Structural Calculations:

Stair Tower: Buckling

Analysis

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S-MECH LTD
7 Windsor Road – Chorley – Lancashire – PR7 1LN • 01257 367 580 • info@s-mech.co.uk • www.s-mech.co.uk •

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1 Introduction

The purpose of this report is to investigate the critical buckling loads of the Haki-style stair tower system, which in turn will be used to derive the effective length of the standards. This will allow the relevant formulae presented in BS EN 1993-1-1:2005 to be implemented to calculate the allowable loading. Applying the safety factors detailed in BS EN 12811-1:2003 will then allow safe working loads to be presented.

Results are calculated when the long face of the tower is parallel to a supporting structure, and also when the short face is parallel to a supporting structure. In the latter condition wing braces are provided back to the supporting structure from the outer standards.

2 Arrangement Details

The structure is simplified back to the components necessary to perform the analysis, omitting ancillary components.

Each lift is modelled with a ledger beam to the long face and a single tube beam to the short face. Between lifts, three sides have pin-ended guardrail frames present as these will impact the buckling lengths.

A typical frame analysed is shown in Figure 2-1, with the global axis shown for reference. The plan size is 3.05m x 1.65m with a 2m lift height. A foot lift at 0.5m is adopted. Total frame height is 20.5m.

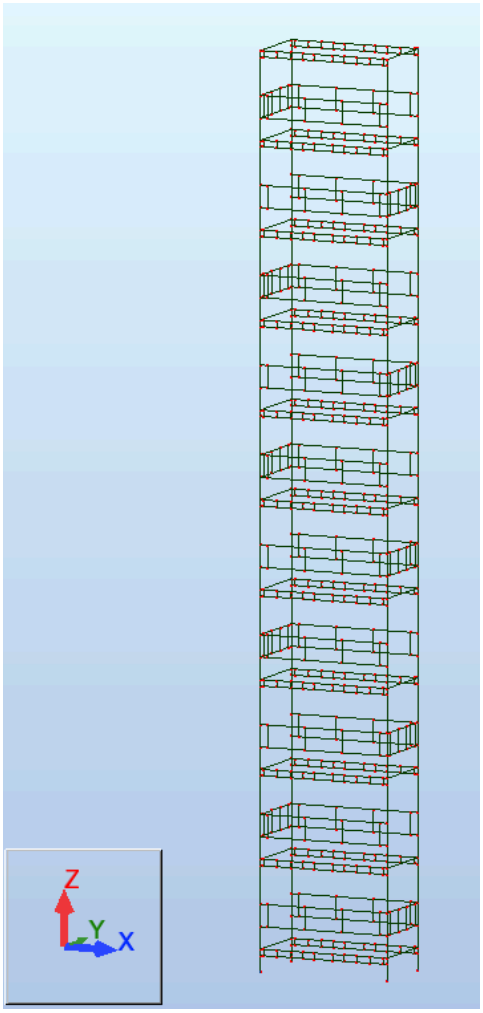

Figure 2-1 - Frame General Arrangement

3 Data Input

3.1 Structural data

The required data input relates to the section properties and the joint stiffnesses. The relevant inputs are as shown in the tables below, and relate to the local member axis in the European convention as shown below:

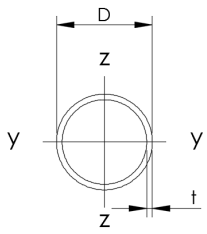

Figure 3-1 Axis Convention

	Standard	Single Tube Beam	Guardrail Frame Chords	Guardrail Frame Verts	Ledger Beam Chords	Ledger Beam Verts (1)	Ledger Beam Verts (2)
Area (mm^2)	453	427	192	161	247	240	480
I_{yy} (mm^4)	115856	109940	14590	65920	30880	18000	144000
I_{zz} (mm^4)	115856	109940	14590	14790	30880	1280	2560
I_{xx} (mm^4)	231712	219880	2910	131840	61760	36000	288000

Table 3-1 Section Properties

The proprietary connection between members has been tested and analysed in accordance with the requirements of BS EN 12811-3:2002 as described in the Oxford Brookes report Ref #408. Typical of this type of connection, the stiffness varies by the direction of rotation, and the values are shown in Table 3-2. Positive rotation denotes the joint rotating down.

