DESIGN PRINCIPLES FOR ROOF STEEL TRUSS

INTRODUCTION:

Steel trusses are being used for both buildings and bridges. But the design principles are different for different uses. Many books are course oriented and not with a practical principles. Now an attempt has been made to gather information on the design principles from various references ON THE LAYOUT AND OTHER DESIGN PRINCIPLES.

Steel roof trusses are used for mainly for the Industrial buildings where free space requirement are essential for more working areas. The span of truss varies from 10’-0” to 300’-0” depending on the type of requirement and the available spaces.

The following steps should be considered when designing a truss:

1. Select the general layout of truss members and truss spacing.
2. Estimate external loads to be applied including self weight of truss, purlins and roof covering together with wind loads.
3. Determine critical (worst combination) loading. It is usual to consider Dead loads alone and then Dead and Imposed loads combined.
4. Analyze the frame work to find forces in all members.
5. Select material and section to produce in each member a stress value which does not exceed the permissible value. Particular care must be taken with compression members (struts) or members normally in tension but subject to stress reversal due to wind uplift.

For span up to about 20.00 m, the spacing of steel trusses is likely to be about 4.00m i.e. 1/5 of span.
A slope of 220(degree) is common for corrugated steel and asbestos roofing sheets.
For economic spacing of roof trusses, the cost of truss should be equal to twice the cost of purlins +the cost of roof covering. As a guide the spacing of the roof trusses can be kept:

a. ¼ of span upto 15.0m.
b. 1/5 of span upto 15m to 30m.

Trusses with parallel chords are often referred to as LATTICE GIRDERS.
DIFFERENT SHAPES OF TRUSSES FOR DIFFERENT SPANS.

7.0M TO 11.0m

Belgium truss
CONFIGURATIONS:

The pitch of roof truss depends on the roofing materials.

a) Min. recommended for GI sheet—1 in 6 i.e $h/l=1/6$  $h=l/6$

b) For A.C sheet                         -1 in 12 i.e $h=l/12$.

Parallel chord trusses: The economical span to depth ratio =12 to 24.
Trapezoidal trusses: The configuration shown below reduces the axial forces in the chord members adjacent to supports.
Economical span to depth ratio is around 10. The slope is 1/5. Spacing of trusses should be in the region of 1/4 to 1/5 of span. Fan trusses are used when the Rafter members of the roof trusses have to be subdivided into ODD number of panels. Pitch = L/h = 4 to 10

It is good practice to use the same depth of a truss at the supports h s for trusses with different spans.

- slope i = 1 in 12 for h upto 3.8m
- slope i = 1 in 8 for h > 3.8m

h = L/4 to L/10

For transportation facility, the trusses would be required of 2 halves. The depth of a truss at the middle of span as a rule is taken as not over 3.8m (between the entire points of a member)
The mass per sq.m of:

a) Fink trusses is lowest for spans from 15m upwards.
b) Pratt trusses from 10 m to 20m.
c) And of Portal frames from 10m to 20m.

The roof slope is normally chosen to 1:16 or 1:10 depending on type of roofing. A slope less than 1:16 should be used with caution since the deflection decreases the inclination and if the actual roof slope becomes too small trouble with water run-off can give problems with water accumulation (Ponding). The smallest possible slope depends on the size of the snow load.

A rough estimate of section height for a gabled truss is that for roof slope 1:16, \( H = L/25 \) to \( L/30 \).
For slope 1:10, \( H = \frac{L}{35} \) to \( \frac{L}{40} \) where \( H \) is the depth at support. For parallel trusses the relation is approximately \( H = \frac{L}{20} \).

The most advantageous angle between the diagonals and the bottom chord is \( 45^\circ - 50^\circ \) in a triangular lattice and \( 35^\circ - 45^\circ \) in a diagonal one.

In the practice of designing industrial and residential buildings, the most frequent case is the use of **support diagonals upwards**. Triangular trusses are employed only in roofs with steep pitches.

In the diagram, \( h_s = 0.02h \), where \( h \) is the height of the truss. For a triangular truss, the formula \( h_s = 0.02h \) is illustrated.

**Loadings:**
- False ceiling: \(-200 \text{ N/sq.m}\)
- Duct: \(-40 \text{ N/sq.m}\)
- G.I. Sheet: 0.63mm thick to 1.6 mm thick: \(-55 \text{ to } 140 \text{ N/sq.m}\)
- Asbestos sheet: \(-171 \text{ N/sq.m}\)
- Roofing tiles: \(-350 \text{ to } 850 \text{ N/sq.m}\)
- Bracings: \(-12-15 \text{ N/sq.m}\)
- Purlins: \(-200 \text{ to } 400 \text{ N/sq.m}\)
- Mangalore tiles with battens: \(-650 \text{ N/sq.m}\)

**Self weight of truss:**

Various Handbooks and text book furnish different formulae for the self weight of steel truss. One has to make use of it judiciously and with engineering judgement.
Welded sheeted roof trusses is given approximately as:

A. \[ W = \frac{1}{100}(5.37 + 0.0534A) \text{Kn/sq.m} \] where \( A \) is the plan area in \( \text{sq.m} \).

From the HB for Building Engineers in Metric system,

a) Fink type roof truss (From Ketchum’s structural engineers HB)
   \[ W = 0.0222P.A.L(1 + 0.3622L/\sqrt{A}) \text{in Kg} \]
   where 
   \( P = \) capacity of truss in Kg/sq.m in horizontal projection of roof (150-400 Kg/sq.m)
   \( A = \) spacing c/c of truss in m.
   \( L = \) span of truss in m.

b) for steel truss in general
   \[ W = 0.4(4.42VL+L) \text{ Kg/sq.m of horizontal covered area} \]
   \( L = \) span in m.

