BEHAVIOUR OF REINFORCED CONCRETE BEAM UNDER HIGH TEMPERATURE USING FINITE ELEMENT ANALYSIS

N. PARTHASARATHI¹ & K.S. SATYANARAYANAN²

¹Research Scholar, Department of Civil Engineering, SRM Institute of Science and Technology, Chennai, India

²Professor, Department of Civil Engineering, SRM Institute of Science and Technology, Chennai, India

ABSTRACT

Numerous levels of research work have been conducted over the years for the improvement of concrete with newly formed materials and methodologies. In this research work attempted to execute the behaviour of concrete under high temperatures and at different transient levels. The model is experimented with the actual dimension and simulated on Abaqus under the different working load of 40%, 50% and 60% with the ultimate load. In Abaqus software, the exact dimension used in the experimentation is modelled and meshed to find out the solution for each element. The modelled beam is conditioned at transient state analysis and executed for 180minutes (3hrs) on the simulation run with the three different lengths with three faces. Ultimately, the research findings explain that the effect of the transient heating stage under various beam lengths and faces is evaluated. The finding shows, an increment level of effectiveness is made to improve the crack behaviour of concrete when the transient stage is maintained at the temperature of 29°C for the working loads on right and full length and its effective measures on crack behaviour, deflection and rotation are plotted as graphs in the result section respectively.

KEYWORDS: Reinforced Concrete, Transient Thermal, M30 Grade, Finite Element Method, Meshing

Received: May 09, 2019; **Accepted:** Jun 29, 2020; **Published:** Jun 30, 2020; **Paper Id.:** IJMPERDJUN2020232

INTRODUCTION

Concrete technology is considered to be an essential material used all over the world and formed to be a crucial role in the construction field. Though concrete has the ability to bear high compressive and tensile stresses for load-bearing capacity for optimal property improvement [1]. Reinforced concrete structures are developed to improve the properties of the conventional concrete used for large scale building structures [2]. In addition to the working loads, the reinforced concrete has the ability to withstand the risk of high temperatures. Generally, reinforcement materials with a combination of concrete and additive particles to the design mix. The reinforcements can be either the addition of material in the concrete or by improving the structural property by mounting elements over the concrete structure. changes is a significant level of advances are made in the concrete technology over these decades [3]-[5].

Improvement in concrete strength and making alternative changes in concrete through reinforcements are considered as the advanced method and largely utilized. The reinforcements with conventional materials make concrete to be more stable. Steel is generally used as reinforcing component which assumes an auxiliary effort in strengthening concrete structure. With the inclusion of steel in the concrete, the mechanical properties of the structures can be upgraded than the regular strategy.

High-performance concrete which deals with the requirement of improvements in the property change by boosting the mechanical properties and make the concrete to long-lasting service life [6]-[8]. The research made an attempt to evaluate the reinforced concrete beam under transient temperature conditions. Testing the concrete under the thermal conductivity influences the property of the concrete. The transient state of concrete deflects more on the mechanical property and thereby a significant change in the moisture level and can be evaluated by means of steady-state or transient level tests [9]. In this testing, a significant level of physiochemical changes is obtained at a higher temperature over intermittent heat flow direction. Generally, the thermal conduction of conventional concrete at the long-lasting room condition will be in the range of 1.4 and 3.6 W/m-°C [10], [11]. The testing of thermal conductivity of reinforced concrete beam on this research work undergoes three different levels of working loads under stable ultimate load. The effect of the concrete beam placed by one end is pinned and another end with end roller and apply the variable loads on both ends and measure the loading performance under thermal condition. The behaviour of concrete under the applied loads is evaluated by the parameters like deflection and cracking respectively. The research paper is organized in the following ways, a literature survey is reviewed in section 2, the proposed research methodology is described in section 3, analytical modelling and result discussion is explained in section 4 and 5 and conclusion is explained in section 6 respectively.

