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Experimental Test to Determine Cable Tension Necessary to Resist Sphere Pass-Through Requirement of International Building Code

The 2015 International Building Code (IBC) and 2015 International Residential Code (IRC) require that guardrail intermediate railings be spaced so as to prevent a 4.0 in. diameter sphere from passing through them. (IBC 1015.4/IRC R312.1.3) However, the code does not state that a load is to be applied to the 4.0 in. sphere. While the absence of that load specification is not critical to solid railing members, it may be important for wire rope railing infill, since it is flexible. Therefore, in the absence of IBC/CBC guidelines, a rational load requirement has been developed based on the following:

The 2015 IRC Section R301.5 does address a requirement for railing infill by stating that railing infill must withstand a load of 50 lb applied over a 1.0 square foot area, applied horizontally and perpendicular to the railing plane. Applying that pressure over the projected area of a 4.0 in. diameter sphere, the resulting load on the sphere is calculated as follows::

$$F = 50\ \text{lb/sq ft} \times 144\ \text{sq in/sq ft} \times \frac{\pi \times (4.0\ \text{in})^2}{4} = 4.36\ \text{lb}$$

To allow for dynamic/impact loading, a conservative safety factor of 2.0 is applied:

$F_{MAX} = 4.36 \times 2.0 = 8.72$ lb

Therefore, in the absence of a load required by code, 8.7 lb is used as the standard force applied to a 4.0 in. diameter sphere, which cable railing infill must not allow to pass in order to be IBC/IRC compliant.

The railing infill case to be tested is:

.125 in. diameter, 1x19 construction, 316 stainless steel cables

48.0 in. unsupported cable span

3.125 in. cable spacing, center to center

This represents the thinnest cable in the Vista line, hence the largest space between cables, given our standard center to center cable spacing of 3.125 in. The 48 in. cable unsupported span was chosen to be convenient for both design and installation of the railing system.

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Railing Mock-Up and Test Arrangement

A steel frame was constructed to support two tensioned cables. See Fig. 1. The cables had been tensioned to 60% of their ultimate strength prior to installation, to eliminate the possibility of any constructional stretch during testing. A calibrated load cell was anchored to one end of the frame, and one of the cables is attached to its opposite end, allowing direct measurement of the tension in that cable. See Fig. 2.

