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Article

Structural Design for Pressure- And Temperature-Resistant Buildings

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Abstract. Loads from explosions differ from seismic and wind loads due to their greater severity, continuity, rapidity, and thermal extremity. That is, explosions cause massive structural damage by exposing surrounding structures to extremely high pressure and temperature. Thus, structures at risk of explosive damage must be stronger than typical buildings in withstanding both ordinary loads and the additional pressure and temperature loads caused. Explosion-resistant structures are required in the petrochemical industry, explosive armories, power stations, and gas storage facilities, among others. This study aims to examine the structural performance of a building subject to three types of loads: (1) the pressure of 300 bars, (2) the temperature of 300 °C, and (3) the pressure of 300 bars combined with the temperature of 300 °C. The research analyzes three primary reinforced structures, namely columns, beams, and slabs, in terms of the parameters resulting from each scenario to determine a set of criteria for designing the structural components of explosion-resistant buildings.

Keywords: Pressure load, temperature load, pressure- and temperature-resistant buildings.

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1. Introduction

Designing residential buildings in Thailand generally involves the utilization of space and aesthetics as well as fulfilment of the standards and requirements stipulated in the 2522 B.E. Building Control Act. However, some structures at risk of explosions, such as buildings in the petrochemical industry [1], explosive armories [2], power stations [3-4], gas storage facilities [1, 5], and energy research centres [6], must also be designed to resist the additional loads resulting from explosive pressure [7] and temperature [8], to prevent collapse, and ultimately to safeguard life and property. To this end, their design must account for not only dead loads (DLs) [9-12] and live loads (LLs) [9-12], but also blast load (BLs) [13]. Since BLs [13] consist of pressure loads, temperature loads, and combined pressure and temperature loads, they are more severe and occur in exponentially smaller time-windows than either seismic or seasonal wind loads [14-15].

This study focuses on designing explosion-resistant buildings [1] that can ensure the safety of life and property. Its results will provide guidelines for designing constructions susceptible to explosions. The three primary structures under study, namely columns, beams, and slabs, form the structural components of a building prototype designed for the petrochemical industry where the mixing of gases, such as N_2, H_2, H_2S, CO_2, O_2, LPG, LNG, and He, takes place. The building houses the common processes and equipment shown in Fig. 1.1.

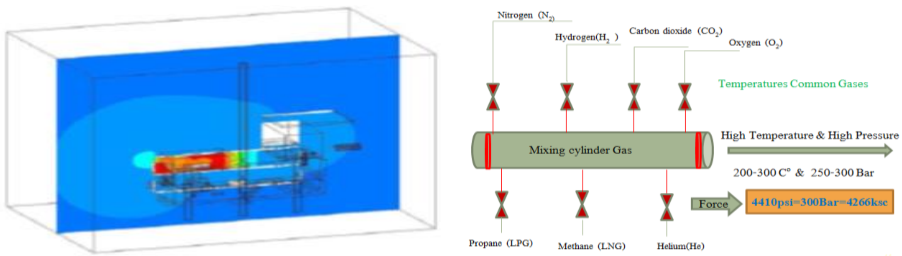

Fig. 1.1. Gas mixing cylinder.

With regards to the characteristics of potential explosions in the building from the ground floor of building, the pressure travels from the bottom to the top and decreases gradually. In addition, the radius of explosions becomes larger, as shown in Fig. 1.2.

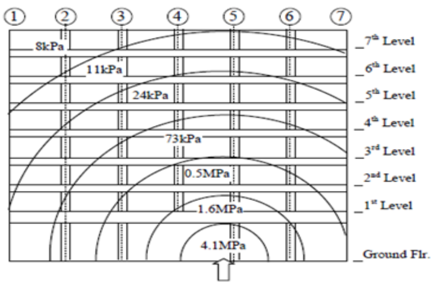

Fig. 1.2. Internal blasts [16].

The pattern of explosive loads is a high and complex pressure expanding in every direction consisting of the pressure from blast waves and reflected waves. Therefore, wall ventilators installed in the construction can reduce severity rates from blasts, as shown in Fig. 1.3 [1, 17].

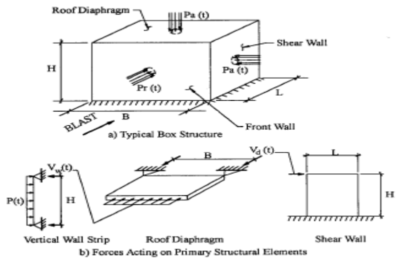

Fig. 1.3. Effects of ventilators on internal blasts [1].

Outside of the building sits the equipment used for gas storage and high-pressure control, as shown in Fig. 1.4. This area is designated as a hazardous or safety alert zone [18].

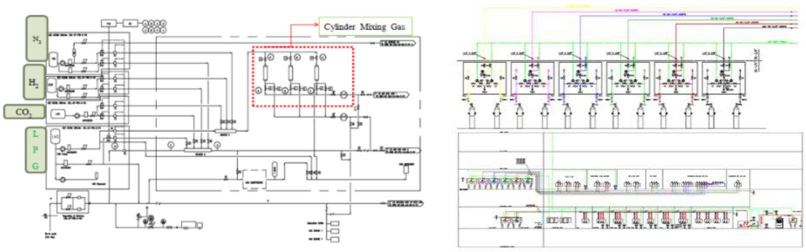

Fig. 1.4. Equipment installed outside the building.

