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Experimental Compression Tests on the Stability of Structural Steel Tabular Props

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ABSTRACT

Experimental studies are presented in this paper on the stability of structural steel props. Three full-scale prop specimens with various geometric properties were constructed and tested statically and elastically in the lab, in order to obtain the elastic strength of the props. The total unsupported length is 6 m for the three props. The outer and inner diameters are 150 mm and 140 mm, 138 mm and 132 mm for the outer and the inner lengths, respectively. Each specimen consisted of two pipes, one sliding inside the other for a certain length, and tightened together by three 20 mm bolts. Three different (outer, inner and inserted) length combinations were tried in order to maximize the elastic buckling capacity of the whole prop. The three props were loaded up to elastic buckling using R.SM/RCS flat jack cylinders with 30 tons (295 kN) capacity. Based on the experimental results, it can be concluded that the typical failure mode of steel prop is the elastic global buckling. The elastic buckling strength of the prop was found to be sensitive to the inserted length of the upper pipe. The prop buckling capacity increases with increasing the inserted length.

KEYWORDS: Structural steel, Prop, Scaffold, Stability, Experimental research.

INTRODUCTION

When an axial load (by definition, columns are subjected to compression axial loads) is applied to a column, the column may fail because the stress in the column exceeds the yield stress of the material. For practical columns, however, this is seldom the cause of failure. A large compression load can cause the column to become unstable, resulting in a sudden lateral deflection of the column. This bowing of the column is called buckling. The purpose of the Euler buckling calculations is to compute the magnitude of the axial load that will create this instability in the column. Factors that dictate the load required to buckle a column include the dimensions and configuration of the column cross-section, the length of the column, the elastic modulus of the column material and the restraint provided by the connections at the column supports. Euler buckling considers an ideal column, which assumes that: 1) the column is perfectly straight before loading, 2) the column material is homogenous, 3) the load is applied through the centroid of the column's cross-section and 4) the material stresses remain in the linear-elastic region of the stress-strain curve. While these assumptions are never truly met in practical or realistic columns, Euler buckling serves to introduce the concept of stability as a failure consideration (McCormac, 2008).

Props are the products that are designed to support formwork shuttering. These products provide the ideal and the most economic method of support for all kinds of slabs, beams, formwork, walls and columns. These

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also find a wide variety of applications in general building construction and repair work. Manufacturers of scaffold tubes offer a wide range of customized scaffold tubes that are widely used on construction sites for supporting man, material and tools.

For many years, the steel scaffold system has been commonly used as a temporary structure to support man, material, tools and structural members during construction all over the world. These are used during construction, alteration, demolition and maintenance works. However, structural failures of these systems have occurred on construction sites in the past, due to inadequate design, poor installation and over-loading, which would cause not only project delays but more seriously injuries and casualties of the construction workers (Hongbo et al., 2010; Milojkovic et al., 2002; Vaux et al., 2002). Being robust and high on strength, scaffold tubes are often used where heavy loads need to be carried. Because of advantages over the conventional type of timber / bamboo scaffoldings, these strong scaffold tubes are used where multiple platforms must reach several stories high. Props are designed according to light weight design which has the same loading bearing capacity as the heavy duty props. This reduces both transport costs and manual handling risks. In order to enhance the safety of steel scaffolds during construction, experimental and analytical studies have been conducted in the past on the structural behavior of high-clearance scaffolds (Peng et al., 1996) and (Peng et al., 1996), as well as multi-storey door-type modular steel scaffolds (Chan et al., 1995; Peng et al., 1998; Yu et al., 2004; Weesner and Jones, 2001; Peng et al., 2001; Peng et al., 1997). Almost all research conducted has focused on the door-type steel scaffolds, and very few have focused on the steel tube and coupler scaffolds. Research has been conducted on the two-wall formed steel tube and coupler scaffolds, which are widely used in the construction of residential and commercial buildings (Goodley and Beale, 1997; Yue et al., 2005; Hong-Fei and Guo-Qiang, 2004). However, almost no research has been conducted on structural steel tube and coupler scaffolds (e.g. three-dimensional multi-span and multi-storey steel tube and coupler scaffolds, which are used in the construction of long-span spatial structures such as, garages, train stations, gymnasiums and bridges).

