Emergency Ventilation System Design - Preliminary Report

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Abstract

The existing stations and tunnels of Metro Railway, Kolkata are not equipped with effective emergency ventilation system. The original design provides only normal ventilation for passengers' comfort and physiological requirements. Hence, it was required to design modifications to enable effective emergency ventilation in case of fire / smoke scenario in station / tunnel / subway premises.

In order to accomplish this objective, following studies were conducted:

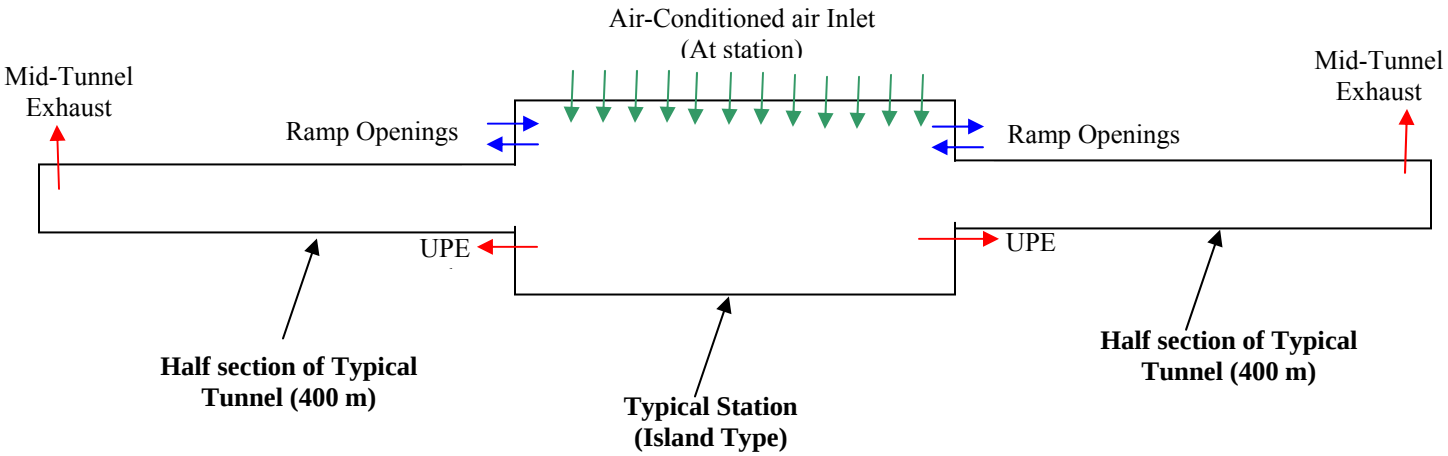
1. Smoke extraction system design for a typical station of Kolkata Metro.
2. Smoke extraction system design for a typical tunnel system.
3. To demonstrate effectiveness through Computational Fluid Dynamic (CFD) analysis (3-Dimensional).

3D CFD analysis was done for emergency ventilation systems. The results of flow analysis were analyzed to compare current system and original system. It was ensured that the CFD results agree to the overall mass balance across the system. Further, it was also observed from the analysis the shortcomings of the current system and possible design changes for better ventilation on station as well as in the tunnel. Based on these simulations, flow velocities across individual inlets, exhausts and ramps were calculated to enhance the mass evenness of flow across the system. These calculations along with depending criteria like heat load, design alternatives etc. were considered in this study. Based on all these considerations and calculations as per the fire protection standards, the design of emergency ventilation system was arrived.

Typical Station Design

The Kolkata Metro Line network incorporates the following tunnel section, station and ventilation structures for fire study:

- Approximately, the average length of tunnel between any two stations in this line is 800mts
- Typical station is an island type station with double Rail track on each side of the platform at the platform level;
- In the current system, each platform has air-conditioned air inlet of 130 cubic meters per second.
- In the current system, each platform has exhaust of 50 cubic meters per second from Under Platform Exhaust (UPE) to exhaust the heat generated due to braking of the trains at each station.
- In tunnel at each side, 80 cubic meters per second exhaust shaft is provided for the current system.



Red Arrow (→) : Exhaust ; Green Arrow (→) : Inlet ; Blue Arrow (→) : Open to atmosphere

Fig 2.1: Schematic representation of Typical station and Typical Tunnel

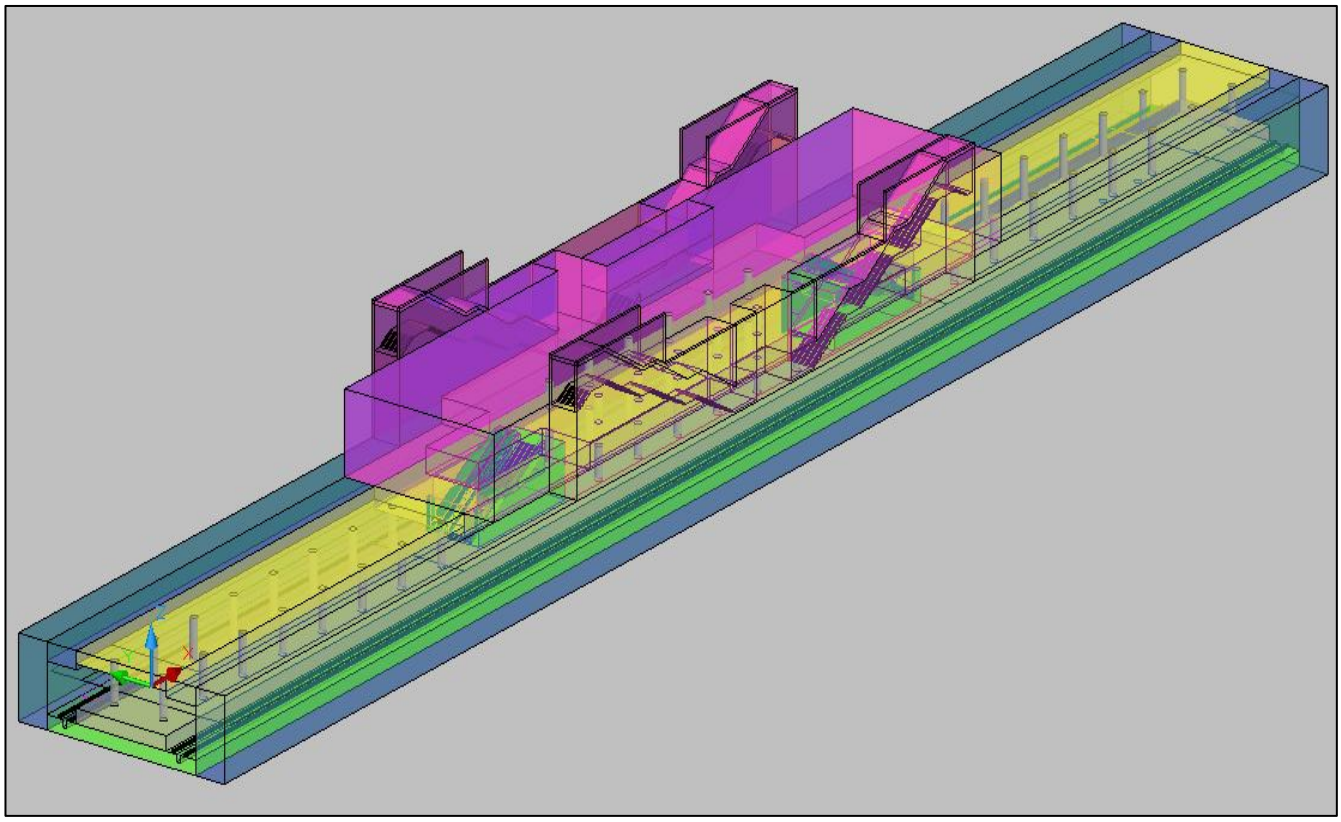


Fig 2.2: Three-Dimensional CAD model for Typical station

In this station design, the system is considered including station platform, both side station track way, first floor (Ticketing counter) and the ground level to platform level stairs passage.**T**wo half typical tunnels on each side of the station represent the complete system under analysis.

It is very much important to consider the whole system with connecting half tunnels for the smoke extraction ventilation system. The model above also shows the converging connection between typical tunnel and typical station.

FIRE DATA

Maximum Fire Size	15 MW	NBC and NFPA standards
Radiation	25%	NBC and NFPA standards
Maximum Fire Perimeter	44.5 m	Assuming fire on one coach

Other relevant information

- Maximum time for fire brigade & personals to reach at the fire point : 1 Hr
- Smoke detector & Heat Detector sensors are already installed in the system
- Emergency Batteries are installed in train to provide back-up power in case of emergency for operation of train
- The rake drivers are trained & instructed to make efforts to bring train to station in case of any emergency like accidental fire
- A water supply line is installed at each station to provide water from 1600 to 2100 Gallon to deal with fire calamities.

Design of emergency ventilation system

Double Speed OTE (Over Track Exhaust): An OTE system shall be installed with exhaust ducts running over the track. The capacity of this system shall be 40 m^3/s (as per 6.4.2) at low speed and 80 m^3/s (as per 6.4.1) at high speed. The OTE system would operate at low speed when air-conditioned coaches are introduced and OTE system would operate at high speed in case of emergency. The fans and ducts for OTE shall be fire rated and AMCA (Air Movement Control Association) certified. Tunnel Ventilation Fans (TVF): Impulse fans called tunnel ventilation fans (TVF) shall be installed in the tunnel directing toward the mid tunnel exhaust. Three number of TVF shall be installed in the 400m tunnel equally spaced between the station and the mid tunnel exhaust. So each tunnel would have 6 TVF at an average installed in the direction toward the mid-tunnel exhaust. TVF shall be fire certified and AMCA approved.

CFD Fire Simulation Results:

(A) Following figures shows the smoke generated from fire inside the Platform on Railway Track at different timings

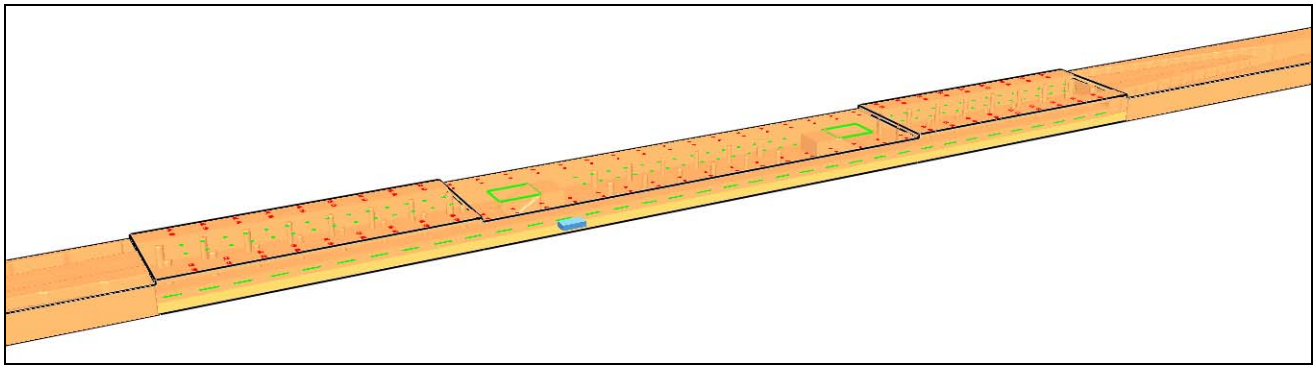


Fig.5 (a) Contours of smoke from burning Coach at starting of time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

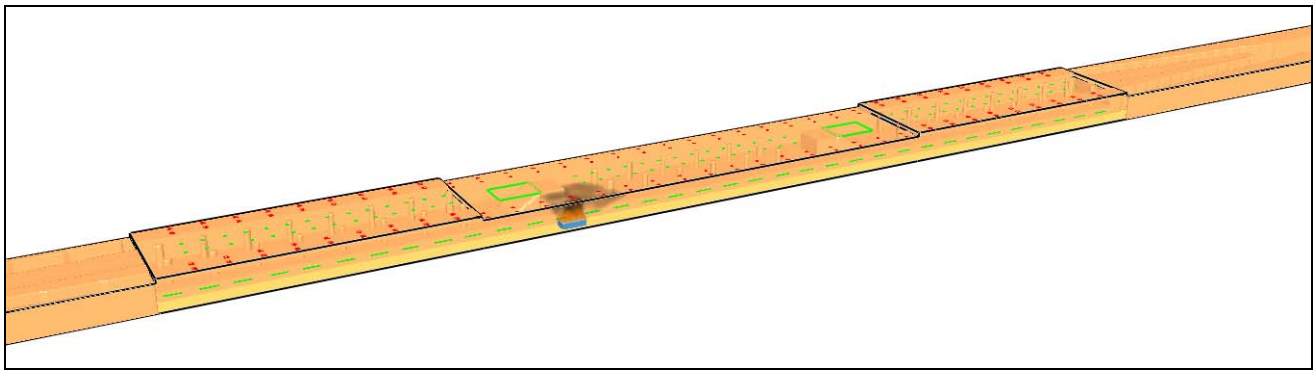


Fig.5 (b) Contours of smoke from burning Coach at 10 seconds time in 'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

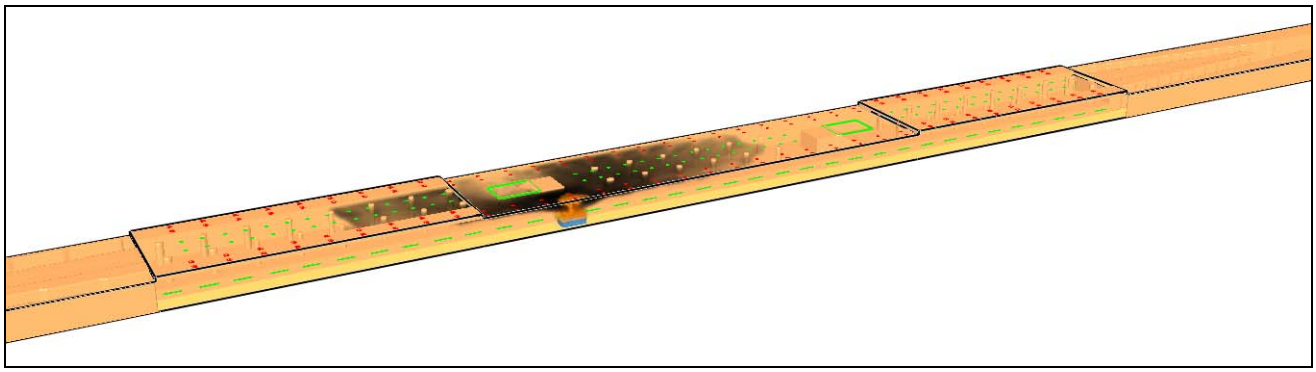


Fig.5 (c) Contours of smoke from burning Coach at 1 minute time in 'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

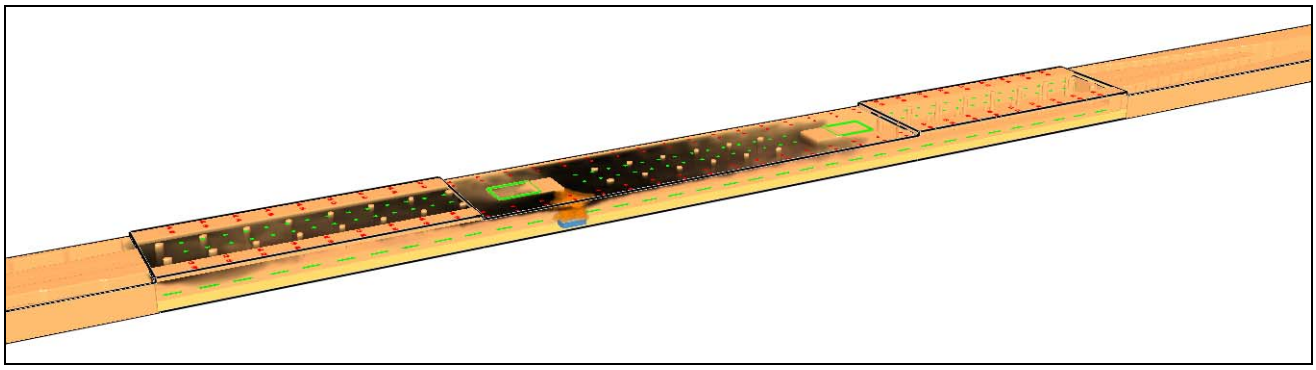


Fig.5 (d) Contours of smoke from burning Coach at 3 minute time in
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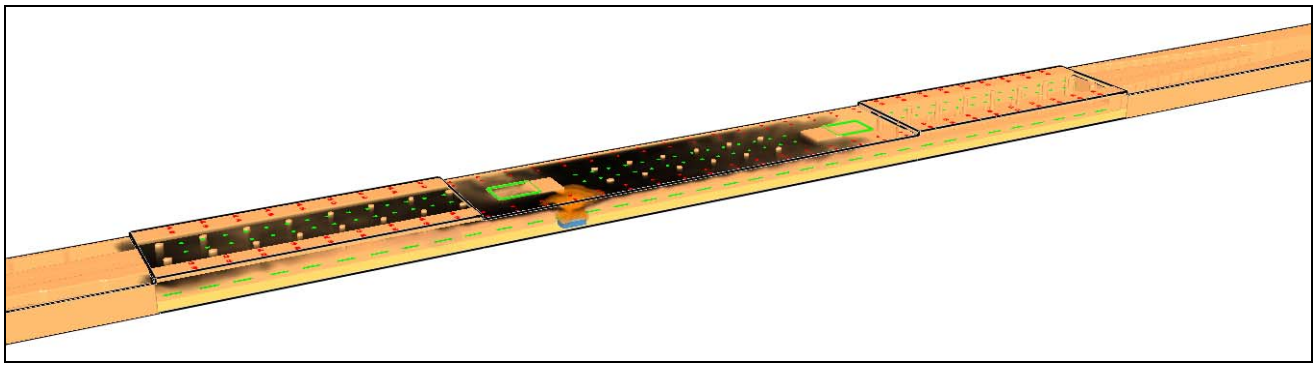

Fig.5 (e) Contours of smoke from burning Coach at 5 minute time in
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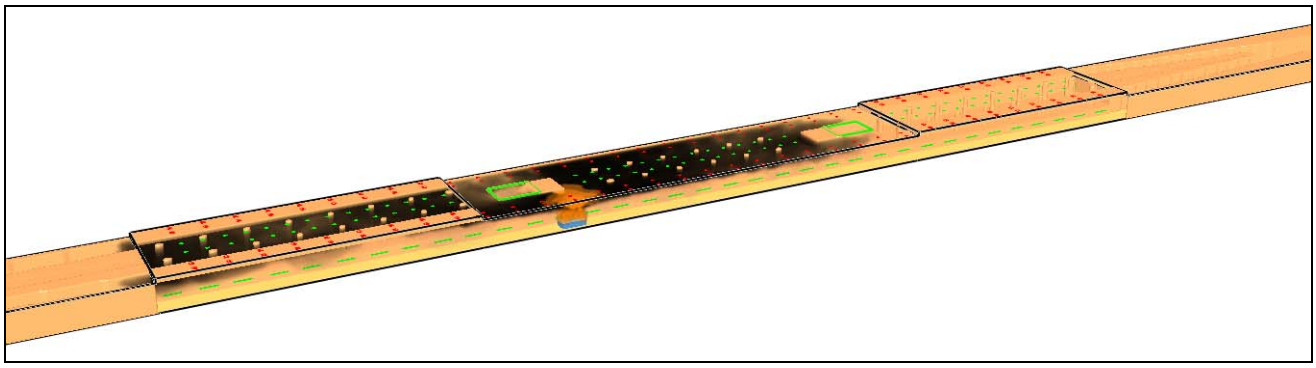

Fig.5 (f) Contours of smoke from burning Coach at 8 minute time in
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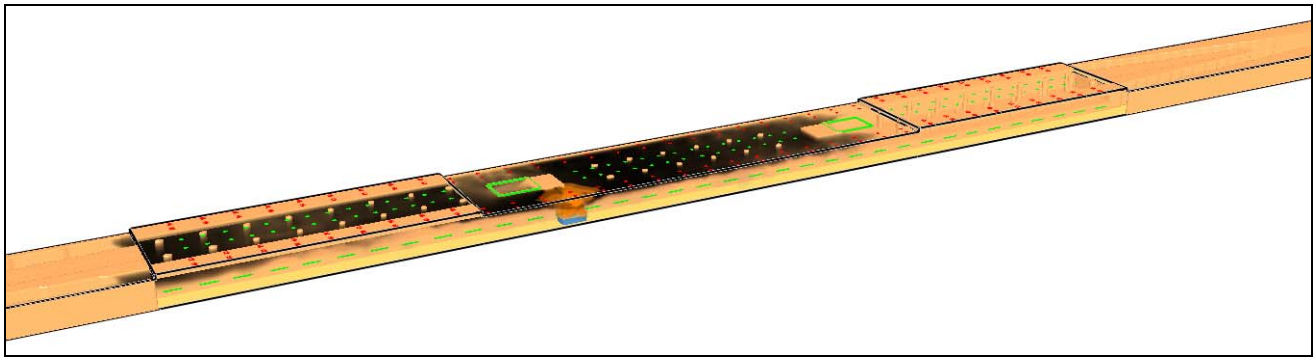

