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Dynamic Analysis of Structural Steel Frame Subjected to Transient Thermal Load

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ABSTRACT

Fire is one of the most severe conditions to which structures can be subjected, and hence, the provision of appropriate fire safety measures for structural members is an important aspect of design. Recent years have seen significant research into the response of structural stainless-steel components, enabling the development and expansion of dedicated design guidance In this project work, dynamic analysis of structural steel frame subjected to transient thermal load is conducted. A two dimensional steel frame of length 3m and breadth 3m is modelled using ANSYS version R19.2. The Steel Frame is of single storey with fixed supports at the base. Transient Thermal load is applied at the joints of steel frame using ANSYS software. By using Finite Element Method, the performance of the steel frame is examined by dynamic analysis subjected to transient thermal load. The behaviour of steel frame under transient thermal load with respect to effect of temperature, rate of transfer of heat, frequency response and thermal analysis is studied.

KEYWORDS: *Ansys, Steel Frame, Transient, Finite Element Analysis*

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INTRODUCTION

Fire is one of the most severe conditions to which structures can be subjected, and hence, the provision of appropriate fire safety measures for structural members is an important aspect of design. Recent years have seen significant research into the response of structural stainless-steel components, enabling the development and expansion of dedicated design guidance.

As a construction material, stainless steel offers great applicability due to its attractive appearance, strong corrosion resistance, easy maintenance and low life cycle cost. In addition, booming growth in the production of stainless steel along with its many varieties and continuing improvements in processing methods have paved the way for its increased use in building structures in recent years. Under the strong urge of the construction market, stainless steel as an architectural material is the new trend of civil engineering and is welcomed by many architects and structural engineers.

The design specifications for structures at normal service conditions are relatively mature, but because structure fires frequently occur, the security of the architectural structure is facing unprecedented challenge under fire conditions. Therefore, the behavior reaction and properties of structures in fire have gained attention in all countries, especially the new materials(such as stainless steel, aluminum alloy and glass)that are without any fire prevention measures for their aesthetic appearance, making the study of the mechanical properties of these structures particularly important.

Structural steel frames are widely used in virtually all types of buildings and industrial installations. Fire-resistant design of structural steel framing is often required, depending on the fire risks associated with the structure, the magnitude of potential losses due to structural failures caused by fire, and the accumulated performance record of similar structures in past fire incidents.

METHODOLOGY IN ANSYS

In general, a finite element solution may be broken into the following four stages. This is a general guideline that can be used for setting up any finite element analysis.

1. Preferences
2. Preprocessing
3. Solution
4. General Post processing

1. Preferences

Select the Thermal option in electromagnetic modes to show in the GUI

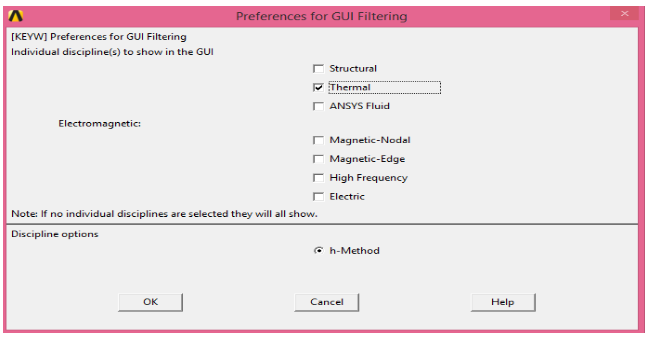


Fig 1. Preferences Window

2. Pre-processing

Defining the problem; the major steps in preprocessing are given below:

- Define element type and material/geometric properties.
- Define key points/lines/areas/volumes.
- Modeling of the structure.
- Meshing of the structure.

