Field Testing of New Cutting Edges for Ice Removal from Pavements

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One of the more severe winter hazards is ice or compacted snow on roadways. Three methods are typically used to combat ice—salting, sanding and scraping—but relatively little effort has been applied to improve methods of scraping ice from roads. A new test facility is described, including a truck with an underbody blade that has been instrumented such that the forces to scrape ice from a pavement can be measured. A test site has been used that is not accessible to the public, and ice covers have been sprayed onto the pavement and subsequently scraped from it while the scraping loads have been recorded. Three cutting edges have been tested for their ice scraping efficiency. Two of the blades are standard (one with a carbide insert, the other without), and the third blade was designed under a SHRP project and has several unusual features. Results from the tests indicate that the SHRP blade removed ice more effectively than the other two blades under equivalent conditions and did so with greater efficiency and more control. Given these results, further field testing of the SHRP prototype blade is warranted.

Each winter, more than half of the roadways in the United States are subject to icing, either through compaction, melting and refreezing of snow, or directly from freezing rain or sleet. The presence of ice on roads is a severe hazard. Typically, this hazard is dealt with by salting, sanding, or scraping, or some combination of these. This study is solely concerned with improving the mechanical methods of ice removal. Specifically, the aim of the work in this project has been (a) to measure forces involved in scraping ice from roads, using a truck with an underbody plow, and (b) to use this mobile test bed to compare the behavior of three cutting edges. One of the cutting edges (referred to hereafter as the prototype) was developed under the Strategic Highway Research Program's (SHRP's) Project H-204A.

In developing the design for the prototype blade, two concerns were paramount. First, the blade had to make the best use of the results found in the laboratory study (*1,2*). In particular, some way of maintaining a nonzero clearance angle was required, since this appeared to be the key parameter from the laboratory study. The second concern was ensuring that the cutting edge was sufficiently robust that it could withstand the shock loading common to ice scraping (e.g., when a pavement joint is encountered). It should be noted that other concerns—such as the wear characteristics and the cost of the blade, which would be very important should such a cutting edge go into production—were not given great weight in the design process. These issues fell beyond the scope of the current study.

The prototype cutting edge is different from existing cutting edges in several ways. In particular, the carbide insert is mounted flush with the front face, so that carbide is exposed to the ice directly (Figure 1). This means that the carbide used is somewhat softer than typical carbide inserts for cutting edges, so as to obtain better shock resistance. Also apparent from Figure 1 is the nonzero clearance angle, which should remain in place during the life of the blade. No estimate of blade lifetime is available yet, for reasons indicated earlier. Four identical cutting edges of this type, each 128 cm (48 in.) long, were obtained from Kennametal, Inc., in Latrobe, Pennsylvania.

The purpose of this project was to develop a test system whereby a truck with an underbody blade could be instrumented to measure the forces required to scrape ice from a pavement, and to do so in a location that was not accessible to the public so that issues relating to safety of the driving public were not a concern. A secondary purpose was to compare the performance of three cutting edges (two standard and one specially developed) when removing ice from the pavement.

EXPERIMENTAL METHOD

Tests were conducted using a 22.7-Mg (25-ton) truck with an underbody plow blade, supplied by the Iowa Department of Transportation (IDoT) for use in its Project HR-334. The truck is shown in Figure 2. The underbody blade can be adjusted to a variety of orientations. The blade angle is the angle that the cutting edge has with the pavement. It might also be called the angle of curl of the blade. When this angle is zero, the front face of the cutting edge is perpendicular to the road surface. The blade angle is controlled by a cylinder on each end of the blade. These two cylinders were connected in parallel so that the blade angle was uniform with the pavement across the full length of the blade.

For this series of tests, three cutting edges were tested. The first of these was the standard steel blade that came with the truck. This blade was 1.9 × 12.7 × 244 cm (0.75 × 5 × 96 in.) and had no carbide inserts. The second cutting edge was a commercially available blade with a carbide insert. The third cutting edge was the prototype edge. The three blades are shown in Figure 3.

