Comparing the methods applied to highways in the fight against snow in the Eastern Anatolia region of Turkey

M Y Çodur

Erzurum Technical University, Civil Engineering, Transportation Department, Erzurum – 25050, Turkey
[E-mail: mycodur@erzurum.edu.tr]

Received 02 April 2019; revised 08 August 2019

Climate changes are very important for traffic safety in both developed and developing countries. Traffic safety has adversely been affected in areas with a high incidence of snow, ice and serious traffic accidents have taken place. In order to prevent these accidents in Turkey, General Directorate of Highways and local municipalities use conventional and modern methods to reduce snow and ice effect. Some of the conventional methods are temporary solutions and damage on both road surface and environment. Modern methods also have application difficulties. Nowadays, different methods have been developed to prevent snow and ice on highways. The newest of these methods are detecting and preventing icing system. In this study, the conventional and developing modern methods were compared in the cities which are included in the task area of 12th Regional Directorate of Highways and were under the heavy effect of snow and icing. As a result, the effective methods in fighting against icing were determined and compared.

[Keywords: Analysis, Continental climate, De-icing, Highway safety, Snow]

Introduction

Snow and ice which occur due to low temperature cause some problems in transportation in many areas. The most important of these problems are ice on the road surface in heavy snowfall areas and gas emissions due to heavy traffic\(^1\). Snowfall and icing prevent traffic-flow safety and substantially reduces the level of service on road, reducing the friction coefficient between the vehicle wheel and the road platform. Friction control cannot be provided in these roads and therefore, safe driving conditions cannot occur. These lead to serious traffic accidents where lives and property losses occur. In cities, where heavy snowfall and extreme low temperature occur, transport departments of The General Directorate of Highways (GDH) and local municipalities use various methods to provide road safety and traffic flow on roads against the harsh winter conditions\(^2\). The most important determinant in the fight against winter conditions in transportation is to remove snow and ice from the roads as quickly and effectively as possible\(^3\). The first conventional method of fight against snow and ice is plowing and salting. Although salt is thought to be advantageous in terms of cost, the damage in the environment and the road infrastructure are being discussed. Due to these negative aspects of salt, different conventional methods have been developed. Some of them are sanding, wetted sanding and warm wetted sanding methods. For a long time, numerous studies mentioned below have been undertaken to fight against snow and ice.

The initial studies regarding ensuring road safety and fighting against icing traces to the 1970s. In one of the initial samples of these studies performed in order to investigate the effect of hardness of aggregate on friction. Furbush\(^4\) revealed that hard materials yield more sliding resistance on the roads without snow and ice than soft materials. Gray and Male\(^5\) emphasized that sands, widely being used in winter maintenance work are easily thrown off the road platform and passage of ten and twelve vehicles is enough for sand drift.

Regarding the studies for detection of the environmental effect of sand; Center\(^6\) and ASTM\(^7\) suggested that friction provider materials can obstruct rainwater flow holes and sewage and abrasive material
can be splatted under the wheel loads. Hallberg and Henrysson\(^9\) applied heated sanding and warm wetted sanding methods together with conventional methods on four different types of materials in their studies. In both methods applied for the first time, friction could be efficient on the road surface for a few days. Nixon\(^9\) stated in his study that abrasive materials are more expensive than salt and as well as the lack of their contribution to traffic safety, it has been failed in recollecting, cleaning and retrieval of them and he concluded that “abrasive materials use in winter maintenance work must be reduced”.