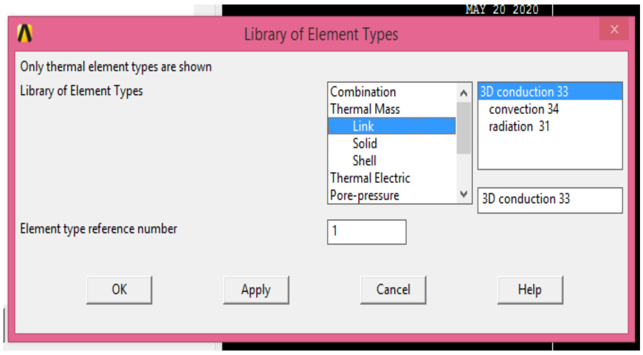


Fig 2. Library of Element Types Window

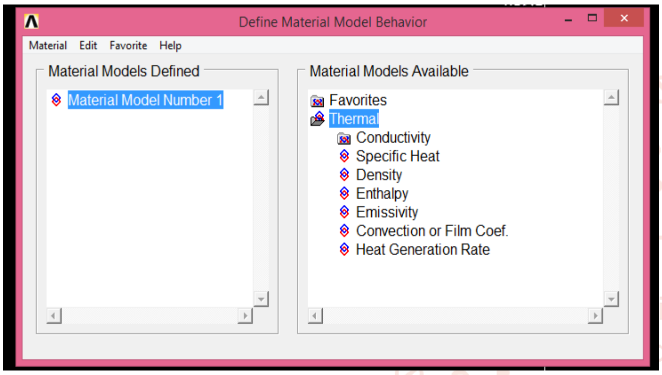


Fig 3. Material properties Window

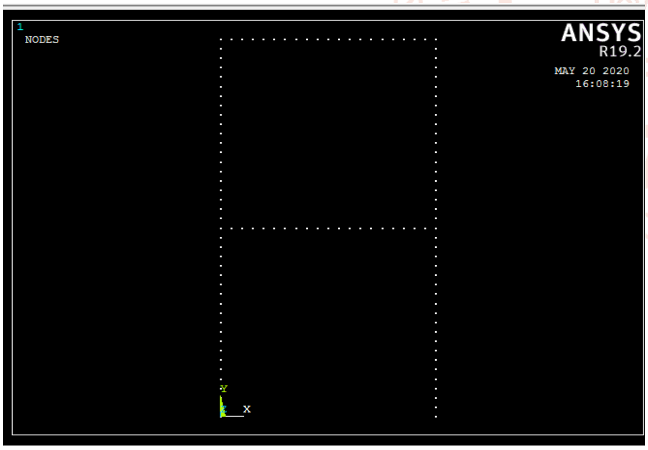


Fig 4. Keypoints of structure Window

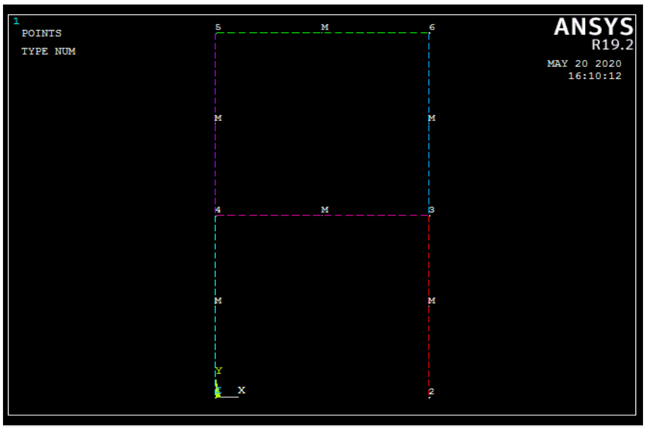


Fig 5. Meshing of structure Window

ANALYSIS RESULTS AND DISCUSSIONS

A. MODEL SPECIFICATIONS:

A two dimensional steel frame of length 3m and breadth 3m is modelled as shown in figure below using ANSYS version R19.2. Steel Frame consists of single storey frame and the supports given are fixed supports at the ends. The input data for modelling and analysis are tabulated below.

