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*Research Original Article*

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## Abstract

Structural analysis is an important part that must be considered when constructing a building, therefore in this paper to design structural elements the following method is used:
The plate load distribution for the beam uses the envelope method, and the earthquake load calculation uses the equivalent static method.
Structural analysis calculations use the cross method for portal and force method for trusses
Reinforcement design for beams uses the ACI flowchart and reinforcement design for columns uses column interaction diagram charts.
With the methods and methods mentioned by the author, the following results will be obtained:

- Beam cross-section 0.3m x 0.5m
- Column cross section 0.3m x 0.4m
- Reinforcing bars for beams are 6D16
- Reinforcing bars for columns are 6D16

**Keywords:** Building, Reinforced Concrete, Reinforced Steel

## Introduction

The nation of Timor Leste is currently undergoing reconstruction in various fields, where infrastructure is an important area that requires special attention from the government or private sector, to encourage the construction and addition of buildings to support the development process. Physically, infrastructure is an important factor in boosting development in Timor Leste to date, combined with continuous infrastructure development which indicates a development process that aims to meet the population's needs. In connection with the construction of the ESG - BAGUIA School building, the structure of which will use reinforced concrete to ensure maximum strength and safety for the welfare of its occupants, it is important to remember that the function of the school is a place of learning where they equip students with the acquisition of knowledge. ESG - BAGUIA School is located in Baguia District, Baucau Municipality. From the description above, we can understand the problem of developing the ESG School - BAGUIA by following standardized technical processes and stages to ensure that the building fulfills its function adequately and provides welfare for its residents. The ESG-BAGUIA School Building, planned to have three floors and use reinforced concrete and cold-formed steel structural materials, requires structural design efforts that can convince the owner to make decisions because the building must be safe and resistant. What is the fundamental basis for the author to take the title STRUCTURAL DESIGN OF ESG-BAGUIA SCHOOL BUILDING USING THE CROSS METHOD FOR PORTAL AND FORCED METHOD FOR TRUSS ' is that the author wants to carry out a deeper analysis using structural analysis methods such as the forced method and the cross method so that The building structure has serviceability, efficiency, construction, economy and safety.

## Literature Review

To design a school building structure using the Cross method for portals and the stiffness method for trusses, an understanding of the basic theories of structure and relevant calculations is required. Here is a basic explanation of the two methods:

**a) Cross Method (Distributive Moment Method)**

The Cross method is a structural analysis method used to determine the forces and moments in a portal, both swaying and non-swaying portals. The Cross method itself was developed by Harry Cross in 1933 with his book "Analysis of Continuous Frames by Distributing Fixed-End Moments". The principle of calculating structural analysis using the moment distribution method or the cross method is generally divided into two parts, namely the Determination of Partial Moments and the Determination of Design Moments. Moment Distribution: The moment that occurs at a node is distributed to the elements (rods) connected to the node based on the relative stiffness of each element.

The formula and steps for analyzing the Cross method structure are as follows:

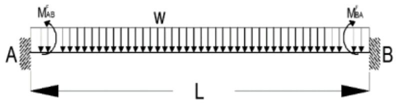
1. Determining Partial Moments (MF)
    - Determining Bar Stiffness (K)

K = (3 I)/4L for Fixed Supports - Joints
K = I/L for Fixed-Fold Supports

- Determining Distribution Factor (μ)

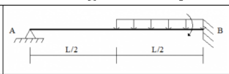
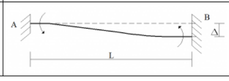
$$\mu = \frac{k_i}{\sum k_i}$$

- Determining Primary Moments (MF) due to Load




MFAB = 1/12 W L^2MFAB (-)
MFBA = - 1/12 W L^2MFBA (+)

- Determining Primary Moments (MF) due to Displacement.

| | | |
|---|---|---|
| – |  | $\frac{9}{128} q L^2$ |
| $-\frac{6EI\Delta}{L^2}$ |  | $-\frac{6EI\Delta}{L^2}$ |

2. Calculation of Final Moments using the Distribution Table (Cross Table)
3. Calculation of Support Reactions.

**b) Forced Method**

The force method is a procedure used to analyze hyperstatic structures so that we can find the support reactions and draw the stress diagram.

