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Analysis of Fire Excitation in Single Bay Frame by Comparing Various Codes

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Abstract **Fire scenario is the major issue in India and that of various structure is badly affected by them. Some of the structure may collapsed after the fire because of temperature effect. In this project, the main focus on the column and beam of the structure. The standard fire curve is introduced in IS code for a heavy-duty steel reinforcement but for concrete neither fire curve is produced nor any problem statement is given so that different codes are used for the problem statement. In this project IS code, Euro Code, National Building codes of Canada and National code of Construction series of Australia are used. In reference of this codes the model to be formed in SAP software with different data. The temperature for analysis is taken same for the entire model. The failure structure is repeatedly analyzed and makes the model safe. Then the column cross-section and beam cross-section are taken and post process for the thermal analysis in SAFIR Software. This software is a problem type of GID Software. In this the model are analyzed by thermal effect and post process in DIAMOND Software for the result. The comparative analysis of the single bay frame model for different codes are displayed with help of graph. The comparison is made in between standard fire curve and different codes.**

Keywords — Fire, SAFIR, DAIMOND, SAP-2000, Various Codes

I. INTRODUCTION

Since the time its most punctual applications, supported cement has been utilized as the principle development material around the world. From extensions and curve dams to passages and high rises, it has permitted humanity to shape the substance of the earth, particularly on the grounds that, among the wide range of various development materials, supported concrete outstands for its solidarity, strength and cost-viability. Other than that, the utilization of this material empowers the development of unpredictable and confounded shapes, either as cast-insitu or on the other hand pre-projected cement, making it the proper primary constituent for current structures, progressively moving towards feel concerns and reconciliation with the encompassing constructed climate prerequisites.

The investigation and plan of built up substantial stands in over one century of acquired insight, concerning gravity loads, wind, snow and seismic activities. Along these lines, the current codes of practice and principles can furnish underlying specialists with the instruments for the plan of cement components with respect to the previously mentioned stacks and considering an exhibition based methodology, implying that the heaps which substantial components are relied upon to withstand rely upon the evaluation seriousness level, and are identified with the level of harm satisfactory as far as possible state in examination. In other words, the underlying model depends on likelihood hazard examination to assess loads and activities at distinctive seriousness levels.

Notwithstanding this, an alternate situation has been seen in the advancement of codes and norms worried about the conduct of substantial components presented to fire. In spite of the fact that fire addresses one of the most extreme natural conditions to which structures might be oppressed in the course of their life, the worldwide wellbeing of built up substantial constructions with respect to fire situations has consistently been disregarded or underestimated.

Generally, fire wellbeing evaluation of supported cement has been founded on a prescriptive single component investigation, disregarding statically redundancies and restrictions to warm developments. For a long time, this methodology was viewed as moderate fundamentally because of the way that, in one hand, concrete individuals show a decent presentation in fire conditions when contrasted and other constituent materials, and in the other hand, substantial material presents without help from anyone else a low warm diffusivity (easing back down the temperature ascend during fire openness) and an impressive non-flammable property.

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II. LITERATURE REVIEW

A Review Of The State Of The Art, With A Case Study Of The Windsor Tower Fire

Audun Borg considered There is an absence of data got from enormous scope tests on concrete structures in regular flames. Other than attempted further fire tests, examples can likewise be gained from genuine flames what's more, the University of Edinburgh has set out upon serious investigations of the genuine fire in the Windsor Tower, Madrid. To appropriately describe the fire and the presentation of the design an information gathering exercise has been attempted and PC displaying instruments are being applied to get better bits of knowledge into the underlying reaction. There stays some uncertainty about the exact system of fire spread, however an outer course is possible, worked with somewhat by the coated drape walling development; absence of fire security on the steelwork was the significant justification behind the ensuing incomplete breakdown of the upper floors and the confined disappointment of a concrte entryway casing can be credited to a similar explanation.

