ID: 0007

An Environmental Method against Icing for Road Pavements I- A New Icy Abrasion Material and Analysis

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ABSTRACT

With more heavy snow and the freezing temperatures, road pavements become very slippery, and some may be difficult to drive on. Drivers should go slow and expect delays. In this context, in cold regions, winter maintenance practices include plowing, sanding to improve traction and applying winter anti-icing liquids. Winter liquids are used to melt snow and ice on the road surface to help prevent snow and ice from sticking to the road and in conjunction with sand to help the sand stick to icy roads. The combination of practices used at each site may vary to accommodate the different climate, traffic and storm conditions. While road salt is also an effective tool for melting snow and ice, it also causes severe rust damage to vehicles, degrades the road surface, corrodes bridges and may harm roadside vegetation. Therefore, abrasive granular material to be used has important role to prevent snow and ice from sticking to the road surface. But generally used sand tends to be easily trafficked from the road surface. Here, a new icy abrasion material not to be easily trafficked from road surface is introduced and performance test is applied by using new testing equipment, "Ice Melter Experiment Mechanism" (IMEM) and test results are analyzed.

Keywords: Road icing, Abrasive materials, Pumice waste.

1 INTRODUCTION

Roads have strong importance for mobility of people and transport of goods throughout world. Snow and ice are of negative effects on the road pavement surface and driving conditions. Keeping roads from ice and snow has therefore a high significance.

The consequences of icing of pavement are serious and varied. They include safety risks to humans, impeded vehicular motion, and the deterioration of highways and bridges. The most basic effect of snowy and icy road pavement surface is that the grip is lowered between wheel tires and pavement surface. Grip is at its lowest values under snowy and icy winter regions. Road pavement conditions have especially a strong effect on traffic flow, driving behaviour and road capacity. Stopping distances on snowy and icy road pavement surfaces are also much longer than they are on dry road pavement surfaces. Hence, traffic accident risk on snowy and icy road pavement surfaces is fairly high.

Friction is an essential parameter for winter maintenance. Low friction is a problem for traffic flow and safety on cold regions. Friction is the most important factor defining the conditions of icy road pavements.

The primary purpose of highway winter maintenance is to improve the safety of road users. Although road traffic accidents will always occur, regardless of weather conditions or the level of maintenance afforded a network, the incidence of road traffic accidents adversely affected by ice, frost or snow should be reduced by the undertaking of preventative and reactionary winter maintenance.

There are a lot of methods against the icing problem at pavement maintenance in winter season. Anti-icing, de-icing and abrasives are used for this purpose. The aim of de-icing applications is to break the bond between ice and pavement, and thus make scraping away of the ice easier [1]. Roadway 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 [2]. Abrasives are used to improve friction on road pavement surfaces. Finally abrasives increase friction, providing better traction and control for vehicles.

There is increasing concern in using waste materials in highway construction and maintenance. Industrial waste slugs are typical examples of this. Waste granular materials have especially a potential for abrasion of pavement surface. Here, pumice waste is introduced for icy road pavement surfaces as a new abrasion material. Pumice waste was tested by using new low-cost abrasion tester, “Ice Melter Experiment Mechanism” (IMEM).

2 TEST METHODS OF MATERIALS USED FOR ICING

Nowadays there are important efforts to avoid the negative effects of icy and snowy road pavement surfaces in winter conditions. Especially chemicals as deicers or anti-icers are researched to enhance the ability of materials applied to pavement surface. Abrasive materials with or without chemicals are used to improve friction on road pavements, but these tend to be easily trafficked from the road surface [3].

Researchers throughout the world are continuously identifying new methods that have the potential to improve efficiency and reduce the amount of deicers to maintain road pavements in the winter. But there are concerns about corrosional effects on vegetation and contribution to water quality deterioration for salts or other chemicals used as deicers. All de-icing strategies have a potential environmental impact risk [3].

Test methods are designed to evaluate the performance of deicers and anti-icers in general. Among the test methods are Ice Melting Test, Ice Penetration Test, and Ice Undercutting Test.

Ice Melting Tests are designed to quantify the volume of ice that can be melted by a unit of deicer at varying test temperatures. This test is designated both for solids and liquids. In general, an ice sample is created in a standard plexiglas dish. After application of a measured amount of chemical, the amount of brine developed (mix of chemical and water) is recorded at time intervals up to 60 minutes. This testing is usually performed at four different temperatures: 25°, 20°, 15°, and 5° F [4].

