ROOF TRUSSES COLLAPSE DURING CONSTRUCTION

Type of building work

The involves the construction of a large single-storey industrial building (measuring 200m long by 60m wide) with long-span pitched roof. The roof comprised 29 numbers of steel trusses of 59m span, supported on reinforced concrete beams and columns.

The top and bottom chords and the longer diagonals of the trusses were made up of double angles connected back to back. As the span of the truss was long (59m), the height of the truss at the mid-span was also large, standing at 10.8m high. A single truss when installed would stand up as a rather slender element. Erection of the trusses did not commence from one of the gable end walls, and as a result the first 3 adjacent trusses that were erected were braced against each other instead of being braced against a rigid gable end wall. Temporary supporting towers were used as intermediate supports to facilitate erection.

Figure 1: Erection of the first 3 trusses

What went wrong

After the first 3 trusses were erected, the contractor removed the temporary supporting towers situated at mid-span of the trusses. The 3 trusses collapsed shortly after that and killed two workers and injured few others.

Figure 2: Collapsed trusses

On completion of the erection process, some of the purlins and tie beams near the temporary supporting towers were not installed so as to provide a clear space for lifting. Temporary diagonal bracings were also not used to provide effective lateral stability and torsional rigidity to the trusses. The tight space available for the removal of the temporary supporting towers, coupled with the use of a crane mounted on a floating barge, warrant skill, precision, and coordination between the crane operator and the personnel giving instructions in order to avoid accidental lateral loads.

While the intention of the knee-joint support is to have a sliding joint, the 8 numbers of holding-down bolts at the support might not had allowed this to be achieved, and the joint was likely to behave as a pin-jointed support.

In view of the large height of the truss and possibility of eccentric loads and uneven distribution of stresses at the joints (from pattern loading due to construction sequence), members at the support could warp easily and invalidate the assumption of plane sections remaining plane.

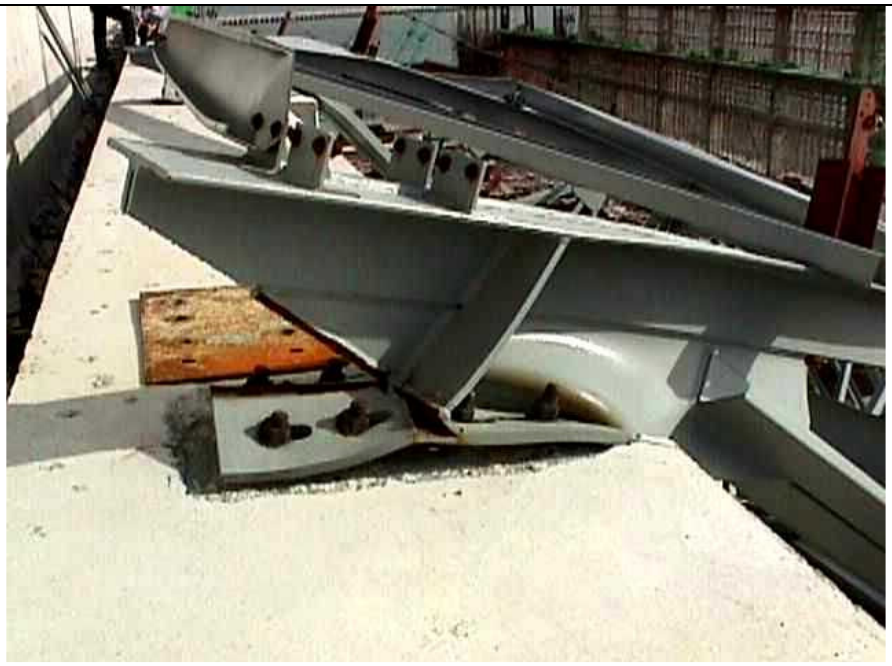

Figure 3: Knee-joint at support. The angle cleats to hold purlins were not continuous.

As most of the key truss members were long and made up of double angles connected back to back, battening of compound compression members had to be carefully addressed in the design to meet code requirements on slenderness ratio of the members. Angle cleats used to hold the purlins were not provided as a continuous piece to tie up the back-to-back compound members together. Thus, the intention to make use of these cleats as battens was not properly carried through. As a result, the top chord members which were in compression were insufficiently battened.

A diagonal strut member was found to be missing from the truss, and as a result, the roof trusses would not behave and act as trusses and bending stresses would be induced in the members.

Learning points

a) Although a large truss member could be designed in the same way as any typical truss, PE should take cognizance of its size effect as the handling and performance of a long and high truss (such as 59m long and 10.8m high truss) could be very different from an ordinary truss. Issues such as lateral stability and torsional rigidity becomes very crucial during the various stages of fabrication and erection.

b) Supervision is very important during the construction of key elements. The builder, QP and site supervisor should be vigilant to ensure that there are no missing elements.

c) When long slender structural steel members are subject to compression, presence of bracing members are very critical, especially for compound angle members as their performance depends very much on the effectiveness of battens as well as the presence of effective lateral bracing elements.

d) Lateral and diagonal restraints for erection of trusses should be connected to sufficiently rigid supports, for example, rigid reinforced concrete frame at the gable end of the building.

e) All temporary supports and bracings should also be designed for any incidental lateral forces during the construction.

f) Connection details should be carefully detailed and constructed to reflect the design intention, so as not to induce unnecessary forces and moments which are not accounted for in the design.