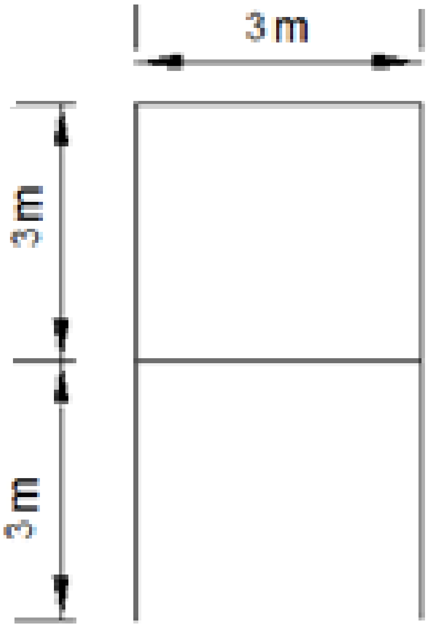


Fig 6. 2D Frame Structure

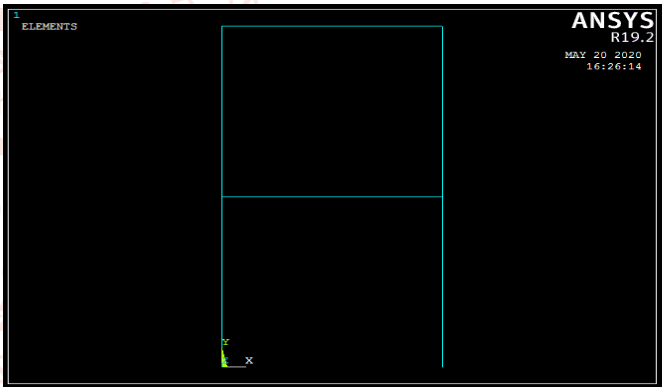


Fig 7. 2D Frame Structure in Ansys

Poisons ratio (μ)	0.3
Density of steel (ϱ)	7850 kg/m³
Young's modulus of steel (E)	2×10^{11} kN/m²
Specific heat (C)	500°C
Coefficient of Thermal conductivity (K)	40 W/m K
Coefficient of Thermal expansion (α)	13×10^{-6}/°C
Initial temperature / Room temperature applied	25°C

Table 1 Input steel frame Specifications for ANSYS

B. DEFINITATION:

For the present study, steel frame of length 3m and breadth 3m is considered, the thermal loads are applied in 4 different cases. Thermal analysis is performed using Ansys software and the respective results are noted.