Fire and Concrete

Gabriel Alexander Khoury (2008) concertrated concrete constructions are often presented to fire. Models incorporate structures and passages. This forces a thermal shock contingent upon the fire. As opposed to normal conviction, the most extreme temperature is significant as well as the rate at which temperature increases (for example the warming rate). The previous decides the most extreme temperatures inside the concrete and the last option impacts the probability that touchy spalling happens. These are the two key subjects covered by this paper. Compressive strength is the most concentrated on property of cement in fire. It fluctuates not just from concrete to concrete contingent upon its constituents and different factors like outside stacking, heating and dampness conditions. During heating cement likewise encounters thermal strain, shrinkage, as well as load prompted thermal strain (LITS). LITS includes a few parts like transient creep. LITS acts to assuage thermal and parasitic stresses. Quick warming during fire could initiate dangerous spalling with genuine results to construction and individuals. The two components of dangerous spalling are thermal pressure spalling and pore pressure spalling. Thermal pressure spalling could be diminished by the utilization of thermal stable totals of low extension, while pore pressure spalling could be diminished by the utilization of polypropylene filaments in the blend. The filaments actually actuate penetrability exactly when it is required. For existing designs, which a thermal obstruction is the arrangement. Standards for the thickness of thermal boundaries depend on most extreme temperatures. A more logical methodology is to consider other rules like heating rate and porousness.

FE Analysis of Reinforced Concrete Frames Exposed to Fire

Anupama Krishna. D, Narayanan S, Priyadarshini R.S (2007) considered its earliest applications, built up concrete was the fundamental development material around the world.Concrete has permitted mankind to shape the face of the earth, in light of the fact that, among the wide range of various development materials, built up reinforced concrete apart for its solidarity, sturdiness and cost-viability. Customarily, fire security evaluation of built up concrete has been founded on a prescriptive single component investigation, ignoring static redundancies and limitations to warm developments. For a really long time, this approach was viewed as moderate because of the way that, concrete individuals show a decent exhibition in fire conditions when contrasted and other constituent materials, and cement material presents without anyone else a low thermal diffusivity and extensively non-ignitable material. In any event, for a design named as protected when presented to fire inside the extent of prescriptive guidelines, primary designers can't survey the genuine degree of fire security, on the grounds that the genuine worldwide primary reaction and extreme breakdown are obscure. For supported reinforced designs the worldwide way of behaving isn't yet completely comprehended, mostly on account of the absence of dependable information concerning material's properties at high temperatures. With current accessible data on temperature inclination in concrete during fire, property variety with temperature, development of temperature during standard fire and FE displaying, the worldwide reaction of 2-D built up reinforced edges presented to fire was investigated. The outcomes along these lines acquired have been approved utilizing accessible writing. Utilizing the approved FE model, parametric examinations for various fire situations were done and the outcomes are dissected and introduced.

A Review on Fire Safety Engineering: Key Issues for High-Rise Buildings

Jian Jiang (2018) considered paper presents a cutting edge survey on the plan, exploration and instruction parts of fire safety engineering (FSE) with a specific concern on tall structures. FSE tracks down its root after Great Fire of Rome in 64 AD, trailed by Great London Fire in 1666. The improvement of present day FSE is persistently determined by industry upheaval, protection local area and unofficial laws. Presently FSE has turned into an exceptional designing discipline and is moving towards execution based plan since 1990s. The performance based fire safety design (PBFSD) includes recognizable proof of fire wellbeing objectives, plan goals, foundation of execution

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measures, and choice of legitimate answers for fire security. The assurance of fire situations and configuration fires have now become significant substance for PBFSD. To experience a quick and positive development in plan and exploration steady with other designing disciplines, it is significant for fire security designing as a calling to set up a unique schooling system to convey the cutting edge fire wellbeing engineers. Elevated structures have their remarkable fire security issues, for example, fast fire and smoke spread, expanded clearing time, longer fire span, mixed occupancies, and so on, acquiring more hardships guaranteeing life wellbeing and insurance of property and climate. A rundown of proposals is proposed to further develop the fire security of elevated structures. Likewise, a few source data for explicit information and data on FSE is given in Appendix.

