International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 05 | May-2016 www.irjet.net p-ISSN: 2395-0072

Finite Element Modeling for Effect of Fire on Steel Structure: A Review

Mr.Madan M. Awatade[1], Dr.C.P.Pise[2], Prof.D.S.Jagtap[3], Prof.Y.P.Pawar[3], Prof.S.S.Kadam[3], Prof.D.D.Mohite[3] .

[1]PG Scholar, Department of Civil engineering, SKN Sinhgad College of Engineering, Pandharpur, India

[2]Associate Professor, Department of Civil Engineering, SKN Sinhgad College of Engineering, Pandharpur, India

[3]Assistant Professor, Department of Civil engineering, SKN Sinhgad College of Engineering, Pandharpur, India

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Abstract - ***Fire performance of structural steel at Elevated temperature includes the study of steel frame Subjected to fire. Also the effect of stress strain Temperature on the fire performance of structural steel Should be observed. The behavior of a steel frame in a Fire depends on many factors including the properties of The steel and the coating material on it. The present Paper shows reviews of various research works carried Out by several researchers on the effects of stress–Strain relationships on the fire performance of steel Frame exposed to uniformly increasing temperature When steel is unprotected and protected with concrete Using FEM.***

***Key Words*: Steel frame, Elevated temperature, Fire performance, Stress-Strain, Finite Element Model (FEM).**

1.INTRODUCTION

FEM Modeling is one of the best method to describe the accurate geometric and nonlinear formulation to predict structural behavior of unprotected steel member of steel frame at elevated temperature[1,2,3].When the unprotected steel column is subjected to repeated fire on a single storey it reduces the stresses and stiffness of the axial member[4].The steel beam and composite beams are exposed to fire it affect on stresses and strains it also depend on support condition and properties of steel.[5].Steel I-beam is also used as structural member when it exposed to fire the main parameter that affect on rotational capacity it include the Parameters like temperature, flange slenderness, web slenderness and effective length.[6,7,8].One of the most important factor i.e. the failure time of unprotected steel columns subjected to various axial restraint ratios[9,10,11].The important property of steel is ductility the benefits of steel ductility in the current design of fire-unprotected structures[12,13].When the large steel building strongly affected by heating it include the aspect like role of expansion, loss of material and strength, the relative stiffness of adjacent parts of the structure, development of large deflections, buckling and temperature gradients[14,15].In the past decade, several experimental and theoretical studies have been carried out on the degradation of column concrete strength due to the short term exposure to fire [16]. These studies of columns exposed to fire have indicated the following observations: Surface cracking in concrete occurs at nearly 300 C with a deeper cracking at 540 C. Spalling occurs followed by breaking off thin concrete cover at corner and edges.[17]Concrete begins to lose about 30% of its compressive strength when heated up to 300 C and loses about 70% of its compressive strength when heated up to 600 ^{0}C.[18] Concrete modulus of elasticity reaches 60% of its original value at 300 C and reaches 15% of its original value at 600 C.[19] Concrete stiffness decreases with the increase in temperature and the reduction in stiffness is accompanied with a reduction in the concrete strength with the increase in the concrete strains.[20] Vertical cracks clearly appear and then crushing of concrete accompanied by crackle sound with a local buckling of the longitudinal reinforcement occurs.[21] Columns with large longitudinal bars diameters lead to fire resistance appreciably smaller than columns with smaller bar diameters and the increase in concrete cover has a positive effect on the columns fire resistance.[22,23]. Boundary restraints experienced by an actual heated column within a building have not been considered.[24,25]. The Broad gate development fire and the series of Cardington fire tests have shown that strong interactions exist among slabs, columns and beams.[26,27,28] For columns in a compartment fire, they are likely to be axially and rotationally restrained by their adjoining unheated members.[29,30].Failure of corrugated web under shear; was due to buckling of the web. That buckling of the web is local and global for the coarse and dense corrugations, respectively.[31] suggested a buckling formulae, which are based on local buckling of the corrugation folds as isotropic flat plates or global buckling of the entire web panel as an orthotropic plate[32].Failure of corrugated webs under uniform bending; was sudden and due to vertical buckling of the compression flange into the web after the stress in the flange reached the yield stress.[33] Failure of corrugated webs under partial compressive edge loading; was due to a flange collapse mechanism and web crippling or web yielding, followed by crippling and vertical bending of the flange into the crippled web[34,35,36] In additional to the above mentioned modes of failures; Abbas presented a theoretical formulae for the linear elastic in-plane and torsional behavior of corrugated web I-girders under in-plane loads. Using a typical corrugated web steel I-girder consists of two steel flanges welded to a corrugated steel web. [37, 38, 39].

2. PRESENT STUDIES AND THEORIES:

There are many researchers have been carried out on FEM Modeling on steel frame for investigating its behavior under fire with considering parameters like stress-strain-temperature relation ,thermal time.

Chi Kin Iu et al [1].R. B. Caldas.et al.[2]. Lenka Lausová et.al [3] have invested an accurate and robust geometric and material nonlinear formulation To predict structural behavior of unprotected steel members at elevated temperatures. A fire Analysis including large displacement effects for frame structures is presented. This finite Element formulation of beam–column elements is based on the plastic hinge approach to Model the elasto-plastic strain-hardening material behavior.

Lyle P. Carden, Ahmad M. Itani [4].An evaluation of a single story unprotected steel structure Exposed to repeated fire during the training of fire fighters is described. Temperatures are monitored on the structure using resistance temperature detectors connected to a data acquisition system. Temperatures of up to 384 C are measured in the steel of the structures, which are below levels likely to cause much degradation in stiffness or strength. Uniform heating of the columns was shown to result in minimal stresses in the structure as the columns were relatively free to deform axially.

