SKY LIFT ROOF RISER HARDWARE
Testing of Skylift and shade-sails hardware: Tipping, Uplift, and Hook Strength

Submitted by

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INTRODUCTION

Performance of shade sail (SS) posts and SkyLift (SL) risers posts were evaluated under lateral and uplift loads. Moreover, the connection strength of the shackle used to connect the sails to the post was also evaluated.

MATERIALS

Three sets of rising fixtures were received for testing along with hardware that will attach the shade sails to the hardware. The two different rising fixtures' details are as follows:

- Custom designed post for the SkyLift roof systems of length 24" (Product code: SK24B) that sits on the top plate of the wall and is attached using 4 proprietary fasteners. In the report this will be designated as SL.
- Custom Designed post for shade sails, which also sits on the top plate but is connected using 8 proprietary fasteners. The risers were of two different length - 18" and 24" – from here onwards referred to as SS1 and SS2, respectively.
- Connections to connect sails to the SS posts were also tested in the form of shackles.

No. 2, 2x6 dimension lumber of Douglas-Fir Larch (DFL) species was procured from a local supplier for testing purposes. During testing it was important to simulate realistic conditions that would occur in the field during testing. As a result, for each test 2 pieces of 2x6 material was nailed together and clamped or anchored to the testing machine base to simulate a top plate.

TESTING

Four things were of prime interest and as a result the testing plan was designed to test for the properties of interests. These properties were:

1. Tipping of SS1 and SS2 in both the possible directions that is, along the long base and along the short base.
2. Testing of the shackle ring hardware that would connect the sails to the risers.
3. Tipping of SL.
4. Uplift of SL.

All tests were conducted on a Universal Testing Machine equipped with a 36 kip (160 kN) actuator (MTS 244.41) and 25 kip (110 kN) load cell. The hydraulic actuator operated load head has a static stroke of 10 inches. The machine is operated using a data acquisition system that operates LabView software which logs load and displacement data to plot a load deflection diagram.

Tipping test. The tipping test along long axis is shown in Fig. 1a, while along short axis is shown in Fig. 1b. The test set up consisted of double stud top plate clamped to a metal frame to replicate the boundary conditions in the field. The post was connected at the base plate to the double top plate using the provided fasteners. The load head applied a tipping load near the top end of the riser at a rate of 0.5 in/ minute. The test was continued until a visible failure was noticed and the load went past the maximum and dropped to at least 80% of the maximum load. Six samples each of SS1 and SS2 was tested in both directions, i.e., a total of 24 tipping tests were conducted.

