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Guidelines for Erection process of Pre-Engineered Building

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***Abstract*— Erection process of structural steel involves the assembly of steel components into a frame on the site which also forms the major part of project cost. This process briefly involves lifting and placing components into position, then connecting them as a whole member and finally bolting. So, to ensure that the processes should be completed safely, quickly and economically, it has to be greatly influenced by the decisions made before the erection commences. Erection cost comprises of 7-10% of the total project cost which is mainly dependent on the speed of execution of erection of the structure. During execution of erection of structure, it is subjected to carry temporary loads which would not be the part of loading in future. The aspects that are to be ensured during execution are safe erection procedures and structural stability of the structure. To focus these aspects, the guidelines for the erection process are presented in this paper.**

***Index Terms*— Erection process, Pre-engineered building, PEB construction process, metal building erection technique, Erection Sequence**

I. INTRODUCTION

In steel erection process it involves positioning of the components, aligning it and securing them on prepared foundations to form a complete frame. As a result, a skeletal steel frame can be erected by bolting-up the connections. To enhance the speed of construction and ensure safe process, careful planning is needed. Careful planning involves the maintaining of practical erection sequence and maintaininng simplicity in assembly formation. Site work involves labour intensive tasks and hence cannot be controlled for time purposes. It is also relatively expensive and our primary aim is to minimise the costs by reducing the time on site. For shortening the time on site some of the principal design factors are to be considered such as repetition and standardisation, achievable tolerances, frame type and choice of floor systems. Erection sequence should be formed so as to establish a stable unit as quickly as possible and to attach the subsequent elements directly or indirectly to it. There should also be the proper knowledge of equipment usage and planning for performing safe tasks.

II. ESSENTIAL EQUIPMENTS FOR ERECTION

The essential equipments for erection activities are as follows:

a. Mobile Equipments: Mobile equipments mostly comprises of delivery trucks, truck cranes, hoists etc. for PEB construction. To ensure safe processes, certified mobile equipment operators and qualified mobile equipment operators are permitted to enter the site. It is is primarily advised not to operate the equipment closer than 4.5 m to a voltage line of 220V or more. On a site, only a signalman is given right to give signals to the operators. Only in case of emergency, others can use this right.

b. Slings:

Slings are used in lifting operations and hence it should be well inspected for its wear and tear condition. So, to protect slings, they should be padded by sharp corners and the lifted load should not be jerked in any circumstances as jerking might triple the load. This includes chain, wire rope and synthetic slings with its attachments. General tendency is to hang up the sling when not in use.

c. Scaffolds:

Scaffolds should be placed on a firm ground position and foot bases are well rested on wood planks with minimum size 20cm*20cm. Scaffolds should be planned and installed with some precautions:

1. It should not restrict the crane access and boom clearances making the erection activities complex.
2. Hand rails, midrails, ladders and a platform should be provided at every floor level.

d. ELCB Box:

Electrical system must be standardized including the which should include sealed box, ELCB(30mA-60mA), 3 pin sealed plugs for outlets. For ease in operation and safety, at least 1 ELCB should be put on the roof installation.

e. Hand Tools:

Hand Tools should be fixed to the wrist lanyards to prevent it from dropping. Tools which are to carried for certain purposes should have provision for the safe carriage. Proper use of tools should be made and hand tools should be tampered for serving some other purpose of tool. Never use makeshift device.

