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THE TEACHING BUILDING OF YINGCAI MIDDLE SCHOOL

Akmal Alfarisy Bustami[1,*] , Baoxin Qi[2]
School of Civil Engineering [1] , School of Civil Engineering [2]
Koresponden*, Email: *akmalab3105@gmail.com*, Email : *13072474390@qq.com*

ABSTRACT

Nama proyek ini adalah "Gedung Pengajaran Sekolah Menengah Yingcai". Proyek ini berlokasi di Shenyang, China. Luas area proyek mencakup 1365,54 m² dan luas bangunan 4096,62 m². Bangunan ini memiliki tiga lantai dengan tinggi 13,05 m, termasuk tinggi dinding atap 1,0 m. Perbedaan tinggi antara lantai dalam dan luar adalah 0,45 m. Bangunan ini berbentuk "L" dengan panjang 68,5 m dan lebar 25,8 m. Fasad bangunan menggunakan ubin berpola bata keramik. Semua dinding luar bangunan menggunakan bahan isolasi untuk menjaga kehangatan selama musim dingin yang ekstrem di Shenyang, China. Semua dinding interior menggunakan blok beton kecil berongga 200 mm sebagai partisi antar ruangan. Proyek ini memilih rangka beton bertulang sebagai bentuk strukturnya. Semua kolom menggunakan beton dengan kekuatan C30 dan ukuran penampang 600 x 600 mm. Balok rangka juga menggunakan beton kekuatan C30, dengan variasi ukuran penampang balok, yaitu balok longitudinal 700 x 300 mm, balok melintang 600 x 300 mm dan 550 x 300 mm, serta balok sekunder 500 x 250 mm. Kondisi tanah di lokasi proyek cukup baik, sehingga pondasi mandiri di bawah kolom digunakan dengan beton kekuatan C30. Spesifikasi desain proyek ini didasarkan pada kode dan regulasi di China. Spesifikasi tersebut mencakup perhitungan beban gravitasi, analisis gaya dalam akibat aksi gempa horizontal (metode nilai D), analisis gaya dalam akibat beban angin (metode nilai D), analisis gaya dalam akibat beban vertikal (metode distribusi momen sekunder), kombinasi beban, perkuatan rangka, perkuatan pelat, perkuatan tangga, dan perkuatan pondasi. Semua perhitungan spesifikasi desain hanya dilakukan pada sumbu 4.

Kata kunci : gedung pengajaran sekolah, desain struktural, beton bertulang, pondasi mandiri.

ABSTRACT

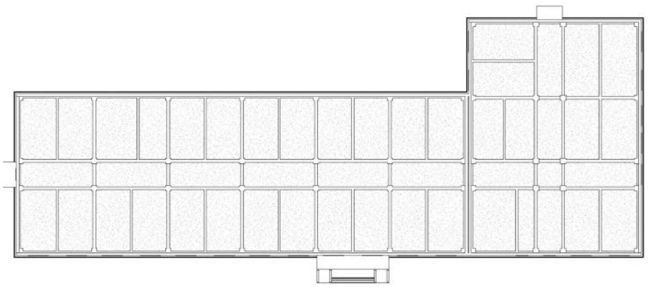
The project name is "The Teaching Building of Yingcai Middle School". The project is located in Shenyang, China. The project area cover 1365.54 m2 and construction area cover 4096.62 m2. The building has three floor 13.05 m height, include 1.0 m roof parapet height. The height different of indoor and outdoor is 0.45 m. The building is "L" shape with 68.5 m length and 25.8 m width. The building using ceramic brick pattern tiles as the facade. All the exterior wall building use insulation material to make warm during the extreme winter in Shenyang, China. All of interior wall use 200 mm concrete small hollow block as the partition between rooms. The project select reinforcement concrete frame as the structure form. All the column are using C30 concrete strength grade, 600 x 600 mm section size. Frame beam also using C30 concrete strength grade, the section of the beam are varieties, longitudinal beam 700 x 300 mm, transverse beam 600 x 300 mm and 550 x 300 mm, secondary beam 500 x 250 mm. The soil condition of the project is good, thus independent foundation under column is used with C30 concrete strength. The design specification of the project is based on the code and regulation in China. The specification include the calculation of representative of gravity load, internal force analysis under the action of horizontal seismic action (D value method), internal force analysis under the action of wind load (D value method), internal force analysis under the vertical load (secondary moment distribution method), load combination, frame reinforcement, slab reinforcement, stairs reinforcement, and foundation reinforcement. All the design specification calculations are only at axis 4.