Fig.5 (g) Contours of smoke from burning Coach at 10 minute time in
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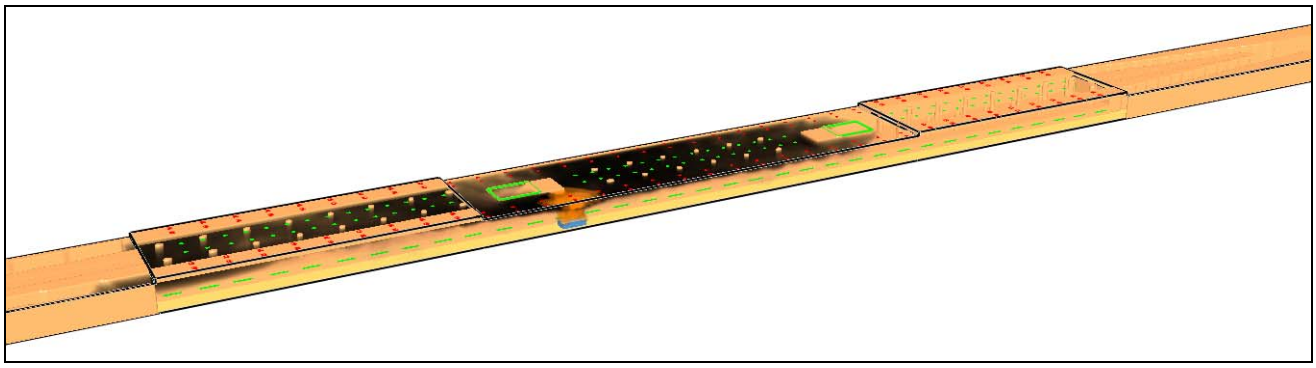

Fig.5 (h) Contours of smoke from burning Coach at 12 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

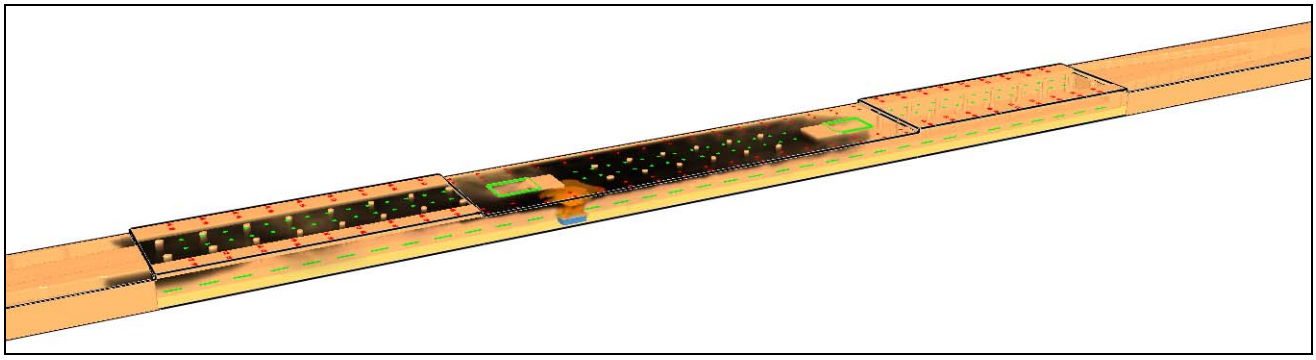

Fig.5 (i) Contours of smoke from burning Coach at 15 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

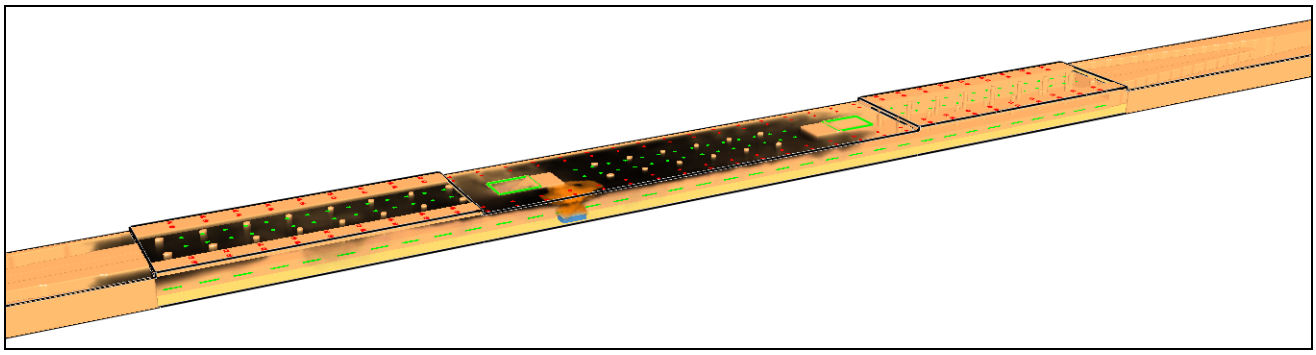

Fig.5 (j) Contours of smoke from burning Coach at 18 minute time in
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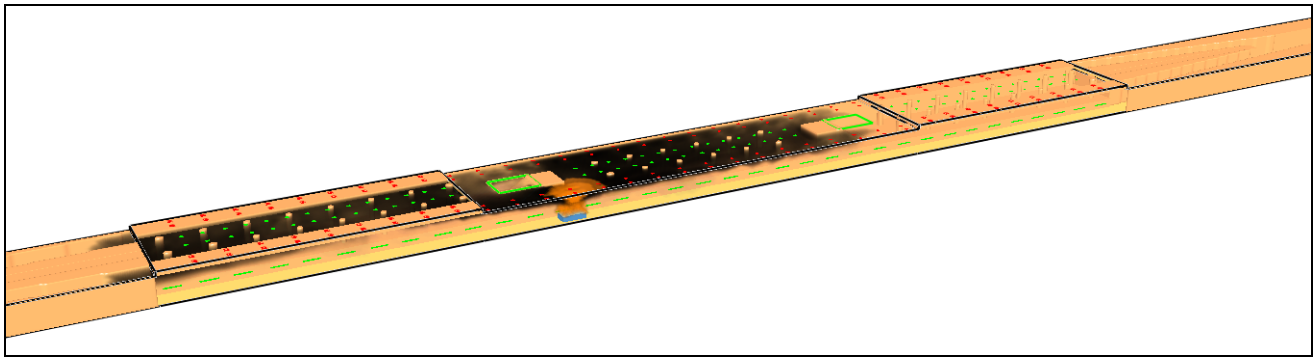

Fig.5 (k) Contours of smoke from burning Coach at 20 minute time in
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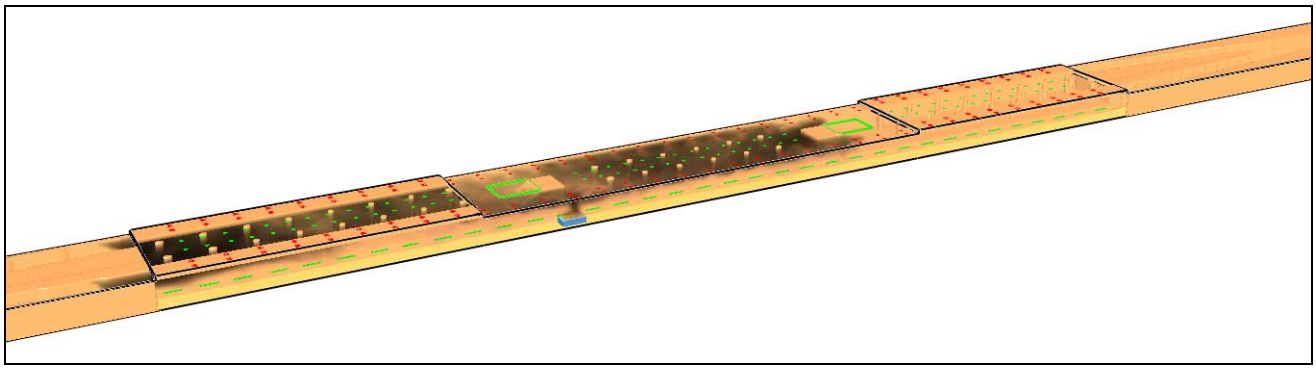

Fig.5 (l) Contours of smoke from burning Coach at 21 minute time in
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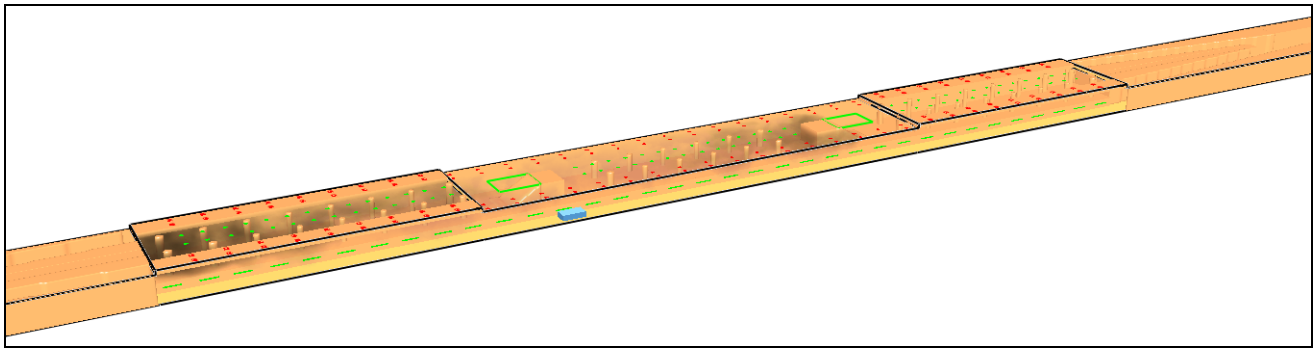

Fig.5 (m) Contours of smoke from burning Coach at 22 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

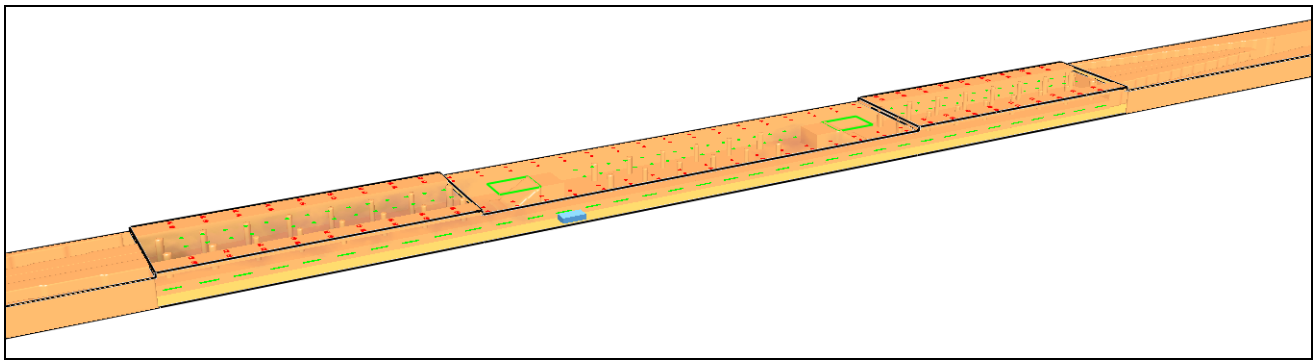

Fig.5 (n) Contours of smoke from burning Coach at 24 minute time in
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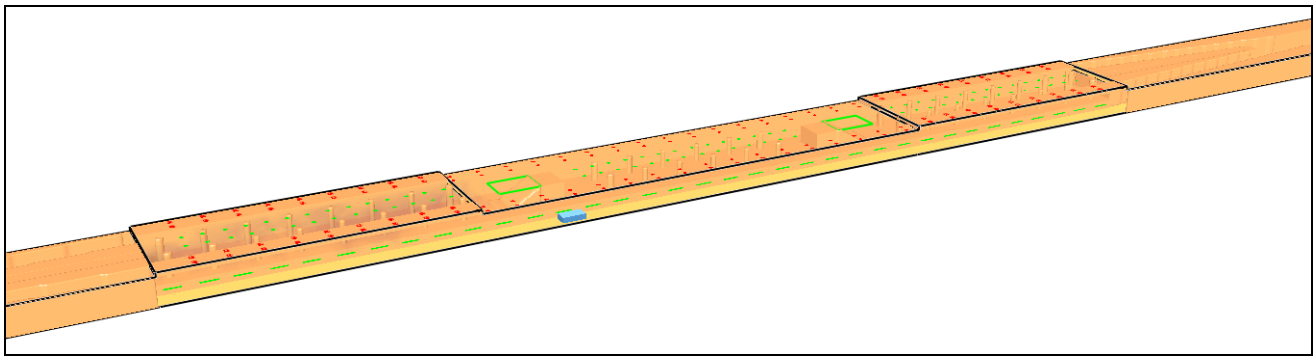

Fig.5 (o) Contours of smoke from burning Coach at 25 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

(E) Following figures shows the Visibility levels in (meters) at 1.8m height from platform level & at different timings

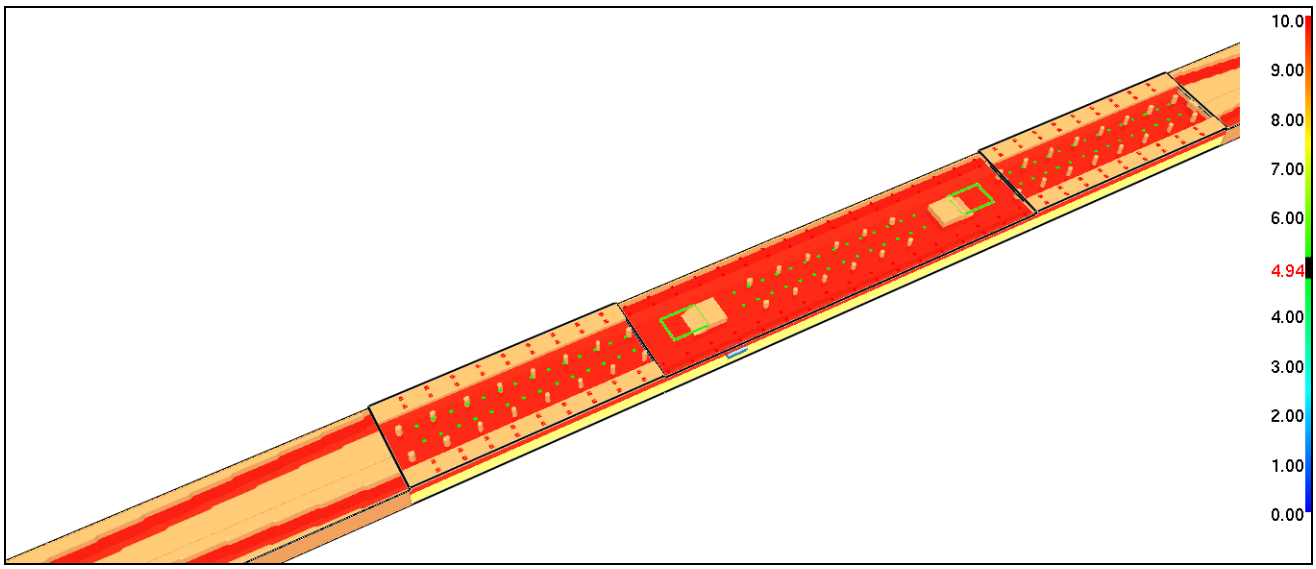

Fig.9 (a) Visibility levels in (meters) at starting of time in
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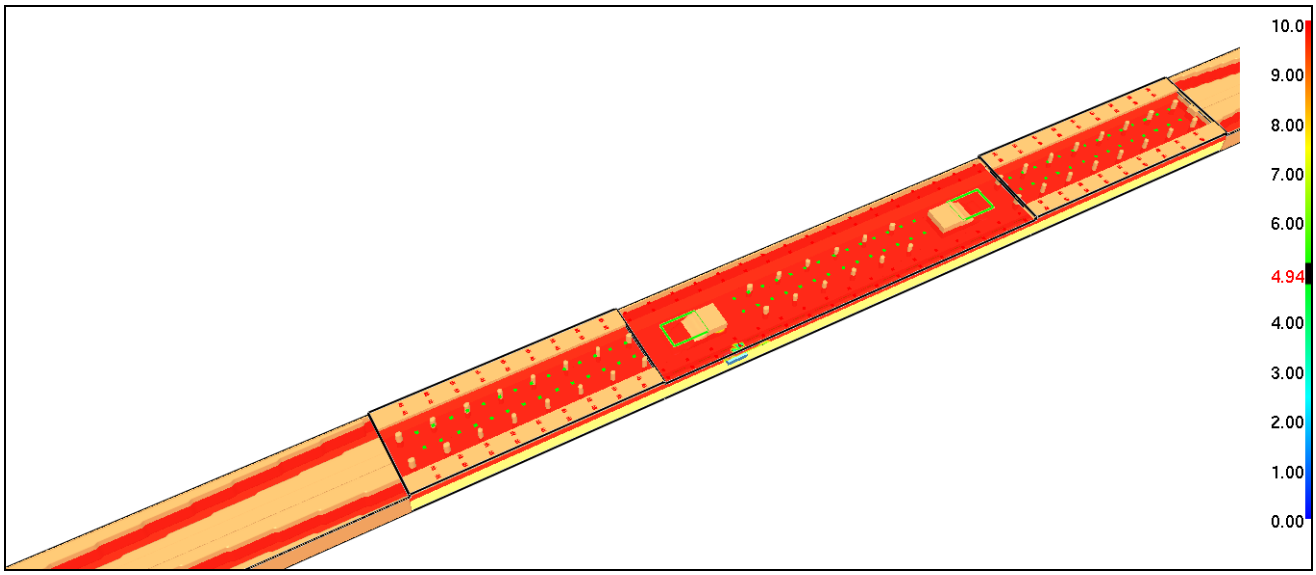

Fig.9 (b) Visibility levels in (meters) at 10 second time in
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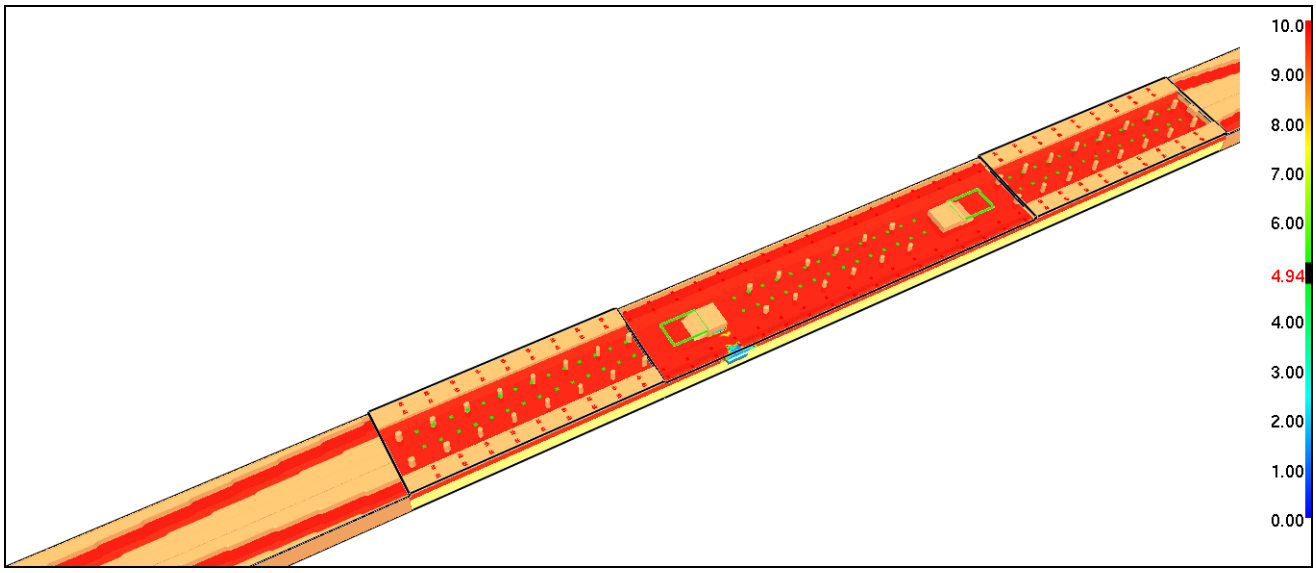

