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The Float Scaffold

By Peter J. Poczynok, P.E.* and Ralph L. Barnett**

ABSTRACT

Unstable work platforms compromise the ability of workers to adjust their bodies to quickly react against the forces generated at their tool/workpiece interfaces. This paper focuses on the flexibility of work platforms with emphasis on the classical float scaffold used by iron workers. The ability to prestress the float gives rise to superior stiffness characteristics.

INTRODUCTION

Figure 1 illustrates a typical float in one of its many rigging configurations. Workers standing on the float with their tools and supplies create a vertical force W which includes the self weight of the float. Activities, such as drilling into a vertical surface, cause a horizontal force F to be applied to the deck as indicated in the end elevation shown in Figure 2.

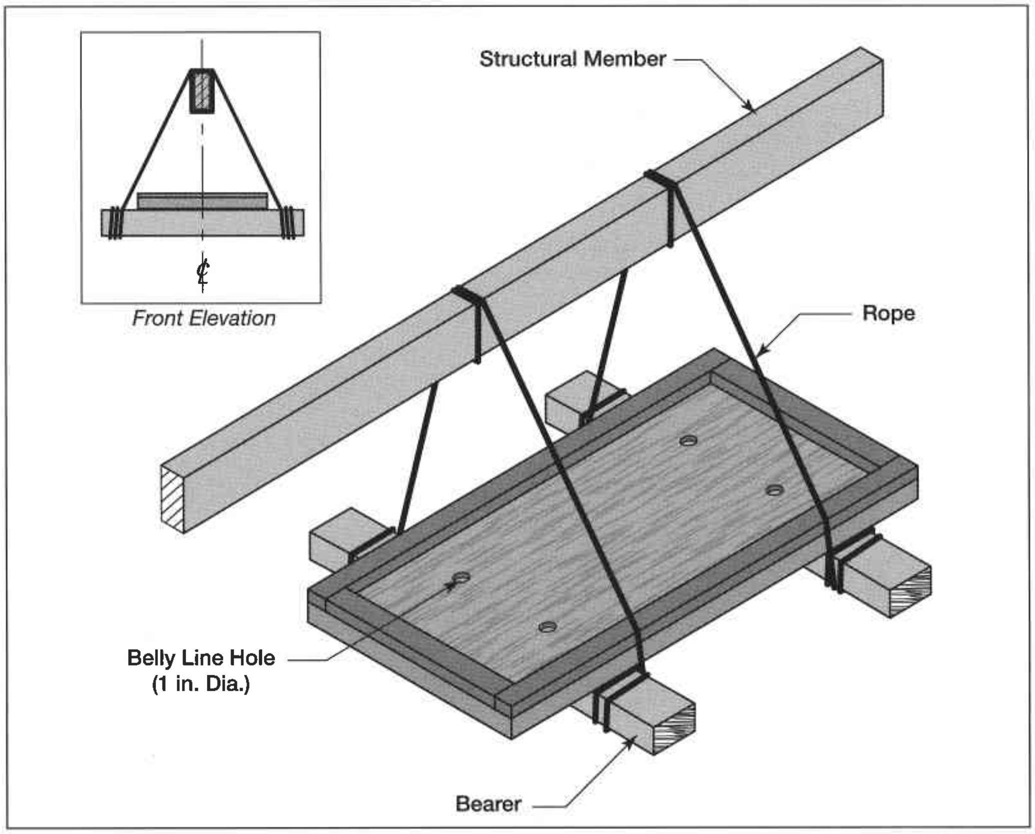

Figure 1 – Typical Float Scaffold

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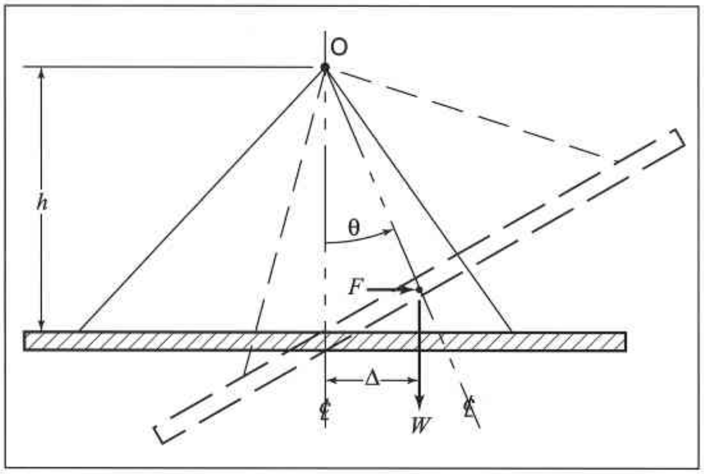