***Keywords** : school teaching building, structural design, reinforced concrete, independent foundation.*

1. INTRODUCTION

The name of the project is “The Teaching Building of Yingcai Middle School”. The project is located in Shenyang, China. The area of the project cover area around 1365.54 m^2 and the construction area around 4096.62 m^2. The building is three-storey cast-in-situ frame reinforced concrete. The height of the building 13.05 m. The building length is 68.5 m and the width is 25.8 m. Difference elevation between outdoor and indoor is 0.45. The roof use 1.0 m high of parapet cast-in-situ concrete. The facade of the building is from ceramic brick pattern tiles give it a gorgeous look. The layout of the building are made as symmetrical as possible. Design on the basis of the design plan descriptions of the graduation project class of 2024, with the provision of the state of the design code, a variety of architectural design, building structure data sets, and other related information. Figure 1 shown the plane design of the building.

Based on the intended use of the school building, the construction scale and standards determine the types of rooms required. These include classroom, teacher’s room, staff’s room, lecture hall, conference room, small library, small laboratory, and bathrooms. Rooms are arranged along a 3.0-meter wide corridor (or a minimum of 1.8 meters if the corridor is longer than 40 meters and has rooms on both sides). The first floor features a main entrance and two side entrances and two staircases to ensure efficient evacuation. The building's design cleverly integrates two sections into a cohesive whole, enhancing connectivity for both horizontal and vertical movement, as shown in figure 1. Every floor has ten classrooms, two bathrooms and one storage room, teacher’s room and staff’s room are located in first floor. A small library, a small laboratory, and conference room are in second floor. The third floor has a lecture hall with the total area of 153.09 m^2. Rooms are rectangular with a length-to-width ratio not exceeding 2:1, except for lecture hall and storage room.



The specification plan of the school building are listed below.

Roof	20	mm	1:3 cement mortar screed-coat
	4	mm	SBS waterproof coil
	20	mm	1:3 cement mortar screed-coat
	100	mm	Rock wool sandwich composite board insulation layer
	20	mm	1:3 cement mortar screed-coat
	120	mm	The thinnest place of cement cinder slope, I = 2%, 120 average, 30 mm is the thinnest
	120	mm	Reinforced concrete slab
Floor	20	mm	Marble floor
	20	mm	1:3 cement mortar screed-coat
	120	mm	Reinforced concrete slab
Ground	20	mm	Marble floor
	20	mm	1:3 cement mortar screed-coat
	60	mm	Slag cushion
			Element of soil compaction
Toilet			Brick on the ground
	20	mm	1:3 cement mortar screed-coat
	2	mm	Waterproofing agent
	15	mm	Cement mortar leveling
	120	mm	Reinforced concrete slab
Outdoor steps			Granite stone
	30	mm	1:3 cement mortar screed-coat
	100	mm	Cast-in-place reinforced concrete slab
	300	mm	Coarse sand cushion
Exterior wall	20	mm	Ceramic tile
	30	mm	1:3 cement mortar screed-coat
	100	mm	Rock wool sandwich composite board insulation layer

	300	mm	Concrete small hollow block Mb7.5 cement mortar masonry
	20	mm	Mixed mortar plaster
Interior wall	20	mm	Mixed mortar plaster
	200	mm	Concrete small hollow block Mb7.5 mixed mortar masonry
	20	mm	Mixed mortar plaster

The building planning design gives full consideration to construction, safety, economy, and aesthetics. First, the building's function is considered. Every building is designed for a specific purpose and must meet specific requirements. This school building design takes into account insulation and soundproofing needs. For example, to keep the building warm in Shenyang's winter, it uses 300 mm thick concrete hollow blocks and 100 mm thick steel mesh rock wool panels. To address heat dissipation, the facade uses materials that cool well. For soundproofing, 200mm thick concrete hollow blocks are used for interior walls.

