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Erection and structural design errors of structural steel warehouses

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Abstract

Structural steel is commonly used to construct warehouses such as storage warehouse, truck terminals, industrial buildings, and warehouse supermarkets. These structures are usually one story structures that it is easy to analysis as two dimensional structures and can be designed and fabricated in a short time. The safety of these structures to withstand vertical and lateral loads is essential. In practice sometimes erection and design errors may cause structural local or global failures to these structures especially under major earthquakes and strong wind loads. In this paper some of the erection and design errors that engineers should avoid are presented.

Keywords: Structural steel; Erection; Design errors; Warehouse; Roof bracing; Earthquake

1. Introduction

Warehouses are commonly used as industrial buildings to store goods. Storage warehouse, cold storage warehouse, truck terminals, and warehouse supermarket are common types of warehouses [1,2]. The structural system of a structural steel warehouse is an assemblage of a group of hot rolled steel members connected to each other by bolted or welded connections. In most cases warehouses are one story structures and the roof system may consist of trusses or portal frame rafters. As an example Fig 1 shows an industrial warehouse steel building .The main structural system of the warehouse consists of a series of steel portal frames braced in the longitudinal direction by longitudinal bracing. Each frame consists of columns and rafters. Vertical loads such as roof own weight and snow loads transfer from roof cladding to the purlins then to the portal frames and to the foundation. Horizontal loads (i.e such as wind and earthquake loads)in the transverse direction transferred to foundation by means of the steel portal frames .However horizontal loads in the longitudinal direction transferred to the foundation by means of both roof and longitudinal bracings. H or I shaped profiles are usually used for columns, rafters and beams. I, U, and Z shaped profiles are used for Purlins .To ensure the safety of structural steel warehouses under vertical and lateral loads effects, their structural system should be design and constructed as it is required by international standards such as AISC 360, and also the site soil conditions should be taken carefully into account in the design process [3,4,5,6]. In this paper some common design and construction errors of structural steel warehouses is presented , and engineers should avoid such errors during design and construction process of such structures.

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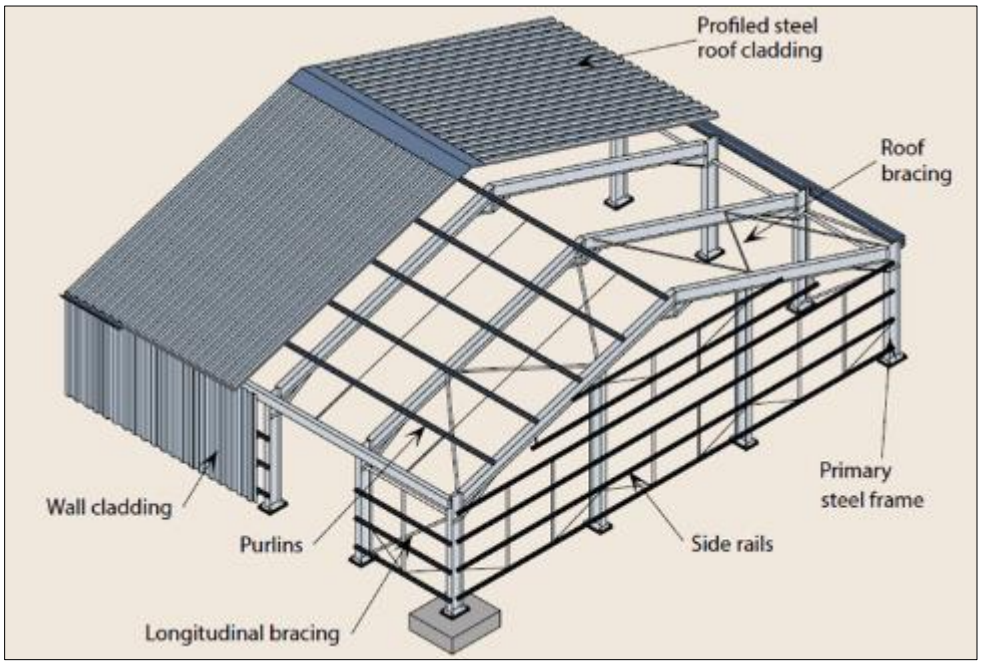

a) Typical general 3D view of steel portal frame warehouse

b) column to rafter connection

c) Portal frames

Figure 1 Component of steel portal frame warehouse

2. Purling locations and roof bracing errors

One of the common construction errors of structural steel warehouse roofs are incorrect supports of purlins on the structural steel roof trusses as it is shown in Fig2. As it is shown in the figure the purlins are not supported on the joints of the structural steel trusses , instead they support on the mid of the upper cored members of the trusses. This error will cause bending moments in the upper cord truss members and these members were not designed to carry such internal moments. And this may cause failures of these members under heavy snow loads .This error can be avoided by selecting the correct purlin spacing to coincides with the truss joints. And purlins loads, analysis and design should be done according to the selected correct purlin spacing. Also connection details between the trusses and columns may be not enough to withstand future earthquake loads .These pure connection details should be avoided in warehouses constructed in high seismic area such as Istanbul. Furthermore It is better not to use rod roof bracing as shown in Fig 3 because these bracing may be not able to transfer lateral loads from the roof to the vertical bracings (i.e these rod bracing are weak and not rigid enough to make rigid diaphragm to transfer seismic or wind loads).