Ice Penetration Tests are performed both for solids and liquids. This test is designated to assess the thickness of ice that can be penetrated by a deicer to allow it to reach the pavement surface and start debonding. Five repetitions of penetration are usually made for each chemical [4].

Ice Undercutting Test is designed to assess the amount of ice that can be loosened from the pavement by undercutting at the bond interface. At least five repetitions are made for undercutting for each chemical. These three tests can be grouped to get an overall effectiveness rating for a set of chemicals [4].

Except these tests, there are a few tests applied for chemicals in addition: Friction Test, Frost Formation Test, and Controlled Site Testing. However, there is no test for abrasive materials applied for icing conditions. In the study, a new abrasive material is introduced and tested by using new low-cost test apparatus, IMEM.

3 PUMICE

Pumice is amorphous foam produced during volcanic eruptions. It is constituted mostly of silica and alumina in relative amounts varying according to the geological area of origin, and also includes other chemical species, such as different oxides and water [5]. Pumice is a volcanic rock of which porous structure is formed by dissolved gases precipitated during the cooling as the lava hurtles through the air. The connectivity of the pore structure may range from completely closed to completely open [6].

Pumice is formed during explosive volcanic eruptions when liquid lava gets into the air as a froth containing masses of gas bubbles. As the lava solidifies, the bubbles are frozen into the rock. Any type of igneous rock — andesite, basalt, dacite or rhyolite — can form pumice given suitable eruptive conditions. When larger amounts of gas are present, the result is a finer-grained variety of pumice known as pumicite. It is considered a glass because it has no crystal structure. Pumice varies in density according to the thickness of the solid material between the bubbles; many samples float on water. The cellular structure of pumice is created by the formation of bubbles or air voids when gases contained in the molten lava flowing from volcanoes become trapped on cooling. The cells are elongated and parallel to one and another and are sometimes interconnected. They may be small and big size [7].

The main use for pumice continued to be as an aggregate in light-weight building blocks and assorted building products. Other major applications for pumice and pumicite include abrasives, absorbents, concrete aggregate and admixture, filter aids, horticulture (including landscaping), and the stonewashing of denim. Imports were used primarily as a light-weight aggregate, but a small percentage of pumice imports were used in abrasive applications [8].

Crushed and screened pumice is used in the construction industry in light-weight concrete, light-weight prefabricated building elements, wall plasters and internal and external masonry, and structural masonry elements. Pumice is also used in denim and garment washing, polishing silverware, glass, mirrors, and base metal, plastics manufacture (in tumbling operations and operations where an abrasive is required), manufacture of abrasive wheels, railway carriage cleaning, as a floor absorbent, cosmetics, dental supplies, pastes, face cream bases, when added to soap, it makes an excellent exfoliating or scrub bar and etc. Pumice is searched and used in various other sectors.

4 PROCEDURE BRIEF AND EXPERIMENTAL STUDY

In the study, pumice waste belonging to Isparta-Karakaya region of Turkey is introduced as a new abrasion granular waste material. In order to make a comparison between Isparta-Karakaya pumice waste and sand which is regularly used as an abrasion material, each of the material's abrasion amounts has been tested with a new experimental device which is called as "Ice Melter Experiment Mechanism (IMEM)".

Before starting the experimental works, abrasive materials that will be used in the study have been prepared. By sieve analysis, pumice waste and sand's gradation has been assigned to desired conditions (Table 1). After that, 60 gr specimens determined in testing procedure have been prepared from each of the abrasive material.

Sieve	Passing Material Percentage by Weight
No 4	%100
No 8	%55
No 10	%44
No 40	%7
No 200	%3

Table 1: Prepared abrasive gradation

Trays, which will be used for making ice, have been weighed empty and values have been written on the tray with the tray number (Figure 1).

Figure 1. Tray samples

One day before the experiment, three of the trays have been filled with the same amount of water and put into the deep freezer. It is very important to get homogeneous ice blocks. All the trays, which will be used on the next day, waited for 21 hours in the deep freezer at -17 ^{o}C under constant temperature conditions before the experiment time (Figure 2).

Figure 2. The deep freezer and the water filled tray

On the experiment day, the trays have been taken one by one for each of the test. Every tray has been weighed with the ice inside it immediately after it had been taken from the freezer. Tray number, empty weight, full weight and the temperature of the room were noted to experimental results page. For a better road condition modelling, the tray has waited for 10 minutes on a smooth surface to get some wateriness (Figure 3).