Next, the materials are considered. Materials are essential for the construction's technical and practical aspects. The choice of materials influences the construction plan. This school building design uses common materials like C15 and C30 concrete and HRB335 and HRB400 steel. These materials are readily available and reliable. The construction techniques, such as using rock wool boards and cast-in-place reinforced concrete, are efficient and well-established.

Environmental factors are also considered. The design must fit the local climate. Shenyang has a cold climate and reach up to -25oC in winter, so the building needs good insulation, frost protection, and moisture prevention. The building uses rock wool panels for the roof and walls, and the building's layout is compact for better heat retention.

Economic factors are important too. Construction requires significant investment, so cost efficiency is crucial. The design balances quality and cost, using economical materials like cast-in-place reinforced concrete. This approach ensures the building is both cost-effective and high-quality. Overall planning is considered, the building's layout should harmonize with the surroundings and provide good lighting and ventilation. The final layout is an "L" shape, which fits well with the site. From an aesthetic perspective, the building should be pleasing to look at. Unlike brick structures with limited window options, this design uses large windows, making the building appear open and light. In conclusion, this school building design meets the basic requirements of architectural design and graduation design specification of requirements, considering functionality, safety, economy, and aesthetics.

2. METHOD

D value method on the basis of the inflection point method for resistance to lateral stiffness of column and the inflection point height modification, more precise. Interlaminar shear distribution to the layer of each pillar, namely the shear of pillars; Again by the shear and inflection point pillar, pillar height obtained from top to bottom end bending moment. Finally according to node bending moment equilibrium condition, the nodes around the sum of the bending moment at the end of the up and down according to the beam stiffness ratio of beam end bending moment distribution obtained.

The I layer for the j column shear :

$$V_{ij} = \frac{D_{ij}}{\sum D_i} V_i \quad \text{.............(i)}$$

$$yh = (y_0 + y_1 + y_2 + y_3)h$$

$$M_{c\ upper} = V_{ij}(1 - y)h$$

$$M_{c\ lower} = V_{ij}yh$$

y	-	Inflection point height ratio of the D value method.
y_0	-	Standard height than inflection point, according to the form, the action of horizontal loading, the total number of piles in the layer position, and the beam stiffness ratio. Look the table to determine y_0.
y_1	-	Up and down the beam stiffness ratio affect the revised, look the table to determine y_1.
y_2	-	The upper storey height h_u changes affect the revised accord $\alpha_2=\frac{h_u}{h}$, $\overline{K}$, look the table to determine y_2.
y_3		The upper storey height h_u changes affect the revised accord $\alpha_3=\frac{h_l}{h}$, $\overline{K}$, look the table to determine y_3.

Table 1 Middle frame, side column. Correction inflection point height ratio. (A D axis)

Floor	h (m)	$\overline{K}$	y_0	y_1	y_2	y_3	y
3	3.6	0.522	0.311	0	0	0	0.311

2	3.6	0.522	0.489	0	0	0	0.489
1	4.85	0.703	0.699	0	0	0	0.699

Internal force diagram under horizontal earthquake action within the framework

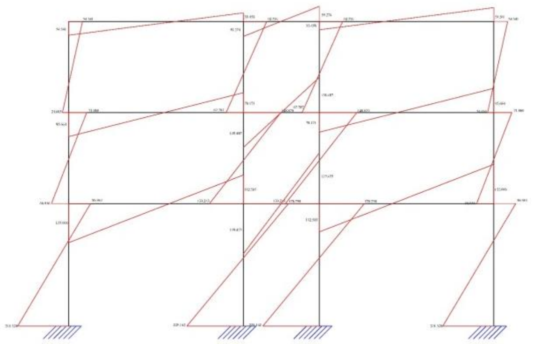
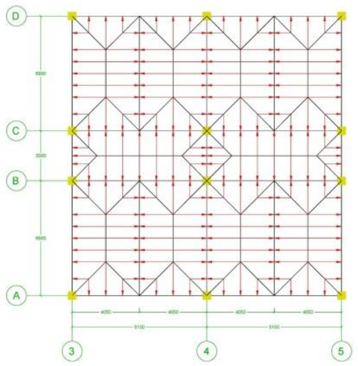


Figure 1 Bending moment diagram under the action of horizontal earthquake

Vertical Load Calculation. Take the axis 4 transverse frame to calculate. The width is 6.90 m.

