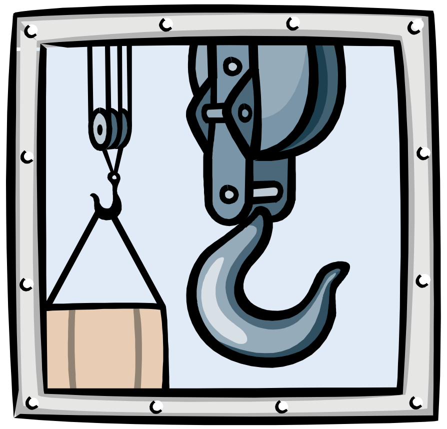

Pulleys Used to Ensure Known Applied Load & Even Load Distribution

by SBCRI staff

In the November issue, we updated you on the new WB4 device in SBCRI, which is helping us evaluate and systematize BCSI temporary and permanent lateral restraint and diagonal bracing. The latest step in fine-tuning in situ truss assembly testing is ensuring that we know the load going into a given truss at a given location through a uniform distribution of applied loads. To do this, the SBCRI team turned to a very basic theoretical means of applying a uniform load across multiple trusses: the pulley.

The Problem

What's unique about SBCRI is its capacity to test full scale component assemblies. This means a given amount of force is applied to the assembly through devices called actuators, and then load cells placed at certain points in the assembly record and analyze how the trusses in the assembly react in response to those forces.

Tests performed on a five-truss assembly over the past few months made it clear that it is important to have the ability to apply load at specific points, measure what the exact applied load is at each point, and determine how that load distributes itself through web members monitored by WB4. To accomplish each of these things, the SBCRI team needed a way to apply the same load across the assembly in an accurate manner that was easy to set up. So they set out to address the challenge to ensure the most accurate load application possible. This led to the pulley load application concept.

The Approach

The team first researched previous truss tests that found a solution to the challenge at hand. A thesis written by University of British Columbia PhD student Xiaobin Song[1] addressed this very topic. The paper demonstrates tests on a single roof truss and a truss assembly (containing five trusses—similar to the assembly in SBCRI) that employed a system of pulleys to evenly distribute loads throughout the truss(es).

SBCRI staff adopted Song's pulley approach for its system of trusses. They installed a pulley system by running cable between pulleys straddling each truss in the system (photos 1 and 2). The load was applied from one side of the system (photo 1).

According to the pulley theory, with one end of the cable solidly affixed to a bearing point and the cable wrapped around two pulleys, the total load going into the system (the tension on the cable (P)) should have been twice the load being applied by the actuator (see Illustration 1 in sidebar). Four identical pulley systems were installed at joints J2, J4, J6 and J8, and load was applied at all four locations.

Photo 1.

Photo 2.

Flaws in the Theory

The first tests using the pulley fixture yielded unexpected results; they revealed a flaw in the theory Song had applied. The pulley arrangement did not allow the load to distribute evenly as the theory suggests. The friction in the cable-pulley system was too great. The tests indicated that the tension on the cable (P) was only 1.5 times the load exerted by the actuator onto the roof system. According to the theory (see inset), the cable's tension should have been twice the load applied by the actuator. After investigating the setup and test results, the team realized that the load distribution resulting from