Fig.9 (c) Visibility levels in (meters) at 1 minute time in
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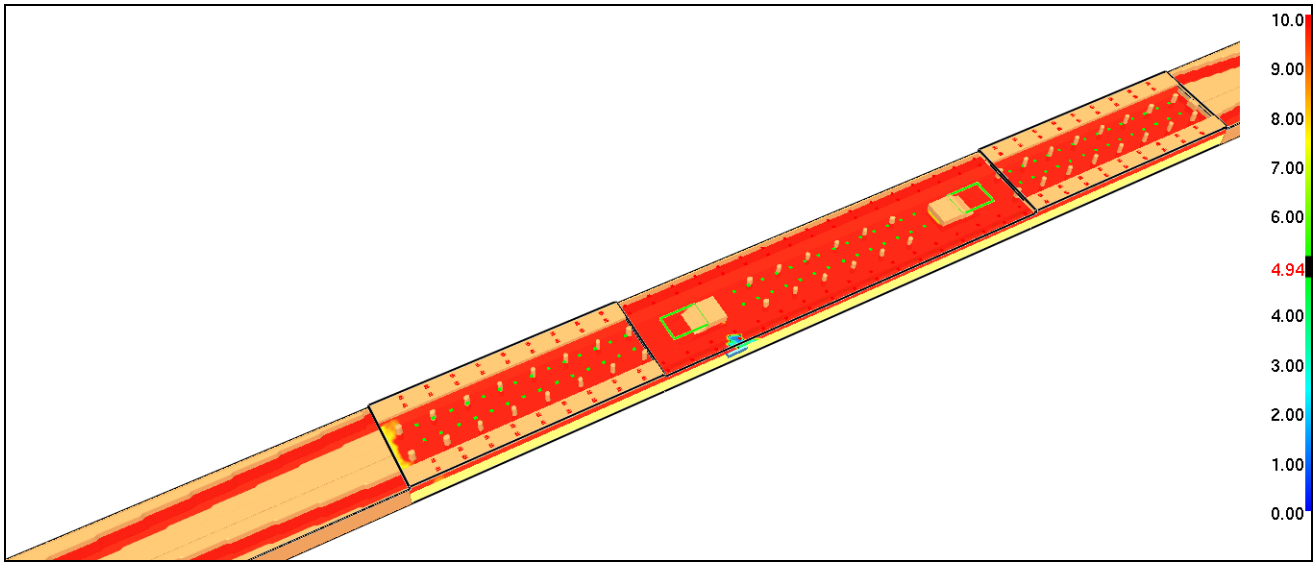

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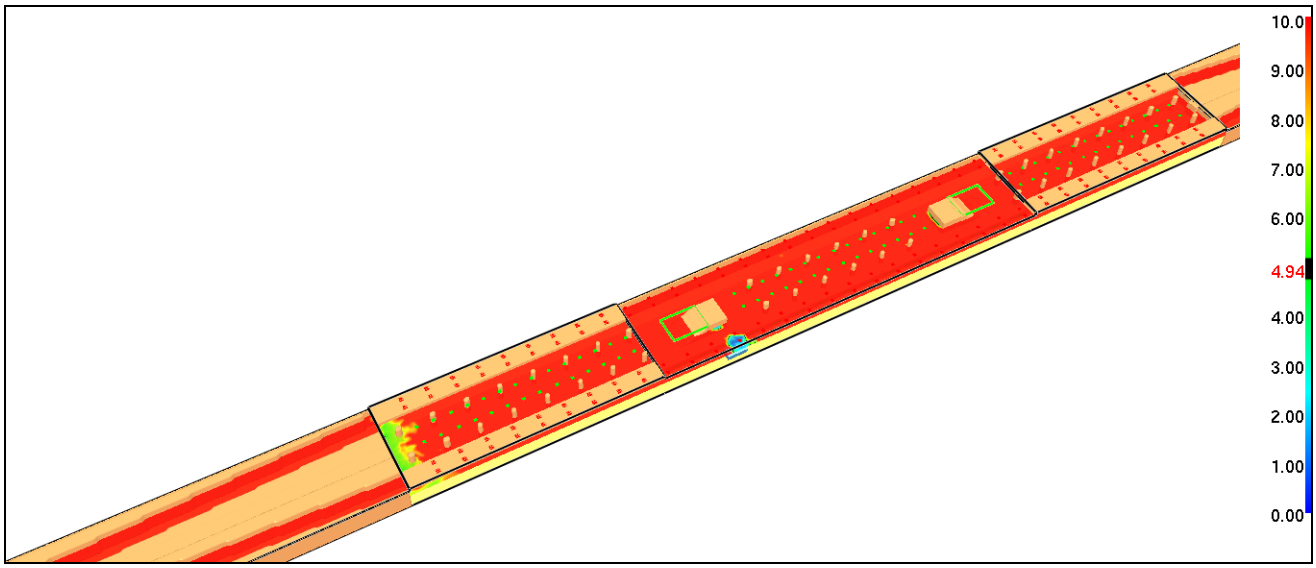

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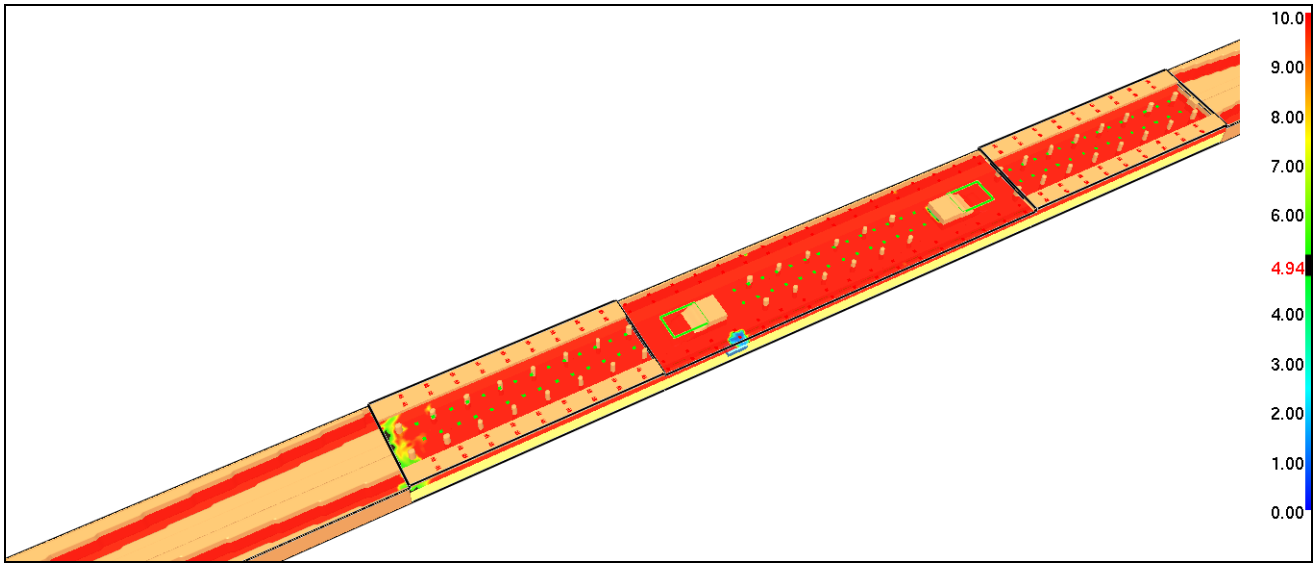

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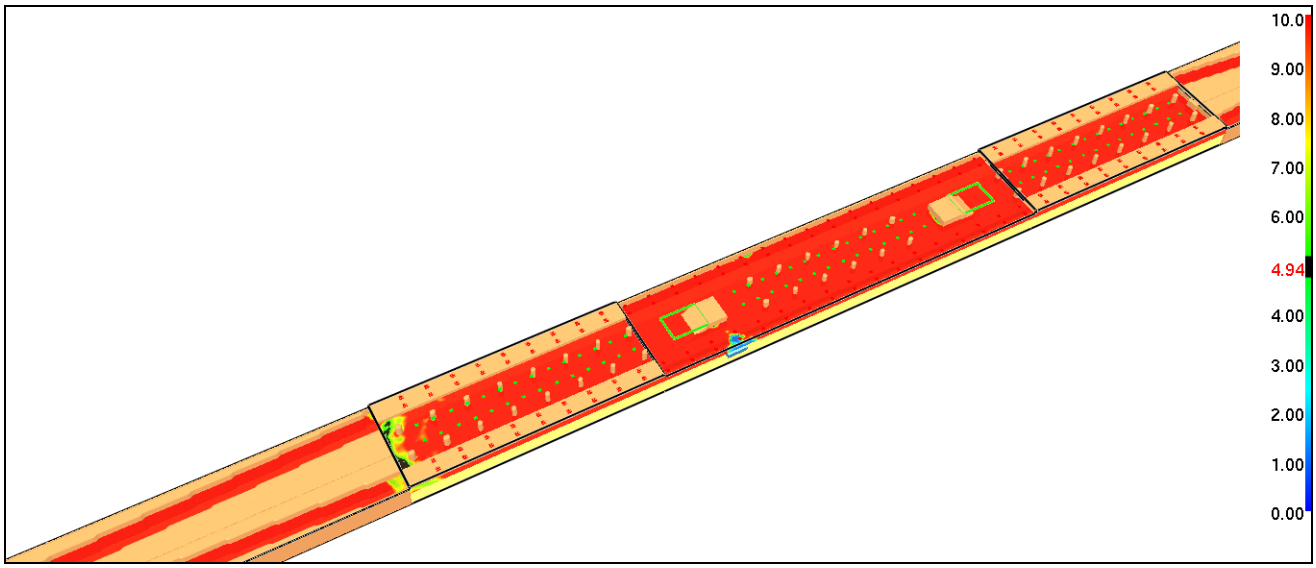

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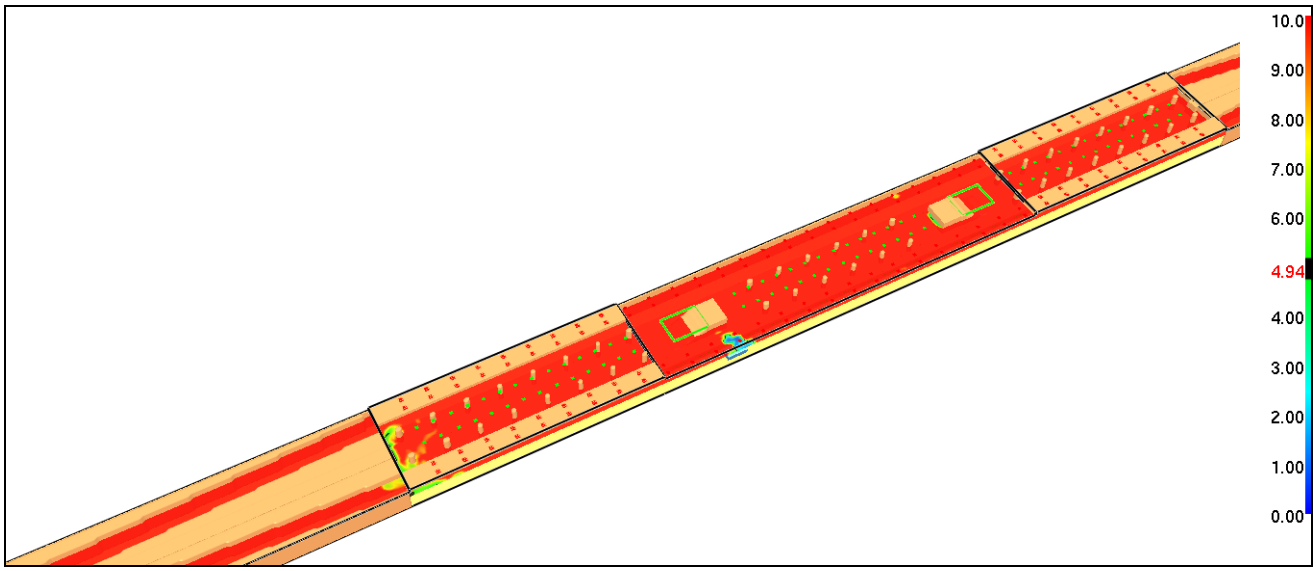

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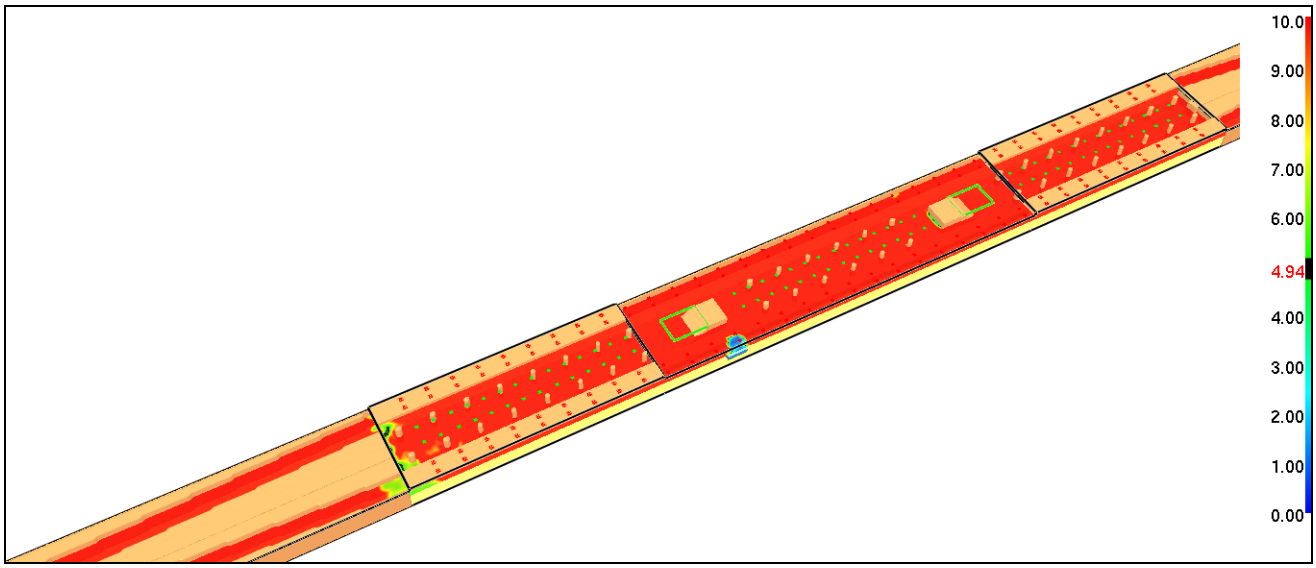

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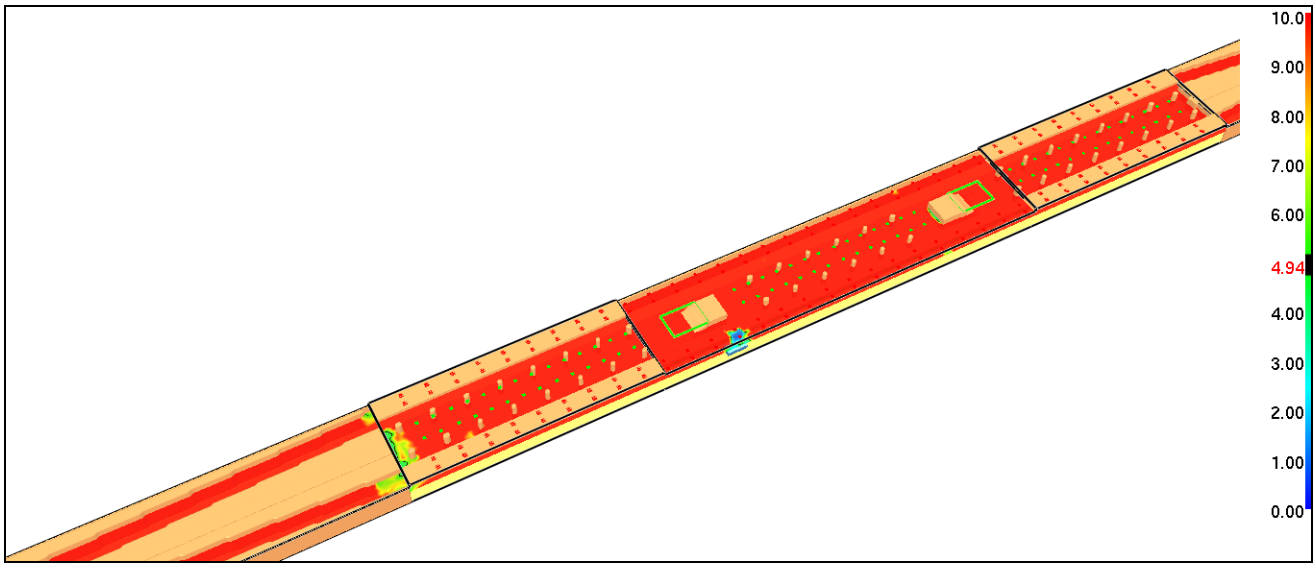

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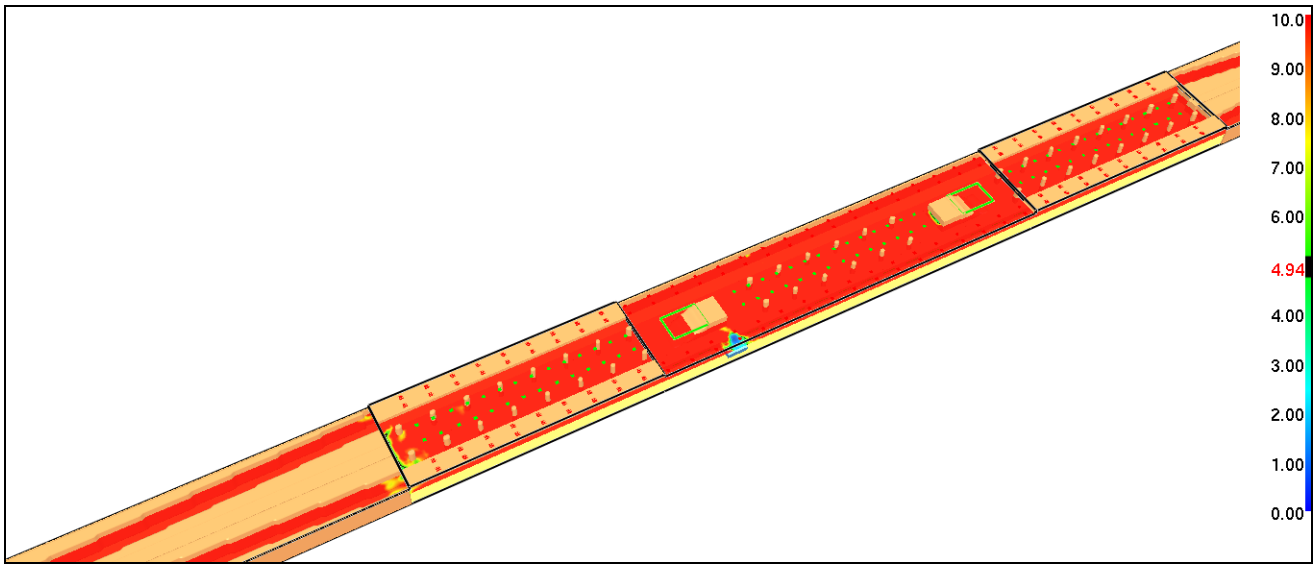

Fig.9 (k) Visibility levels in (meters) at 20 minute time in
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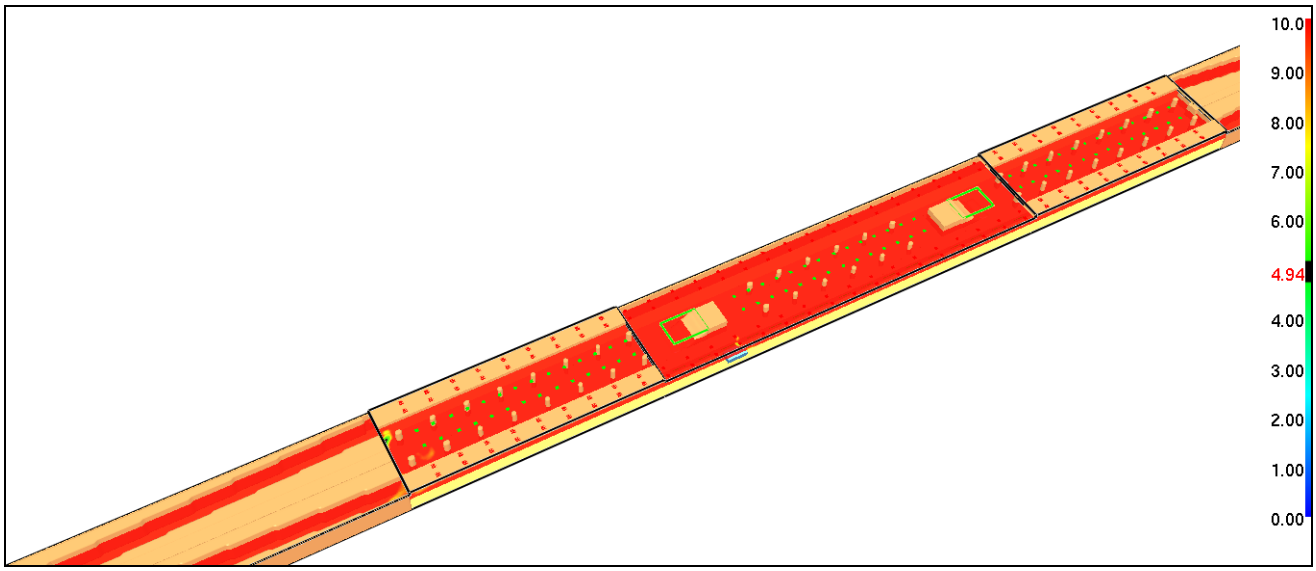