	Positive Rotation (kN.m/rad)	Negative Rotation (kN.m/rad)	Average (kN.m/rad)
Single Tube Beam	60.6	150.13	105.37
Ledger Beam	74.15	134.92	104.54

Table 3-2 Connection Design Stiffness

3.2 Tie Patterns

The allowable axial load in the standards in an unbraced structural system is related to the support pattern used to restrain overall structure. The patterns investigated are as follows:

- Long face parallel tied at each rear standard at every lift.
- Short face parallel tied at each rear standard at every lift and at the ends of the wing braces.

NB – no ties were provided at the foot lift.

These are shown in Figure 3-2 and Figure 3-3.

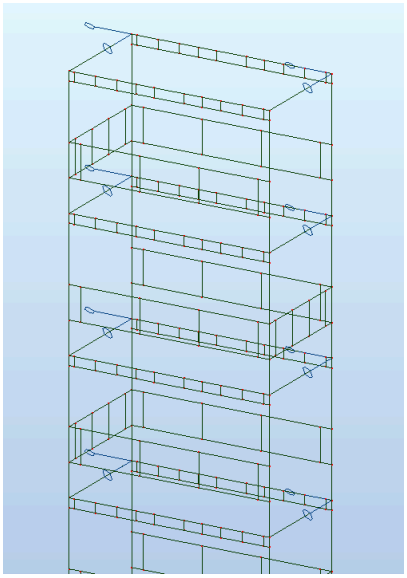

Figure 3-2 Extract of LFP showing restraints

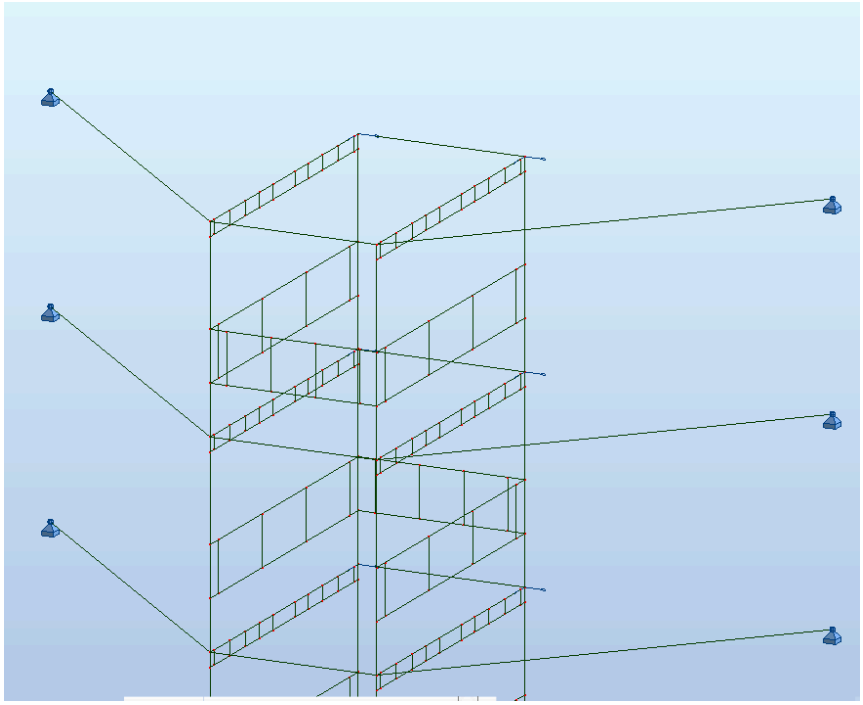

Figure 3-3 Extract of SFP showing restraints

4 Buckling Analysis

A buckling analysis was carried out for each of the arrangements described previously in this report and the findings are summarised in the table below:

	Tie Pattern	Critical Buckling Load (kN)
Haki Style Stair Tower	LFP	78.95
	SFP	78.64

Figure 4-1 Critical Buckling Loads

The above values were then used to calculate the effective lengths of the standard at 2m lift heights. The effective length could then be used to calculate the allowable load in accordance with BS EN 1993-1-1:2005. An alpha value of 0.49 has been adopted in the table shown in Figure 4-2.