The behaviour of concrete structures in fire

Ian A. Fletcher, Stephen Welch (2007) the impacts of high temperature on concrete and concrete designs, stretching out to a scope of types of development, including novel turns of events. The idea of concrete-based structures implies that they for the most part perform very well in fire. Be that as it may, concrete is in a general sense a complex material and its properties can change drastically when presented to high temperatures. The chief impacts of fire on concrete are loss of compressive strength, and spalling - the forcible discharge of material from the outer layer of a part.

However a lot of data has been accumulated on the two phenomena, there stays a requirement for more deliberate investigations of the impacts of thermal openings. The reaction to practical flames of entire concrete designs presents yet more prominent difficulties because of the connections of primary components, the effect of perplexing limited scope peculiarities at full scale, and the spatial and fleeting varieties in openings, including the cooling period of the fire.

Progress has been made on demonstrating the thermo mechanical conduct yet the treatment of details ways of behaving, including hygral effects and spalling, stays a test. Besides, there is as yet a serious absence of information from genuine constructions for approval, however a few significant bits of knowledge may likewise be acquired from investigation of the presentation of concrete constructions in genuine flames.

Fire Impacts on Concrete Structures

Shoib Bashir Wani (2020) expressed Concrete has been utilized as a development material because of its adaptable way of behaving. It displays a serious level of imperviousness to fire. The trademark capacity of concrete designs to battle quite possibly the most destroying calamity can be credited to its constituent materials which make it inactive and have moderately unfortunate warm conductivity. Nonetheless, substantial constructions should be intended for fire episodes. The properties of cement should be adjusted against worries about its imperviousness to fire and powerlessness to spalling at raised temperatures. In this paper, the causes, impacts and a cures of crumbling in concrete because of fire peril will be introduced.

Conclusion of Literature Review

- To know the temperature of the structural elements as a function of time, it is necessary to calculate the heat flux to these elements.
- Trace the development of inside stresses and distortions of the built up concrete frame, submitted to various fire situations, every one of them dependent on the ISO 834 standard fire curve
- Investigate if the fire evaluation situated in the EN 1992 1-2 improved on strategies (disregarding fire-actuated activities) lead to non-moderate outcomes analyzed against the worldwide conduct reaction (representing fire-incited activities);
- Propose an improved on system for shear failure assessment of built up concrete components at raised temperatures, which utilizing the outcomes got with the high level computation technique, demonstrates if dismissing shear impacts might prompt non-conservative outcomes.

III. METHODOLOGY

Brief software description

The thermo-mechanical analysis of built up substantial edges presented to fire introduced in this work has been performed with the product SAFIR. SAFIR is a non-straight material and mathematical limited component program, created in the University of Lige, expected to the analysis of constructions at both raised and surrounding temperatures. As some other limited component program, the design is divided into various discrete parts, called limited components, associated by hubs. SAFIR incorporates distinctive limited component types, fit for obliging a few underlying admirations.

Procedure for Model

1. Prepare a model in SAP2000 to find out the failure of the beam and column of the frame by application of dead load and live load to the frame.
2. The dimension of column and beam are 0.35 m x 0.50 m and 0.40 m x 0.40 m respectively. When the model is prepared then the column and beam design to be checked by the software for the failure condition. In that condition the failure column and beam to be replaced by another dimension but in this frame

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structure neither beam nor column to be failed in single bay frame models. In the following figure the procedure to be followed are shown.