Objectives and Scope of Investigation

Compression tests on three steel tabular props marked as (AB, CD and EF) are performed at the structural labs at the University of Sharjah/UAE. The specimen consists of two pipes, one sliding inside the other for a certain length. The outer prop is 10 mm thick and 150 mm in diameter, while the inner prop is 6 mm thick and 138 mm in diameter. Dimensions of the specimens and the inserted lengths are shown in Table 1 and Fig. 1.

The objective of the test was to investigate the ability of these specimens to sustain axial load within the elastic region without buckling. Test set-up, test procedure, test results and conclusions are given in this study.

Table 1: Geometrical properties of the test specimens

Prop Ref.	Outer Pipe Length L_o (m)	Inner Pipe Length L_i (m)	Inserted Length L_{ins} (m)	Prop Total Length (m)
AB	4.50	4.00	2.50	6.00
CD	5.00	3.00	2.00	6.00
EF	5.50	2.00	1.50	6.00

TEST PROCEDURE

a) Preparation of Specimens

Both ends of the specimen were milled, and end plates were welded to specimen ends, matching the geometric center of the specimen.

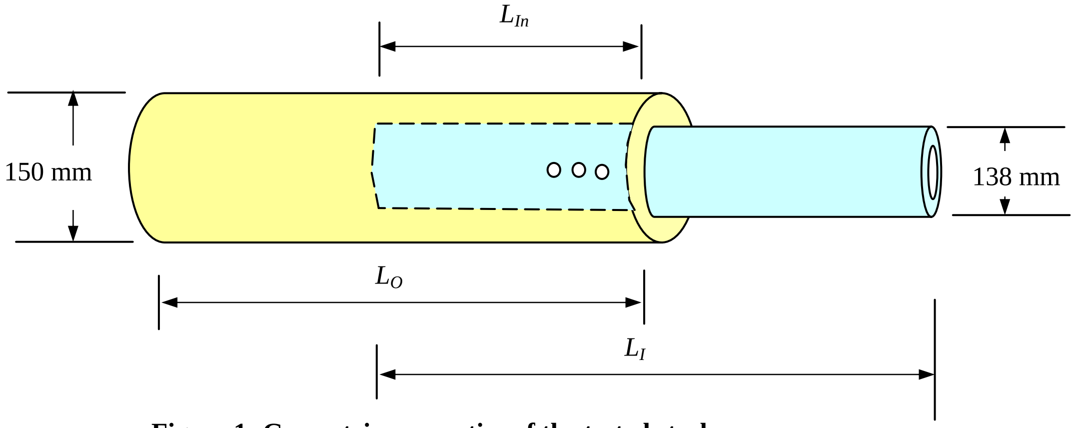

Figure 1: Geometric properties of the tested steel props

b) Aligning of the Specimen

This is the most important step in the column testing procedure. In this alignment method, the prop was carefully aligned geometrically to be horizontal and mounted between supports (see Photos 1, 2 and 3). This was done with respect to specific reference points.

