APOLLO SALES LTD
PUBLIC ACCESS SCAFFOLD STEP DESIGN CHECK CALCULATIONS

Alan N White B.Sc., M.Eng., C.Eng., M.I.C.E., M.I.H.T.

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Somerset House
11 Somerset Place
GLASGOW G3 7JT
Tel:0141 354 6579
Fax:0141 354 6549
Brief

To carry out a design check on the Apollo Site Tread scaffold step to the relevant Standards and Codes.

Layout

The step varies in length, supplied up to 1.5m wide tread

The step is 305mm wide with a non slip grating, non-see through grating.

Section

From BS 5395 Stairs Ladders and walkways the min going is 225mm

![Diagram of the section with dimensions 45mm, 15mm, 275mm, 305mm, and 305mm.

Loading

BS EN 1991-1-1 Table NA.3

<table>
<thead>
<tr>
<th>UDL</th>
<th>w= 3.00 kN/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point load</td>
<td>W= 4.00 kN</td>
</tr>
<tr>
<td>on 200 by 200mm</td>
<td></td>
</tr>
</tbody>
</table>
Factor of safety

From BS EN 12811-1

1.1.1.1 Partial safety factors for actions, $g_F$

Except where stated otherwise, the partial safety factors, $g_F$, shall be taken as follows:

Ultimate limit state

- $\gamma_F = 1.5$ for all permanent and variable loads
- $\gamma_F = 1.0$ for accidental loads

Serviceability limit state

$\gamma_F = 1.0$

10.3.2.2 Partial safety factors for resistance $g_M$

For the calculation of the design values of the resistances of steel or aluminium components the partial safety factor, $\gamma_M = 1.1$ of other materials the partial safety factor, $g_M$, is to be taken from relevant standards.
Section properties

From autocad massprop using the section as shown below
This is conservative as the section chosen is the minimum

8mm
r=5mm

\[ \begin{align*}
A &= 732 \text{ mm}^2 \\
I_x &= 145250 \text{ mm}^4 \\
I_y &= 9054649 \text{ mm}^4 \\
r_x &= 14.1 \text{ mm} \\
r_y &= 111.2 \text{ mm} \\
W_{pl,y} &= 8236 \text{ mm}^3 \\
\end{align*} \]

Slenderness
\[ \frac{C}{t} = \frac{291}{8} = 36.38 \]

Section is class 2 so plastic design allowable

Material is mild steel \( f_y = 275 \text{N/mm}^2 \)

Moment capacity

From BS EN 1993-1-1- 6.2.5
\[ M_{c,Rd} = \frac{W_{pl}f_y}{\gamma_M} \]
\[ W_{pl} = 8.24 \text{cm}^3 \]
\[ f_y = 275 \text{N/mm}^2 \]
\[ \gamma_M = 1.1 \]
\[ M_{c,Rd} = \frac{8.24 \times 275}{1100} = 2.06 \text{kNm} \]

Shear capacity

From BS EN 1993-1-1- 6.2.6
\[ V_{c,Rd} = \frac{A_v(f_y/\sqrt{3})}{\gamma_M} \]
\[ A_v = 2 \times 45 \times 2 = 180 \text{mm}^2 \]
\[ f_y = 275 \text{N/mm}^2 \]
\[ V_{c,Rd} = \frac{180 \times (275/\sqrt{3})}{1100} = 25.98 \text{kN} \]

Lateral Torsional Buckling

From BS EN 1993-1-1- 6.3.2.1

As bending is about minor axis LTB verification is not required.
Loading

As before

UDL on stair  \( w = 3.00 \text{ kN/m}^2 \)
and point load  \( W = 4.00 \text{ kN on 200mm by 200mm} \)

Moment

so for UDL on 225mm wide stair with span of 1.6m

\[ M_{Ed} = \gamma w B L^2 / 8 \]
\[ \gamma = 1.5 \]
\[ w = 3 \text{ kN/m}^2 \]
\[ B = 0.305 \text{m} \]
\[ L = 1.5 \text{m} \]
\[ = 1.5 \times 3 \times 0.305 \times 1.5^2 / 8 \]
\[ = 0.39 \text{ kNm} \]

for a point load of 4kN over a width of 200mm

\[ W_u = \gamma W \]
\[ \gamma = 1.5 \]
\[ = 1.5 \times 4 \]
\[ = 6.00 \text{ kN} \]

\[ W_u = 6 \text{ kN} \]
\[ s = 0.2 \]
\[ Ra = W_u / 2 \]
\[ = 6 / 2 \]
\[ = 3.00 \]

\[ M_{Ed} = Ra L / 2 - W_u s / 4 \]
\[ s = 0.2 \text{m} \]
\[ W_u = 6 \text{ kN} \]
\[ L = 1.5 \text{m} \]
\[ = 3 \times 1.5 / 2 - 6 \times 0.2 / 4 \]
\[ = 1.95 \text{ kNm} \]

from previous calculations

\[ M_{c, Rd} = 2.06 \text{ kNm} \]
\[ > 1.95 \text{ ok} \]
Shear

so for UDL on 225mm wide stair with span of 1.6m

\[ V_{Ed} = \gamma w B L / 2 \]
\[ \gamma = 1.5 \]
\[ w = 1 \text{kN/m}^2 \]
\[ B = 0.225 \text{m} \]
\[ L = 1.6 \text{m} \]
\[ = 1.5 \times 1 \times 0.225 \times 1.6 / 2 \]
\[ = 0.27 \text{kN} \]

for a point load of 4kN over a width of 200mm

\[ W_u = \gamma W \]
\[ \gamma = 1.5 \]
\[ = 1.5 \times 1.5 \]
\[ = 2.25 \text{kN} \]

\[ W_u = 2.25 \text{kN} \]
\[ W_u / 2 = 2.25 / 2 \]
\[ = 1.13 \text{kN} \]

from previous calculations

\[ M_{o, Rd} = 25.98 \text{kN} \]
\[ > 1.13 \text{kN} \quad \text{ok} \]