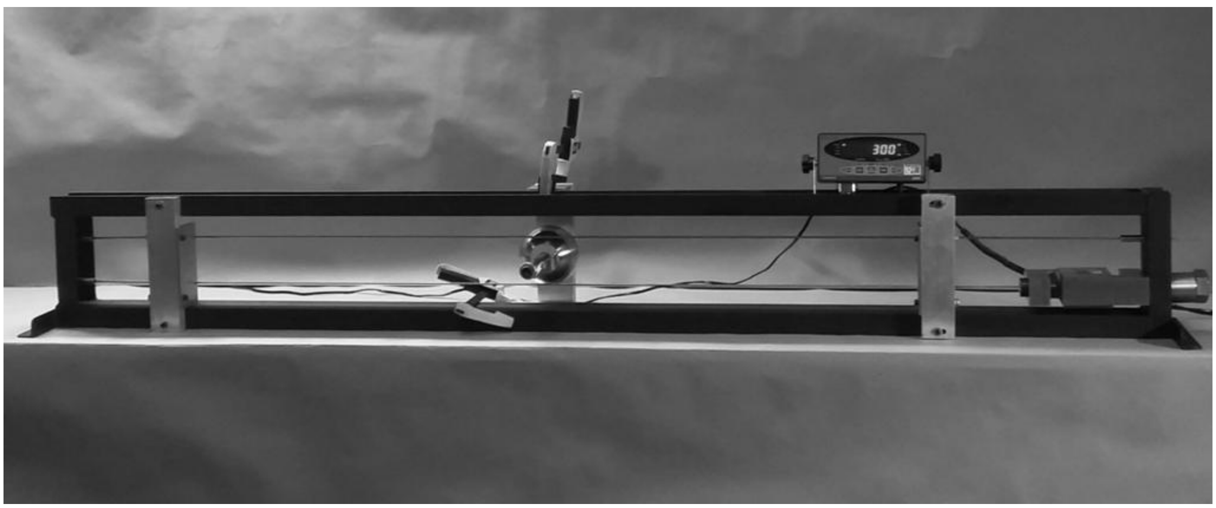

Fig. 1

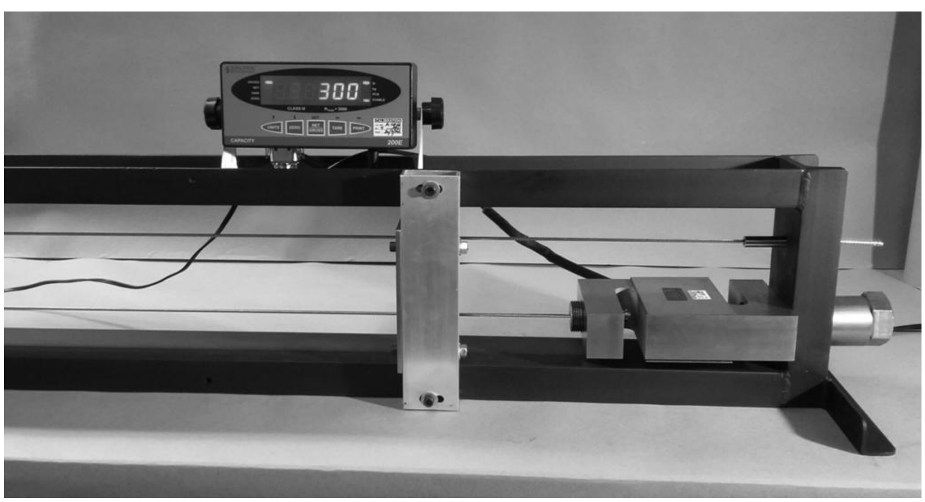

Fig. 2

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Since there was only one available load cell, a calibrated electronic tension meter was used to duplicate the tension in the second cable. See Fig. 3. Variation between the two instruments was ruled out by using the tension meter to first measure the tension in the cable attached to the load cell, and then to tension the second cable, reproducing the same reading on the tension meter as for the first cable.

Fig. 3

A fixture to support and precisely guide a 4.0 in. diameter steel sphere was built and clamped to the center of the frame. See Fig.4. The guide rod for the steel sphere was centered between the two cables and checked for perpendicularity to the plane containing the cable centerlines. The steel sphere was machined to within +/-.001 in. of its 4.0 in. diameter. Its central bore was machined to be .005 in. larger than the precision ground .750 in. diameter guide rod. As such, the sphere had no detectable play in the vertical direction, and ran smoothly on the guide rod.

