PROCEDURE FOR CHECKING THE REQIUREMENT REFERRING TO FIRE INSULATION CAPACITY OF A NON–STRUCTURAL WALL FROM THE FIRE COMPARTMENT

D. Diaconu, M. Ibanescu
Universitatea Tehnica "Gh. Asachi" Iasi

INTRODUCTION

The present paper shows the procedure for checking the capacity of a multilayered non-structural wall belonging to the fire compartment to satisfy the required insulation capacity.

The problem involves a complex analysis of a conductive heat transfer in non–stationary state.

The temperature distribution at different, interesting moments and in different, characteristic sections of the element is obtained by using the finite element method. The problem of non–stationary state is solved by using the technique of direct numerical integration, step by step.

1. STRUCTURE AND BOUNDARY CONDITIONS MODELLING

The non–structural wall is made of two layers of reinforced plaster, $0.025m$ in thickness and between them a layer of mineral wool, $0.10m$ in thickness, exists. The element separates two rooms and before the fire eruption the temperature inside them was 15^0C. It can be considered that the temperature over the whole wall thickness is also 15^0C.

The fire eruption in one of the compartments leads to the temperature increasing in the environmental medium, according to the standard curve presented in *ISO 834*. The environmental medium temperature in the next compartment is still 15^0C, at least till the temperature of the wall face, which is not in a direct contact with the fire, gradually changes.

As the conductive heat transfer over the element thickness is of a great interest, a parallelepiped is imaginably cut from the wall thickness. The two end faces are in direct contact with the fired medium and the unfired medium, respectively. The calorific characteristics of the component materials are:

material 1 - plaster reinforced by glass fibers
- coefficient of thermal conductibility

$$\lambda = 0.41W/(m^2\,{}^0C)$$

- specific heat $c_p = 840J/(kg^0C)$
- density $\rho = 1100Kg/m^3$
- product $C = c_p \cdot \rho = 924000\,j/(m^3\,{}^0C)$

material 2 - mineral wool
- coefficient of thermal conductibility $\lambda = 0.04W/(m^2\,{}^0C)$
- specific heat $c_p = 750J/(kg^0C)$
- density $\rho = 115Kg/m^3$
- product $C = c_p \cdot \rho = 86250\,j/(m^3\,{}^0C)$

The boundary conditions on the two faces, in direct contact with the medium, are of Cauchy type, that is, heat exchange by convection, variable in time on one of the faces and constant on the opposite one. The average convection coefficients (according to European Codes) are:
for the fired surface $\alpha = 25W/(m^2\,{}^0C)$ and
for the outer, unfired surface $\alpha = 8W/(m^2\,{}^0C)$.

The finite element method presumes to establish a virtual finite element model in order to simulate the conductive heat transfer. For this simulation both one-dimensional and three-dimensional finite elements can be used. For the reason of imposing boundary conditions of convection type on the end faces, a model that consists of *32* nodes and *7* three–dimensional finite element (*TBRIK*) is adopted (Figure 1).

In order to study the time history of nodes temperature variation, which represents an analysis of a conductive heat transfer in a non–stationary state, the computer program SAPLI (05) is used. It performs this type of analysis by direct numerical integration, step-by-step.

The principal problem in establishing the in put data is the way of expressing the function that describes the variation of fired medium temperature. This problem is generated by the way of conceiving the finite element matrices $[C_e]$ (of element thermal capacity) and $[\lambda_e]$ (of element thermal permeability), that presume the boundary conditions are constant. For other boundary conditions, the element matrices must be

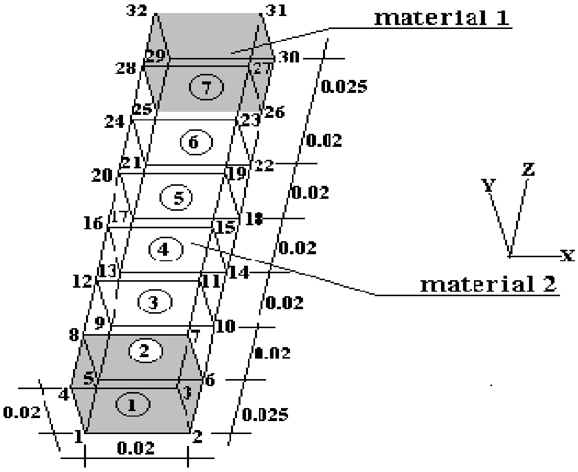

Figure 1. Virtual model of structure.

reevaluated and the computer program must be run once again.