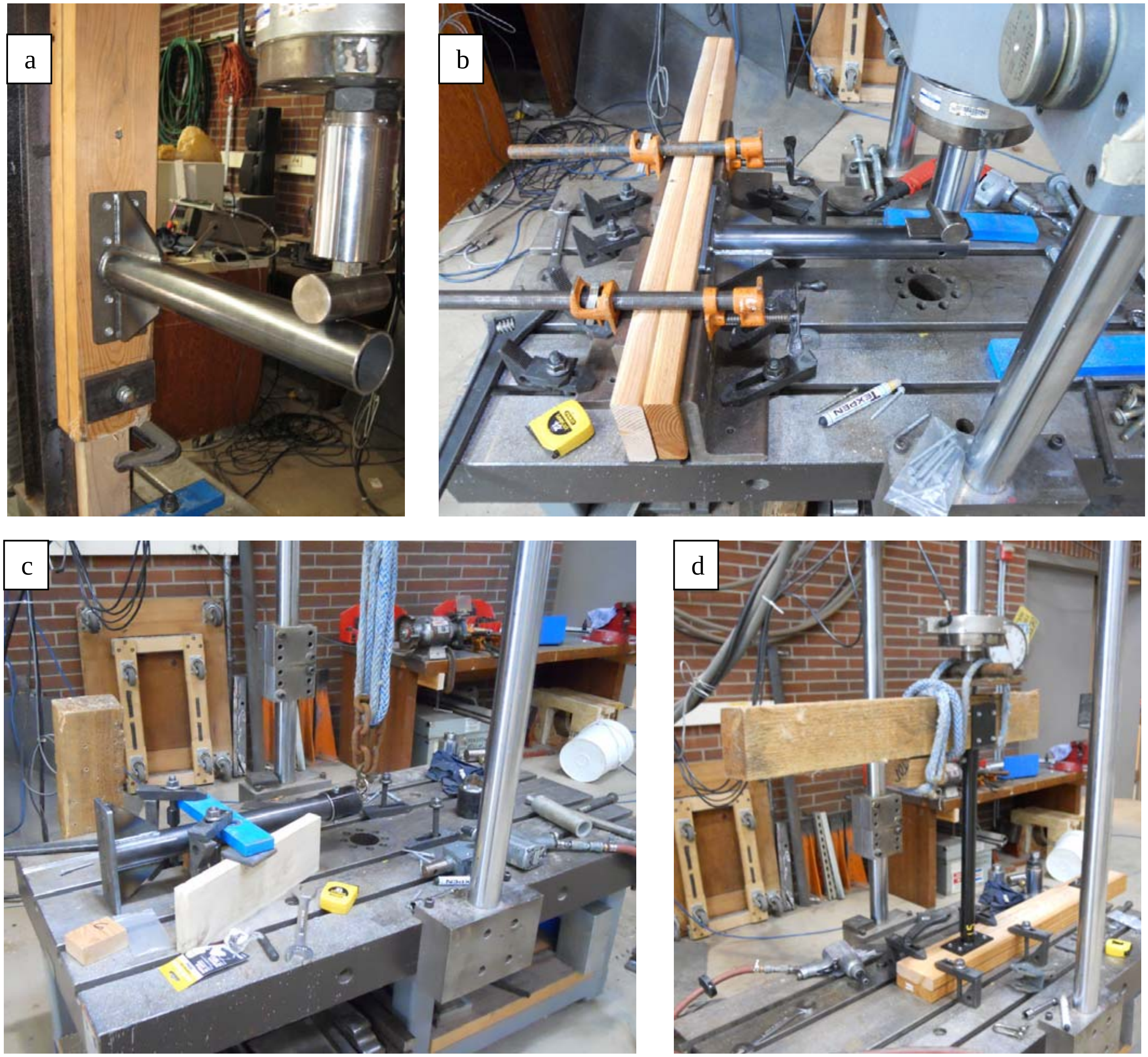

Fig.1 Test Set ups. (a) Long base tipping for shade sail posts; (b) short base tipping for shadesail posts; (c) Shackles (shade sails connector) test set up; (d) SkyLift post uplift test set up.

T**esting of connecting hardware:** The shackles and eye hook was tested to see the failure load of the ring connector. The test set-up is shown in Fig.1c. A SS post was clamped to the metal base of the testing frame with the shackle hardware connected to it using the standard pin arrangement. The shackle was then pulled upon until failure at a rate of 0.5 in/ min. As the connection arrangement through which the shackle pin could be inserted had three holes at 120 degrees apart. This gave rise to 2 different loading arrangements – (a) pin and the shackle are in axis with the loading head, and (b) pin and shackle are off-axis with loading head. In addition, an eye bolt was also tested.

Uplift Test: The test set up for the uplift test for SL is shown in Fig. 1d. The test set up is similar where the post is connected to a double top plate, which is clamped to the metal base. The complete post setup was assembled which means it was fitted using a bolt, with a holder for the cross-beam, which essentially is 4 by as shown in the Fig. 1c. A 4 by material is connected to the SkyLift set up using 4 lag screws to act as the cross-beam. The crossed beam is then attached to the load head and is pulled up creating an uplift force on the SL post. The loading speed was similar to that of tipping test. Six posts were tested for uplift. Moreover, 6 tipping tests along short base axis was also conducted for SL posts.