Photo 1: Alignment of the prop between the two supports

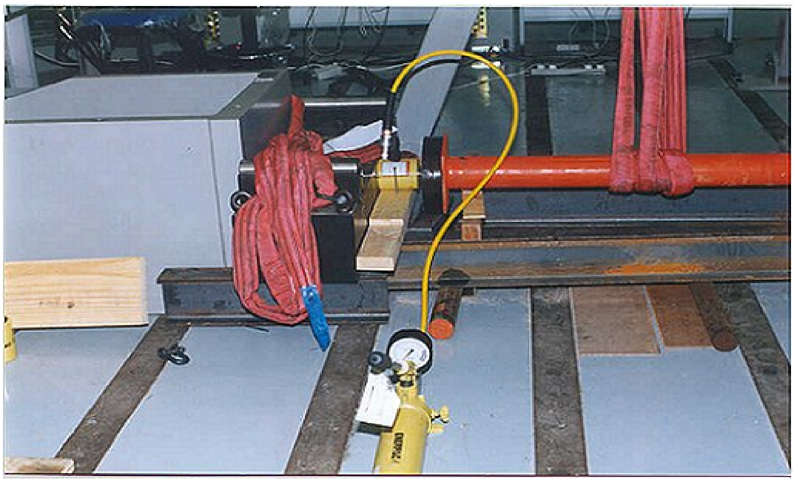

Photo 2: Hydraulic jack at one end of the prop

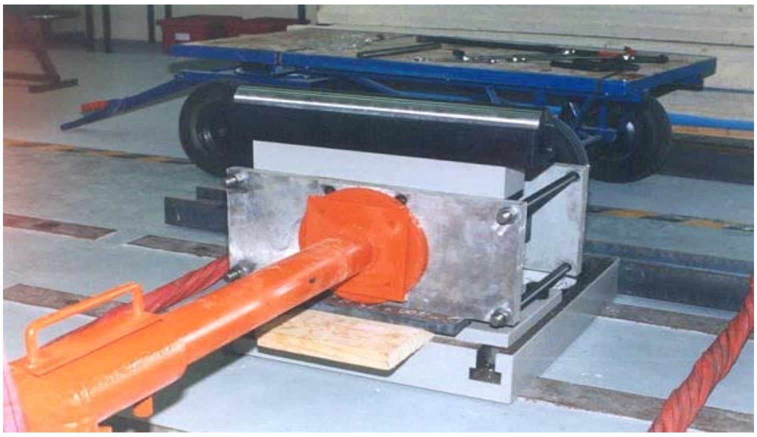

Photo 3: End support conditions –no sliding

c) **Instrumentation**

- R.SM/RCS flat jack cylinders with 30 tons (295kN) capacity were used for load application (see photos 2 and 4).
- Dial gauges for lateral displacement were mounted, back-to-back at the middle of the specimen length (Photo 5). The overall shortening was determined by measuring the movement of the jack piston.

Photo 4: 30 tons capacity hydraulic jack

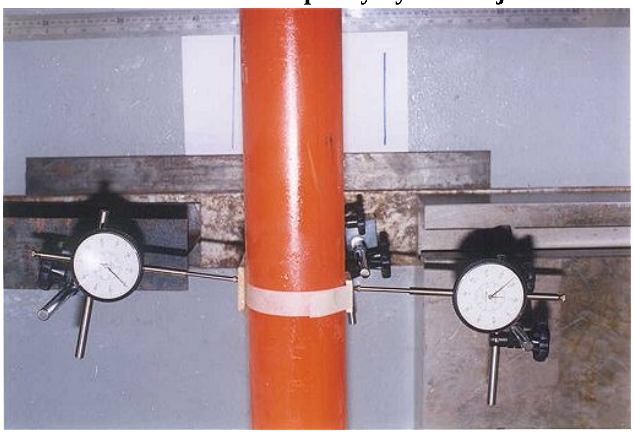

Photo 5: Dial gauges' locations

d) Testing

After the specimen is aligned horizontally between the two supports, all measuring devices are adjusted for initial readings (Photo 6). The test started with an initial load of 50 bars, and the load was increased at an increment of 50 bars (Photo 7), and the corresponding lateral displacement was recorded instantly. The test continued until the maximum load was reached. The load was then released and the specimen reverted back to its original shape (elastic deformation- see Photo 8). Pines, holes, and end support were checked before and after testing (Photo 9).

Photo 6: Final setup checking before loading

Photo 7: Pressure was applied incrementally

Photo 8: (a) Loaded prop-buckled (b) Unloaded prop-straight

Photo 9: Holes were checked after testing and no damage was encountered

TEST DATA PRESENTATION

The behavior of the tested specimens under static axial loading was determined by measuring the lateral displacement at various loading stages along the two principal directions. Figs. 2, 3 and 4 show the applied axial load versus the lateral displacement at midpoint of prop AB, CD and CE, respectively. See also Tables 3, 4 and 5.