Figure 3. Tray and ice on a smooth surface

After the 10 minute waiting period, tray has been taken to IMEM. In order to avoid concussion, movement amortizer sheet had been put under the tray and the IMEM. 60 gr of sand or pumice specimen has been poured onto located ice block through the track of wheel (Figure 4).

Figure 4. Placement of abrasive specimen onto ice surface

With switching on the device, wheels have started to turn over the abrasive covered ice surface (Figure 5). As a constant, working time of the device has taken 10 minutes.

Figure 5. Working experimental mechanism

Experiments have been done in 4 different weights: when the scales were empty, 1 kg per scale, 2 kg per scale and 3 kg per scale. Without any weight in the scale, the device was affecting 3 kg per wheel. By using 1,2 and 3 kilograms, 4,5 and 6 kilograms of load had been simulated.

After the working period of IMEM, the tray has been taken immediately and the water-wet abrasive mixture has been put in a plate in order to wait 24 hours in 110 ± 5 °C in the stove. Tray with the ice block left behind has been weighed and the result was noted to the experimental results page. On the next day the plate has been taken from the stove and the weight of dry abrasive was noted to the results page as well.

Experiments have been done three times for each of the intended weight for both pumice and sand. Additionally experiments have also been done three times for without material situation. For determining the melted water amount without any experimental device, tray with ice also waited for 20 minutes (10 minute waiting time+10 minute device time)on a smooth surface and melted water amount has been noted to the results page for calculations.

In the experiments which are using abrasives;

A = Tray + Ice
B = A + 60
C = Tray + Ice without abrasive and melted water after the test
D = C + dry abrasive taken from the stove
E = B - D

In the experiments which are not using abrasives;

AA = Tray +Ice
CC = Tray + Ice without melted water after the test
F = AA - CC

After the 20 minutes of waiting time without any experiment;

AAA = Tray + Ice
CCC = Tray + Ice without melted water
G = AAA - CCC

The amount of water produced from each of the abrasive for each of the weight is:

S = E - F - G

4.1 Experiments with comparison material

For the experimental studies, limestone granular material from Isparta-Minasım region of Turkey was used as a comparison. IMEM test results are shown in Table 2.

Applied Weights (kg)	Melted ice amount (g)
3	29
4	39
5	51
6	59

Table 2: Isparta-Minasım limestone sand, ice melting test results

One can show these results in a graphic from Figure 1.

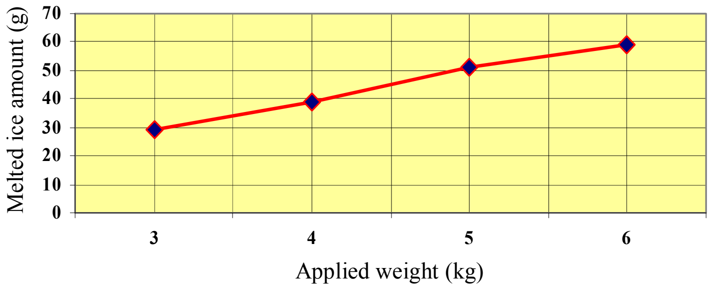

Figure 1. Melted ice amounts for Isparta-Minasım limestone material using IMEM

In normal conditions, weight of a car can be considered 1 ton (250 kg per wheel) and the diameter of a wheel can be measured 60 cm. Because of planning to use 1/6 ratio in the experimental works, diameter of the wheel has been used as 10 cm and the weight that effects to one wheel has been taken as below:

$$\frac{250}{6} = 42 \text{ kilograms}$$

Due to the overage of the weight for IMEM, if the melted ice amount for 42 kg is desired to be calculated, a curve formulation has to be taken from the diagram below.

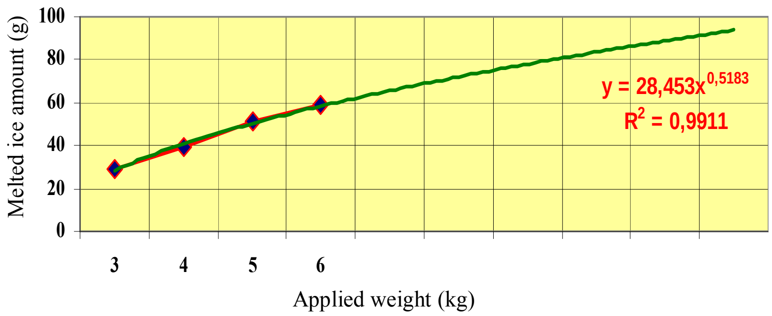

Figure 2. Obliquity line over Isparta-Minasım limestone material

If 42 kg wheel load is applied to curve formulation;

$$y = 28{,}453x^{0{,}5183}$$
$$y = 28{,}453 \times 42^{0{,}5183}$$
$$y = 197 \text{ gram}$$

In normal conditions one wheel can melt 197 grams of ice by using Isparta-Minasım limestone in IMEM.