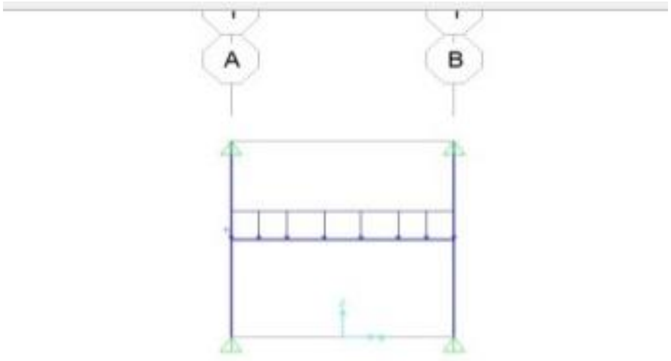

Figure 3.1 Single bay frame models in SAP2000

Modelling of single bay frame in SAP2000. In this the various type of loading are applied on the frame. The column size of the bay frame is 0.35m x 0.50m and the size of column is 0.40m x 0.40m.

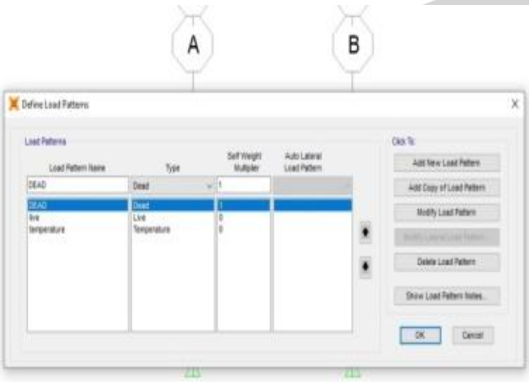

Figure 3.2 define the loading condition on the model

The loading condition is defined on the model. In this analysis the dead load, Live load and temperature loading condition are placed.

Figure 3.3 Assign of uniformly distributed load on the model

For analyse the loading effect on the frame then uniformly distributed load are applied. The intensity of dead load applied on the frame is 4 KN. as that of live load it is 3 KN applied on the frame.

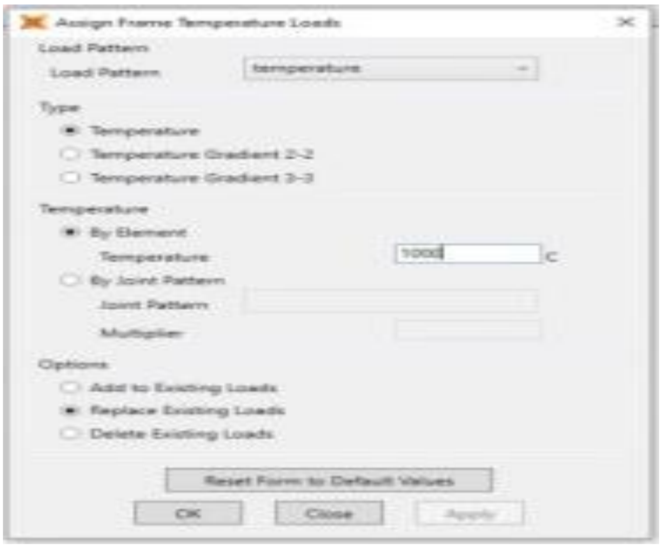

Figure 3.4 Application of temperature loading on model with different codes

The temperature loading is applied on the frame by using various codes. There are 1000˚c temperature loading is applied and analyse the model.

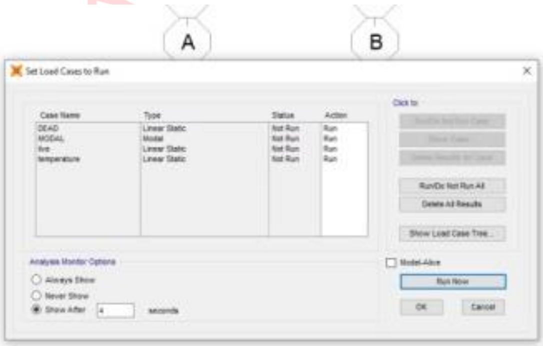

Figure 3.5 Run analysis of the model

The all loading conditions are assigning to the model then check the warning message for the model and then analyse the model frame.