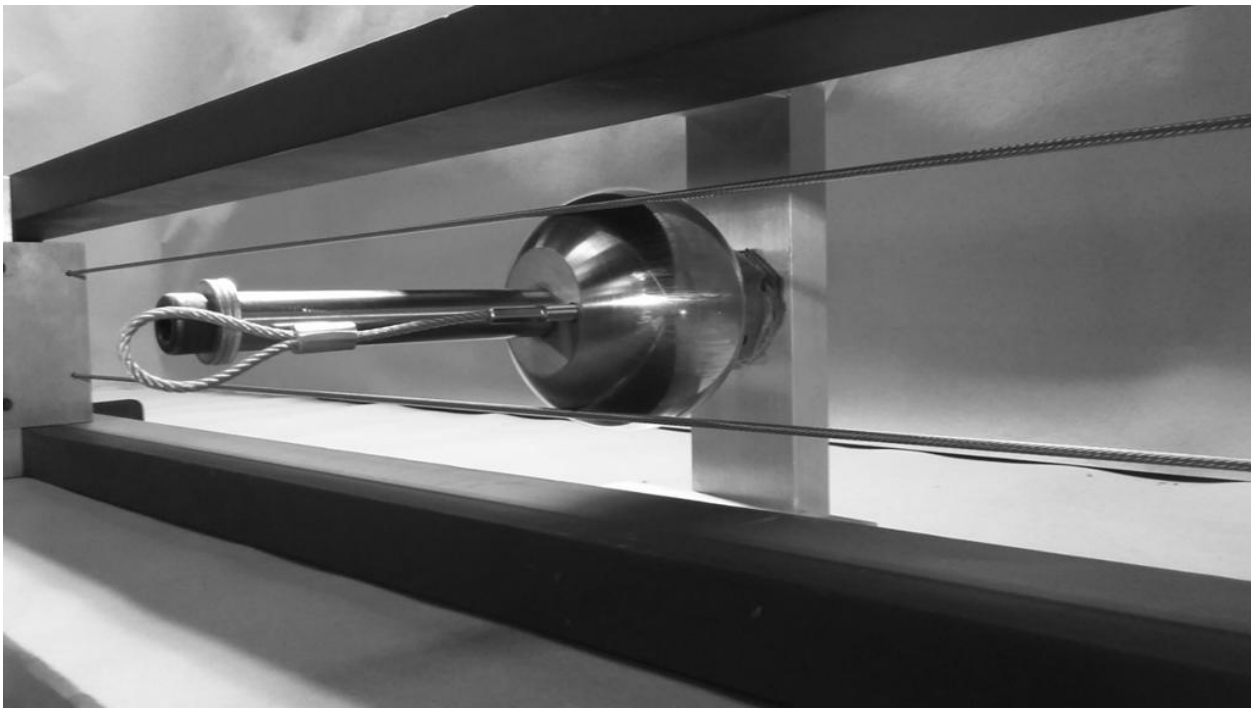

Fig. 4

A short cable with a swaged eye was threaded into the sphere. The sphere was then pulled through the two cables using a calibrated electronic handheld pull-force meter, as shown in Fig. 5 .

Fig. 5

The frame was built to be adjustable for both cable to cable spacing and cable unsupported span. The guide rod fixture was clamped to the frame rather than being permanently attached, to allow for different cable unsupported spans to be tested.

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Test Procedure

Several different combinations were tested before settling on the 3.125 in. cable to cable spacing and 48.0 in. unsupported span case.

The sphere pull-through test was performed with cable tension set at 175, 200, 225, 250, 275, and 300 lb.

For each individual trial, the force required to overcome the friction between the sphere and the guide rod was recorded as the sphere was pulled to contact the cables. The total force required to pull the sphere through the cables was then recorded, and the friction force deducted from the result.

Care was taken to move the sphere slowly, so as not to impart a dynamic load to the cables.

Care was also taken to pull the sphere with the pulling cable parallel to the guide rod. It was not considered necessary to constrain the motion of the handheld pull-force meter, since it was found to be easy to keep the pulling cable very close to parallel by eye. The cable was always held to closer than 5 degrees of parallel, which may easily be discerned by the naked eye. The error introduced by a 5 degree variance would only be .38%, which may be considered negligible.

Twenty trials were performed at each tension level, recording both the friction force on the sphere and the total pull-through force for each trial. The friction force was deducted from each total pull-through force, and the average net force of the twenty trials calculated.