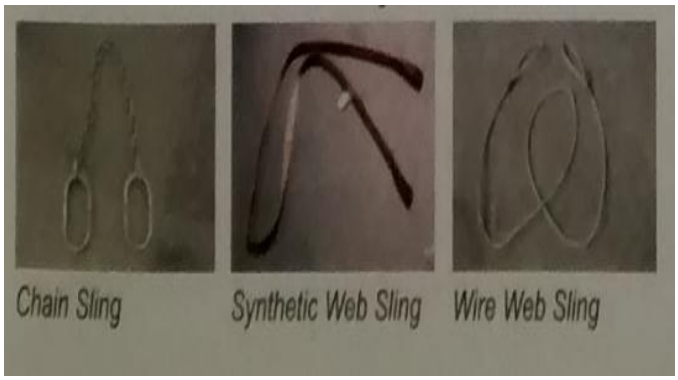

Fig. 1: Accessories for lifting components

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III. ENGINEERING DOCUMENTS REQUIRED FOR ERECTION

Before starting of erection work, it is necessary to have clear understanding of engineering documents. Erection drawings and Shipper's list are referred especially for erection work.
Erection drawings which are to be referred on site should "ISSUED FOR CONSTRUCTION" which is of latest revision. 'FOR APPROVAL' drawings have some modification in it and so should not be adopted for construction. It is predicted from the revision boxes held at the bottom of the sheet.

1. Anchor Bolt Setting Plan

It is a plan consisting layout of all bolts for the building. It is normally presented on one sheet but if extent of work is large then it may exceed one page. There are few precautions taken by the engineers that the

i. Drawings for erection are proportioned drawings and not up to scale which can be misleading.
ii. All the dimensions are given in mm and it includes anchor bolt schedule which is in the orm of table displaying quantities and sizes of anchor bolts.
iii. Key plan should be well studied for c/c dimensions, bay spacing, dimensions, bolt setting details and critical dimensions for the span.
iv. Also, most important locations where grout is required and identified specifying grout thickness, grout projection considering the tolerance limit for bolt setting which should not exceed the limits of standards.

2. Roof framing Plan

This plan shows the purlins, bracing and other miscellaneous details. It shows part numbers for purlins, bracings, sag rods, strut tubes etc. Hence, these drawings should be studied carefully else critical details might get slipped. For example, nested purlins, strut purlins and strut clips.

3. Cross-Section

It is one of the most important drawings as it is referred most frequently. It contains lot of information about columns, rafter refernces, purlins, girts, vertical and roof bracings, conection details, bolt schedules, flange brace schedules and other details as applicable, such as strut tubes, flashing etc.
Essential quantity of members can be found out by referring this drawing which is required for cross-checking with shipper's list at pre-planning stage.

4. Roof Sheeting Layout

It displays roof panels with length and its part number. It also denotes panel lap details, skylight positions, downspout positions, standard details of fasteners, trims and insulation are included.

5. Sidewall Sheeting and Framing

This drawing shows the sidewall framing and sheeting on one or more drawings depending on the extent of work. It shows the part number of girts, eaves struts, bracing and sag rods which helps in finding the position of panels.

6. Other Drawings

It includes mostly accessories drawings such as sliding doors, roll-up doors, personnel doors, windows, louvers and ventilators. Also, mezzanine layots if any are included in it.

7. Shippers List

It is generally termed as customer's bill of material. The BOM comprises a coversheet which include job number, building number and phase, customer name, Location, and Building size. The cover sheet also shows the number of phases in the building, any revisions, plus any special notes.

The shipper List has 7 columns indicating

i. Serial Number
ii. Part Number
iii. Quantity
iv. Revision Number
v. Description Of part
vi. Colour
vii. Length of item

IV. GUIDELINES FOR ERECTION SEQUENCE

The structural frames and other parts of the building can be erected in various ways which will depend upon the following key factors:

1. The type of structures such as: small clear span, large clear span, low rise building, high building, open web structure etc.
2. The availability of equipment such as cranes , winch, manually lift, etc.
3. .In case of long rafters/members spreader bars multiple cranes must be used.
4. The site conditions
5. The experience level of erectors.

Step 1: Anchor Bolt Checking

This step requires anchor bolt setting plan to be referred where the anchor bolt casted are checked for the compliance with details provided. Its ensured by checking it roughly that the concerned template fits freely over the bolting arrangement. If it does not fits, then the bolts are made vertical by using the pipe without damaging the threads of the anchor bolt. This ensures proper and correct erection.

After that foundation levels are checked and shim packs are placed in the centre of bolt pattern. Top level of all shims should be at the same level and it should be checked by the dumpy level.

