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Traction and Slip Testing of Competitive Walk Ramps under Controlled Conditions

Technical Report by:

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I. Purpose

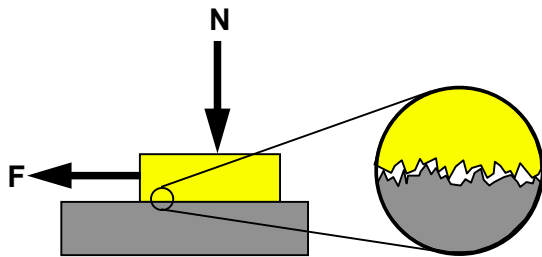
As a prominent manufacturer of walk ramps used in the food transportation industry, R.O.M Corporation required information on the traction performance of these ramps to guide future product development.

The company authorized their engineering department to conduct testing and analysis of competitive walk ramps under controlled conditions to supplement laboratory coefficient of friction testing that was performed in 1995.

The purpose of the testing was to measure and compare the actual effectiveness of walk ramps under typical operating conditions including different types of footwear, different levels of ramp and shoe wear, and different surface conditions caused by the environment.

II. Theoretical Analysis

Most ramp testing that has been performed in the past has involved measuring the coefficient of friction between the ramp surface and a typical shoe or boot material. These tests use standard test equipment and loads to determine the coefficient of friction in the following manner.



The two samples are placed in contact with each other and a standard load (N) is applied. The force (F) necessary to start moving one sample relative to the other is measured. Microscopic roughness on the surface resists this motion and the rougher the surface, the higher the force required. The coefficient of static friction (μ) is the ratio of the force required to start motion (F) and the load (N) applied. It is calculated as follows:

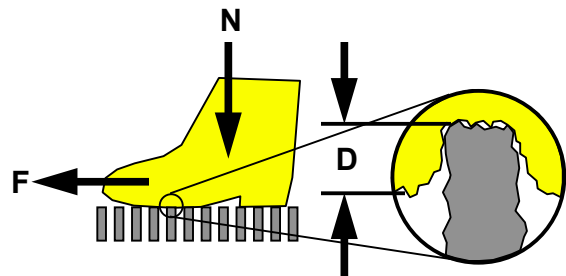
$$\mu = F / N$$

The force (F) is not dependent on the contact area and it is generally accepted that the coefficient of friction remains constant regardless of the normal force (N) applied.

The coefficient of friction is different for every material combination and gets smaller as the materials wear. The coefficient of static friction is always greater than the coefficient of kinetic friction, meaning the force required to start the object in motion is always greater than the force required to keep it moving after it has started.

Friction coefficients are meaningful in situations where the two surfaces being tested cannot substantially penetrate into each other. However, friction coefficients become less meaningful when the surfaces are allowed to penetrate into each other. In such cases, contact stress and material hardness effect traction more than the coefficient of friction. This is an important principle in the design of traction surfaces.

Consider the following scenario:



The force (F) required to move the boot is only dependent on the coefficient of friction for very small loads (N). As the load (N) increases the deflection (D) increases in direct proportion to the contact stress and the hardness of the shoe material. This deflection has a tendency to mechanically lock the shoe and greatly increases the force (F) required to move the shoe.

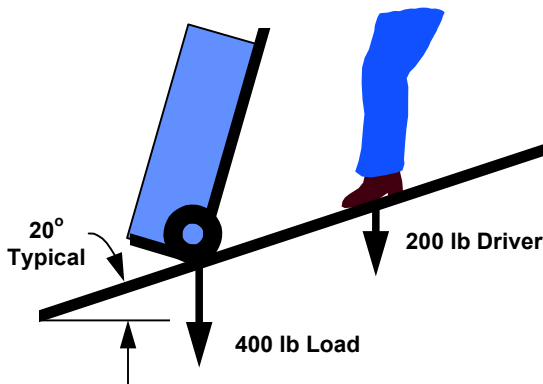
In this case, the force (F) is dependent on the contact area. The deflection (D) is a function of the shoe material modulus of elasticity and the contact area. For a given material, the deflection (D) increases as the contact area decreases.

