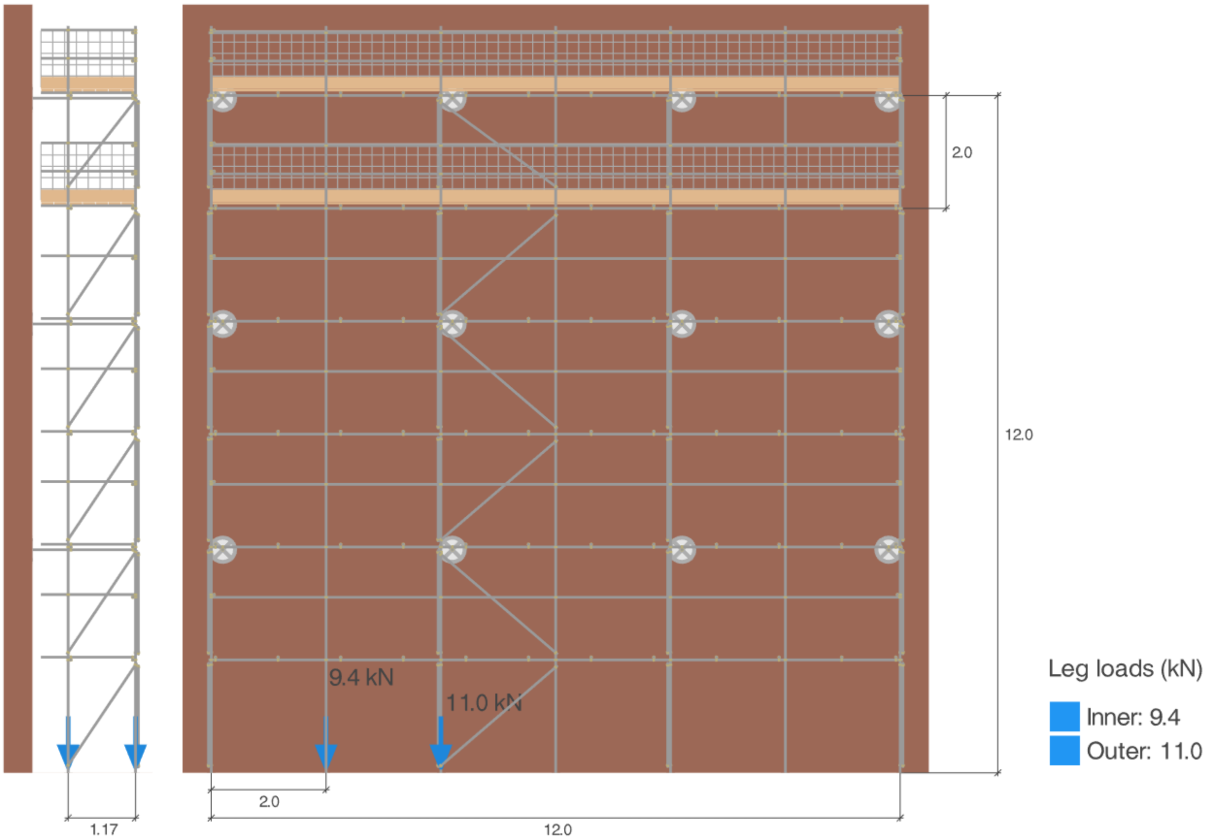
Tied independent scaffolding leg loads

For tube and fitting scaffolding, in accordance with BS EN 12811-1:2003 and NASC TG20:13.

ℹ This calculation should be read in conjunction with the wind factor and tie duty calculation reports.



Site location

Description	Value
Site address	East Overcliff Drive, E Overcliff Dr, Bournemouth BH1, UK
TG20:13 wind factor, $S_{TG20:13}$	26.6
Peak velocity pressure at 13.00 m, $q_{p(z = 13.00m)}$	0.888 kN/m²

Scaffold dimensions

Description	Value
Number of boarded lifts, n_b	2
Number of unboarded lifts, n_u	4
Maximum lift height, H_{lift}	2.00 m
Maximum bay length, L_{bay}	2.00 m
Number of main boards wide, n_m	5
Number of inside boards, n_i	2

Edge protection

Description	Value
Guard rails at boarded lifts, $n_{gr,b}$	2
Guard rails at unboarded lifts, $n_{gr,u}$	1
Inner guard rails at boarded lifts	None
Inner guard rails at unboarded lifts	None
Inner toe boards	None

Scaffold configuration

Description	Value
Cladding	Brick guards
Facade permeability (1)	Impermeable
Tie pattern	TG20:13 A
Structural transoms	None

(1) No significant openings.

Loading

Description	Value
Main platform working load, P_m	2.00 kN/m²
Inner platform working load, P_i	0.75 kN/m²
Number of loaded lifts, n_l	1
Number of 50% loaded lifts, $n_{l,50}$	1

Component dimensions

Description	Value
Tube diameter, d_t	48.3 mm
Board width, W_b	225 mm
Board thickness, t_b	38 mm

Component weights

Component	Unit mass	Unit weight
Tubes, P_t	4.37 kg/m	0.043 kN/m
Boards, P_b	25.00 kg/m²	0.245 kN/m²
Right-angle couplers, P_{ra}	1.25 kg	0.012 kN
Swivel couplers, P_{sc}	1.33 kg	0.013 kN
Putlog couplers, P_{pc}	1.00 kg	0.010 kN
Brick guards, P_{bg}	1.60 kg/m²	0.016 kN/m²

Calculated dimensions

Toe board thickness	$t_{tb} = 0.038$ m
Main platform width between ledger centres	$W_m = n_m \cdot W_b + t_{tb} - d_t = 5 \cdot 0.225 + 0.038 - 0.048 = 1.115$ m
Cantilever width beyond inner ledger	$W_i = n_i \cdot W_b + 1.5 \cdot d_t = 2 \cdot 0.225 + 1.5 \cdot 0.048 = 0.522$ m
Total platform width	$W_{total} = W_m + W_i = 1.115 + 0.522 = 1.637$ m

