THE USE OF ABRASIVES IN WINTER MAINTENANCE

FINAL REPORT OF PROJECT TR 434

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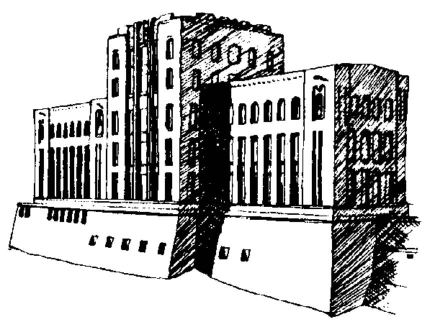
by
Wilfrid A. Nixon, Ph. D., P. E.



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Iowa Institute of Hydraulic Research
College of Engineering
The University of Iowa
Iowa City, Iowa 52242-1585

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ABSTRACT

The use of abrasives in winter maintenance is a well-established practice. The sand or other abrasive is intended to increase friction between vehicles and the (often snow or ice covered) pavement. In many agencies (and in many Iowa Counties, the focus of this study) the use of sand is a standard part of winter maintenance. Yet very little information exists on the value of sanding as a winter maintenance procedure. Some studies suggest that friction gains from sanding are minimal. In addition, there are increasing environmental concerns about sanding. These concerns focus on air quality and stormwater quality issues. This report reviews the state of the practice of abrasive usage in Iowa Counties, and classifies that usage according to its effectiveness. Possible changes in practice (with respect to abrasive usage) are presented and discussed.

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CHAPTER 1: INTRODUCTION

The use of abrasives in winter maintenance is a well-established practice. Typically sand is placed on the road in amounts up to 1,200 lbs per lane mile (340 kg per lane km). The sand is intended to increase friction between vehicles and the (often snow or ice covered) pavement. The sand may be applied "straight," it may be pre-wet with liquid brine (at the spinner or in the box during loading), or it may be delivered mixed with salt (with mixtures ranging from 1:1 sand:salt up to 4:1 sand:salt). In many agencies (and in many Iowa Counties, the focus of this study) the use of sand is a standard part of winter maintenance.

Minsk (1999) reports that sand (or other abrasives) constituted the major part of winter maintenance activities (in addition, of course, to plowing) up until the 1970's in the United States. At that time, the use of salt and other de-icing chemicals became more widespread. However, the use of abrasives continued.

Yet very little information exists on the value of sanding as a winter maintenance procedure. What information does exist tends not to support sanding as a process. Studies from the late 1950's suggest that at highway speeds sand is swept off the roads by relatively few (8 to 12) vehicle passes. More recent studies suggest that friction gains from sanding (when sand remains on the road) are minimal.

In addition to these factors, there are increasing environmental concerns about sanding. Some U. S. cities have already stopped sanding because of air quality concerns. Others are required to clean up all sand as soon as possible after application, using street sweepers. It remains unclear to what extent the Phase II Stormwater regulations will have on sand usage, but they may cause further limitations in their use.

This report reviews the state of the practice of abrasive usage in Iowa Counties. Chapter 2 presents a complete review of the published literature, discussing how various factors (e.g. amount of sand, temperature, type of sand) influence the friction experienced after an application of abrasives. It will become apparent from Chapter 2 that when placed "dry" on the road surface (that is, without significant pre-wetting at the spinner) abrasives provide at best a very short term increase in road surface friction, especially on roads where vehicle speeds are typically high (greater than 30 mph or 48 kph). Accordingly, Chapter 3 presents some novel approaches to placing sand on highways, although it should be noted that these “novel” methods have been considered over a number of years, and some of them are close to standard practice in some locales.

Chapter 4 reviews current practice in Iowa and attempts to set the context within which decisions on abrasive usage must be made. Chapter 5 presents recommendations for best practices for abrasive usage.

Chapter 6 presents some suggestions for further research. This focuses primarily on how the more “novel” abrasive application methods might be evaluated for use here in Iowa, and fulfills a central part of the original project. Chapter 7 summarizes the conclusions of the report.

