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An Environmental Method against Icing for Road Pavements
I- Development of Test Equipment and Procedure

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ABSTRACT

In cold regions, snow and ice in winter times can have serious threats on the road surface and driving conditions. Icing always occurs on road in winter. It hindrances traffic and causes traffic accidents. The grip is lessened between wheel tires and pavement surface by icing. In these cases, traffic accident risk on icy road pavement surfaces is very high. In general, mixture of abrasive granular materials and chemicals as salts are used to keep away snow and ice from bonding to the pavement.

The aim of this work is to introduce a new low-cost test equipment to evaluation the abrasion materials. The test equipment, Ice Melter Equipment Mechanism (IMEM), on the evaluation of the abrasive granular materials of snowy or icy pavement surfaces has been proposed for the first time. Working procedure of the equipment is also given in the study.

Keywords: Road icing, Deicing, Anti-icing, Abrasive materials.

1 INTRODUCTION

Weather causes a variety of impacts on the transportation system. While severe winter storms, hurricanes, or flooding can result in major stoppages or evacuations of transportation systems and cost millions of dollars, day-to-day weather events such as rain, fog, snow, and freezing rain can have a serious impact on the mobility and safety of the transportation system users. These weather events can result in increased fuel consumption, delay, number of accidents, and significantly affect the performance of the transportation system [1]. One of the most important problematic events is the icing for pavement surfaces in cold regions in winter.

Highway agencies face demands maintain or improve the existing winter roadway level of service. The impact of snow and ice storms has long concerned the travelling public. The demand for complete removal of snow from the all-weather roads grew yearly, and the need for bigger, more capable equipment and better removal techniques became apparent [2].

Winter maintenance is an important issue. Without close attention to the effective removal of snow and ice from streets, roads, and highways during periods of snow and icy conditions, local economies will suffer, traffic accidents will escalate, and most activities of individuals, industries, utilities, schools, and governments are handicapped in social and economic ways [3].

The road pavement is the actual surface on which the vehicles will travel. Its purpose is two fold, to provide friction for the vehicles and to transfer normal stresses to the underlying soils. It is generally of two types, rigid or flexible. Flexible pavement is built with several layers; the above layer, called surface course, which is made by hot mixture asphalt, the bottom layer, called base course, which is made by hot mixture asphalt or unbound granular material. The subbase course is the layer of material beneath the base course, which builds depending on subgrade bearing ratio and climatic factors.

In cold regions, icing always occurs on road in winter. It hindrances traffic and causes traffic accidents. It also damages roads after it thawed in spring breakup period [4]. First, roads covered with ice or snow is slippery and inherently less safe for driving. The number of accidents always increases during and just after winter storms [3]. Snow and ice control operations have two goals. First, make roadways passable. Second, provide adequate pavement friction to allow vehicles to brake, turn, and accelerate safely. There are three general strategies for snow and ice removal/control; Anti-icing—applying chemicals to prevent snow and ice from bonding to pavement. Plowing—removing accumulated snow and ice from pavement. Deicing—applying chemicals to break the bond between snow/ice and pavement. Generally speaking, anti-icing is used immediately before or at the beginning of a storm. Plowing is conducted when the storm is active or while the wind is still blowing. Deicing is conducted after the storm and when snow and ice are frozen solid to the roadway surface [5].

In contrast to anti-icing operations, a common procedure of traditional snow and ice control practice is to wait until an inch or more of snow accumulates on the pavement before beginning to plow and treat the highway with chemicals or abrasives [6]. The use of abrasives in winter maintenance is a well-established practice. The sand is intended to increase friction between vehicles and the pavement. The sand may be delivered mixed with salt [7].

When snow began to accumulate, agencies would typically perform mechanical removal of snow accompanied by deicing with chemicals or traction enhancement with abrasives. Some agencies did use chemicals to try to prevent snow and ice from compacting and adhering to pavement [8]. Salt is used to keep snow and ice from bonding to the pavement and to allow snowplows to remove ice and snow as quickly and efficiently as possible. Prewetted salt and liquid chemicals were used during the anti-icing experiments [9].

In this study, a new low-cost test equipment to evaluate the abrasion materials is introduced. Working procedure of the equipment is also given in the study.

2 HIGHWAYS AND WINTER CONDITIONS

The road pavement may be flexible or rigid and the selection of a pavement depends on various factors like type of load, volume of traffic, type of subgrade, life of road, funds available, availability of construction material, etc [10]. A flexible pavement is a multilayer structure composed of asphalt surfacing layer and combined unbound aggregate road-base, on a subgrade of natural soil [11]. Wheel loading is firstly met with wearing course in flexible pavements. The magnitude of load is distributedly transmitted to lower layers and to subgrade lastly. Flexible pavements must also carry the axle loading of vehicles as safety and economically [12]. The flexible pavements are composed of wearing course, base course, subbase and subgrade layers as can be seen in Figure 1 [13].