Figure 2 – End Elevation of a Rotated Float

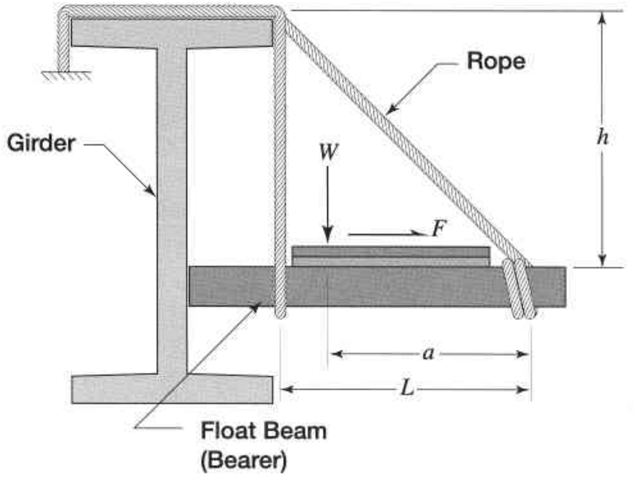


Figure 3a – Truss Type Rigging

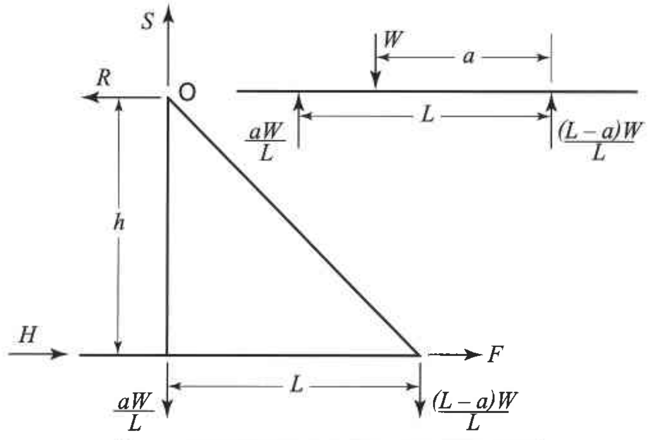


Figure 3b – Free Body Diagrams

Figure 3 – Float with Truss Type Rigging

Under a lateral force F the float will rotate about its suspension axis just like a porch swing. It will undergo a deflection Δ in the same direction as F.

If the sideways force F is plotted against the corresponding deflection Δ, the slope of the resulting force-deflection curve is defined as the stiffness, i.e., the relationship between force and deflection. In particular, the slope near the origin is significant because the first few inches of side shift may dramatically affect the worker's balance and resistance. The lateral stiffness of a work platform may be thought of as the side force required to shift the platform one inch.

For a float subjected to a symmetrical downward load distribution, the mathematical model based on Figure 2 provides an expression for F when the moment of forces is taken about point zero and when the relationship, $\Delta = h\sin\theta$, is used for simplification; thus,

$$F(\Delta) = \frac{W}{\sqrt{\left(h/\Delta\right)^2 - 1}} \approx \frac{W\Delta}{h} \qquad \textit{Equation 1}$$

The derivative of F(Δ) provides the required stiffness,

$$\text{Stiffness} = \frac{dF(\Delta)}{d(\Delta)} \doteq \frac{W}{h} \qquad \textit{Equation 2}$$

When $W = 267$ lbs and $h = 32$ in., the stiffness becomes 267/32 = 8.34 lbs/in. Thus, a side shift of three inches requires only 3(8.34) = 25.02 lbs of side force which is easily generated by a worker when drilling or riveting. This low value of stiffness for the float shown in Figure 1 is consistent with one's intuition and experience. It will be shown that a slight change in the float's rigging will lead to a radical increase in its stiffness.

PRESTRESSED FLOATS

Consider the truss type rigging of the float shown in Figure 3a. The float's reactions to the resultant vertical load W are illustrated in the free body diagrams in Figure 3b; they act at the nodes of the truss formed by the rigging lines. The load F shown in Figure 3 is, once again, taken as the horizontal reaction developed by a worker on the float. Referring to the free body diagram of the truss, the reaction H may be established by taking moments about the point O; thus,

$$H = \frac{W(L-a)}{h} - F \qquad \textit{Equation 3}$$

The first term in this expression, $W(L-a)/h$, is a prestressing force. It derives from the gravity load W in much the same way that gravity preloads a masonry arch. As long as H is greater than zero the wooden float beams (bearers) will stay in contact with the web of the girder. This contact implies through Equation 3 that,

