Mitigating The Shortage of Public-School Building Through the Application of Pre-Engineered Building System

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Abstract: - Shortage of public-school classrooms is one of the challenges that our country is dealing nowadays, however there is still hope to minimize this problem, behind the limited budget, and it is through the application of Pre-Engineered Building (PEB) System. This capstone project takes pride, in introducing PEB system as an economical substitute to the conventional type buildings. To prove the competitive advantage of PEB system; structural integrity, material and labor costs, and construction speed are the parameters considered. Structural integrity was determined through the design and analysis of the structure using software. Material and labor costs were calculated by carrying out the detailed estimate. Through a thorough activity scheduling, and also based on the existing PEB, it was found out that, construction of PEB are really can be built in a shorter amount of time.

Key Words— ***Pre-Engineered Building, School Building.***

I. Introduction

One of the major problem that the Philippines facing today is the shortage of classrooms for public schools nationwide. According to the data recorded by the Department of Education (DepEd), additional of 91,000 classrooms are need to be construct to accommodate the 27.1 million enrollees as of school year 2022-2023. The ratio of student population to the number of classrooms is out of the equilibrium, which just indicates a serious problem that has to be mitigate by the government.

DepED proposed P86.5 billion budget for 2023 for the construction of classrooms, however, the proposed budget will not totally solve the issue, since only 34,552 classrooms in first to sixth class municipalities are able to be constructed under the mentioned budget.

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But there is another problem; the Department of Budget and Management (DBM) only approved P5.9 billion to be included in the 2023 proposed budget.

Completing the required number of classrooms demands a staggering amount of money, due to the following factors; construction materials and labor cost. Majority of the public schools, were constructed using reinforced concrete materials. Although application of this material is a common practice in the construction industry, it is still undeniable that it has its drawbacks, which are the high material and labor costs.

Using the concept of value engineering, through shifting the method of construction of the public school buildings, will be a great help. Reintroduction of Pre Engineered Building (PEB) System, for the building construction is a sustainable solution that will mitigate the tight spot. According to its definition, Pre-Engineered Buildings (PEBs), are the building components that are assembled on site, after being manufactured from the factory. PEBs are structural steel that can be a more economical alternative for the conventional reinforced building, without compromising the structural integrity of a structure. This method is very popular in the Middle East, especially in the gulf region, since it is proven that PEB structures are lesser expensive than the reinforced concrete structures. Employing this system for the construction of classrooms will lessen the project costs, therefore number of classrooms to be built will be increased too.

II. Conceptual Framework

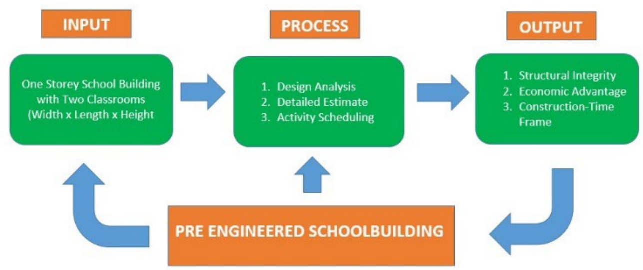

Fig.1. Conceptual Framework of the Study

Technological improvement over the year has contributed immensely to the enhancement of quality of life through various new products and services. One such revolution was the Pre-Engineered Buildings (PEB). Educational Building adopt PEB System as a new form of construction since PEB's offer ultimate design flexibility and an extremely short construction time (right from initial design to completion). The process of PEB System starts with the Structural Design Process which includes the Loadings (Dead, Live, Wind & Seismic Loads), Basic design criteria and design Codes to be use. After applying the Design Parameters next process is to choose the Materials (Built-Up Steel Sections) in each members (Column & Beam). The next stage is Final design (Evaluation) which include the Optimization in order to have an effective and adequate design in terms of economy, harmony and serviceability. The Design result of PEB System are economical in terms of value engineering, time saving, future expansion, design flexibility and safety.

III. Modeling And Analysis

3.1 Skeletal Modelling (STAAD.Pro Design Software)

The type of structure is clear span with 7m width and 22.50m length are considered. An eave height of 4m and bay spacing of 4.50m are consider for the model. Using these dimensions, the primary members of columns, rafter bracing and lateral support shall be modeled in STAAD Pro. Connect Edition software. The structure is modeled as 3-D structures. Pinned support is provided for the columns in PEB model as pinned support helps to get an optimal structural design. The grade of steel used are ASTM A 36.