B. DL of truss = \((\text{Span}/3+5)\times10 \text{ N/sq.m}\)

Refering to page 273 of Design of Metal Structures by k. Mukhanov-MIR publication.

The Minimum weight of truss is approximately obtained when the weight of the chords equal to that of the lattice (including the gusset plate) which will be the case with comparatively large truss depth to span ratio. \((h/L \approx 1/5)\).

The weight of standard trusses \( g \) in kg/sq.m area covered depending up on the design load \( q \) (in Kg/sq.m) is:

<table>
<thead>
<tr>
<th>Span</th>
<th>( g ) (Kg/sq.m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L = 18.0 \text{m} )</td>
<td>( g = 2.2 + q/125 )</td>
</tr>
<tr>
<td>( L = 24.0 \text{m} )</td>
<td>( g = 2.78 + q/54.2 )</td>
</tr>
<tr>
<td>( L = 30.0 \text{m} )</td>
<td>( g = 4.44 + q/34.7 )</td>
</tr>
<tr>
<td>( L = 36.0 \text{m} )</td>
<td>( g = 5.27 + q/21 )</td>
</tr>
</tbody>
</table>

Ref: P391 Design of Metal structures by K. Mukhanov.

Approximate weights of elements of steel Industrial building framework in Kg/sq.m of building area:

<table>
<thead>
<tr>
<th>Sl. #</th>
<th>Element of steel frame work</th>
<th>Group of shops</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Light</td>
</tr>
<tr>
<td>1.</td>
<td>Roof:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Roof trusses</td>
<td>16-25</td>
</tr>
<tr>
<td></td>
<td>Secondary trusses</td>
<td>0-6</td>
</tr>
<tr>
<td></td>
<td>Purlins</td>
<td>10-12</td>
</tr>
<tr>
<td></td>
<td>Skylights</td>
<td>0-10</td>
</tr>
<tr>
<td></td>
<td>3-4</td>
<td>3-5</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>30-40</strong></td>
<td><strong>45-70</strong></td>
</tr>
</tbody>
</table>

2. **Columns with tie & platforms**
   - 10-18
   - 18-40
   - 70-120

   **Crane girder with bracing beams**
   - 0-14
   - 14-40
   - 50-150

   **Wall frame work**
   - 0-3
   - 5-14
   - 12-20

   **Miscellaneous**
   - -
   - 0-10
   - 3-12

**Grand total**

- **35-80**
- **75-170**
- **200-400**

Ref: Table 2A-Reynold’s handbook on RC Design:

**Roof Trusses:**

<table>
<thead>
<tr>
<th>Span of trusses</th>
<th>25’0”</th>
<th>30’0”</th>
<th>40’0”</th>
<th>50’0”</th>
<th>60’0”</th>
<th>80’0”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lbs/sft or Kg/sq.m</td>
<td>7.5m</td>
<td>9.0m</td>
<td>12.0m</td>
<td>15.0m</td>
<td>18.0m</td>
<td>25.0m</td>
</tr>
<tr>
<td>Spacing of truss</td>
<td>2</td>
<td>2.5</td>
<td>2.75</td>
<td>3.0</td>
<td>4.25</td>
<td>5.0</td>
</tr>
<tr>
<td>Weight(approx) of steel roof trusses.</td>
<td>1.5</td>
<td>1.5</td>
<td>1.75</td>
<td>2.25</td>
<td>3.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Weight(approx) of steel roof trusses.</td>
<td>10</td>
<td>11.5</td>
<td>14.0</td>
<td>15.0</td>
<td>21.0</td>
<td>25.0</td>
</tr>
</tbody>
</table>

**GRAVITY LOADS:**

Gravity loading about 1kpa(including LL but excluding the self weight of purlins and roof principals) and basic wind speed 46m/s.

Where the maximum gravity loading(DL+LL) exceeds the net uplift loading(DL+WL) as usual in roofs of buildings, the web compression members under gravity loading attract higher forces because of their slope.

**LIVE LOADS:**

<table>
<thead>
<tr>
<th>Roof slope</th>
<th>Access</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤10°</td>
<td>provided</td>
<td>1500N/sq.m of plan area</td>
</tr>
<tr>
<td>≤10°</td>
<td>not provided</td>
<td>750N/sq.m of plan area.</td>
</tr>
<tr>
<td>≥10° every</td>
<td></td>
<td>750N/s.m reduced by 10N/sq.m for degree increase upto &amp; including 20°.</td>
</tr>
</tbody>
</table>
Reduced by 20N/sq.m for each one degree increase above 20°.