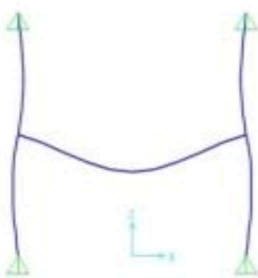

Figure 3.6 Deflected shape of the model after analysis

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After the analysis of the model the deflected shape of the structure are find out this is shown in figure no. 3.6.

Figure 3.7 Support reaction of the model after analysis

The support reaction of the model to be calculated this is 2831.91KN are find out. In all the support, that value is same.

3. After the analysis of the model the column section is designed in the SAFIR software with a base application of GID software. For thermal analysis GID, SAFIR and Diamond software are used which shown the behaviour of the column after the application of fire load.
4. The standard fire curve are presented in IS 3809-1979 code which is taken as reference code for the analysis. The standard fire curve is shown below.

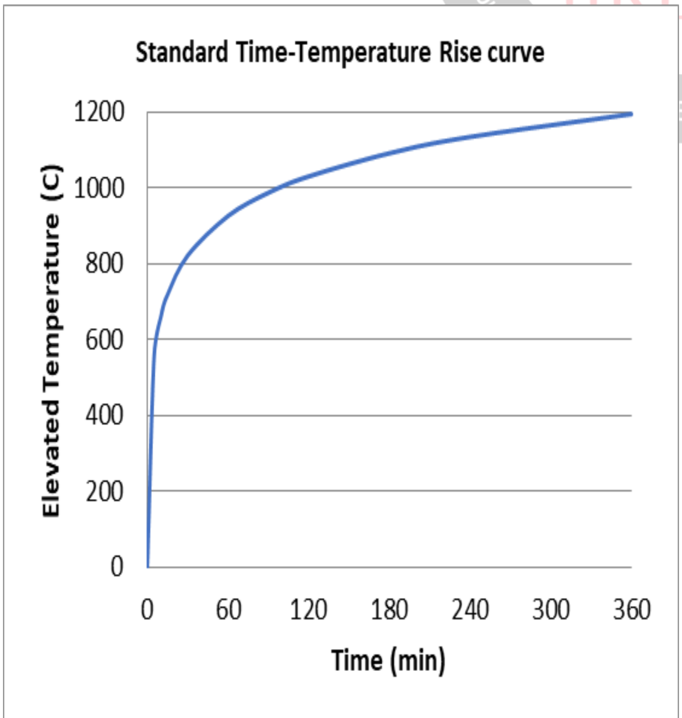


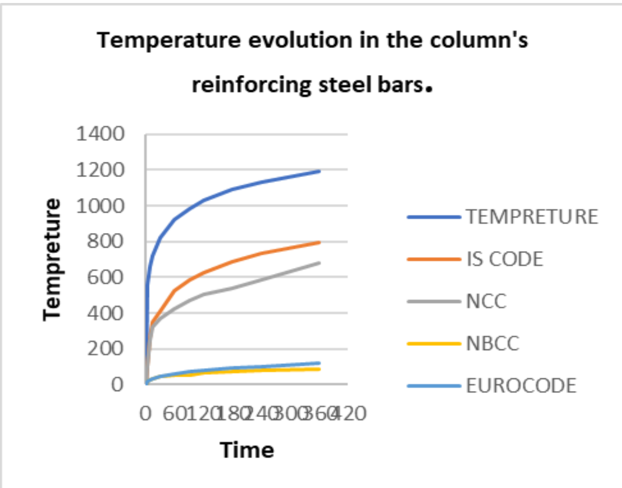
Figure 3.8 Standard Fire Curve by IS code 3809- 1979.