However, even though the deflection (D) gets larger with softer materials, there is a point of diminishing returns when a material is so soft that it can roll over the mechanical lock. It is also possible for the contact area to get so small that the deflection is too high. An example of this would be to step on a nail. The grip would be good, but the deflection would not be comfortable to the user.

Another problem with coefficient of friction tests is the effect of different surface conditions. The effects of water, snow, dirt, and grease, can be measured using pure friction testing, but the results are considerably different when contact stresses and self cleaning surfaces come into play.

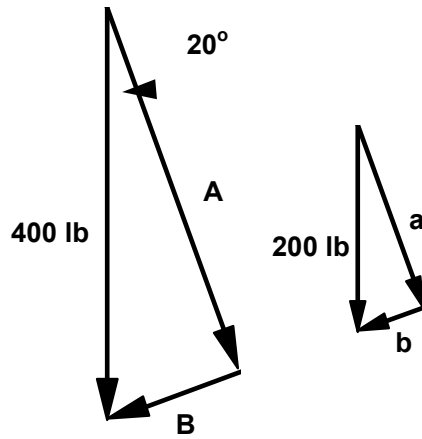
This analysis shows why coefficient of friction test results may be helpful, but by no means should be the only consideration in designing traction surfaces. A far better correlation between controlled testing and actual field use can be obtained considering realistic forces, contact area, and surface contamination.

In order to set up a realistic test scenario, the following loading assumptions and force calculations were performed.



A 200 pound driver is unloading a 400 pound load using a hand truck on a ramp at a 20° angle. The driver is expected to be able to restrain the load using one foot without slipping.

The forces involved in the above example are diagrammed below. Using trigonometry to calculate the resultant forces, realistic forces for the testing were established.



Total Force Perpendicular to Ramp = A + a
Total Force Parallel to Ramp = B + b

A = cos(20°) x 400 lb = 375.9 lb (hand truck)
a = cos(20°) x 200 lb = 187.9 lb (driver's foot)

B = sin(20°) x 400 lb = 136.8 lb (load)
b = sin(20°) x 200 lb = 68.4 lb (driver)
205.2 lb

The driver is exerting a force of 187.9 pounds perpendicular to the ramp. At that load, the friction between the footwear and the ramp must be capable of restraining the total load parallel to the ramp which is 205.2 pounds.

III. Test Equipment

In order to test the footwear deflection (D) and the pull force (F), the following test samples and test equipment were procured.

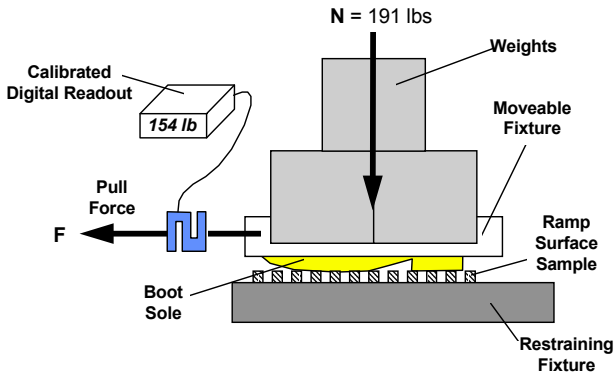
Test Samples:

- Flat Aluminum Plate (Anodized satin finish)
- Magliner Slider Ramp
- Magliner Posi-Step Ramp
- Todco Grate Ramp
- R.O.M Surefoot Ramp
- R.O.M Surefoot Roadwarrior Ramp

- Rubber soled cleated work boots
- Leather soled "Cowboy style" boots (both size 10, obtained new from Wal-Mart)

A calibrated strain gage type load cell and digital readout was used to measure the forces. A calibrated scale was used to measure the weights used and a calibrated dial indicator was used to measure the deflection of the shoe material into the ramp surface.

A test fixture was built to restrain the ramp sample and set of moveable fixtures were used to apply weight to the boot soles. The soles were glued to the moveable fixtures on a wood profile approximating a human foot. The weight of the fixture moveable fixture was five pounds and the external weight applied was 186 pounds for a total force (N) of 191 pounds.