The loads that the blade experiences during scraping were recorded by the use of pressure transducers connected by a T-section to the hydraulic supply lines of the cylinders. The pressure gauges used were International Pressure Products

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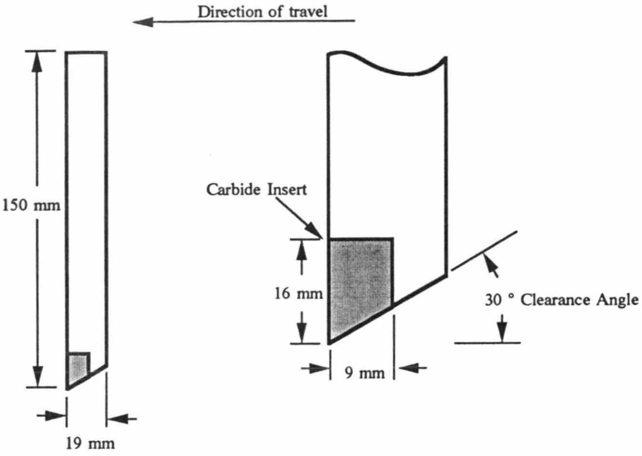

FIGURE 1 **Schematic of prototype blade.**

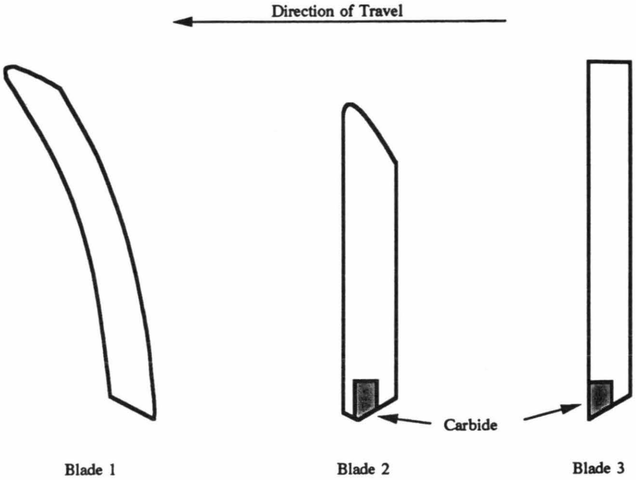

FIGURE 3 **Geometry of blades used in tests.**

ST-420 0- to 20.7-MPa (0- to 3,000-psi) gauges. A transducer was located in each of the vertical motion cylinders to measure the down pressures on each side of the blade. Another transducer was located in the supply hose for the cylinders that rotate the blade angle. This gauge recorded the loads that the blade experienced in the horizontal direction.

The angle that the cutting edge made with the pavement was measured by means of an inclinometer. A Schaevitz Angle Star Protractor System was used. The inclinometer was on the left side of the blade.

Data from the sensors were collected on a portable PC: a Kontron IP Lite, chosen because it is shock-rated for operation up to 5 *g*. The shock rating was needed to guarantee normal data acquisition because the truck bounced greatly during testing. An analog-to-digital circuit board in the PC allowed the software to collect and store the data. A Metrabyte DAS-8 analog-to-digital board was used along with the CODAS data acquisition software by Dataq Instruments. Data were written to the hard drive of the PC during testing and were examined and analyzed after testing at the ice laboratory at the Iowa Institute of Hydraulic Research (IIHR). Power for the computer and sensors was obtained from the truck batteries through a power inverter and filter system built at IIHR.

A 2800-L (750-gal) tank of water in the truck was used to create the ice necessary for the testing. A 2.2-kW (3-hp) pump at the back of the tank delivered the water at 413 kPa (60 psi) to a spray nozzle on a boom offset from the truck, as seen in Figure 4. The spray nozzle allowed the water to be sprayed uniformly over the pavement with a spread 6 m (20 ft) wide. Further details on the method of spraying are reported elsewhere (*3*). Testing took place at the spillway apron of the Coralville Reservoir when weather conditions were favorable. The area covered by spraying was approximately 6 × 55 m (20 × 120 ft). The total weight of the truck during scraping was 20 000 kg (44,000 lb). Air temperature, concrete temperature, ice thickness, and ice condition were recorded before testing. The angle of the blade was set, and as the truck approached the ice sheet, the down pressure was applied to the blade. The tests were performed at about 6.7 m/sec (15 mph) over the entire length of the ice sheet.