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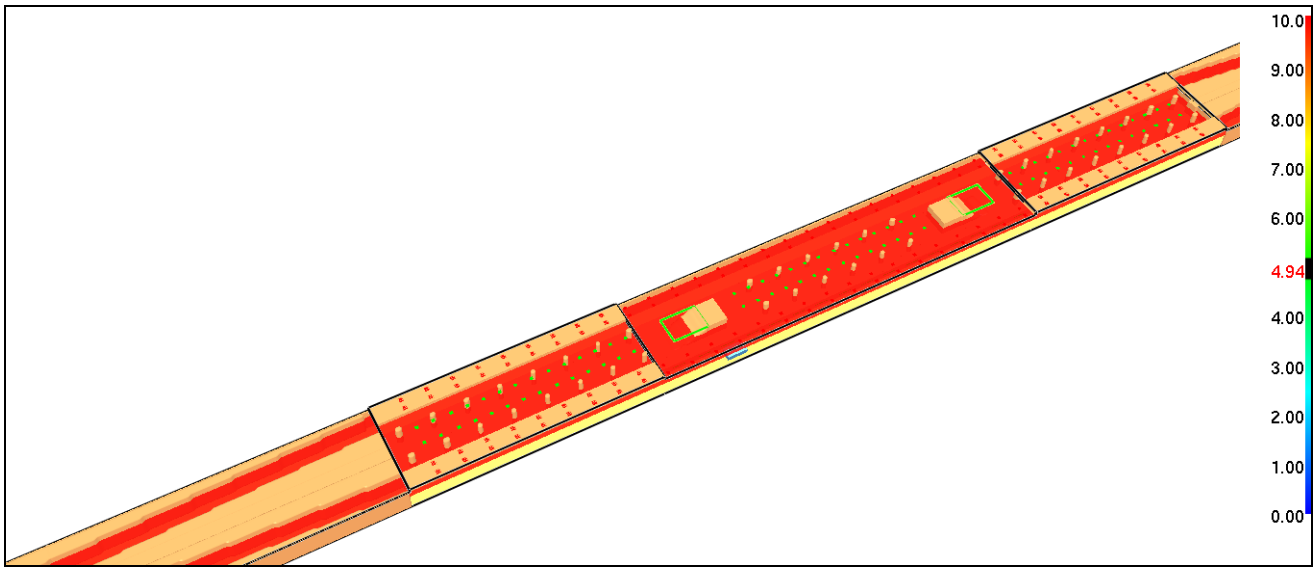

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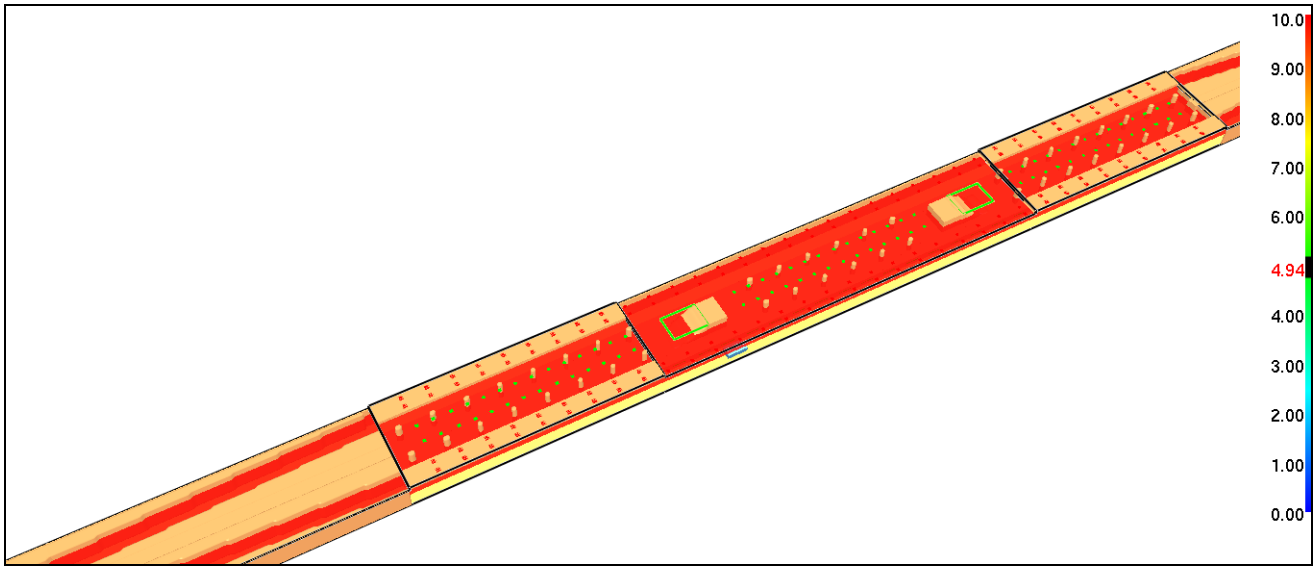

Fig.9 (n) Visibility levels in (meters) at 24 minute time in
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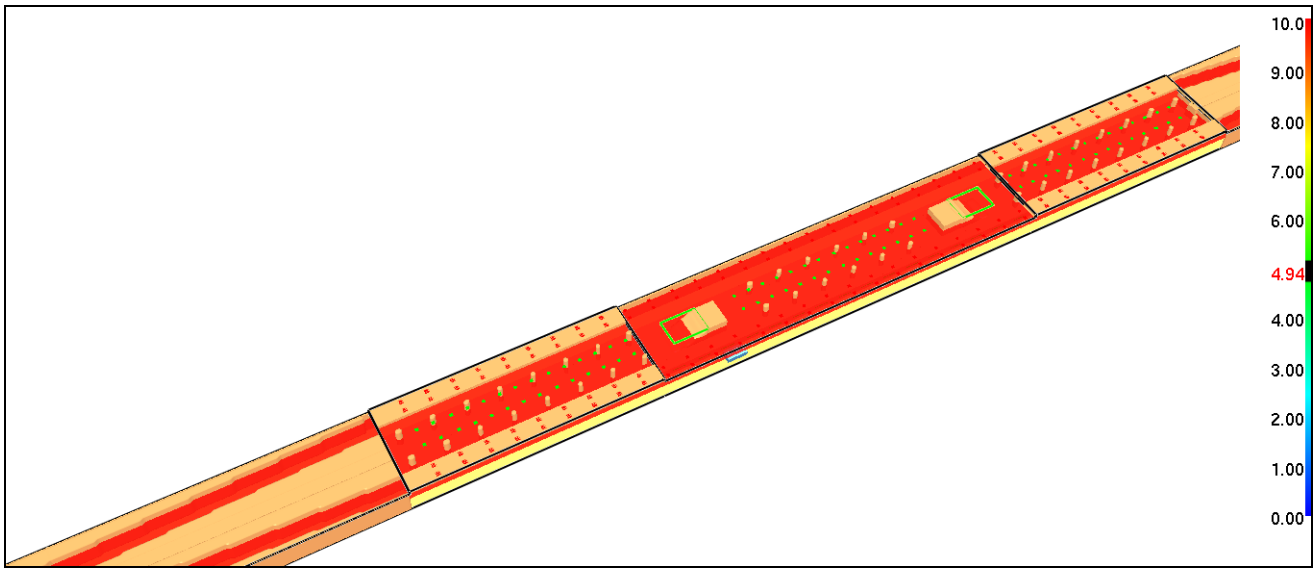

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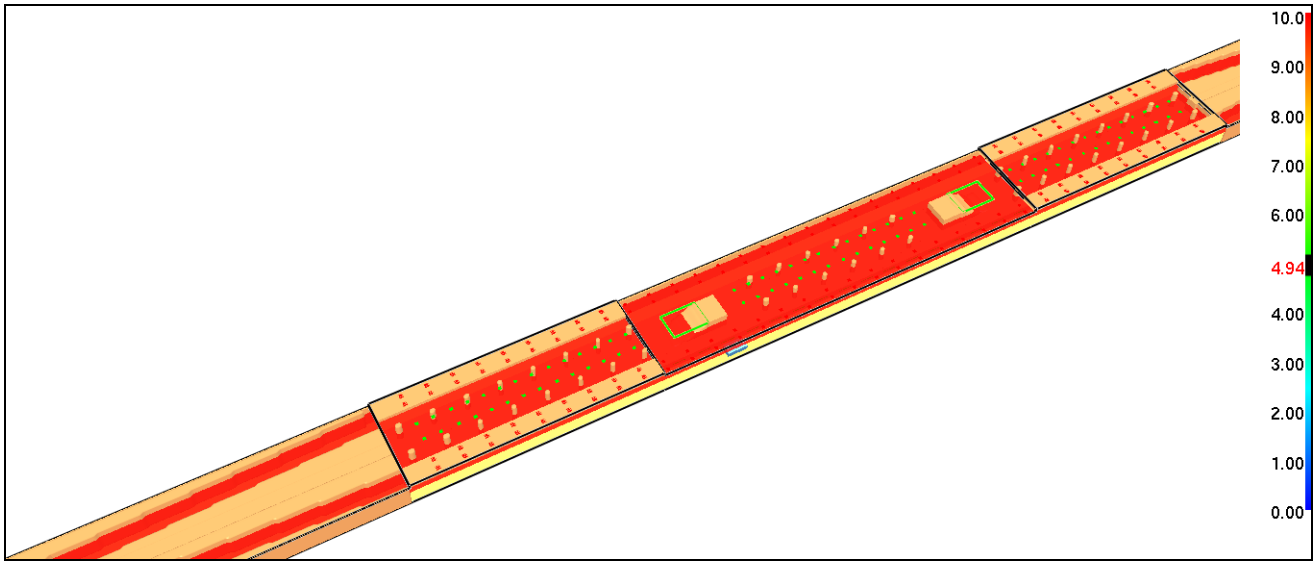

Fig.9 (p) Visibility levels in (meters) at 26 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

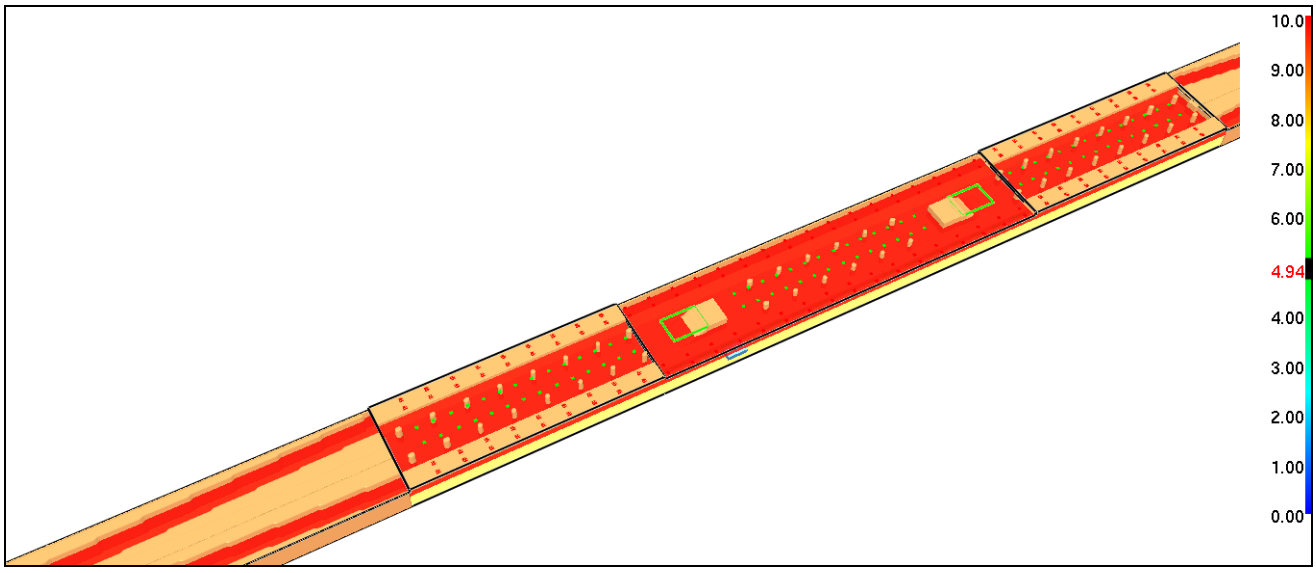

Fig.9 (q) Visibility levels in (meters) at 27.5 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

(B) Following figures shows the Temperatures generated from burning Coach in side the Basement in different vertical planes & at different timings (Here the maximum temperatures generated are approximately 400 ^{o}C at fire location, but in order to see the lower temperature levels inside the basement we have taken 150 ^{o}C maximum range)

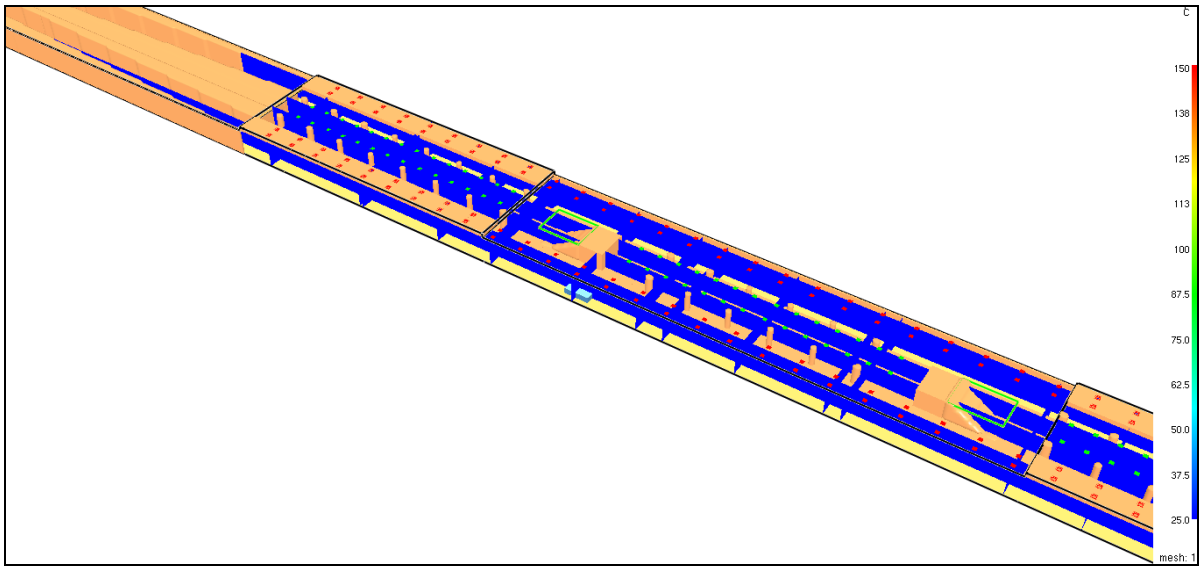

Fig.6 (a) Contours of Temperature in (°C) at starting of time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

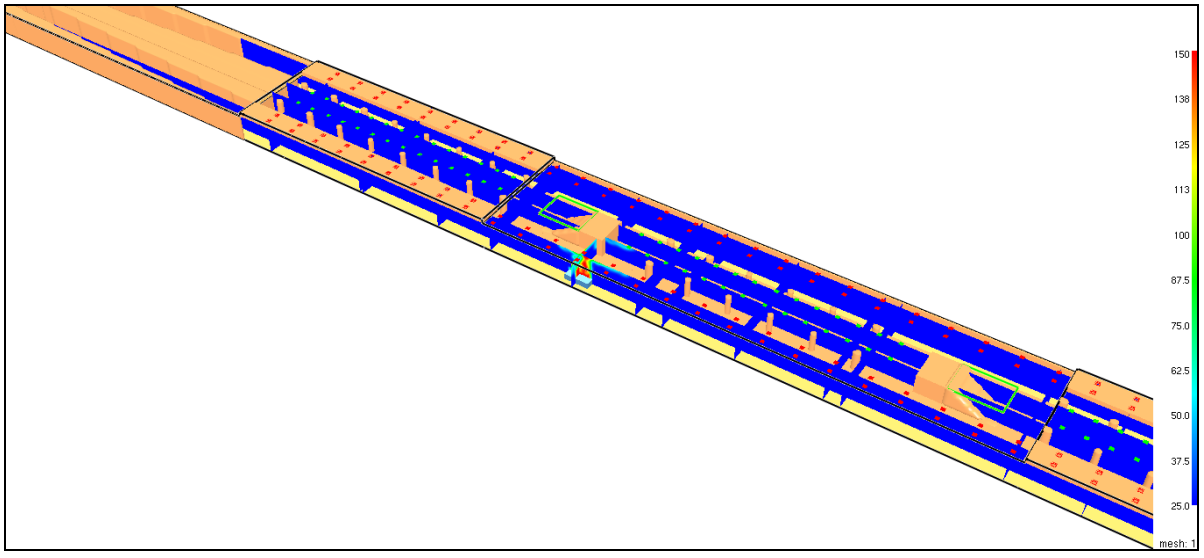

Fig.6 (b) Contours of Temperature in (°C) at 10 second time in
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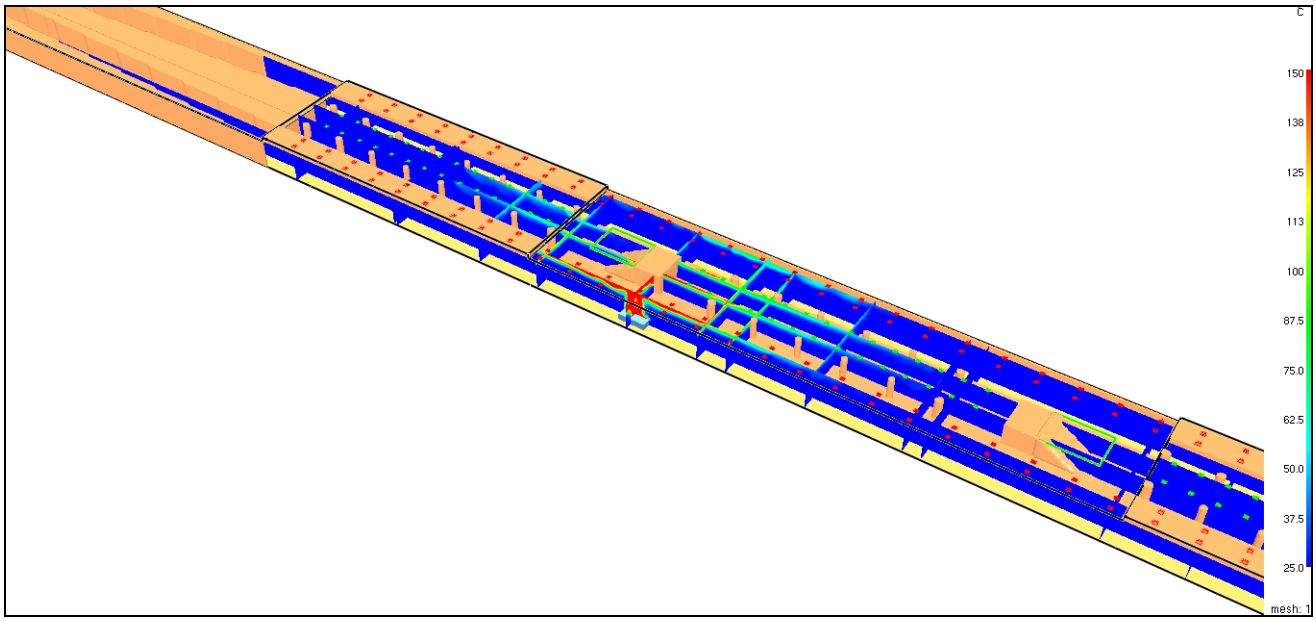

Fig.6 (c) Contours of Temperature in (°C) at 1 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