The method for solving hyperstatic structures must always consider the following conditions:

- Equilibrium conditions.
- Compatibility conditions.
- Conditions that govern the behavior of the materials used (constitutive laws of materials)

## Materials & Methods

This research uses field study and literature study methods. Data was obtained from the field study after the author visited the location or field directly, while the library study method was used to get references from reference books. After the data is obtained, the next step is to determine the truss dimensions, beam dimensions, column beam dimensions, and control building elements. This research was conducted at the ESG - BAGUIA school building located in Alawa Kraik Village, Baguia Post Administrative, Baucau Municipality. Building data are as follows:

1. Building description

| | |
|---|---|
| Building function | : Classroom |
| Total floors | : Three (3) floors |
| Location | : Baguia - Baucau- Timor Leste |
| Portal Structure | : Reinforced Concrete Construction |
| Roof structure | : Light steel roof frame construction (cold form) |
| Building materials | : Concrete and cold-formed steel |

2. Main structure data

| | |
|---|---|
| Floor plates I – III | : 130 mm |
| Column C1 | : 300x300 mm² |
| Column C2 | : 300x400 mm² |
| Beam | : 300x500 mm² |
| Roof truss | |
| Gording | : Canal 3HU3x075x3.2 mm |
| Truss | : Canal C75x3.2 mm |
| Zinc Weight | : 3.7 Kg/m² |

3. Material specification

| | |
|---|---|
| Specific gravity of reinforced concrete (ɤb) | : 24 KN/m3 |
| Concrete compressive strength (f'c) | : 32 MPa |
| Reinforcing steel capacity | : Flexural reinforced f'y 400 MPa |

Concrete Modulus of Elasticity (Ec) : 4700 * √(f'c)
Reinforcement Modulus of Elasticity : 210000 MPa