Figure 2 Incorrect supporting of purlins on the steel trusses

Figure 3 Weak roof bracing

3. Design and Construction Errors of connections

Incorrect connections of roof truss diagonal members are one of the common constructions errors of structural steel roof warehouses as it is shown in Fig 4.To avoid this error ,connection details should be drawn to ensure that all the center lines of the connected members meet at one point as shown in Fig 5.

Figure 4 Incorrect connections of roof truss diagonal members

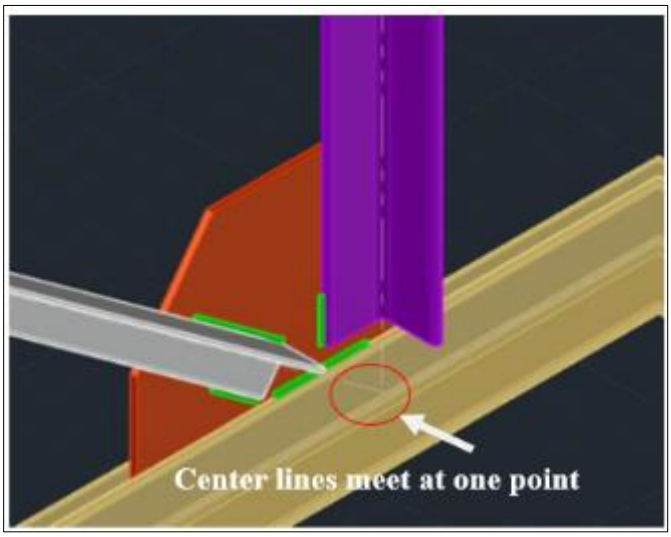

Figure 5 At joint connection truss members center lines should meet at one point

Another connection design error that may be seen in practice is incorrect design of rafter to column connection as it is shown in Fig 6. In the figure the there is a failure in the upper part of the connection due to inadequate number of bolts or incorrect choice of bolt materials which lead to bolt yielding ,and as a result cause a gap between the connected plates. This error can be avoided by replacing the existing bolts by higher strength material or increasing the number of bolts .And it is better to check the design loads and the analysis and redesign bolts number accordingly.

Figure 6 Inadequate number of bolts or incorrect choice of bolt materials

In structural steel warehouses , connection between roof bracing and vertical bracing plays an important role in transferring lateral loads (i.e wind and earthquake loads) from the roof to the foundation. Incorrect bracing erection or design may cause lateral instability of the structure under wind and earthquake loads. Hence design, drawing details and erection of these connections should done correctly according to design codes to ensure safety of steel warehouse structures under seismic loads. Fig 7 shows incorrect erection of roof bracing - vertical bracing connection .The two bracing are far away from each other .They should be connected so close to each other.

Figure 7 Incorrect roof bracing - vertical bracing connection

4. Structural analysis and design errors

Sometimes errors due to incorrect load calculations result in under-designed or over-designed structures. Fig 8 shows over-designed structure due to over estimation of loads. These errors can be avoided by correct estimation of snow, wind, and seismic loads according to location, environmental factors, and seismic activity specified by codes. Furthermore use of professional engineering software and consulting experienced structural engineers will lead to precise load calculations. Structural analysis errors such as ignoring p-delta effects in the analysis may lead to under estimation of internal bending moment's values in the structure and this may cause connection failures during future earthquakes. Furthermore, in case of warehouses that have moving loads such as cranes, the designers commonly design the structure without considering fatigue action, and by time fatigue cracks may develop in the steel structural members or in its connections .Crack length may become critical and cause local or global failure of the structure.

Figure 8 Over-designed structure due to over estimation of loads

5. Conclusions

Incorrect erection and structural analysis and design errors of structural steel warehouses may lead to local or total failure of these structures during future earthquakes. Structural engineers and contractor should be aware of common errors in practice. Specifying incorrect materials may cause connection or member failures and longevity of the structure. Erection or design errors in roof bracing-vertical bracing connections will affect structural stability of warehouses during winds or seismic loads and the structural engineers should detail these connections according to the design codes. Correct purlin locations is important for safe transfer of gravity loads such as snow loads from the roof to the foundation. Erection and design errors of purlins locations should be avoided. Furthermore, in steel roof trusses, at joint connection truss member's center lines should meet at one point to prevent any discontinuity of load transfer. Moreover, incorrect load calculations result in under-designed or over-designed structures. This can be overcome by correct load estimations according to local and international standards and consulting experienced structural engineers.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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