The testing parameters to be studied were the cutting edge type, the down pressure, and the angle of the blade. For each of the three cutting edges previously described, the down pressure was tested at a low value and a high value: 3450 kPa (500 psi) and 8370 kPa (1,200 psi), respectively. These values were set on the blade by adding enough pressure to the down pressure to get within these ranges as seen on the computer screen in the cab. The angle of the blade was varied from a set of 0, 15, or 30 degrees. These values were set by using

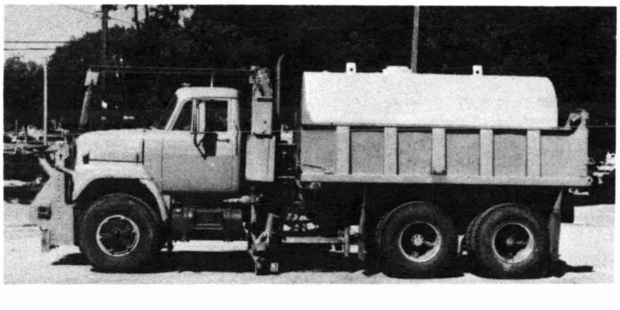

FIGURE 2 **Truck used to conduct tests.**

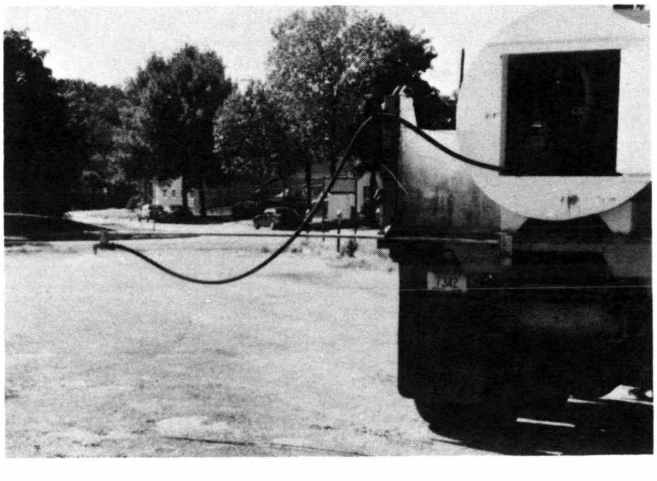

FIGURE 4 **Spraying equipment used to make ice sheet.**

the display of the inclinometer in the cab and adjusting for the desired value. Because the angle of the cutting edge changed when the truck moved forward, this angle was set low. As the truck pulled ahead with the desired down pressure applied, the angle adjusted to the correct value. Only one test with high down pressure was performed on Blade 3, because the blade cut the ice so effectively and so deeply in this configuration that the truck could not provide enough horizontal force to continue cutting.

EXPERIMENTAL RESULTS

Tests performed with the standard (noncarbide) blade showed that the ice was completely removed from the pavement in only a few places. Much of the ice was removed only partially or not at all. Accordingly, no single value for the thickness of ice removed in each test has been reported here. From observations it appeared that more ice was removed with a high down pressure and a 0-degree blade angle for this blade. At the high down pressure it was more difficult to maintain a constant velocity because of a loss of traction. Typical data output from the gauges for a test is shown in Figure 5. Table 1 provides a listing of the vertical and horizontal loads for all tests, indicating also whether the down pressure was low or high and giving the angle of the blade.

Because the second and third (prototype) cutting edges were not of the same geometry as the first, the 0-degree case could not be achieved and only the 15- and 30-degree cases could be studied for the two carbide blades. As with the standard blade, the second and third blades performed best at the smallest blade angle and highest down pressure. The second blade appeared to remove more ice than the first blade and maintained its shape much better because of the carbide insert.