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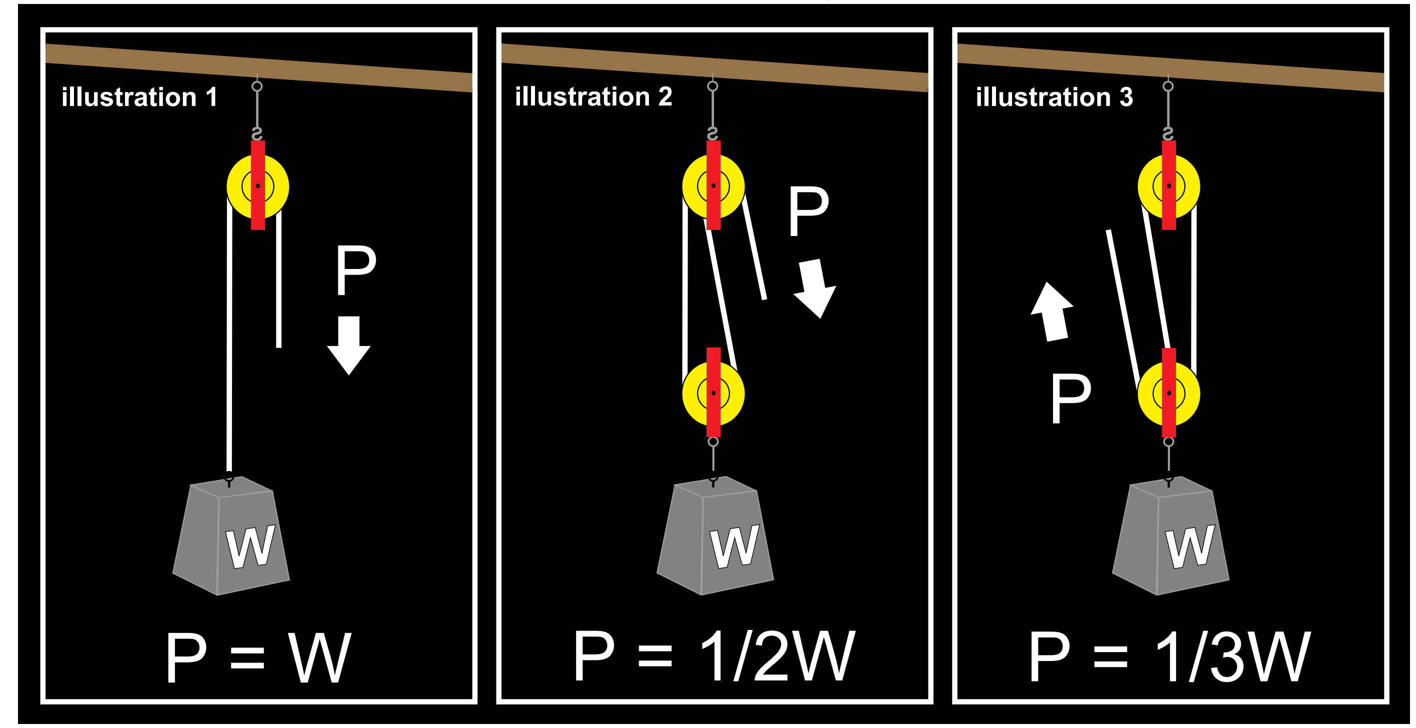
[1] Stability and Reliability Analysis of Metal Plate Connected Wood Trusses Assemblies, Xiaobin Song, Faculty of Graduate Studies (Forestry), University of British Columbia, Vancouver, March 2009.

How Do Pulleys Work?



According to basic pulley statics theory, with a simple fixed pulley (illustration 1) the tension on the rope (P) is equal to the weight of the object (W). By adding the movable pulley to the fixture (illustration 2), the tension (P) on the rope is reduced to one-half the weight. Theory further states that you reduce the tension on the rope by one-third by re-orienting the pulley/rope configuration (illustration 3).


Photo 3.


Photo 4.

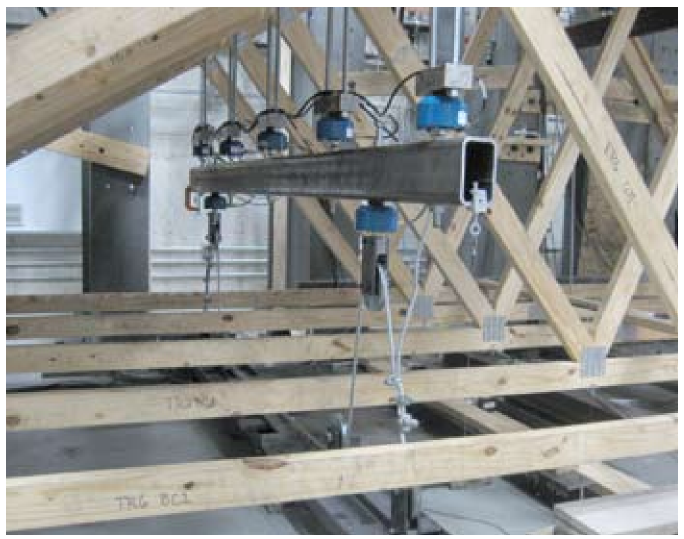


Photo 5.