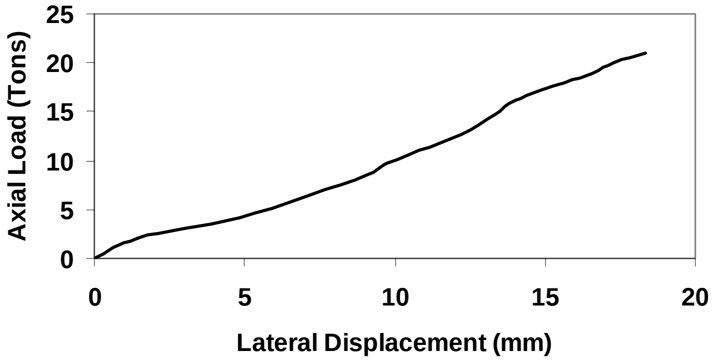

Figure 2: Axial load – lateral displacement curve for prop AB

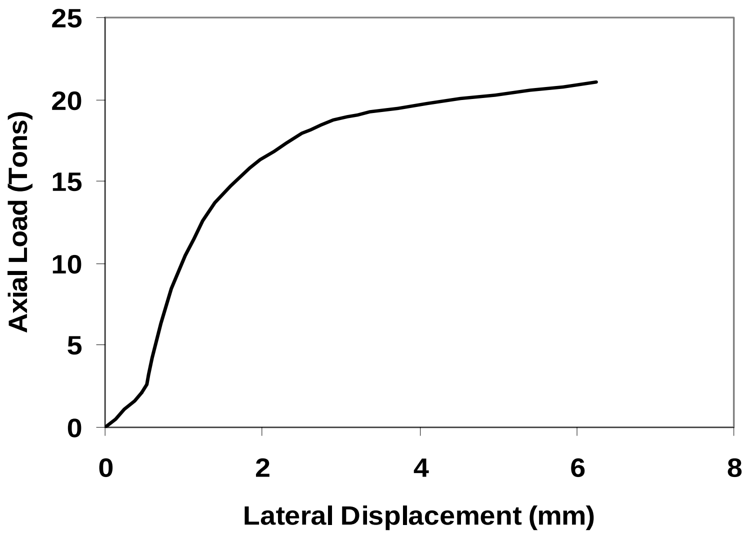

Figure 3: Axial load – lateral displacement curve for prop CD

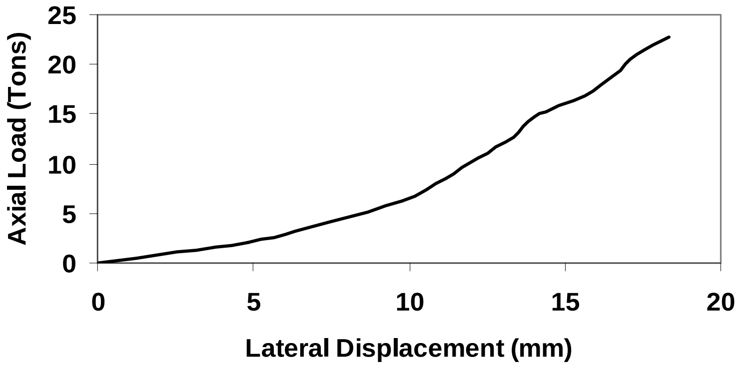

Figure 4: Axial load – lateral displacement curve for prop EF

OBSERVATIONS

- Props were unloaded and returned to initial condition and no permanent deformations were observed.
- Prop AB was reloaded up to Jack capacity (28.63 ton) without buckling failure, while props CD and EF were loaded to 23.56 and 22.734 ton, respectively. It can be seen from Table 5 that increasing the inserted length relative to prop EF by 33 % and 66 % (6% and 13% material wise), increased the buckling capacity by 1% and more than 26% for prop CD and prop AB, respectively.
- Pines and holes in the three props were checked and no damage was encountered.
- Other visual records of the tests can be seen in Photos 10-13.

