boothking PARTNERSHIP LIMITED
CONSULTING CIVIL AND STRUCTURAL ENGINEERS

Consultant Advice Note

Job Number:	14934
Project Title:	Victoria Warehouse, Balcony Check, Manchester.
Purpose of Note:	Review of an existing balcony structure at Victoria Warehouse
Date:	24 August 2023

Introduction:

Booth King Partnership Ltd (BKPL) have been appointed to review the structual stability of the balcony at Victoria Warehouse, Stretford, Manchester, from the proposed public crowds loading.

This report assesses the existing and proposed loads imparted on the structure, to determine if any structural alteration is required to suit.

This is to satisfy two principal questions in the immediate short term to satisfy all that the balcony can continue in use:

- Are the calculations provided by Harry Seymour & Associates in accordance with the as built situation.
- Are the ties fixing the columns back to the existing structure within design capacity.

All detail information has been provided by Harry Seymour & Associates in drawing and calculation package, Victoria warehouse, Old Trafford – 10104 - Rev B – Oct 2013 *(Figure 1).*

1 Loading

1.1 Load Assessment

The balcony has been designed to comply with imposed loadings as specified in BS6399-1:1996 and BS EN 1991-1-1:2002 category C5.

1.1.1. Load takedown:

	Weight (kN/m^2)
Deck Lightweight	0.68
Steel Frame	0.20
Cat C5	5.00
Total	**5.88kN/m^2**

1.1.2. Loading Combinations:

- STR – 1.0G + 1.5Q + 1.5RQ

1.1.3. Applied Loading:

Line load calculated based on the assumption each balcony steelwork section carries 4.1m spanning deck.

Loads - General				
	Dead kN/m^2	Imposed kN/m^2	SLS kN/m	ULS kN/m
Deck Lightweight	0.68		2.79	3.77
Steel Frame	0.20		0.82	1.11
Cat C5		5.00	20.50	30.75
Total			**24.11kN/m**	**35.63kN/m**