Transverse tube oversail length	$L_{t,tr} = 0.100$ m
Service gap	$W_{gap} = 0.15$ m
Board transom or end guard rail length	$L_{tr} = W_{total} + 2 \cdot L_{t,tr} = 1.637 + 2 \cdot 0.100 = 1.837$ m
Tie tube length	$L_{tt} = W_{total} + L_{t,tr} + W_{gap} = 1.637 + 0.100 + 0.15 = 1.887$ m
Bracing tube oversail length	$L_{t,b} = 0.200$ m
Facade brace analytical model length	$L_{fb,1} = \sqrt{L_{bay}^2 + H_{lift}^2} = \sqrt{2.00^2 + 2.00^2} = 2.828$ m
Facade brace length	$L_{fb} = L_{fb,1} + 2 \cdot L_{t,b} = 2.828 + 2 \cdot 0.200 = 3.228$ m
Ledger brace length	$L_{lb} = \sqrt{W_m^2 + H_{lift}^2} + 2 \cdot L_{t,b} = \sqrt{1.115^2 + 2.00^2} + 2 \cdot 0.200 = 2.690$ m
Maximum board transoms per bay	$n_t = \text{ceiling}\left(\frac{L_{bay}}{1.2}\right) + 1 = \text{ceiling}\left(\frac{2.00}{1.2}\right) + 1 = 3$

Dead loading

Dead load per standard per lift	$F_{st} = H_{lift} \cdot P_t = 2.00 \cdot 0.043 = 0.086$ kN
Dead load per ledger brace	$F_{lb} = L_{lb} \cdot P_t = 2.690 \cdot 0.043 = 0.115$ kN
Dead load of a board transom or end guard rail	$F_{tr} = P_t \cdot L_{tr} = 0.043 \cdot 1.837 = 0.079$ kN
Dead load of a tie tube	$F_{tt} = P_t \cdot L_{tt} = 0.043 \cdot 1.887 = 0.081$ kN
Dead load of toe boards	$F_{tb} = P_b \cdot W_b = 0.245 \cdot 0.225 = 0.055$ kN/m
Dead load of an end toe board	$F_{etb} = F_{tb} \cdot L_{tr} = 0.055 \cdot 1.837 = 0.101$ kN
Dead load of brick guards	$F_{bg} = P_{bg} \cdot H_{bg} = 0.016 \cdot 1.0 = 0.016$ kN/m
Dead load of the end brick guards	$F_{ebg} = W_{total} \cdot F_{bg} = 1.637 \cdot 0.016 = 0.026$ kN

Dead loading on the outer ledgers

Distribution factor for permanent dead loading to the outer face	$f_o = \frac{0.5 \cdot (W_m - W_i)}{W_m} = \frac{0.5 \cdot (1.115 - 0.522)}{1.115} = 0.266$
Dead load of board transoms at the outer face	$F_{tr,o} = (f_o \cdot F_{tr} + P_{pc}) \cdot \frac{n_t}{L_{bay}} = (0.266 \cdot 0.079 + 0.010) \cdot \frac{3}{2.00} = 0.046$ kN/m
Dead load of boards at the outer face	$F_{b,o} = 0.5 \cdot W_m \cdot P_b = 0.5 \cdot 1.115 \cdot 0.245 = 0.137$ kN/m
Dead load on unboarded lift outer ledgers	$F_{l,u,o} = P_t + F_{tr,o} = 0.043 + 0.046 = 0.089$ kN/m
Dead load on boarded lift outer ledgers	$F_{l,b,o} = P_t + F_{tr,o} + F_{tb} + F_{b,o} + F_{bg} = 0.043 + 0.046 + 0.055 + 0.137 + 0.016 = 0.297$ kN/m

Dead loading on the outer standards

Dead load per tie tube at the outer face	$F_{tt,o} = f_o \cdot F_{tt} + P_{ra} = 0.266 \cdot 0.081 + 0.012 = 0.034$ kN
Dead load per unbraced standard per lift	$F_{s,u} = F_{st} = 0.086$ kN
Dead load per ledger-braced standard per lift	$F_{s,l} = F_{st} + 0.5 \cdot F_{lb} + P_{sc} = 0.086 + 0.5 \cdot 0.115 + 0.013 = 0.156$ kN
Dead load of couplers to outer standards at unboarded lifts	$F_{c,u,o} = \left(1 + n_{gr,u}\right) \cdot P_{ra} = \left(1 + 1\right) \cdot 0.012 = 0.025$ kN
Dead load of couplers to outer standards at boarded lifts	$F_{c,b,o} = \left(1 + n_{gr,b}\right) \cdot P_{ra} + P_{pc} = \left(1 + 2\right) \cdot 0.012 + 0.010 = 0.047$ kN
Dead load per outer end standard per unboarded lift	$F_{es,u,o} = F_{s,l} + f_o \cdot n_{gr,u} \cdot F_{tr} + n_{gr,u} \cdot P_t \cdot \frac{L_{bay}}{2} + 2 \cdot F_{c,u,o}$ $= 0.156 + 0.266 \cdot 1 \cdot 0.079 + 1 \cdot 0.043 \cdot \frac{2.00}{2} + 2 \cdot 0.025 = 0.269$ kN
Dead load per outer end standard per boarded lift	$F_{es,b,o} = F_{s,l} + f_o \cdot \left(n_{gr,b} \cdot F_{tr} + F_{etb} + F_{ebg}\right) + n_{gr,b} \cdot P_t \cdot \frac{L_{bay}}{2} + 2 \cdot F_{c,b,o}$ $= 0.156 + 0.266 \cdot (2 \cdot 0.079 + 0.101 + 0.026) + 2 \cdot 0.043 \cdot \frac{2.00}{2} + 2 \cdot 0.047$ $= 0.411$ kN
Dead load per outer unbraced intermediate standard per unboarded lift	$F_{is,u,u,o} = n_{gr,u} \cdot P_t \cdot L_{bay} + F_{s,u} + F_{c,u,o} = 1 \cdot 0.043 \cdot 2.00 + 0.086 + 0.025 = 0.196$ kN
Dead load per outer ledger-braced intermediate standard per unboarded lift	$F_{is,u,b,o} = n_{gr,u} \cdot P_t \cdot L_{bay} + F_{s,l} + F_{c,u,o} = 1 \cdot 0.043 \cdot 2.00 + 0.156 + 0.025 = 0.267$ kN
Dead load per outer unbraced intermediate standard per boarded lift	$F_{is,b,u,o} = n_{gr,b} \cdot P_t \cdot L_{bay} + F_{s,u} + F_{c,b,o} = 2 \cdot 0.043 \cdot 2.00 + 0.086 + 0.047 = 0.304$ kN
Dead load per outer ledger-braced intermediate standard per boarded lift	$F_{is,b,b,o} = n_{gr,b} \cdot P_t \cdot L_{bay} + F_{s,l} + F_{c,b,o} = 2 \cdot 0.043 \cdot 2.00 + 0.156 + 0.047 = 0.375$ kN