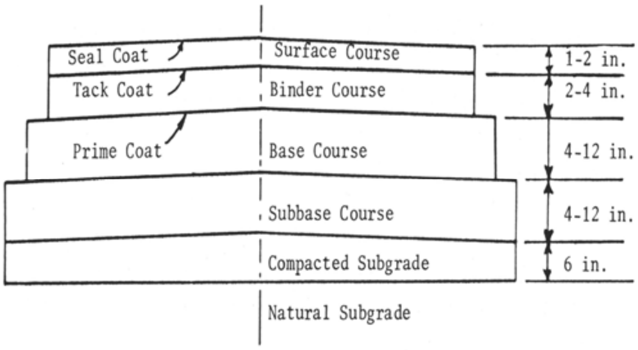

Figure 1. Typical Cross-section of Conventional Flexible Pavement

Road surface properties should be smooth for comfort and low vehicle operating costs, minimizing rolling resistance and therefore reducing fuel costs, tire wear and vehicle wear; able to provide a surface of sufficient friction between the tire contact patch and the surface to maintain control of the vehicle at all speeds and in all weather conditions; quiet, glare-free and able to create no spray under wet conditions; durable, resisting wear and deterioration of its required characteristics; economical to place and economical to maintain; and (preferably) capable of being re-used or recycled at the end of its useful life span [14].

"Weather" usually refers to the measurable or identifiable meteorological events that occur at a given site or in a given area at a particular point in time. Weather can be characterized by describing the meteorological elements associated with those events (e.g., precipitation type and amount, visibility, wind speed and direction, temperature, and relative humidity).

Roads must be cleared of ice and snow rapidly and efficiently both to provide a safe road surface for the driving public, and to ensure timely delivery of goods that are carried by road. Vehicle performance in winter conditions is largely determined by the low friction and deformable surface material that affects vehicle traction, motion resistance, haggling, and maneuvers [15].

Weather-related crashes are defined as those crashes that occur in adverse weather (i.e., rain, sleet, snow, and/or fog) or on slick pavement (i.e., wet pavement, snowy/slushy pavement, or icy pavement). Nearly 7,400 people are killed and over 673,000 people are injured in weather-related crashes each year. Each year over 17 percent of fatal crashes, 22 percent of injury crashes, and 25 percent of property-damage-only crashes occur in the presence of adverse weather or slick pavement. Most weather-related crashes happen on wet pavement and during rainfall. Seventy-five (75) percent of weather-related crashes occur on wet pavement, forty seven (47) percent happen during rainfall, fifteen (15) percent of weather-related crashes happen during snow or sleet, thirteen (13) percent occur on icy pavement, eleven (11) percent of weather-related crashes take place on snowy or slushy pavement and only two (2) percent happen in the presence of fog [16].

Road Weather Variables	**Roadway Impacts**	**Traffic Flow Impacts**	**Operational Impacts**
Pavement condition	• Pavement friction • Infrastructure damage	• Roadway capacity • Traffic speed • Travel time delay • Accident risk	• Vehicle performance • Driver capabilities/behavior (e.g., route choice) • Road treatment strategy • Traffic signal timing • Speed limit control

Table 1. Weather Impacts on Roads, Traffic and Operational Decisions [17]

3 CONTESTATION METHODS AGAINST ICING

Nearly all weather conditions affect the roadway environment in some way, typically by affecting visibility, surface traction, or maneuverability of vehicles. Winter weather conditions, including snow accumulation, freezing rain, icy surfaces, and blowing snow, have received the most attention by the transportation community because they can significantly impair the operability of the roadway system over a large region [18].

Roadway snow and ice control strategies used in winter maintenance operations can be classified into six general categories [9]:

- Anti-icing,
- Deicing,
- Mechanical removal of snow and ice together with traction enhancement,
- Mechanical removal alone,
- Traction enhancement, and
- Combinations of strategies.