CASE 1: Thermal load is applied at one joint upto 0.3m as shown in figure

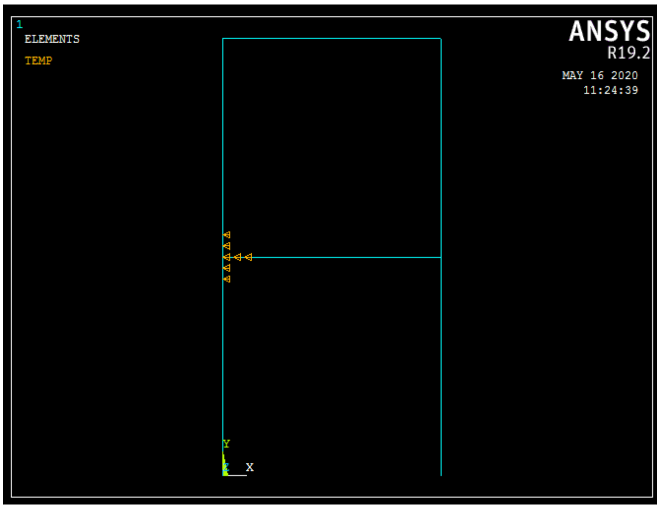


Fig 8. CASE 1

CASE 2: Thermal load is applied at two joint upto 0.3m as shown in figure

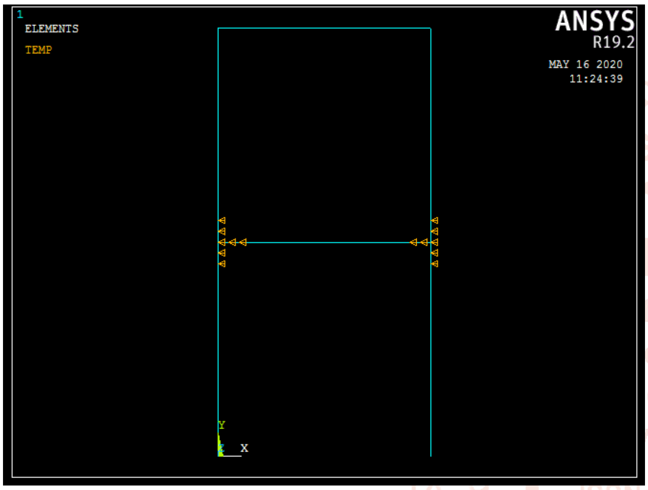


Fig 9. CASE 2

CASE 3: Thermal load is applied at all joint upto 0.3m as shown in figure

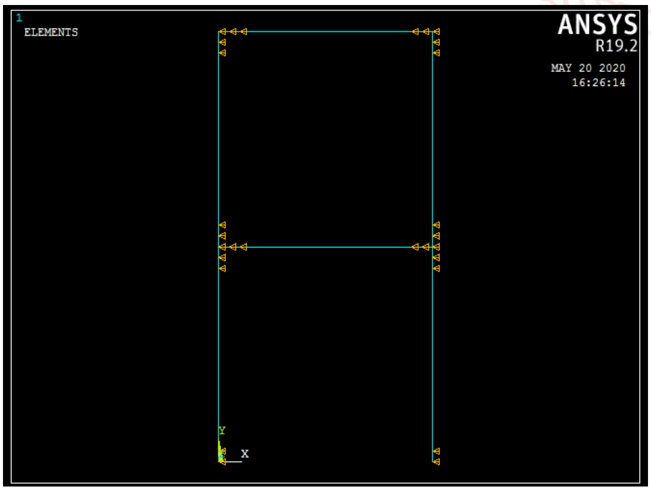


Fig10. CASE 3

CASE 4: Thermal load is applied at one column as shown in figure

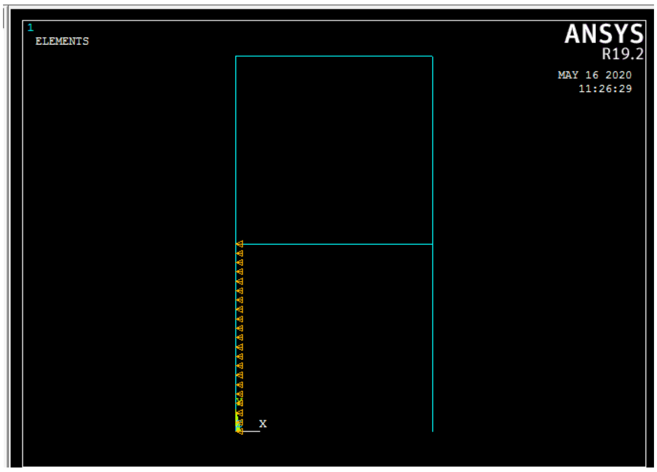


Fig 11. CASE 4

Applying different temperature loads as mentioned below for all the cases

Condition A : Temperature of 250˚C is applied at different time intervals of 600 seconds, 900 seconds and 1200 seconds.

Condition B : Temperature of 500˚C is applied at different time intervals of 600 seconds, 900 seconds and 1200 seconds.

Condition C : Temperature of 1000˚C is applied at different time intervals of 600 seconds, 900 seconds and 1200 seconds.

C. ANALYSIS:

The considered steel frame with various conditions of thermal loading as per problem definition is analysed using ANSYS version R19.2. Effect of temperature and variation of temperature is compared.

THERMAL ANALYSIS RESULTS

The defined problem is analysed for thermal loads and for the study of transfer of temperature, 3 nodes are selected at next to the load applied. The node numbers selected for the study of transfer of temperature are node number 25, node number 26 and node number 27.

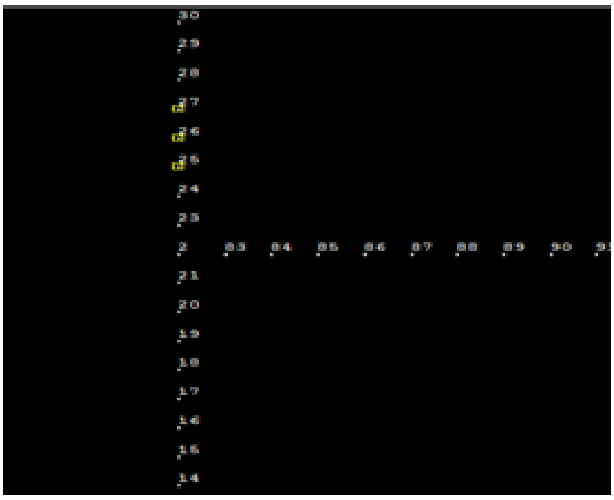
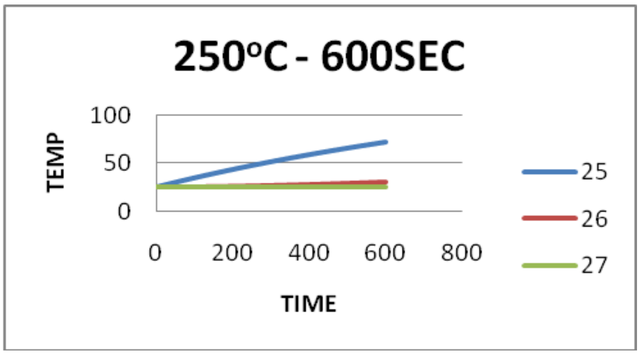