4. Building drawings

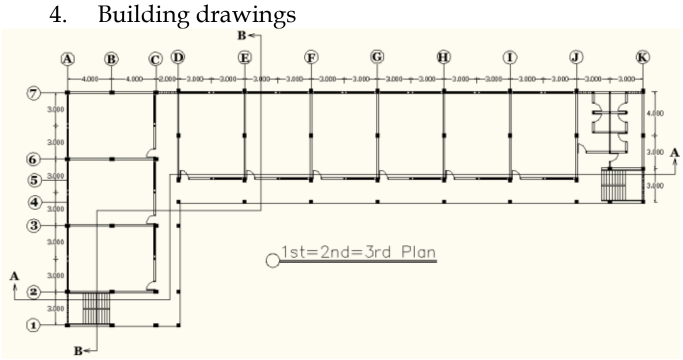


Figure 1. Plant

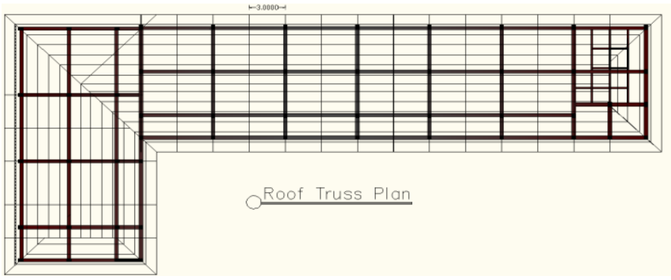


Figure 2. Roof truss plan

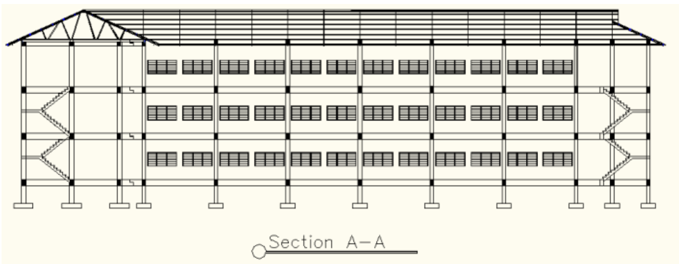


Figure 3. Section A-A

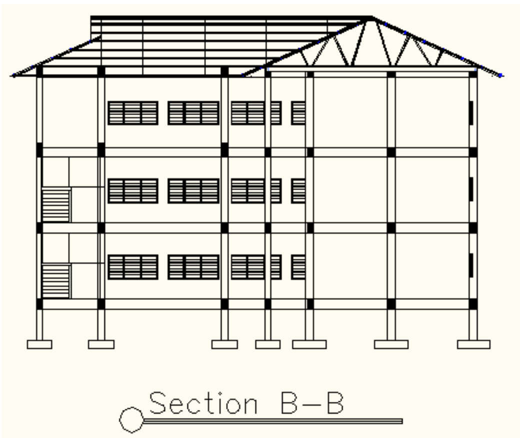


Figure 5. Section B-B

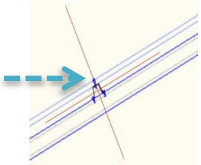
## Results and Discussion

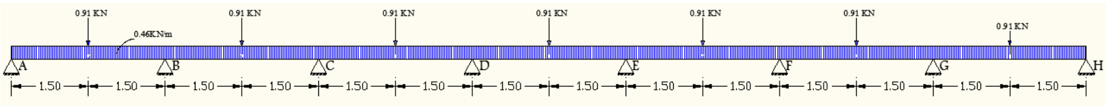
### Gording

In this calculation, Gording is considered as a continuous beam and used the cross method to analyze it.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Channel= | **3HU3x075** | | | | | | | | | | |
| Area (A)= | 0,761 | inchi² | = | 4,91 | cm² | = | 0,00049097 | m² | | | |
| Ix = | 1,520 | inchi⁴ | = | 63,27 | cm⁴ | = | 0,00000063 | m⁴ | | | |
| wx = | 0,648 | inchi³ | = | 10,62 | cm³ | = | 0,00001062 | m³ | | | |
| Iy= | 0,977 | inchi⁴ | = | 40,67 | cm⁴ | = | 0,00000041 | m⁴ | | | |
| wy = | 0,585 | inchi³ | = | 9,59 | cm³ | = | 0,00000959 | m³ | | | |
| L = | 3,000 | m | = | 300,00 | Cm | = | 3,00000000 | m | | | |
| E= | 550000 | Mpa | | | | = | 550000000,00000000 | KN/m² | | | |
| EI= | | | | | | = | 347,96947180 | KN/m² | | | |
| Zinc weight, g1 = | 3,700 | kg/m² | | | | = | 0,03700000 | KN/m² | | | |
| a'=Gording distance = | 1,021 | m | | | | = | 1,02080000 | m | | | |
| Angle of Truss = | 24,000 | ° | | | | = | 24,00000000 | ° | | | |
| Gording weight = g2 = | 2,59 | Lb/ft | | | | = | 0,00000000 | KN/m | | | |
| Live Load (P) centered in the middle of Gording= | 100,000 | Kg | | | | = | 1,00000000 | KN | | | |
| Wind load = | 40,000 | kg/m² | | | | = | 0,40000000 | KN/m² | | | |
| | | | | | Py | = | 1,00000000 | KN | | | |
| | | | | | Wy | = | 0,40000000 | KN/m² | = | 0,41 | KN/m |
| | | | | | g1 y | = | 0,03700000 | KN/m² | = | 0,04 | KN/m |
| | | | | | g2 y | = | 0,00000000 | KN/m² | = | 0,00 | KN/m |
| | | | | | | | **Concentrated Load** | | = | **1,00** | **KN** |
| | | | | | | | **Distributed load** | | = | **0,45** | **KN/m** |

Direction X






From this data, analyzing using the cross method, we get the final moment and reaction force at the support as follows:

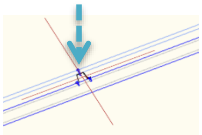
Final Moment

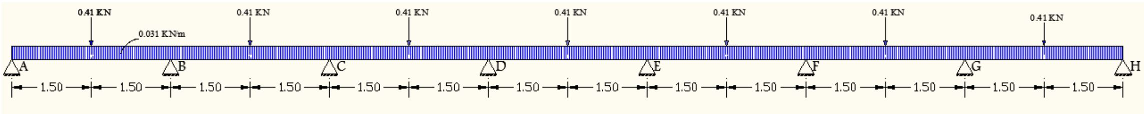
| | | | |
|---|---|---|---|
| AB | = | 0,000 | KN.m |
| BA | = | -0,894 | KN.m |
| BC | = | 0,894 | KN.m |
| CB | = | -0,632 | KN.m |
| CD | = | 0,632 | KN.m |
| DC | = | -0,697 | KN.m |
| DE | = | 0,697 | KN.m |
| ED | = | -0,697 | KN.m |
| EF | = | 0,697 | KN.m |
| FE | = | -0,632 | KN.m |
| FG | = | 0,632 | KN.m |
| GF | = | -0,894 | KN.m |
| GH | = | 0,894 | KN.m |
| HG | = | 0,000 | KN.m |

