed. Extensive research hasbeen done using FRP on concrete and masonry structures but very few literatures are
available on strengthening of steel concrete composite structures. Guidelines regarding the application of externally bonded FRP strengthening is available but to analyse its behaviour pattern one has to rely on the hypothesis posed by the elastic behaviour. In this research, focus has been devoted towards the analytical procedure to predict the behaviour of the FRP reinforced steel-concrete composite structure. Also the non-linear behaviour is taken into account. In order to provide a basis of research the analytical results obtained are to be compared to that of some previously available experimental results. In general sense, in this
research an approach towers analytical prediction of behaviour based on the strain

compatibility and cross-sectional compatibility in steel-concrete composite structures is proposed.

Marian and Khalil (2010)
In this research, the aspect that when a steel concrete composite beam is subjected to extreme bending or hogging moment , the bottom flange of the used steel section preferably a steel I-section of the steel concrete composite beam is found to be under compression and
thus is very sensitive toward the phenomenon of restrained distortional buckling. As it is known that the design criterion suggested in the Eurocode 4 is based on the inverted U-frame model, thus it does not consider the inelastic moment redistribution mostly in case of the steel
concrete composite beams which are statistically indeterminate. In this research, the emphasis is given on the present methods of the calculation of the buckling strength in distortion in steel-concrete composite beams and suggests some improvements over the presently prevailing methods.

Patil and Kumbhar (2013)
In this paper, a ten storied tall Reinforced concrete framed building structure is considered for the purpose of analysis by the technique of non-linear dynamic analysis. The ideology behind this research is to run the analysis for the different seismic intensities and then to
study the seismic responses of those buildings. For the purpose of analysis, a software platform called SAP2000 is used. For the purpose of experimentation 5 different time histories are considered by the researchers, which consider 5 different intensities of earthquake i.e. V, VI,VII, IX AND X as per the Modified Mercalli's Intensity Scale i.e.MMI. Thus an attempt to study the relation between the seismic intensity and seismic response is made. Thus from this study it concludes that it is essential for a designer to carry out detailed time history analysis of a structure to ensure its full safety against the earthquake forces. In conclusion, it is said that the seismic responses in the form of base shear and story drifts and story displacements vary in similar manner for all intensities and all time histories
considered. This also concludes that Time History Method is very much more realistic
method used for the purpose of seismic analysis of a building and gives better check results for the safety of the considered structure.

Wagh and Waghe (2014)
In this research paper, it is said that since recent times widespread acceptance has been given to use of composite structures i.e. the structures with steel and concrete it need to compared on practical grounds with conventional reinforced concrete structures. Here, four different tall
buildings are considered to be analysed by using Staad. Pro and also a detailed estimations of cost is carried out using MS-Excel. It was observed that, in case of composite structures due to smaller section sizes the self-weight of the structures reduces significantly and ultimately affects the cost the structure. Also due to less bending moments incurred in composite structures the size of foundations also reduce. Due to enhanced ductility from steel composite structures also tend to perform better under the action of earthquakes. And to summarize,
composite structures also take less time as compared to reinforced concrete structures for constructions and are economical in overall scene.

Sebastian and McConnel (2015)
In this research paper, a nonlinear finite element program of advanced level was developed for the purpose of analysis of in general structures made of composite materials i.e. steel and concrete. Here the concrete used is described as nonlinear isotropic and elastic before the cracks appear and orthotropic and nonlinear afterwards. Whereas the steel is taken as initially elastic and strain hardening capabilities after yielding. It is observed that the results obtained from the use of this program on steel-concrete composite sections yielded results very similar
to the ones observed on actual experiments performed on the sample till the failure of the sections. Thus it can be concluded that the program developed is extremely effective in the predictions of behaviour during failure in case of general steel concrete composite structures.

Yu-Tao-Guo et al. (2018)
In this research paper, it is stated that the steel-concrete-steel composite structures having orthogonal longitudinal and transverse steel webs generally showcase higher values in ductility, strength, blast resistance , construction efficiency, impact value, etc when compared with the conventional systems like Reinforced concrete structures or steel structures and thus offering a competitive option of multiple types of projects. It mainly finds its applications in protective structures, marine structures like bridges etc. The steel-concrete-steel composite structures have multiple mechanisms to resist and transfer the shear forces as compared to
steel beams or RC beams. In order to study this through a total of 16 tests for shear transfer mechanisms were carried out and a thus a theoretical analysis was conducted. It was observed that the major reason for the failure ofsteel-concrete-steel composites under shear was due to
shear compression. The angle formed in concrete cracks was somewhere around 45 degrees initially and later on developed to be around 30 degrees when the loads were increased.