Fig 12. – Node Numbers

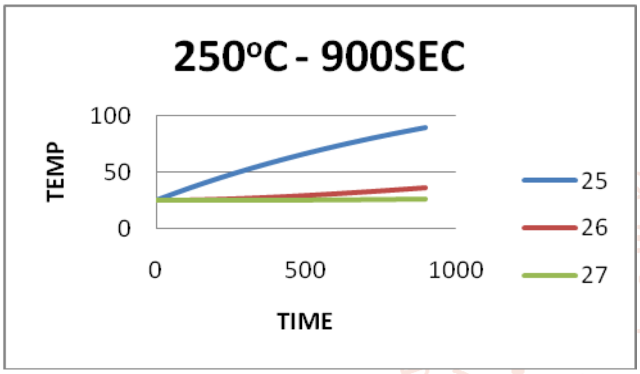
The results are summarized with respect to different nodes and plotted graphs

RESULTS FOR THERMAL LOAD OF 250˚C

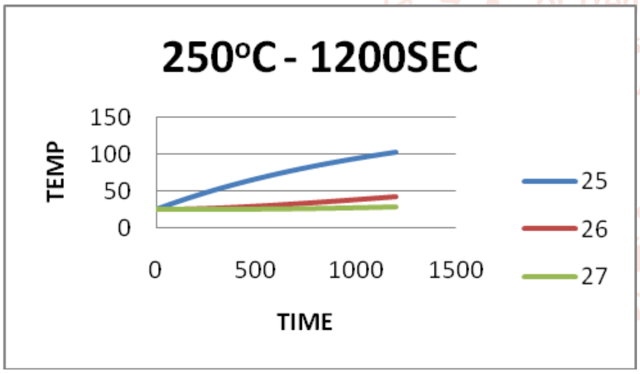
Thermal load of 250˚C is applied for 600seconds, 900seconds and 1200seconds and the results extracted for Node numbers 25, 26 and 27 are as follows



Graph 1: Temperature v/s Time curve for 250˚C for 600 seconds



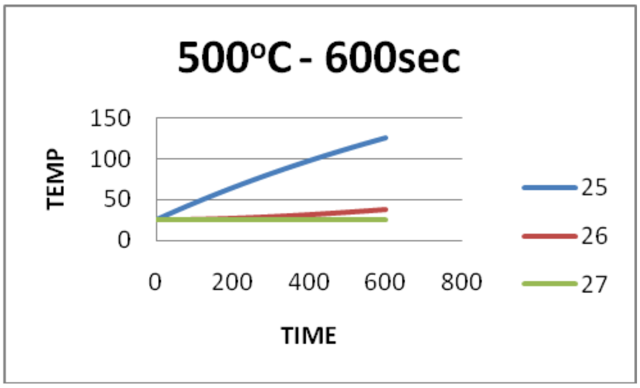
Graph 2: Temperature v/s Time curve for 250˚C for 900 seconds



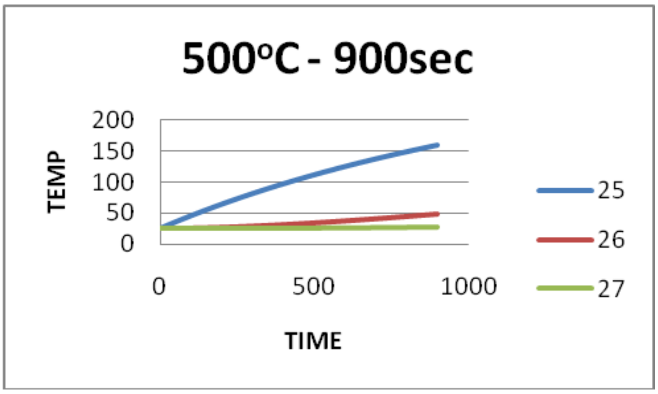
Graph 3: Temperature v/s Time curve for 250˚C for 1200 seconds