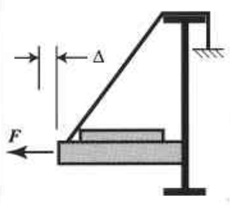
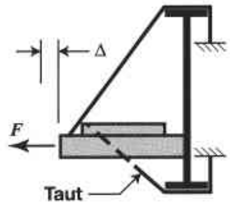
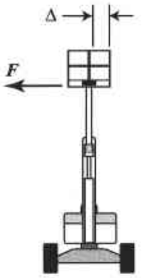
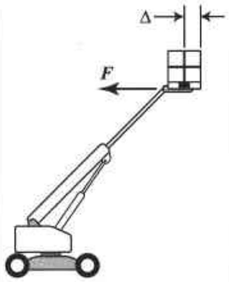
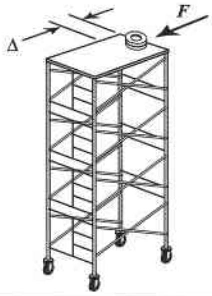
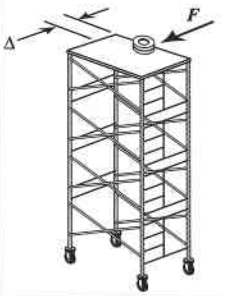
$$F < \frac{W(L-a)}{h} \qquad \textit{Equation 4}$$

Using $W = 267$ lbs, $L = 36$ in., $a = 24$ in. And $h = 32$ in., Equation 3 becomes

$$F < \frac{267(36-24)}{32} = 100.1\ lbs$$

As long as F does not exceed the prestressing load, 100.1 lbs, the float is practically rigid in the horizontal direction. When F is greater than the preload, the float bearers separate from the web of the girder and the float behaves as a free swinging unit such as that shown in Figure 1.

Table I – Load-Deflection Measurements

											
Δ	*F*	Δ	*F*	Δ	*F*	Δ	*F*	Δ	*F*	Δ	*F*
0	10	0.001	10	1.0	40	0.5	96	0.50	43.7	0.10	2.82
0	20	0.001	20	2.0	71	1.0	177	1.01	66.8	0.30	32.47
0	30	0.001	30	3.0	94	1.5	291	1.51	109.6	0.40	43.42
0.001	40	0.001	40	4.0	109			2.01	132.7	0.50	50.15
0.002	50	0.001	50	5.0	139			2.52	138.9	1.00	68.58
0.002	60	0.001	60	6.0	170			3.07	143.5	1.50	82.52
0.002	70	0.001	70	7.0	194			3.51	146.4	2.00	95.10
0.003	80	0.001	80	8.0	231			4.07	150.0	2.51	96.88
0.015	90	0.001	90	9.0	269			5.08	154.1	3.00	95.92
0.040	100	0.001	100	10.0	302			6.03	155.1	3.50	98.04
0.750	110	0.005	110					7.02	154.9	4.01	97.56
1.500	120	0.010	120					8.05	153.8	5.01	95.47
2.250	130	0.020	130					9.09	153.5	6.01	90.80
3.000	140	0.030	140					10.02	151.7	7.00	86.38
3.625	150	0.040	150					11.07	149.4	8.01	87.82
4.625	160	0.050	160					12.01	148.1	9.00	87.51
5.500	170	0.058	170					13.03	146.3	10.01	83.74
6.250	180	0.069	180					14.01	145.0	11.01	79.71
7.125	190	0.080	190					15.06	143.3	12.02	76.08
7.750	200	0.098	200					16.09	140.1	13.02	74.54
								17.09	135.9	14.00	73.21
								18.09	132.2	15.02	72.05
								19.06	131.0	16.03	69.92
										17.01	67.50
										18.02	65.99
										19.03	63.71
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)