4.1 Experiments with pumice waste

Ice melting test results obtained from Isparta Karakaya pumice waste are shown in Table 2.

Applied Weights (kg)	Melted ice amount (g)
3	15
4	19
5	32
6	40

Table 2. ice melting test results of Isparta-Karakaya pumice waste

These results can be shown in a diagram from Figure 3. Melted ice amounts for 42 kg are given in Figure 4.

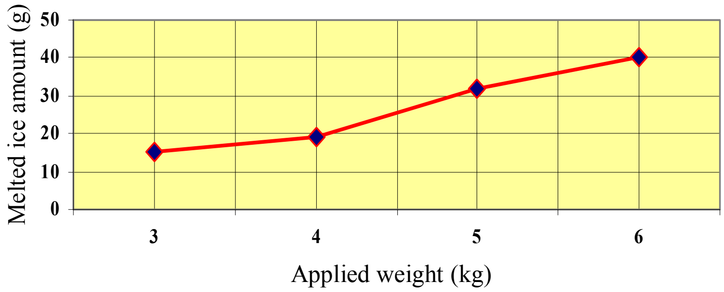

Figure 3. IMEM test results for Isparta-Karakaya pumice waste

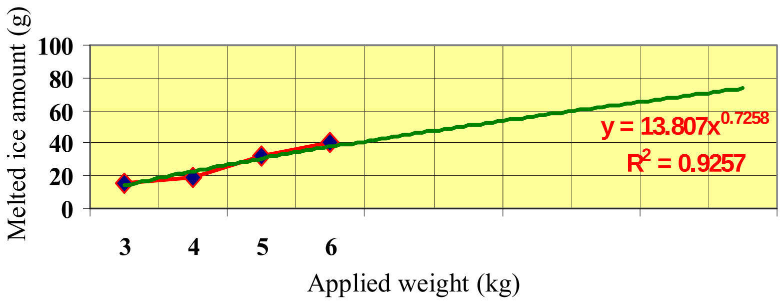

Figure 4. Obliquity line over Isparta-Karakaya pumice waste results

$$y = 13{,}807x^{0{,}7258}$$
$$y = 13{,}807 \times 42^{0{,}7258}$$
$$y = 208 \text{ g}$$

In normal conditions one wheel can melt 208 grams of ice by using Isparta-Karakaya pumice waste in IMEM.

In spite of sand's better experimental test results in all the weights, pumice had produced an increasing behavior through the increasing load quantity. Eventually at a specific weight, pumice has reached to sand's melting value and continued to give better results. As seen during the experimental works, while sand material particles were trafficking easily, pumice waste material has broken into small pieces and held onto ice. Because of the importance of continuous friction on icy surfaces, it can be said that, pumice waste can be more useful in winter conditions as an abrasion material. Moreover, the pumice waste used is carried with melted water outside the road surface. Pumice is used as manure in agriculture. Hence, carried icy abrasive pumice waste will provide additional contribution to roadside vegetation as manure.

5 CONCLUSION

Weather significantly affects the safety and capacity of the highway roads. Weather conditions often cause the reducing road capacity, increasing travel times, contributing to chain reaction accidents. People can suffer from delays on the nation's highways and principle arterial roads because of the fog, snow, and icy road surfaces. Abrasive granular materials play an important role to prevent snow and ice from sticking to the road surface. But generally used sand tends to be easily trafficked from the road surface. In this study, pumice waste as a new icy abrasion material is introduced and performance analysis of the material is applied by using new testing equipment, "Ice Melter Experiment Mechanism" (IMEM). While sand material particles were trafficking easily, pumice waste material used in the study has broken into small pieces and held onto ice. Pumice has also high abrasion property. Because of the importance of continuous friction on icy surfaces, it is shown from the study that pumice waste can be more useful in winter conditions as an abrasion material.

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ACKNOWLEGEMENTS

This research supported by Suleyman Demirel University Scientific Research Project Unit (BAP).