LITERATURE SURVEY

Solid concrete structures when it is presented to thermal state, the temperature in the concrete rises at 1000°C, which may, thusly, lead to a ton of chemical and physical changes, at last prompting the disappointment of the structure. Jessie et al [12] developed the methodology for lessening the basic component failure when presented to raise temperature, which thus expands the departure time of the inhabitants during fire accidents. The solid structure when presented to high temperatures shows the various substance changes in the solid which prompts crumbling of the structure. The flexural conduct of the solid crystal with steel fibre volume part of 1.35% and without steel fibre, at room temperature (28°C) and when presented to raised temperatures of 150°C, 350°C, 550°C and 750°C for the time span of 1 hour were examined.

Prakash et al [13] built up a 2-D model that has been created for envisioning the level of spalling in HSC. The numerical model evaluates pore pressure inside the concrete as a component of time using the laws of thermodynamics. Spalling is said to happen when the pore pressure created inside concrete outperforms its flexibility.

The model relies upon a few parameters, for example, porousness, starting dampness content, and thermo mechanical properties of cement concrete. These parameters are considered by the model through a two-course coupling between the pore pressure assessment and heat examination, both completed using the FEM procedure. Parametric investigations indicated that the porousness of concrete significantly affects the degree of cement spalling. Higher penetrability prompts lower spalling and the other way around. Likewise, the higher rigidity of solid prompts lower spalling and the other way around. Goremikins et al [14] investigated the impact of steel fibre strengthened solid which containing polymer filaments (FRC) under high temperature. A restricted part based model was made to predict the temperature dissemination inside a model during both the thermal and the cooling method. The made FEM based model authorized foreseeing the heating vehicle inside the FRC model during the heating and cooling technique.

A rapidly expanding utilization of HSC in the greater part of the development ventures has urged scientists to recognize its conduct at raised temperatures. This has prompted the acknowledgment of insufficient comprehension of raised temperatures impacts on the conduct of HSC. Shah et al [15] reviewed the fundamental data about HSC and relates its advantages. Various distinctive plan gauges for the readiness of HSC are additionally exhibited and compared. Liao et

al [16] built up a combined FE model for forecasting the introduction and production of individual huge through-the-thickness splits inside RC floor slabs at raised temperatures. The created model was approved utilizing the past tried outcomes and the nonlinear model announced in this paper can be utilized for surveying the rectitude failure of the floor slabs in the fire. Aljabar et al [17] expand the present information on CFRP reinforcing steel components in tensile loading to the example of mixed weight and shear stacking. Steel plates were misleadingly parted from a central opening at six novel centres (10° to 90°) with respect to the stacking turn. A moving phenomenon was recognized to depict the impact of blended mode as far as the formation of cracks. A mixture mode change factor was made to assess the disappointment life of CFRP-fortified steel plates with at first slanted cracks. From this perception, this exploration mimics the impact of transient burdens follows up on strengthened cement exposed to extreme working burdens and assesses the avoidance and crack conduct under the loading condition respectively.

PROPOSED RESEARCH METHODOLOGY

Advancements in concrete technology attaining more response towards the building as well as in the construction sector. In that scenario, reinforcements in concrete are one of the advanced processes of refining the concrete with foreign additives make the concrete more stable than the conventional one. However, numerous levels of reinforcements is made earlier for improving the performance of the concrete through numerous level of testing. Since there is a limited level of experiments are conducted on the transient thermal effect of the reinforced concrete. On the basis of the finding, this research study made an attempt to uncover the effect of the concrete beam under the high temperature condition. The testing is undergone with three phases of beam dimension at three working loads. The whole bunch of testing is undergone on the Abaqus simulation by modelling the exact dimension of reinforced concrete beam and meshed with C3D8T under mentioned phases. In the first phase of analysis, it is carried out with four faces with three lengths of full, middle and right for three working loads of 40%, 50% and 60% with the ultimate load of 174kN. In the second phase, the faces are reduced to three faces and length is the same as the first phase with three working loads. In the third phase, the face is again reduced to two faces with the same length of the beam with the same three working loads and ultimate load. Note that all this three analysis process uses the same working loads of 40%, 50% and 60% with the ultimate load of 174kN for the simulation run of 180 minutes.

Figure 1: Architecture of Research Methodology.