Anti-icing techniques involve the application of chemicals to the pavement to lower the freezing point of water. Anti-icing is a snow and ice control strategy of preventing the formation or development of bonded snow and ice to a pavement surface by timely applications of a chemical freezing point depressant. Tactics employed during anti-icing operations consist of chemical applications coordinated with plowing. As a result, the road stays wet or slushy, rather than icy. This makes driving safer and plowing operations easier. For an anti-icing strategy to work, the chemicals must be applied at the right time. By using advanced weather information technologies, highway departments can pinpoint exactly when and where to begin their anti-icing operations. Deicing is a snow and ice control strategy of removing compacted snow or ice already bonded to the pavement surface by chemical or mechanical means or a combination of both. Mechanical removal of snow and ice together with traction enhancement is a strategy in which abrasives or a mixture of abrasives and a chemical are applied to a layer of compacted snow or ice already bonded to the pavement surface that may or may not have been partially removed by mechanical means (plowing and scraping). This strategy provides an increase in the coefficient of friction for vehicular traffic, although this increase may be short lived. Abrasives play an important role in snow and ice control operations. Researches and practices clearly indicate that abrasives can improve traction on icy or snow-covered roads. Abrasives, by themselves, are not ice control chemicals and will not support the fundamental objective of either anti-icing or deicing. Mechanical removal alone is a strategy that involves the physical process of attempting to remove accumulated snow or ice by means such as plowing, brooming, blowing, and so on, without the use of snow and ice control chemicals. This strategy is strictly a physical process that has some merit during or after frozen precipitation has occurred at very low pavement temperatures [9].

Other techniques enhance the traction of snow and ice surfaces. For example, mechanical roughening, grooving, or texturing provides a small level of traction and directional stability enhancement. This technique, however, is not suitable for higher-volume roads as its effect is short lived, but may provide an option in environmentally sensitive areas with low traffic volume [9].

Chemicals and abrasives are quite critical materials because of their harmful environmental effects and high costs. Finding a local material, which is not affecting the nature in a bad way, not damaging the superstructure elements and has a appropriate cost, will provide a significant benefit to country economy.

The most common technique for enhancing friction on a snow or ice surface is to apply abrasive materials such as sand, cinders, ash, tailings, and crushed stone. These materials may be applied straight or with varying amounts of ice control chemical in a mixture [9].

Common to many snow and ice control operations is the use of abrasives. It is recognized that abrasives may be necessary when a rapid increase in friction coefficient is required, particularly at temperatures so low that chemical action is slow, and in conditions where snow or ice is strongly bonded to the pavement and cannot easily be removed. As these latter conditions are more likely to occur in the course of deicing, abrasives treatments can be an important tool for deicing operations. Abrasives are not ice-control chemicals, however, and will not support the fundamental objective of either anti-icing or deicing. Their sole function is to increase the coefficient of friction. This increase may be short lived, because traffic will rapidly disperse abrasives [6].

In the study, friction experiments have been done over Isparta-Karakaya pumice waste and sand which is used as an abrasive material for highways in Turkey. In order to compare, abrasion amount of each material on the ice surface has measured [19].

4 A NEW MODEL OF LOW-COST ABRASION TEST EQUIPMENT

Some problems appear on the flexible pavements with snowing in winter. As the result of the friction reduction between vehicle and road surface, vehicles are either not controlled or not drive. Highway agencies use the abrasive materials for solving the friction problem for years. Due to the properties of abrasive material type, friction value of road surface texture and the amount of the dissolved water may be different.

In the study, a new low-cost abrasion testing apparatus was developed for testing the abrasive materials used in ice covered road surfaces. This test equipment is both low-cost and user friendly with its simplicity as can be seen from the Figure 2.

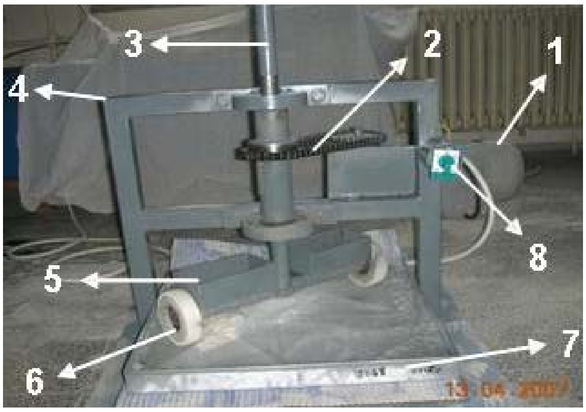

Figure 2. New low-cost test equipment

The equipment is composed of eight segments. As seen from the figure, these segments are:

1. Motor and reducer,
2. Chain and gears,
3. Rod for ensuring the up and down movements,
4. Main body,

5. Pans for putting weights,
6. Rubber tire in 10 cm diameter and 2.5 cm width,
7. 48x48 cm square tray with 4 cm depth,
8. On/off button.

4.1 Testing Procedure

Three trays are filled with water at same levels for producing ice. Trays are kept in freezer for 21 hours at -17^{o}C under constant temperature conditions. Abrasive materials within new testing equipment to be tested are performed the sieve analysis test. Gradations of the abrasive materials are standardized as Table 2.