Dead loading on the inner ledgers

Distribution factor for dead loading to the inner face	$f_i = \frac{0.5 \cdot \left(W_m + W_i\right)}{W_m} = \frac{0.5 \cdot (1.115 + 0.522)}{1.115} = 0.734$
Dead load of board transoms at the inner face	$F_{tr,i} = \left(f_i \cdot F_{tr} + P_{pc}\right) \cdot \frac{n_t}{L_{bay}} = (0.734 \cdot 0.079 + 0.010) \cdot \frac{3}{2.00} = 0.101$ kN/m
Dead load of boards at the inner face	$F_{b,i} = f_i \cdot W_{total} \cdot P_b = 0.734 \cdot 1.637 \cdot 0.245 = 0.295$ kN/m
Dead load on unboarded lift inner ledgers	$F_{l,u,i} = P_t + F_{tr,i} = 0.043 + 0.101 = 0.144$ kN/m
Dead load on boarded lift inner ledgers	$F_{l,b,i} = P_t + F_{tr,i} + F_{b,i} = 0.043 + 0.101 + 0.295 = 0.439$ kN/m

Dead loading on the inner standards

Dead load per tie tube at the inner face	$F_{tt,i} = f_i \cdot F_{tt} + P_{ra} = 0.734 \cdot 0.081 + 0.012 = 0.072\ kN$
Dead load of couplers to inner standards at unboarded lifts	$F_{c,u,i} = (1 + n_{gr,u,i}) \cdot P_{ra} = (1 + 0) \cdot 0.012 = 0.012\ kN$
Dead load of couplers to inner standards at boarded lifts	$F_{c,b,i} = (1 + n_{gr,b,i}) \cdot P_{ra} = (1 + 0) \cdot 0.012 = 0.012\ kN$
Dead load per inner end standard per unboarded lift	$F_{es,u,i} = F_{s,l} + f_i \cdot n_{gr,u} \cdot F_{tr} + n_{gr,u,i} \cdot P_t \cdot \frac{L_{bay}}{2} + F_{c,u,o} + F_{c,u,i}$ $= 0.156 + 0.734 \cdot 1 \cdot 0.079 + 0 \cdot 0.043 \cdot \frac{2.00}{2} + 0.025 + 0.012 = 0.251\ kN$
Dead load per inner end standard per boarded lift	$F_{es,b,i} = F_{s,l} + f_i \cdot (n_{gr,b} \cdot F_{tr} + F_{etb} + F_{ebg}) + n_{gr,b,i} \cdot P_t \cdot \frac{L_{bay}}{2} + F_{c,b,o} + F_{c,b,i}$ $= 0.156 + 0.734 \cdot (2 \cdot 0.079 + 0.101 + 0.026) + 0 \cdot 0.043 \cdot \frac{2.00}{2} + 0.047 + 0.012$ $= 0.424\ kN$
Dead load per inner unbraced intermediate standard per unboarded lift	$F_{is,u,u,i} = n_{gr,u,i} \cdot P_t \cdot L_{bay} + F_{s,u} + F_{c,u,i} = 0 \cdot 0.043 \cdot 2.00 + 0.086 + 0.012 = 0.098\ kN$
Dead load per inner ledger-braced intermediate standard per unboarded lift	$F_{is,u,b,i} = n_{gr,u,i} \cdot P_t \cdot L_{bay} + F_{s,l} + F_{c,u,i} = 0 \cdot 0.043 \cdot 2.00 + 0.156 + 0.012 = 0.169\ kN$
Dead load per inner unbraced intermediate standard per boarded lift	$F_{is,b,u,i} = n_{gr,b,i} \cdot P_t \cdot L_{bay} + F_{s,u} + F_{c,b,i} = 0 \cdot 0.043 \cdot 2.00 + 0.086 + 0.012 = 0.098\ kN$
Dead load per inner ledger-braced intermediate standard per boarded lift	$F_{is,b,b,i} = n_{gr,b,i} \cdot P_t \cdot L_{bay} + F_{s,l} + F_{c,b,i} = 0 \cdot 0.043 \cdot 2.00 + 0.156 + 0.012 = 0.169\ kN$

Dead loading of the facade bracing

Dead load of facade bracing	$F_{fb} = \frac{P_t \cdot L_{fb} + 2 \cdot P_{sc}}{L_{fb,1}} = \frac{0.043 \cdot 3.228 + 2 \cdot 0.013}{2.828} = 0.058\ kN/m$

Imposed loading

Imposed load per loaded lift at the outer face	$F_{i,o} = 0.5 \cdot P_m \cdot W_m = 0.5 \cdot 2.00 \cdot 1.115 = 1.115\ kN/m$
Imposed load per loaded lift at the inner face	$F_{i,i} = 0.5 \cdot P_m \cdot W_m + P_i \cdot W_i + \frac{0.5 \cdot P_i \cdot W_i^2}{W_m}$ $= 0.5 \cdot 2.00 \cdot 1.115 + 0.75 \cdot 0.522 + \frac{0.5 \cdot 0.75 \cdot 0.522^2}{1.115} = 1.598\ kN/m$
Imposed load per 50% loaded lift at the outer face	$F_{i,o,50} = 0.5 \cdot F_{i,o} = 0.5 \cdot 1.115 = 0.557\ kN/m$
Imposed load per 50% loaded lift at the inner face	$F_{i,i,50} = 0.5 \cdot F_{i,i} = 0.5 \cdot 1.598 = 0.799\ kN/m$

Out-of-service imposed loading

Out-of-service imposed load on the main platform (EN 12811-1 cl.6.2.9.2.b2)	$P_{m,o} = 0.50$ kN/m²
Out-of-service imposed load on the inner platform	$P_{i,o} = 0.00$ kN/m²
Out-of-service imposed load per loaded lift at the outer face	$F_{io,o} = 0.5 \cdot P_{m,o} \cdot W_m = 0.5 \cdot 0.50 \cdot 1.115 = 0.279$ kN/m
Out-of-service imposed load per loaded lift at the inner face	$F_{io,i} = 0.5 \cdot P_{m,o} \cdot W_m = 0.5 \cdot 0.50 \cdot 1.115 = 0.279$ kN/m

