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NON-LINEAR FINITE ELEMENT ANALYSIS OF REINFORCED CONCRETE BEAMS WITH TEMPERATURE DIFFERENTIALS: A REVIEW

Samina Nusrat[1], Haiyah Qureshi[2]

[1]*Department of Civil Engineering, Sharda University,*
[2]*Department of Civil Engineering, Sharda University,*

Abstract*—NLFEA conducted to simulate simply supported reinforced concrete beam over their depth with temperature differentials tested at room (15^{o}C) and low temperature (25^{o}C).Three dimensional FE modals were developed to verify geometry, material, loading, boundary conditions and temperature profile. The results are verified against experimental values in terms of cracking loads, yield loads and cracking pattern. The validated NLFEA models are explored with same beams, uniform temperature as well as statically indeterminate reinforced concrete with or without temperature differentials. The values were capable of predicting the ultimate strength at both room and low temperature. In addition to this, it was observed clearly indeterminacy of fixed ends increases the strength of reinforced concrete beam (upto 110%). NLFEA showed that low temperature increases the strength of beam without stirrups.

Keywords- NLFEA, ABAQUS, Concrete damage plasticity, Temperture differentials.

INTRODUCTION

Bridges are predominant elements in surface transportation networks. . Many of these aging bridges with severe environmental conditions such as significant and continual temperature fluctuations and prolonged freezing seasons that cause the bridges to be subjected to frequent freeze-thaw cycles and lengthy freezing periods. Nevertheless, most previous research focused on the effect of low temperature on concrete as a material rather than on structural performance of reinforced concrete members. However, limited research was conducted on the seismic behaviour of reinforced concrete at low temperature.

Genikomsou et *al* (2015) studied the punching shear behaviour of slabs without shear reinforcement by conducting a nonlinear finite element analysis (NLFEA) on three-dimensional models of five concrete slab-column connections that were subjected to either static loading or pseudo seismic horizontal loading. To simulate the behaviour of the concrete, the concrete damage plasticity model was incorporated as the constitutive model with the secant modulus of elasticity of the concrete determined using the Hognestad parabola.as significant because of the absence of shear reinforcement

.Liang et al. (2005) conducted a numerical study on the flexural and shear strengths of simply supported composite beams that were tested Chapman and Balakrishnan A three dimensional finite element model using a smeared cracking constitutive model was adopted, and reinforcing bars in the concrete slabs were modelled as smeared layers in the shell elements.

LITERATURE REVIEW

Mehdi et *al* (2017) conducted an experimental investigation on four reinforced concrete beams whose temp was kept different with uniform room temperature at lower degrees were tested.Non-linear finite element analysis(NLFEA) were studied on different temperature profiles such as -40^{o}C ,-20^{o}C, 40^{o}C, 20^{o}C on statically indeterminate and determinate temperature profiles in order to investigate about the ultimate load and cracking pattern of reinforced concrete beams due to indeterminacy and temperature effects.The temperature difference between -40^{o}C to 40^{o}C may not affect the cracks or ultimate loads of beam provided with shear reinforcement.On the other hand,lower temperatures 20^{o}C and 40^{o}C on the beams without stirrups will have increment of ultimate load by 19% and number of cracks will decrease.

Alih,(2012) conducted an experiment and developed a concept on simply supported beam tested for bending in order to observe and record the phenomenan of tension stiffening in concrete composite.The parameters used in tension stiffening are acceptable and modelling strategies made in ABAQUS can closely represent the actual condition.By improving the parameters they achieved a more accurate global response of model.

Mehdi, et *al* (2016) conducted an experimental investigation and studied that there can be a delay in the initiation because of low temperature and the propogation of shear cracks and flexure at service load can retard,and low temperature reduces the depth and number of cracks.It indicated that there is an improvement at lower temperature in the cracking behaviour of RCC.The crack propogation had no effect because of 48 hours sustained load but this load period initiated the shear cracks in shear spans of beams specially to those which were tested at room temperature.When the first shear crack was observed on shear span due to load temperature it (cracks) increased by 125% in beam without reinforcement and 75% in beams with reinforcement.During the initial load stages the width of cracks were reduced.It was observed the beams which were tested on lower temperature under cyclic loading the crack width was less and crack spacing was higher.

Birtel (2005) conducted an experimental investigation on spatial finite element models with concrete solids embedded truss elements-modelling stirrup and longitudinal bars.In one case global parameters like ultimate loads or deformations close to reality were evaluated reliably,complex loading conditions like biaxial ones hold the same while in other case the basic parameters that experiments because of their demand on time and cost are not able to give,are allowed for extended variations.The parametric inputs of a user for such variations are minimised.

DeRosa, (2012) conducted an experimental investigation for both strain and crack widths in RCC and compared to electric resistance strain gauges which are conventional techniques were checked in order to determine the sensor systems in both.Correction in sensor results for temperature consideration of preliminary work was done.In the both sensor systems because of the variation in temperature in range of 21^{o}C to 20^{o}C a significant strain errors are detected.In order to lower this error some techniques were addressed.In order to improve structural monitoring and numerical models used for analysis a better understanding on the effects of temperature on crack width,stiffness,strength and short term creep behaviuor of RCC beams was explored.Room temperature and low temperature test results were compared.It showed that at lower temperature in the member that are free to expand and contract has tendency to fill the cracks.There is an increase in shear capacity of beams at lower temperature.

DeRosa et *al* (2015) conducted an experimental investigation on RC beams which were loaded to failure at -20^{o}C it was noticed that there was a significant increase in capacity of beam with no stirrups at the room temperature, while there was no noticeable increase in stiffness at that temperature as per load deflection plots at lower temperature effect of creep was minimized after the internal temperature of specimen went below 0^{o}C.It was found that crack width are effectef by temperature and there is potential for shear capacity of an RC structure to change over the entire day and over the entire year due to effect of temperature on shear cracks

Teng et *al* (2010) conducted an experimental investigation presenting a modified plastic damage model within the theoretical framework of concrete damage plasticity model (CDPM IN ABAQUS). Two methods were proposed for defining the flow rule of non uniformly confined concrete which were obtained. Second method appeared more reasonable, it took into account the difference in the flow rule between different points over a non circular section. FE agreement with existing test result in terms of overall behaviour included the axial stress-strain behaviour and hoop strain-axial strain behaviour. The difference between the two lies in axial stress-strain behaviour and their distribution. It is very important to note while the proposed constitutive model had a rigorous bases for uniformly confined concrete, it needs to rely on certain assumptions derived from empirical evidences for confined concrete in non circular section.

CONCLUSIONS

Based on the study done,it can be concluded that temperature differentials and changes in ambient temperatures between -40^{o}C and 40^{o}C do not significantly affect the ultimate loads or number of the cracks on beams with shear reinforcement. On the other hand, lower temperatures (i.e., 20^{o}C and 40^{o}C) increase the ultimate load of the beams without stirrups by up to 19%, and decrease the number of the cracks. The results of the present finite element analysis showed that the models developed in this study were capable of predicting the response of the reinforced concrete to temperature effects, monotonic, sustained, and very low cyclic loads. This NLFEA can be employed as a tool to investigate the strength and cracking pattern of the statically determinate and indeterminate reinforced concrete beam, and thus paves the way for further parametric studies.

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