The results finding from these three test procedure are identical for the following result of Deflection with and without Temperature for time 15min, 30min, 45min, 60min and 75mins, and parameters such as Maximum Deflection, Rotation, Moment and Horizontal Deflection and Cracking over transient temperature for working loads of 40%, 50% and 60% respectively. Hence, the outcome from the research is explained through graphical results plotted in the following result section respectively.

ANALYTICAL MODELLING OF REINFORCED CONCRETE

In this section, all the geometrical evaluation parameters required for the simulation process is defined with the optimal structural equation and boundary condition for the study is presented. The step followed in this section will make the root cause of finding optimal solutions through analysis are revealed.

Beam Geometry and Cross Section

The concerned models used in the simulation process designed with the dimensions of 3000mm in length with the beam breadth and depth of 300mm each. The boundary condition is set on the beam with one is pinned and another end is fixed with steel roller of four reinforcements with the diameter of 16mm on both zones of compression and tension and a stirrup of 8mm diameter is given at the spacing of 150mm c/c. The beam is constructed by the grade property of M30 mix with the

reinforcement steel rod is chosen with the yield strength of fe415. The loading condition is applied with two points at the L/3 distance using the modelled roller as reinforcement material on the top position of beam is shown in given figure 2.

Figure 2: 3D Modelled Reinforced Concrete Beam.

In modelling phase, the geometry of the concrete and the added reinforcement part is individually modelled by the 3D deformable solid elements and combined the parts together by the assembly module with the use of parallel face constrain for align the designed reinforcement part on the same direction towards the beam and place the reinforcement elements on the consistent location. It needs to be revised that the concrete is placed with the corresponding reinforcement elements [18].

Parameter Setting and Testing Criteria

In the FEM analysis, the meshing on the model with the Hexahedron type of 25mm size is employed using a surface to surface interaction for relating the interconnection between steel roller and concrete specimen. Initial setting of material properties such as elastic modulus, thermal conductivity, specific heat, expansion is extracted from the property table of euro code EN 1992-1-2 and EN 1993-1-2 respectively. The following figure 3 describes the relation of temperature which is exposed as per the ISO standard temperature curve.

Figure 3: Furnace Temperature with Respect to Time.

Procedure of Analyzing

The analytical study is defined for estimating the deflection of concrete by Abaqus Finite Element Software. The model is studied to know about the structural behaviour of the RC beam under high temperatures in a real-time scenario. The RC prototype is analysed under transient state conditions. In a transient state, the load is subjected to 40%, 50%, 60% of the ultimate load will give in the form of two-point loading and temperature will be gradually increased till failure.

Setting Boundary Condition

The boundary condition is initialized for the concrete beam one is fixed with steel roller and the other is pinned is taken for the study. To make sure that the boundary condition of the beam is modelled numerically and the test results from experiments are similar. The structural model is numerically analysed in the simulation uses reinforcement elements are modelled with solid elements. If the ends of the beam are fixed, the nodes are constrained withal degrees of freedom. The projectile of the steel rod is modelled with the actual deformation using solid elements. The projectile is a cylindrical shape with the dimension of 16 mm diameter of 4 Nos with stirrup of 8mm in diameter is applied at 150mm c/c spacings.

Thermal Analysis

Thermal analysis performed on the concrete with the actual cross section of the beam under transient heat conduction is

$$k\nabla^2 T + Q = \rho c \frac{\partial T}{\partial t} \quad (1)$$

Where, k is denoted as the thermal conductivity coefficient, c and q is defined as the acting specific heat and mass density of the material with heat source Q and temperature T at time t . Therefore, the effect of heat radiation over the boundary condition is given by

$$k\nabla T \cdot n = h(T - T_\infty) \quad (2)$$

Where, the ambient temperature of the beam be T_∞ and h be the coefficient of convective radiative and n be the normal boundary vector. For the transient state, the concrete can be combined with the T_∞ with the transient temperature. Therefore, the structural element is subjected as per the ASTM E standard, T_∞ is defined as

$$T_\infty = T_0 + 750(1 - \exp(-3.9953\sqrt{t_h})) + 170.41\sqrt{t_h} \quad (3)$$

