STRUCTURAL ENGINEERING

To: Ryan Schultz

From: Luis

Subject: OXApp. Corridor floor sheathing and joists. Fire design.

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1 Floor sheathing

Three layers of 4x8 foot, 19/32 plywood panels are installed as corridor floor sheathing over corridors joists (nominal 3.5 inch wide) spaced 32 inches on center. The panels are installed with the long panel direction (strength axis) perpendicular to the corridor joists. The design loads are:

$$q_{live} = 1.92\ kN/m^2 (40\ psf) \tag{1}$$
$$q_{dead} = 0.72\ kN/m^2 (15\ psf) \tag{2}$$

The allowable live load deflection is span/540 and the allowable total load deflection span/360.

1.1 Structural design of the panels

1.1.1 Mechanical properties of the plywood panel

The mechanical properties used to compute the floor deflection are the elastic modulus $E = 4200\ MPa$ and its thickness $t = 15.09\ mm$ (19/32 inch). Each layer works independently, otherwise said, they are connected only over the joists.

1.1.2 Bending stiffness

The deflection obtained under live load is:

$$\Delta_{LL} = 1.34\ mm = \frac{span}{607} < \frac{span}{540} \implies OK \tag{3}$$

and the deflection under total load is:

$$\Delta_{TL} = 1.84\ mm = \frac{span}{441} < \frac{span}{360} \implies OK \tag{4}$$

1.1.3 Bending strength

The allowable bending stress for the 5-ply plywood panel is $F_b = 4.33\ MPa$ (the panel grade and construction factors are already been applied to this capacity). The load duration factor for the live load on the corridor is $C_D = 1.6$. The adjusted allowable bending stress is therefore $F'_b = 6.94\ MPa$.

The maximum bending stress obtained under total load (three-span condition) is:

$$\sigma_{max} = 1.69\ MPa < 6.94\ MPa = F'_b \implies OK \tag{5}$$

1.1.4 Shear strength

The allowable shear stress of the panel is $F_v = 0.2\ MPa$ and the adjusted allowable shear stress is (under the same conditions that we used for the bending stress) $F'_v = 0.33\ MPa$.

The maximum shear stress obtained under total load is:

$$\tau_{max} = 0.04\ MPa < 0.33\ MPa = F'_v \implies OK \tag{6}$$

1.2 Fire design of the panels

According the table 1 the time assigned to a 19/32 inch panel is 15 minutes, so after 30 minutes of fire only one of the three panels remains in place. Accordingly, we perform the bending and shear checks to the remaining panel.

1.2.1 Bending strength

The maximum bending stress obtained under total load (three-span condition) is:

$$\sigma_{max} = 4.59\ MPa < 6.94\ MPa = F'_b \implies OK \tag{7}$$

1.2.2 Shear strength

The maximum shear stress obtained under total load is:

$$\tau_{max} = 0.12\ MPa < 0.33\ MPa = F'_v \implies OK \tag{8}$$

2 Joists

Simply supported 3.5x6 LVL floor joists span a maximum of $L = 2.49\ m$ (94.25 inches) and are spaced at $s = 0.81\ m$ (32 inches). The design loads are:

$$q_{live} = 1.92\ kN/m^2 (40\ psf) \tag{9}$$
$$q_{dead} = 0.72\ kN/m^2 (15\ psf) \tag{10}$$

Timber decking nailed to the compression edge of the joists provides lateral bracing for at least the same fire resistance time as the joists (i.e. $C_L = 1.0$).

722.6.2 Walls, Floors and Roofs

These procedures apply to both load-bearing and nonload-bearing assemblies.