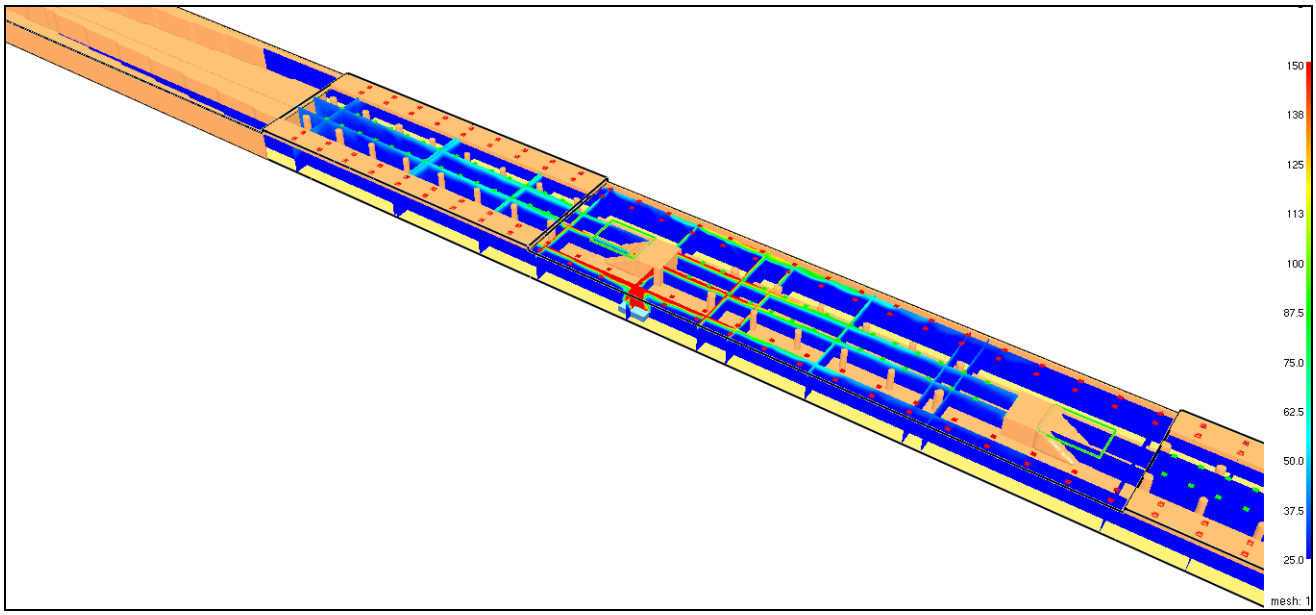

Fig.6 (d) Contours of Temperature in (°C) at 3 minute time in
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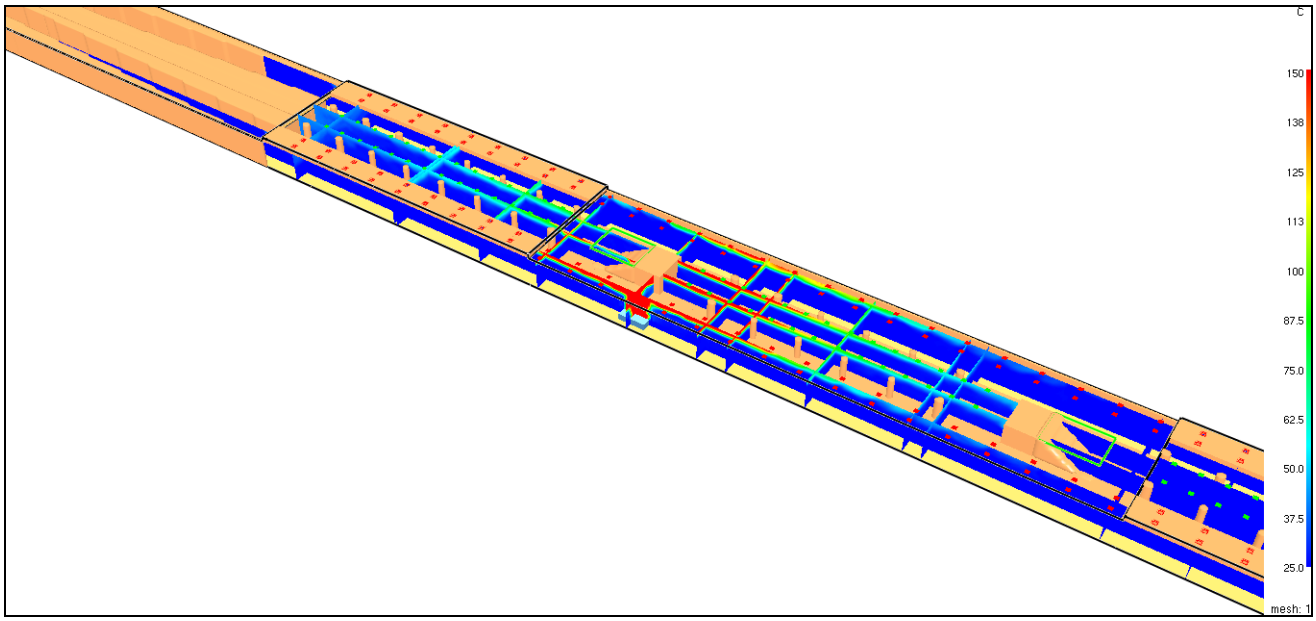

Fig.6 (e) Contours of Temperature in (°C) at 5 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

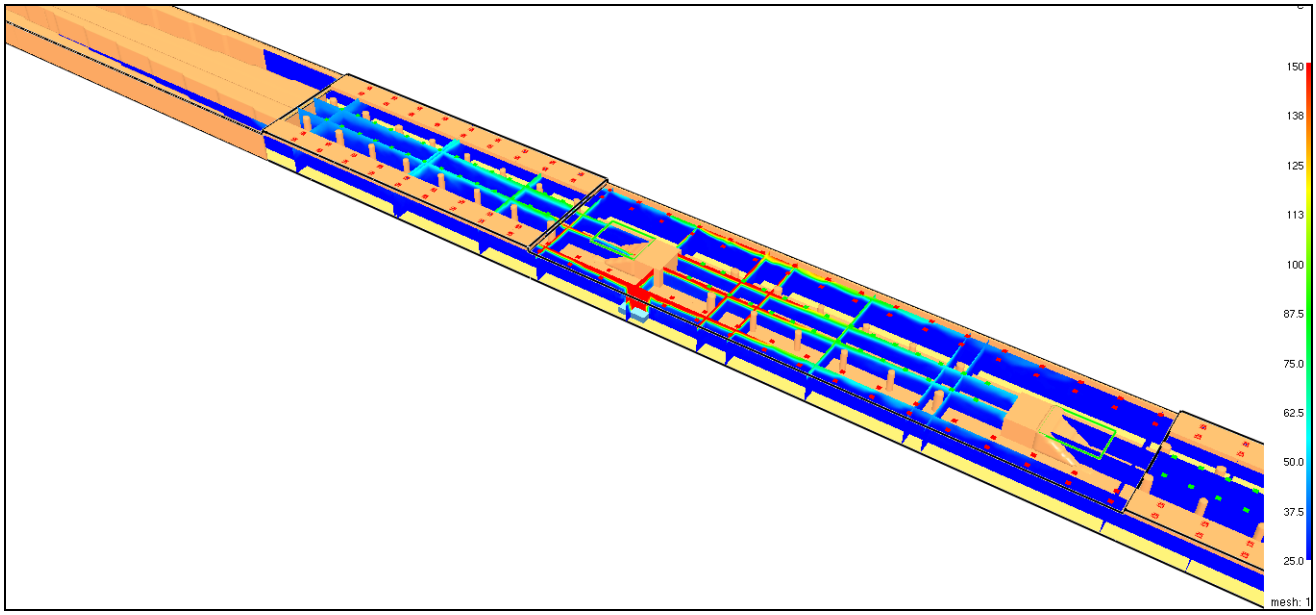

Fig.6 (f) Contours of Temperature in (°C) at 8 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

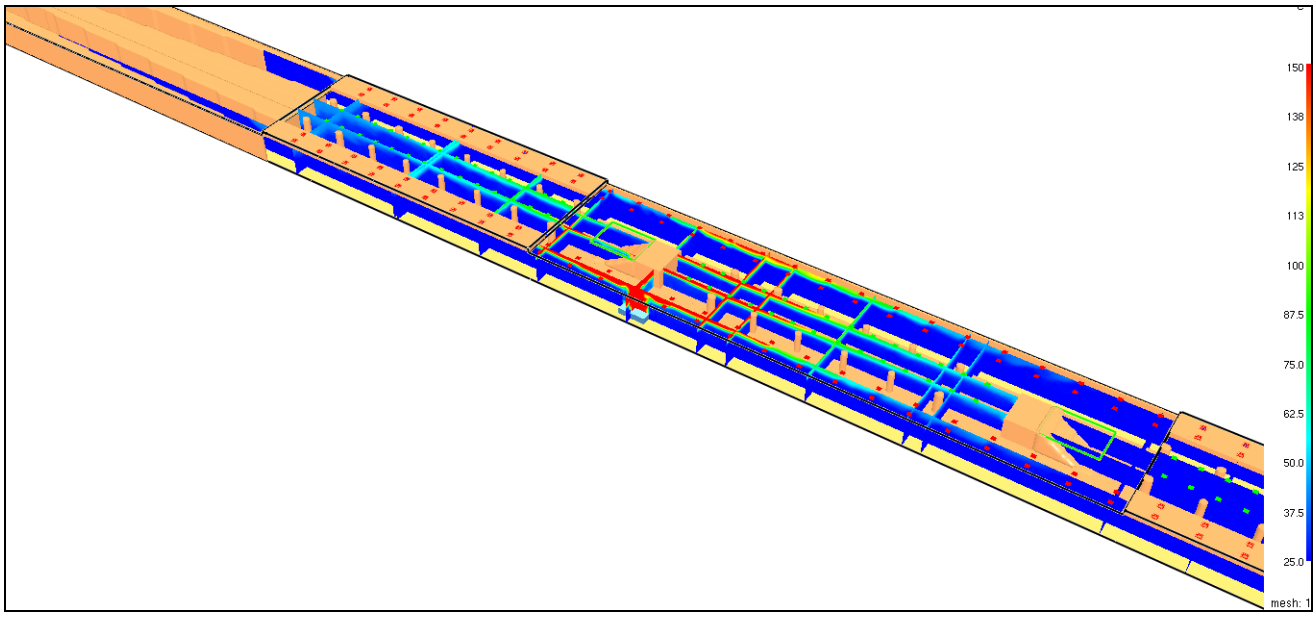

Fig.6 (g) Contours of Temperature in (°C) at 10 minute time in
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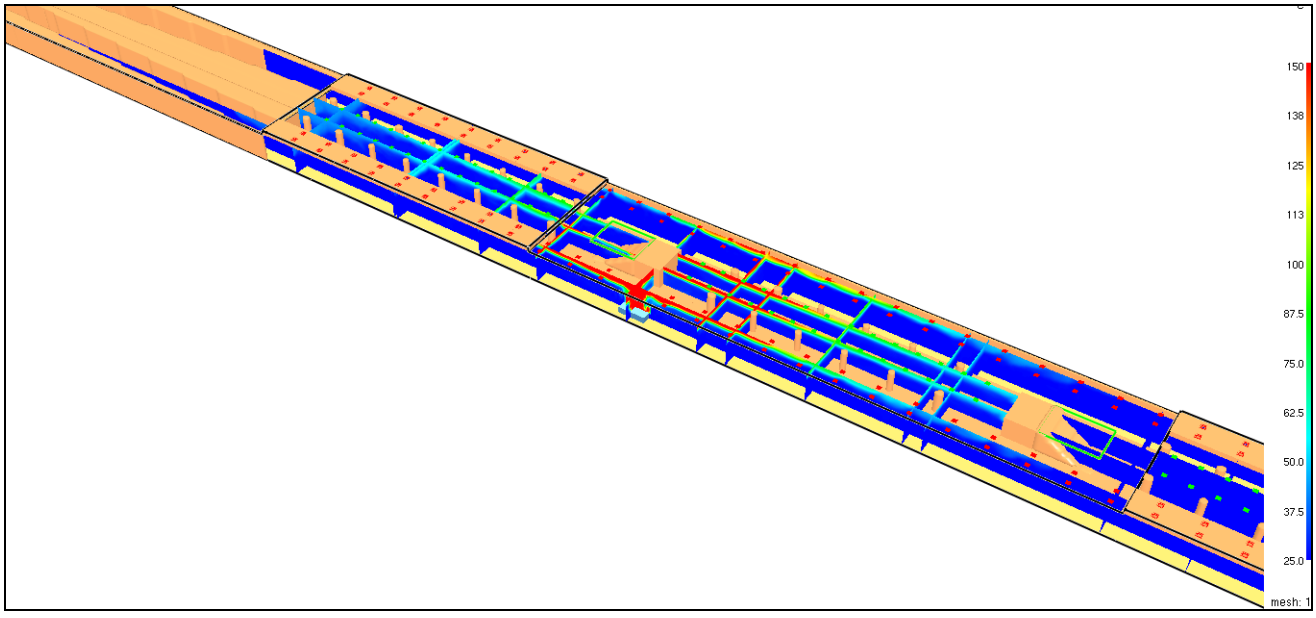

Fig.6 (h) Contours of Temperature in (°C) at 12 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

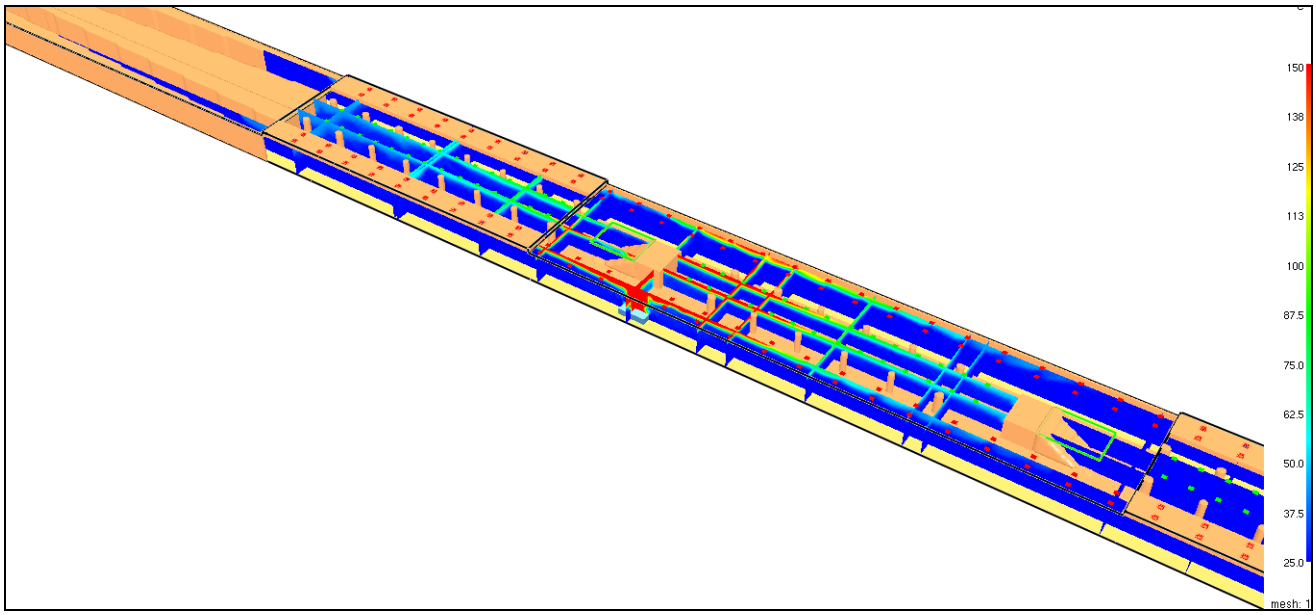

Fig.6 (i) Contours of Temperature in (°C) at 15 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

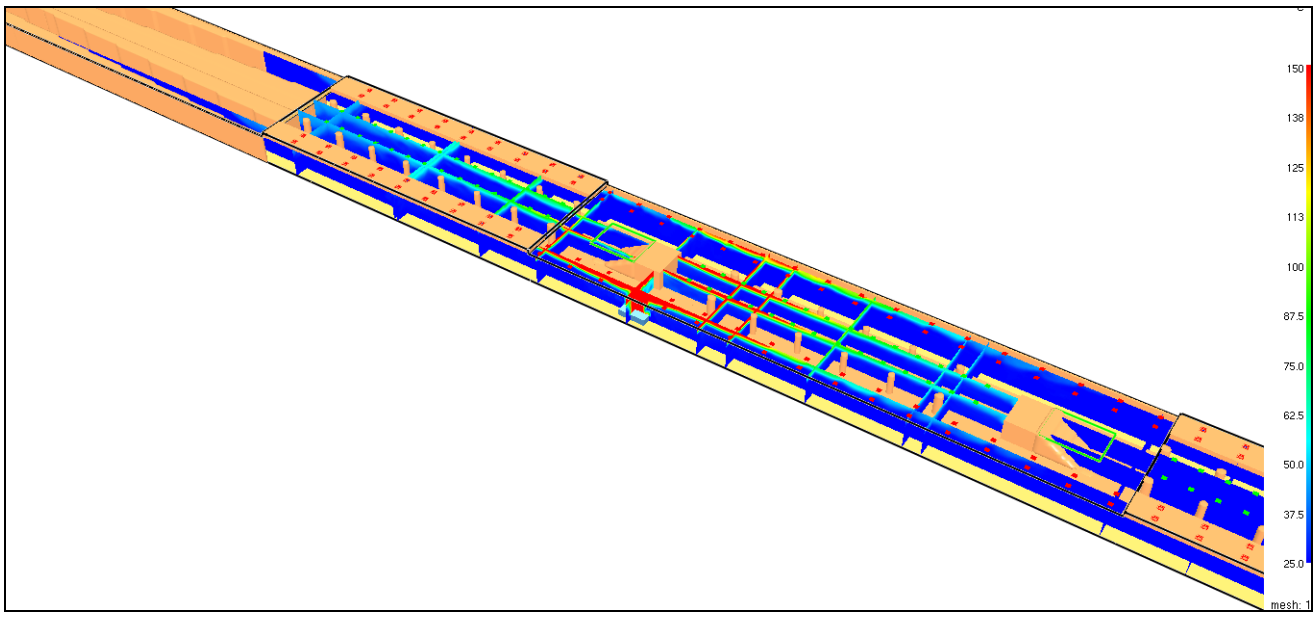

Fig.6 (j) Contours of Temperature in (°C) at 18 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

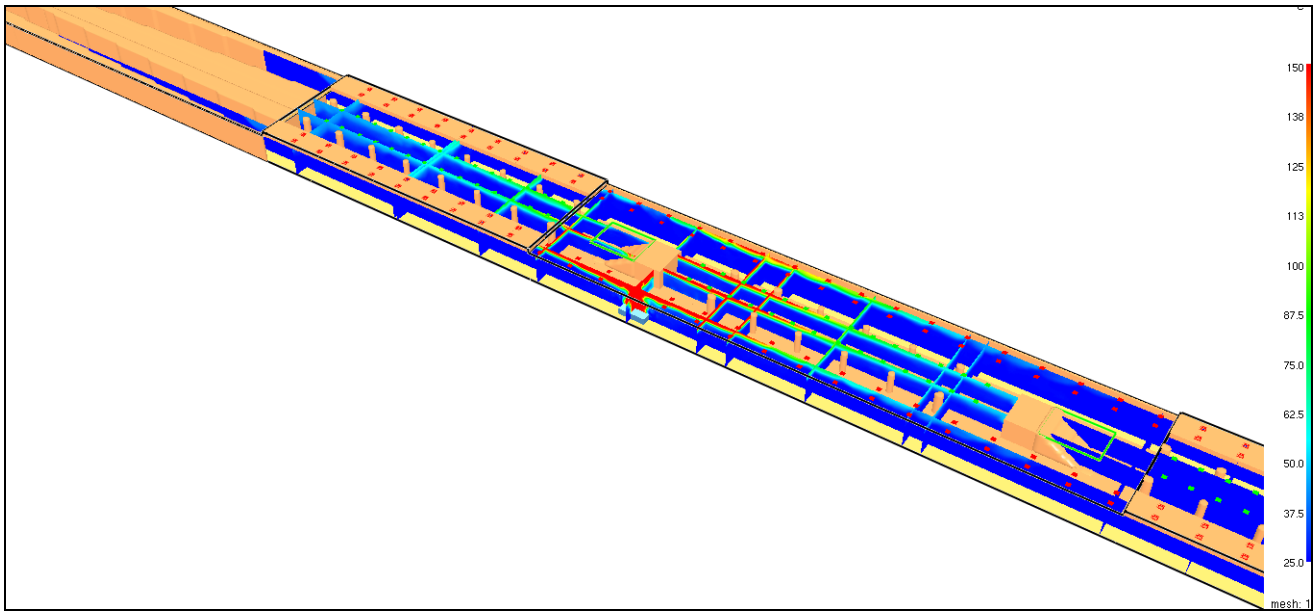

Fig.6 (k) Contours of Temperature in (°C) at 20 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