Support Reaction

| | | | | | | |
|---|---|---|---|---|---|---|
| RA= | 1,164 | KN | | | | |
| RB left = | 1,125 | KN | | | | |
| RB rigth= | 1,796 | KN | | | | |
| RC left = | 0,494 | KN | | RA = | 1,164 | KN |
| RC rigth= | 0,729 | KN | | RB = | 2,921 | KN |
| RD left = | 1,560 | KN | | RC = | 1,222 | KN |
| RD rigth= | 0,663 | KN | | RD = | 2,223 | KN |
| RE left = | 1,626 | KN | | RE = | 2,355 | KN |
| RE rigth= | 0,729 | KN | | RF = | 3,881 | KN |
| RF left = | 1,560 | KN | | RG = | 2,921 | KN |
| RF rigth= | 2,321 | KN | | RH = | -0,663 | KN |
| RG left = | -0,032 | KN | | | | |
| RG kanan= | 2,952 | KN | | | | |
| RH = | -0,663 | KN | | | | |

Direction Y






From this data, analyzing using the cross method, we get the final moment and reaction force at the support as follows:

Final Moment

| | | | |
|---|---|---|---|
| AB | = | 0,000 | KN.m |
| BA | = | -0,229 | KN.m |
| BC | = | 0,229 | KN.m |
| CB | = | -0,162 | KN.m |
| CD | = | 0,162 | KN.m |
| DC | = | -0,179 | KN.m |
| DE | = | 0,179 | KN.m |
| ED | = | -0,179 | KN.m |
| EF | = | 0,179 | KN.m |
| FE | = | -0,162 | KN.m |
| FG | = | 0,162 | KN.m |
| GF | = | -0,229 | KN.m |
| GH | = | 0,229 | KN.m |
| HG | = | 0,000 | KN.m |

Support Reaction

| | | |
|---|---|---|
| RA= | 0,428 | KN |
| RB left = | 0,072 | KN |
| RB rigth.= | 0,590 | KN |
| RC left = | -0,090 | KN |
| RC rigth= | 0,316 | KN |
| RD left. = | 0,184 | KN |
| RD rigth= | 0,300 | KN |
| RE left = | 0,200 | KN |
| RE rigth= | 0,316 | KN |
| RF left= | 0,184 | KN |
| RF rigth= | 0,724 | KN |
| RG left = | -0,224 | KN |
| RG rigth= | 0,886 | KN |
| RH = | -0,386 | KN |

| | | |
|---|---|---|
| RA = | 0,428 | KN |
| RB = | 0,662 | KN |
| RC = | 0,227 | KN |
| RD = | 0,483 | KN |
| RE = | 0,517 | KN |
| RF = | 0,908 | KN |
| RG = | 0,662 | KN |
| RH = | -0,386 | KN |

The final Reaction is Resultant of Rx and Ry

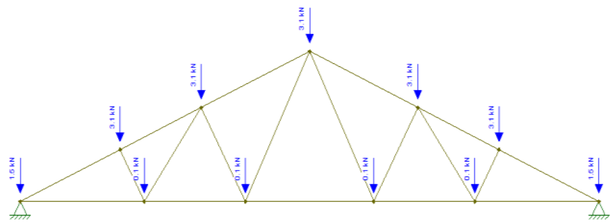
Rx = 2.92 KN

Ry = 0.91 KN

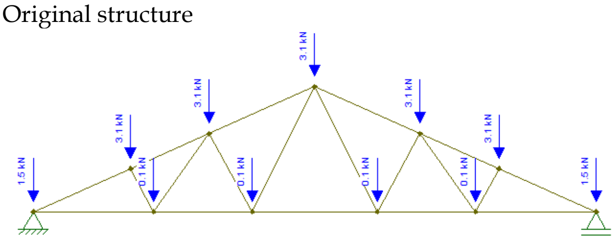
So, the final Reaction (RF) = $(Rx^2 + Ry^2)$^0.5

= 3,06 KN

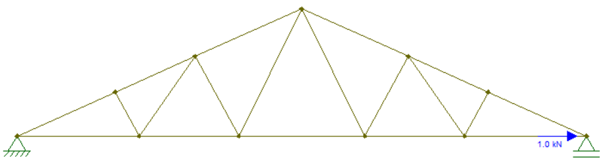
**Roof Trusses**




Original structure




Base structure




Virtual structure 1

From the data analyzed using the Forced method obtained the final reaction at the support is as follows:

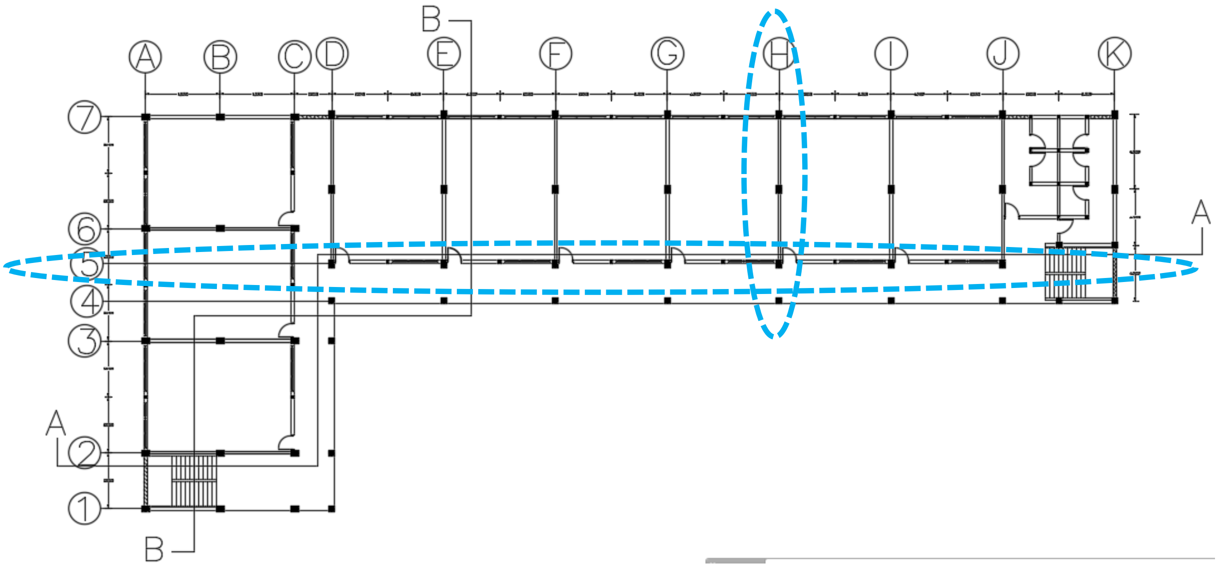
Tabel T.T.V

| Element | L | E | A | N0 | N1 | EA | S10 (N1*N1*L) / EA | S11 (N1*N1*L) / EA | t0 | a | X1 S10+S11*x = 0 | NF N0+N1*X1 | Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1,99 | 550000000 | 0,000166451 | -41 | 0 | 91548,204 | 0,000 | 0,000 | 0,000012 | 0,3 | | -41,000 | *Compression* |
| 2 | 2,26 | 550000000 | 0,000166451 | 37,4 | 1 | 91548,204 | 0,001 | 0,000 | 0,000012 | 0,3 | | 5,496 | *Tension* |
| 3 | 0,92 | 550000000 | 0,000166451 | -5,8 | 0 | 91548,204 | 0,000 | 0,000 | 0,000012 | 0,3 | | -5,800 | *Compression* |
| 4 | 1,8 | 550000000 | 0,000166451 | 6,1 | 0 | 91548,204 | 0,000 | 0,000 | 0,000012 | 0,3 | | 6,100 | *Tension* |
| 5 | 1,85 | 550000000 | 0,000166451 | 31,2 | 1 | 91548,204 | 0,001 | 0,000 | 0,000012 | 0,3 | | -0,704 | *Compression* |
| 6 | 2,34 | 550000000 | 0,000166451 | 22,4 | 1 | 91548,204 | 0,001 | 0,000 | 0,000012 | 0,3 | | -9,504 | *Compression* |
| 7 | 1,68 | 550000000 | 0,000166451 | -9,4 | 0 | 91548,204 | 0,000 | 0,000 | 0,000012 | 0,3 | | -9,400 | *Compression* |
| 8 | 2,63 | 550000000 | 0,000166451 | 9,4 | 0 | 91548,204 | 0,000 | 0,000 | 0,000012 | 0,3 | | 9,400 | *Tension* |
| 9 | 1,85 | 550000000 | 0,000166451 | 31,2 | 1 | 91548,204 | 0,001 | 0,000 | 0,000012 | 0,3 | | -0,704 | *Compression* |
| 10 | 1,68 | 550000000 | 0,000166451 | -9,4 | 0 | 91548,204 | 0,000 | 0,000 | 0,000012 | 0,3 | -31,90 | -9,400 | *Compression* |
| 11 | 2,63 | 550000000 | 0,000166451 | 9,4 | 0 | 91548,204 | 0,000 | 0,000 | 0,000012 | 0,3 | | 9,400 | *Tension* |
| 12 | 2,26 | 550000000 | 0,000166451 | 37,4 | 1 | 91548,204 | 0,001 | 0,000 | 0,000012 | 0,3 | | 5,496 | *Tension* |
| 13 | 0,92 | 550000000 | 0,000166451 | -5,8 | 0 | 91548,204 | 0,000 | 0,000 | 0,000012 | 0,3 | | -5,800 | *Compression* |
| 14 | 1,8 | 550000000 | 0,000166451 | 6,1 | 0 | 91548,204 | 0,000 | 0,000 | 0,000012 | 0,3 | | 6,100 | *Tension* |
| 15 | 1,99 | 550000000 | 0,000166451 | -41 | 0 | 91548,204 | 0,000 | 0,000 | 0,000012 | 0,3 | | -41,000 | *Compression* |
| 16 | 1,62 | 550000000 | 0,000166451 | -37,9 | 0 | 91548,204 | 0,000 | 0,000 | 0,000012 | 0,3 | | -37,900 | *Compression* |
| 17 | 1,62 | 550000000 | 0,000166451 | -37,9 | 0 | 91548,204 | 0,000 | 0,000 | 0,000012 | 0,3 | | -37,900 | *Compression* |
| 18 | 2,16 | 550000000 | 0,000166451 | -29,1 | 0 | 91548,204 | 0,000 | 0,000 | 0,000012 | 0,3 | | -29,100 | *Compression* |
| 19 | 2,16 | 550000000 | 0,000166451 | -29,1 | 0 | 91548,204 | 0,000 | 0,000 | 0,000012 | 0,3 | | -29,100 | *Compression* |
| | | | | | | | **0,004** | **0,000** | | | | | |