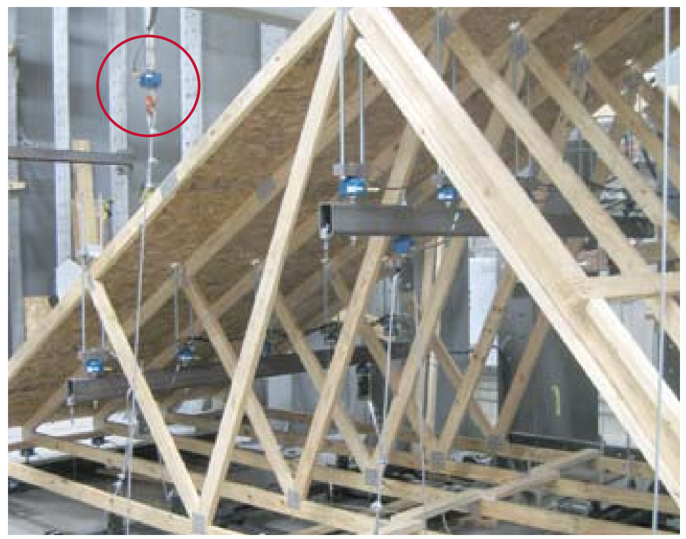


Photo 6.

Pulleys...
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the pulley and cable set-up was not going to be theoretically uniform.

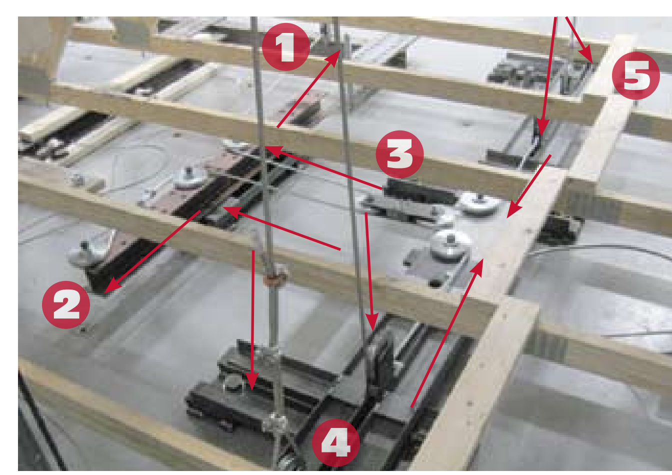
Reducing Friction. To cut down on the amount of friction between the pulleys and cable, the team reduced the number of contact points and installed a steel beam to distribute the load more evenly (photo 3). The new arrangement used a combination of fixed pulleys anchored to the floor (photo 4), and movable pulleys attached to long steel beams (photo 5).

The load or tension on the cable (P) is applied by the actuator at the upper right corner of Photo 3. The cable attached to the pulleys and steel beam is fixed at either end of the beam. Tension force is applied to both pulleys by the floor pulley attached to the cable that originates at the actuator (photo 6). Current tests are focused on evaluating this arrangement to ensure that the applied load onto each truss is accurate.

Why These Tests Are Significant. Perfecting the pulley fixture is critical to the success of future industry testing in SBCRI because it allows us to apply loads with precision and know the magnitude of the load at each applied load point. With this information we now have a defined approach to knowing loads applied to specific points on individual trusses inside the assembly *and* are beginning to understand the load paths that take place through the overall roof system.

Additionally, the pulley approach has helped us understand the differential stiffness of each truss within the system by defining the variation in the load applied at each load point. This means we can also see how the stiffness of each truss influences load distribution through the entire assembly. This system generates data that will make modeling more accurate because we know the exact load applied at specific points on each truss member or joint, the stiffness of the assembly at those load application points, and the resulting displacements emanating from specific applied loads.

While small adjustments to the pulley fixture and load application system will be ongoing, the SBCRI team is confident that this type of fixture will ultimately be the long-term solution to accurate applied load and understanding the resulting load distribution. **SBC**



This image further illustrates the path of the tension placed in the steel cable. Tension, or load, enters the system from point 1, the cable then is tied off at point 2. This tension pulls on the pulley device at point 3, which in turn pulls equally on the cable affixed at points 4 and 5.

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