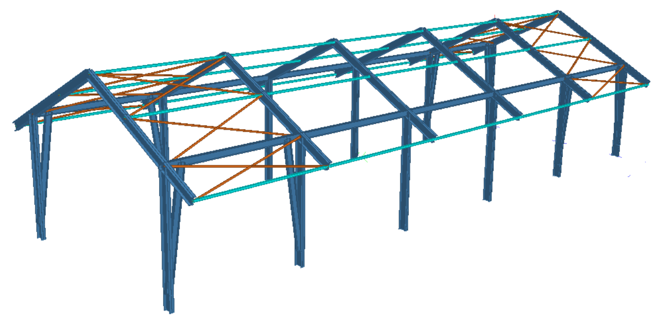

Fig.2. 3D Model of PEB Structural Configuration

3.2 Loads

1. Dead Loads

   The self-weight and a multiplication factor of 1.10 is taken to account for the weight of connections.

   Calculations:

   Weight of roof sheeting (0.50mm thick corrugated sheet).

   Weight of roof sheeting is 0.50kN/m2

   Weight of sag rods, flange braces is 0.50kn/m2

   Total weight = 0.10kN/m2

   U.D.L on main rafter = 0.10kN/m2 x 4.50m

   = 0.45kN/m2

   U.D.L on gable rafter = 0.10kN/m2 x 2.25m

   = 0.225kN/m2

   Load due to purlins:

   Nos. of purlins = (5.46/0.5) + 1

   = 12 nos. (purlins spaced at 0.50m c/c)

   Self-weight of lipped zed section LC 150 x 65 x 20 x 1.50 = 3.77 kg/m2

   U.D.L on main rafter = 0.038kN/m2 x 4.50m

   = 0.171kN/m2

   U.D.L on gable rafter = 0.038kN/m2 x 2.25m

   = 0.0855kN/m2

   Total load on main rafter = 0.45 + 0.171

= 0.621 kN/m2

Total load on gable end rafter = 0.225 + 0.0855

= 0.310 kN/m2

2. Collateral Loads

Weight of Ceiling is 0.10 kN/m2

Weight of Electrical is 0.05 kN/m2

Total weight = 0.15 kN/m2

U.D.L on main rafter = 0.15kN/m2 x 4.50m

= 0.675kN/m2

U.D.L on gable rafter = 0.15kN/m2 x 2.25m

= 0.338kN/m2

3. Live Loads

Live load is taken from NSCP-Chapter 2 Table 205-3 (Minimum Roof Live Loads). As per the table for flat or rise less than 4 units vertical in 12 units horizontal (33.3% slope), the uniform loads for 0 to 20 tributary area (m2) is 1.0 KPa, while for 20 to 60 m2 is 0.75 kPa and or over 60 m2 is 0.60 KPa. For this study, the uniform live load used is 0.60 kPa since the Roof area of the school building is 158 m2 (above 60 m2).

The live load applied as follows:

U.D.L on main rafter = 0.60kN/m2 x 4.50m

= 2.70kN/m2

U.D.L on gable rafter = 0.60kN/m2 x 2.25m

= 1.35kN/m2

4. Wind Loads

Wind load is taken from NSCP-Chapter-2 Table 207-1 (Wind Zone for the Different Provinces of the Philippines). For study, the project location under category of Zone-2 with wind speed of 250 kph. An importance factor (Iw) of 1.15 under the Occupancy Category I (Essential) base on Table 207-3 (Important Factor, Iw for Wind Loads).

Wind load data

Location = Marinduque

Wind basic speed (Vb) = 69.44m/s (250kph)

Building Mean Height = 4.00 m

Wind Exposure = C

Occupation Category = I

Important Factor = 1.15

Velocity Pressure (qz)

Velocity pressure qz, evaluated at height z shall be calculated by the following equation:

qz= 0.613.Kz.Kzt.Kd.I.(V)^2 [SI Units] (207-15)

Kzt = 1.00 Topographic factor (Table 207-4)

Kd = 0.85 Wind Directionality Factor (Table 207-2)

I = 1.15 Importance Factor (Table 207-3)