Investigations have been performed on environmental harmful effects of salt rather than on its implementation, in the studies regarding salt. Mangold\(^10\) and Kasperovicius & Oskinis\(^11\) revealed in their study that as well as salt is easily applicable and low cost, application temperature can melt ice until minus 10 degrees but it is not effective at lower temperatures. Also, they suggested that melting range of salt could be extended adding another chemical material to salt after minus 4 degrees. In Vaa’s\(^12\) study, he applied a warm wetted sanding method on intercity roads and other roads in Norway and revealed that warm wetted sanding method yields approximately desired friction value in terms of traffic safety. In the study of Vaa\(^12\), the friction coefficient of the method between the road surface and vehicle wheel was observed at certain intervals in the adverse winter conditions, on a road platform where Annual Average Daily Traffic (AADT) volume is 1200. During this observation, the first measurements were performed at certain times of the day and 5 days later a final measurement was made for sand and effectiveness of sand on the surface. It was seen in the last measurement that despite most of the sand got away from the road, there were sands on the road platform enough to increase the coefficient of friction. It was proven in this study that the wetted sanding method is much better than other methods in terms of durability\(^12\). As well as the conventional methods applied in fighting against icing, the methods have recently been developed in the countries with severe winter conditions, notably in Norway. These are wetted sanding and warm wetted sanding methods. Wetted sanding and warm wetted sanding have advantages in terms of cost and traffic safety compared to plowing and salting methods.

Kuloglu and Kok\(^13\) experimentally investigated the effects of salt for asphalt coating. It was explored that salt, which has been used to reduce and prevent the frost effect in winters, forms a solution, melting on the road platform and causes serious damage, leaking through concrete asphalt pavement.

Compared with conventional methods for snow and ice control (e.g., deicing and sanding), anti-icing (if applied appropriately) can lead to decreased applications of chemicals and abrasives, decreased maintenance costs, improved level of service, and lower accident rates\(^14\).

Anti-icing, a proactive snow and ice control strategy that is sometimes practiced as the first line of defense in a winter maintenance operation, came into practice during the 1990s. As anti-icing is the most commonly conducted, a small amount of liquid chemical is applied to the roadway or bridge deck prior to a storm to prevent ice from forming a bond with the surface. The benefits of anti-icing are well documented in national studies, manuals and in field tests conducted by various state departments of transportation\(^15\).

Wright et al.\(^16\) examined the influence that the chemical modifications have on the durability of the pavement surface course. The study has demonstrated that specific low surface energy materials (sodium formate and sodium silicate) can be incorporated into pavement surface course to reduce the adhesion between ice and the pavement surface, thereby allowing the ice to be easily removed.

**Materials and Methods**

Notably, the Eastern Anatolia Region in Turkey stands out with harsh climate and snowfall in winters. In this context, it is a region where heavily been struggled with snow in Turkey. Nowadays, in Turkey, as in many countries, conventional methods have been used for fighting against icing. GDH have 18 regional directorates in the total and central office is in Ankara. One of the offices in Eastern Anatolia is the 12th Regional Directorate and is located in Erzurum (Fig. 1). This region covers an area of 38,000 km\(^2\), all 2 provinces (Erzurum, Ağrı) and a part of 4 provinces (Artvin, Bayburt, Erzincan, Kars). It has the 1,517 km state road with a population of 1,312,755 and has a total of 2,216 km of the road network, of which 699 km is the provincial road. In this region; population per km\(^2\): 34.5 people, road per km\(^2\): 57.5 m, number of vehicles registered in the traffic: 132,375(ref. 17).

Table 1 is an example of which method should be used depending on temperature and weather conditions. Winter conditions are very severe in the
regions and in Table 2 and 3 show that some
temperature of measurements of Erzurum and Ağrı
provinces. These provinces included in the task area
of the 12th Regional Directorate of Highways located
in Eastern Anatolia Region of Turkey, which has
different climate types due to its geographical location
and formations, are the country’s highest and coldest
cities. These cities covered with snow for 95 to 125
days a year are those where adverse climatic
conditions prevalence due to the high altitude. The
conventional methods have been used for elimination
of the negative effects of winter conditions in these
cities where snowfall and icing frequently occur.
Turkey’s average annual numbers of days covered
with snow are shown in Figure 2. As can be seen, the
average number of days covered with snow in
Erzurum is between 97.4 to 111 days and Ağrı is
between 112 to 125 days. These numbers are higher
than in many cities in Turkey.