Sieve	Passing weights (%)
No 4	%100
No 8	%55
No 10	%44
No 40	%7
No 200	%3

Table 2. Material gradation

Trays are weighed with and without ice. Before the test, the tray is kept for 10 minutes with ice under test temperature. Then tray with ice is put into the test equipment. A rubber pad is placed under the test equipment as vibration damper (Figure 3).

In Turkish Highways, 360 kg abrasive material is spread per kilometer under snow conditions. Because of this, 60 g abrasive material was used for the 48x48 cm^2 tray for testing in adapting the real conditions to testing conditions. After the tray is put into the equipment, abrasive material specimen is sprinkled on the icing surface where the wheels are passed (Figure 3). After the abrasive material is sprinkled, the test is started and continued for 10 minutes duration (Figure 4).

Figure 3. Materials preparation

Figure 4.Test equipment application

A standard vehicle weighs around 1000 kg, each wheel carries around 250 kg of weight. The wheel that is used for the test is one sixth of a standard wheel. Thus, test wheel carries 42 kg. Scope of this study is to figure out the amount of melted ice under the test wheel.

When the pans are empty, each wheel applies load of 3 kg. With 1, 2 and, 3 kg of weights, loads of 4,5 and, 6 kg are transmitted to icing surface (Figure 5). Water and wet abrasive material on the icing surface are taken from the tray after the equipment is performed for 10 minutes. All materials taken from the tray are put into an oven for determining the dissolved water amount. For checking the results, tray and left material in the tray also weighed. After the materials put into the oven, they are kept for 24 hours at 110 °C±5°C, and then the materials are weighed again.

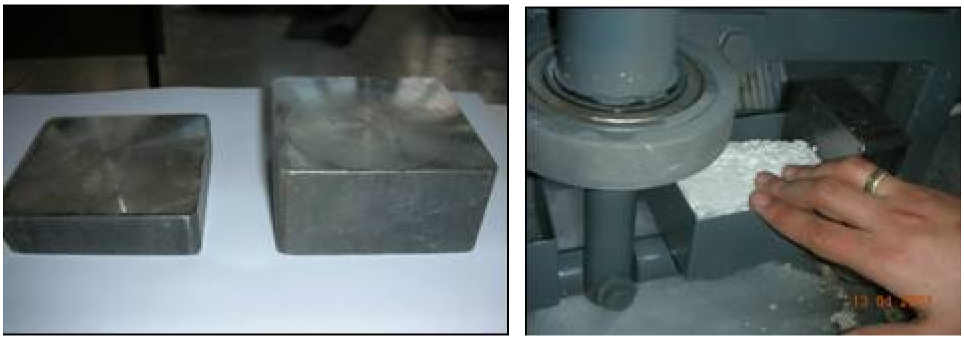

Figure 5. Pans and weights

After all test stages are completed, melted water amount from abrasive materials is determined as below:

$$A = \text{tray} + \text{ice (in gram)} \qquad (1)$$
$$B = A + 60\text{ g} \qquad (2)$$
$$C = \text{tray} + \text{ice after test} \qquad (3)$$
$$D = C + \text{dry materials from oven} \qquad (4)$$
$$E = B - D \qquad (5)$$

The test is repeated without abrasive material and ice mass is kept for test duration In these situations, for the without abrasion materials:

$$AA = \text{tray} + \text{ice} \qquad (6)$$
$$CC = \text{tray} + \text{ice after test} \qquad (7)$$
$$F = AA - CC \qquad (8)$$

And not to perform the test

$$AAA = \text{tray} + \text{ice} \qquad (9)$$
$$CCC = \text{tray} + \text{ice} \qquad (10)$$
$$G = AAA - CCC \qquad (11)$$

For every different weight, melted water amount by abrasive material is calculated as

$$S = E - F - G \qquad (12)$$

During the planning of the test equipment, weight of a standard car is 1 000 kg and a wheel of the car is weight of 250 kg. The diameter of a car wheel is 60 cm. For the test equipment, parameters are 1 to 6 of standard real parameters. In this context, wheel diameter is accepted as 60/6 = 10 cm. After a lot of applications, the new tester, IMEM, is extremely beneficial for understanding the ability of the granular abrasion material used for icy road pavement surfaces.

5 CONCLUSION

Traffic accident risk on snowy and icy road pavement surfaces is very high. Hence, road pavement winter maintenance works with abrasives and chemicals leads to rapid reduce of the traffic accident risk. Here, we have developed a new low-cost test equipment for abrasive materials used for snowy and icy pavement surface in cold regions. This test equipment is small size, simple, and user-friendly. By using this test equipment, all kinds of abrasive materials with or without chemicals for icing pavement surface can be tested in view of efficiency. In the study, this new testing equipment is introduced and testing procedure is given.

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