TABLE 722.6.2(1) TIME ASSIGNED TO WALLBOARD MEMBRANES[a, b, c, d]

DESCRIPTION OF FINISH	TIME[e](minutes)
$^{3}/_{8}$-inch wood structural panel bonded with exterior glue	5
$^{15}/_{32}$-inch wood structural panel bonded with exterior glue	10
$^{19}/_{32}$-inch wood structural panel bonded with exterior glue	15
$^{3}/_{8}$-inch gypsum wallboard	10
$^{1}/_{2}$-inch gypsum wallboard	15
$^{5}/_{8}$-inch gypsum wallboard	30
$^{1}/_{2}$-inch Type X gypsum wallboard	25
$^{5}/_{8}$-inch Type X gypsum wallboard	40
Double $^{3}/_{8}$-inch gypsum wallboard	25
$^{1}/_{2}$-inch + $^{3}/_{8}$-inch gypsum wallboard	35
Double $^{1}/_{2}$-inch gypsum wallboard	40

For SI: 1 inch = 25.4 mm.

Table 1: Time assigned to wallboard membranes

2.1 Structural design of the joist

2.1.1 Loads

$$w_{load} = s \cdot (q_{dead} + q_{live}) = 1.56 \; kN/m \tag{11}$$

2.1.2 Internal forces

Maximum induced moment:

$$M_{max} = w_{load} \frac{L^2}{8} = 1.54 \; kNm \tag{12}$$

Maximum induced shear:

$$V_{max} = w_{load} \frac{L}{2} = 2.57 \; kN \tag{13}$$

2.1.3 Joist mechanical properties

Joist section modulus:

$$S_s = 344.13 \times 10^{-6} \; m^3 \tag{14}$$

Tabulated bending stress:

$$F_b = 21.59 \; MPa \tag{15}$$

Adjusted allowable bending stress with $C_r = 1.0$, $C_D = 1.0$,$C_M = 1.0$, $C_t = 1.0$,$C_V = 0.62$:

$$F_b' = 13.59 \; MPa \tag{16}$$

Tabulated shear stress:

$$F_v = 1.97\ MPa \tag{17}$$

Adjusted allowable shear stress with $C_D = 1.0$,$C_M = 1.0$, $C_t = 1.0$:

$$F_v' = 1.97\ MPa \tag{18}$$

2.1.4 Structural bending check

Design resisting moment:

$$M_s' = 4.67\ kNm \tag{19}$$

Structural bending check: $M_s' = 4.67 > 1.54 = M_{max} \implies OK$

2.1.5 Structural shear check

Design resisting shear:

$$V_s' = 17.74\ kNm \tag{20}$$

Structural shear check: $V_s' = 17.74 > 2.57 = V_{max} \implies OK$

2.2 Fire design of the joist

For the fire design of the joist, mass loss due to charring is conservatively neglected, so the loading is unchanged. Therefore, the maximum induced moment and shear are unchanged. The fire resistance must be calculated.

2.2.1 Mechanical properties of the burned section

Effective char depth:

$$a_{eff} = 0.7 \times 10^{-3} \times 30 + 7 \times 10^{-3} = 28\ mm \tag{21}$$

section modulus for a joist exposed on three sides:

$$S_s = 84.86 \times 10^{-6}\ m^3 \tag{22}$$

shear area for a beam exposed on three sides:

$$A_f = 40.93\ cm^2 \tag{23}$$

Adjusted allowable bending stress with $C_{fire} = 2.85$, $C_r = 1.0$, $C_D = 1.0$,$C_M = 1.0$, $C_t = 1.0$,$C_V = 0.62$:

$$F_{b,f}' = 38.74\ MPa \tag{24}$$

Adjusted allowable shear stress with $C_{fire} = 2.85$, $C_D = 1.0$,$C_M = 1.0$, $C_t = 1.0$:

$$F_{v,f}' = 5.40\ MPa \tag{25}$$

2.2.2 Structural bending check

Design resisting moment:

$$M_f' = 3.28\ kNm \tag{26}$$

Structural bending check: $M_s' = 3.28 > 1.54 = M_{max} \implies OK$

2.2.3 Structural shear check

Design resisting shear:

$$V_f' = 14.74\ kNm \tag{27}$$

Structural shear check: $V_s' = 14.74 > 2.57 = V_{max} \implies OK$