Deflection

for central point load of 1.5kN

\[ d = \frac{W L^2}{48 E I} \]
\[ W = 1.5 \text{kN} \]
\[ L = 1.6 \text{m} \]
\[ E = 205 \text{kN/mm}^2 \]
\[ I = 123982 \text{mm}^4 \]
\[ = 1500 \times 1600^3 / (48 \times 205 \times 123982) \]
\[ = 5.04 \text{mm} \]

From BS EN 12811-1 the max deflection is

\[ d = \frac{L}{100} \]
\[ L = 1600 \text{mm} \]
\[ = 1600 / 100 \]
\[ = 16.00 \text{mm} \]
\[ > 5.04 \text{mm} \quad \text{ok} \]
Rotation

If the loading was eccentric, i.e. at the step edge the moment applied to the support couplers would be

\[ M = W_u \cdot l_a \]

\[ W_u = 2.25 \text{kN} \]

\[ l_a = \frac{0.225}{2} \]

\[ = 0.11 \text{m} \]

\[ = 2.25 \times 0.11 \]

\[ = 0.248 \text{kNm} \]

This is conservative as the load is spread over a patch not a point.

This is resisted by two couplers so the twisting moment is

\[ M = 0.124 \text{kNm} \]

From BS EN 12811-1 the resistance to rotation of a double coupler is

\[ M_r = 0.130 \text{kNm} \]

\[ > 0.124 \text{ ok} \]

If the load is considered a patch 200mm wide on a 225mm wide step then the eccentricity

\[ l_a = \frac{225}{2} - \frac{200}{2} \]

\[ = 12.50 \text{ mm} \]

and

\[ M = W_u \cdot l_a \]

\[ = 2.25 \times 0.0125 \]

\[ = 0.03 \text{kNm} \]

\[ < 0.13 \text{ ok} \]
Length of stringer

From BS EN 12811-1, the load on the stringer is:

The structure of the stairways shall be capable of supporting a uniformly distributed load of 1.0 kN/m² on all treads and landings within a height of 10 m. but the load on the tread is 3kN/m

so the stringer will carry the load as shown below

\[
\begin{align*}
\text{w} &= 3.0 \text{kN/m}^2 \times 1.5 \text{m}/2 \\
&= 3 \times 1.5/2 \\
&= 2.25 \text{kN/m unfactored}
\end{align*}
\]

and

\[
\begin{align*}
\text{L} &= \text{length between stringer supports} \\
\text{H} &= \text{height varies with angle between 30 and 55 deg}
\end{align*}
\]

taking allowable values from TG20 as

\[
\begin{align*}
\text{Moment } M &= 1.1 \text{kNm} \\
\text{Axial } P &= \text{varies as below}
\end{align*}
\]

<table>
<thead>
<tr>
<th>Angle °</th>
<th>Moment kNm</th>
<th>Axial kN</th>
<th>Combined</th>
<th>Length m</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>0.84</td>
<td>3.37</td>
<td>1.00</td>
<td>2.59</td>
</tr>
<tr>
<td>35</td>
<td>0.83</td>
<td>3.79</td>
<td>1.00</td>
<td>2.40</td>
</tr>
<tr>
<td>40</td>
<td>0.81</td>
<td>4.17</td>
<td>1.00</td>
<td>2.21</td>
</tr>
<tr>
<td>45</td>
<td>0.80</td>
<td>4.51</td>
<td>1.00</td>
<td>2.00</td>
</tr>
<tr>
<td>50</td>
<td>0.79</td>
<td>4.82</td>
<td>1.00</td>
<td>1.80</td>
</tr>
<tr>
<td>55</td>
<td>0.78</td>
<td>5.09</td>
<td>1.00</td>
<td>1.59</td>
</tr>
</tbody>
</table>

Above table found by Excel Goal seeking
Summary

The scaffold step has been checked for the required loading and found to be adequate for a maximum width of 1.5m.

Loading from BS EN 1991-1-1 Table NA.3

<table>
<thead>
<tr>
<th>Angle</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degrees</td>
<td>Spacing m</td>
</tr>
<tr>
<td>30</td>
<td>2.59</td>
</tr>
<tr>
<td>35</td>
<td>2.40</td>
</tr>
<tr>
<td>40</td>
<td>2.21</td>
</tr>
<tr>
<td>45</td>
<td>2.00</td>
</tr>
<tr>
<td>50</td>
<td>1.80</td>
</tr>
<tr>
<td>55</td>
<td>1.59</td>
</tr>
</tbody>
</table>

The stringer which supports the steps requires to be supported by standards at a spacing as shown in the table below dependant on the angle of the stair.