IV. Result

1.Comparison of Temperature Evolution in the columns reinforcing steel bar

Time	Temperature (˚C)				
	Standard Fire Curve	IS CODE	Eurocode	NBCC	NCC
0	0	0	0	0	0
5	556	106	105	22	22
10	659	259	250	25	25
15	718	350	320	34	34
30	821	410	368	44	44
60	925	525	422	50	60
90	986	586	468	55	70
120	1029	629	503	65	80
180	1090	690	540	75	90
240	1133	733	588	80	100
360	1193	793	679	84	120

In the above table it is shown that, for the same model with different code data is used and due to this the fire capturing capacity is also different. The data which is present in the codes are established by their weather condition. In India there is high temperature as compare to Europe, Canada and Australia. Due to which the temperature absorbing capacity is also high in India as compare to other country. In Canada there is very much low temperature condition. The data which is present in codes are formed by considering the weather condition of that area. As per the graph, in software the column cross-section exposed to fire with different data then it is found that IS code endure maximum temperature at a given time period and NBCC gives minimum temperature when it is exposed to the fire. In Europe and Canada there is maximum temperature of 20˚C and minimum is -15˚C. In that temperature fire couldn't take action on the concrete and steel so that the result is getting minimum as compare to the IS Code and NCC series of Australia.



Graph 4.1 Temperature Evolution in the columns reinforcing steel bar

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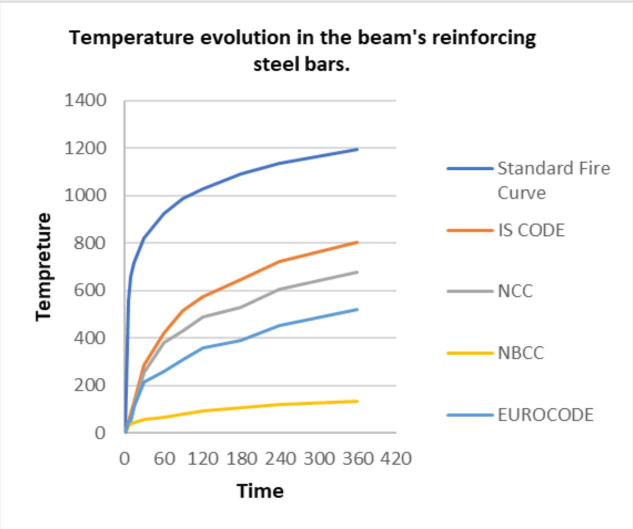
2.Temperature Evolution in the beam's reinforcing steel bars

Time	Temperature				
	Standard Fire Curve	IS CODE	NCC	NBCC	EURO CODE
0	0	0	0	0	0
5	556	50	50	30	50
10	659	80	55	38	55
15	718	130	110	45	110
30	821	285	255	56	215
60	925	420	380	68	260
90	986	515	430	79	310
120	1029	576	488	95	358
180	1090	645	530	109	390
240	1133	720	605	120	455
360	1193	805	678	135	518

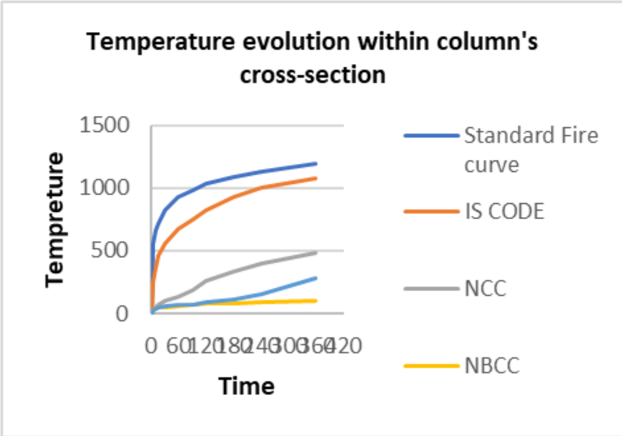


Graph 4.2 Temperature evolutions in the beam's reinforcing steel bars.

As per the graph no 4.2 which shows that the standard fire curve for heavy duty steel get larger value but as per the code design in the beams, IS code gives greater value as compare to another codes and NBCC gives smaller value. When the beam is exposed to fire then it is comes in contact with outer environment which result heating and cooling process occur inside the beam and due to which at 360 min it acquire maximum temperature of 135˚C.