Explosive severity depends on the distance from the sources of blasts, as shown in Fig. 1.5 [5, 19].

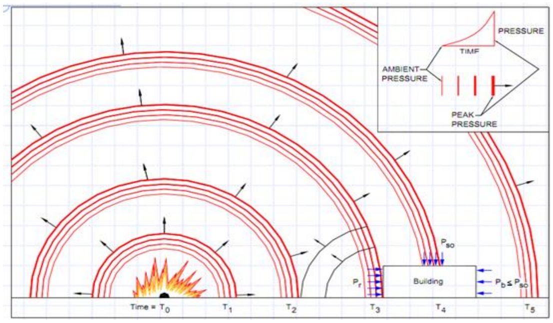

Fig. 1.5. Externals blasts [5].

Figure 1.5 shows the characteristics of external blasts and pressure wave expansion. To determine the scaled distance (Z), the following equation is used [16]: R is the actual effective distance from the explosion. W is generally expressed in kilograms. Scaling laws provide parametric correlations between a particular explosion and a standard charge of the same substance

$$Z = R/W^{1/3} \tag{1}$$

$Z > 10$ $\quad$ *Far Field Blast*
$3 < Z < 10$ $\quad$ *Near Fild Blast*
$Z < 3$ $\quad$ *Close − in Blast*
$W = Mass\ of\ the\ explosion$
$R = Distance\ from\ the\ detonation\ source$

For extensive charts for predicting blast pressures and blast durations Ratio of explosive mass to distance from the detonation source as shown in Table 1.1.

Table 1.1. Ratio of explosive mass to distance from the detonation source [16].

R \ W	100 kg TNT	500 kg TNT	1000 kg TNT	2000 kg TNT
1m	165.8	354.5	464.5	602.9
2.5m	34.2	89.4	130.8	188.4
5 m	6.65	24.8	39.5	60.19
10m	0.85	4.25	8.15	14.7
15m	0.27	1.25	2.53	5.01
20m	0.14	0.54	1.06	2.13
25m	0.09	0.29	0.55	1.08
30m	0.06	0.19	0.33	0.63

The pressure caused by explosions will flow up through the atmosphere until reaching a peak P_{so}, referred to as the positive phase, and will then flow back through the atmosphere to the point underneath it $-P_{so}$, referred to as the negative phase, as shown in Fig. 1.6 [1]. This cycle will repeat until there is no pressure left.

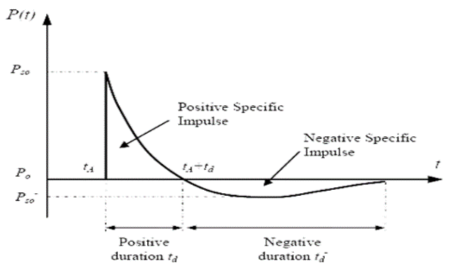

Fig. 1.6. Relationships between explosive duration and pressure [1, 20].

$$I_0 = \int_0^{td} P(t)dt \tag{2}$$

$$= 0.5P_{so}t_d, for\ a\ triangular\ wave$$
$$= 0.64P_{so}t_d, for\ a\ half - sine\ wave$$
$$= cP_{so}t_d, for\ an\ exponentially\ decaying\ shock\ wave$$

where:

$I_0 = Phase\ Impulse$
$P(t) = Overpressure\ function\ with\ respect\ to\ time$
$P_{so} = Peak, or\ incident, side - on\ overpressure$
$t_d = Duration\ of\ the\ positive\ phase$
$c =\ A\ value\ between\ 0.2\ and\ 0.5\ depending\ on\ P_{so}$

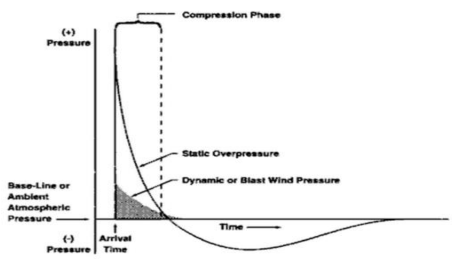

Fig. 1.7. Relationships between the negative phase and vibration waves [1, 20].

Before the negative phase, the pressure increases, and the compressed air causes a shockwave. During this period, the pressure is a dynamic waveform expanding in a circular pattern. The wave characterizing an explosion is referred to as a shock load, which is a vibration wave [20].

Since fuel is a high-temperature hydrocarbon affecting the strength requirements of a building, the structural components of the construction need to be considered in conjunction with the temperature generated from the combustion of a blast. The thermal resistance characteristics of steel and concrete are shown in Table 1.2.

Table 1.2. Comparison of the strength of concrete and steel.

Properties	**Mild Steel**	**Concrete**
Mass per unit kg (m^3)	7850	2400
Elastic modulus (ksc)	2100000	200000
Thermal resistance (°C)	250-550	300-600
Lifespan (y)	10-20	30-50
Compressive strength (ksc)	3500-5000	200-500
Tensile strength (ksc)	3500-5000	0-50

Table 1.2 shows that steel is less resistant to heat than concrete, whereas concrete is less resistant to strain than steel. The relationships between temperature and steel strength are shown in Fig. 1.8 [21].