CHAPTER 2: PREVIOUS STUDIES ON ABRASIVE USAGE

This chapter presents results of a literature review conducted for this study. The review included a survey of the TRIS database, combined with a request for information posted on the snow and ice e-mail based list-serve. This chapter concentrates primarily on what might be termed "standard" methods of abrasive application. Chapter 3 examines more "novel" methods of application.

Traffic Effects

While the practice of sanding as part of a winter maintenance program is widespread, the few studies that have been done on this do not indicate that this practice is particularly valuable. Gray and Male (1981) note that even in the 1950's studies in Germany indicated that sand was swept from snow-covered highway surfaces after only ten to twelve vehicle passages (at highway speeds). More recently, a study conducted by the Ontario Ministry of Transportation (Comfort and Dinovitzer, 1997) showed that at low temperatures (below –15º C) the friction gains due to application of abrasives were substantially reduced by the passage of relatively light traffic (5 to 10 vehicles and 3 to 5 logging trucks).

This Ontario study also showed that substantial application rates had to be used to obtain substantial gains in friction. In one series of tests on hard packed snow under cold (below –15º C) conditions, the friction factor of the untreated roadway was measured as 0.18. After application of 300 kg per lane kilometer (kg/lkm) the friction factor increased to 0.40. After light traffic, this value reduced to 0.23. Table 1 shows the stopping distance for a passenger vehicle with an initial velocity of 40 kilometers per hour (kph) for these friction values.

Table 1: Stopping Distances After Abrasive Treatment (from Comfort and Dinovitzer, 1997)

Road Condition	Friction Factor	Stopping Distance (m)
Hard packed snow cover (below –15° C)	0.18	35.0
Abrasives freshly applied (300 kg/lkm)	0.40	15.7
Same surface after light traffic	0.23	29.5

Comfort and Dinovitzer did find some circumstances in which traffic did not reduce the effectiveness of abrasives to the extent indicated in Table 1. At warmer temperatures on a snow-pack covered road, the abrasives were less likely to be swept off the road by vehicle passage, although friction still decreased with traffic. In addition, on a warmer ice covered road, traffic appeared to increase friction. This latter effect was attributed to two factors – strong sunlight during the test that melted the sand into the ice; and mechanical action by the traffic that roughened the road surface. However, in spite of these results, a major result of this study is that abrasives have little friction enhancing value on a road with any substantive level of traffic. What benefits accrue are temporary, unless steps are taken to make the abrasives adhere to the snow or ice surface.

Effect of Ice Type and Abrasive Type

Other studies have been conducted on the usage of sand as a friction enhancer. Borland and Blaisdell (1993) examined five different ice types. They found that coarse sand gave more friction enhancement at low temperatures, while find sand was better close to the melting point of ice. They also found that friction enhancement was a strong function of application rates. They applied at rates up to 580 kg/lkm. They found that abrasives could provide gains in friction factor from about 0.10 (for bare ice) up to 0.31.

Hossain et al. (1997) conducted a study for New York Department of Transportation in which three different sand types were tested over a range of temperatures and application rates. The sand was also applied with salt and salt-brine mixtures. They found that sand alone gave little benefit in friction factor, while best results appeared to be obtained with a 2:1 sand – brine mix (using a 25% brine solution) at warmer temperatures.

Cost Benefit Analysis

A study by Kuemmel and Bari (1996) examined how cost effective it was to use either abrasives or a salt-abrasive mixture for winter maintenance. This study built off an earlier study (Kuemmel and Hanbali, 1992) which examined the cost benefits of using salt (not mixed with abrasives) for winter maintenance purposes.

The results from these studies are unambiguous. While the use of salt shows a clear benefit/cost ratio of using straight salt was 12:1 for two lane highways and 3:1 for freeways (divided highways). In contrast the benefit/cost ratio for abrasives and salt/abrasive mixtures on two lane highways was 0.8:1. In other words, the use of abrasives or salt/abrasive mixtures is not economically justifiable for two lane highways. Freeways gave somewhat better results, with a cost/benefit ratio of 2.8:1 indicating that abrasive usage can be justified economically on freeways, although not as easily as straight salt. The authors noted, however, that on freeways the use of straight salt led to a safe pavement (as determined by reductions in accidents) surface much more rapidly than when abrasives or abrasive/salt mixtures were used.