3.Temperature Evolution within column's cross-section

Time	Temperature				
	Standard Fire curve	IS CODE	NCC	NBCC	EURO CODE
0	0	0	0	0	0
5	556	250	27	28	29
10	659	370	48	38	39
15	718	459	69	47	48
30	821	560	97	51	59
60	925	670	138	58	65
90	986	750	189	65	74
120	1029	820	260	78	88
180	1090	930	335	81	109
240	1133	1000	400	89	153
360	1193	1080	485	96	285



Graph 4.3 Temperature evolution within column's cross-section

In the above graph shows that the comparative analysis of thermal evolution by different codes used in the modelling of the single frame structure. It is clear that IS Code follows standard fire curve with less temperature with respect to time and it reaches up to 1080˚C with respect to other codes. It is clearly shows that the fire impact on the column is adversely affected due to IS code data but in case of another codes, they are not affected as the time elapsed. It reaches up to 485˚C which is very less as compare to IS code and Standard fire curve. This thermal effect impact on the cross-section of the column which is made up of concrete. In case of steel it is very less affected.

4.Temperature evolutions within beam's cross-section

Time	Temperature				
	Standard Fire Curve	IS CODE	NCC	NBCC	EURO CODE
0	0	0	0	0	0
5	556	208	26	26	26
10	659	368	48	33	42
15	718	458	73	62	70
30	821	562	100	73	83
60	925	675	139	84	91
90	986	753	198	92	102
120	1029	813	255	105	118
180	1090	910	337	134	162
240	1133	987	402	158	240
360	1193	1082	560	189	369

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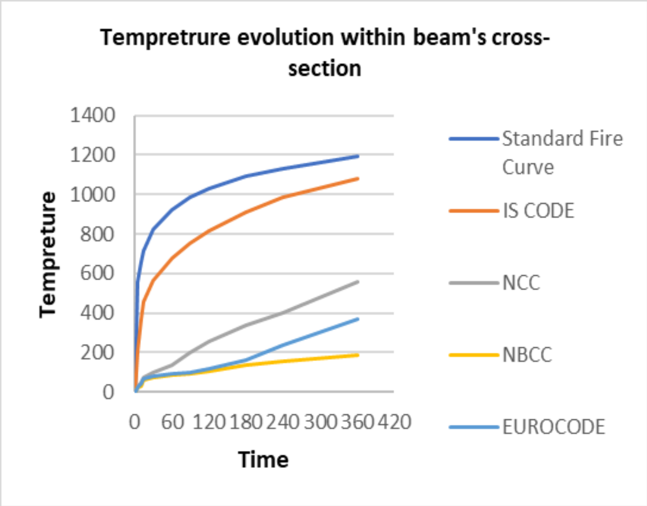


Graph 4.4 Temperature evolutions within beam's cross-section

The above graph shows that, the comparison of various codes with standard fire curve. In this graph, at 360 min. IS code value nearly reaches to the standard fire curve value i.e. 1082˚C. As per the explanation beam has a greater value of temperature as compare to the column. In NCC code, it reaches 560˚C in 360 min. which is nearly half of the IS code data temperature. When the fire starts, up to five min. the temperature is same for all the code data rather that it will take another path as per the graph. From this it is concluded that at the same effect of fire on the beam cross-section with various codes result different temperature effect with the same time period.

Evolution of Vertical displacement

The main observation is made that is vertical displacement. The displacement occurs due to the loading applied on the beam and column. The below figure shows the displacement of the single frame.