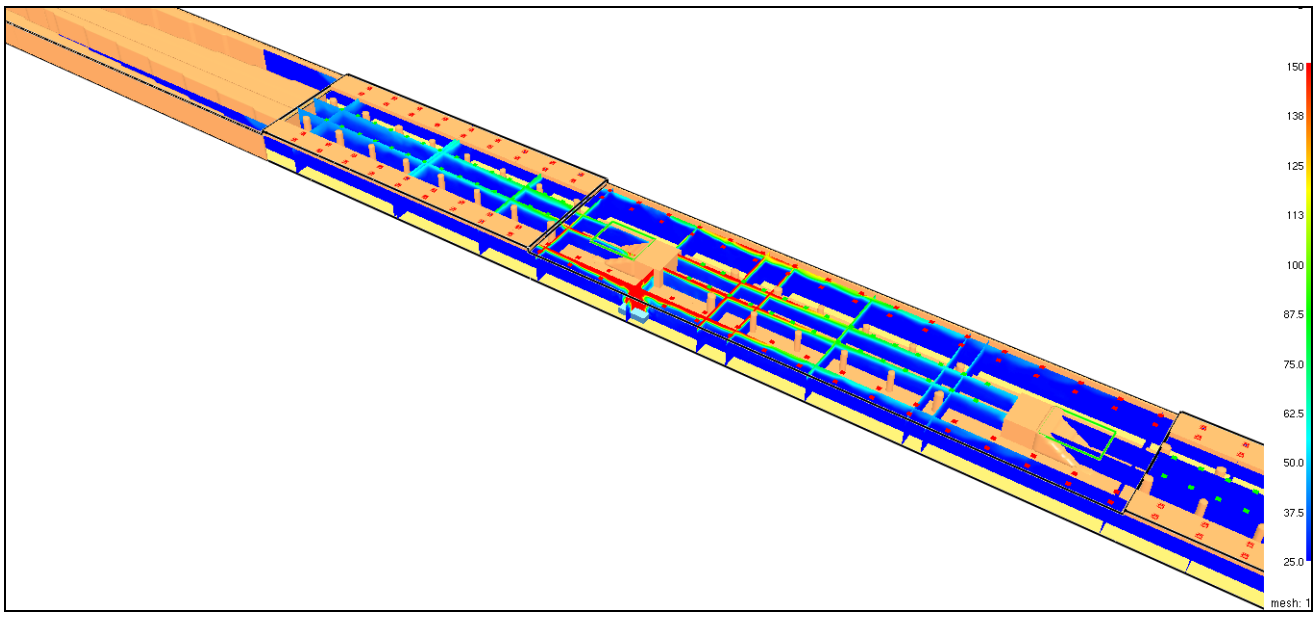

Fig.6 (l) Contours of Temperature in (°C) at 21 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

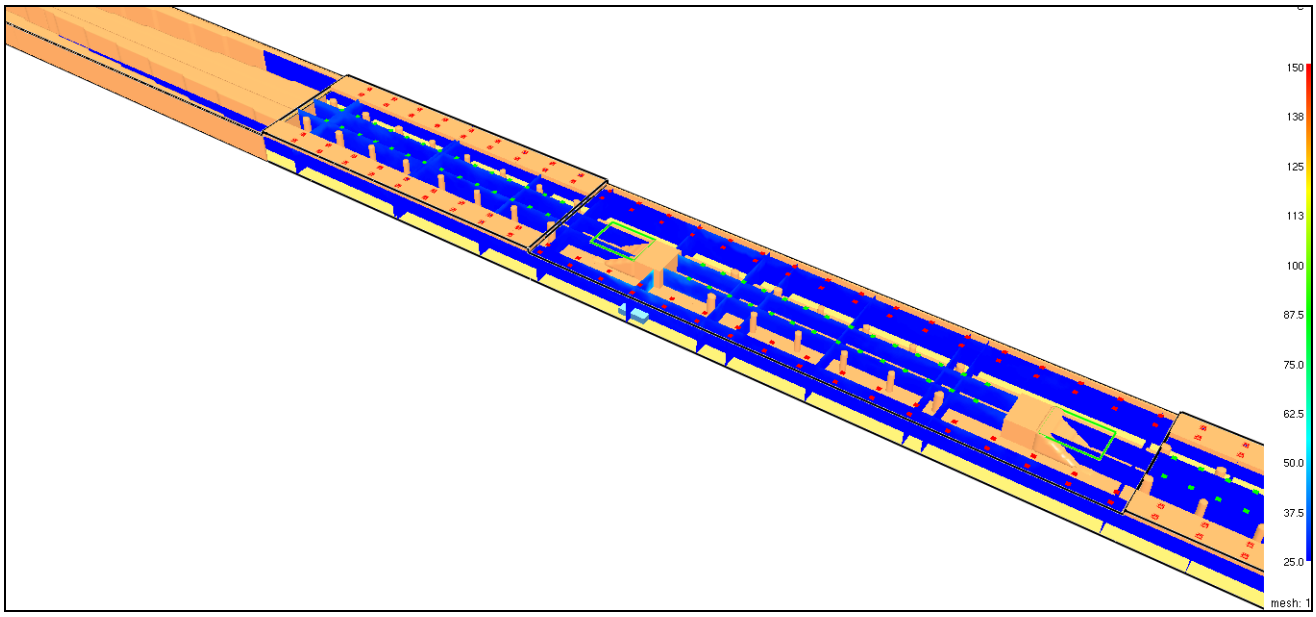

Fig.6 (m) Contours of Temperature in (°C) at 22 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

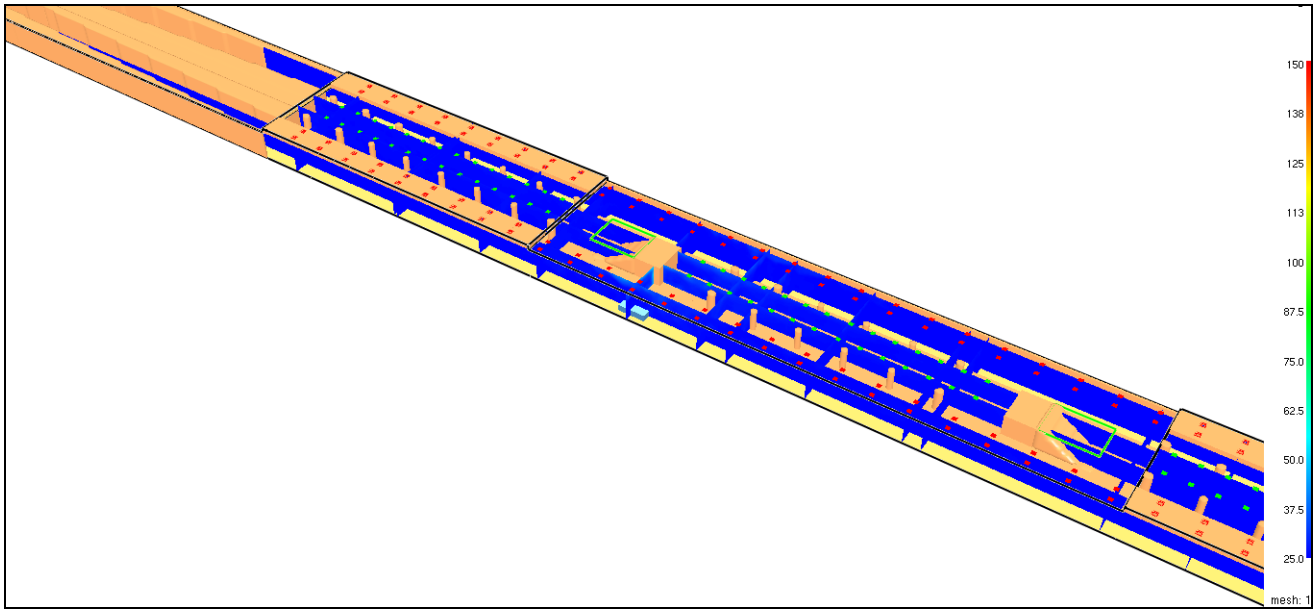

Fig.6 (n) Contours of Temperature in (°C) at 24 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

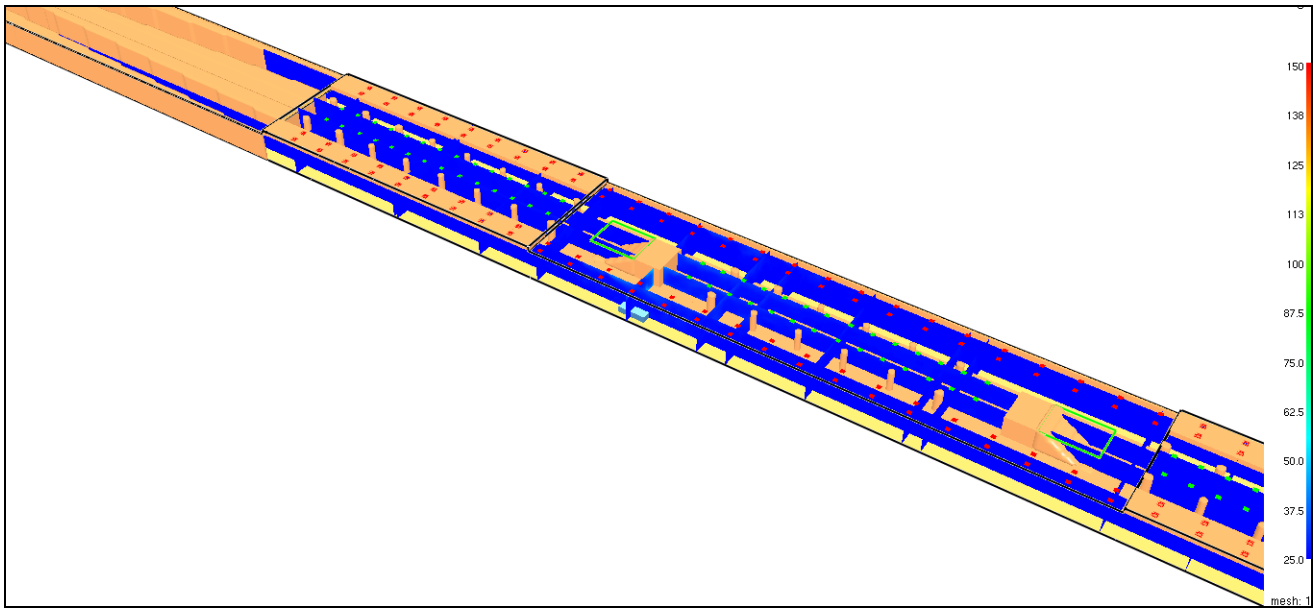

Fig.6 (o) Contours of Temperature in (°C) at 25 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

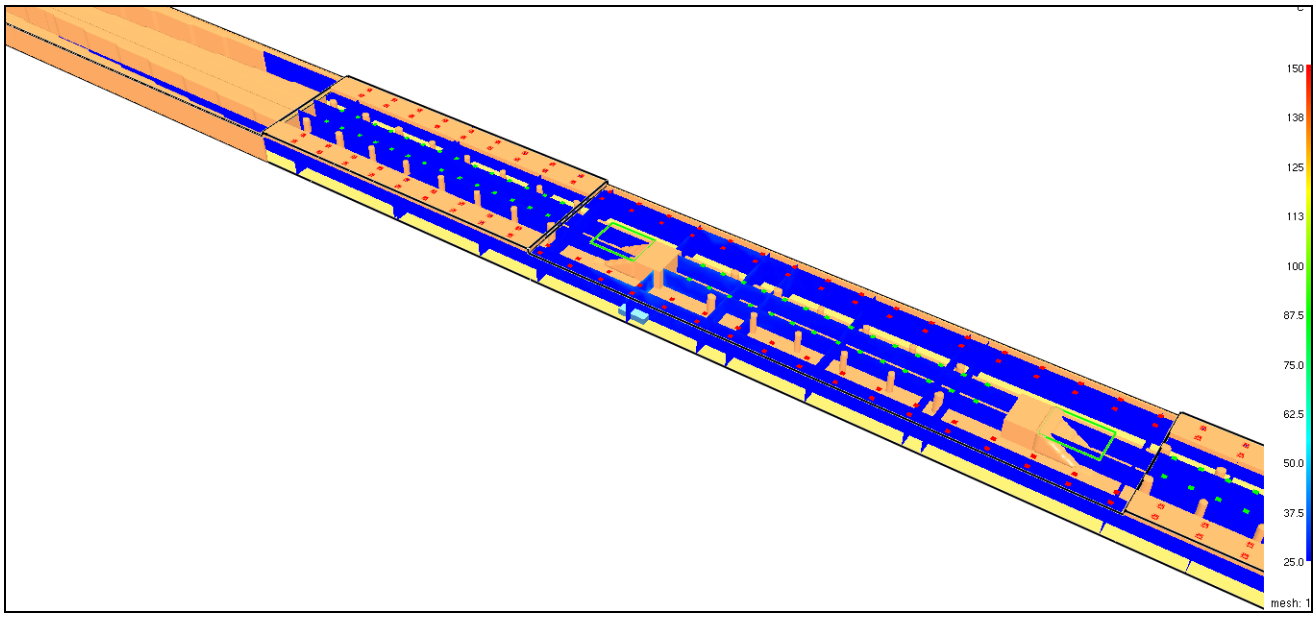

Fig.6 (p) Contours of Temperature in (°C) at 26 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

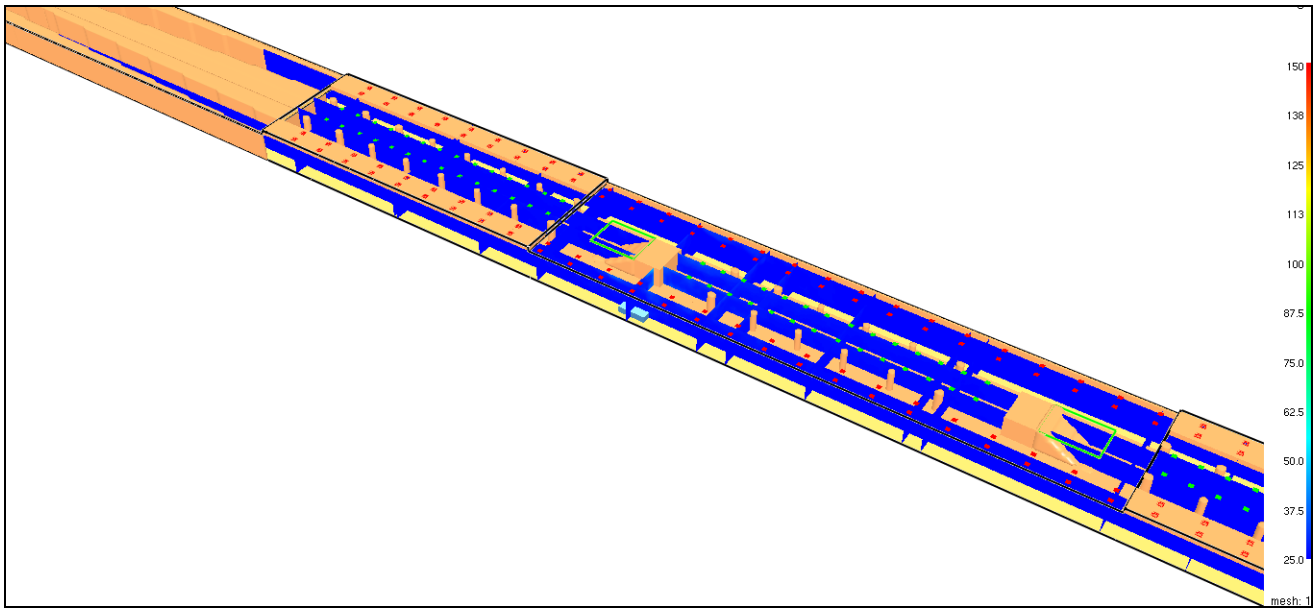

Fig.6 (q) Contours of Temperature in (°C) at 27.5 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

(C) Following figures shows the Temperatures generated from fire inside Platform in horizontal plane at 1.8m height from platform level & at different timings

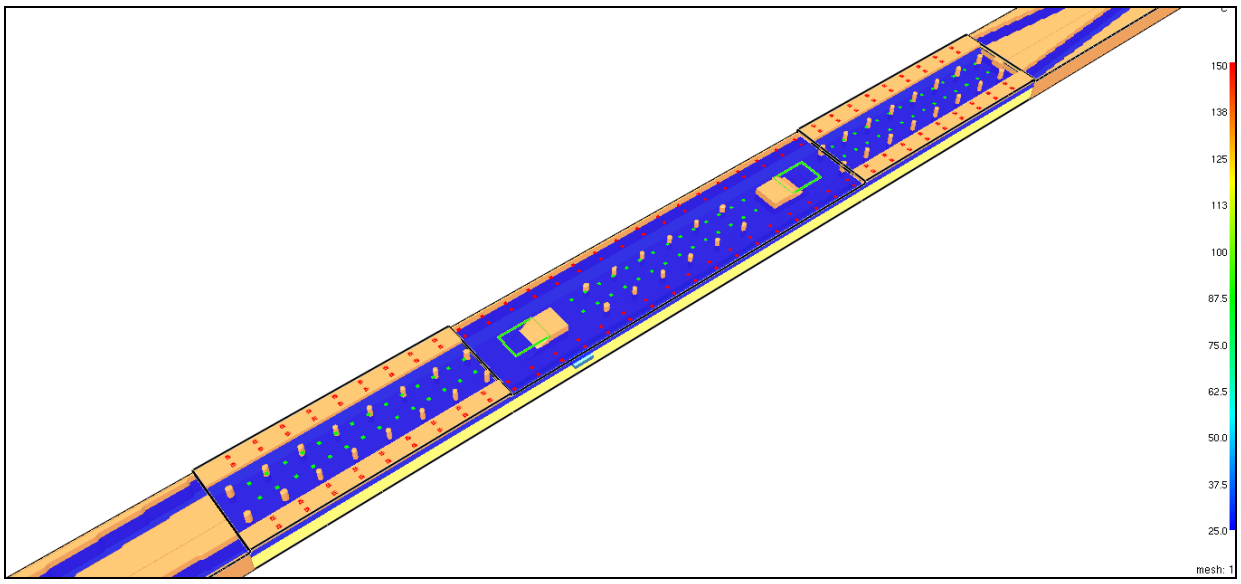

Fig.7 (a) Contours of Temperature in (°C) at start of time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

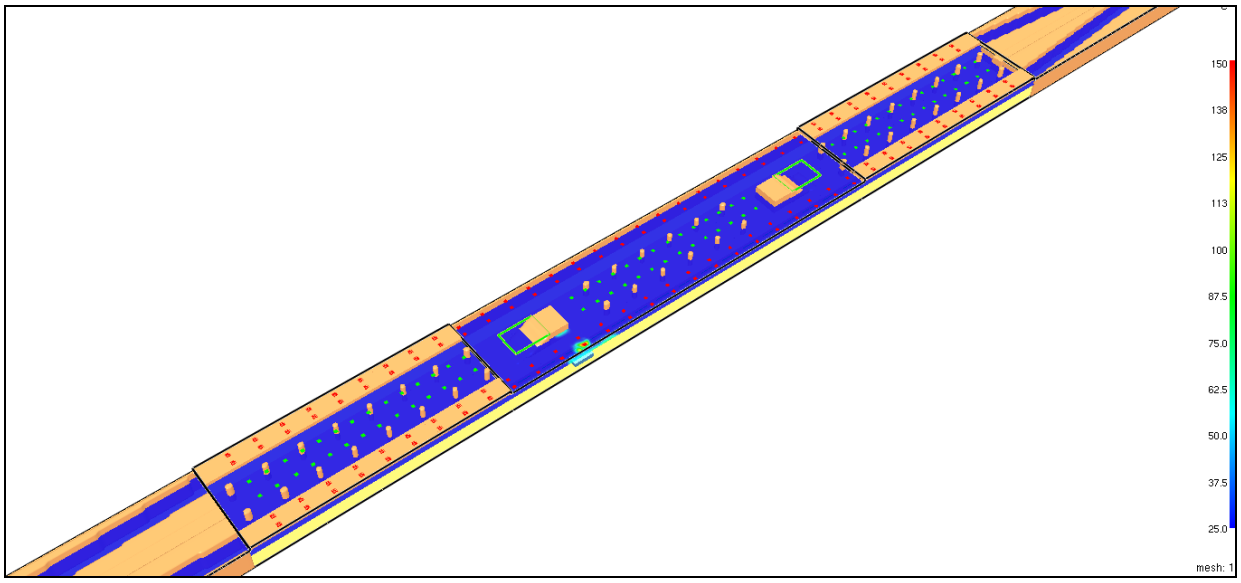

Fig.7 (b) Contours of Temperature in (°C) at 10 second time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