Environmental Factors

As noted in the Introduction, there are increasing concerns about the environmental effects of abrasives when used in winter maintenance. In the United States, these concerns (at present) focus primarily on particulate emissions and air quality concerns (PM 10 considerations) and these are discussed below. It is interesting to note, however, that a recent study from Germany (Hanke, 1998) considered the use of abrasives as an alternative to using salt. The study was prompted by environmental concerns arising from salt use.

Hanke's study found a number of additional concerns related to the use of abrasives. He notes that they cost more than salt (primarily because more applications must be made) and that traffic safety is no better after abrasives are spread than before they are spread. In other words, abrasives cost a lot and don't improve road safety. In addition he notes that the process of gathering abrasives up after a storm, cleaning them and either re-using them or disposing of them is not yet fully developed. The final conclusion of the study is "the use of abrasives in winter maintenance must be minimized." The study further notes that abrasives should only be used in situations where heavy snowfalls and low temperatures are encountered.

With regard to PM10 air quality concerns, an EPA document (EPA, 1991) provides guidance on selecting abrasive materials. The document notes that high PM 10 loadings can be expected if the material used has a high silt fraction (percentage that passes a No. 200 mesh or < 74 µm). It is worth noting that Keyser (1973) found that fines passing a No. 50 sieve (<300 µm in diameter) contribute almost nothing to skid resistance. This suggests that abrasives for winter maintenance use be specified to have a low quantity of material passing a No. 50 sieve.

The EPA study also notes that the hardness or durability of the abrasive material is important. Material that crumbles under tire loadings will produce a higher silt content while on the road surface. The best method for determining the silt generating potential of an abrasive material is the Los Angeles abrasion loss test (ASTM, 1989). The EPA document suggests that the best abrasives from the point of view of durability show a low abrasion loss (from 0.90% to 4.0% by the Los Angeles method) and a high Vickers hardness (550 to 1200 kg/mm^2)

Conclusions from the Surveyed Literature

It is apparent from the literature that a major problem with abrasives is that they do not, in general, stay on the road for a sufficient length of time to be valuable enhancers of the pavement surface friction during winter storm events. In combination with several other deleterious aspects of their use (air quality and clean-up concerns especially) this suggests that abrasives only be used when there is no other option.

At first glance, such a recommendation seems prudent. However, the inevitable conclusion of such a recommendation is that in many situations encountered in winter storms, especially in the climate of Iowa, the only action taken would be plowing. This may not be acceptable to the travelling public. Accordingly, it is worth considering what might be done to address the primary drawback of abrasives, namely that they do not remain on the pavement surface under the effect of traffic. Chapter 3 considers approaches that could be taken to keep abrasives in place.

CHAPTER 3: NOVEL METHODS OF ABRASIVES APPLICATION

It is clear from the literature survey reported in Chapter 2 that a primary problem with using abrasives is keeping the abrasives on the road surface under traffic conditions. When abrasives stay on the road, they can provide an increase in friction. Three possible ways of keeping abrasives on the road present themselves: pre-wetting the abrasives with a chemical deicing brine, heating the abrasives prior to application, and mixing the abrasives with water prior to application. Each of these methods will be considered in this chapter.

Pre-wetting Abrasives

Abrasives can be pre-wet in three different ways: on the stockpile, when the abrasives are loaded into the truck, and when they are delivered at the spinner or tailgate. In general in Iowa almost all abrasives are pre-wet in the stockpile to prevent freezing of the stockpile. Such pre-wetting has little effect on the ability of the abrasives to remain on the pavement surface when delivered. Clearly, if abrasives are to be used then the stockpile must be pre-wet with de-icing chemicals, and no change of practice is envisaged here.

Sometimes, abrasives are pre-wet as they are loaded into the delivering truck. A load of sand might be pre-wet with 10 gallons of liquid brine (typically a salt or calcium chloride brine at the eutectic mixture) per ton of abrasives. While such pre-wetting requires no special delivery systems, there is no evidence in the published literature that such pre-wetting improves the ability of abrasives to remain on the road surface. Absent such evidence, this practice cannot be recommended as improving abrasive performance.