The final blade tested was the prototype blade. This cutting edge provided superior performance for ice removal. The blade was able to remove half of the ice thickness, typically

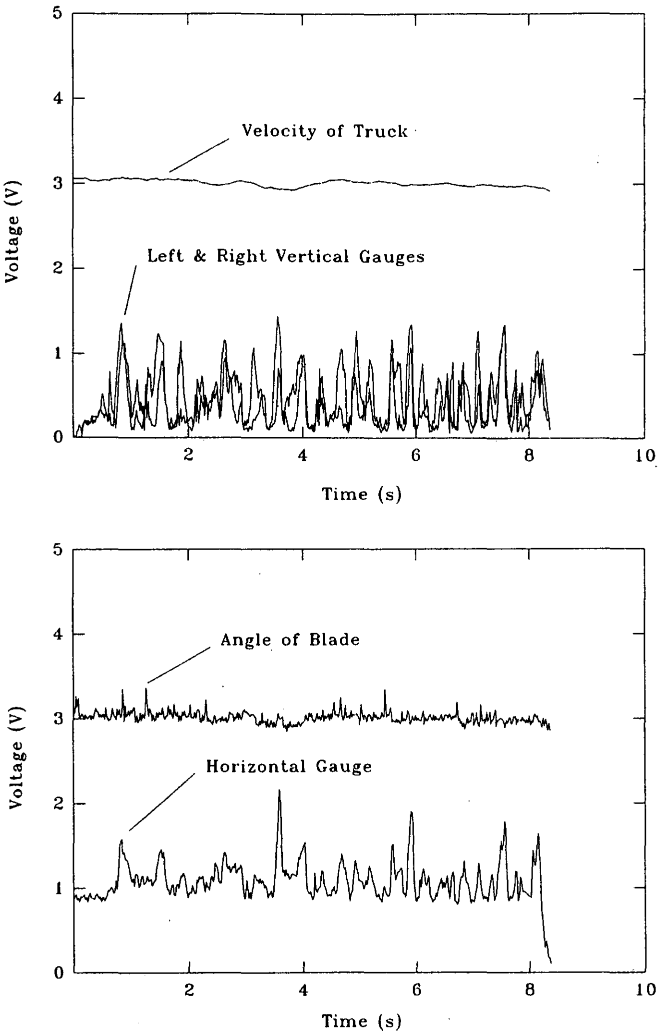

FIGURE 5 Data output from gauges for Blade 2 at 15 degrees and low down pressure.

TABLE 1 Forces Measured for Test Series

		Horizontal Force (kN)		Vertical Force (kN)		Ratio vert/horz	
Blade	load/Angle	Mean	Peak	Mean	Peak	Mean	Min
1	Low 0°	83.9	126	68.9	119	1.22	0.473
1	Low 15°	76.3	106	105	177	1.42	0.532
1	Low 15°	62.9	112	87.2	137	1.49	0.468
1	Low 30°	67.7	104	67.8	85.7	1.06	0.258
1	High 0°	90.5	250	127	174	1.70	0.635
1	High 15°	69.9	121	112	140	1.71	0.586
1	High 15°	78.9	182	112	151	1.46	0.626
1	High 30°	92.6	179	125	147	1.63	0.722
1	High 30°	39.9	76.6	83.2	101	2.32	1.21
2	Low 15°	103	174	76.6	131	0.793	0.138
2	Low 15°	33.9	93.6	30.5	84.6	0.952	0.509
2	Low 15°	49.9	96.5	30.0	73.7	0.581	0.181
2	Low 30°	34.4	76.2	49.6	94.2	1.46	0.789
2	Low 30°	20.2	61.7	37.1	70.6	2.19	0.919
2	Low 30°	46.0	96.0	76.0	104	1.73	0.754
2	High 15°	77.7	204	101	149	1.33	0.686
2	High 30°	76.6	127	101	127	1.44	0.883
2	High 30°	54.6	95.2	91.0	119	1.78	1.04
3	Low 15°	87.0	235	63.2	141	0.701	0.133
3	Low 15°	97.3	235	75.1	139	0.789	0.160
3	Low 15°	78.9	169	50.9	133	0.607	0.192
3	Low 30°	46.7	123	36.0	66.5	0.838	0.341
3	Low 30°	56.3	137	41.3	82.2	0.799	0.391
3	Low 30°	76.8	159	58.7	128	0.761	0.243
3	High 15°	173	263	134	158	0.781	0.489