2 Existing Structure

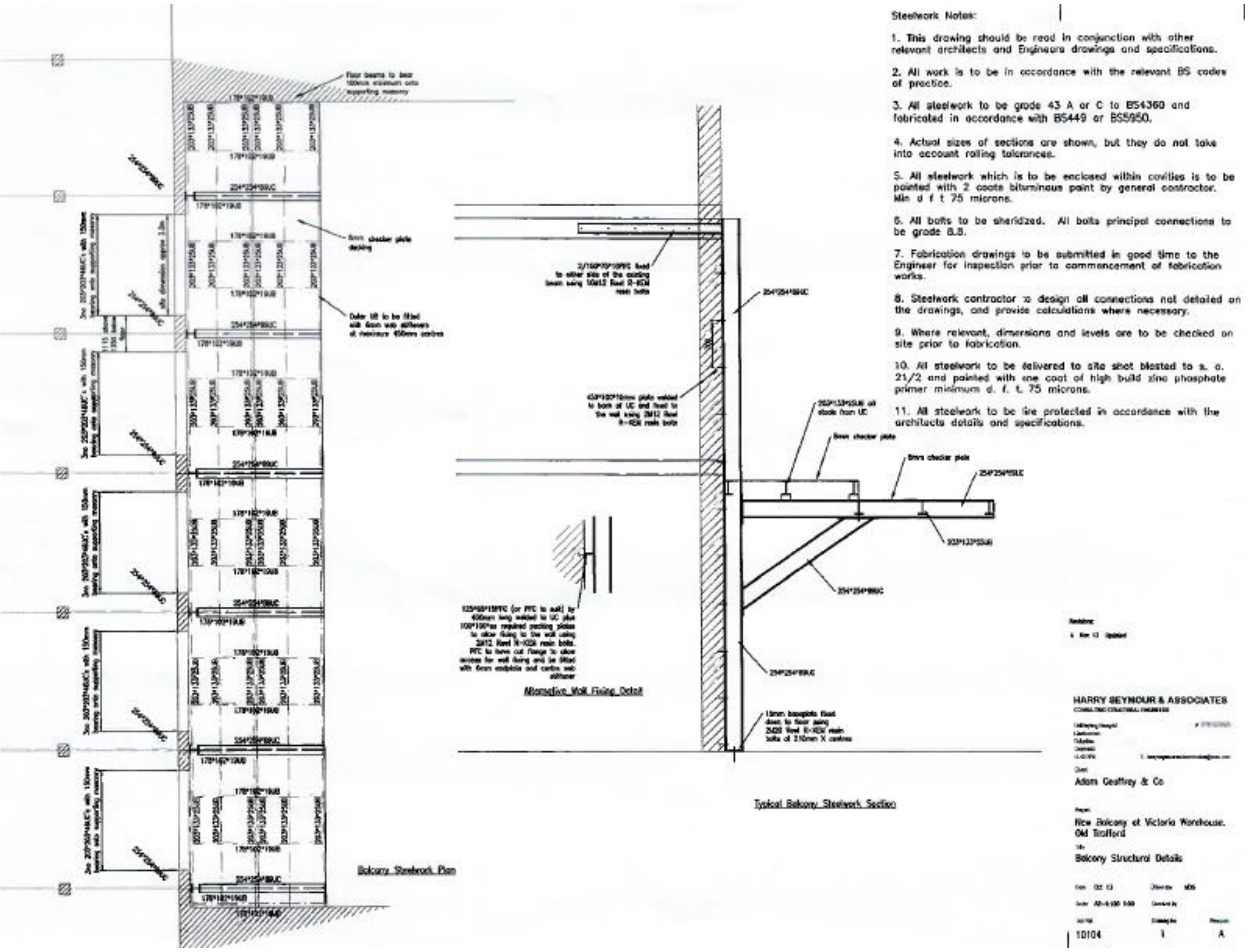

Figure 1 - Typical section detail of the balcony steelwork.

BKPL attended site on 16/08/2023 to review the existing balcony structure. Following our site inspection, the as built situation closely follows the drawing, with some minor differences in the cleat fixing back to masonry (these make no difference to the design results). The principal structural tie back to the structure is at the head of the columns, formed by 2no. PFCs, each with a minimum of 4 bolts fixed into the concrete encased steel beams.

3 Analysis

The following section provides the structural justification for capacity of existing balcony, and further calculations were carried out to see the pullout resistance of the ties from the balcony back to the main building.

- Steel sizes are as per the existing drawing.
- Existing Steel Beam & Plate Grade S355.

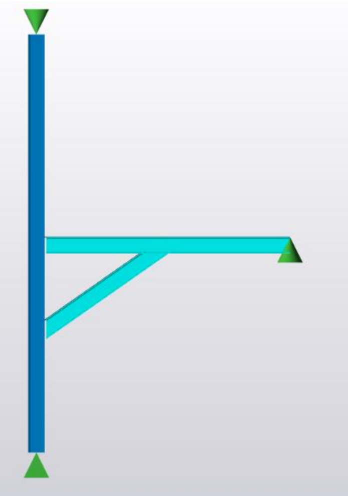

Figure 2 - The image shows the steel work for the balcony.

The model was simplified by ignoring the masonry ties along the height of the column back into the masonry piers, and only includes the pair of ties at the head of the column – this is a conservative assumption.

Following multiple analyses of the balcony steelwork, under loading in both favourable and unfavourable positions, the balcony members are within strength design limits for resultant forces, design shears and moments.

The deflection on the tip of the cantilever is within serviceability parameters.

It should be noted that the applied design load of $5kN/m^2$ is approximately double the maximum capacity of people on the balcony. The design situation is therefore conservative.

The resultant design reaction at the head of the column is a 45kN (ULS) tie force (see Figure 3) – a visual confirmation on site shows that there are at least 8 M12 fixings on each frame fixed back into the existing concrete encased steel structure. This equates to 5.6kN per bolt, which is within the capacity of an M12 bolt fixed to concrete.