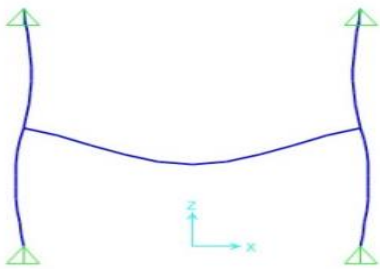
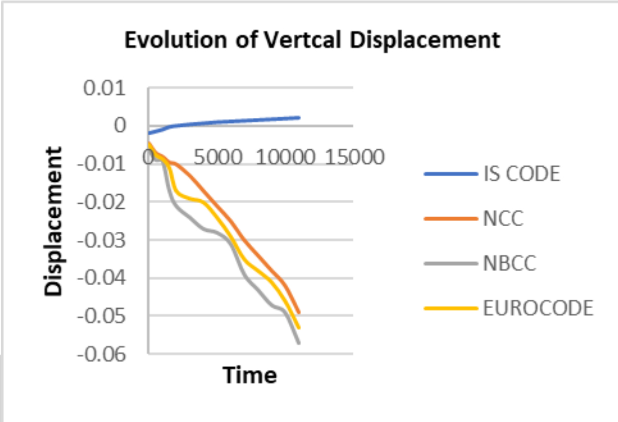


Figure 4.5 Vertical displacement of single Frame.

5. Evolution of Vertical displacement of the frame

Time	Vertical Displacement			
	IS CODE	NCC	NBCC	EURO CODE
0	-0.002	-0.005	-0.006	-0.0048
500	-0.0015	-0.007	-0.009	-0.0075
1000	-0.001	-0.008	-0.009	-0.0086
1500	-0.0003	-0.01	-0.017	-0.011
2000	0	-0.01	-0.021	-0.017
3000	0.0004	-0.013	-0.024	-0.019
4000	0.0007	-0.017	-0.027	-0.02
5000	0.001	-0.021	-0.028	-0.024
6000	0.0012	-0.025	-0.031	-0.029
7000	0.0014	-0.03	-0.039	-0.035
8000	0.0016	-0.034	-0.043	-0.038
9000	0.0018	-0.038	-0.047	-0.041
10000	0.002	-0.042	-0.049	-0.046
11000	0.0022	-0.049	-0.057	-0.053



Graph 4.6 Evolution of vertical displacement

V. CONCLUSION

FINAL REMARKS TO THE WORK

Fire evolution in the structure get a major impacted on column and beam. When the fire evolved the condition of structure to be rebuilt is very difficult. In this project by using different codes, the temperature evolution of the beam and column to be studied because the design criteria of different codes are different and due to this the behaviour of column and beam is also different. According to safety factor, all the structure should be designed and thermal analysis is also done according to the code. In this chapter, the concluded part to be discussed.

1. The temperature evolution of column steel is greater in IS code according to the graph present in previous chapter. Another codes used which give lesser result as compare to the IS code and standard fire curve.
2. The temperature evolution of beam steel is also greater impacted in IS code rather it is greater than column reinforcement steel. Instead of this other codes give safer result than IS code.
3. The temperature evolution of column cross-section in IS code gives better result as compare to the standard fire curve but give greater result as compere to the other codes. This is happen in beam cross-section also.
4. The axial force applied on the column and beam gives reverse result which shows that the load

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applied in direction of gravitational force and due to temperature force it will get slightly increased in upward direction. The graph that were made in between axial force vs. time period for the various codes which is shown in the previous chapter.

5. The bending moment graph also plotted and gives slight bending in the column and beam due to various codes. In IS code, the bending moment is greater than other codes.
6. The vertical displacement of the structure shown greater in IS code as compare to the other codes.

After the whole analysis it is concluded that the suitable design for the thermal analysis is seen in the IS code. The room temperature and the thermal temperature both are different. Thermal temperature impacted on the structure that of room temperature does not adversely affected on the structure.

Future Scope

1. Thermal design for the multi-storeyed structure to be analysed by this software with the various codes.
2. Manual calculation for thermal design procedure is imparted in the IS codes.
3. Blasting effect on the structure to be analysed by the software.

ABBREVIATION

IS Code- Indian Standard Code

NCC- National Construction Code Series

NBCC- National Building Code of Canada

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