Final Reaction

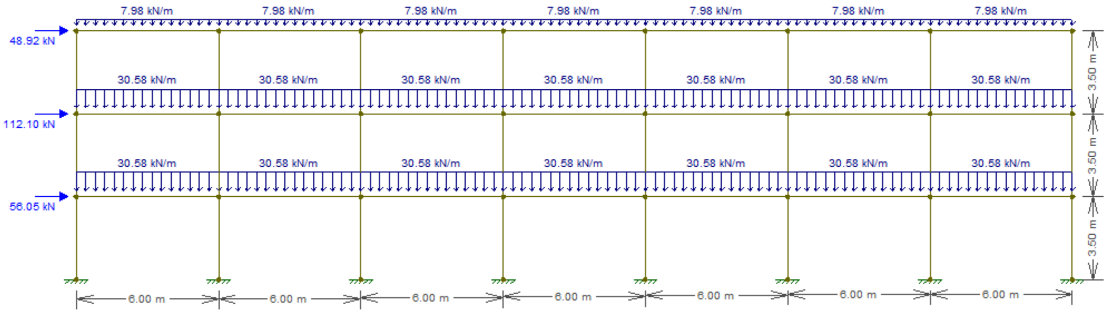
| | | | |
|---|---|---|---|
| **RAv** | = | 24,8 | KN |
| **RAh** | = | 31,9 | KN |
| **RBv** | = | 24,8 | KN |
| **RBh** | = | -31,9 | KN |

**Portal**

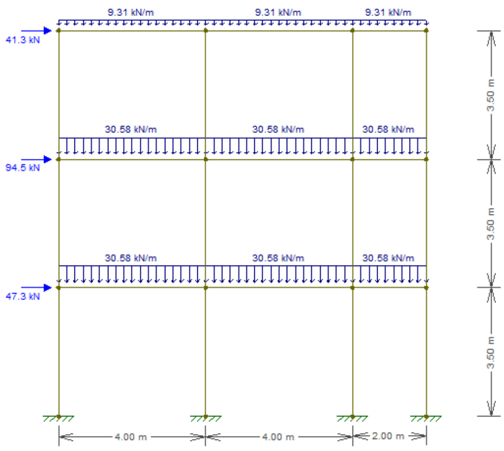


From this layout, the portal structure model is taken from the X direction is portal 5-K, and from the Y direction is portal H-4.