Measuring the initial temperature T_0 at the ambient condition measure at the time interval in hours rate [19]. Based on the spatial discretization, the first order nonlinear for the conventional condition at time rate is described as

$$M_T \dot{T} + K_T T = F \quad (4)$$

Where the heat capacity matrix is defined to be MT and the conductivity matrix to be KT , the heat flux vector be F . The generalized equation of the system is defined in the algebraic form is defined as

$$(M_T + \tau\beta K_T)T_{n+1} = (M_T - \tau(1-\beta)K_T)T_n + \tau(\beta F_{n+1} - (1-\beta)F_n) \quad (5)$$

Where, τ is defined as the time step, β is the constant variable between 0 and 1, and the subscripts n (or) $n+1$ represent the evaluated functions at utilized time t_n (or) t_{n+1} , respectively. The following condition in equation 5 is outstandingly nonlinear due to material properties in temperature-subsidary similarly as the convective

radiative limit conditions and is clarified iteratively using the Newton–Raphson (NR) methodology. The iteration converges until the residual attains a definite tolerance level of 10^{-4} [20].

Bending Deflection Vs Temperature Variation

The constructed beam is analysed under the transient temperature condition over the reinforcement element then,

$$\Delta T = T_t - T_b \quad (6)$$

Where, T_t and T_b is the temperature at the top surface and bottom surface of the beam.

Figure 4: Deflection of Beam Due to Variation in Temperature.

A schematic illustration of the beam deflection under the variation of temperature acted is highlighted in above figure 4 [21].

EXPERIMENTATION AND RESULT DISCUSSION

Based on the research objective, a 3D simulation is carried out in the study with the use of finite element analysis on the reinforced concrete beam. A linear static analysis is undergone on the developed concrete beam with ABAQUS/Standard and executed for the simulation time of 180 minutes on an Intel core i5 configured the system with the processing capability of 3.5 GHz and 16 GB of memory. During the whole simulation run, results are concluded at every 15 minutes from the total time of iterations.

Process Parameters and Model Calibration

The calibration of the numerical model is based on the actual experimentation with the specimen as a fundamental reference. This model is numerically calibrated on the nonlinear finite element analysis to evaluate the deflection caused by the reinforcements. Initial parameters setting which consists of Young's modulus, compressive and tensile strength is predefined in the model, where the Poisson's ratio (ν), is set to be 0.2 for the concrete material.

For the numerical simulation, there is a need for an actualized model with the structural elements act as reinforcing elements made from steel rods. The perpetual model is constructed based on the actual dimension followed in the experimentation process. The model sketch is developed in the Abaqus and extruded the design to an actual 3D model using solid elements in the modelling space which uses deformable type using 8-node continuum solid element for creating the beam structure. The developed model on the solid elements consists of 8 nodes with 3 DOF for the transformation of each node in the x, y, and z direction. This element possesses plastic deformation that tends to crack in all three directions. Therefore, required partitions are made on the beam of dimension size 3000 x 300 x 300mm are made to withstand the applied load and by meshing. Four reinforcement is made over the concrete surface with a diameter of 16mm each is modelled on the software with 8 node elements of a beam connected over the solid elements. After finalizing the model, the material properties are set based on the concrete and steel material standard and create an input file for the open mesh of the model. This open mesh only contains model elements and nodes, not the created geometry. The process of meshing

will generate the nodes and connected the nodes to define the elements [22]. This process will create the surface on the concrete and apply the loads and nodes boundary conditions. On the modelled beam, the nodes are placed at the distance of 25mm from the edge and move along the direction of the Y axis to another end of X and Y direction which is shown in figure 5.

Figure 5: Meshing of 3D Modelled RC Beam.

Mesh System

An important characteristic function of the finite element analysis is the meshing process which divides the model regions in to finite elements and the simulation software evaluates the solution for each element. The initial step of the meshing process is by choosing the right element type in the 3D generated model [23]. In this objective the meshing is performed with the mesh C3D8T type of 8-node thermally coupled brick is used in the beam with the mesh size of 25mm is used under loading point.

Result and Discussion

The following result concluded form the simulation for three identical lengths of beam named to be full length, middle length and right length which is analysed on three different faces such as four faces, three faces, and two faces respectively. The effect of temperature act on each with variable length and its deflection towards the working loads are described briefly in this section.