Wind coefficients

Description	Value
Site coefficient for parallel wind on unclad scaffolding, $c_{s\|\|u}$	1.0
Aerodynamic force coefficient for tubes, $c_{f,t}$	1.2
Aerodynamic force coefficient for board-bearing transom tubes, $c_{f,tr}$	0.8
Aerodynamic force coefficient (normal) for toe boards, $c_{f,b}$	1.3

Description	Value
Aerodynamic force coefficient (parallel) for toe boards, $c_{f\|\|tb}$	0.1
Aerodynamic force coefficient (parallel) for platform boards, $c_{f\|\|b}$	0.02
Aerodynamic force coefficient (normal) for brick guards, $c_{f,bg}$	0.177
Aerodynamic force coefficient (parallel) for brick guards, $c_{f\|\|bg}$	0.073

In-service wind loading

In-service wind peak velocity pressure	$q_{p,i} = 0.200$ kN/m²

In-service wind loading on the end frames

Reference height for materials at in-service working lifts, TG20:13 Design Guide Table 4.3	$H_{r,m} = 0.438$ m
Toe board height	$H_{tb} = 0.225$ m
Tube length of boarded end frame	$L_{t,be} = 2 \cdot H_{lift} + L_{lb} + n_{gr,b} \cdot L_{tr} = 2 \cdot 2.00 + 2.690 + 2 \cdot 1.837 = 10.364$ m
Tube length of unboarded end frame	$L_{t,ue} = 2 \cdot H_{lift} + L_{lb} + n_{gr,u} \cdot L_{tr} = 2 \cdot 2.00 + 2.690 + 1 \cdot 1.837 = 8.527$ m
Area of toe boards and materials at in-service working lift end frame	$A_{tb,we} = H_{r,m} \cdot W_m + (H_{tb} + t_b) \cdot W_i = 0.438 \cdot 1.115 + (0.225 + 0.038) \cdot 0.522 = 0.626$ m²
In-service wind load on working lift end frame	$F_{wi\|\|we} = q_{p,i} \cdot c_{s\|\|u} \cdot (c_{f,t} \cdot L_{t,be} \cdot d_t + c_{f,b} \cdot A_{tb,we}) = 0.200 \cdot 1.0 \cdot (1.2 \cdot 10.364 \cdot 0.048 + 1.3 \cdot 0.626) = 0.283$ kN

In-service wind load on unboarded lift end frame	$F_{wi\|\|ue} = q_{p,i} \cdot c_{s\|\|u} \cdot c_{f,t} \cdot L_{t,ue} \cdot d_t = 0.200 \cdot 1.0 \cdot 1.2 \cdot 8.527 \cdot 0.048 = 0.099$ kN
Area of brick guards at working lift end frame	$A_{bg,we} = (1.0 - H_{r,m}) \cdot W_{total} = (1.0 - 0.438) \cdot 1.637 = 0.920$ m²
In-service wind load on working lift end frame with brick guards	$F_{wi\|\|bgwe} = q_{p,i} \cdot c_{s\|\|u} \cdot c_{f,bg} \cdot A_{bg,we} + F_{wi\|\|we} = 0.200 \cdot 1.0 \cdot 0.177 \cdot 0.920 + 0.283 = 0.315$ kN

In-service wind loading per bay

Tube length of unbraced intermediate frame	$L_{t,ui} = 2 \cdot H_{lift} = 2 \cdot 2.00 = 4.000$ m
Tube length of ledger-braced intermediate frame	$L_{t,bi} = 2 \cdot H_{lift} + L_{lb} = 2 \cdot 2.00 + 2.690 = 6.690$ m
Tube length of board transoms per bay	$L_{tr} = n_t \cdot L_{tr} = 3 \cdot 1.837 = 5.511$ m
In-service parallel wind on boards and transoms per bay	$F_{wi\|\|b} = q_{p,i} \cdot c_{s\|\|u} \cdot (c_{f\|\|b} \cdot W_{total} \cdot L_{bay} + c_{f,tr} \cdot L_{tr} \cdot d_t) = 0.200 \cdot 1.0 \cdot (0.02 \cdot 1.637 \cdot 2.00 + 0.8 \cdot 5.511 \cdot 0.048) = 0.056$ kN
In-service parallel wind on toe boards per bay	$F_{wi\|\|tb} = q_{p,i} \cdot c_{s\|\|u} \cdot c_{f\|\|tb} \cdot H_{tb} \cdot L_{bay} = 0.200 \cdot 1.0 \cdot 0.1 \cdot 0.225 \cdot 2.00 = 0.009$ kN
In-service parallel wind on brick guards per bay	$F_{wi\|\|bg} = q_{p,i} \cdot c_{s\|\|u} \cdot c_{f\|\|bg} \cdot L_{bay} \cdot 1.0 = 0.200 \cdot 1.0 \cdot 0.073 \cdot 2.00 \cdot 1.0 = 0.029$ kN
In-service wind on transoms per unboarded lift bay	$F_{wi\|\|tu} = q_{p,i} \cdot c_{s\|\|u} \cdot c_{f,t} \cdot L_{tr} \cdot d_t = 0.200 \cdot 1.0 \cdot 1.2 \cdot 5.511 \cdot 0.048 = 0.064$ kN
In-service wind on unbraced intermediate frame tubes	$F_{wi\|\|ui} = q_{p,i} \cdot c_{s\|\|u} \cdot c_{f,t} \cdot L_{t,ui} \cdot d_t = 0.200 \cdot 1.0 \cdot 1.2 \cdot 4.000 \cdot 0.048 = 0.046$ kN
In-service wind on ledger-braced intermediate frame tubes	$F_{wi\|\|bi} = q_{p,i} \cdot c_{s\|\|u} \cdot c_{f,t} \cdot L_{t,bi} \cdot d_t = 0.200 \cdot 1.0 \cdot 1.2 \cdot 6.690 \cdot 0.048 = 0.078$ kN