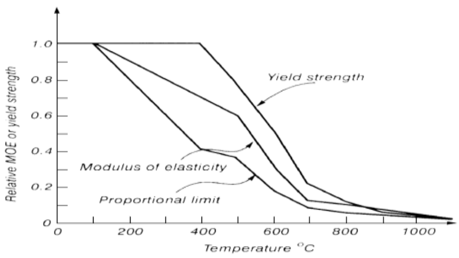

Fig. 1.8. Relationships between temperature and steel strength [21].

For concrete, a rise in temperature will decrease its strength, as shown in Fig. 1.9. As the temperature rises, concrete will expand, which in turn increases its strain percentage and lowers its strength, causing the material to collapse [21].

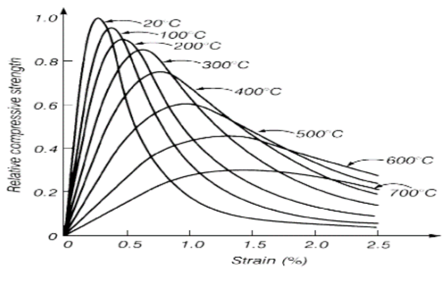

Fig. 1.9. Relationships between temperature and strain percentage [21].

2. Designing a Building That Can Resist the Pressure Load of 300 Bars

Figure 2.1 shows a model of the test building, whose dimensions are 40.00 m x 30.00 m x 22.00 m.

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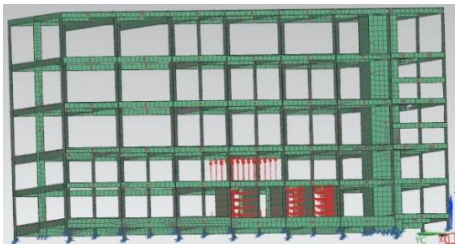

Fig. 2.1. Model of the pressure-resistant building.

The specifications of the building designed to resist the pressure load of 300 bars include the dimensions of rooms and details of the building components with the columns, beams, and slabs being the primary structural components affected by the pressure loads, as shown in Fig. 2.1.

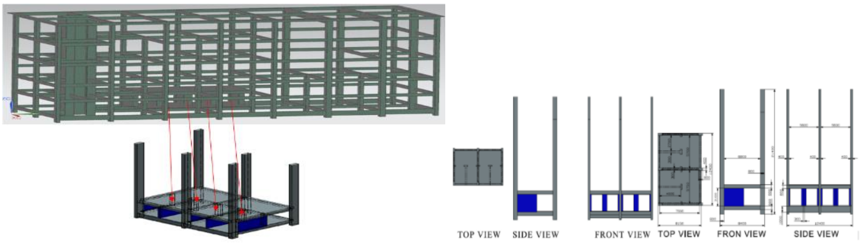

Fig. 2.2. Floor plan of the test building.

As shown in Fig. 2.2, four rooms were used to test the pressure load of 300 bars. Their dimensions were 8.00 m x 6.00 m x 4.00 m. The pressure load not only affected all the rooms, as shown in Fig. 2.3, but also caused the maximum reaction force and moment to the columns, as shown in Table 2.1.

Table 2.1. Maximum reaction force and moment caused to the columns.

Column pressure load of 300 bars	
Items	**Columns**
Reaction force (N)	43704296
Reaction moment (N-mm)	7259233280

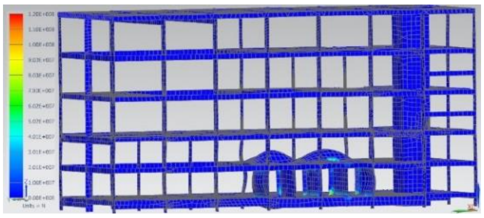

Fig. 2.3. Pressure load of 300 bars.

The columns in the test rooms were 4.00 m in length, as shown in Fig. 2.4.

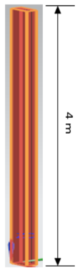

Fig. 2.4. Design of the columns used in the pressure-resistant building.

The columns' cross-sectional areas and the reinforced steel bars used are shown in Fig. 2.5.

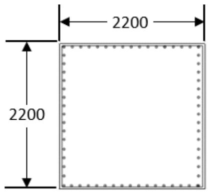

Fig. 2.5. Design of the columns' cross-sectional areas and the reinforced steel bars.

The requirements for designing the pressure-resistant columns are shown in Table 2.2.

Table 2.2. Column design requirements for the pressure load of 300 bars.

No.	Column details	Design requirements
1	Column dimensions (m)	2.20 x 2.20
2	Column length, H (m)	4.00
3	Main bars (mm)	68-DB32
4	Stirrup (m)	1-RB6@0.288
5	Concrete covering (m)	0.05
6	Yield stress, f_y (ksc)	4000
7	Elastic modulus of steel, E_s (ksc)	2040000
8	Compressive stress of concrete, f_c' (ksc)	380
9	Elastic modulus of concrete, E_c (ksc)	294353.18

The beam length of 5.00 m in the rooms used for testing the pressure load of 300 bars, as shown in Fig. 2.6, caused the maximum reaction force and moment to the beams, as shown in Table 2.3.

Table 2.3. Maximum reaction force and moment caused to the beams.