Table 1: Transient State Analysis in Temperature at Three Length Son Four Faces

Time (Mins)	Central Deflection (mm)								
	40% of Ultimate Loading for Length			50% of Ultimate Loading for Length			60% of Ultimate Loading for Length		
	Full	Middle	Right	Full	Middle	Right	Full	Middle	Right
0	-1.93	-1.93	-1.93	-3.036	-3.03	-3.05	-4.32	-4.32	-4.32
15	-2.29	-2.185	-1.99	-3.44	-3.21	-3.13	-4.76	-4.58	-4.45
30	-2.529	-2.52	-1.97	-3.758	-3.7	-3.1	-5.1	-4.98	-4.43
45	-2.885	-2.82	-1.89	-4.11	-4.03	-3.01	-5.50	-5.4	-4.36
60	-3.533	-3.11	-1.75	-4.87	-4.37	-2.89	-6.53	-5.76	-4.25
75	-4.643	-3.48	-1.59	-6.45	-4.76	-2.76	-8.16	-6.15	-4.14
90	-5.989	-3.92	-1.47	-7.874	-5.21	-2.67	-9.92	-6.68	-4.1
105	-5.281	-4.62	-1.34	-7.172	-5.89	-2.59	-9.26	-7.41	-4.07
120	-5.682	-5.14	-1.31	-7.659	-6.7	-2.61	-9.89	-8.4	-4.16
135	-6.63	-6.17	-1.52	-8.692	-7.7	-2.88	11.07	-9.42	-4.46
150	-7.524	-6.58	-1.67	-9.98	-8.3	-3.06	12.25	-10.14	-4.68
165	-8.63	-6.82	-1.71	10.923	-8.6	-3.14	13.48	-10.43	-4.8
180	-9.523	-7.04	-1.70	-12.05	-8.81	-3.17	14.70	-10.73	-4.87

In table 1, the evaluation of transient temperature analysis of the reinforced concrete beam is conducted with three working ultimate loads of 40%, 50% and 60% for three lengths on four faces under the ultimate load of 174kN. The central deflection towards the temperature act on the beam on the length at full, middle and right under loading test were analysed using the simulation for the time interval between 0 to 180 minutes. The measures of deflection are noted down until it converges and continuous with analysing the effect on the other two faces.

Table 2: Horizontal Deflection and Rolling at Transient State of Three Lengths on Four Faces

Working Load	For Length on Four Faces	Temperature at Ultimate Load (°C)	Central Deflection (mm)		Horizontal Deflection at Ultimate Load (mm)	Moment (kN.m)	Rotation
			Initial Cracking	Ultimate Load			
40%	Full	676	-1.93	-5.83	0.144	-127.72	-0.0083
	Middle	675	-1.93	-5.96	0.461	-130.6	-0.0031
	Right	710	-1.93	-1.27	0.909	-27.95	-0.0104
50%	Full	653	-3.03	-7.57	0.159	-167.73	-0.0101
	Middle	657	-3.03	-7.36	0.679	-162.5	-0.0046
	Right	694	-3.03	-2.6	0.648	-56.65	-0.0117
60%	Full	639	-4.32	-9.46	0.473	-195.16	-0.0114
	Middle	637	-4.32	-8.57	0.897	-186.7	-0.006
	Right	665	-4.32	-4.09	0.320	-88.97	-0.0133

In table 2, the horizontal deflection and rotation of the beam influenced under transient state for three lengths at four faces is evaluated. The working loads act the beam at the temperature range between 600°C to 800°C at the percentage of working loads. It is evident that by increasing the temperatures on the beam at loading condition the rotation increases. Therefore, the deflection, rotation and crack behaviour of beam is evaluated at the lengths of the beams at 40%, 50% and 60% of working loads under transient state condition. From the results, it is found at the working load of 60% on right length with the temperature of 665°C, the rotation attains higher of -0.0133 with deflection of 0.320 and crack initiation will be in the range of -4.32 in higher ranges than all other faces respectively.