RESULTS AND DISCUSSIONS

Shade Sails Tipping Tests

A typical load deflection curve is shown in Fig. 2 for tipping of the SS post along long base axis. The test results are summarized in Table 1. Tipping along the long base produced higher loads as expected for both SS1 and SS2. The tipping load for the SS2 (24”) were lower than the tipping loads for SS1. As the moment arms were same for both the load cases, it took higher moment to tip the SS1 set up as compared to SS2. These differences in loads were not statistically significant. As a result, comparative conclusions regarding the performance of SS1 or SS2 in long base tipping cannot be drawn. It however, seems both SS1 and SS2 in the long axis tipping performed more than adequately in terms of resisting realistic tipping loads. On the other hand, for short base tipping a statistically significant difference ($p = 0.02$) was observed in the performances of SS1 and SS2. The predominant mode of failure was pull out of the fasteners connecting base plate to the wall top plate. A slight bent in a few of the SS2 were observed. The failure pictures are attached in Appendix.

Table 1. Failure loads (lbs) of SS posts along with average, standard deviation and Coefficient of variation (%) for long base and short base tipping.

	Long Base axis		Short Base Axis	
No.	SS1 (18")	SS2 (24")	SS1 (18")	SS2 (24")
1	3638	2720	1090	842
2	3632	2869	1101	778
3	2828	2800	1207	1066
4	3539	2577	935	963
5	3125	3531	1388	1077
6	3208	3528	1195	958
AVERAGE	3328	3004	1153	947
STDEV	328	418	151	119
COV (%)	9.86	13.93	13.11	12.58