In-service wind loading distribution to the windward end standards

Wind load distribution factor to outer standards	$f_o = \frac{0.5 \cdot (W_m - W_i)}{W_m} = \frac{0.5 \cdot (1.115 - 0.522)}{1.115} = 0.266$
Wind load distribution factor to inner standards	$f_i = \frac{0.5 \cdot (W_m + W_i)}{W_m} = \frac{0.5 \cdot (1.115 + 0.522)}{1.115} = 0.734$
In-service wind on working lift outer end standards	$F_{wi\|\|we,o} = f_o \cdot F_{wi\|\|bgwe} = 0.266 \cdot 0.315 = 0.084$ kN
In-service wind on working lift inner end standards	$F_{wi\|\|we,i} = f_i \cdot F_{wi\|\|bgwe} = 0.734 \cdot 0.315 = 0.232$ kN
In-service wind on unboarded lift outer end standards	$F_{wi\|\|ue,o} = f_o \cdot F_{wi\|\|ue} = 0.266 \cdot 0.099 = 0.026$ kN
In-service wind on unboarded lift inner end standards	$F_{wi\|\|ue,i} = f_i \cdot F_{wi\|\|ue} = 0.734 \cdot 0.099 = 0.073$ kN

In-service wind loading distribution to the intermediate standards

In-service wind on unbraced intermediate outer standards of boarded lifts	$F_{wi\|\|ui,b,o} = 0.5 \cdot F_{wi\|\|ui} + f_o \cdot F_{wi\|\|b} + F_{wi\|\|tb} + F_{wi\|\|bg}$ $= 0.5 \cdot 0.046 + 0.266 \cdot 0.056 + 0.009 + 0.029 = 0.076$ kN
In-service wind on unbraced intermediate inner standards of boarded lifts	$F_{wi\|\|ui,b,i} = 0.5 \cdot F_{wi\|\|ui} + f_i \cdot F_{wi\|\|b} = 0.5 \cdot 0.046 + 0.734 \cdot 0.056 = 0.064$ kN
In-service wind on ledger-braced outer intermediate standards of boarded lifts	$F_{wi\|\|bi,b,o} = 0.5 \cdot F_{wi\|\|bi} + f_o \cdot F_{wi\|\|b} + F_{wi\|\|tb} + F_{wi\|\|bg}$ $= 0.5 \cdot 0.078 + 0.266 \cdot 0.056 + 0.009 + 0.029 = 0.092$ kN
In-service wind on ledger-braced inner intermediate standards of boarded lifts	$F_{wi\|\|bi,b,i} = 0.5 \cdot F_{wi\|\|bi} + f_i \cdot F_{wi\|\|b} = 0.5 \cdot 0.078 + 0.734 \cdot 0.056 = 0.080$ kN
In-service wind on unbraced intermediate outer standards of unboarded lifts	$F_{wi\|\|ui,u,o} = 0.5 \cdot F_{wi\|\|ui,u} + f_o \cdot F_{wi\|\|tu} = 0.5 \cdot 0.046 + 0.266 \cdot 0.064 = 0.040$ kN
In-service wind on unbraced intermediate inner standards of unboarded lifts	$F_{wi\|\|ui,u,i} = 0.5 \cdot F_{wi\|\|ui,u} + f_i \cdot F_{wi\|\|tu} = 0.5 \cdot 0.046 + 0.734 \cdot 0.064 = 0.070$ kN
In-service wind on ledger-braced intermediate outer standards of unboarded lifts	$F_{wi\|\|bi,u,o} = 0.5 \cdot F_{wi\|\|bi,u} + f_o \cdot F_{wi\|\|tu} = 0.5 \cdot 0.078 + 0.266 \cdot 0.064 = 0.056$ kN
In-service wind on ledger-braced intermediate inner standards of unboarded lifts	$F_{wi\|\|bi,u,i} = 0.5 \cdot F_{wi\|\|bi,u} + f_i \cdot F_{wi\|\|tu} = 0.5 \cdot 0.078 + 0.734 \cdot 0.064 = 0.086$ kN

In-service wind distribution to the leeward end standards

In-service wind on working lift outer leeward end standards	$F_{wi\|\|we,l,o} = f_o \cdot F_{wi\|\|bgwe} + f_o \cdot F_{wi\|\|b} + F_{wi\|\|tb} + F_{wi\|\|bg}$ $= 0.266 \cdot 0.315 + 0.266 \cdot 0.056 + 0.009 + 0.029 = 0.137$ kN
In-service wind on working lift inner leeward end standards	$F_{wi\|\|we,l,i} = f_i \cdot F_{wi\|\|bgwe} + f_i \cdot F_{wi\|\|b} = 0.734 \cdot 0.315 + 0.734 \cdot 0.056 = 0.272$ kN
In-service wind on unboarded lift outer leeward end standards	$F_{wi\|\|ue,l,o} = f_o \cdot F_{wi\|\|ue} + f_o \cdot F_{wi\|\|tu} = 0.266 \cdot 0.099 + 0.266 \cdot 0.064 = 0.043$ kN
In-service wind on unboarded lift inner leeward end standards	$F_{wi\|\|ue,l,i} = f_i \cdot F_{wi\|\|ue} + f_i \cdot F_{wi\|\|tu} = 0.734 \cdot 0.099 + 0.734 \cdot 0.064 = 0.120$ kN

In-service wind loading on additional tubes

In-service wind on facade bracing	$F_{wi\|\|fb} = q_{p,i} \cdot c_{s\|\|u} \cdot c_{f,t} \cdot d_t \cdot \frac{H_{lift}}{L_{fb,1}} = 0.200 \cdot 1.0 \cdot 1.2 \cdot 0.048 \cdot \frac{2.00}{2.828} = 0.008$ kN/m
In-service wind per tie tube at the inner face	$F_{wi\|\|tt,i} = f_i \cdot q_{p,i} \cdot c_{s\|\|u} \cdot c_{f,t} \cdot d_t \cdot L_{tt} = 0.734 \cdot 0.200 \cdot 1.0 \cdot 1.2 \cdot 0.048 \cdot 1.887$ $= 0.016$ kN
In-service wind per tie tube at the outer face	$F_{wi\|\|tt,o} = f_o \cdot q_{p,i} \cdot c_{s\|\|u} \cdot c_{f,t} \cdot d_t \cdot L_{tt} = 0.266 \cdot 0.200 \cdot 1.0 \cdot 1.2 \cdot 0.048 \cdot 1.887$ $= 0.006$ kN

Out-of-service wind loading

The out-of-service peak velocity pressure $q_p(z)$ varies with the height of the scaffold in accordance with clauses 5.3, 7.6 (2), 7.9.2 (5) and 7.11 (4) of BS EN 1991-1-4:2005 + A1:2010.