The final method of pre-wetting involves adding liquid brine at the spinner or tailgate of the truck. Typically, liquid (again either sodium chloride or calcium chloride brine) is added at a rate of about 10 gallons per ton of abrasives from some sort of saddle tank mounted either in the sides of the truck box, or in the tailgate. A recent Iowa DOT document provides a design for such a pre-wetting device.

Studies indicate that pre-wetting salt and other solid de-icing chemicals helps to keep the chemicals on the road surface when first delivered. Specifically, a Michigan DOT study indicated that pre-wetting at the tailgate keeps 96% of the material on the pavement surfaces (after initial delivery). This contrasts markedly with results placing dry chemicals from a tailgate spinner, where 30% of the material immediately (i.e. upon delivery and with no action of subsequent traffic) bounced off the pavement. Clearly, pre-wetting helps material to "land" in the right place. It is less clear that it helps it to stay there.

There is a significant benefit to pre-wetting de-icing chemicals in that this pre-wetting "jump starts" them into solution and helps them to melt the snow pack more quickly. With abrasives, the hope is that the liquid chemical will melt some of the snow pack and allow the abrasive particle to embed into the surface of the snow pack, subsequently refreezing there and providing a permanently roughened surface. However, Comfort and Dinovitzer (1997) found no evidence of improved friction when abrasives were applied pre-wet at the tailgate, although this was not a primary focus of their research. The issue of whether pre-wetting helps to keep abrasives on the road surface and thus improves friction over a longer period of time (than a dry application of abrasives) is not clear and requires further research.

Novel Approaches

Two novel approaches to keeping abrasives on the road surface have been considered and tested to a limited extent. The first of these heats the abrasives to a high temperature, either in the loading location or on the back of the truck. The notion here is that the hot abrasives will melt a small quantity of snow or ice as the abrasive hits the road. The melt water then refreezes around the abrasive and fixes it to the surface of the snow or ice covered road. In theory, this frozen-in abrasive will remain in place for much longer than abrasives applied in the normal manner.

The second approach involves mixing the abrasives with water at the tailgate. The notion here is that a small coating of water on the abrasive particle will cause the particle to freeze rapidly to the road surface, and then remain in place for longer than if applied dry.

With both of these approaches, the goal is to keep the abrasives in place under the effect of traffic. This appears to be a correct approach, insofar as traffic has been shown to rapidly reduce the effectiveness of abrasives by sweeping them off the road very rapidly after deployment.

The heating method was tested by the Finnish Road Administration in a series of tests during the 1990-91 winter season (FinnRA, 1991). In the first part of the study, conducted in the Lappi Road District, sand was heated to about 80° C (176° F) in the maintenance yard, and then placed in the truck and dispersed on the road. Friction measurements were made of sections where the heated sand was used, and on sections where regular application (i.e. unheated) of abrasives was made. No statistically significant difference in friction levels was observed.

The second part of the study was made in the Oulu Road district. Here sand was heated to much higher temperatures (using a drying drum from an old oil gravel plant) and the abrasive temperature in the back of the truck was measured at temperatures as high as 250° C (482° F). In this case, friction values increased substantially immediately after application (from about 0.22 to about 0.37) and the heated sand section of road had higher friction than sections treated with a sand-salt mixture (about 0.26). However, within 24 hours, the friction level had returned to the untreated friction value of 0.22. The AADT for sections used in this test was between 250 and 500 vehicles per day.

A more recent study conducted in Sweden revisited the use of heated sand, and also considered applying sand mixed with water (Hallberg and Henrysson, 1999). In this study, four different applications of materials were made. The most traditional was a sand/salt mixture, which consisted of sand (0 to 8 mm in diameter) with about 25 kg/m^3 of salt (Sodium Chloride) added to prevent caking. The second traditional material applied was cold aggregate chippings (2 to 5 mm in diameter). In addition, two novel applications were made. One, termed Hottstone®, applied the aggregate chippings (2 to 5 mm in diameter) at high temperature (>180º C), using diesel burners to heat the aggregate just prior to placing it on the road. The second novel method (termed the Friction Maker™) applied the (0 to 8 mm) sand with hot (90º C) water. The aim of both novel methods was to encourage the sand to stick to the snow or ice covered road surface. All mixtures were applied at rates of 350 kg/lkm per application.