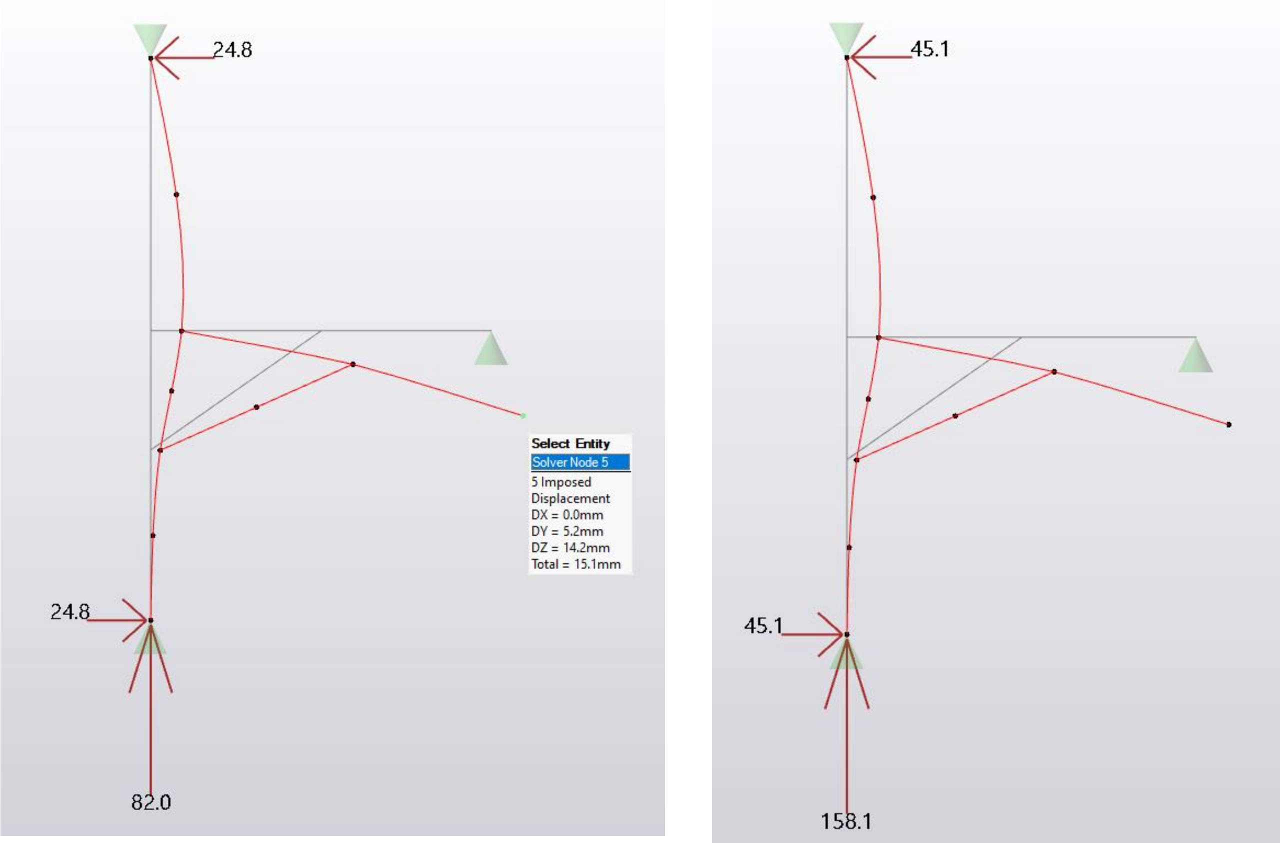

Figure 3 - The image shows the reactions for the balcony structure (SLS and ULS).