Figure 6: Transient State Analysis in Temperature at Three Length on Four Face.

In figure 6, the transient temperature act on the developed concrete beam is analysed with three different lengths on four faces. The deflection of the beam shows at working loads, the load act on the full length decreases when the temperature rises above 1500°C and in the case of middle length, the case is similar to a decreasing point. However, betterment is achieved on the right length, the deflection level is increased with the increase of temperature greater than 1000°C. The result shows the right length on four face forms better than the load act on other lengths and proposes as the optimal level.

Table 3: Transient State Analysis in Temperature at Three Lengths on Three Faces

Time (Mins)	Central Deflection (mm)								
	40% of Ultimate Loading for Length			50% of Ultimate Loading for Length			60% of Ultimate Loading for Length		
	Full	Middle	Right	Full	Middle	Right	Full	Middle	Right
0	-1.93	-1.93	-1.93	-3.037	-3.033	-3.03	-4.322	-4.315	-4.307
15	-2.872	-2.652	-2.146	-4.016	-3.751	-3.25	-5.31	-5.051	-4.562
30	-3.14	-2.757	-2.08	-4.302	-3.885	-3.20	-5.569	-5.2	-4.512
45	-3.633	-3.04	-2.062	-4.9	-4.122	-3.18	-6.198	-5.541	-4.511
60	-4.17	-3.33	-2.059	-5.411	-4.491	-3.18	-6.851	-5.857	-4.532
75	-5.07	-3.651	-2.062	-6.32	-4.817	-3.19	-7.88	-6.208	-4.565
90	-6.48	-3.92	-2.048	-7.81	-5.126	-3.21	-9.502	-6.5	-4.591
105	-7.668	-4.24	-2.025	-9.303	-5.489	-3.21	-11.25	-6.87	-4.629
120	-5.124	-4.62	-2.008	-7.01	-5.826	-3.23	-9.044	-7.25	-4.666
135	-5.151	-5.1	-2.081	-7.07	-6.32	-3.32	-9.089	-7.82	-4.819
150	-7.289	-5.53	-2.166	-9.158	-6.97	-3.48	-11.17	-8.4	-5.036
165	-7.521	-6.11	-2.325	-9.498	-7.42	-3.66	-11.67	-9.12	-5.226
180	-7.985	-6.77	-2.443	-10.05	-8.199	-3.79	-12.30	-9.79	-5.439

In table 3, the above conditions of analysing the transient temperature acting on the beam under variable length for three faces under deflection analysis is estimated through simulation runs for 180 minutes. The acting working loads on the two face beam are in the ratio of 40%, 50% and 60% with a constant ultimate load of 174kN. The temperature act on the two face surface of the beam with the limit of length full length, middle length and right length. Consequently, the deflection on the temperature acted beam is evaluated and its results are plotted in the below section.

Table 4: Horizontal Deflection and Rolling at Transient State at Three Lengths on Three Faces

Working Load	For Length on Three Faces	Temperature at Ultimate Load (°C)	Central Deflection (mm)		Horizontal Deflection at Ultimate Load (mm)	Moment (kN.m)	Rotation
			Initial Cracking	Ultimate Load			
40%	Full	724	-1.93	-5.63	0.78	-123.68	-0.0107
	Middle	-	-	-	-	-	-
	Right	613	-1.93	-2.04	0.8	-43.93	-0.0095
50%	Full	701	-3.03	-7.41	0.49	-164.2	-0.0126
	Middle	-	-	-	-	-	-
	Right	601	-3.03	-3.23	0.43	-71.28	-0.0097
60%	Full	700	-4.32	-9.45	0.14	-206.7	-0.0146
	Middle	-	-	-	-	-	-
	Right	545	-4.32	-4.65	0.42	-102.32	-0.0124

In table 4, the evaluation of deflection and rotation of the beam under transient condition is analysed. For the evaluation, three working loads with two lengths of full and right lengths are considered. At the working loads of 40%, the

temperature ranges from 600°C to 800°C, while for other working loads of 50% and 60%, the temperature range from 500°C to 700°C. Therefore, the final outcome shows that the rotation increases at -0.0124 for the temperature of 700°C for the working load of 60% on right length with deflection of 0.42 and initial crack of -4.32 respectively.