Both novel methods were able to maintain their friction increase for several days. This should be contrasted with the two standard methods, which were not able to provide any lasting friction benefit. As noted by Hallberg and Henrysson (1999): "As early as a couple of hours after having applied conventional methods, there was no longer any friction effect left." These tests were conducted on a road with AADT of 500. A preliminary financial review of the two novel methods indicated that the Friction Maker™ was cheaper than applying a standard sand/salt mixture on a per application basis, and when compared with the multiple applications needed for the sand/salt mixture to achieve comparable road surface friction was much cheaper. The Hottstone® method was more expensive (by about 30%) compared with the sand/salt mixture on a per application basis, but again, if a similar level of quality was required, it was much cheaper to use the Hottstone® than the standard sand/salt method.

Conclusions from Novel Approaches

Three approaches present the possibility of keeping abrasives on the road surface for longer than is currently the case. These three methods are: pre-wetting the abrasive at the spinner or delivery device, heating the abrasive to a high temperature (about 180° C) just prior to application, and mixing the abrasive with water just prior to application. Pre-wetting has been shown to keep dry chemicals on the road surface more effectively than applying them in a simply dry state, but no study has been made of the effect of traffic on removing pre-wet abrasives from the road. Both of the other two methods appear to show substantial promise for keeping abrasives on the road (and thereby keeping the friction of the road surface at a higher level) for a longer period of time.

Given the promise shown by these three methods, it would be prudent to conduct some sort of test and evaluation to determine whether any of these three methods are feasible and effective in the context of Iowa Counties. This issue is considered further in Chapter 6.

CHAPTER 4: CURRENT PRACTICE IN IOWA

At present, the Counties and Cities of Iowa make substantial use of abrasives. A detailed survey (Nixon and Foster, 1996) taken in 1996 examined usage of abrasives (and other winter maintenance practices) for all 99 Iowa Counties and the 30 largest (populations larger than 25,000) municipalities in Iowa. 88 surveys (of the 129 sent out) were returned, providing a 68% response rate. The survey provides some insight into the use of abrasives in Iowa Counties.

Specifically, the amount of sand used in a typical winter for these agencies varied between 0 tons (reported by four agencies) up to 26,000 tons. Figure 1 provides a histogram of this usage. The average number of paved miles of road for each agency was 219, versus 635 miles of unpaved road. The histogram shows how much usage varies between agencies. However, of the agencies responding to the survey, fewer than ten indicated that they were using pre-wetting of their sand in the truck (most pre-wet sand stockpiles to avoid caking).

With such a wide range of applications, average values have only limited applicability, but it is worth noting that the average application rate (over the whole winter) per lane kilometer of unpaved road is 2,550 kg/lkm. This is not a high rate of application, in comparison to values noted above of 350 to 500 kg/lkm in a single application. It suggests about 5 to 10 applications of abrasives each winter over the whole network.