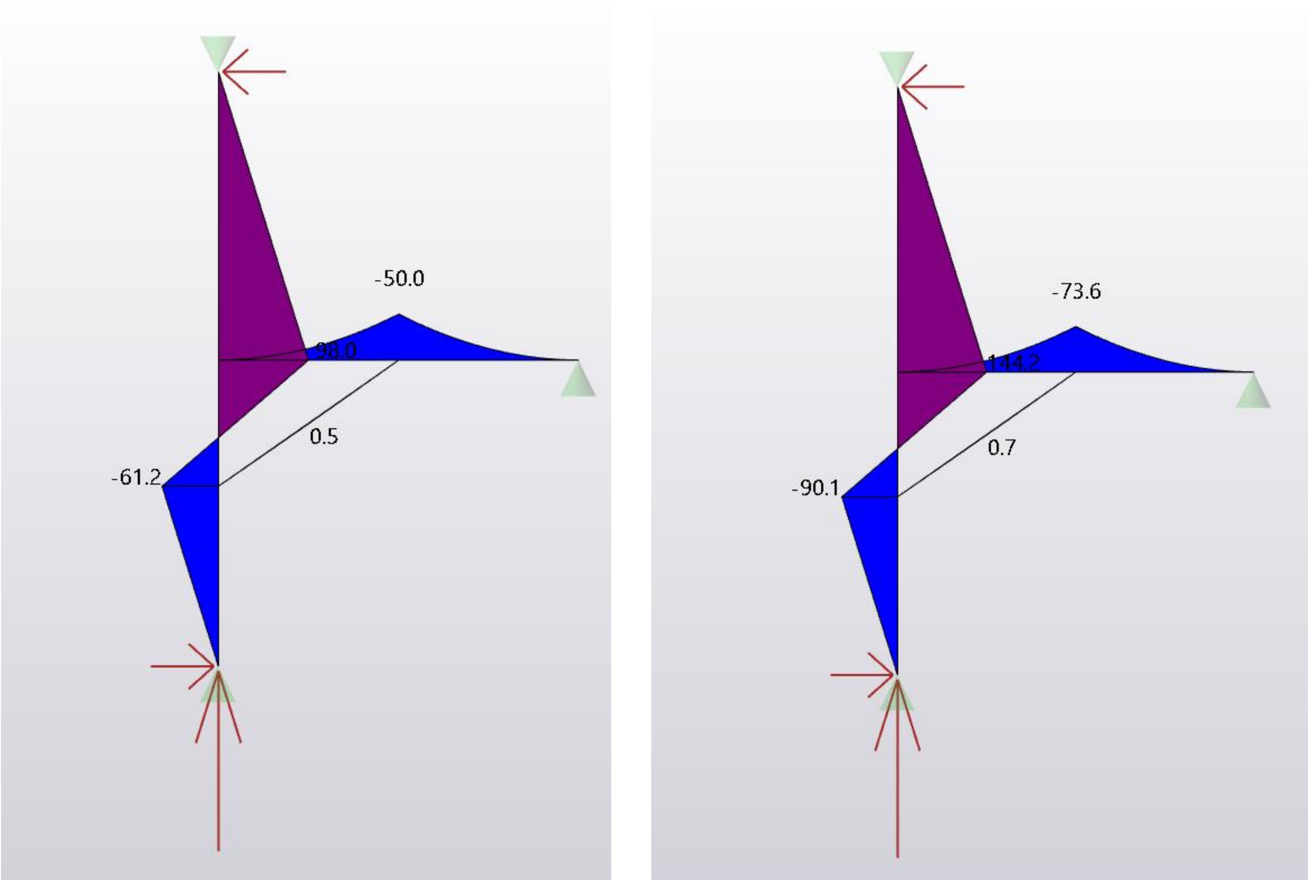

Figure 4 -The images show the bending moments for the balcony structure (SLS and ULS)

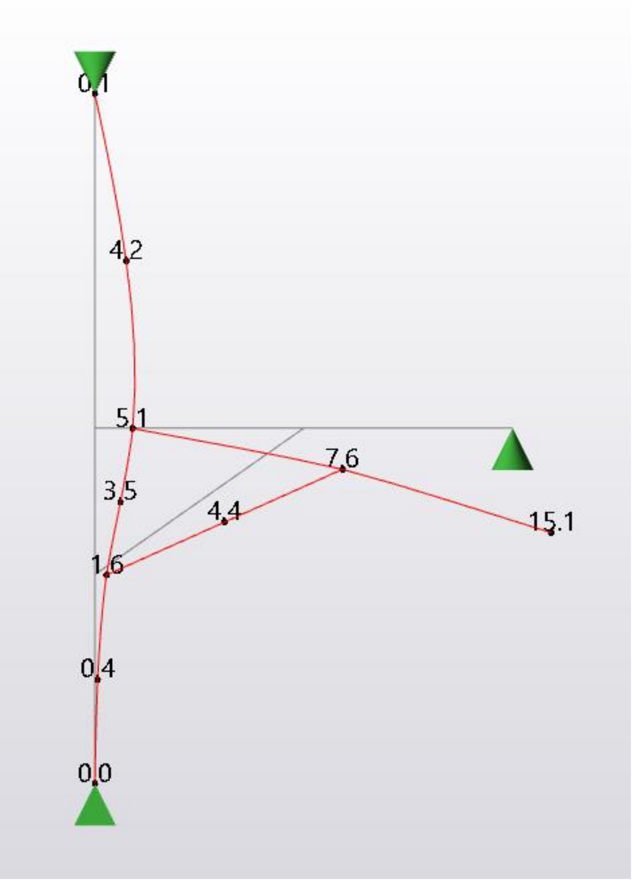

Figure 5 - The image shows the deflected shape of the balcony (imposed)

Summary UC 254x254x89(S355)

Design Condition	#	Design Value	Design Capacity	Units	U.R.	Status
Classification	1	Class 1	-	-	-	✔ Pass
Shear Major	1	73.6	704.8	kN	0.104	✔ Pass
Shear Minor	-	No forces		kN	-	Not required
Buckling Shear Web	-	21.913	59.423	-	-	✔ Pass
Moment Major	1	-73.6	429.8	kNm	0.171	✔ Pass
Moment Minor	-	No forces		kNm	-	Not required
Axial	1	-212.4	3979.9	kN	0.053	✔ Pass
Axial Bending Combined	1	-	-	-	0.173	✔ Pass
Buckling Lateral Torsional	1	-73.6	429.8	kNm	0.171	✔ Pass
Buckling Compression	No forces					Not required
Buckling Combined	No forces					Not required
Torsion	No Significant Forces					Not required
Deflection Slab	-	No loads		mm	-	Not required
Deflection Dead	1	-0.3	8.0	mm	0.034	✔ Pass
Deflection Imposed	1	-1.5	11.1	mm	0.138	✔ Pass
Deflection Total	1	-1.9	20.0	mm	0.094	✔ Pass

Figure 6 - The image shows the summary of analysis results for the balcony beam.

4 Discussion and Conclusion

The balcony beam has fixed connections to the column, with the brace strut modelled as pinned, forming a 2D frame. This is then repeated at 4.1m c/c, and linked with secondary steelwork. Each column is tied back to the existing structure.

Based on the existing design information, the vertical load applied to the elevation is 5.88kN/m^2.

Therefore, per frame, the applied load is 35.63kN/m.

This results in a conservative tie force (45kN) to the concrete encased steel beams. Appendix A presents an equivalent fixing into concrete, which is satisfactory.