Out-of-service peak velocity pressure at 2.00 m	$q_{p(z = 2.00m)} = 0.713\ kN/m^2$
Out-of-service peak velocity pressure at 13.00 m	$q_{p(z = 13.00m)} = 0.888\ kN/m^2$

Out-of-service wind loading on the end frames

Area of toe boards at non-working boarded lift end frame	$A_{tb,ne} = W_{total} \cdot (H_{tb} + t_b) = 1.637 \cdot (0.225 + 0.038) = 0.431\ m^2$
Out-of-service wind load on boarded lift end frame	$F_{wo\|\|be} = q_{p(z = 13.00m)} \cdot c_{s\|\|u} \cdot (c_{f,t} \cdot L_{t,be} \cdot d_t + c_{f,b} \cdot A_{tb,ne})$ $= 0.888 \cdot 1.0 \cdot (1.2 \cdot 10.364 \cdot 0.048 + 1.3 \cdot 0.431) = 1.030\ kN$
Out-of-service wind load on unboarded lift end frame	$F_{wo\|\|ue} = q_{p(z = 8.00m)} \cdot c_{s\|\|u} \cdot c_{f,t} \cdot L_{t,ue} \cdot d_t = 0.838 \cdot 1.0 \cdot 1.2 \cdot 8.527 \cdot 0.048$ $= 0.414\ kN$
Out-of-service wind load on boarded lift end frame with brick guards	$F_{wo\|\|bgne} = q_{p(z = 13.00m)} \cdot c_{s\|\|u} \cdot c_{f,bg} \cdot A_{bg,ne} + F_{wo\|\|be}$ $= 0.888 \cdot 1.0 \cdot 0.177 \cdot 1.269 + 1.030 = 1.230\ kN$

Out-of-service wind loading per bay

Out-of-service parallel wind on boards and transoms per bay	$F_{wo\|\|b} = q_{p(z = 13.00m)} \cdot c_{s\|\|u} \cdot (c_{f\|\|b} \cdot W_{total} \cdot L_{bay} + c_{f,tr} \cdot L_{tr} \cdot d_t)$ $= 0.888 \cdot 1.0 \cdot (0.02 \cdot 1.637 \cdot 2.00 + 0.8 \cdot 5.511 \cdot 0.048) = 0.247\ kN$
Out-of-service parallel wind on toe boards per bay	$F_{wo\|\|tb} = q_{p(z = 13.00m)} \cdot c_{s\|\|u} \cdot c_{f\|\|tb} \cdot H_{tb} \cdot L_{bay} = 0.888 \cdot 1.0 \cdot 0.1 \cdot 0.225 \cdot 2.00$ $= 0.040\ kN$
Out-of-service parallel wind on brick guards per bay	$F_{wo\|\|bg} = q_{p(z = 13.00m)} \cdot c_{s\|\|u} \cdot c_{f\|\|bg} \cdot L_{bay} \cdot 1.0 = 0.888 \cdot 1.0 \cdot 0.073 \cdot 2.00 \cdot 1.0$ $= 0.130\ kN$
Out-of-service wind on transoms per unboarded lift bay	$F_{wo\|\|tu} = q_{p(z = 8.00m)} \cdot c_{s\|\|u} \cdot c_{f,t} \cdot L_{tr} \cdot d_t = 0.838 \cdot 1.0 \cdot 1.2 \cdot 5.511 \cdot 0.048 = 0.268\ kN$
Out-of-service wind on unbraced intermediate frame tubes	$F_{wo\|\|ui} = q_{p(z = 13.00m)} \cdot c_{s\|\|u} \cdot c_{f,t} \cdot L_{t,ui} \cdot d_t = 0.888 \cdot 1.0 \cdot 1.2 \cdot 4.000 \cdot 0.048$ $= 0.206\ kN$
Out-of-service wind on unbraced intermediate frame tubes of unboarded lifts	$F_{wo\|\|ui,u} = q_{p(z = 8.00m)} \cdot c_{s\|\|u} \cdot c_{f,t} \cdot L_{t,ui} \cdot d_t = 0.838 \cdot 1.0 \cdot 1.2 \cdot 4.000 \cdot 0.048$ $= 0.194\ kN$
Out-of-service wind on ledger-braced intermediate frame tubes	$F_{wo\|\|bi} = q_{p(z = 13.00m)} \cdot c_{s\|\|u} \cdot c_{f,t} \cdot L_{t,bi} \cdot d_t = 0.888 \cdot 1.0 \cdot 1.2 \cdot 6.690 \cdot 0.048$ $= 0.344\ kN$
Out-of-service wind on ledger-braced intermediate frame tubes of unboarded lifts	$F_{wo\|\|bi,u} = q_{p(z = 8.00m)} \cdot c_{s\|\|u} \cdot c_{f,t} \cdot L_{t,bi} \cdot d_t = 0.838 \cdot 1.0 \cdot 1.2 \cdot 6.690 \cdot 0.048$ $= 0.325\ kN$

Out-of-service wind loading distribution to the windward end standards

Out-of-service wind on boarded lift outer end standards	$F_{wo\|\|be,o} = f_o \cdot F_{wo\|\|bgne} = 0.266 \cdot 1.230 = 0.327\ kN$

Out-of-service wind on boarded lift inner end standards	$F_{wo\|\|be,i} = f_i \cdot F_{wo\|\|bgne} = 0.734 \cdot 1.230 = 0.903$ kN
Out-of-service wind on unboarded lift outer end standards	$F_{wo\|\|ue,o} = f_o \cdot F_{wo\|\|ue} = 0.266 \cdot 0.414 = 0.110$ kN
Out-of-service wind on unboarded lift inner end standards	$F_{wo\|\|ue,i} = f_i \cdot F_{wo\|\|ue} = 0.734 \cdot 0.414 = 0.304$ kN