RESULTS FOR THERMAL LOAD OF 500˚C

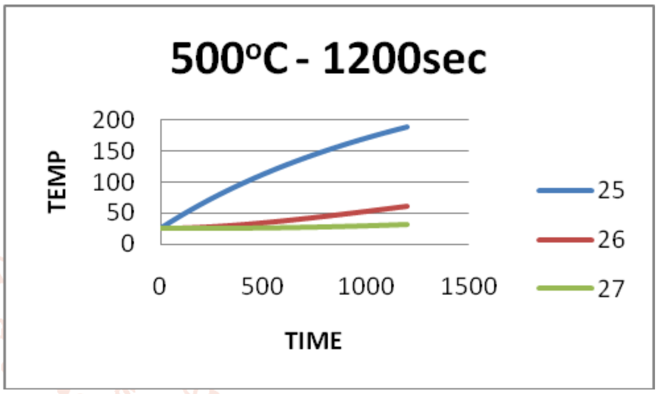
Thermal load of 500˚C is applied for 600seconds, 900seconds and 1200seconds and the results extracted for Node numbers 25, 26 and 27 are as follows.



Graph 4: Temperature v/s Time curve for 500˚C for 600 seconds



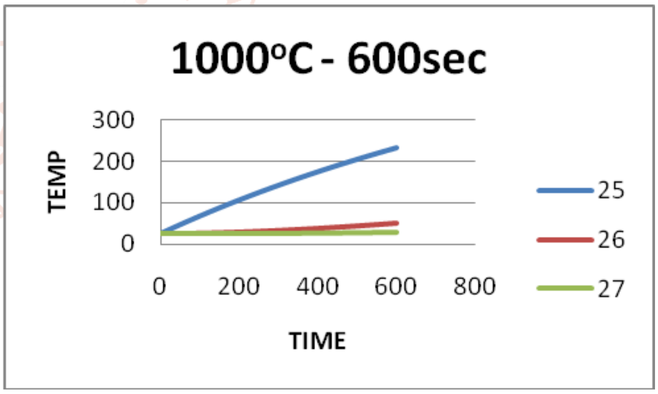
Graph 5: Temperature v/s Time curve for 500˚C for 900 seconds



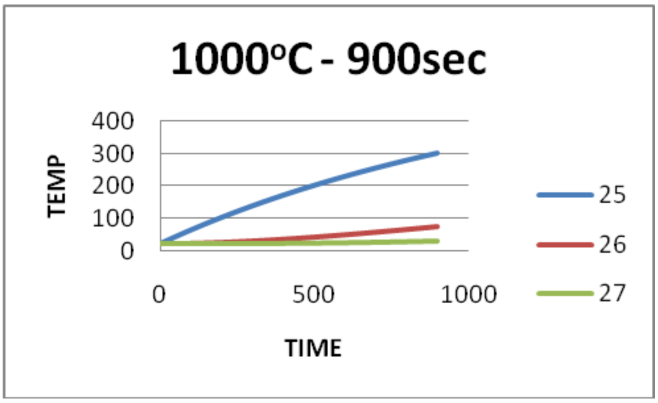
Graph 6: Temperature v/s Time curve for 500˚C for 1200 seconds

RESULTS FOR THERMAL LOAD OF 1000˚C

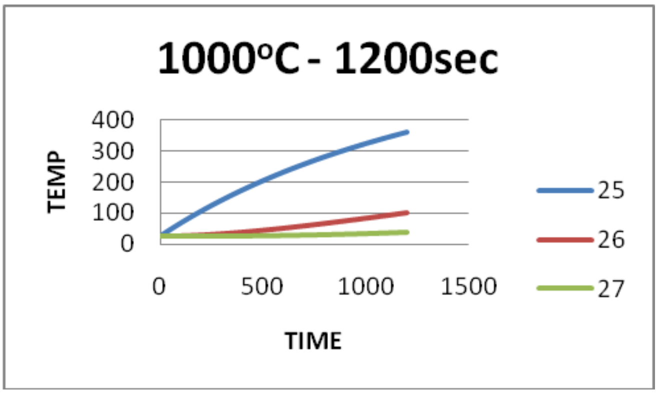
Thermal load of 1000˚C is applied for 600seconds, 900seconds and 1200seconds and the results extracted for Node numbers 25, 26 and 27 are as follows.