Table 2: Test results for prop AB (L_o = 4.50 m, L_i = 4.00 m)

Pressure (bar)	**Load (Ton)**	**Lateral Displacement (mm)**
50	2.11	1.45
100	4.21	4.85
150	6.32	9.05
200	8.42	9.75
250	10.53	11.15
300	12.63	12.19
350	14.74	13.35
400	16.84	14.01
425	17.89	15.64
450	18.95	16.57
475	20.00	17.28
500	21.05	18.34
Unloading stage without inelastic deformation		
680	**>28.63**	Jack capacity reached without buckling

Table 3: Test results for prop CD (L_o = 5.0 m, L_i = 3.00 m)

Pressure (bar)	**Load (Ton)**	**Lateral Displacement (mm)**
50	2.11	0.47
100	4.21	0.6
150	6.32	0.7
200	8.42	0.85
250	10.53	1.03
300	12.63	1.25
350	14.74	1.6
400	16.84	2.16
450	18.95	3.08
500	21.05	6.25
Unloading stage without inelastic deformation		
560	**23.56**	**Buckling**

Table 4: Test results for prop EF (L_o = 5.00 m , L_i = 2.00 m)

Pressure (bar)	Load (Ton)	Lateral Displacement (mm)
0	0	1.45
50	2.105	4.85
100	4.21	9.05
150	6.315	9.75
200	8.42	11.15
250	10.525	12.19
300	12.63	13.35
350	14.735	14.01
400	16.84	15.64
450	18.945	16.57
500	21.05	17.28
540	22.734	18.34
Unloading stage without inelastic deformation		
540	22.734	**Buckling**

Table 5: Buckling results for the tested steel props

Prop Ref.	Outer Pipe Length L_o (m)	Inner Pipe Length L_i (m)	Inserted Length L_{ins} (m)	Prop Total Length (m)		Prop Capacity (Ton)
				Support	Material	
AB	4.50	4.00	2.50	6.00	8.5	>28.63
CD	5.00	3.00	2.00	6.00	8.0	23.56
EF	5.50	2.00	1.50	6.00	7.5	22.74

Photo 10: Recording lateral displacements

Photo 11: Load (pressure) increasing (=650 bars)

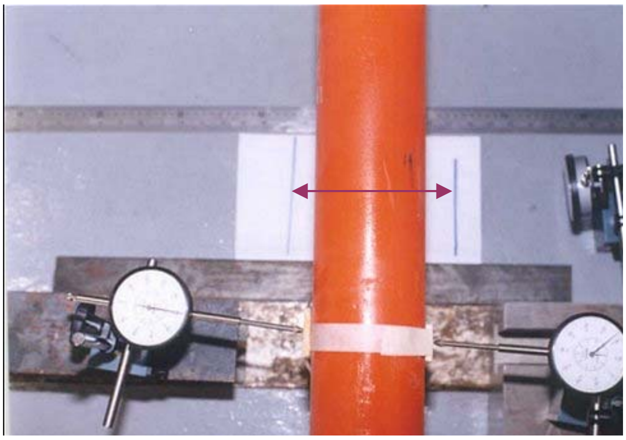

Photo 12: Observe the two blue lines before loading

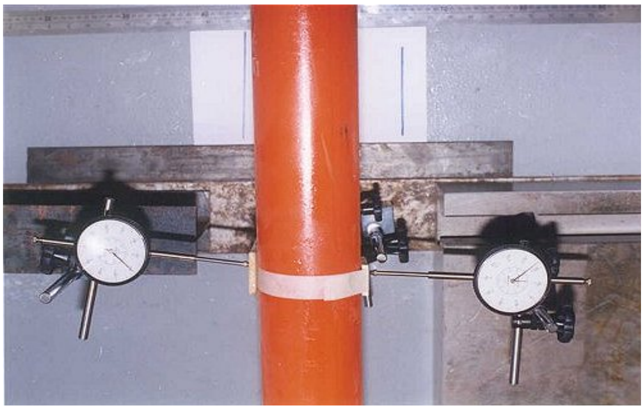

Photo 13: Observe the two blue lines after loading– lateral buckling

CONCLUSIONS

An experimental study was conducted on the stability and strength of steel props through three full-scale tests. The following conclusions were made:

1. From the full-scale tests, it was clear that the global flexural buckling is the main failure mode of the three steel props.
2. It was observed that all three specimens come back to their original shape after removing the load. Therefore, the three props failed in elastic buckling.
3. Holes and pines were checked after testing and negligible deformation was encountered for all specimens.
4. From the full-scale tests, it was clear that the strength of the prop is sensitive to the inserted length of the inner pipe. The longer the inserted length, the larger the buckling capacity.

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REFERENCES

Ao Hong-Fei and Li Guo-Qiang. 2004. Investigation of overall load-bearing stability capacity of tube-and-coupler scaffolds, *Chinese Quart. Mech.*, 25: 213-218 [in Chinese].

Chan, S.L., Zhou, Z.H., Chen, W.F., Peng, J.L. and Pan, A.D. 1995. Stability analysis of semi-rigid steel scaffolding, *Eng. Struct.*, 17: 568-574.

Godley, M.H.R. and Beale, R.G. 1997. Sway stiffness of scaffold structures, *Struct. Eng.*, 75 (1): 4-12.

Hongbo Liu, Qiuhong Zhao, Xiaodun Wang, Ting Zhou, Dong Wang, Jie Liu and Zhihua Chen. 2010. Experimental and analytical studies on the stability of structural steel tube and coupler scaffolds without X-bracing, *Engineering Structures*, 32 (4): 1003-1015.

Jack C. McCormac. 2008. Structural steel design, 4th edition, Prentice Hall.

Milojkovic, B., Beale, R.G. and Godley, M.H.R. Determination of the factors of safety of standard scaffold structures. In: Proceedings of international conference on advances in steel structures, (1): 303-310.

Peng, J.L., Pan, A.D., Rosowsky, D.V., Chen, W.F., Yen, T. and Chan, S.L. 1996. High clearance scaffold systems during construction-1: Structural modeling and modes of failure, *Eng. Struct.*, 18: 247-257.

Peng, J.L., Pan, A.D., Rosowsky, D.V., Chen, W.F., Yen, T. and Chan, S.L. 1996. High clearance scaffold systems during construction-2: Structural analysis and development of design guidelines, *Eng. Struct.*, 18: 258-267.

Peng, J.L., Pan, A.D.E. and Chan, S.L. 1998. Simplified models for analysis and design of modular falsework, *J. Constr. Steel. Res.*, 48: 189-209.

Peng, J.L., Pan, A.D.E. and Chen, W.F. 2001. Approximate analysis method for modular tubular falsework, *ASCE J. Struct. Eng.*, 127: 256-263.

Peng, J.L., Pan, A.D.E., Chen, W.F., Yen, T. and Chan, S.L. 1997. Structural modeling and analysis of modular falsework systems, *ASCE J. Struct. Eng.*, 123: 1245-1251.

Vaux, S., Wong, C. and Hancock, G. 2002. Sway stability of steel scaffolding and formwork systems. In: Proceedings of international conference on advances in steel structures, 1: 311-319.

Weesner, L.B. and Jones, H.L. 2001. Experimental and analytical capacity of frame scaffolding, *Eng. Struct.*, 23: 592-599.

Yu, W.K., Chung, K.F. and Chan, S.L. 2004. Structural instability of multi-storey door-type modular steel scaffolds, *Eng. Struct.*, 26: 867-881.

Yue, F., Yuan, Y., Li, G.Q., Ye, K.M., Chen, Zh.M. and Wang, Zh.P. 2005. Wind load on integral-lift scaffolds for tall buildings, *ASCE J. Struct. Eng.*, 131: 816-824.