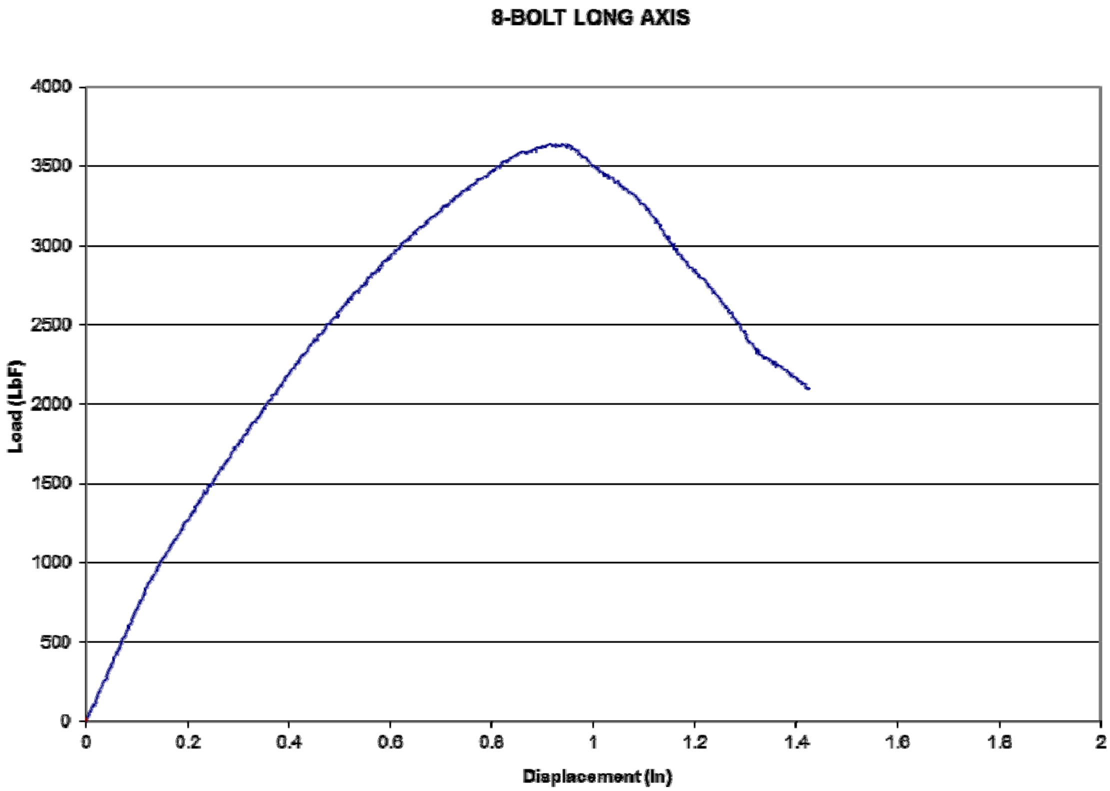

Fig.2 Typical load deflection diagram for tipping loads on SS post along the long base axis.

Eye ring and shackles connector: Two different types of connectors were tested. One test of the eye bolt revealed it was not adequate for holding the sails. Although it failed when the hook fractured at 2000 lbs, it is not advisable to use these to connect to shade sails. Other type of connections was shackles, which were either tested in axis with the connector or off axis. When the shackles were tested in axis, the predominant mode of failure was pulled shackle pin through the hole, with an average load of 7285 lbs, which is much higher than the rated load of the shackles. When tested off axis the shackles failed at 7600 lbs. The predominant mode of failure was yielding of shackle. Interestingly, if pin was pointed towards the bottom, the shackles performed better. More tests of the shackles are needed, however, to gain any statistical significance and compare the results between in axis and off-axis connections.

Given the failure load, regardless of the axis, for the shackles were a few magnitudes higher than the tipping load for the posts. It is assumed that if everything is installed and detailed properly, the shackle connections will not be performance limiting component of the shade sail riser posts.

A shade sail is presumably designed by manufacturers to withstand 2000 lbs of force (shadesails.com/FAQ), which is evenly distributed in three or four posts to which the sails attach. As a result, each post will experience a tipping load of around 700 lbs, which is significantly less than the tipping loads of SS1 or SS2 in either direction. It appears that the current connection practices will withstand a high speed wind exerting a load of 2000 lbs or less on the sails, if all other specifications are met. In these scenarios, the sail shall fail earlier than the posts.

Testing of SkyLift post in tipping and uplift.

Uplift will be a major concern for the SL posts. The uplift as tested was on an average 5437 lbs. Details are presented in Table 2. This value is higher than the maximum allowable load as per the design sheets provided. The failure mode was pull out of the fasteners from the top plate of the wall, which was expected. There was slight bent observed in the cross beam holder during the test, which is a result of huge amount of load transfer that is taking place through that holder during testing for uplift.

The average tipping load for SL posts were about 508 lbs along the short base axis. Only short base axis was tested as this would be the limiting condition. While testing, the SL posts experienced significant bents and as a result long base axis tipping wasn't possible on the same samples. Prior experience has shown that long base axis yields higher values for tipping loads.

Table 2. Tipping l and uplift loads for SkyLift posts along with their averages and standard deviation.

test ID	Tipping Load (lbs)	Tipping Deflection (in)	Uplift (lbs)
13	549	1.3	6100
14	526	1.5	4553
15	499	1.4	5480
16	560	2.2	5614
17	396	1.6	5861
18	519	2.1	5012
Average	**508**		**5437**
StDev	59		568

Conclusions:

The testing for the Skylift posts (SK24B) and Shade sails posts and shackle connections were conducted and their performance was evaluated. Both SL (SK24B) and SS (1 and 2) performed expectedly and adequately in tipping loads. The predominant failure mode was pulling out of the fastener connecting the base plate and the top plate of the wall. The shackles connecting the shade sails and posts performed adequately and failed in shackle yielding and pulled pin. The uplift for the SL posts exceeded the designed value and failure observations revealed pull out of the base plate – top plate fasteners.

Reference:

Shadesail.com/FAQ.html – shade sail pull test value. Accessed on October 2, 2012.

Appendix: Picture of observed failure mode