Graph 7: Temperature v/s Time curve for 1000˚C for 600 second



Graph 8: Temperature v/s Time curve for 1000˚C for 900 seconds

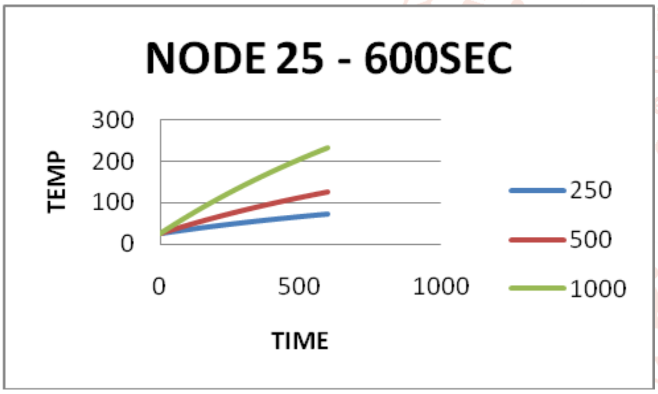


Graph 9: Temperature v/s Time curve for 1000˚C for 1200 seconds

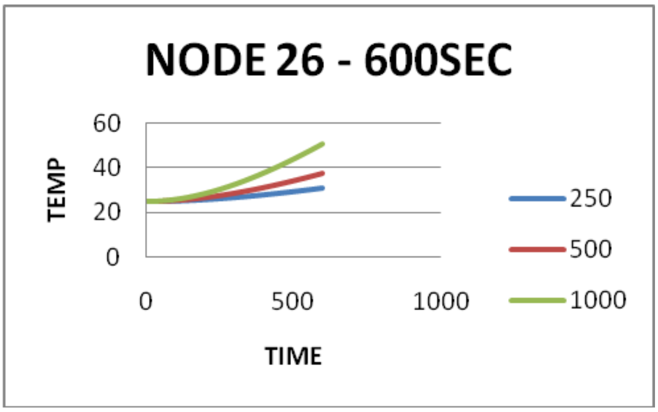
From above graphs, we can say that temperature is directly proportional to the time i.e, temperature increases with increasing time and temperature is indirectly proportional to the distance from the thermal load applied i.e, temperature decreases with increasing the distance from the thermal load.

From above graphs, temperature of Node 25 is greater when compared to Node 26 and Node 27 because Node 25 is nearer to the thermal load applied. Transfer of temperature decreases with increasing distance from the thermal load.

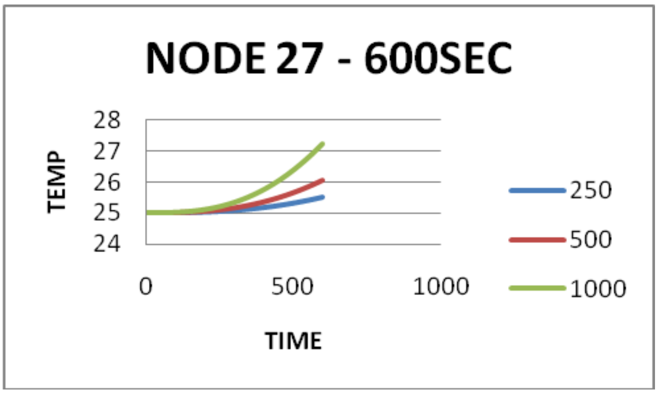
Thermal load of 250˚C, 500˚C and 1000˚C is applied for 600 seconds and the results extracted for Node number 25, 26 and 27 are as follows



Graph 10: Temperature v/s Time curve for Node 25 for 600 seconds



Graph 11: Temperature v/s Time curve for Node 26 for 600 seconds



Graph 12: Temperature v/s Time curve for Node 27 for 600 seconds

From above graphs, we can say that temperature is directly proportional to the thermal load applied ie, increase in thermal load increases the temperature in structure.

Temperature is directly proportional to the duration of thermal load applied ie, increase in duration of thermal load increases the temperature of the structure.

Thermal load of 250˚C, 500˚C and 1000˚C is applied for 900 seconds and the results extracted for Node number 25, 26 and 27 are as follows

CONTOUR PLOTS FOR THERMAL LOAD OF 250˚C

Thermal load of 250˚C is applied for 600, 900 and 1200 seconds and the contour results are as follows.