Figure 7: Transient State Analysis in Temperature at Three Length on Three Face.

In figure 7, the change in deflection of the beam constructed under thermal conditioning is analysed for two face beam for three varying lengths. In the resulting plot, the loads are applied on the full length and over a temperature of 800°C the deflection range is gradually increased and for the middle length, the steady decrease of deflection is formed at a higher temperature. While the right length maintains the deflection and gradual decrease at the temperature level above 800°C. Therefore, the result shows in the loads act on the two faces show betterment in the right length with a decent level of deflection ratio respectively.

Table 5: Transient State Analysis in Temperature at Three Lengths on Two Faces

Time (Mins)	Central Deflection (mm)								
	40% of Ultimate Loading for Length			50% of Ultimate Loading for Length			60% of Ultimate Loading for Length		
	Full	Middle	Right	Full	Middle	Right	Full	Middle	Right
0	-1.93	-1.93	-1.93	-3.027	-3.037	-3.05	-4.32	-4.32	-4.32
15	-2.89	-2.34	-2.127	-3.999	-3.48	-3.266	-5.38	-4.8	-4.55
30	-2.89	-2.63	-2.151	-4.03	-3.76	-3.291	-5.38	-5.06	-4.6
45	-3.14	-2.73	-2.117	-4.32	-3.872	-3.264	-5.62	-5.18	-4.577
60	-3.418	-2.89	-2.107	-4.59	-4.04	-3.259	-5.98	-5.37	-4.575
75	-3.841	-3.05	-2.108	-5.048	-4.217	-3.268	-6.48	-5.541	-4.587
90	-4.251	-3.199	-2.118	-5.519	-4.356	-3.286	-6.97	-5.719	-4.608
105	-4.891	-3.318	-2.14	-6.179	-4.5	-3.314	-7.68	-5.854	-4.638
120	-5.622	-3.45	-2.148	-7.002	-4.623	-3.328	-8.49	-6.004	-4.663
135	-6.406	-3.603	-2.151	-7.78	-4.801	-3.345	-9.46	-6.183	-4.691
150	-7.34	-3.78	-2.161	-9.01	-4.981	-3.37	-10.7	-6.381	-4.735
165	-7.24	-3.92	-2.176	-8.93	-5.119	-3.408	-10.9	-6.55	-4.77
180	-5.14	-4.13	-2.179	-7.03	-5.358	-3.428	-9.1	-6.767	-4.83

In table 5, the estimation of deflection in the beam considered for two faces under three working loads and a constant ultimate load of 174kN for the simulation run of 0 to 180 minutes. The length considered for the evaluation will be at a full, middle and right length at working ultimate loads of 40%, 50%, and 60%. The beam is initially under temperature and the loads are applied on the beam length and find out the deflection of the beam under temperature increases or decreases and at which length the deflection affects more. The simulation runs for 180 minutes and the results are evaluated for a 15mins time interval and stops at the defined time schedule. Hence, the maximum outlet of the results concluded from the evaluation is plotted as performance graphs in the below section respectively.

Table 6: Horizontal Deflection and Rolling at Transient State at Three Lengths on Two Faces

Working Load	For Length on Three Faces	Temperature at Ultimate Load (°C)	Central Deflection (mm)		Horizontal Deflection at Ultimate Load (mm)	Moment (kN.m)	Rotation
			Initial Cracking	Ultimate Load			
40%	Full	641	-1.93	-7.64	0.461	-165.8	-0.0117
	Middle	-	-	-	-	-	-
	Right	-	-	-	-	-	-
50%	Full	636	-3.03	-9.36	0.465	-203	-0.0133
	Middle	-	-	-	-	-	-
	Right	-	-	-	-	-	-
60%	Full	612	-4.32	-11.21	0.675	-231	-0.0145
	Middle	-	-	-	-	-	-
	Right	-	-	-	-	-	-

In table 6, the analysis of beam under transient state is evaluated in terms of horizontal deflection, rotation and formation of initial cracks. In this analysis, only full length is taken and measured under the temperature load between 600 to 700°C for the working loads of 40%, 50% and 60%. The maximum deflection obtained on the full length at temperature of 612°C with higher rotation of -0.0145 and deflection of 0.675 for the initial cracking of -4.32 respectively.