Axial Buckling Capacities							
	LFP	SFP					
Critical Buckling Load (kN)	78.95	78.64	0.1	0.1	0.1	0.1	0.1
Effective Length (mm)	1744	1747	49003	49003	49003	49003	49003
$\bar{\lambda}$	1.408	1.411	39.556	39.556	39.556	39.556	39.556
Φ	1.787	1.791	792.464	792.464	792.464	792.464	792.464
χ	0.346	0.345	0.001	0.001	0.001	0.001	0.001
$N_{b,Rd}$ (kN)	54.18	54.02	0.10	0.10	0.10	0.10	0.10
Permissible Axial Force (kN)	32.83	32.74	0.06	0.06	0.06	0.06	0.06

Figure 4-2 Allowable Axial Loads on Standards

Buckling occurred parallel to the short face in both cases as shown in the figures below:

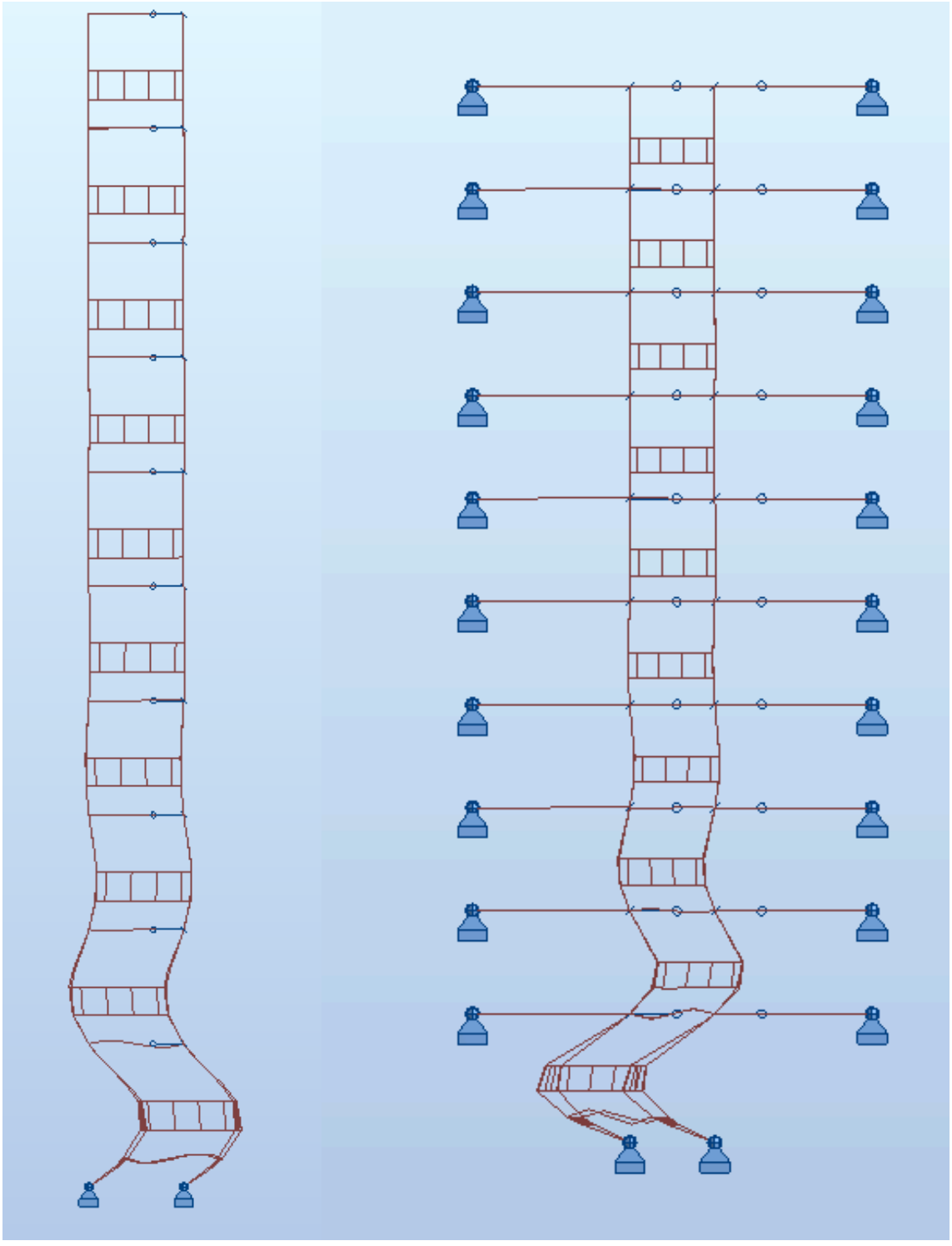

Table 4-1 LFP and SFP Mode Shape 1

5 Conclusions

The buckling analyses have derived the following safe working loads for the geometric conditions discussed within this report:

	Tie Pattern	Permissible Load on Standard (kN)
Haki-Style Stair	LFP	32.83
	SFP	32.74

Figure 5-1 Permissible Loads on Standard

Appendix A Relevant Component Drawings