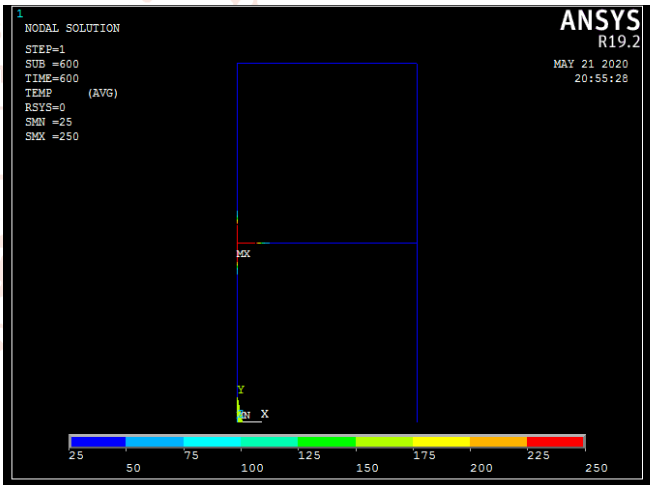


Fig 13. Contour plot for 250˚C for 600seconds

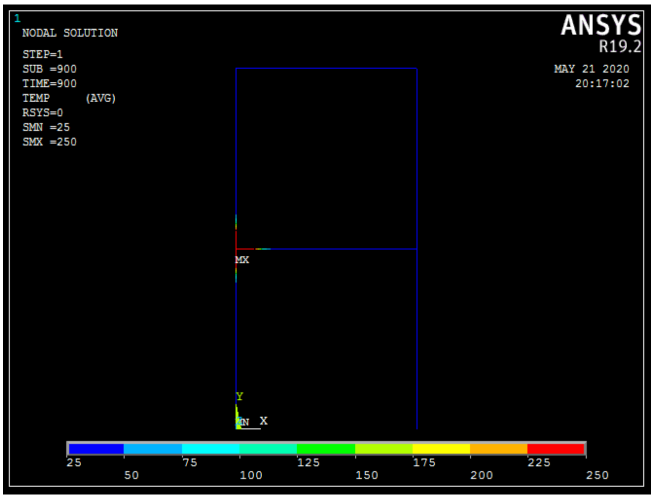


Fig 14. Contour plot for 250˚C for 900 seconds

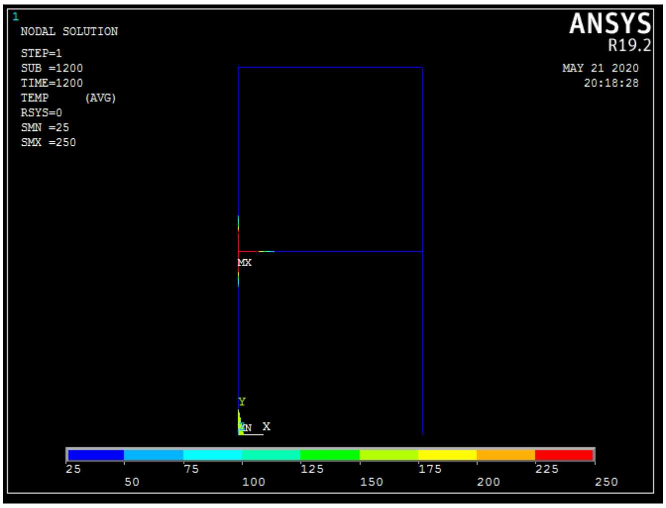


Fig 15. Contour plot for 250˚C for 1200 seconds

From above figure, we can say that there is a little rate of transfer of heat for 600sec, 900sec and 1200sec. Rate of transfer of heat decreases with the increase in distance. When thermal load is applied at one joint as shown in figure, there is no effect on other joints

Conclusion

- Higher the intensity of thermal load applied, higher is the rate of transfer of heat along the length.
- The duration of thermal load on the surface is directly proportional to the rate of transfer of heat along the length. Therefore, longer the duration higher is the heat transferred.
- Rate of transfer of heat is not dependent on the portion of load applied *i.e.*, even if the load was applied at the beam-column joint or the entire column, rate of transfer of heat to the adjacent members is same.

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