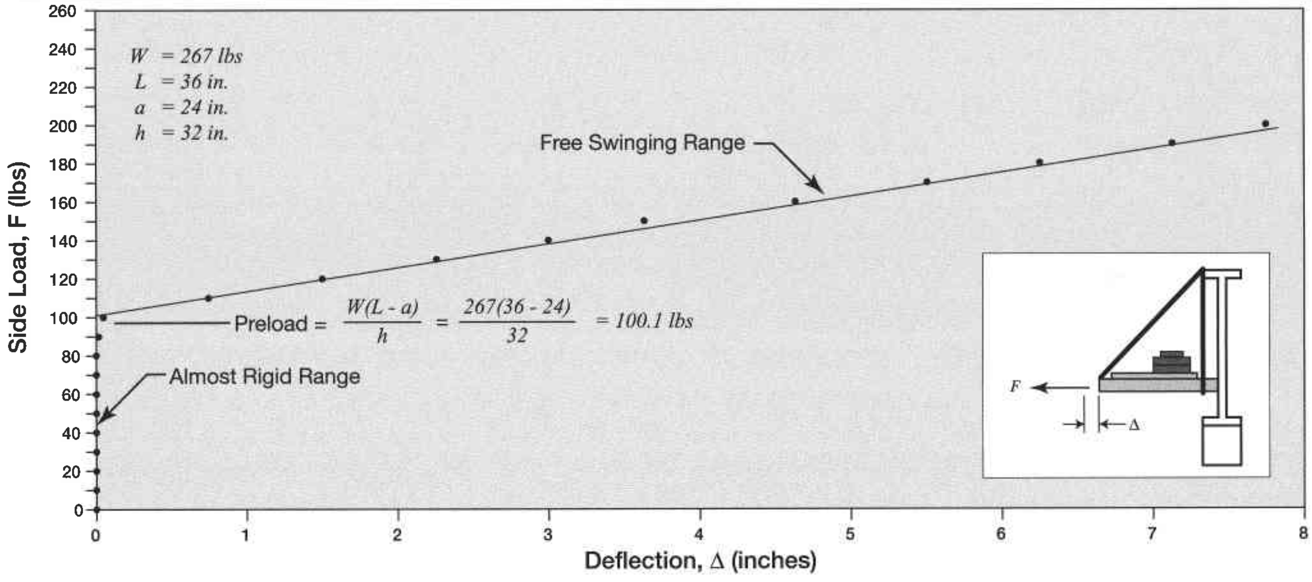


Figure 4 – Load-Deflection Diagram: Truss-Rigged Float Scaffold

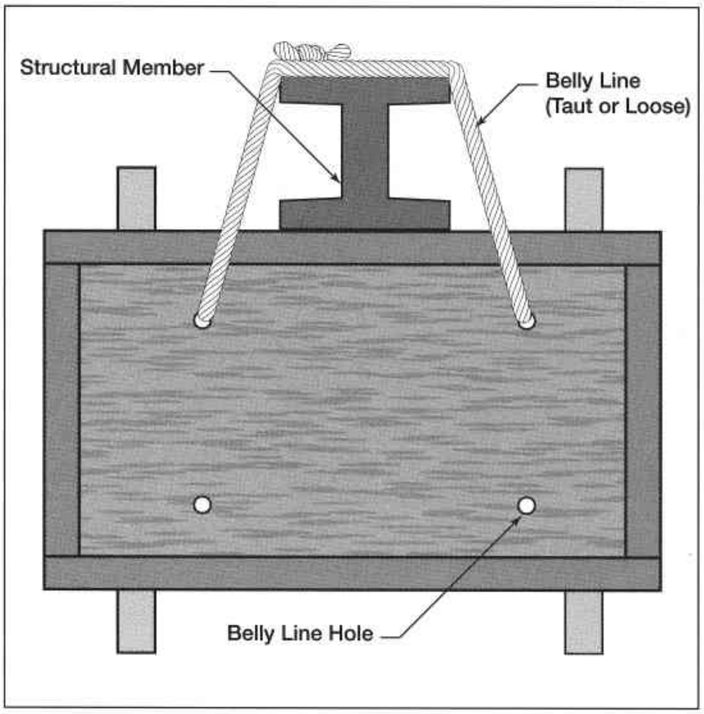


Figure 5 – Typical Belly Line Rigging - Plan View

Tests were conducted on the truss-rigged float scaffold shown in Figure 3a. Measuring the horizontal deflection Δ of the float platform in the direction of the horizontal force F, load-deflection data were collected and tabulated in Table I, Columns 1 and 2. These data were used to construct the load-deflection diagram in Figure 4. The results of the testing confirm the theoretical predictions; almost rigid behavior below the preload and very low stiffness in the free swinging range above the preload. Observe in Figure 4 that after F achieves 100 lbs, an additional 13 lbs produces a one inch deflection. This is comparable to the scaffold depicted in Figure 1 with a stiffness F/Δ = 8.34 lbs/in.

When workers generate horizontal loads greater than the gravity preload, the float moves into the free swinging range where excessive sway may be experienced. Iron workers often limit the magnitude of this sway through the use of belly lines as illustrated in Figure 5 with the normal rigging removed for clarity. Quoting from an iron worker's manual (Ref. A), "there are four 1" holes in the float platform which are referred to as 'belly line' holes. A separate 3/4" or 7/8" line (belly line) will pass through one hole around the steel structure and back through the other hole and be tied off. This will prevent the float from excessively swaying or drifting."