Referring to (Table 207-5) Terrain Exposure Constants

Alpha = 9.50 --- Zg = 274.32 M --- Zmin = 4.57 M

Kz = 2.01x(Z/Zg)^(2/Alpha) = 0.85 Velocity Pressure Exposure Coefficient (Table 207-5)

where Z = Maximum of Mean Height & Minimum Height = 4.57 M

qz = 0.613 x 0.85 x 1.00 x 0.85 x 1.15 x 69.44^2 (N/Sqm)

qz = 2.46 kN/m²

Wind Pressure Coefficients

External and Internal wind coefficient are calculated for all the surfaces for both pressure and suction. Opening in the building has been considered less than 5% and accordingly internal coefficients are taken +0.18 and -0.18. The external coefficients and internal coefficients calculated as per NSCP Chapter-2 (2-44).

Wind Load Coefficient Calculation for Columns and Rafter

Surface	Wind-1		Wind-2		Long-Wind	
Id	Left	Right	Left	Right	1	2
1	0.32	-0.58	0.68	-0.22	-0.63	-0.63
2	-0.87	-0.64	-0.51	-0.38	-0.87	-0.55
3	-0.64	-0.87	-0.28	-0.51	-0.55	-0.87
4	-0.58	0.32	-0.22	0.68	-0.63	-0.63

Fig.3. Wind Load Coefficient

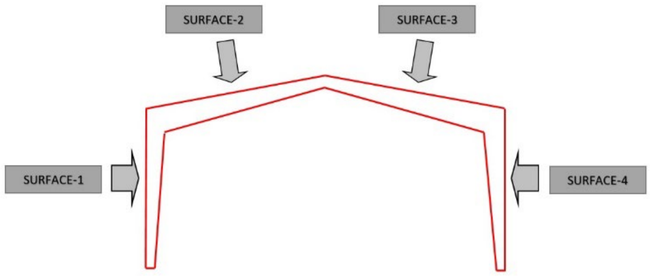

Fig.4. Wind Load Surface Direction

5. Seismic Loads

When an earthquake occurs, vibration are produced in the ground near the surface that creates inertia forces and movements in the structure. The magnitude of this force is directly proportional to the dead load of the structure. Pre-Engineered Building (PEB Systems), due to their low dead load, do not usually have their design governed by seismic forces and hence, in this study, the seismic load doesn't govern the design and the most critical load is found to be wind load. However, for seismic analysis, the following data has been used as per NSCP Chapter (208.4.4.1).

Zone = 4 (Table 208-3 Seismic Zone Factor Z)

Response reduction factor = 4 (for Steel frame)

Importance Factor = 1.0

3.3 Procedure for Analysis and Design

- Collection of data for the proposed model-span of school building, location of building, initial proportional of building as per Department of Education specifications, wind and seismic parameters as per NSCP Code.
- Modelling in Staad and applying the loads as per code specifications.
- Optimization is done so as to arrive at an economic structural configuration.
- Extract the results required for comparison.

3.4 Serviceability Checks

Refer table from NSCP Chapter for Deflection Limits

For Rafters, the permissible deflection is taken as span/180.

For Columns. The permissible deflection is taken as height/100.

The applied loads in the model are calculated in the previous sections using STAAD.Pro Connect Edition with user interface features for the application of dead, live, wind, and seismic loads.

The Pre-Engineered Building model is designed after assigning the design parameters as follows:

Lz, Kz (Effective length along z-direction for columns and rafters respectively) = full length of columns and length of rafters from tie to tie.

Lx, Kx (Effective length along x-direction for columns and rafter respectively) = 0.50m

(The cold formed purlins spacing is 0.50m c/c).

Ly, Kz (Effective length along y-direction for columns and rafter respectively) = 0.50m

(The cold formed purlins spacing is 0.50m c/c).

Fyld (Yield Strength of Stee) = 350 Mpa

Fu (Ultimate Strength of Steel) = 490 MPa

The design is done as per the provision of Hot Rolled Section for Mainframe and Cold formed Section.

for Secondary framing base on AISC & AISI. The members are further optimize to give the Maximum stress Ratio close to 1.