Andy Buchanan et al [5]. Ahmed S. Elamary [6]. Z.H. Yao et.al [7]. Jing-Si Huo et.al [8].This paper describes a detailed analytical investigation into the effects of stress–strain relationships on the fire performance of steel beams and composite steel–concrete beams exposed to uniformly increasing temperatures on three sides. The support conditions include simply supported, pin–pin, fixed sliding and fully fixed. In each case, a comparison of the deflected shape with the evolving internal forces shows unusual but predictable behavior, strongly dependent on the stress–strain relationship of the structural steel.

Ronny Budi Dharma, Kang-Hai Tan [9].he describes the use of finite element models to study the inelastic behavior of a steel I-beam in terms of its rotational capacity at elevated temperature. Two main objectives of this study are to investigate the feasibility of applying the finite element method to study the moment–rotation relationship of steel I-beams at elevated temperature and to investigate the main parameters affecting rotational capacity at elevated temperatures through parametric study. The finite element (FE) model was validated against published test results [Lukey AF, Adams PF. Rotation capacity of beams under moment gradient. Journal of the Structural Division, ASCE 1969;95(ST6):1173–88] at ambient temperature and test results reported in Part I of the paper.

Ronny Budi Dharma, Kang-Hai Tan [10].An extensive experimental programme has been conducted to investigate the rotational capacity of steel I-beams under fire conditions. Two main objectives are to study the effects of temperature on the rotational capacity and to identify key parameters which affect the rotational capacity. Parameters including temperature, flange slenderness, web slenderness and effective length were varied in the test programme. The test set-up was designed to represent the internal joint of a continuous beam. The segments between the plastic hinge and adjacent point of inflection where hogging moment occurs were represented by each half of a simply supported beam subjected to a mid-span point load. The specimens were heated to the desired temperature before they were subjected to an increasing point load up to failure (isothermal test).

Kang-Hai Tan, Wee-Siang Toh, Zhan-Fei Huang , Guan-Hwee Phng et al [11].he give outlines a research program on an experimental investigation to determine the failure time of unprotected steel columns subjected to various axial restraint ratios. Axial restraints were applied to simulate the thermal restraint effects due to adjacent cooler parts of a steel framed structure in fire. All columns had an effective length of 1.74 m, and were divided into 4 groups according to their minor-axis slenderness ratios of 45, 55, 81 and 97, respectively. The columns were axially loaded and exposed to a monotonically increasing heating condition. Initial imperfections such as column crookedness and load eccentricity were measured by a specially designed facility.

Alexander Landesmanna, et al [12].A non-linear transient heat transfer analysis is performed on the basis of the finite element method (FEM), following the main guidelines proposed by the European Code for steel structures under fire conditions. The computational analysis program is used to assess the structural load-bearing functions and to estimate the structural behavior and the corresponding time-resistance period. The original refined plastic hinge method is extended for fire design analysis considering both tangent modulus model and inelastic stiffness degradation concepts in the developed computational program. A tangent modulus model is developed for the European column buckling-curve for fire condition. The results obtained are compared with those from an FEM computational program and those from the Euro code simplified design recommendations. The benefits of using steel ductility in the current design of fire-unprotected structures are outlined

A.S.Usmani [13]. Fires are a relatively likely event consequent to earthquakes in urban locations and in general are an integral part of the emergency response strategies focused on life safety in most developed economies. Similarly building regulations in most countries require engineers to consider the effect of seismic and fire loading on the structures and provide an adequate level of resistance to these hazards, however only on a separate basis. To the authors knowledge there are no current regulations that require buildings to consider these hazards in a sequential manner to quantify the compound loading and design for the required resistance. It is accepted that in many cases this may not be feasible or even desirable, but on the other hand there will be many high value structures where it would be economically and technically sensible to provide such resistance.

J.M.Rotter et. al [14].discusses the response of a structural element under fire within a highly redundant structure, such as a large building. The behavior of the element under fire is strongly affected by the restraint provided by the surrounding parts which are not subjected to heating. A number of responses in quite simple structures are shown, to illustrate the roles of expansion, loss of material strength, the relative stiffness of adjacent parts of the structure, development of large deflections, buckling and temperature gradients. These aspects are illustrated with simple examples, and it is shown that there are several counter-intuitive phenomena in structures of this kind. The significance of these findings for the design of large buildings is explored briefly

K. W. Poh [15].have presents a new mathematical relationship for representing the stress-strain behavior of structural steel at elevated temperatures. The relationship is constructed by fitting two versatile, continuous equations to experimental data. The first equation, a general stress-strain equation previously proposed by Poh, is used for characterizing the stress-strain data. The second equation is proposed in this paper. It is used for representing the variation of the stress-strain behavior with temperature. A simple two-stage procedure is used for fitting the equations to the experimental data. This gives a set of curve fitting coefficients that can be simply expressed in a matrix format. It is shown that the resulting relationship accurately represents the experimental data.

3. CONCLUSION:

Based on the studies so far carried out by several researchers following conclusions can be drawn.

1.From the review of the studies carried out by various researchers it can be concluded that as temperature increases the stresses and strains are increases when steel is unprotected.

2. As we provide insulating material like concrete on the all sides of the steel frame with a suitable thickness so that there is decrease in stresses and strains hence behavior of steel exposed to fire becomes essential.

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