Beam pressure load of 300 bars	
Items	**Beams**
Reaction force (N)	83746000
Reaction moment (N-mm)	4326300000

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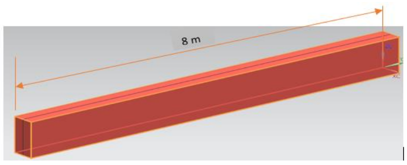

Fig. 2.6. Design of the beams used in the pressure-resistant building.

The beams' cross-sectional areas and the reinforced steel bars used are shown in Fig. 2.7.

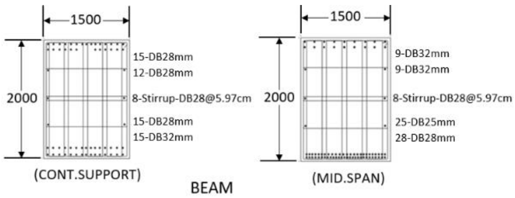

Fig. 2.7. Designs of the beams' cross-sectional areas and the reinforced steel bars

The requirements for designing the pressure-resistant beams are shown in Table 2.4.

Table 2.4. Beam design requirements for the pressure load of 300 bars.

No.	**Beam details**	**Design requirements**
1	Beam dimensions (m)	1.50 x 2.00
2	Beam length, H (m)	8.00
3	Main bars (mm)	15-DB28,12-DB28,15-DB28,15-DB32 9-DB32,9-DB32,25-DB25,28-DB28
4	Stirrup (cm)	8-DB28@5.97
5	Concrete covering (m)	0.05
6	Yield stress, f_y (ksc)	5000
7	Elastic modulus of steel, E_s (ksc)	2040000
8	Compressive stress of concrete, f_c' (ksc)	320
9	Elastic modulus of concrete, E_c (ksc)	270117

The slab dimensions of 8.00 m x 6.00 m in the rooms used for testing the pressure load of 300 bars, as shown in Fig. 2.8, caused the maximum reaction force and moment to the slabs, as shown in Table 2.5.

Table 2.5. Maximum reaction force and moment caused to the slabs.

Slab pressure load of 300 bars	
Items	**Slabs**
Reaction force (N)	72967000
Reaction moment (N-mm)	607430000

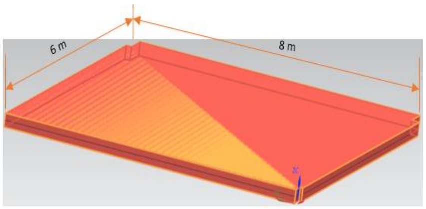

Fig. 2.8. Design of the slabs used in the pressure-resistant building.

The slabs' cross-sectional areas and the reinforced steel bars used are shown in Fig. 2.9.

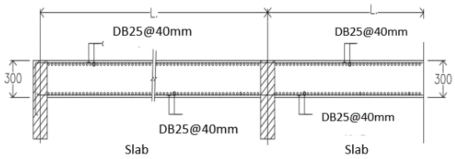

Fig. 2.9. Design of the slabs' cross-sectional areas and the reinforced steel bars.

The requirements for designing the pressure-resistant slabs are shown in Table 2.6.

Table 2.6. Slab design requirements for the pressure load of 300 bars.

No.	Slab details	Design requirements
1	Slab dimensions (m)	8.00 x 6.00
2	Slab thickness (cm)	30
3	Main bars (mm)	DB25@40
4	Concrete covering (cm)	2.5
5	Yield stress, f_y (ksc)	4000
6	Elastic modulus of steel, E_s (ksc)	2040000
7	Compressive stress of concrete, f_c' (ksc)	280
8	Elastic modulus of concrete, E_c (ksc)	270117

3. Designing a Building That Can Resist the Temperature Load of 300 °C

Figure 3.1 shows a model of the test building, whose dimensions are 40.00 m x 30.00 m x 22.00 m.

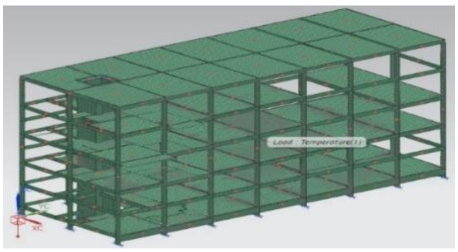

Fig. 3.1. Model of the temperature-resistant building.

The specifications of the building designed to resist the temperature load of 300 °C include the dimensions of rooms and details of the building components with the columns, beams, and slabs being the primary structural components affected by the temperature loads, as shown in Fig. 3.2.

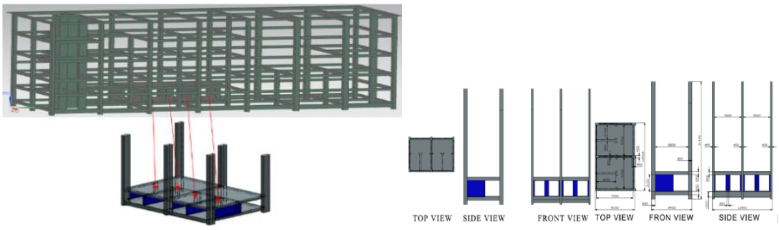

Fig. 3.2. Floor plan of the test building.