0.6 to 1.2 cm (0.25 to 0.5 in.), across the entire 2.4 m (8 ft) length of the blade at low down pressure. In the one high-down-pressure test performed with this blade, the cutting edge removed nearly all the ice except for a small residual layer across the length of the blade. This performance was significantly better than the other two blades.

DISCUSSION OF RESULTS

In reviewing data from the tests, it became apparent that the loads alone did not provide the full story. Indeed, it appeared that the higher the horizontal load was during a test, the more successful the scrape was, insofar as more ice was being scraped. The horizontal load seemed to correlate very well with the depth of ice scraped, though it should be noted that no direct measurements have been made of scraping force as a function of depth of ice scraped, either in the laboratory or in the field. In addition to the horizontal force indicating the depth of cut, the vertical force also gave a good indication of the difficulty of the cut. The higher the vertical force, the harder it was to control the vehicle, and the more the opportunity for damage to the pavement. Thus, two factors were important in evaluating the tests: the depth of cut, as indicated by the horizontal load, and the ratio of the vertical to horizontal load. If the latter was low, the truck was easily controlled. If the former was high, much ice was scraped.

Figures 6 through 8 show the horizontal and vertical loads for the three blades in the low-pressure configuration at one scraping angle (15 degrees). From these figures it is apparent that the prototype blade gave the greatest depth of cut and had the best factor of controllability (ratio of vertical to hor-

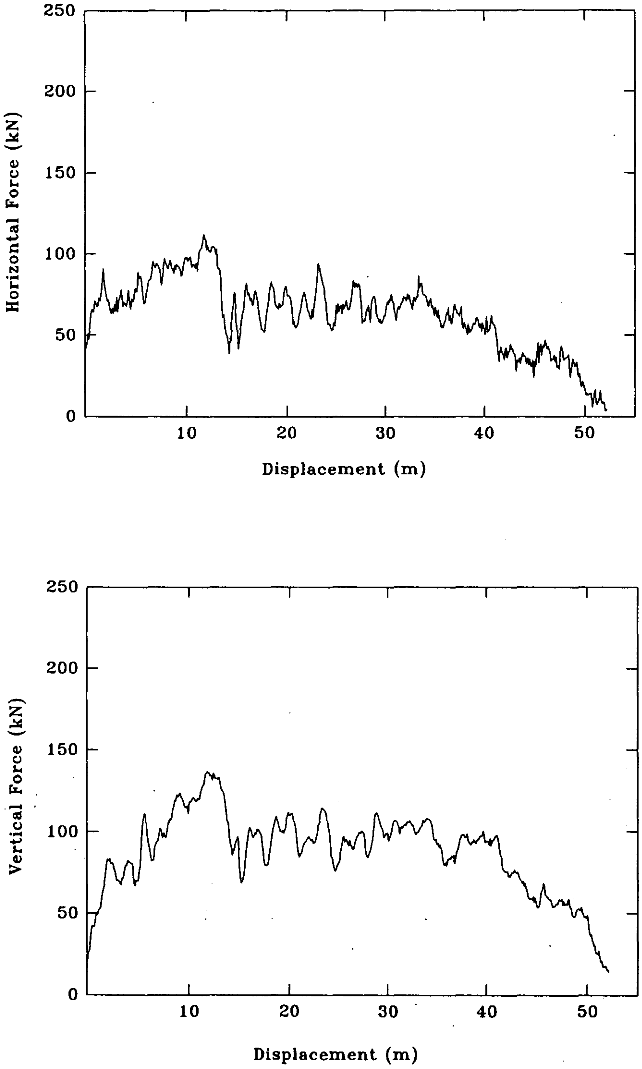

FIGURE 6 Forces on Blade 1 at 15 degrees and low down pressure: *top*, horizontal (maximum = 112 kN, average = 62.9 kN); *bottom*, vertical (maximum = 137 kN, average = 87.2 kN).