Portal 5-K

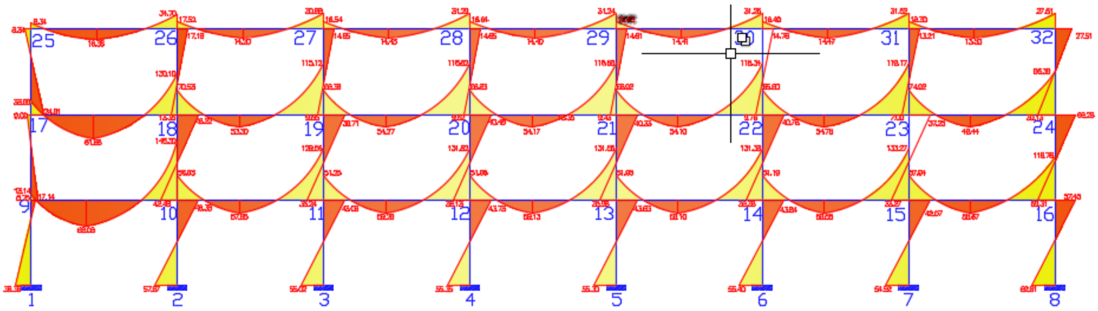



Portal H-4

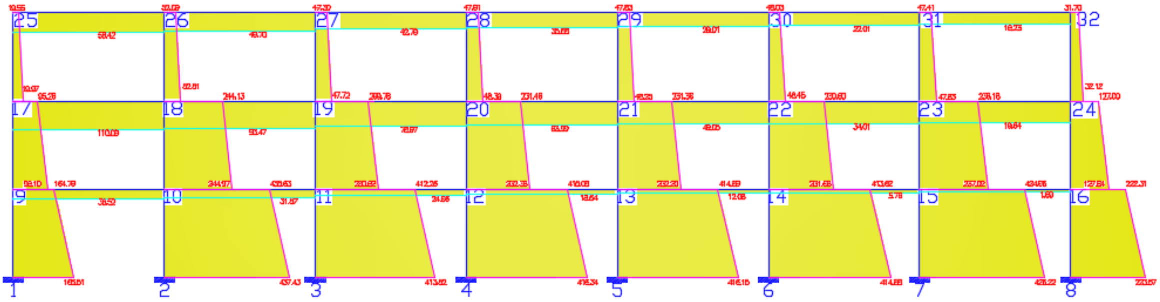



Using the Cross method to analyze the structure and produce the Final Moment, Final Horizontal Force, and Final Vertical Force as follows:

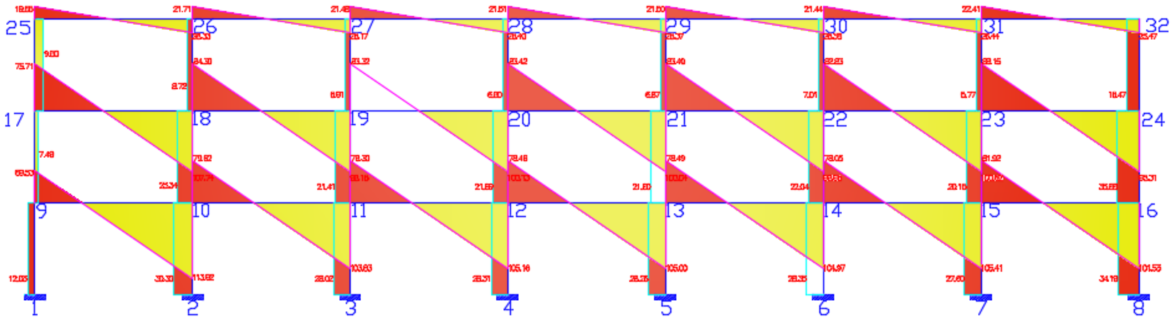
Final Moment portal 5-K



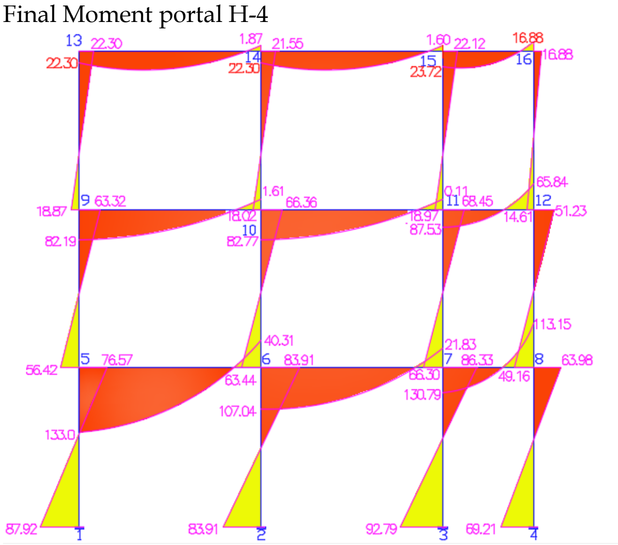
Axial Force portal 5-K



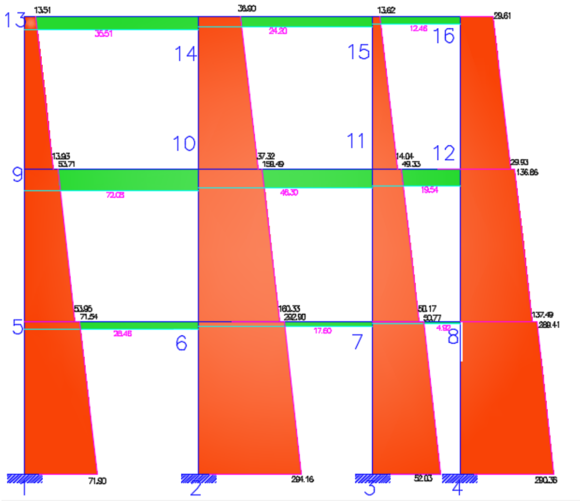
Latitude Force portal 5-K



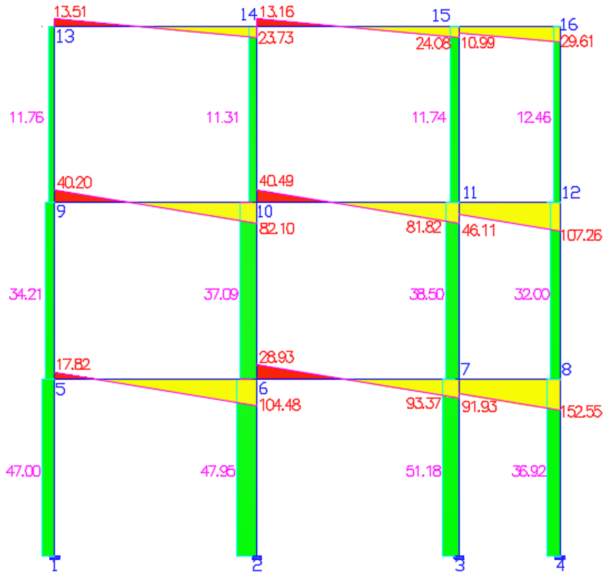
Final Moment portal H-4




Axial Force portal H-4

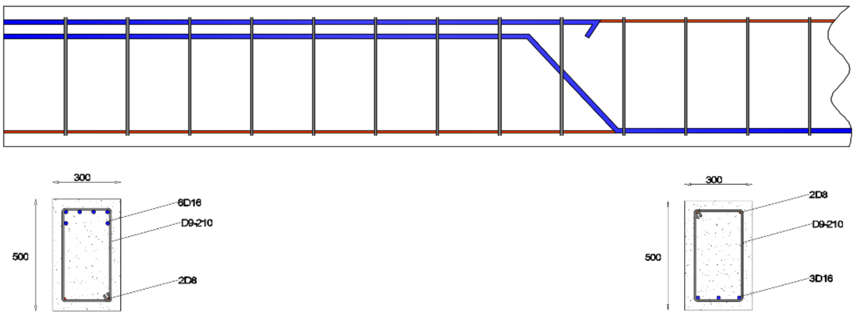



Latitude Force portal H-4

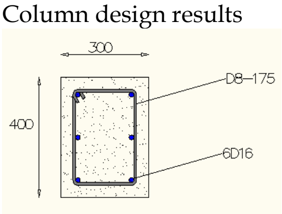



The results of the Final Moment, Final Horizontal Force, and Final Vertical Force, it is used to plan the beam and column dimensions as follows:

Beam design results




Column design results




## Conclusions

After carrying out analysis and design using the Cross method for the portal and the Stiffness method for the roof frame, the researchers concluded as follows:

a) The dimensions of the beams used for this building are (0.3 m x 0.5 m), and the dimensions of the columns are (0.3 m x 0.4 m).
b) The reinforcement used for the beam in the support area is (6D16), this section has been controlled "OK" and there are no changes to the existing beam dimensions.
c) The reinforcement used for the beams in the field area is (3D16), this section has been controlled "OK" and there are no changes to the dimensions of the existing beams.
d) The reinforcement used for the column is (6D116)

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