As shown in Fig. 3.2, four rooms were used to test the temperature load of 300 °C. Their dimensions were 8.00 m x 6.00 m x 4.00 m. The temperature was controlled at a constant level throughout the building. The temperature load not only affected all the rooms and caused a temperature rise throughout the building, as shown in Fig. 3.3, but also caused the maximum reaction force and moment to the columns, as shown in Table 3.1.

Table 3.1. Maximum reaction force and moment caused to the columns.

Column temperature load of 300 °C	
Items	**Columns**
Reaction force (N)	2431292.75
Reaction moment (N-mm)	18412986

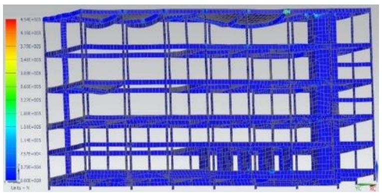

Fig. 3.3. Temperature load of 300 °C.

The columns in the test rooms were 4.00 m in length, as shown in Fig. 3.4.

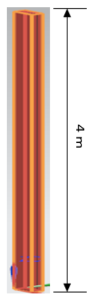

Fig. 3.4. Design of the columns used in the temperature-resistant building.

The columns' cross-sectional areas and the reinforced steel bars used are shown in Fig. 3.5.

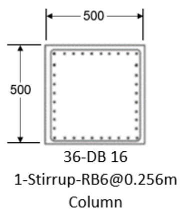

Fig. 3.5. Design of the columns' cross-sectional areas and the reinforced steel bars.

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The requirements for designing the temperature-resistant columns are shown in Table 3.2.

Table 3.2. Column design requirements for the temperature load of 300 °C.

No.	Column details	Design requirements
1	Column dimensions (m)	0.50 x 0.50
2	Column length, H (m)	4.00
3	Main bars (mm)	36-DB16
4	Stirrup (m)	1-RB6@0.256
5	Concrete covering (m)	0.05
6	Yield stress, f_y (ksc)	2400
7	Elastic modulus of steel, E_s (ksc)	2040000
8	Compressive stress of concrete, f_c' (ksc)	380
9	Elastic modulus of concrete, E_c (ksc)	296498

The beam length of 8.00 m in the rooms used for testing the temperature load of 300 °C, as shown in Fig. 3.6, caused the maximum reaction force and moment to the beams, as shown in Table 3.3.

Table 3.3. Maximum reaction force and moment caused to the beams.

Beam temperature load of 300 °C	
Items	**Beams**
Reaction force (N)	1156800
Reaction moment (N-mm)	62675000

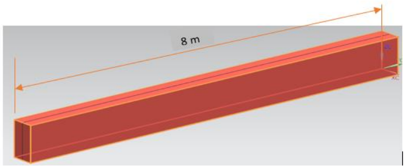

Fig. 3.6. Design of the beams used in the temperature-resistant building.

The beams' cross-sectional areas and the reinforced steel bars used are shown in Fig. 3.7.

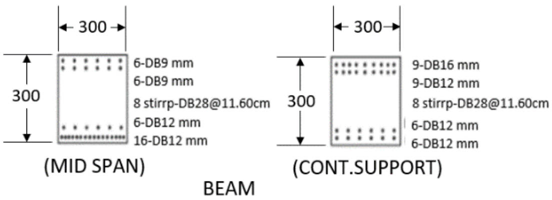

Fig. 3.7. Designs of the beams' cross-sectional areas and the reinforced steel bars.

The requirements for designing the temperature-resistant beams are shown in Table 3.4.

Table 3.4. Beam design requirements for the temperature load of 300 °C.

No.	Beam details	Design requirements
1	Beam dimensions (m)	0.30 x 0.30
2	Beam length, H (m)	8.00
3	Main bars (mm)	6-DB9,6-DB9, 6-DB12,16-DB12 9-DB16,9-DB12, 6-DB9,6-DB9
4	Stirrup (cm)	8-DB28@11.60
5	Concrete covering (m)	0.05
6	Yield stress, f_y (ksc)	2400
7	Elastic modulus of steel, E_s (ksc)	2040000
8	Compressive stress of concrete, f_c' (ksc)	320
9	Elastic modulus of concrete, E_c (ksc)	272085

The slab dimensions of 8.00 m x 6.00 m in the rooms for testing the temperature load of 300 °C, as shown in Fig. 3.8, caused the maximum reaction force and moment to the slabs, as shown in Table 3.5.

Table 3.5. Maximum reaction force and moment caused to the slabs.

Slab temperature loads at 300 °C	
Items	**Slabs**
Reaction force (N)	465620
Reaction moment (N-mm)	62675000

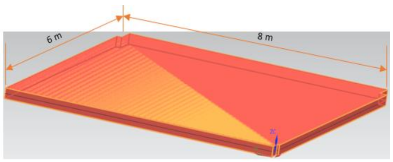

Fig. 3.8. Design of the slabs used in the temperature-resistant building.

The slabs' cross-sectional areas and the reinforced steel bars used are shown in Fig. 3.9.

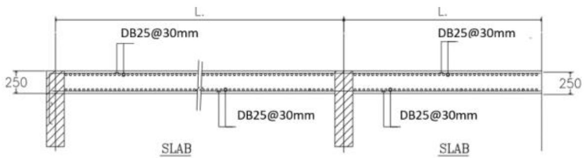

Fig. 3.9. Design of the slabs' cross-sectional areas and the reinforced steel bars.