1. **Load transverse route**



2. **Dead load**

(1) Beam weight :
Side frame : 25 x 0.60 x 0.30 = 4.5 KN/m
Middle frame : 25 x 0.55 x 0.30 = 4.125 KN/m

(2) Plate load transfer :
AB, CD side frame : 4.05 m x 6.90 m, two way slab, to transverse frame beam trapezoidal load. Reduction factor $1 - 2\alpha^2 + \alpha^3$

$$\alpha = \frac{0.5a}{b} = \frac{0.5 \text{ x } 4.05}{6.90} = 0.293$$

Reduction factor $= 1 - 2 \text{ x } 0.293^2 + 0.293^3 = 0.853$

BC middle frame : 3.00 m x 8.10 m, two way slab, to transverse frame beam triangular load. Reduction factor 0.625

(3) Line load standard values of roof beam
Total roof weight = 6.8 KN/m
AB, CD side frame : g_1 = 6.8 x 4.05 x 0.853 + 4.5 = 27.992 KN/m
BC middle frame : g_2 = 6.8 x 3.00 x 0.625 + 4.125 = 16.875 KN/m

(4) Line load standard values of floor beam
Total floor weight = 4.05 KN/m
AB, CD side frame : g_3 = 4.05 x 4.05 x 0.853 + 4.5 = 18.492 KN/m
BC middle frame : g_4 = 4.05 x 3.00 x 0.625 + 4.125 = 11.719 KN/m

3. **Live load**

(1) Line load standard values of roof beam

Roof live load = 0.4 KN/m

AB, CD side frame : q_1 = 0.4 x 4.05 x 0.853 = 1.382 KN/m

BC middle frame : q_2 = 0.4 x 3.00 x 0.625 = 0.750 KN/m

(2) Line load standard values of floor beam

Floor live load = 2.5 KN/m

AB, CD side frame : q_3 = 2.5 x 4.05 x 0.853 = 8.637 KN/m

BC middle frame : q_4 = 2.5 x 3.00 x 0.625 = 4.688 KN/m

3. RESULT AND DISCUSSION

Structural Frame Reinforcement Calculation Results. Based on the results, the cast-in-place floor should be considered as to the influence of the floor flange on the stiffness of the beam and its bearing capacity. According to rectangular sections calculated under the influence of negative bending moments.

(1) Section size

Table 2 Span information of the frame

Span	h (mm)	b (mm)	h_0 (h-a_s) (mm)	Length (mm)
AB	600	300	565	6900
BC	550	300	515	3000
CD	600	300	565	6900

According to the T section, calculated under the effect of positive bending moment, beam compressive zone effective flange width take the minimum value of bf'

Table 3 bf' of the beam

Span	$b_f' = 1/3\ l$	$b_f' = b+sn$	h_f'/h_0
AB	2300	3450	0.212
BC	1000	1500	0.233
CD	2300	3450	0.212

(2) Strength of materials

Concrete strength grade, C30. f_c = 14.3 N/mm^2, f_t = 1.43 N/mm^2

Longitudinal reinforcement, HRB400. $f_y = f_y'$ = 360 N/mm^2

Stirrup reinforcement, HRB335. $f_y = f_y'$ = 300 N/mm^2

Floor Slab Reinforcement Calculation:
The thickness of the floor slab, h = 120 mm.