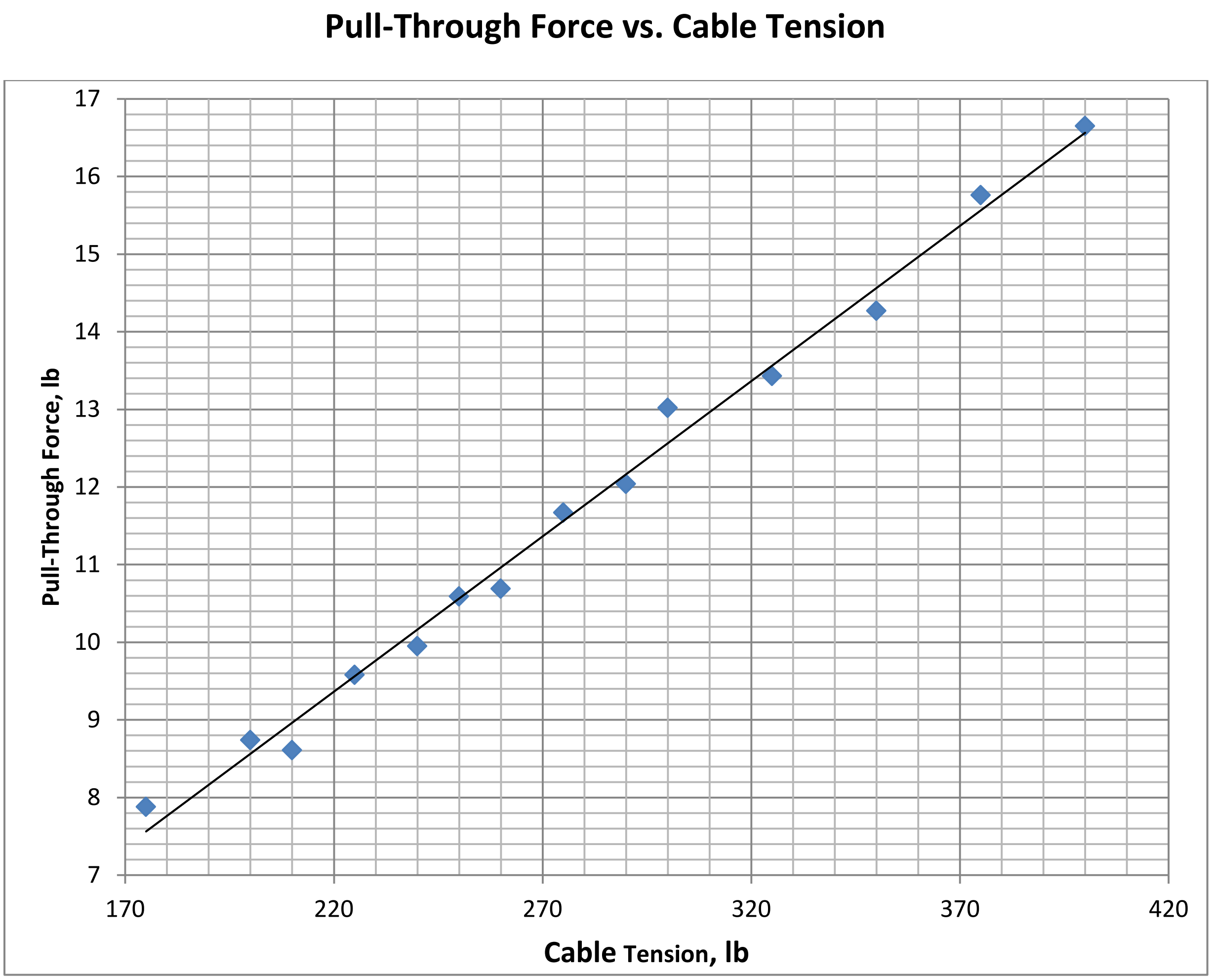
Results

The average net force required to pull a 4.0 in. diameter steel sphere through .125 in. diameter, 1x19 lay, 316 stainless cables spaced at 3.125 in. center to center, with 48.0 in. unsupported span is tabulated in Table 1. The values shown are for the cable tension levels of greatest interest.

Cable Tension	Pull-Through Force
175 lb	7.88 lb
200 lb	8.74 lb
225 lb	9.58 lb
250 lb	10.59 lb
275 lb	11.67 lb
300 lb	13.02 lb

Table 1

All of the average pull-through force results are plotted below in Graph 1.



Graph 1

While the results show some scatter, it is clear that pull-through force is linearly related to cable tension.

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Recommendations

Based on these results, it is our recommendation that Vista cable railing infill be installed per the following guidelines:

Cable Spacing, Center to Center:	3.125 in.
Maximum Unsupported Span:	48.0 in.
Cable Tension:	225 lb

All Vista cable railing infill should be so installed, regardless of cable diameter.

The 225 lb cable tension provides an additional margin of safety of 10% beyond the safety factor of 2.0 applied for dynamic loading. (Using the 9.58 lb avg. push force result from the test data.)

Cable railing infill which is capable of resisting an 8.7 lb load to a 4.0 in sphere is more robust than the requirements of 2015 IBC/IRC, since the IBC/IRC codes only specify the size of the infill openings and make no mention of force required to expand them to a larger size.