Utilizing these tables and figures, it can be seen
that the winter conditions are severe in these regions.
Therefore, the fight against snow and ice in these
regions has become an important issue and continues
to be effective. Due to the geographical nature of the
region, the methods and materials used must be
specific to that region. However, if specific methods
and materials cannot be developed, what is available
should be evaluated in the best possible way. These
available methods used worldwide are examined in
detail in this paper.

Many methods have been used in the World to
ensure traffic safety fighting against icing. These
methods are conventional methods such as plowing,
salt, sand, wetted sanding, and warm wetted sanding
methods. In addition, warm wetted sanding, a special
application of conventional methods. Some of the
modern methods such as electrically conductive
asphalt coating (snow-free) systems, spraying and
detecting systems and preventing systems are used in addition to conventional methods. Snow and ice fighting methods are mentioned below.

**Plowing:** Plowing is the process of scraping and cleaning on the road using human power, tools, and vehicles to remove the snow and ice effect on the road. To ensure traffic safety on highways, snow and ice should be cleaned from the road surface immediately after a snowfall. Reduced friction coefficient due to the effect of snowfall, it can be recovered to acceptable levels by removing snow and ice from the road surface. Plowing is generally accepted as the most effective technique for snow and ice control.

Plowing can be extremely effective when ice or compacted snow is present on the pavement surface. A variety of road cleaning vehicles are used in plowing methods. These vehicles can be used to remove snow and ice on the road and salting. The blades in these vehicles may vary from region to region and there are many studies in this area.

**Salting method:** Salt was first used for snow and ice control in the 1940s, but it didn’t use become widespread until the 1960s. Removal of snow on road

---

Table 2 — Erzurum Ağrı’s maximum temperature measurements

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average minimum temperature (°C)</strong></td>
<td>-13.9</td>
<td>-12.6</td>
<td>-7.2</td>
<td>0.1</td>
<td>4.4</td>
<td>7.4</td>
<td>11.2</td>
<td>11.2</td>
<td>6.5</td>
<td>1.8</td>
<td>-3.6</td>
<td>-10.3</td>
<td>-0.4</td>
</tr>
<tr>
<td><strong>Lowest temperature (°C)</strong></td>
<td>-36.0</td>
<td>-37.0</td>
<td>-33.2</td>
<td>-22.4</td>
<td>-7.1</td>
<td>-5.6</td>
<td>-1.8</td>
<td>-1.1</td>
<td>-6.8</td>
<td>-14.1</td>
<td>-34.3</td>
<td>-37.2</td>
<td>-37.2</td>
</tr>
</tbody>
</table>

Table 3 — Erzurum and Ağrı’s maximum measurements

<table>
<thead>
<tr>
<th></th>
<th>Daily total highest precipitation</th>
<th>Fastest wind daily</th>
<th>Highest snow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>59.6 mm</td>
<td>110.2 km/h</td>
<td>110.00 cm</td>
</tr>
<tr>
<td>Ağrı</td>
<td>23.06.1964</td>
<td>12.08.1972</td>
<td>21.02.1985</td>
</tr>
<tr>
<td></td>
<td>125.9 mm</td>
<td>119.9 km/h</td>
<td>225.0 cm</td>
</tr>
</tbody>
</table>

---

Fig. 2 — Turkey snow annual average number of days analysis (1970-2016)
and prevention of icing by spreading chemicals on road are primary works that have to be performed for struggling against snow and icing. To prevent icing, chemicals lowering freezing point should be spread on road immediately after the start of precipitation or before the start of precipitation. Thus, the formation of a connection between snows or ice surface is prevented. The solid chemical which has mostly been used in this process is rock salt. Due to being low cost, it is generally used in the solid state as a defroster and icing preventer. Because of salt is effective until certain temperatures, icing is prevented more quickly using some liquid chemicals. These chemicals are generally in the fluid state and spread to road pavement with certain time intervals in smaller amounts than salt to be used. However, the cost of chemicals used with salt to make fighting against snow and ice more effective is much higher than salt.