Based on the information available, the loading will have a negligible impact on the existing structure.

Whilst the frame analysis raises no alarms, we would suggest some further analysis is undertaken to demonstrate a footfall analysis on the full balcony structure to check if there are any vibration issues. The fact there is no sign of distress, nor complaints of ‘bounce’ in the balcony over the years of use suggests this is a conservative check, but it would close out any concerns.

5 Appendices

5.1 Appendix A

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Design:	Concrete - 15 Aug 2023	Date:	15/08/2023
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Specifier's comments:

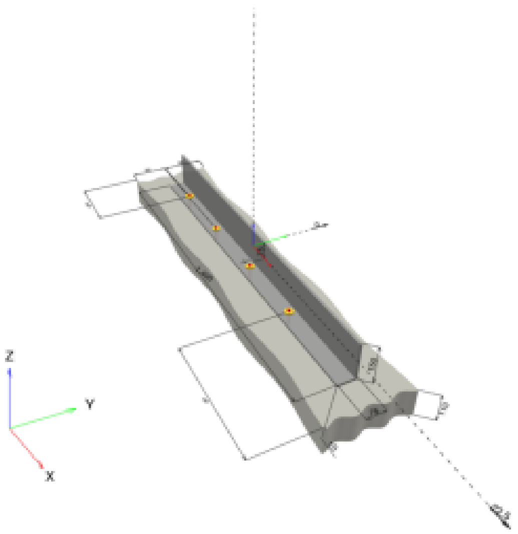
1 Anchor Design

1.1 Input data

Anchor type and size:	**HUS4-H 12 h_nom1**
Return period (service life in years):	50
Item number:	2293565 HUS4-H 12x70 10/-/-
Hilti Filling Set or any suitable annular gap filling solution	
Effective embedment depth:	h_{ef} = 45.9 mm ($h_{ef,ETA}$ = 45.9 mm), h_{nom} = 60.0 mm
Material:	Carbon Steel
Approval No.:	ETA-20/0867
Issued I Valid:	14/07/2022 | -
Proof:	SOFA based on EN 1992-4, Mechanical
Stand-off installation:	e_b = 0.0 mm (no stand-off); t = 10.0 mm
Ledger Angle[CBFEM] :	$L_1 \times L_2 \times t_{L1} \times t_{L2} \times l$ = 150.0 mm x 75.0 mm x 10.0 mm x 10.0 mm x 1,400.0 mm;
Load Point Height:	h_{pl} = 75.0 mm
Base material:	cracked concrete, C20/25, $f_{c,cyl}$ = 20.00 N/mm^2; h = 110.0 mm, User-defined partial material safety factor γ_c = 1.500
Installation:	**hammer drilled hole, Installation condition: Dry**
Reinforcement:	No reinforcement or Reinforcement spacing >= 150 mm (any Ø) or >= 100 mm (Ø <= 10 mm)
	no longitudinal edge reinforcement

CBFEM - The anchor calculation is based on a component-based Finite Element Method (CBFEM)

Geometry [mm] & Loading [kN, kNm]



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1.1.1 Load combination

Case	Description	Forces [kN] / Moments [kNm]	Seismic	Fire	Max. Util. Anchor [%]
1	Combination 1	$N = 0.000$; $V_x = 22.500$; $V_y = 0.000$; $M_x = 0.000$; $M_y = 0.000$; $M_z = 0.000$;	no	no	52

1.2 Load case/Resulting anchor forces

Anchor reactions [kN]
Tension force: (+Tension, -Compression)

Anchor	Tension force	Shear force	Shear force x	Shear force y
1	0.356	5.733	5.714	-0.474
2	0.078	5.691	5.689	-0.158
3	2.709	5.528	5.498	0.574
4	0.746	5.600	5.600	0.059

resulting tension force in (x/y)=(-410.5/-22.1): 3.889 [kN]
resulting compression force in (x/y)=(14.1/-21.3): 4.643 [kN]

Anchor forces are calculated based on a component-based Finite Element Method (CBFEM)

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1.3 Tension load (EN 1992-4, Section 7.2.1)

	Load [kN]	Capacity [kN]	Utilization β_N [%]	Status
Steel failure*	2.709	52.667	6	OK
Pull-out failure*	2.709	6.667	41	OK
Concrete Breakout failure**	2.709	7.139	38	OK
Splitting failure**	N/A	N/A	N/A	N/A

* highest loaded anchor **anchor group (anchors in tension)

1.3.1 Steel failure

$$N_{Ed} \leq N_{Rd,s} = \frac{N_{Rk,s}}{\gamma_{M,s}}$$ EN 1992-4, Table 7.1

$N_{Rk,s}$ [kN]	$\gamma_{M,s}$	$N_{Rd,s}$ [kN]	N_{Ed} [kN]
79.000	1.500	52.667	2.709