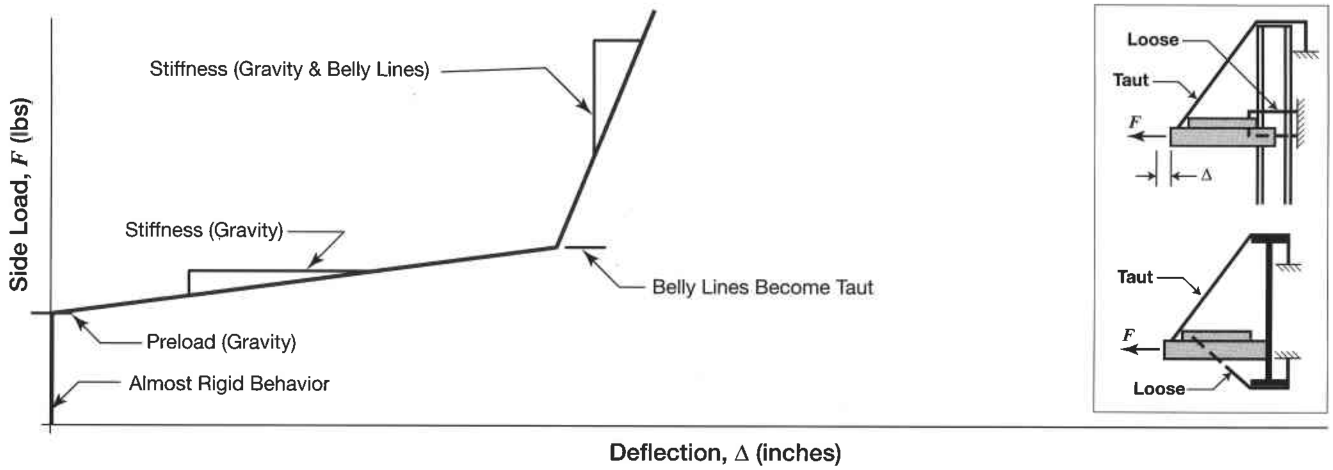


Figure 6a – Loosely Tethered Belly Lines

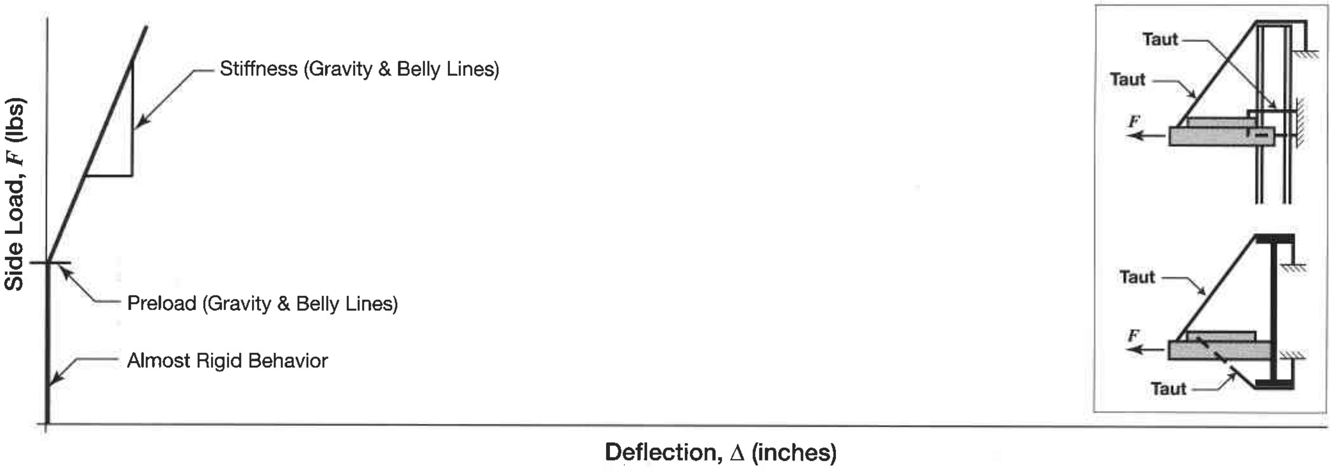


Figure 6b – Tightly Cinched Belly Lines

Figure 6 – Truss-Rigged Float Stiffness with Belly Lines

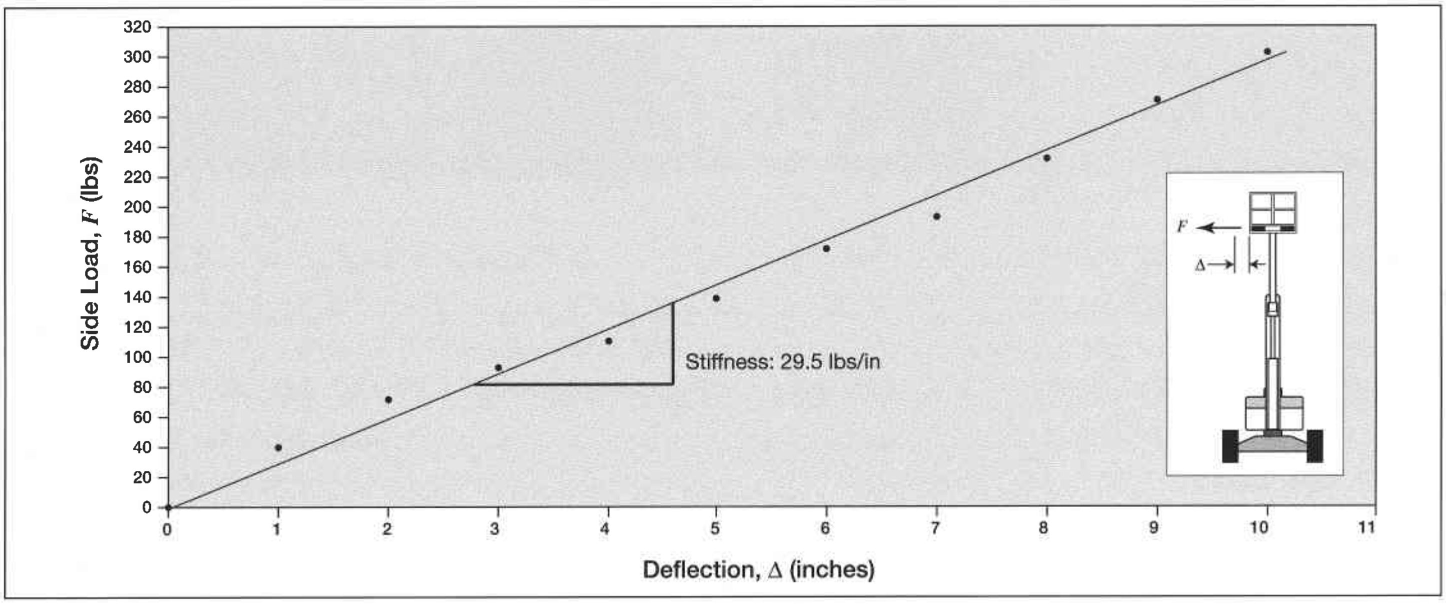


Figure 7 – Load-Deflection Diagram: Manlift/Lateral Direction

The prescription for rigging belly lines initially produces either a loose or a taut tether. If it's loose, the load-deflection diagram will resemble the curve shown in Figure 4 up to the point where continued side loading F brings the belly lines to the end of their tether. Then, the stiffness of the belly lines kicks in and the load-deflection diagrams assume the generic form depicted in Figure 6a. When the belly lines are active (taut) their stiffness is very high; this is reflected by the large slope on the right side of the load-deflection diagram in Figure 6a. At the front end of the curve (left side) the float is almost rigid until the gravity preload is exceeded. Between these two high stiffness extremes we find the free swinging region where the float is generally unstable; the platform shifts easily underfoot.

A preload P can be introduced into the float by tensioning the belly lines by cinching them tight. This adds to the gravity preload, $W(L\text{-}a)/h$; the side load F must overcome both preloads to separate the float from the supporting structure. As a consequence, almost rigid behavior is experienced whenever,

$$F < \frac{W(L-a)}{h} + P \qquad \text{Equation 5}$$

When F exceeds the total preload, the belly lines are already active and no free swinging phase is encountered. The combined gravity and belly line stiffness is achieved immediately after float separation and the associated generic load-deflection diagram is shown in Figure 6b.