Out-of-service wind loading distribution to the intermediate standards

Out-of-service wind on unbraced intermediate outer standards of boarded lifts	$F_{wo\|\|ui,b,o} = 0.5 \cdot F_{wo\|\|ui} + f_o \cdot F_{wo\|\|b} + F_{wo\|\|tb} + F_{wo\|\|bg}$ $= 0.5 \cdot 0.206 + 0.266 \cdot 0.247 + 0.040 + 0.130 = 0.338$ kN
Out-of-service wind on unbraced intermediate inner standards of boarded lifts	$F_{wo\|\|ui,b,i} = 0.5 \cdot F_{wo\|\|ui} + f_i \cdot F_{wo\|\|b} = 0.5 \cdot 0.206 + 0.734 \cdot 0.247 = 0.284$ kN
Out-of-service wind on ledger-braced outer intermediate standards of boarded lifts	$F_{wo\|\|bi,b,o} = 0.5 \cdot F_{wo\|\|bi} + f_o \cdot F_{wo\|\|b} + F_{wo\|\|tb} + F_{wo\|\|bg}$ $= 0.5 \cdot 0.344 + 0.266 \cdot 0.247 + 0.040 + 0.130 = 0.407$ kN
Out-of-service wind on ledger-braced inner intermediate standards of boarded lifts	$F_{wo\|\|bi,b,i} = 0.5 \cdot F_{wo\|\|bi} + f_i \cdot F_{wo\|\|b} = 0.5 \cdot 0.344 + 0.734 \cdot 0.247 = 0.354$ kN
Out-of-service wind on unbraced intermediate outer standards of unboarded lifts	$F_{wo\|\|ui,u,o} = 0.5 \cdot F_{wo\|\|ui,u} + f_o \cdot F_{wo\|\|tu} = 0.5 \cdot 0.194 + 0.266 \cdot 0.268 = 0.168$ kN
Out-of-service wind on unbraced intermediate inner standards of unboarded lifts	$F_{wo\|\|ui,u,i} = 0.5 \cdot F_{wo\|\|ui,u} + f_i \cdot F_{wo\|\|tu} = 0.5 \cdot 0.194 + 0.734 \cdot 0.268 = 0.294$ kN
Out-of-service wind on ledger-braced intermediate outer standards of unboarded lifts	$F_{wo\|\|bi,u,o} = 0.5 \cdot F_{wo\|\|bi,u} + f_o \cdot F_{wo\|\|tu} = 0.5 \cdot 0.325 + 0.266 \cdot 0.268 = 0.233$ kN
Out-of-service wind on ledger-braced intermediate inner standards of unboarded lifts	$F_{wo\|\|bi,u,i} = 0.5 \cdot F_{wo\|\|bi,u} + f_i \cdot F_{wo\|\|tu} = 0.5 \cdot 0.325 + 0.734 \cdot 0.268 = 0.359$ kN

Out-of-service wind distribution to the leeward end standards

Out-of-service wind on boarded lift outer leeward end standards	$F_{wo\|\|be,l,o} = f_o \cdot F_{wo\|\|bgne} + f_o \cdot F_{wo\|\|b} + F_{wo\|\|tb} + F_{wo\|\|bg}$ $= 0.266 \cdot 1.230 + 0.266 \cdot 0.247 + 0.040 + 0.130 = 0.562$ kN
Out-of-service wind on boarded lift inner leeward end standards	$F_{wo\|\|be,l,i} = f_i \cdot F_{wo\|\|bgne} + f_i \cdot F_{wo\|\|b} = 0.734 \cdot 1.230 + 0.734 \cdot 0.247 = 1.084$ kN
Out-of-service wind on unboarded lift outer leeward end standards	$F_{wo\|\|ue,l,o} = f_o \cdot F_{wo\|\|ue} + f_o \cdot F_{wo\|\|tu} = 0.266 \cdot 0.414 + 0.266 \cdot 0.268 = 0.181$ kN

Out-of-service wind on unboarded lift inner leeward end standards	$F_{wo\|\|ue,l,i} = f_i \cdot F_{wo\|\|ue} + f_i \cdot F_{wo\|\|tu} = 0.734 \cdot 0.414 + 0.734 \cdot 0.268 = 0.500$ kN

Out-of-service wind loading on additional tubes

Out-of-service wind on facade bracing	$F_{wo\|\|fb} = q_{p(z = 13.00m)} \cdot c_{s\|\|u} \cdot c_{f,t} \cdot d_t \cdot \frac{H_{lift}}{L_{fb,1}} = 0.888 \cdot 1.0 \cdot 1.2 \cdot 0.048 \cdot \frac{2.00}{2.828} = 0.036$ kN/m
Out-of-service wind per tie tube at the inner face	$F_{wo\|\|tt,i} = f_i \cdot q_{p(z = 13.00m)} \cdot c_{s\|\|u} \cdot c_{f,t} \cdot d_t \cdot L_{tt} = 0.734 \cdot 0.888 \cdot 1.0 \cdot 1.2 \cdot 0.048 \cdot 1.887 = 0.071$ kN
Out-of-service wind per tie tube at the outer face	$F_{wo\|\|tt,o} = f_o \cdot q_{p(z = 13.00m)} \cdot c_{s\|\|u} \cdot c_{f,t} \cdot d_t \cdot L_{tt} = 0.266 \cdot 0.888 \cdot 1.0 \cdot 1.2 \cdot 0.048 \cdot 1.887 = 0.026$ kN

Structural properties for 2D frame analysis

Tie support spring stiffness at the outer frame	$k_o = 10.4$ kN/m
Tie support spring stiffness at the inner frame	$k_i = 54.3$ kN/m
Type 4 steel tube section area	$A_{g,t} = 5.57$ cm²
Type 4 steel tube moment of inertia	$I_{x,t} = 13.77$ cm⁴

Structural analysis

Analysis approach

The scaffold is idealised as two 2D vertical plane frames, one for the inner and one for the outer standards and ledgers. The dead and imposed loads from the boarding are apportioned to the inner and outer frames as noted above using simple statics. Self weights of tubes and components are also calculated and applied to the ledger and standard members. Wind forces acting in the direction parallel to the facade are also calculated as tabulated below.

The guard rails are not included in the stiffness analysis but their load reactions are applied to the standards as point loads. As an exception, if the scaffold is clad with sheeting or debris netting the guard rails at the top lift are included as members in the stiffness analysis.

In the frame analysis, the ledgers and standards are modelled as continuous at the internal joints but discontinuous (pinned) to the orthogonal members at the outer joints. For the relevant types of loads, this idealisation gives a satisfactory correlation with the 3D analysis developed for TG20:13 which allowed for the finite stiffness of right angle couplers.

The facade bracing members are considered to be pinned to the nodes at the ledger - standard intersections. The axial stiffness of the facade brace members is reduced substantially to allow for the actual stiffness of the end couplers and typical permissible eccentricity relative to the node points. The reduction factor was established by calibration of simplified models against accurate 3D analysis of braced bays and amounts to 1 / 75.

The foundations / base plates of the scaffold standards are modelled as pinned lift-off supports, which requires iterative analysis in some load combinations.