IV. Test Procedure

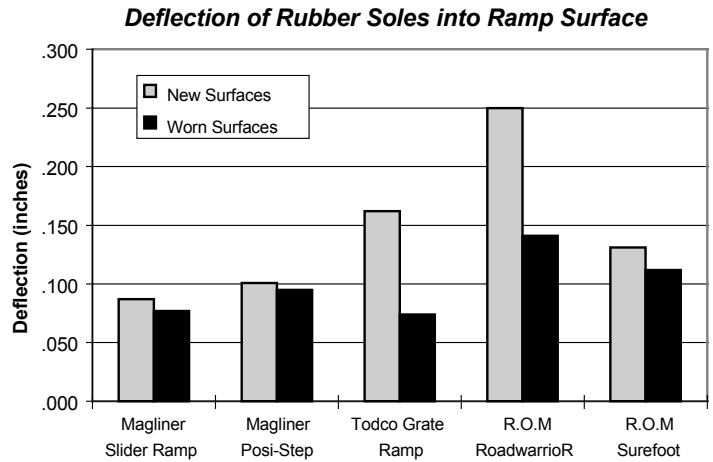
1. The boot sample was placed on top of the ramp sample. The three weights totaling 186 pounds were then lowered onto the moveable fixture. A dial indicator was used to measure the deflection of the boot sole into the ramp sample.
2. A winch was hooked onto the force gage attached to the moveable fixture and tension was applied until the fixture began to move. Peak force was recorded for each of four pulls before slipping occurred. Slipping was judged to occur when the force required to pull the fixture began to decrease. This test was repeated for each ramp sample using both rubber and leather soled boot samples.
3. The testing was repeated using water sprayed on the ramp samples and boot soles.
4. The testing was repeated again using grease (Mobil Synthetic Universal Grease) generously applied to both the ramp surface and the boot sole.
5. With tests completed for the new surfaces, wear was induced by rubbing a concrete cinder block loaded with a 100 pound weight back and forth over each ramp sample (except the flat plate sample) for 50 cycles. The boot soles were dressed down using a grinder to wear away the cleats and induce

generous radii on all sharp edges of the boot soles.

6. The same tests that were performed on the new surfaces were then repeated.

V. Results

Results of the pull tests are shown in the table and graphs below. All forces shown are the average of four readings.