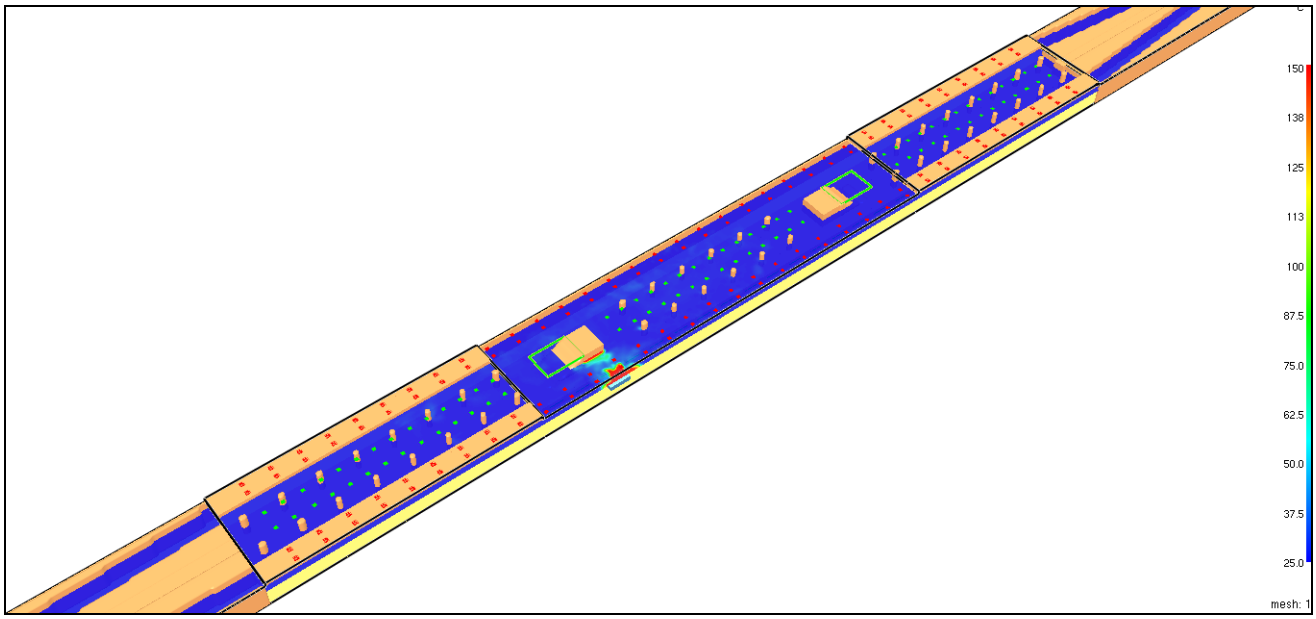

Fig.7 (c) Contours of Temperature in (°C) at 1 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

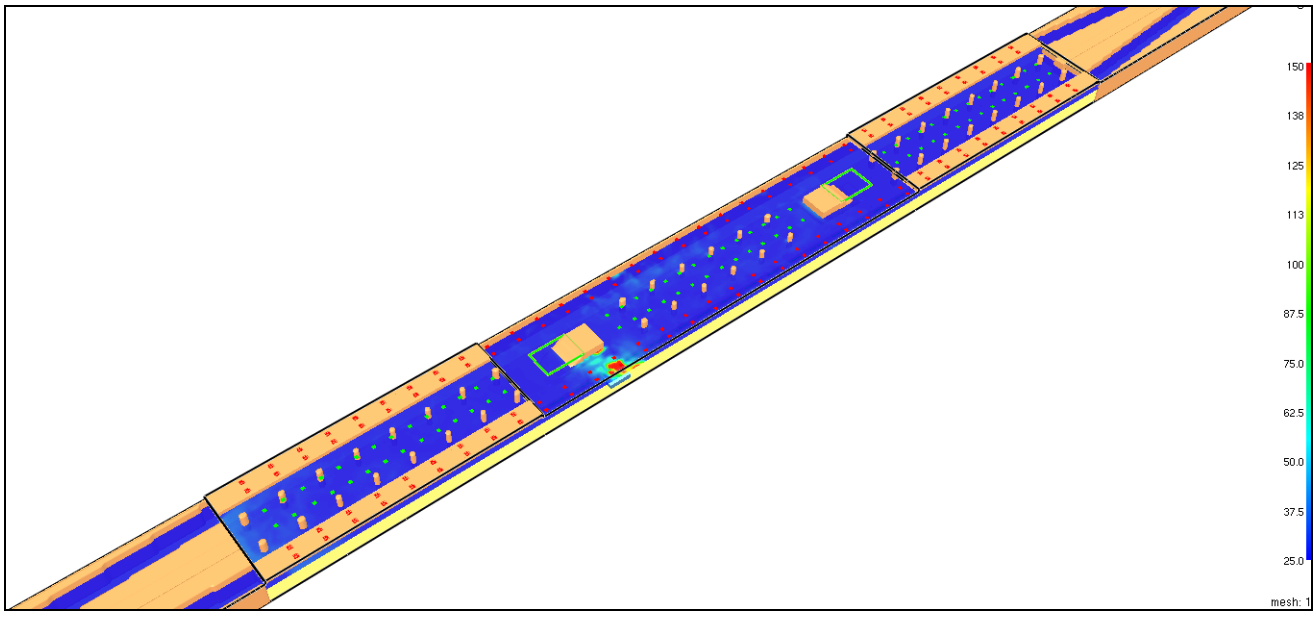

Fig.7 (d) Contours of Temperature in (°C) at 3 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

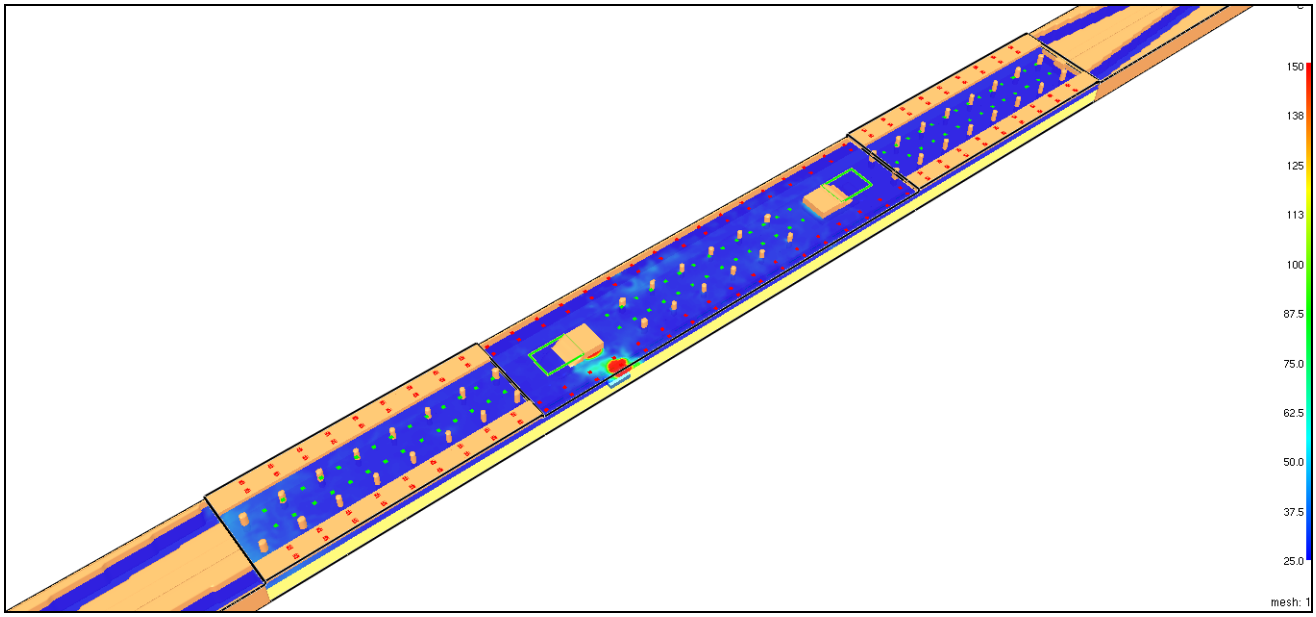

Fig.7 (e) Contours of Temperature in (°C) at 5 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

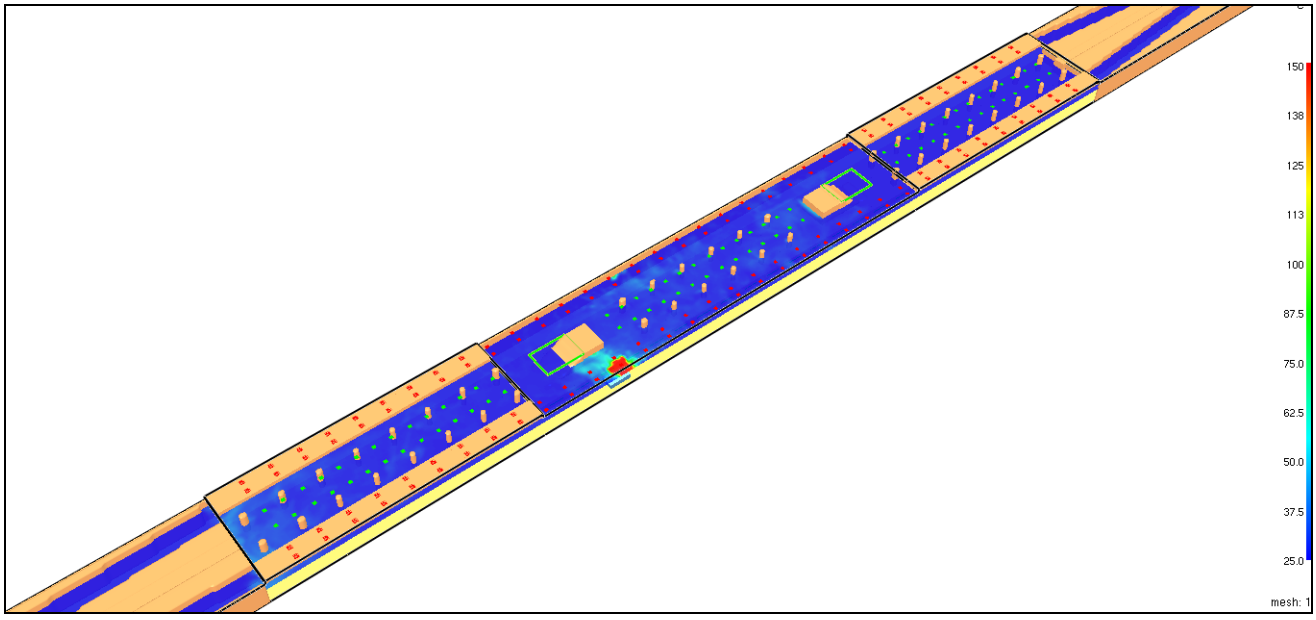

Fig.7 (f) Contours of Temperature in (°C) at 8 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

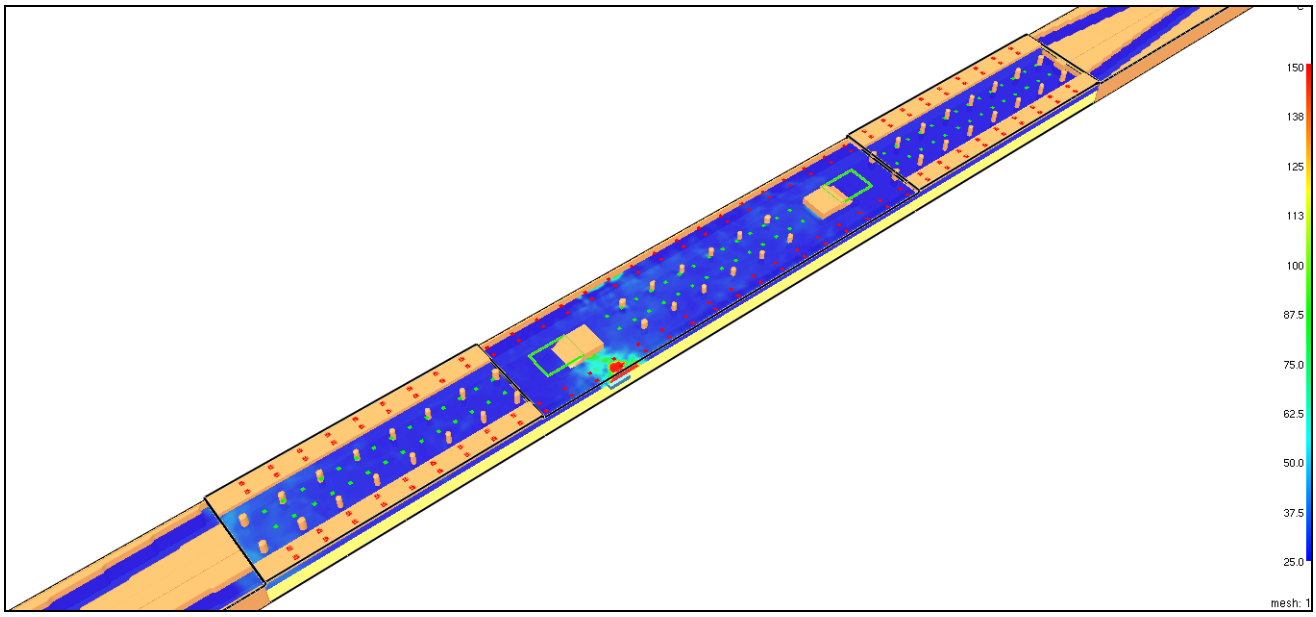

Fig.7 (g) Contours of Temperature in (°C) at 10 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

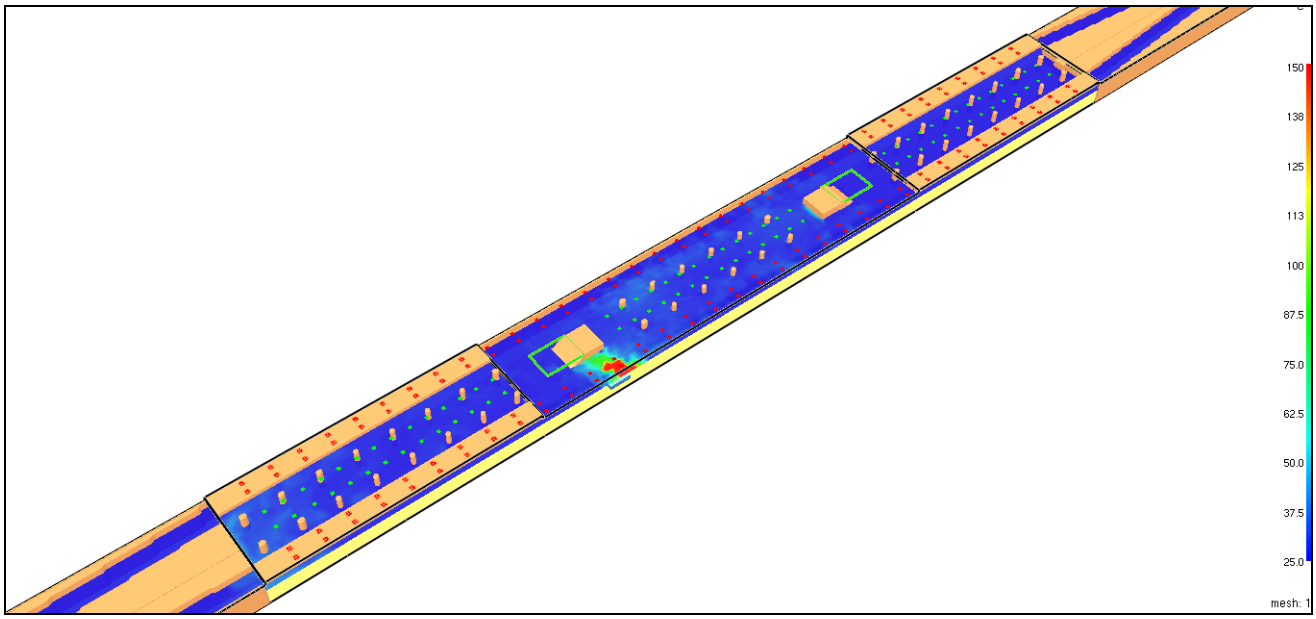

Fig.7 (h) Contours of Temperature in (°C) at 12 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

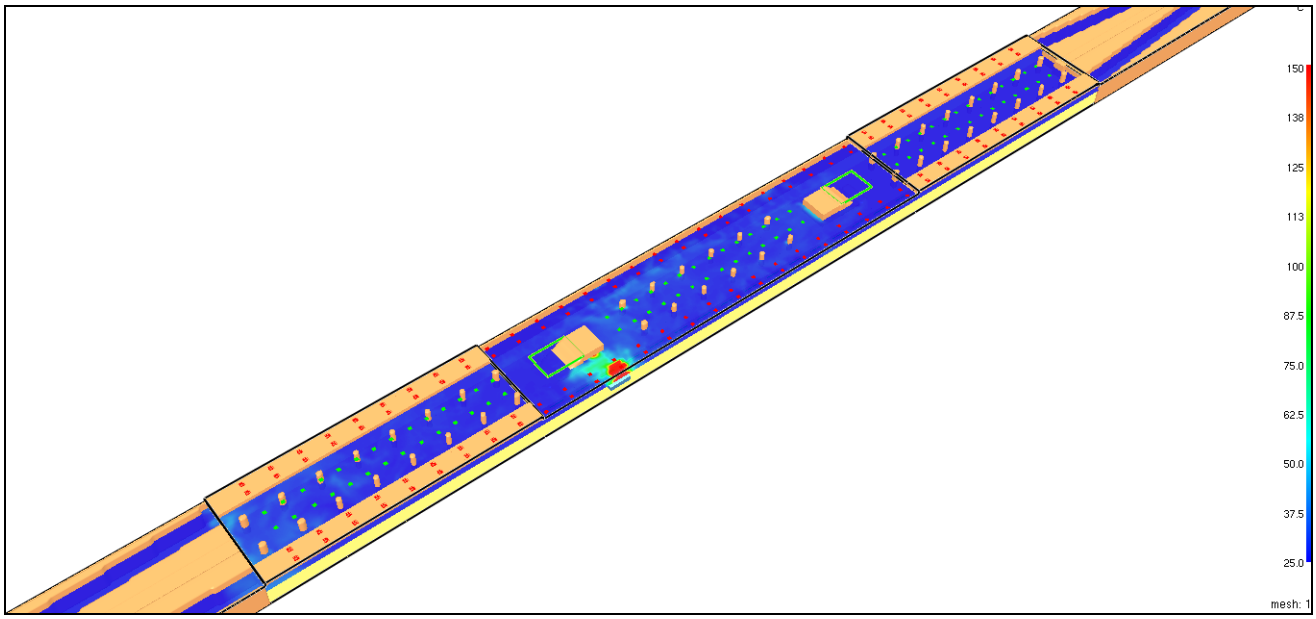

Fig.7 (i) Contours of Temperature in (°C) at 15 minute time in 'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

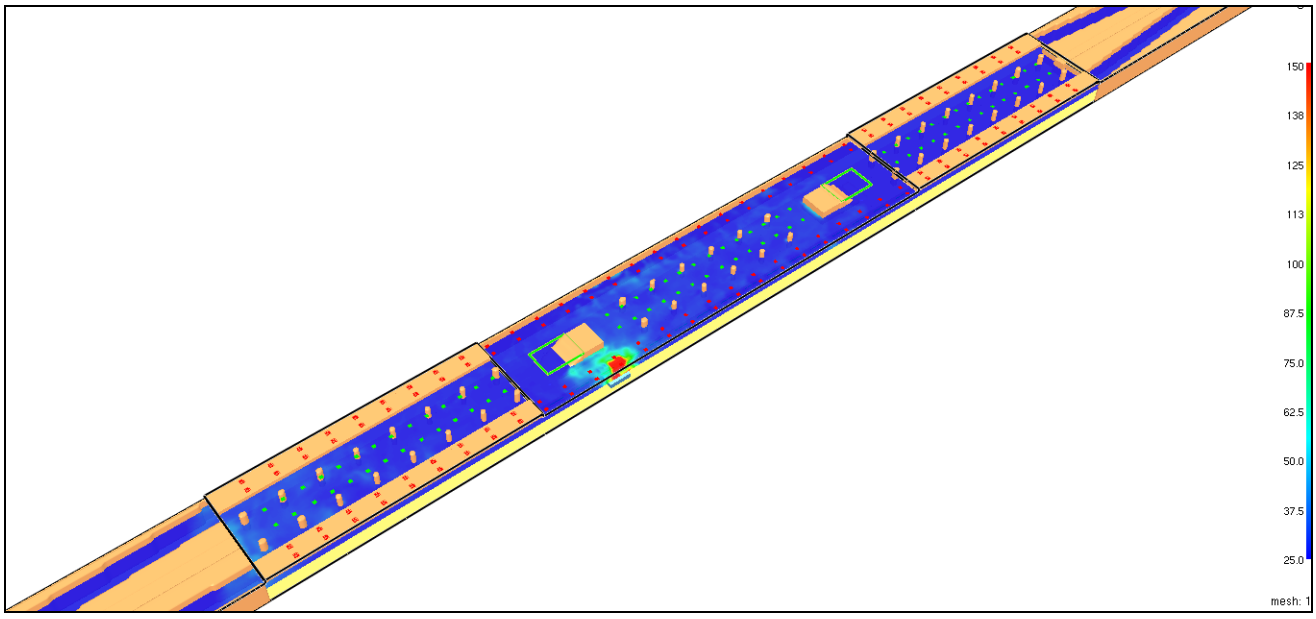

Fig.7 (j) Contours of Temperature in (°C) at 18 minute time in 'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