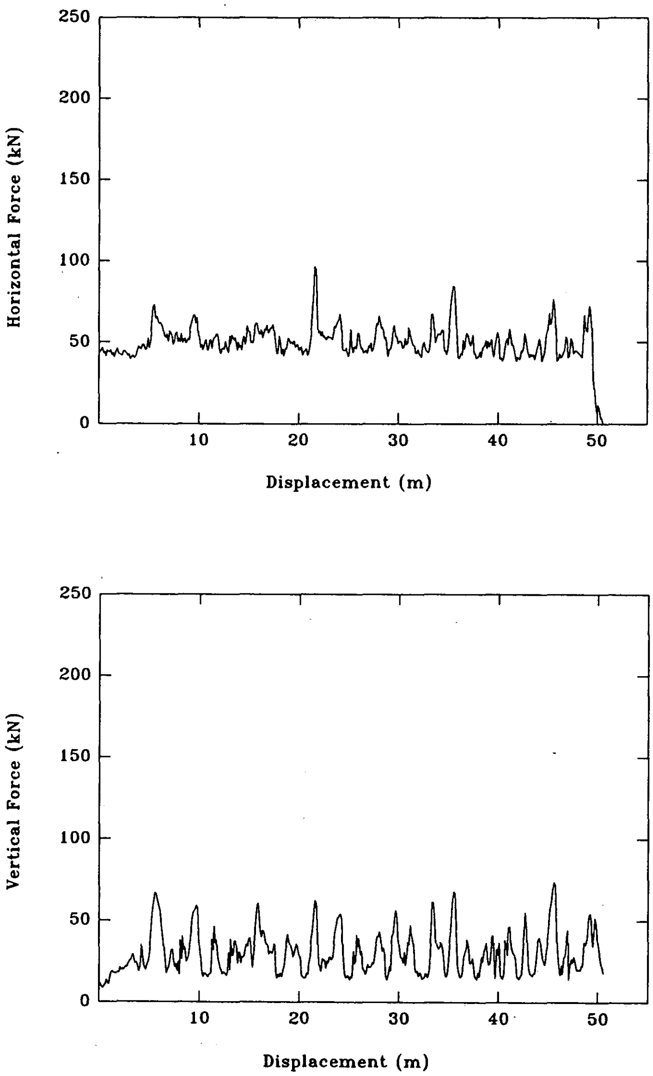

FIGURE 7 Forces on Blade 2 at 15 degrees and low down pressure: *top*, horizontal (maximum = 96.5 kN, average = 49.9 kN); *bottom*, vertical (maximum = 73.7 kN, average = 30.0 kN).