Load-deflection data were obtained for the truss rigged float illustrated in Figure 3a where taut belly lines were added in accordance with the schematic profile shown in the lower insert in Figure 6b. The data are tabulated in Columns 3 and 4 in Table I where the recorded deflection at $F = 200$ lbs is only 0.098 inches. This may be compared to the float without the preloaded belly lines in Column 1 where the equivalent deflection is 7.75 inches. Clearly, the "almost rigid behavior range" is over twice as large when preloaded belly lines are used.

WORK PLATFORMS

Iron workers engaged in critical activities that are physically demanding require stable work platforms to minimize injuries to their muscular/skeletal systems. The available work platforms, of which there are many, are not rated for their stability or stiffness characteristics; only load capacity and reach are specified. The stability of two commonly used platforms, the tubular steel scaffold and a telescoping manlift, were evaluated and compared to the float scaffold. For each candidate the test loading was a 160 lbs dead weight supported at an elevation of 20 feet.

Telescoping Manlift

A Marklift Model 30 was subjected to a horizontal load F in either the lateral or longitudinal direction. At each load level the resulting horizontal deflection Δ of the platform was measured in the direction of F. The resulting load-deflection data are tabulated in Table I, Columns 5 and 6 and in Columns 7 and 8, respectively, for the lateral and longitudinal loading. The corresponding load-deflection diagrams are given in Figures 7 and 8. The curves are both linear and their slopes or stiffnesses are 29.5 lbs/in. in the lateral direction and 187.5 lbs/in. in the longitudinal direction.

