First Semester Examination
Academic Session 2020/2021

February 2021

EAF525 – Structural Design for Fire Safety

Duration : 2 hours

Please check that this examination paper consists of **FIVE (5)** pages of printed material before you begin the examination.

Instructions : This paper contains **FOUR (4)** questions. Answer **ALL** questions.

Each question **MUST BE** answered on a new page.

(1). (a). A simply supported reinforced concrete slab is subjected to fire as shown in **Figure 1**. The compression zone is not exposed to elevated temperatures, therefore the strength under fire conditions is solely a function of the temperature of the reinforcing steel. Determine the flexural capacity after 60 minutes exposure to standard fire requirements.

Given:

Span of slab	l=6.50 m
Slab thickness	h=200 mm
Concrete density	ρ=24 kN/m^3
Characteristic strength of concrete	f_{ck}=30 MPa
Yield stress	f_{yk}=410 MPa
Diameter of reinforcement	D_b=16 mm
Concrete Cover	C_v=15 mm
Permanent Load	G_1=0.5kN/m (Excluding self-weight)
Variable load	Q=2.5kN/m
Bar spacing	s=125 mm

[25 marks]

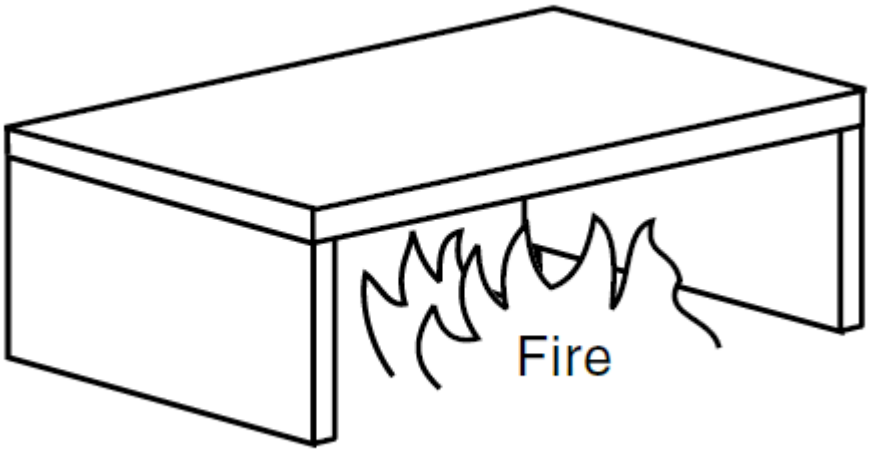

Figure 1: Simply supported reinforced concrete slab exposed to fire

(2). (a). Consider a floor joist of 50 x 250 mm supporting floor boarding of 30 mm with a span of 3 m. The floor joist is using Kempas, SG2 in the category of standard grade and dry condition. Calculate the fire rating of the floor joist. Given the variable load is 5 kN/m^2 and permanent load (including self weight) of 0.4 kN/m^2.

[12 marks]

(b). 6 m long steel beam supporting a concrete slab located in an office building where 60 minutes of fire resistance is required. The floor slab provides full lateral restraint to the compression flange. The steel beam is subject to the standard fire curve. Use the following member properties and loadings. Any assumptions shall be made in accordance with EN 1993-1-1 and EN 1993-1-2.

Member properties,
Section size, 457x152x60UB S275
Cross-section class ambient temperature, Class 1
Cross-section class elevated temperature, Class 1
Plastic modulus, W_{pl} = 1287 cm^3
Steel strength, f_y = 275 Nmm^2
Partial material factor for resistance of cross-section, $\gamma_{M,0}$ = 1.0
Shear area, A = 3031.9 mm^2

Loadings,
Permanent action, G_k = 25 kN/m
Primary variable action, $Q_{k,1}$ = 50 kN/m
Partial factor for permanent action, γ_G = 1.35
Partial factor for primary variable action, γ_G = 1.50
Design load, N_{ED} = 108.75 kN
Maximum bending moment, M_{ED} = 489.38 kNm
Maximum shear force, V_{ED} = 326.25 kN

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Determine,

(i). Design resistance (bending and shear resistance) at ambient temperature.

[4 marks]

(ii). Design loading in fire.

[3 marks]

(iii). Design resistance in fire (calculated at t = 0s and θ_a = 20°C).

[4 marks]

(iv). Degree of utilization and critical temperature.

[2 marks]

(3). Determine the parametric fire curve for a fire compartment in an office building as shown in **Figure 2** in accordance with MS EN 1991-1-2. The floor and ceiling are made from reinforced concrete. The solid brick walls have several openings namely 2 doors and 3 windows. The thermal properties of the walls and floors are given in **Table 1**. The size of each door and window are approximately 2 m^2 and 2.2 m^2, respectively. State any assumptions that are considered in developing the parametric fire curve.

[25 marks]

Table 1: Thermal properties

Part	**Density (kg/m^3)**	**Specific heat ($J\ kg^{-1}\ K^{-1}$)**	**Thermal conductivity ($W\ m^{-1}\ K^{-1}$)**
Floor	2300	840	1.6
Ceiling	2300	840	1.6
Wall	1600	800	1.2

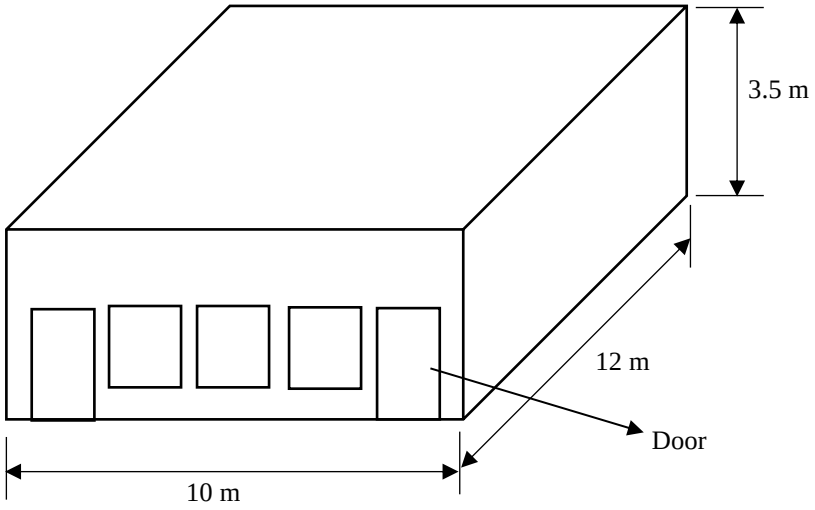

Figure 2

(4). (a). Designing a building having a number of redundant members allows the structure to survive fire without collapse. Discuss this phenomenon with respect to a beam-column connection during a fire event in a building compartment.

[10 marks]

(b). Calculate the fire severity using Eurocode for a 6.0 m × 6.0 m × 3.5 m height reinforced concrete compartment in a building. The compartment has 2 windows 1.2 m × 2.0 m each, a roof opening 1.5 m × 1.5 m and a fire door 1.0 m × 2.1 m. Take the design fire load, $q_{f,d}$ = 700 MJ/m^2, thermal conductivity of concrete, k = 1.5 W/mK, concrete density, ρ = 2400 kg/m^3 and specific heat, c_p = 880 J/kgK. If the standard fire resistance of all structural members is R 60, comment your findings.

[15 marks]

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