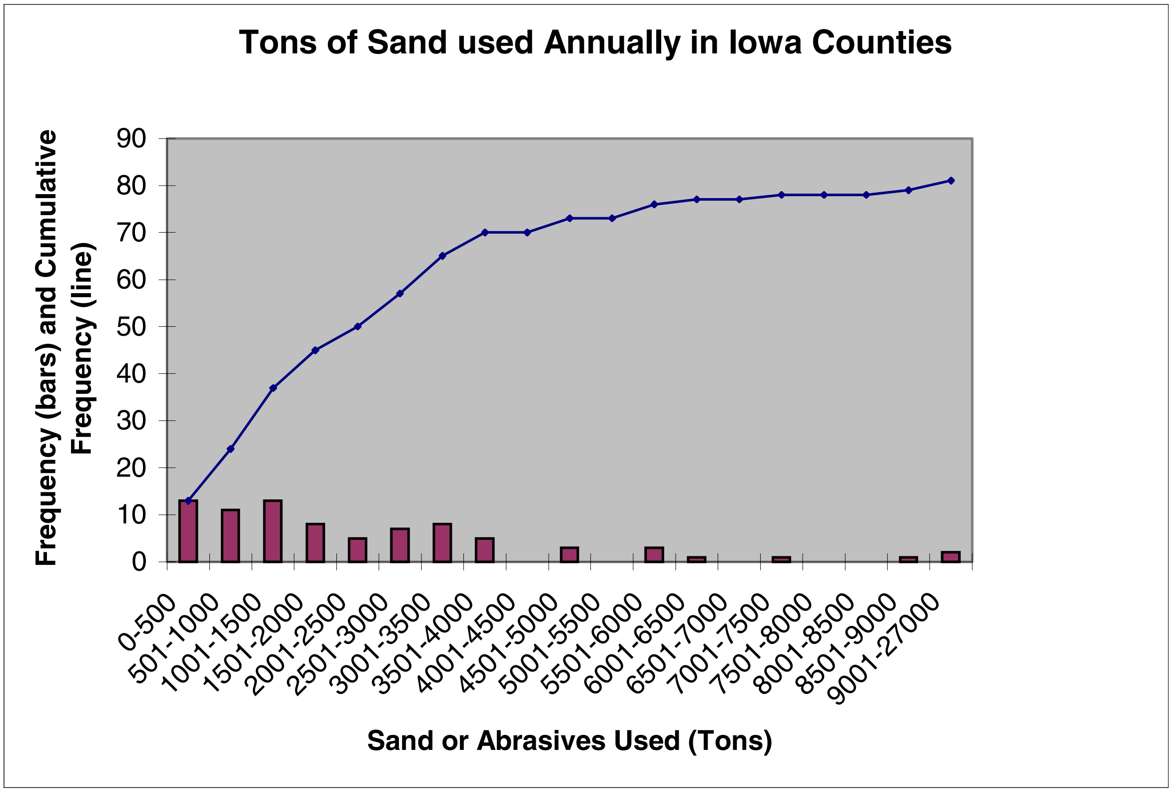

Figure 1: Annual Abrasive and Sand Usage by Counties in Iowa

In reality of course, not all county roads are treated with abrasives. Based on discussions with County Engineers and Directors of Public Works, as much as 75% of the roads in a County may not be treated at all with chemicals or abrasives. The only treatment may be grooming the snow-pack with a grader or underbody plow. Unpaved or gravel roads are not treated with de-icing chemicals at all (although many may have calcium chloride applied as a dust reduction treatment). The challenge facing the County Engineer is that people still travel these roads in winter, and expect levels of service that they find on paved roads elsewhere in the State. Such expectations may be unreasonable, but that doesn't stop the public from venting their feelings on the County Engineer!

CHAPTER 5: RECOMMENDATIONS FOR CHANGES IN PRACTICE

From the foregoing, it may appear that abrasives are of little use at all. Some caution is needed however. The studies quoted above show that on roads where vehicles travel at high speeds, abrasives do indeed have little value as friction enhancers, unless pro-active steps are taken to fix the abrasives in place. Absent such steps, any increase in friction levels from the abrasive application disappears after very few vehicle transits. However, abrasives are much more likely to remain on the roadway and act as friction enhancers on low speed roads (such as in towns) and at intersections. In developing recommendations for abrasive use, six different road types have been considered. These are: freeways, rural roads, rural intersections, high-speed urban roads, low speed urban roads, and urban intersections. At this stage, the recommendations are limited to dry application of abrasives. As noted above in Chapter 3, more novel applications methods (pre-wet, heated, or mixed with water) might allow abrasives to be used in applications where, under present circumstances, their use is not advisable.

The value of dry abrasive treatment on each road type will be discussed, and the results of this discussion will then be presented in a simple table.

Freeways

Freeways may be considered as divided arterial highways with full control of access. Such roads typical carry high AADTs (>10,000) and have speed limits of 55 or 65 mph in Iowa. Given the high speed limits and high traffic volumes, the use of abrasives is of little value for freeways. The friction increase due to application of abrasives will disappear in a matter of minutes. Only in special emergency situations should abrasives be used on such roads. Standard treatment for such roads would include plowing and application of chemicals to achieve bare pavement in a timely manner.