1.3.2 Pull-out failure

$$N_{Ed} \leq N_{Rd,p} = \frac{\psi_c \cdot N_{Rk,p}}{\gamma_{M,p}}$$ EN 1992-4, Table 7.1

$N_{Rk,p}$ [kN]	ψ_c	$\gamma_{M,p}$	$N_{Rd,p}$ [kN]	N_{Ed} [kN]
10.000	1.000	1.500	6.667	2.709

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1.3.3 Concrete Breakout failure

$N_{Ed} \leq N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{M,c}}$	EN 1992-4, Table 7.1
$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec1,N} \cdot \psi_{ec2,N} \cdot \psi_{M,N}$	EN 1992-4, Eq. (7.1)
$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck}} \cdot h_{ef}^{1.5}$	EN 1992-4, Eq. (7.2)
$A^0_{c,N} = s_{cr,N} \cdot s_{cr,N}$	EN 1992-4, Eq. (7.3)
$\psi_{s,N} = 0.7 + 0.3 \cdot \frac{c}{c_{cr,N}} \leq 1.00$	EN 1992-4, Eq. (7.4)
$\psi_{ec1,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{N,1}}{s_{cr,N}}\right)} \leq 1.00$	EN 1992-4, Eq. (7.6)
$\psi_{ec2,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{N,2}}{s_{cr,N}}\right)} \leq 1.00$	EN 1992-4, Eq. (7.6)
$\psi_{M,N} = 1$	EN 1992-4, Eq. (7.7)

$A_{c,N}$ [mm²]	$A^0_{c,N}$ [mm²]	$c_{cr,N}$ [mm]	$s_{cr,N}$ [mm]	$f_{c,cyl}$ [N/mm²]
18,961	18,961	68.8	137.7	20.00

$e_{c1,N}$ [mm]	$\psi_{ec1,N}$	$e_{c2,N}$ [mm]	$\psi_{ec2,N}$	$\psi_{s,N}$	$\psi_{re,N}$
0.0	1.000	0.0	1.000	1.000	1.000

z [mm]	$\psi_{M,N}$	k_1	$N^0_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]
424.6	1.000	7.700	10.708	1.500	7.139	2.709

Group anchor ID
3

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1.4 Shear load (EN 1992-4, Section 7.2.2)

	Load [kN]	Capacity [kN]	Utilization β_V [%]	Status
Steel failure (without lever arm)*	5.733	24.896	24	OK
Steel failure (with lever arm)*	N/A	N/A	N/A	N/A
Pryout failure**	5.733	14.278	41	OK
Concrete edge failure in direction **	N/A	N/A	N/A	N/A

* highest loaded anchor **anchor group (relevant anchors)

1.4.1 Steel failure (without lever arm)

$V_{Ed} \leq V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{M,s}}$ EN 1992-4, Table 7.2

$V_{Rk,s} = k_7 \cdot V^0_{Rk,s}$ EN 1992-4, Eq. (7.35)

$V^0_{Rk,s}$ [kN]	k_7	$V_{Rk,s}$ [kN]	$\gamma_{M,s}$	$V_{Rd,s}$ [kN]	V_{Ed} [kN]
38.900	0.800	31.120	1.250	24.896	5.733

1.4.2 Pryout failure

$V_{Ed} \leq V_{Rd,cp} = \frac{V_{Rk,cp}}{\gamma_{M,c,p}}$ EN 1992-4, Table 7.2

$V_{Rk,cp} = k_8 \cdot N_{Rk,c}$ EN 1992-4, Eq. (7.39a)

$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec1,N} \cdot \psi_{ec2,N} \cdot \psi_{M,N}$ EN 1992-4, Eq. (7.1)

$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck}} \cdot h_{ef}^{1.5}$ EN 1992-4, Eq. (7.2)

$A^0_{c,N} = s_{cr,N} \cdot s_{cr,N}$ EN 1992-4, Eq. (7.3)

$\psi_{s,N} = 0.7 + 0.3 \cdot \frac{c}{c_{cr,N}} \leq 1.00$ EN 1992-4, Eq. (7.4)

$\psi_{ec1,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{V,1}}{s_{cr,N}}\right)} \leq 1.00$ EN 1992-4, Eq. (7.6)

$\psi_{ec2,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{V,2}}{s_{cr,N}}\right)} \leq 1.00$ EN 1992-4, Eq. (7.6)

$\psi_{M,N} = 1$ EN 1992-4, Eq. (7.7)

$A_{c,N}$ [mm²]	$A^0_{c,N}$ [mm²]	$c_{cr,N}$ [mm]	$s_{cr,N}$ [mm]	k_8	$f_{c,cyl}$ [N/mm²]
18,961	18,961	68.8	137.7	2.000	20.00