IV. Results And Discussion

4.1 Comparison of Base Reactions

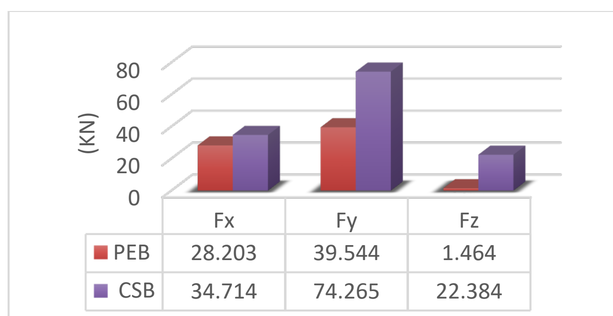

Fig.5. Base Reaction Summary

The maximum horizontal forces of Fx and Fz for PEB are 28.203 Kn and 1.464 Kn respectively and for CSB are 34.714KN and 22.384Kn respectively. The Fx and Fz are lesser by 23.09% and 52.89% respectively in PEB as compared to CSB. The maximum vertical reactions Fy for PEB and CSB are 52.974Kn and 74.265Kn respectively, thus the vertical reaction in PEB is lesser by 40.19% as compared to CSB.

4.2 Comparison of Member Forces

The maximum Axial Force in PEB is 39.544 Kn and in CSB is 60.873 Kn. Hence, it is seen that the axial force in CSB is greater than PEB by 53.94% as the frame action in Pre-Engineered Building system offers resistance-against moment which reduces the axial force considerably.

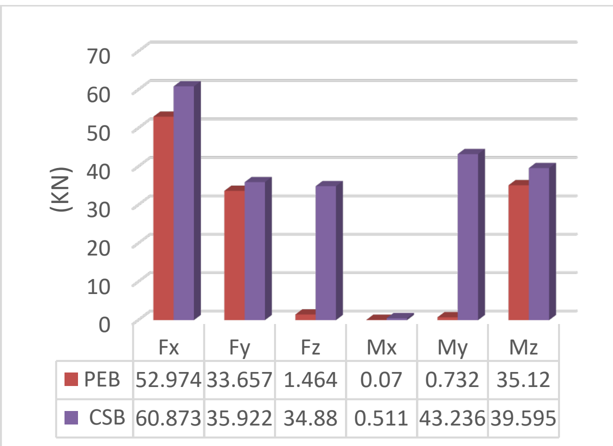

Fig.6. Member Forces Summary

4.3 Comparison of Displacements

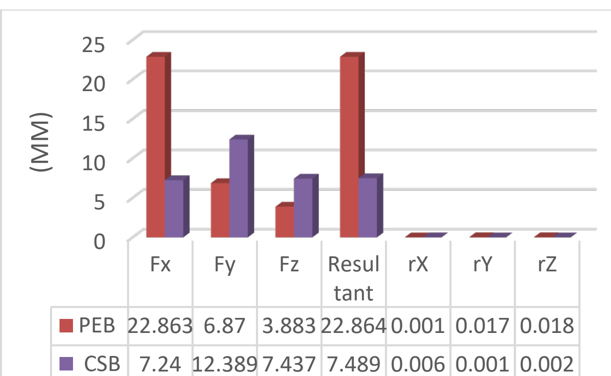

Fig.7. Displacement Summary

The maximum rafter deflection for PEB is 6.87 mm and for CSB is 12.389 mm. The CSB shows a deflection greater than that of PEB by 46.73%.

4.4 Comparison of Material Take-Off

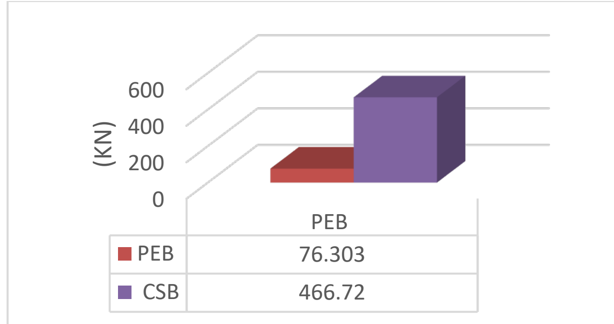

Fig.8. Material Take-Off Summary

The Total weight for PEB is 76.303 KN while for CSB the total weight is 466.721 KN. The weight of CSB shows that it is more than 6 times heavy compare to PEB System.

4.5 Comparison of Price for Main Structure

The total price of PEB (Main Frame Only) is PhP 504,580.13 while for the CSB (Main Frame Only) is PhP 626,582.28. The price of PEB System is 19.47% lesser compare to CSB.