Tubular Steel Scaffold

Using the same test protocol described for the manlift, load-deflection tests were conducted on a free standing, four frame, 20 foot high tubular steel scaffold. The scaffold was tested in the long and short directions and in each case the 160 lbs dead weight was located at the edge of the platform opposite the loading direction. This position maximizes the scaffolds' overturning resistance. Once again, the associated load-deflection data for the long and short directions are displayed in Table I, Columns 9 and 10 and in Columns 11 and 12, respectively. The associated load-deflection curves are shown in Figures 9 and 10.

The stiffness of the tubular scaffold is provided by the initial slope of the load-deflection curve. In the long direction, the stiffness is 73.3 lbs/in.; in the short direction , it is

Figure 8 – Load Deflection Diagram: Manlift/Longitudinal Direction

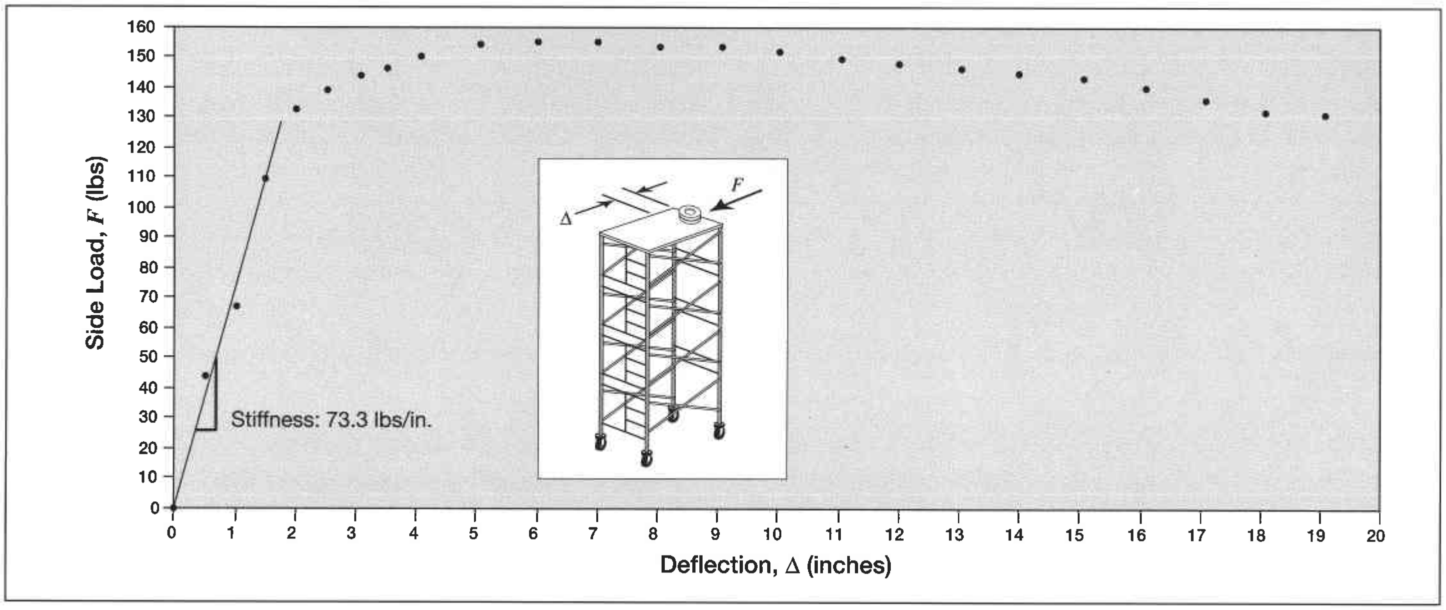


Figure 9 – Load Deflection Diagram: Tubular Scaffold/Long Direction

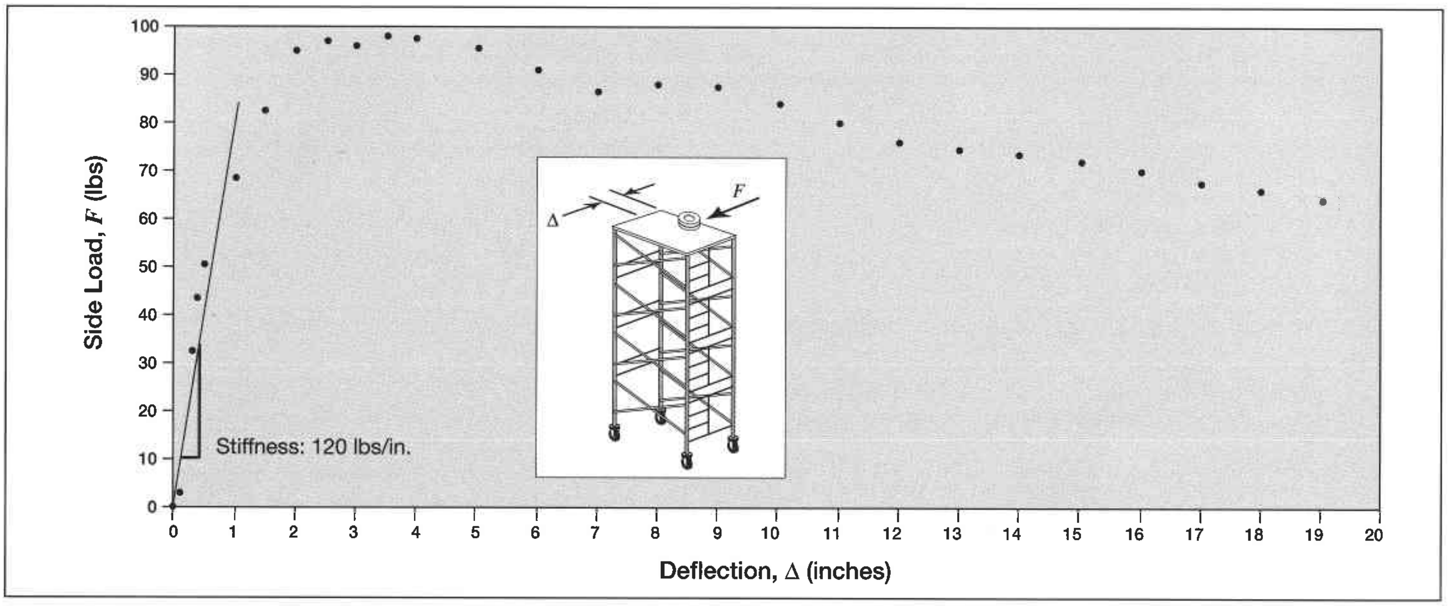


Figure 10 – Load Deflection Diagram: Tubular Scaffold/Short Direction

120 lbs/in. Both load-deflection curves peak and then assume a negative slope; this is caused by the rigid body tipping of the scaffold.

CONCLUSIONS AND OBSERVATIONS

1. The various work platforms studied in this paper are ranked in Table II in order of their increasing stiffness. The truss rigged floats, with or without pretensioned belly lines, are clearly superior to the other candidate platforms. They are practically rigid under foreseeable side loadings.

2. Floats with swing type rigging, according to Equation 1, exhibit a linear load-deflection curve. Their stiffness is far too low for them to be used in stiffness critical applications.