Rathore and Gupta (2020)
In this paper, a time history analysis report performed on a 10 storey reinforced concrete building is presented. As per the researcher, in case a building is improperly or inadequately designed and analysed for earthquake response, it leads to a devastating collapse of partial or entire building structure causing great losses of life and property. Time History analysis being a reliable and practical oriented approach for the analysis of a building by non-linear dynamic method is preferred by the researcher to carry out his research in this report. The software platform used by the researcher used in this research is ETABs by Computes and Structures Inc. i.e. CSI and earthquake time history used by the researcher to analyse the 10 storey RCC structure is El-Centro 1940 Earthquake. As per the report the main parameters in seismic analysis of a structure are the mass, ductility, damping, load carrying capacity and the stiffness of the structure. Also different response parameters like story displacements, base shears and story drifts are also determined and compared against the desirable limits from the IS 1893:2002.

Research Gap and Methodology Adopted:
In India, IS 11384 is the code designated for the guidelines regarding the construction of Steel-Concrete Composite Buildings. However, it does not provide a detailed design and analysis procedure for the same. Furthermore, the concept of Steel-Concrete Composite Column has been totally neglected in the code. Due to this reason, in India most of the design of Steel-Concrete Composite Column is carried out using the American code AISC 360-16. This gives rise to differences in design approaches as for analysing and designing a steel-concrete composite building we rely on both Indian and American standards. This can be explained as, for designing of the steel-concrete composite column AISC 360-16 is used, for beam and other structural member design the prominent Indian Standards like IS 456:200 is used and for earthquake analysis IS 1893:2016 is used. Hence, the project focuses on analysis and design of a building using the practices followed in India for construction of steel-concrete composite structures To carry out this analysis and design, the finite element modelling based software from The Computers and structures Inc., ETABs is used. The time histories for performing nonlinear time history analysis are obtained from Pacific earthquake Engineering Research (PEER) ground motion database. A software developed by a Seismosoft software company named as “Seismomatch” is used for the purpose of spectral matching of the earthquake time histories with respect to the target response spectrum.

Objective of the Study:
The present study is aimed at determining the seismic behaviour of a building under nonlinear time history analysis. The objectives of the present study includes :
a) To analyse and design a steel-concrete composite regular building using Indian standards.
b) To compare the difference in the section sizes obtained after the design.
c) To perform nonlinear time history analysis using scaled time histories of 11 earthquakes on the above buildings in both the directions using their respective codes of practices.
d) To compare the results from nonlinear analysis in form of factors like capacity curve, story displacements, story drifts and base shears of the buildings with each other and tabulate the observations.
e) To draw conclusions based on the observations from comparisons.

Conclusion:
The building designed using Indian Standards differ in terms of section sizes.
The study has been carried out on the behaviour of the buildings using different sections of steel-concrete composites. The study involves the effect of use of such sections on the building when compared to the regular reinforced concrete building. Various aspects of building behaviour are considered in different studies to predict the appropriateness of the steel-concrete composite sections under different circumstances. Also, studies have been carried out on the safety and serviceability of these sections in events of adversities like fire outbreaks. Furthermore, effect of change in intensities of the earthquakes on the response of the structures have been studied. Different softwares offer different specialities and can be used based on the need and nature of the study. Extensive research has been carried out to understand the seismic behaviour of the buildings under varied circumstances. Thus, it can be concluded that, the steel-concrete composite sections used in a building result in imparting higher ductility to the building which constitutes to better seismic performance. The nonlinear dynamic analysis i.e. the time history analysis, among all other methods of seismic analysis including the equivalent static analysis, response spectrum method and pushover analysis, proves to be a very reliable method of assessing the performance of the building in the real time.

Future Scope
The present study is carried out for a regular building with concrete encased steel column sections and RC beams. So, the area of research that has to be done are,
1. Different shape of column section can be used for analysis.
2. Study can be carried out on behaviour of building with concrete in filled steel column and steel beams.
3. The building selected in this study was a regular building, hence irregularities can be introduced in the building to study the change in behaviour.

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