The requirements for designing the temperature-resistant slabs are shown in Table 3.6.

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Table 3.6. Slab design requirements for the temperature load of 300 °C.

No.	Slab details	Design requirements
1	Slab dimensions (m)	8.00 x 6.00
2	Slab thickness (cm)	25.00
3	Main Bars (mm)	DB25@30
4	Concrete covering (cm)	0.05
5	Yield stress, (ksc)	2400
6	Elastic modulus of steel, (ksc)	2040000
7	Compressive stress of concrete, (ksc)	240
8	Elastic modulus of concrete, (ksc)	235632

4. Designing a Building That Can Resist the Pressure Load of 300 Bars and the Temperature Load of 300 °C

Figure 4.1 shows a model of the pressure- and temperature-resistant building, whose dimensions are 40.00 m x 30.00 m x 22.00 m.

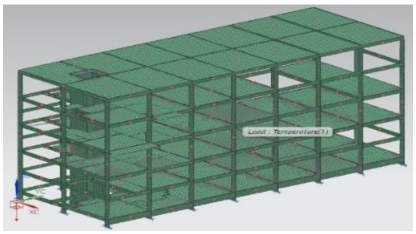

Fig. 4.1. Model of the pressure- and temperature-resistant building.

The specifications of the test building designed to resist the pressure load of 300 bars and the temperature load of 300 °C include the dimensions of rooms and details of the building components with the columns, beams, and slabs being the primary structural components affected by the pressure and temperature loads, as shown in Fig. 4.2.

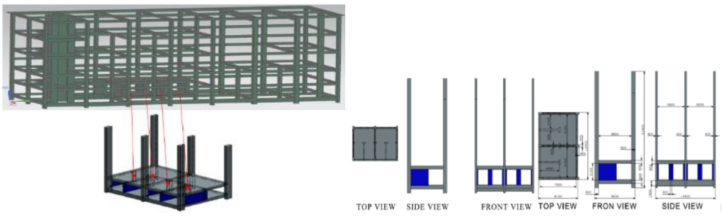

Fig. 4.2. Floor plan of the building exposed to pressure and thermal loads.

As shown in Fig. 4.2, four rooms were used to test the pressure load of 300 bars and the temperature load of 300 °C. Their dimensions were 8.00 m x 6.00 m x 4.00 m. The combined pressure and temperature loads not only affected all the rooms, as shown in Fig. 4.3, but also caused the maximum reaction force and moment to the columns, as shown in Table 4.1.

Table 4.1. Maximum reaction force and moment caused to the columns.

Combined column pressure load of 300 bars and temperature load of 300 °C	
Items	**Columns**
Reaction force (N)	46135588.75
Reaction moment (N-mm)	7277646266

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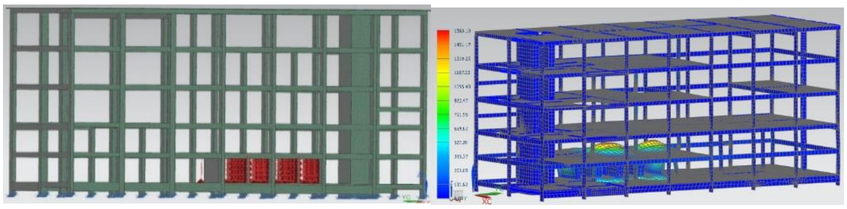

Fig. 4.3. Combined pressure load of 300 bars and temperature load of 300 °C.

The columns in the rooms were 4 m in length, as shown in Fig. 4.4.

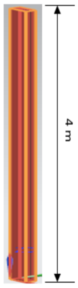

Fig. 4.4. Design of the columns used in the pressure- and temperature-resistant building.

The columns' cross-sectional areas and the reinforced steel bars used are shown in Fig. 4.5.

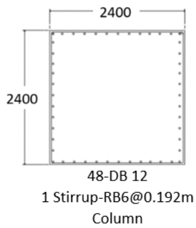

Fig. 4.5. Design of the columns' cross-sectional areas and the reinforced steel bars.

The requirements for designing the pressure- and temperature-resistant columns are shown in Table 4.2.

Table 4.2. Column design requirements for the pressure load of 300 bars and the temperature load of 300 °C.

No.	Column details	Design requirements
1	Column dimensions (m)	2.40 x 2.40
2	Column length, H (m)	4 .00
3	Main bars (mm)	48-DB12
4	Stirrup (m)	1-RB6@0.192
5	Concrete covering (m)	0.05
6	Yield stress, f_y (ksc)	4000
7	Elastic modulus of steel, E_s (ksc)	2040000
8	Compressive stress of concrete, f_c' (ksc)	380
9	Elastic modulus of concrete, E_c (ksc)	296498

The beam length of 8.00 m in the rooms used for testing the pressure load of 300 bars and the temperature load of 300 °C, as shown in Fig. 4.6, caused the maximum reaction force and moment to the beams, as shown in Table 4.3.

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Table 4.3. Maximum reaction force and moment caused to the beams.