The effect of ties to the facade is modelled by means of equivalent spring supports acting horizontally. The stiffness values of these supports have been established by calibration against 3D analysis models in which the tie tubes are connected to both the inner and outer ledgers with right angle couplers. The stiffness values depend on the width of the platform and whether the frame is the inner or outer relative to the facade.

The inner and outer 2D frames are subjected to a total of six load categories (in the positive and negative directions) applied horizontally in-plane:

1. Notional loads of 0.15 kN applied to the nodes at working lifts as required by BS EN 12811-1 clause 6.2.3.

2. Working wind loads applied to the members based on a peak velocity pressure of 0.2 kN/m².

3. Out-of-service wind loads applied to the members based on the peak velocity pressure calculated for the site exposure and the vertical position of the member.

All the above idealisations and approximations made to reduce complexity for 2D structural analysis have been validated against examples taken from the more accurate 3D analyses carried out during the development of TG20:13.

Vertical loads

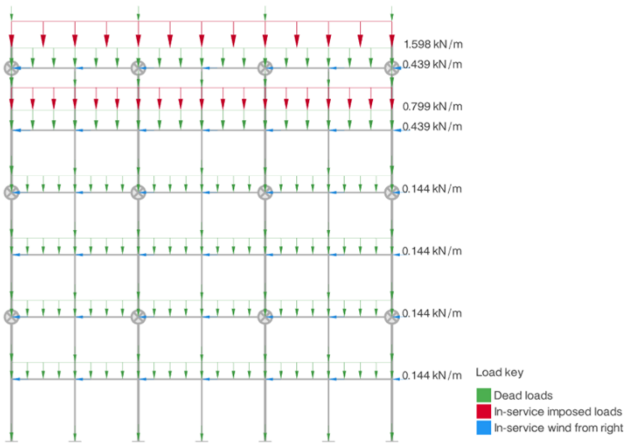
Load description	Inner face	Outer face	Unit
Dead load on unboarded lift ledgers	0.144	0.089	kN/m
Dead load on boarded lift ledgers	0.439	0.297	kN/m
Dead load per end standard per unboarded lift	0.251	0.269	kN
Dead load per end standard per boarded lift	0.424	0.411	kN
Dead load per unbraced intermediate standard per unboarded lift	0.098	0.196	kN
Dead load per ledger-braced intermediate standard per unboarded lift	0.169	0.267	kN
Dead load per unbraced intermediate standard per boarded lift	0.098	0.304	kN
Dead load per ledger-braced intermediate standard per boarded lift	0.169	0.375	kN
Dead load of facade bracing	-	0.058	kN/m
Dead load per tie tube	0.072	0.034	kN
Imposed load on loaded lift ledgers	1.598	1.115	kN/m
Imposed load on 50% loaded lift ledgers	0.799	0.557	kN/m
Out-of-service imposed load on loaded lift ledgers	0.279	0.279	kN/m

Horizontal loads

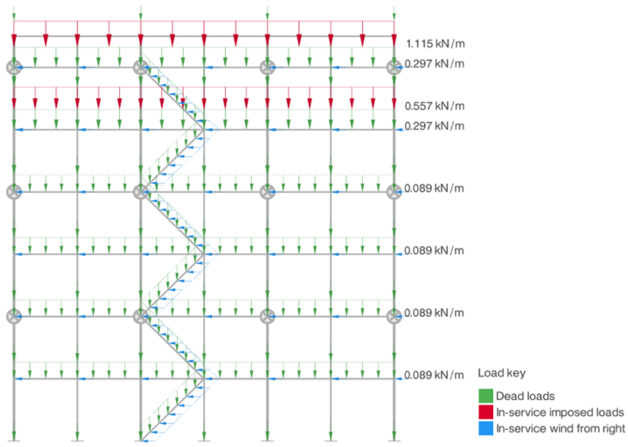
Load description	In service		Out of service		Unit
	Inner	Outer	Inner	Outer	
Notional horizontal load per working bay	0.150	0.150	-	-	kN
Wind on working lift end standards	0.232	0.084	0.903	0.327	kN
Wind on unboarded lift end standards	0.073	0.026	0.304	0.110	kN
Wind on unbraced intermediate standards of boarded lifts	0.064	0.076	0.284	0.338	kN
Wind on ledger-braced intermediate standards of boarded lifts	0.080	0.092	0.354	0.407	kN
Wind on unbraced intermediate standards of unboarded lifts	0.070	0.040	0.294	0.168	kN
Wind on ledger-braced intermediate standards of unboarded lifts	0.086	0.056	0.359	0.233	kN
Wind on working lift leeward end standards	0.272	0.137	1.084	0.562	kN

Load description	In service		Out of service		Unit
	Inner	Outer	Inner	Outer	
Wind on unboarded lift leeward end standards	0.120	0.043	0.500	0.181	kN
Wind per tie tube	0.016	0.006	0.071	0.026	kN
Wind on facade bracing	-	0.008	-	0.036	kN/m

Inner face



Outer face



The analytical model is shown for the load combination which produces the maximum leg load: 5 - Dead + in-service imposed + wind (-ve).

For clarity, the point loads and horizontal loads are not labelled in the figures. Refer to the load tables above for values.

Analysis results

No.	Load combination	Maximum leg load (kN)	
		Inner	Outer
1	Dead + in-service imposed	9.3	7.6
2	Dead + in-service imposed + notional (+ve)	9.4	10.4
3	Dead + in-service imposed + notional (-ve)	9.4	10.9
4	Dead + in-service imposed + wind (+ve)	9.3	10.6
5	Dead + in-service imposed + wind (-ve)	9.3	11.0
6	Dead + out-of-service imposed	4.6	4.8
7	Dead + out-of-service imposed + wind (+ve)	4.7	9.1
8	Dead + out-of-service imposed + wind (-ve)	4.7	10.6
	Maximum	**9.4**	**11.0**

Results summary

Description	Inner	Outer

Description	Inner	Outer
Maximum unfactored leg load (kN)	9.4	11.0

TG20:13 check

Check	Result
TG20:13 compliance criteria check	✓ Pass
TG20:13 safe height check	✓ Pass

The scaffold height of 12.00 m is within the maximum safe height of a TG20:13 compliant tied independent scaffold of the given location and configuration.

ℹ This scaffold is TG20:13 compliant, with the following conditions in addition to the design criteria specified above:

No.	TG20:13 compliance note
1	The maximum leg load should be communicated to the Engineer responsible for the scaffold foundation design.
2	Tie tubes should be connected to the inner and outer standards or ledgers with right-angle couplers.