Fig. 2: Anchor Bolt Checking

Step 2: Install Columns at Braced Bay

Erection activity always should be proceeded from the start of the braced bay. So the position for the columns should be marked along with their part numbers. From the given figure, refer the columns of braced bays 2-3 and 4-5. To install column A2 follow the procedure as follows:

i. Firstly, tighten the anchor nuts and set up the scaffold/ladder at columns.
ii. Tie temporary bracings on the two sides of the column which are of PP rope of 20mm dia or wire rope of 12 mm dia minimum.

iii. Check the plumb of the column on either sides and slightly release the load on the slings and check the stability of the column and finally remove the slings.

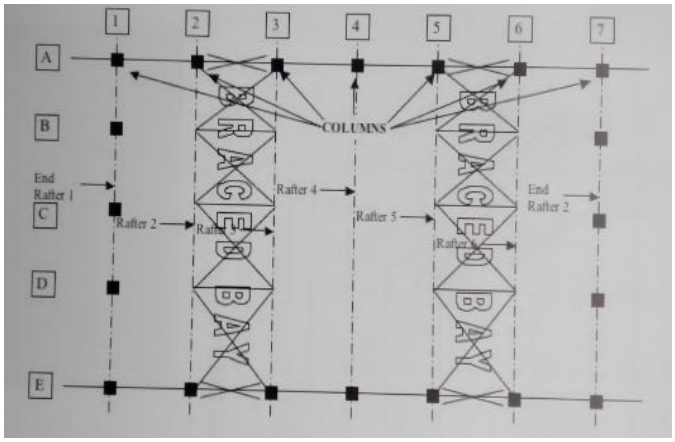

Fig. 3: Plan of proposed site

Step 3: Install column A3 as per step 2

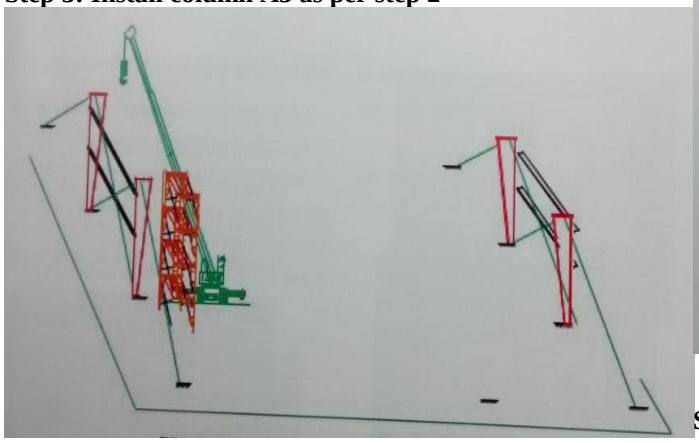

Fig.4: Erection of columns

Step 4: Fixing of girts as per the general guidelines stated as below:

i. To fix up the all the side girts and tie them between each column provided with the rope with safety-lock hook to lift girts.

ii. To tighten the bolts with normal torque and install temporary bracings on two sides of each column.

Step 5: Install other side wall columns

Install other sidewall columns E1 and E2 and girts by repeating Step 2, Step 3 and Step

Step 6: Install the 1st rafter (RF-2)

1st rafter that should be selected should be from the braced bay. Hence, shift all the material towards first braced erection. While shifting, ID mark of the rafter members should be noted and then should be displaced.

i. First rafter member is assembled on the ground and then lifted to the lifting position.

ii. Torque wrench to tighten hi-strength bolts with recommended torque which is given in the Torque table for high strength bolts.

iii. Attach temporary bracing at every 6m and fly bracing to rafters. Attach support pipes D 50*2mm*2m and out-flange of rafters, one at 1m distance from the eave and other right at the top ridge of the rafter end, the pipe on top is used for both roof slopes. Static lines are fixed from pipe to pipe by brackets at 800 mm high from outside flange.

iv. Also, the slings are attache to the member at two points about 1/4 from the ends (minimum 3.5m) and next to purlin cleats towards ends.

v. It is advised to use more than two points and calculate two major parameters to ensure safe erection. They are as follows:

Belt pick-up angle: To avoid distortion of material caused by force

Overhang: To prevent distortion of the member caused by weight itself.

vi. Install assembled rafter with the help of crane to columns and workers on scaffolds at columns should be made to tighten bolts to a snug tight condition at rafter-column connection plates.

vii. Temporary bracing at every 6m to hold the first rafter on 2 sides to anchor bolts groups by V shape cleats or any other immovable object and then the crane is slightly released to check the stability of the rafter before releasing the crane

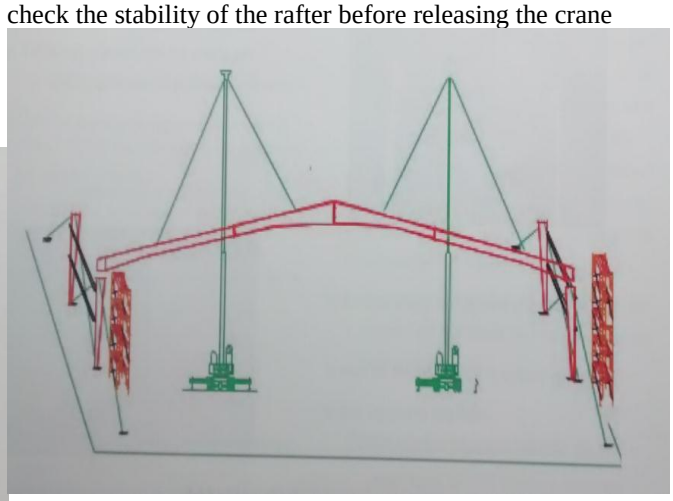

Fig. 5: Erection of rafter in progress

Step 7: Install the second rafter by repeating the above procedure.

Fig. 6: Installing of 2nd rafter

In this step, the only difference in this step is not releasing the crane until the purlins are installed and fly bracings are attached at 6 m on both sides of the rafter. These purlins are provided with rope with safety lock hook to pull the purlins above or below. Also, roof and wall bracings are to be erected.

Step 8: Finish 100% of the braced bay

The braced bay can be installed fully by

i. Placing the struts, purlins, fly bracing on the bays and

ii. Installing permanent cross bracing for roofs and sides fully at this bay.

Fig. 7: Installation of bracing

Step 9: Alignment and Tightening of Braced Bay

After completion of the braced bay erection, it should be checked for alignment which is the most critical activity in the erection sequence which avoids future problem in erection.

It is recommended as follows:

i. Check level of columns and plumb of column on both sides for verticality.

ii. Check the rafter alignment by dropping of plumb from rafter at ridge and at every 6m. Alterations can be made by loosening and tightening of cross bracing and also using temporary bracings where required.

iii. Fly bracings are also fixed in correct position and finally the coincidence of ridge line and centre-line of the building should be checked.

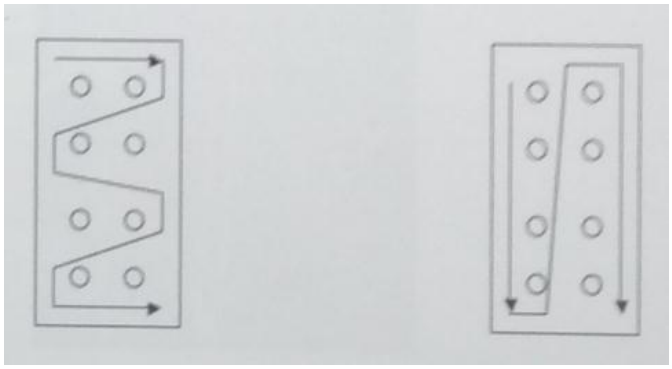

Fig 8: Tightening Sequence

After all these, the situation should be well inspected and tightening the permanent bracing.

Step 10: Install the first end frame

i. Install all the side and internal columns at line 1 and girts

ii. Adjust alignment, position and level with Scaffolds which are set up at each column and tighten anchor bolts. Finally, check the plumb line and tape measure.

iii. Tighten all anchor bolts

iv. Install the first rafter member to columns

Release the crane slightly to check the stability of the rafter before fully releasing of crane.