Combined beam pressure load of 300 bars and temperature load of 300 °C	
Items	**Beams**
Reaction force (N)	84902800
Reaction moment (N-mm)	4388975000

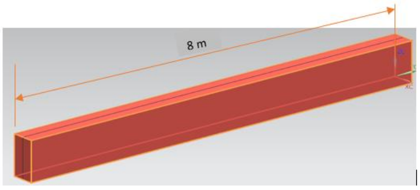

Fig. 4.6. Design of the beams used in the pressure- and temperature-resistant building.

The beams' cross-sectional areas and the reinforced steel bars used are shown in Fig. 4.7.

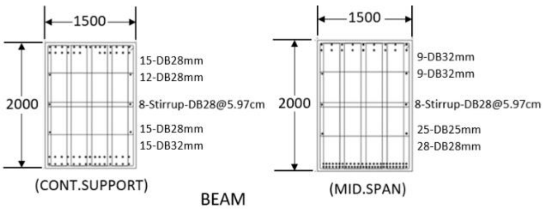

Fig. 4.7. Design of the beams' cross-sectional areas and the reinforced steel bars.

The requirements for designing the pressure- and temperature-resistant beams are shown in Table 4.4.

Table 4.4. Beam design requirements for the pressure load of 300 bars and the temperature load of 300 °C.

No.	Beam details	Design requirements
1	Beam dimensions (m)	1.50 x 2.00
2	Beam length, H (m)	8 .00
3	Main bars (mm)	15-DB28,12-DB28, 15-DB28,15-DB32 9-DB32,9-DB32, 25-DB25,28-DB28
4	Stirrup (cm)	8-DB28@5.97
5	Concrete covering (m)	0.05
6	Yield stress, f_y (ksc)	5000
7	Elastic modulus of steel, E_s (ksc)	2040000
8	Compressive stress of concrete, f_c' (ksc)	320
9	Elastic modulus of concrete, E_c (ksc)	272085

The slab dimensions of 8.00 m x 6.00 m in the rooms used for testing the pressure load of 300 bars and the temperature load of 300 °C, as shown in Fig. 4.8, caused the maximum reaction force and moment to the slabs, as shown in Table 4.5.

Table 4.5. Maximum reaction force and moment caused to the slabs.

Combined slab pressure load of 300 bars and temperature load of 300 °C	
Items	**Slabs**
Reaction force (N)	73432620
Reaction moment (N-mm)	670105000

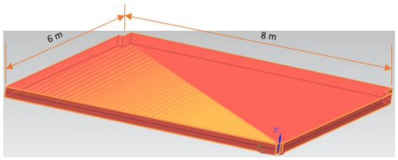

Fig. 4.8. Design of the slabs used in the pressure- and temperature-resistant building.

The slabs' cross-sectional areas and the reinforced steel bars used are shown in Fig. 4.9.

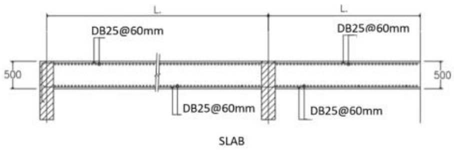

Fig. 4.9. Design of the slabs' cross-sectional areas and the reinforced steel bars.

The requirements for designing the pressure- and temperature-resistant slabs are shown in Table 4.6.

Table 4.6. Slab design requirements for the pressure load of 300 bars and the temperature load of 300 °C.

No.	Slab details	Design requirements
1	Slab dimensions (m)	8.00 x 6 .00
2	Slab thickness (cm)	50.00
3	Main bars (mm)	DB25@60
4	Concrete covering (cm)	0.05
5	Yield stress, f_y (ksc)	4000
6	Elastic modulus of steel, E_s (ksc)	2040000
7	Compressive stress of concrete, f_c' (ksc)	280
8	Elastic modulus of concrete, E_c (ksc)	254512

5. Summary

The structure design for pressure and temperature-resistant building. As followed ACI 318-08 of building structure design standard code with column, beam and slab

5.1 Table 5.1 shows the results of the three structural design tests on the columns: the high-pressure (HP) test (300 bars), the high-temperature (HT) test (300 °C), and the high-pressure/high-temperature (HP/HT) test (300 bars and 300 °C).

Table 5.1. Comparison of the structural properties of the columns.

Items	HP test	HT test	HP/HT test
Reaction force (N)	43704296	2431292.75	46135588.75
Reaction moment (N-mm)	7259233280	18412986	7277646266
Dimensions of columns' cross-sectional areas (m)	2.20 x 2.20	0.50 x 0.50	2.40 x 2.40
Compressive stress of concrete f_c'(ksc)	380	380	380
Yield stress of steel bars f_y(ksc)	4000	2400	4000

The columns' cross-sectional areas and the reinforced steel bars used for the HP, HT, and HP/HT tests are shown in Fig. 5.1.

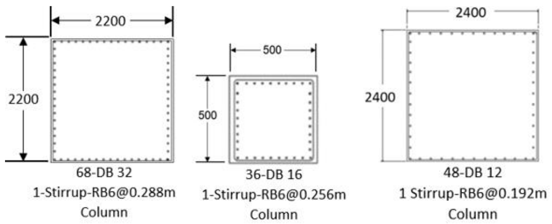

Fig. 5.1. Designs of the columns' cross-sectional areas and the reinforced steel bars.

Table 5.2 shows the results of the three structural design tests on the beams: the high-pressure (HP) test (300 bars), the high-temperature (HT) test (300 °C), and the high-pressure/high-temperature (HP/HT) test (300 bars and 300 °C).