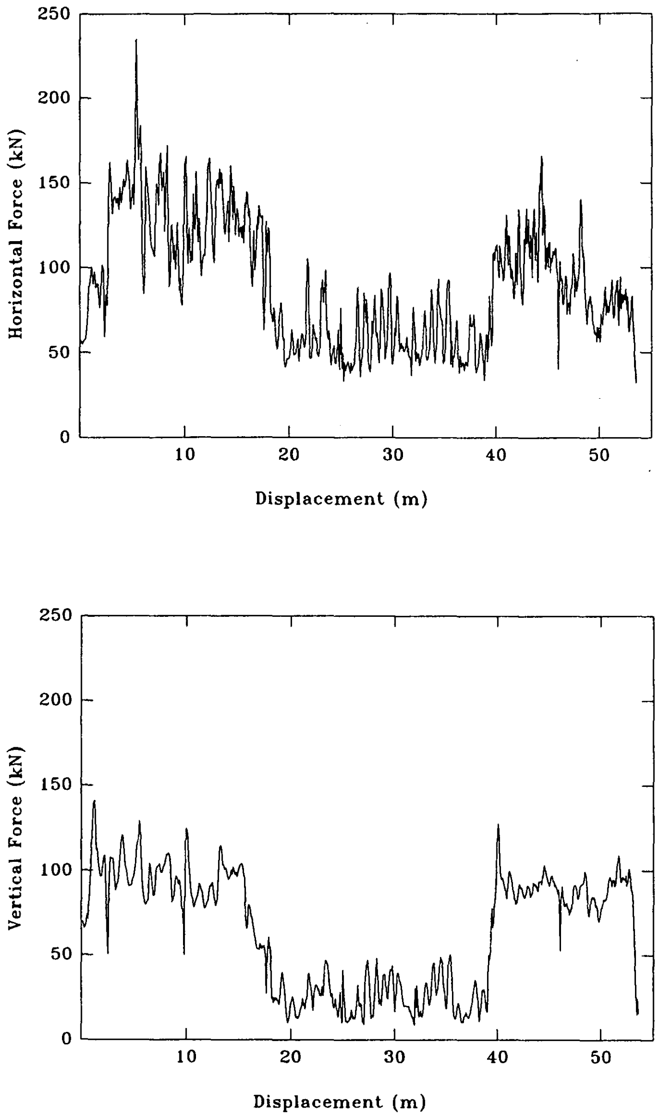

FIGURE 8 Forces on Blade 3 at 15 degrees and low down pressure: *top*, horizontal (maximum = 235 kN, average = 87.0 kN); *bottom*, vertical (maximum = 141 kN, average = 63.2 kN).

izontal forces) of the three blades. The controllability is seen clearly in Figure 9, which shows the ratio of vertical to horizontal forces for the three blades for all tests. It is apparent that the prototype blade gives the best performance.

CONCLUSIONS

A mobile test system mounted on a truck with an underbody blade has been developed and shown to be capable of measuring the force required to scrape ice from pavement. A series of tests have been performed to evaluate the performance of three cutting edges. From the results of these tests, and from the visual observations made in the preceding, it appears clear that the prototype cutting edge provides significantly better ice scraping than either of the other two blades. However, although the prototype cutting edge has performed very well in these controlled field situations, it has not yet been tested in the field, where issues of durability and ruggedness will be important. Nonetheless, results to date indicate that the prototype blade may be a major improvement over existing cutting edges.

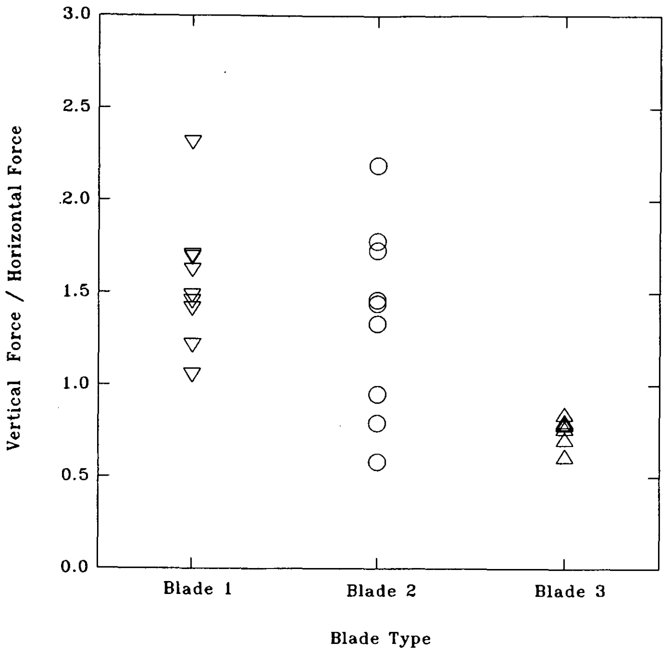

FIGURE 9 Ratios of vertical to horizontal forces for different blades.

It should be noted that the prototype cutting edge was not fabricated with wear resistance in mind. Nonetheless, it retained its shape throughout the tests reported here. In later testing, reported elsewhere (*3*), the blade experienced significant wear when scraping cold ice at −15°C (5°F).

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