$e_{c1,V}$ [mm]	$\psi_{ec1,N}$	$e_{c2,V}$ [mm]	$\psi_{ec2,N}$	$\psi_{s,N}$	$\psi_{re,N}$	$\psi_{M,N}$
0.0	1.000	0.0	1.000	1.000	1.000	1.000

k_1	$N^0_{Rk,c}$ [kN]	$\gamma_{M,c,p}$	$V_{Rd,cp}$ [kN]	V_{Ed} [kN]
7.700	10.708	1.500	14.278	5.733

Group anchor ID
1

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1.5 Combined tension and shear loads (EN 1992-4, Section 7.2.3)

Steel failure

β_N	β_V	α	Utilization $\beta_{N,V}$ [%]	Status
0.007	0.230	2.000	6	OK

$\beta_N^\alpha + \beta_V^\alpha \leq 1.0$

Concrete failure

β_N	β_V	α	Utilization $\beta_{N,V}$ [%]	Status
0.406	0.402	1.500	52	OK

$\beta_N^\alpha + \beta_V^\alpha \leq 1.0$

1.6 Warnings

- The anchor design methods in PROFIS Engineering require rigid baseplates as per current regulations (ETAG 001/Annex C, EOTA TR029, etc.). This means load re-distribution on the anchors due to elastic deformations of the baseplate are not considered - the baseplate is assumed to be sufficiently stiff, in order not to be deformed when subjected to the design loading. PROFIS Engineering calculates the minimum required baseplate thickness with CBFEM to limit the stress of the baseplate based on the assumptions explained above. The proof if the rigid base plate assumption is valid is not carried out by PROFIS Engineering. Input data and results must be checked for agreement with the existing conditions and for plausibility!
- Design is only valid if hole is filled to remove clearance, clearance as per EN 1992-4 Table 6.1
- In general, the conditions given in ETAG 001, Annex C, section 4.2.2.1 and 4.2.2.3 b) are not fulfilled because the diameter of the clearance hole in the fixture acc. to Annex 3, Table 3 is greater than the values given in Annex C, Table 4.1 and AS5126 for the corresponding diameter of the anchor. Therefore the design resistance for anchor groups is limited to twice the steel resistance (of a single anchor) in accordance with the approval.
- Checking the transfer of loads into the base material is required in accordance with EN 1992-4, Annex A!
- The design is only valid if the clearance hole in the fixture is not larger than the value given in Table 6.1 of EN 1992-4! For larger diameters of the clearance hole see section 6.2.2 of EN 1992-4!
- The accessory list in this report is for the information of the user only. In any case, the instructions for use provided with the product have to be followed to ensure a proper installation.
- For the determination of the $\psi_{re,V}$ (concrete edge failure) the minimum concrete cover defined in the design settings is used as the concrete cover of the edge reinforcement.
- The anchor design methods in PROFIS Engineering require rigid baseplates, as per current regulations (AS 5216:2021, ETAG 001/Annex C, EOTA TR029 etc.). This means that the baseplate should be sufficiently rigid to prevent load re-distribution to the anchors due to elastic/plastic displacements. The user accepts that the baseplate is considered close to rigid by engineering judgment."
- The characteristic bond resistances depend on the return period (service life in years): 50

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1.7 Installation data

Ledger Angle: $L_1 \times L_2 \times t_{L1} \times t_{L2} \times l$ = 150.0 mm x 75.0 mm x 10.0 mm x 10.0 mm x 1,400.0 mm; Steel: S 235; E = 210,000.00 N/mm^2; f_{yk} = 235.00 N/mm^2

Hole diameter in the fixture: d_f = 16.0 mm

Plate thickness (input): 10.0 mm

Drilling method: Hammer drilled

Cleaning: Clean the drill hole. Under the conditions - according to fastener size and drilling direction - given in the ETA and MPII (IFU), the cleaning of the drill hole may be omitted.

Anchor type and size: HUS4-H 12 h_nom1

Item number: 2293565 HUS4-H 12x70 10/-/-

Maximum installation torque: Hilti SIW 22T-A

Hole diameter in the base material: 12.0 mm

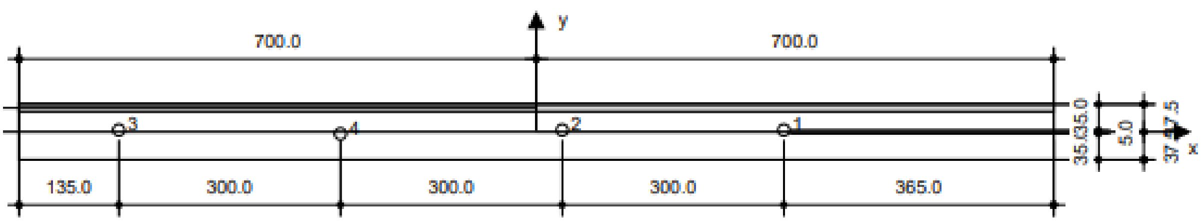
Hole depth in the base material: 70.0 mm