Table 5.2. Comparison of the structural properties of the beams.

Items	HP test	HT test	HP/HT test
Reaction force (N)	83,746,000	1,156,800	84,902,800
Reaction moment (N-mm)	4,326,300,000	62,675,000	4,388,975,000
Dimensions of beams' cross-sectional areas (m)	1.50 x 2.00	0.30 x 0.30	1.50 x 2.00
Compressive stress of concrete f_c' (ksc)	320	320	320
Yield stress of steel bars f_y (ksc)	5000	2400	5000

The beams' cross-sectional areas and the reinforced steel bars used for the HP, HT, and HP/HT tests are shown in Fig. 5.2.

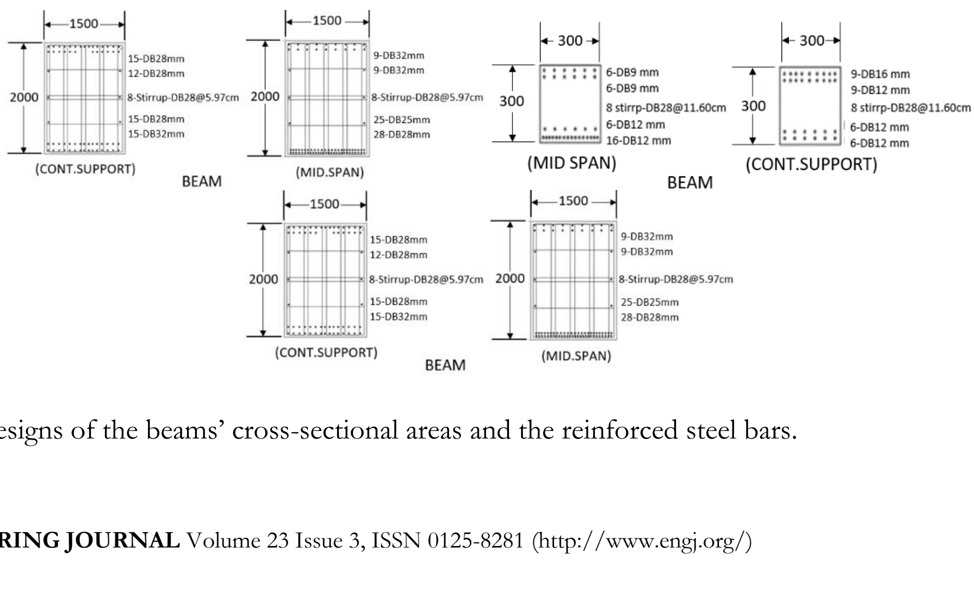

Fig. 5.2. Designs of the beams' cross-sectional areas and the reinforced steel bars.

Table 5.3 shows the results of the three structural design tests on the slabs: the high-pressure (HP) test (300 bars), the high-temperature (HT) test (300 °C), and the high-pressure/high-temperature (HP/HT) test (300 bars and 300 °C).

Table 5.3. Comparison of the structural properties of the slabs.

Items	HP test	HT test	HP/HT test
Reaction force (N)	72,967,000	465,620	73,432,620
Reaction moment (N-mm)	607,430,000	62,675,000	670,105,000
Dimensions of slabs' cross-sectional area (m)	8.00 x 6.00 x 0.30	8.00 x 6.00 x 0.25	8.00 x 6.00 x 0.50
Compressive stress of concrete f_c' (ksc)	280	240	280
Yield stress of steel bar f_y (ksc)	4000	2400	4000

The slabs' cross-sectional areas and the reinforced steel bars used for the HP, HT, and HP/HT tests are shown in Fig. 5.3.

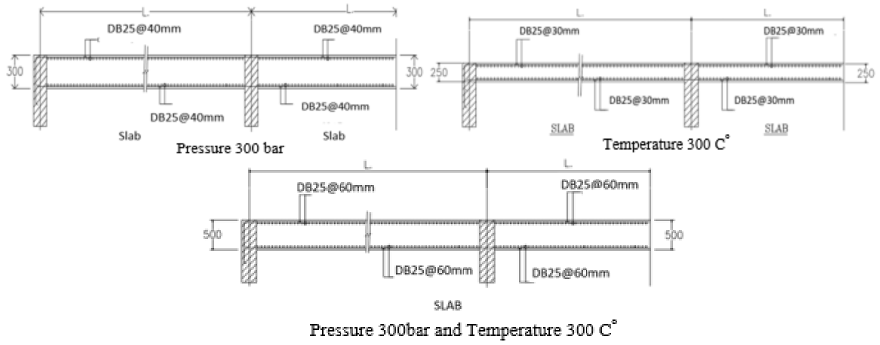

Fig. 5.3. Designs of the slabs' cross-sectional areas and the reinforced steel bars.

6. Conclusions

It can be concluded from the present findings that (1) pressure loads on structures are greater than temperature loads, (2) the cross-sectional areas and the hardness of structural components, such as concrete and reinforced steel bars, affect their pressure and thermal resistance, (3) the dimensions of buildings constitute vital factors in the design of their structural components, and (4) pressure from explosions is generally greater than the load allowances of buildings. These parameters must therefore be taken into consideration in designing pressure- and temperature-resistant buildings.

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