Rural Roads

Rural roads must be further classified into paved and gravel roads. However, both types of roads can expect to see high-speed traffic. In Iowa, the speed limit on such roads is typically 55 mph (88 kph). As above, this means that abrasives applied dry will simply not stay on the road for any reasonable amount of time. The approach to paved rural roads should be to use plowing and chemical applications to achieve bare pavement in a timely manner. For gravel rural roads, until such time as the novel methods described above are proven of value, the approach should be simply to groom the snow pack. The application of abrasives on hills and curves should only be done on low-speed low-volume roads.

Rural Intersections

Again, the issue of gravel versus paved roads must be taken into account for rural intersections. In this context, an intersection should only be considered "paved" if all roads intersecting at the location are paved. If any roads are gravel, then the intersection should be considered gravel.

In general, intersections (at least for the road segment that must stop or yield) are not high-speed traffic locations, thus abrasives could be placed "dry" if needed, but the preferred approach for paved roads is use of plowing and chemicals to achieve bare pavement. On gravel parts of intersections, abrasives may be applied over that part of the road where speeds less than 30 mph (48 kph) are expected.

High Speed Urban Roads

In this discussion, it is assumed that all urban roads (whether high speed or low speed) are paved. The differentiation between high and low speed is somewhat subjective, and no studies exist that have examined the effect of traffic speed on abrasive dispersion in any substantial detail. For the sake of this study, high-speed urban streets are defined as those with posted speed limits above 30 mph (48 kph). For these roads, there is no value in placing abrasives "dry." The winter maintenance methodology for such roads is to plow and apply chemicals to achieve bare pavement.

Low Speed Urban Roads

Here the issue of abrasive dispersion due to high-speed vehicle is somewhat diminished. However, abrasives should be limited to those parts of the road where braking, accelerating, or maneuvering are being done, and should only be used when it is likely to take a long time to bring the road surface to bare pavement (perhaps due to substantial ice accumulations or very low temperatures).

Urban Intersections

As for rural intersections, urban intersections are not high-speed traffic locations, thus abrasives could be placed "dry" if needed. However, they should only be used in situations where the intersection is likely to be snow or ice-covered for a longer than normal period of time, as above.

Table of Recommended Practice

Table 2 presents the recommended practices for abrasives application, classified according to road type and application method.

Table 2: Recommended Abrasives Application Practices

Road Type	**Use of Dry Abrasives**
Freeways	Inappropriate
Rural Roads, Paved	Inappropriate
Rural Roads, Gravel	Only on low speed sections (perhaps hills and curves)
Rural Intersections	Only on low speed approach length of gravel roads
High Speed Urban Roads	Inappropriate
Low Speed Urban Roads	Only in certain locations, and when snow pack will persist
Urban Intersections	Only when snow pack will persist

Using Salt/Sand Mixes

On paved roads, a number of agencies use salt/sand mixes (except in very cold conditions, or when drifting is a possibility). To the extent that the salt will act as a de-icer and thus eventually remove or diminish the snow-pack or ice cover, this practice is to be encouraged. However, it is much preferable to apply such mixtures pre-wet at the spinner, as they will then stay on the road after application, and the pre-wet with brine effectively "jump starts" the melting process.

Affordable Pre-Wetting

Many of the County agencies in Iowa have limited equipment budgets, and thus it is simply not useful to recommend the purchase of expensive equipment. This was a concern for with regard to recommending pre-wetting. However, the Iowa Department of Transportation (Smithson, 2000) has developed a specification for a simple tailgate mounted pre-wetting unit that can easily be self-fabricated. This may address the cost concern with regard to the use of pre-wetting. Nonetheless, issues concerning operator training, brine making, and the use of what for many crews will be novel technology remain. This is discussed further in Chapter 6.

CHAPTER 6: RECOMMENDATIONS FOR FURTHER STUDIES

The primary problem with using abrasives in winter maintenance is that the abrasives do not remain on the road surface under the action of (even low volumes of) traffic. Accordingly, if dry abrasives are to be used to provide friction as part of winter maintenance activities, then either repeated applications must be made, or friction levels (and thus road safety and drivability) will diminish rapidly over time. In general, neither situation is acceptable.