Figure 8: Transient State Analysis in Temperature at Three Lengths on Two-Face.

In figure 8, the beam considered as two faces are evaluated for the three varied lengths and three working ultimate loads of 40%, 50%, and 60%. The experimentation is conducted by the simulation process, where it totally runs for 180mins with the validation approximate at each 15mins. In the result section, at full length, the deflection rate of the beam decreases above 600°C and a slight increase towards 800°C, while in middle length, the deflection totally goes to a decreasing level at above 400°C. In the final length of the beam, the right length maintains the deflection level throughout the temperature level of above 600°C. From the result findings, it shows the right length of the beam performance better than other lengths under transient temperature state respectively.

At Temperature 29°C		
Time Duration in Minutes	Initial Crack	Final Crack
30 Minutes
60 Minutes
90 Minutes
120 Minutes
150 Minutes
180 Minutes

Figure 9: Crack Behaviour of Beam at Constant Temperature and Different Time Intervals.

In figure 9, the effect of crack obtained on the concrete beam reinforced with steel rollers at one end and other as pinned. The crack obtained when the beam is subjected to transient temperature rises above 29°C for variable-length with acting working ultimate loads. The simulation is rundown for 180 minutes and the crack deformation is evaluated at every 15-minute interval. The result plotted in the given figure 9 shows the crack formation of the beam at the initial and final level when the temperature kept constant at 29°C and measure the level starts from 30minutes and ends on 180minutes. For the first run, the initial cracks obtained slightly between the roller and final crack gradually increases over all surfaces and also it is noted that the crack formation on the final run at 180minutes is maintained and not to overcome the crack obtained on the first run by the reinforcements and temperature is maintained accurately. Hence the result shows, the active temperature on the beam under different loads can bear the crack formation and improves the property of the concrete beam respectively.

CONCLUSIONS

The effect of transient temperature influences the concrete beam under testing of deflection considered as the main objective of the research. Initially, the concrete beam is made from M30 grade which is reinforced with the steel roller in one end and another end is pinned. The analytical modelling is constructed on the RC beam with the use of Abaqus software and evaluate the maximum deflection is obtained on the developed beam. When working with a simulation strategy, the beam is thermally analysed on three independent faces of four, three and two with three variable lengths named as full, middle and right length respectively. The transient temperature is induced on the concrete beam and made the beam in a transient state and tested the deflection by varying the ultimate working loads at 40%, 50%, and 60% while

keeping the ultimate load at 174kN. In the simulation phase, the beam is meshed at 25mm size and evaluate the acting parameters such as elastic modulus, thermal conductivity, specific heat, expansion, are taken from euro code EN 1992-1-2 and EN 1993-1-2. Total simulation runs for 180 minutes where the deflection in the beam is evaluated at 15min intervals from 0 to 180 minutes. Finalizing the outcome of the beam structure, it is evaluated in terms of Maximum Deflection, Rotation, Moment and Horizontal Deflection and Cracking over transient temperature with the working loads under different length orientation. The following outcomes of the research are listed as below.

- The outcome of the findings in the research shows the effect of temperature and working loads influences the deflection, cracks and rotation for the three length and three faces obtained to be common crack behaviour of -4.32.
- Firstly, On the four face, the right length at 60% working attains with the maximum horizontal deflection of 0.32 and rotation of -0.0133 increases with the increase of temperature at above 600°C.
- Secondly, on the three face, the maximum horizontal deflection of 0.42 obtained at the right length when the working loads at 60% and rotation of -0.0124 for the temperature increase above 500°C.
- Thirdly, on the two faces, the length of the beam considered to be full length with the maximum horizontal deflection of 0.675 and rotation of -0.0145 with the temperature increase of 600°C.
- Hence, the research shows that under the transient condition the behaviour of the beam managed to perform betterment in cracking for the temperature maintained at 29°C for the whole simulation and finds to be optimal for the developed reinforced beam respectively.

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