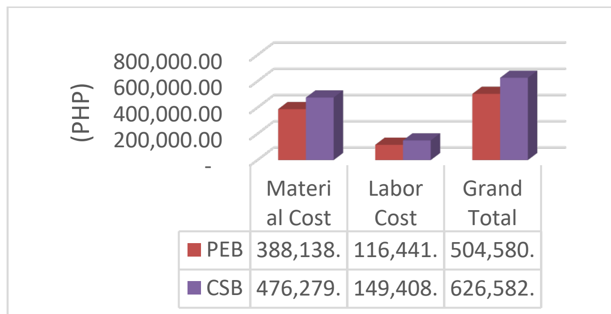

Fig.9. Price Summary (Main Structure)

4.6 Comparison of Project Scheduling

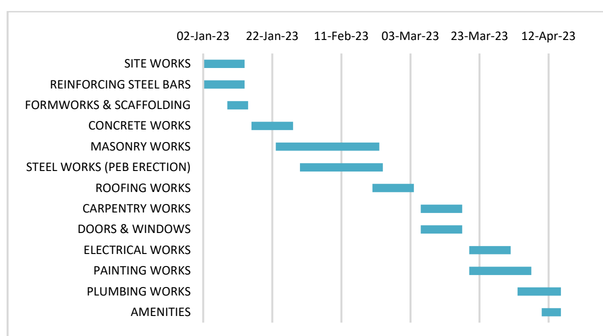

Fig.10. Project Scheduling for PEB

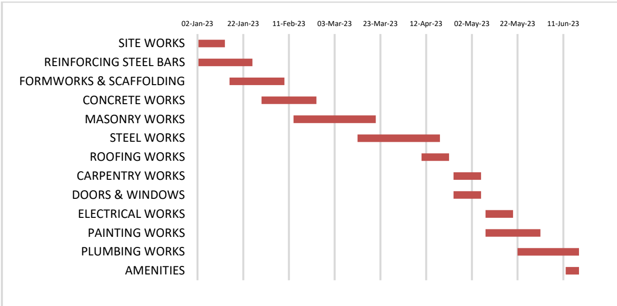

Fig.11. Project Scheduling for CSB

The total duration for PEB is 84 workings days to complete the project while for CSB it takes 144 working days to finish it. Using the PEB method in construction save 41.67% compare to traditional CSB method.

V. Conclusion

Based on the results gathered through employing the appropriate methodologies for this study, a reasonable and positive conclusion have been formulated. It was proven that Pre-Engineered School Building offers greater advantages against the Conventional School Building based on the following aspects; structural integrity, material and labor cost, and the construction time frame.

Relying on the reactions which are the result of designing and analyzing the building using STAAD, it was found out that PEB gives the lower base reactions. The horizontal reactions (x, z) and vertical reaction (y) of PEB is lower by 15.01%, 52.89% and 14.91% than that of CSB, which is just a manifestation that smaller size foundation is required to support the PEB. Considering the axial, moment, and torsion acting on the members, it was indicated that, lower values of forces were transmitted, in fact axial force of CSB is greater by 53.94% than that of PEB which means PEB just require lighter members. When it comes to member deflections, it can be noticed that PEB offers lesser deflection compared than that of CSB under a common loading. It was known that CSB deflection is 23.38% higher than the PEB frame deflection, which just indicates that PEB gives higher resistance. Based on the given results, it can reasonably conclude that PEB possesses a higher level of structural integrity against the CSB. Lesser column base reactions, gives an economical foundation design, minimum axial forces results to having economical material size and quantity, and also the higher deflection resistant indicates, a bigger span than could possibly supported, this claims are just clear proof that PEB is indeed advantageous in structural integrity aspects.

Other aspects which measure the differences of the two structure (PEB & CSB) is the material and labor cost. By performing a thorough and detailed quantity take off for both structures, the researchers found out that PEB is less costly compared to CSB by 19.47% considering the main frame only. At this case, implementing bodies can really save budget if PEB is to be used. Likewise it can finally say that PEB is way better than CSB if time frame is to be considered. By carrying out the activity scheduling, the researcher arrived at reasonable outcome, and it was determined that, construction of PEB is 41.67% faster if to be compared against CSB.

According to the stated data above, it can be finally concluded that PEB system will be the solution to the expanding shortage of classrooms in the country specifically in the remote rural communities.

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