Step 11: Install all remaining columns, rafters and roof purlins

i. Install all side and internal columns along with girts in line 4,5 and 6.

ii. Adjust alignment, position and level, scaffolds setup at each column and put shims under the base plates which are required. Then the set up should be well inspected and the anchor bolt nuts are tighten after measurement of alignment checks.

iii. Repeat the same [step 6] and [step 7] for all rafters and roof purlins.

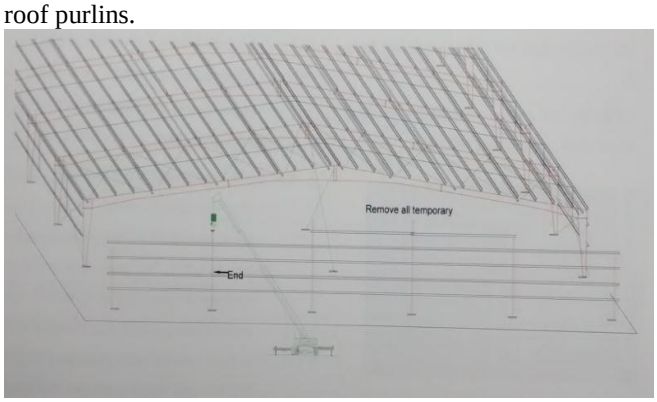

Fig 9: Erection of columns at gable end

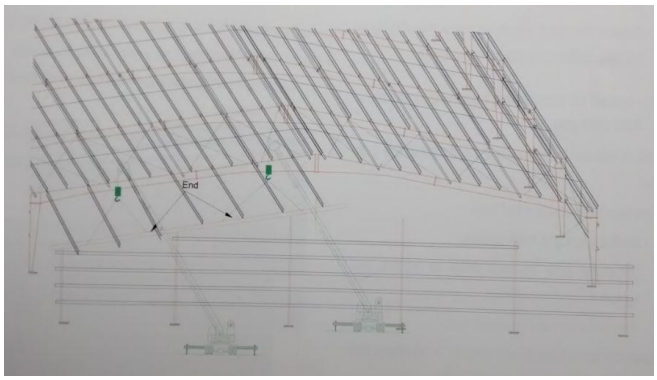

Fig 10: Erection of rafters at gable end

Step 12: Install the second end frame

i. Install all side and internal columns along with girts at line 4.5 and 6.

ii. Adjust the alignment, position and level with the set up of scaffolds at every column. After inspection, anchor bolt nuts are tightened after the alignment checks.

iii. Install the first rafter member to the columns by guidelines of above steps.

Step 13: Finish 100% Frame & Roof Purlins

i. Installion of struts, purlins and fly bracing 100 % for 2 end bays. Cranes are used to pick up struts to roof which possess rope with safety lock hook to pull up purlins, struts manually

ii. Installation of permanent cross bracings for columns fully at these bays. Leave the bracing in loose condition.

Step 14: Alignment and Tightening

Follow [step 9] for alignment and tightening

Release some temporary bracings of the building if required.

Fig.11: Tightening of anchor bolts

Step 15: Final Inspection

i. The draft of 'Final Inspection' should be done between the product consultant and Builder. It is done to ensure the quality compliance and planning for repair, clean and touch up. As a part of contract. it is signed off between the technical personnels.

ii. The official final inspection shall be completed with a witness of client's representative. The record must be signed off and documented as a part of contract.

V. CONCLUSION

During erection, it is mandatory to maintain the stability of the structure at all times. It is observed that structures collapse during erection and major reason behind collapse is due to lack of understanding on someone's part of what another has assumed in the erection procedure. So, the guidelines are necessary to understand the erection procedure with proper safety as it is a critical consideration during steel erection. It is generally a case for partly erected structure which is vulnerable to collapse where cranes can overturn or drop large components if not taken proper care during erection. Hence, these regulations and guidelines regarding the provision of equipment and arrangements minimize the risk of accident.

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