The continuous variation of the temperature of the environmental medium in the fire compartment leads to the change of the function that describes the fired medium temperature variation, so that the boundary conditions to be constant along a longer or a shorter time interval.

The curve for fired medium temperature variation is given by the relation:

$$T = T_o + 345\cdot\log_{10}\cdot(8\cdot t+1) \qquad (1)$$

where T is the temperature in the neighbourhood of the tested element and T_0 is the initial temperature in the compartment.

It results a stepped variation of the fired medium temperature, as shown in Table 1.

Table 1. Variation of the medium temperature

Interval (s)	*Interval limits (min)*	*T (^oC)*	*Moments (min)*
15	0.00-0.25	110	-
30	0.25-0.75	265	-
45	0.75-1.50	365	-
270	1.50-6.00	565	-
360	6.00-12.00	665	-
675	12.00-23.25	765	15
1350	23.25-45.75	865	30
2610	45.75-89.25	965	60
5100	89.2-174.25	1065	90
9945	174.25-340.00	1115	180

This variation assures constant boundary conditions along the whole time interval.Further, for each time interval such a heat transfer analysis is performed, the boundary conditions being constant. The time step, imposed by integration method for each interval, is kept constant, $\Delta t = 1.0s$ and satisfies the safety condition for stability of the algorithm for step-by-step direct integration.

$$\Delta t \le \delta^2/10\cdot\alpha \qquad (2)$$

where Δt is the value of the numerical integration step, α is the thermal diffusivity and δ represents the thermal conductibility length.

At the beginning of each time interval, non–stationary analysed, as initial temperatures are considered the final temperatures from the previous time interval. For the first time interval, the initial temperatures result from the thermal balance, the boundary conditions being those prior to fire

Table 2. Distribution in time of temperatures

Time (min.)	*Section node 1*	*Section node 5*	*Section node 9*	*Section Node 13*	*Section node 17*	*Section node 21*	*Section node 25*	*Section node 29*
0.25	*17.95*	*15.03*	*15.00*	*15.00*	*15.00*	*15.00*	*15.00*	*15.00*
0.75	*31.70*	*15.36*	*15.00*	*15.00*	*15.00*	*15.00*	*15.00*	*15.00*
1.50	*59.53*	*16.74*	*15.04*	*15.00*	*15.00*	*15.00*	*15.00*	*15.00*
6.00	*239.00*	*59.10*	*19.81*	*15.40*	*15.03*	*15.00*	*15.00*	*15.00*
12.00	*388.00*	*155.90*	*44.47*	*19.71*	*15.59*	*15.06*	*15.00*	*15.00*
15.00	*453.20*	*204.70*	*62.23*	*23.91*	*16.03*	*15.08*	*15.00*	*15.00*
23.25	*558.00*	*344.30*	*131.60*	*49.26*	*23.37*	*16.67*	*15.05*	*15.01*
30.00	*651.70*	*441.60*	*191.60*	*77.72*	*33.98*	*19.57*	*15.14*	*15.02*
45.75	*747.00*	*613.20*	*331.70*	*163.60*	*76.78*	*36.40*	*16.34*	*15.47*
60.00	*854.10*	*729.80*	*435.30*	*240.70*	*124.10*	*58.55*	*18.42*	*16.36*
89.25	*915.80*	*853.90*	*589.70*	*379.10*	*223.80*	*112.70*	*27.31*	*21.50*
90.00	*921.80*	*854.30*	*590.90*	*380.90*	*224.60*	*112.90*	*27.70*	*21.40*
174.25	*1043.00*	*1012.00*	*792.50*	*586.00*	*395.90*	*221.60*	*58.50*	*42.51*
180.00	*1066.00*	*1018.00*	*797.40*	*591.70*	*401.00*	*225.10*	*59.67*	*43.27*
340.00	*1099.00*	*1074.00*	*873.50*	*674.00*	*475.90*	*279.50*	*84.44*	*61.34*

2. RESULTS PRESENTATION

The results of the conductive heat transfer analysis for the multi-layered element are presented in Table 2. The nodal temperatures on the same characteristic section are equal; the geometry and the boundary conditions are symmetrical.

References

1. ***Diaconu*, D.**, *Principii si aplicatii in calculul automat al structurilor termodeformabile, Editura "Gh. Asachi", Iasi, 2000.*
2. ***Diaconu*, D.**, *Raspunsul sistemelor structurale la variatii dinamice din temperatura-teza de doctorat, Universitatea Tehnica "Gh. Asachi", Iasi, 1997.*