3. For floats with truss-type rigging, pretensioned belly lines are very effective for extending the range where "almost rigid behavior" is experienced.

4. The stiffness of the manlift platform is strongly dependent on the flexibility of its cantilevered telescoping boom. The deflection of this bending member is proportional to the cube of its height. Recall that our tests were all conducted using a platform elevation of 20 feet.

5. The flexibility of tubular scaffolds is attributable primarily to shear deformation. As a consequence, the platform deflection is proportional to the scaffold height.

6. The stiffness of the float scaffold is independent of its elevation.

Table II – Stiffness Ranking: Various Work Platforms

Description: Work Platform	**Defining Figure**	**Stiffness (Initial Slope)**
Typical Swing Float	Figure 1	8.34 lbs./in.
Manlift – Lateral Direction	Figure 7	29.5 lbs./in.
Tubular Scaffold – Long Direction	Figure 9	73.3 lbs./in.
Tubular Scaffold – Short Direction	Figure 10	120.0 lbs./in.
Manlift – Longitudinal Direction	Figure 8	187.5 lbs./in.
Truss Rigged Float	Figure 3a	Rigid
Truss Rigged Float With Taut Belly Lines	Figure 6b	Rigid

7. The stiffness of floats with swing type rigging can be seen from Equation 2 to increase proportionally as the resultant downward load W increases.

8. For truss rigged floats without belly lines, the gravity preload is proportional to W. It follows that the range of "almost rigid behavior" increases in proportion to W.

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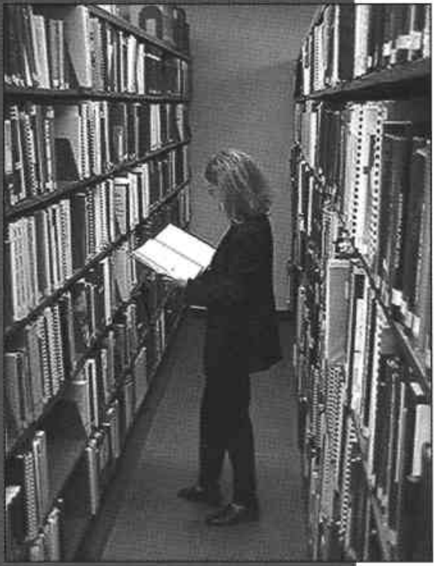

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