Minimum thickness of the base material: 100.0 mm

Hilti HUS screw anchor with 60 mm embedment, 12 h_nom1, Steel galvanized, installation per ETA-20/0867, with annular gaps filled with Hilti Filling Set or any suitable gap solutions

1.7.1 Recommended accessories

Drilling	Cleaning	Setting
• Suitable Rotary Hammer • Properly sized drill bit	• Manual blow-out pump	• Hilti SIW 22T-A impact screw driver



Coordinates Anchor [mm]

Anchor	x	y	c_{-x}	c_{+x}	c_{-y}	c_{+y}
1	335.0	2.5	-	-	-	-
2	35.0	2.5	-	-	-	-
3	-565.0	2.5	-	-	-	-
4	-265.0	-2.5	-	-	-	-

2 Baseplate rigidity check

2.1 Input data

Baseplate:	Ledger angle: height = 150.0 mm, width = 75.0 mm, thickness = 10.0 mm, length = 1,400.0 mm Calculation: Baseplate Rigidity Check Material: S 235; F_y = 235.00 N/mm²; ε_{lim} = 5.00%
Anchor type and size:	HUS4-H 12 h_nom1, h_{ef} = 45.9 mm
Anchor stiffness:	The anchor is modelled considering stiffness values determined from load displacement curves tested in an independent laboratory. Please note that no simple replacement of the anchor is possible as the anchor stiffness has a major impact on the load distribution results.
Design method:	EN based design using component-based FEM
Stand-off installation:	e_b = 0.0 mm (No stand-off); t = 10.0 mm
Base material:	Cracked concrete; C20/25; $f_{c,cyl}$ = 20.00 N/mm²; h = 110.0 mm; E = 30,000.00 N/mm²; G = 12,500.00 N/mm²; ν = 0.20
Mesh size:	Number of elements on edge: 8 Min. size of element: 10.0 mm Max size of element: 50.0 mm

2.2 Baseplate plate classification

Results below are displayed for the decisive load combinations: Combination 1

Anchor tension forces	Equivalent rigid baseplate (CBFEM)	Component-based Finite Element Method (CBFEM) baseplate
Anchor 1	0.000 kN	0.356 kN
Anchor 2	0.018 kN	0.078 kN
Anchor 3	1.132 kN	2.709 kN
Anchor 4	0.533 kN	0.746 kN

User accepted to consider the selected baseplate as rigid by his/her engineering judgement. This means the anchor design guidelines can be applied.

2.3 Warnings

- By using the CBFEM calculation functionality of PROFIS Engineering you may act outside the applicable design codes and your specified baseplate may not behave rigidly. Please, have the results validated by a professional designer and/or structural engineer to ensure suitability and adequacy for your specific jurisdiction and project requirements.
- The anchor is modelled considering stiffness values determined from load displacement curves tested in an independent laboratory. Please note that no simple replacement of the anchor is possible as the anchor stiffness has a major impact on the load distribution results.

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3 Summary of results

	Load combination	Max. utilisation	Status
Anchors	Combination 1	52%	OK

Fastening meets the design criteria!

Input data and results must be checked for conformity with the existing conditions and for plausibility!

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Fastening Point:			

4 Remarks; Your Cooperation Duties

- Any and all information and data contained in the Software concern solely the use of Hilti products and are based on the principles, formulas and security regulations in accordance with Hilti's technical directions and operating, mounting and assembly instructions, etc., that must be strictly complied with by the user. All figures contained therein are average figures, and therefore use-specific tests are to be conducted prior to using the relevant Hilti product. The results of the calculations carried out by means of the Software are based essentially on the data you put in. Therefore, you bear the sole responsibility for the absence of errors, the completeness and the relevance of the data to be put in by you. Moreover, you bear sole responsibility for having the results of the calculation checked and cleared by an expert, particularly with regard to compliance with applicable norms and permits, prior to using them for your specific facility. The Software serves only as an aid to interpret norms and permits without any guarantee as to the absence of errors, the correctness and the relevance of the results or suitability for a specific application.
- You must take all necessary and reasonable steps to prevent or limit damage caused by the Software. In particular, you must arrange for the regular backup of programs and data and, if applicable, carry out the updates of the Software offered by Hilti on a regular basis. If you do not use the AutoUpdate function of the Software, you must ensure that you are using the current and thus up-to-date version of the Software in each case by carrying out manual updates via the Hilti Website. Hilti will not be liable for consequences, such as the recovery of lost or damaged data or programs, arising from a culpable breach of duty by you.

Input data and results must be checked for conformity with the existing conditions and for plausibility!

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