An alternative approach is to find a way of "sticking" the abrasives to the snow or ice-covered pavement more effectively. Three such approaches have been found in the literature, and offer promise of being effective. These are: pre-wetting the abrasives at the spinner, as they are placed on the road, heating the abrasives to high temperatures (about 180º C seems to be effective) just prior to being placed on the road, and mixing the abrasives with hot water (about 90º C) as they are placed on the road. Each works by melting some of the snow or ice around the individual abrasive particles, and then allowing this melt to refreeze, thus freezing the abrasive into the top surface of the snow or ice on the roadway.

While all three of these methods show some promise, none is fully deployed as part of the standard winter maintenance strategy for any agency either in the United States, or elsewhere around the world. Pre-wetting at the spinner is of course standard for some agencies when applying chemicals, but not when applying abrasives. Given this, before such practices are deployed in Iowa, a field trial seems appropriate. Further, a field trial will allow valuable experience to be gained with the equipment. The additional steps that each of these three methods involve over and above dry application of abrasives suggest added complexity that will need to be dealt with.

In addition, a field trial will address some of the cost issues that are currently unanswered. Although trials of the heated sand and the sand-water mix in Sweden showed excellent financial benefits, it is not clear that such benefits will be replicated in Iowa.

Accordingly, the following field trial program, which should take place over two winter seasons, is proposed. Four suitable stretches of gravel road, between one half and one mile in length, should be identified, with similar levels of traffic. Ideally, traffic should be between 250 and 500 vehicles per day. During the winter season, these four stretches of road should be treated with one of the four methods (dry abrasives, pre-wet abrasives, heated abrasives, and abrasives mixed with hot water). The friction of these road sections should them be measured either by measuring stopping distance, or by using a deceleration device such as the Coralba meter. This will allow the friction level of the roads to be determined as a function of time, traffic, and application method. Traffic on each of the four stretches should be determined by an automatic monitoring device.

Should it become apparent during the testing process that one of the methods is not effective, and its continued use places the public at risk, then that testing method will be discontinued. The experience of the equipment operators using the various types of equipment will be recorded, and any difficulties will be noted. Given that much of the new equipment is unfamiliar, some difficulties are to be expected, but if these difficulties persist over time, then they may be indicative of a flawed delivery method.

The goal of the research will be to determine primarily which of the methods (the three novel methods, together with the control method) provide acceptable levels of friction enhancement over time. In this regard, the aim would be to maintain the friction level achieved just after abrasive placement for a period of between 24 and 72 hours. A secondary goal will be to determine costs associated with operating each of the four methods.

If the research is successful, then after the study is completed it should be apparent which methods provide friction enhancement over an extended period of time. Such information will extend the fruitful use of abrasives into areas where 9see Table 2) their use is currently ineffective and thus unwarranted.

CHAPTER 7: CONCLUSIONS

On the basis of a review of both the existing literature, and the current practice of abrasive usage in Iowa Counties, a series of recommended practices for abrasive usage as part of a winter maintenance strategy has been presented. A primary result of this is that applying abrasives dry is of limited value in providing lasting friction enhancement. This represents a substantial change in current practice. Nonetheless, the results of a variety of studies are unequivocal in finding that abrasives applied to roads where significant traffic travels at high speeds are swept off the road rapidly, remaining in place (and providing friction enhancement) for somewhere between 10 and 100 vehicle passages, at most.

Given this evidence, and the environmental burden of abrasive usage, it is clear that alternative approaches must be found. Three possibilities exist for modifying the application of abrasives, so that abrasives will stay in place (and provide friction enhancement) longer. These practices are: pre-wetting the abrasives at the spinner, as they are placed on the road, heating the abrasives to high temperatures (about 180º C seems to be effective) just prior to being placed on the road, and mixing the abrasives with hot water (about 90º C) as they are placed on the road. These three methods have all exhibited the potential of keeping abrasives on the road surface (and thereby enhancing friction) for much longer than dry abrasives would remain, under the effects of traffic.

A field trial of these three methods has been proposed that could be undertaken on a gravel road (or on several such roads) during a forthcoming winter season. Such a field trial would establish how effective these three methods are at keeping a high friction level on a snow covered road, and would determine the best application rates to keep such high friction levels.

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