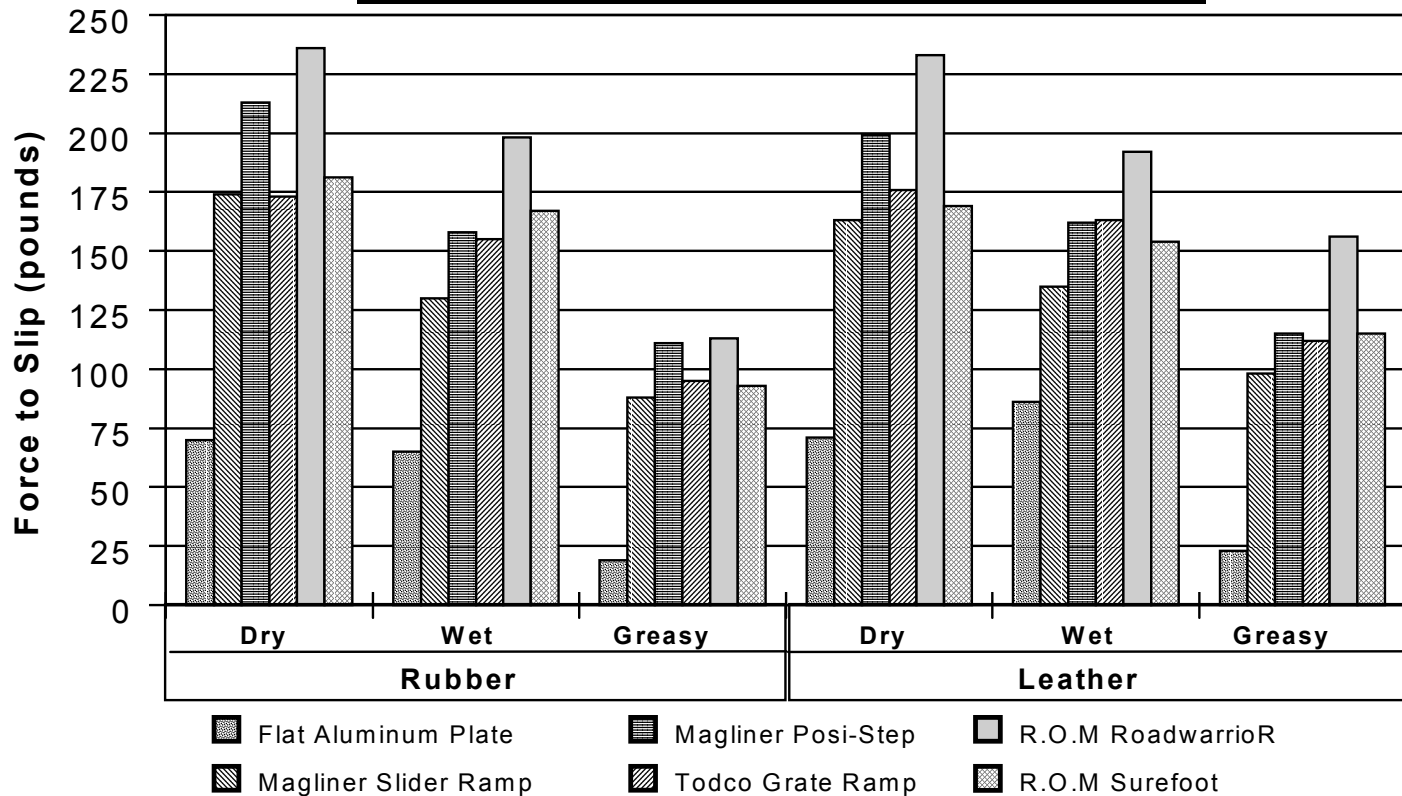
Force to Slip (pounds)
New Boot Soles and New Ramp Surfaces

	Rubber			Leather		
	Dry	Wet	Greasy	Dry	Wet	Greasy
Flat Aluminum Plate	70	65	19	71	86	23
Magliner Slider Ramp	174	130	88	163	135	98
Magliner Posi-Step	213	158	111	199	162	115
Todco Grate Ramp	173	155	95	176	163	112
R.O.M RoadwarrioR	236	198	113	233	192	156
R.O.M Surefoot	181	167	93	169	154	115