Concrete strength grade, C30. f_c = 14.3 N/mm^2, f_t = 1.43 N/mm^2

Reinforcement grade, HRB 400. f_y = 360 N/mm^2

Minimum reinforcement ratio. ρ_{min} = max (0.15%, $0.45f_t/f_y$) = 0.179%

The efficient sectional height, h_0 = 100 mm

Along short span direction, h_{0x} = 100 mm

Along long span direction, h_{0y} = 90 mm

Floor A :4.05 m x 6.90 m, two way slab

Floor B : 3.00 m x 8.10 m, two way slab

Two cases should be considered for load combination

(1) Live load control

$q = 1.4 \times 2.5 = 3.500$ KN/m^2

$g = 1.2 \times 4.05 = 4.860$ KN/m^2

$$g + \frac{q}{2} = 4.860 + \frac{3.500}{2} = 6.610 \text{ KN/m}^2$$

$g + q = 4.860 + 3.5 = 8.360$ KN/m^2

(2) Dead load control

$q = 1.4 \times 0.7 \times 2.5 = 2.450$ KN/m^2

$g = 1.35 \times 4.05 = 5.468$ KN/m^2

$$g + \frac{q}{2} = 5.468 + \frac{2.450}{2} = 6.693 \text{ KN/m}^2$$

$g + q = 5.468 + 2.450 = 7.918$ KN/m^2

Use live load control to calculate.

For the calculation of the maximum negative moment at the middle span, $g+\frac{q}{2}$

For the calculation of simply support end, $\frac{q}{2}$

Slab A (4.05 m x 6.90 m), $\frac{l_{01}}{l_{02}} = \frac{4.05}{6.90} = 0.587$

Slab B (3.00 m x 8.10 m), $\frac{l_{01}}{l_{02}} = \frac{3.00}{8.10} = 0.370$ (four edge is fixed, less than 0.5, so take 0.5)

Table 4 Mx and My for slab A and slab B

Slab	At the middle span		At the end of the slab	
	M_x	M_y	M_x	M_y
Slab A	0.0372	0.0071	-0.0798	-0.0571
Slab B	0.0400	0.0038	-0.0829	-0.0570

Table 5 Mx and My for slab A and slab B when all the edges are hinge support

Slab	M_x	M_y
Slab A	0.0839	0.0234
Slab B	0.0965	0.0174

$m_x^v = m_x + vm_y$

$m_y^v = m_x + vm_x$

$\gamma_s = 0.95$

$$A_s = \frac{M}{0.95 f_y h_0}$$

m_x^v - Bending moment value in a short side span, Poisson's ratio = 0.

m_y^v - Bending moment value in a long side span, Poisson's ratio = 0.

Table 6 Bending moment calculation

m		Slab A	Slab B
v = 0.2	mx^v	7.270	4.255
	my^v	4.071	2.080

m'x	-10.949	-6.237
m'y	-7.830	-4.289

Stairs Reinforcement Calculation:

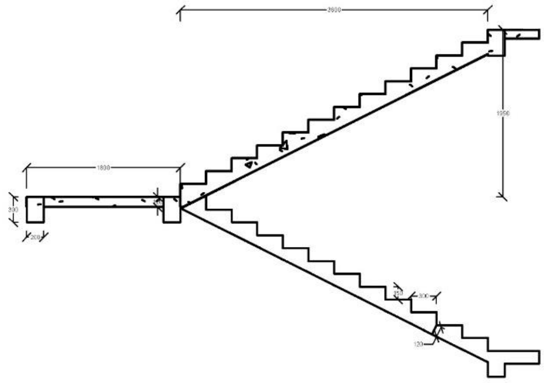


Figure 2 Stairs section size

Concrete strength grade, C30. f_c = 14.3 N/mm^2, f_t = 1.43 N/mm^2

Reinforcement grade, HRB 400. f_y = 360 N/mm^2

Distribution and stirrup reinforcement, HRB 335. f_{yv} = 300 N/mm^2

Minimum reinforcement ratio. ρ_{min} = max (0.15%, 0.45f_t/f_y) = 0.179%

Stairs span = 12 x 300 = 3600 mm

There is no soft cohesive soil at the foundation. The building is no more than eight floor and the height under 25 m. According to code for seismic design of building can not conculate natural subsoil and foundation seismic bearing capacity. The depth of side column foundation is 2.1 m, the height of foundation is 800 mm. The depth of middle column foundation is 2.3 m, the height of foundation is 1000 mm. The foundation bearing capacity is 220 Kpa. The shape of side columns foundation are square and the middle columns are rectangle. The foundation use C30 concrete, the strength grade f_c = 14.3 N/mm^2, f_t = 1.43 N/mm^2. The reinforcements are steel grade HRB 400, f_y = 360 N/mm^2.