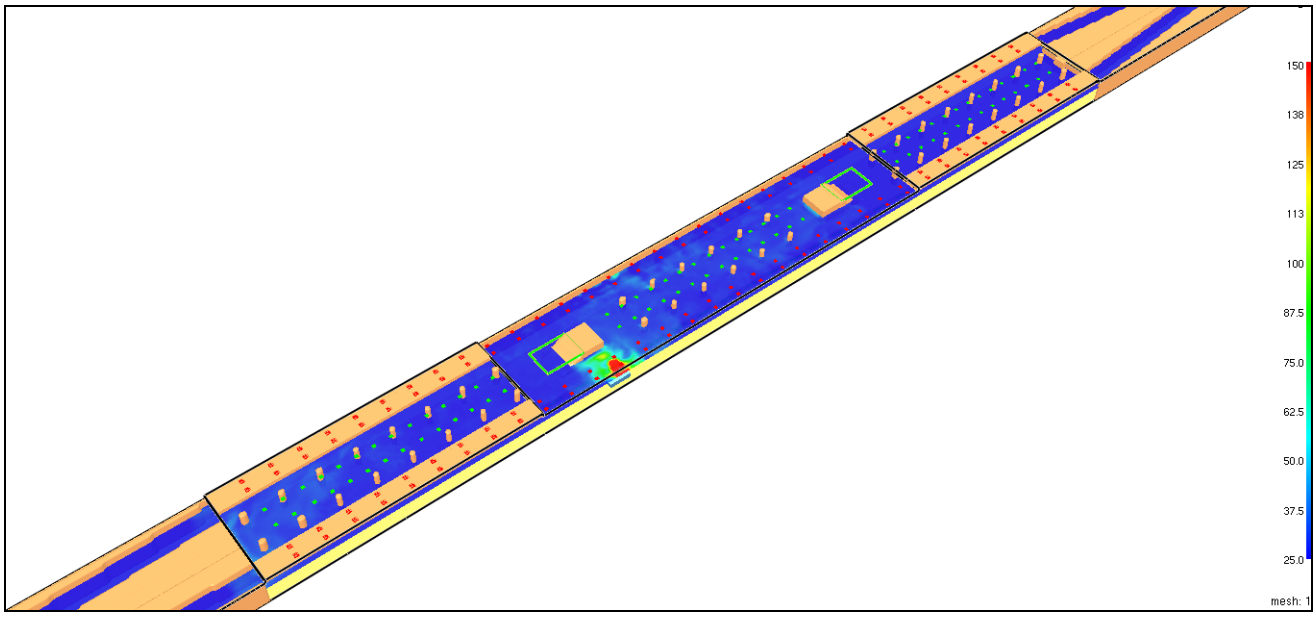

Fig.7 (k) Contours of Temperature in (°C) at 20 minute time in 'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

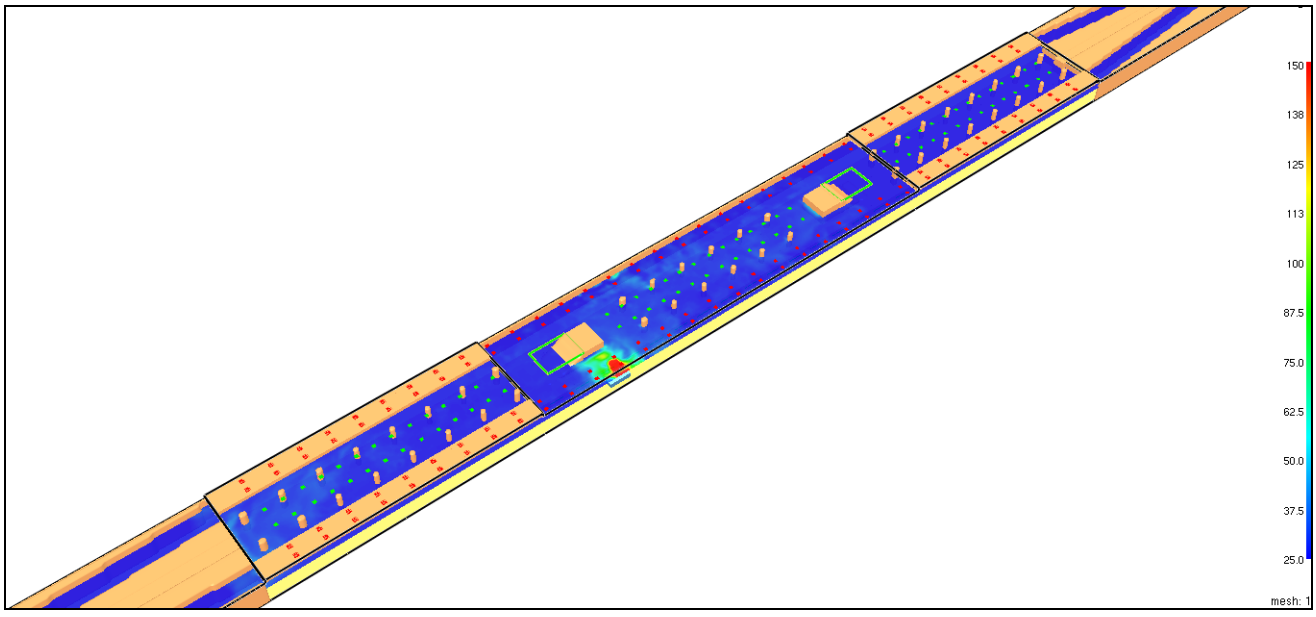

Fig.7 (l) Contours of Temperature in (°C) at 21 minute time in 'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

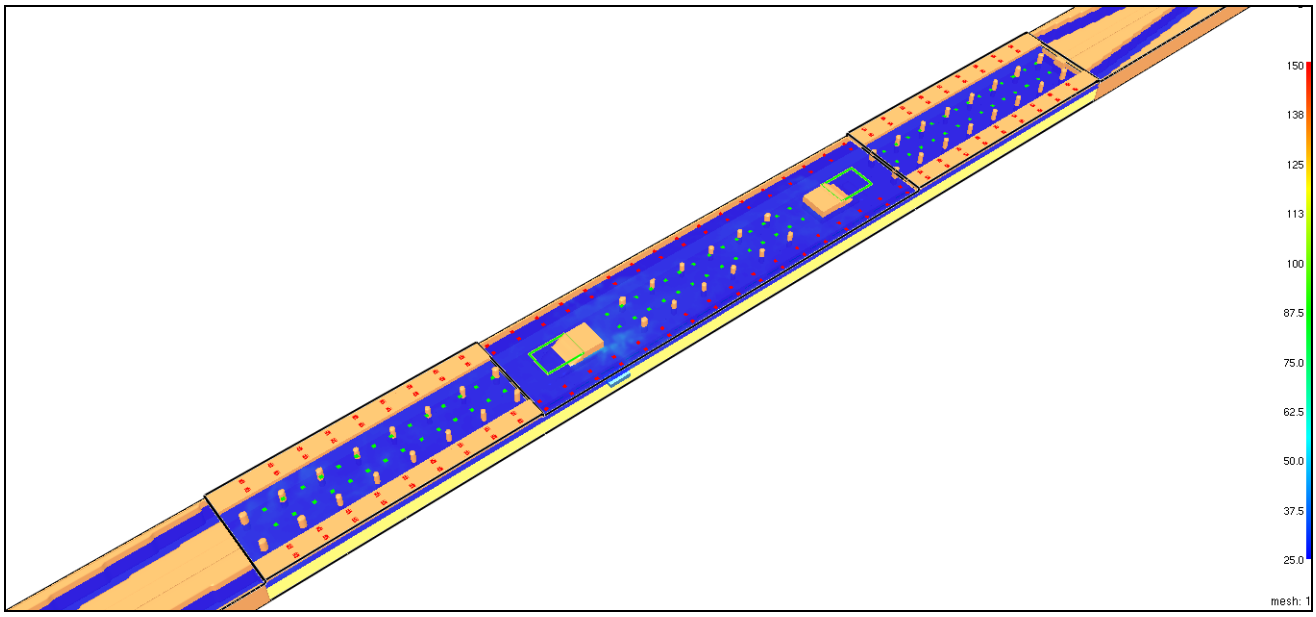

Fig.7 (m) Contours of Temperature in (°C) at 22 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

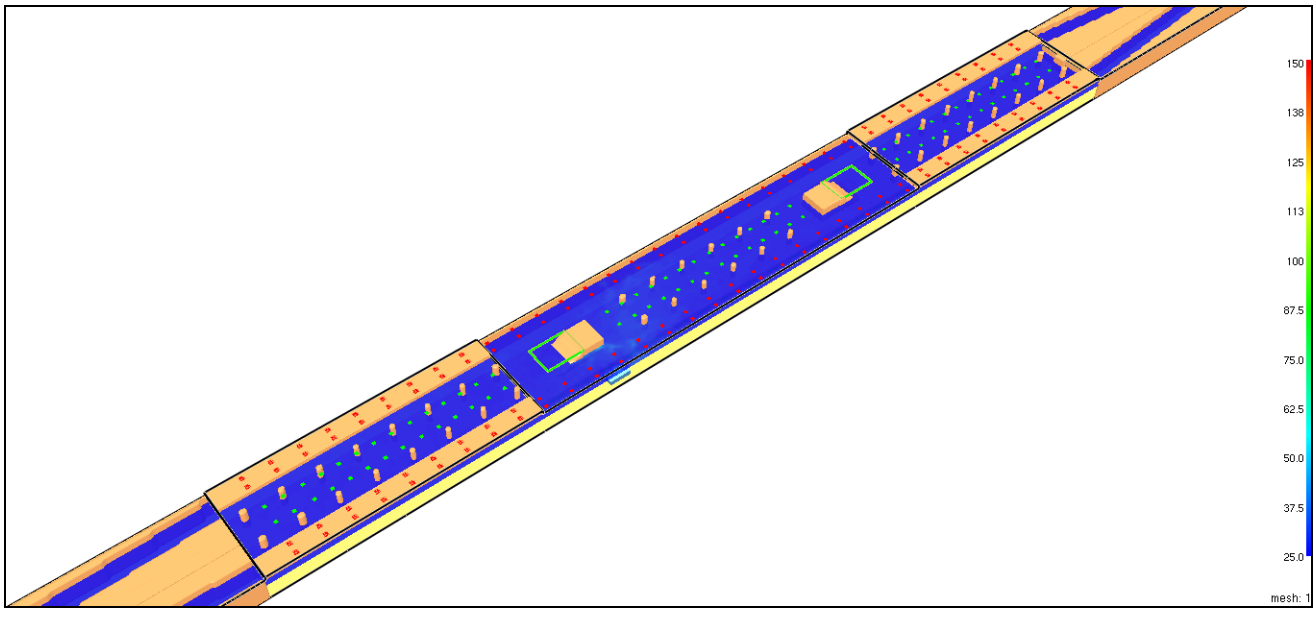

Fig.7 (n) Contours of Temperature in (°C) at 24 minute time in 'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

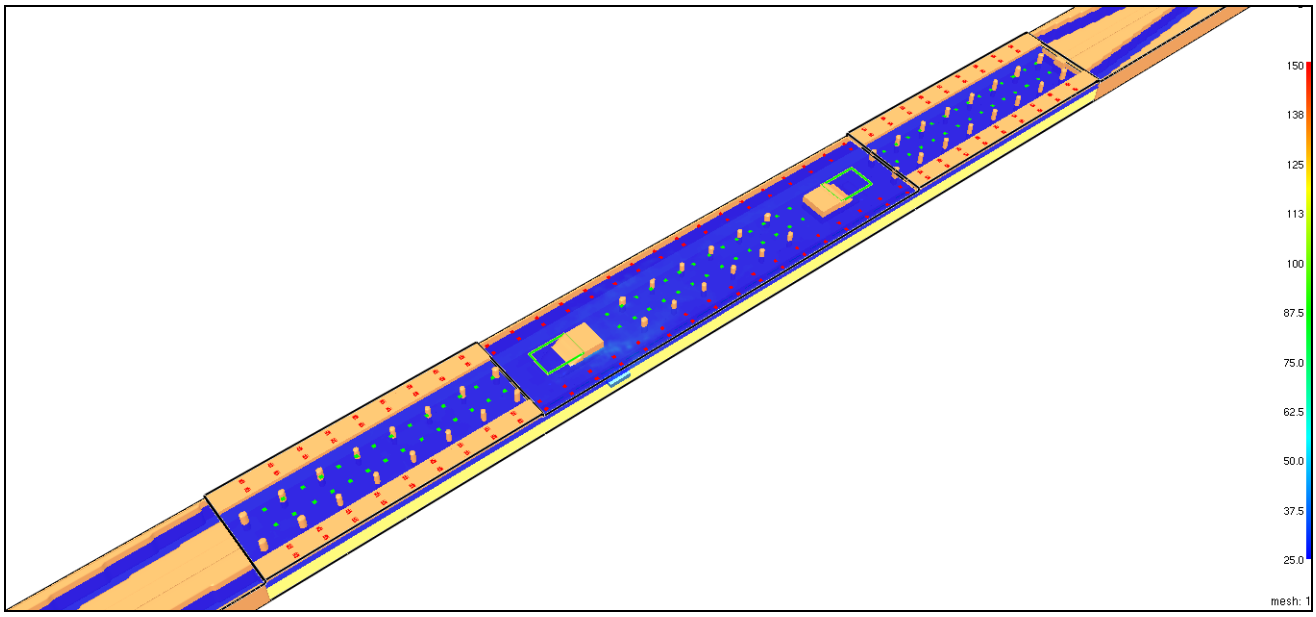

Fig.7 (o) Contours of Temperature in (°C) at 25 minute time in 'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

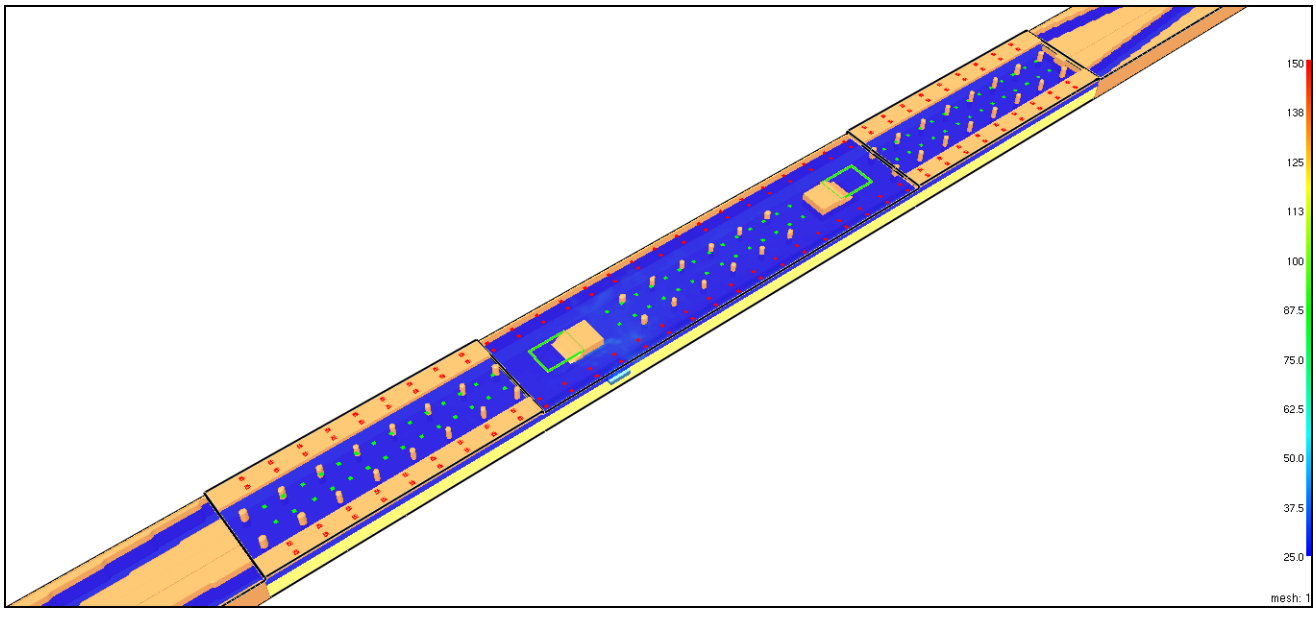

Fig.7 (p) Contours of Temperature in (°C) at 26 minute time in 'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

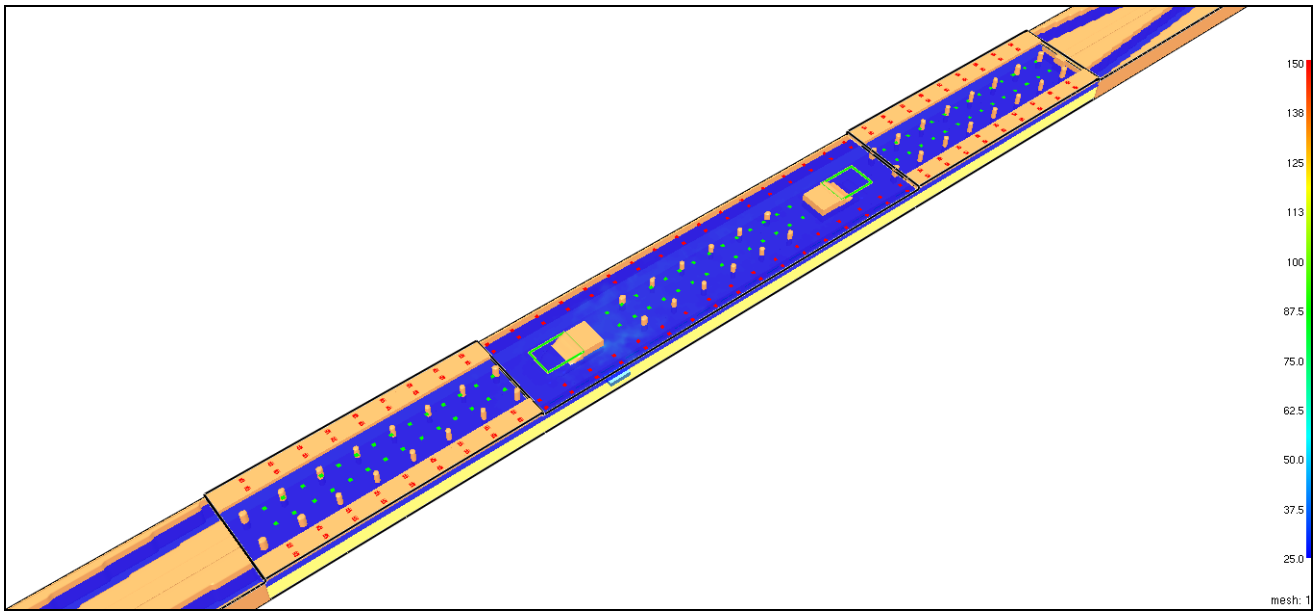

Fig.7 (q) Contours of Temperature in (°C) at 27.5 minute time in
'EMERGENCY VENTILATION SYSTEM DESIGN, METRO RAILWAY KOLKATA'

CONCLUSION

Conclusion

The emergency ventilation system has been designed as per the guidelines and calculations from NBC, NFPA, ASHRAE and BS Standards for emergency and fire protection. The detailed design and its operation can be seen in the chapter above. The scope of this study was the design of emergency ventilation system. This design has been arrived with the consideration that air-conditioned coaches might be introduced in future. Efforts have been made to make minimum changes in the current system and take care of retrofitting limitations.

Once the design of the system is approved by MRK with regard to feasibility of execution, CFD simulations would be conducted using FDS to validate the capacities and design parameters of the final design.

REFERENCES

1) National Building Code (NBC) of India – Bureau of Indian Standards.
2) National Fire Protection Association (NFPA) 130 – 2010 edition Standard for Fixed Guideway Transit and Passenger Rail Systems.
3) American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) Handbook series
4) British Standards (BS) 7346-4:2003
5) Report on Kolkata Metro ventilation studies by IIT Kharagpur.