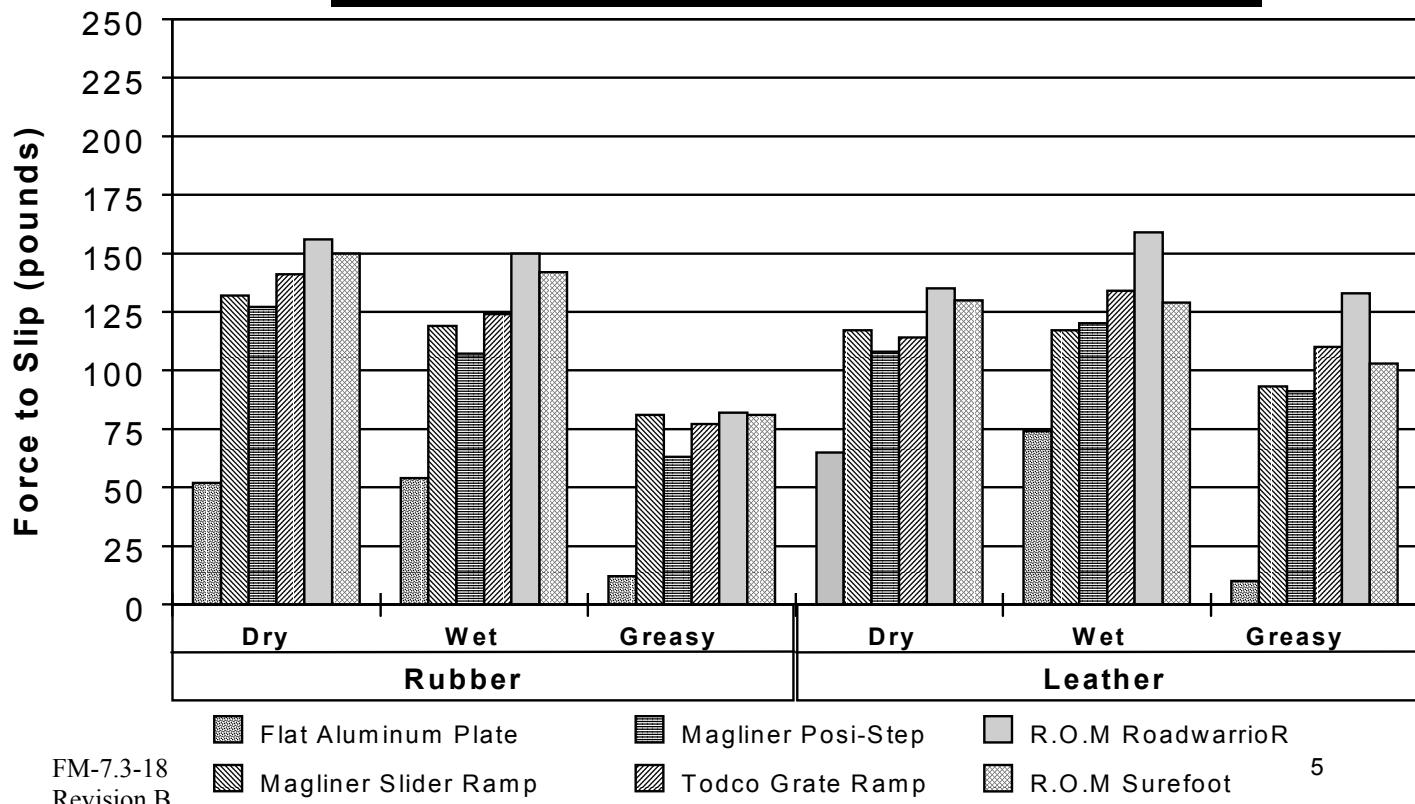
Force to Slip (pounds)
Worn Boot Soles and Worn Ramp Surfaces

	Rubber			Leather		
	Dry	Wet	Greasy	Dry	Wet	Greasy
Flat Aluminum Plate	52	54	12	65	74	10
Magliner Slider Ramp	132	119	81	117	117	93
Magliner Posi-Step	127	107	63	108	120	91
Todco Grate Ramp	141	124	77	114	134	110
R.O.M RoadwarrioR	156	150	82	135	159	133
R.O.M Surefoot	150	142	81	130	129	103

**Ramp Test Data
New Boot Surface & New Ramp Surface**



**Ramp Test Data
Worn Boot Surface & Worn Ramp Surface**



VI. Conclusions

Based on the theoretical analysis and data gathered during this testing, the following conclusions can be drawn.

1. The magnitude of contact stress between footwear and the ramp surfaces is a much better indicator of overall traction level than is the coefficient of friction.
2. On new surfaces, water decreases the overall traction by an average of 14.3%. Grease reduces traction by 44.7%.
3. Wear has significant effect on dry surface traction and a smaller effect on more highly lubricated surfaces. Typical wear of ramp and footwear surfaces reduces traction by an average of 30.6% in dry conditions, 19.0% in wet conditions, and 17.7% in greasy conditions.
4. Leather footwear has higher traction than rubber footwear under greasy conditions. It is believed that the obvious stepped heel on a leather boot is better than the transition heel on most rubber boots under these conditions.
5. Under worn surface conditions, leather boots actually grip better on wet surfaces than on dry. There are two potential explanations for this phenomena. First, the water may have washed dust from the surface much like a wet tennis shoe grips better on basketball court, and second, the water has a tendency to soften the leather allowing more deflection and grip on the ramp surface.
6. The R.O.M Roadwarrior has the best traction of the ramps tested regardless of the surface contamination or the amount of wear.
7. The R.O.M Roadwarrior is the only ramp tested that has enough traction for a 200 pound driver to stop a 400 pound load with one foot.

***For additional information concerning this technical report,
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