In addition, these high-cost solutions can damage the environment and vegetation existing within the range of 18 m from the road platform where they spread. The salt affecting under certain conditions has many negative effects on the pavement layer and environment. Saltwater leaking from pavement edges or micro cracks in the road surface can damage to the pavement by causing freezing-melting interaction depending on temperatures varying within a day and it may also lead to aging of the coating with bitumen oxidation. In addition, these salts increase salt concentration of rivers and streams over time and they adversely affect drinking water, irrigation, and aquatic life.

Sanding method: Regarding struggling with snow and icing, some substances have been applied on the road surface as anti-skid in case of the road roughness decreases rapidly very low temperatures at which effect of the chemical decreases, snow stick on road steadying. The abrasive substances such as sand, coal dust and ballasts prevent vehicles from slipping on the road platform and getting out of the lane, increasing the roughness of the surface layer of snow stuck. This method allowing the coefficient of friction to increase, scatter around by the effect of traffic and provide a short-term solution since abrasive substances cannot stick on road steadying. Use of abrasive substances increasing the friction between the ice coated-road platforms and wheels are a common solution, because of that they can easily be applied to the road surface and can be used at any temperature. They are applied especially in horizontal bends and cross-roads. Abrasive substances scattering around and losing their effectiveness in a short time by traffic impact, cause air pollution, being smashed under heavy axle loads.

Wetted sanding and warm wetted sanding: Conventional methods used in the World and Turkey continue to be developed. Two of the developed methods are wetted sanding and warm wetted sanding method, but it is not used much in Turkey and many countries yet. These methods applied for the first time in Norway and preventing ice on the road platform. The warm sanding method called Hot Stone is a process of spreading of aggregate particles of 2-5 mm in diameter on road after being heated up to 180 degrees. The aim of this method using diesel fuel in the heating of abrasive materials is to increase the coefficient of friction by fixing sand (abrasive material) to snow or ice on the road pavement thereby providing a safe driving. In the conventional sanding method, abrasive substance scatters out of the road through the passing of a certain number of the vehicle on road pavement or its impact lasting only for a few hours after being applied. On the other hand, its impact lasts longer by fixing sand to the upper structure in a warm sanding method.

It has been revealed in some scientific research that the wetted sanding method tested in Norway in the winter season 1998/99 for the first time; have an effect lasting longer than conventional sanding methods have. It has been found that the effectiveness of the friction force decreases with the passage of fewer than 50 vehicles from a road where the sandblasting method is applied. However, on a road with warm wetted sanding, it is seen that the method is effective despite the fact that 2000 vehicles have been passed through and that the road surface has a friction force above the standards.

In the research, it was observed that the effectiveness of the friction force decreased with less than 50 vehicles passing through a road where sanding was applied. However, on a road where warm wetted sanding has been applied, it has been found that the method is effective despite the fact that 2000 vehicles have been passed through and that the road surface has a friction force above the standards.

It was proven that while the effect of conventional sanding (dry sanding) method on a road on which vehicles less than 50 passes, decreases rapidly, the wetted sanding method has a frictional force above standards even after the passage of 2000 vehicles. When it is compared with other methods, it is seen...
that its effect on pavement lasts between 3-7 days. Inappropriate weather conditions can be applied on extensive areas (2.5-3 m) can be used in cases of the ineffectiveness of conventional methods (hard blue icing, the roads where heavy vehicles pass intensively, thin icing).

The warm wetted sanding method is the process of spreading of aggregate particles of 0 – 4 mm in diameter on road platform by mixing with hot water in a scrambler at 90 – 95 degrees. The purpose of this method is to increase friction on pavement providing abrasive substance scattering around quickly by traffic impact to stick on the road by means of water. This method bases on the principle of addition of hot water to sand and covering water particles with sand particles.

This method based on the principle of assembling a tank with a certain volume, a heater and a spreader on truck chassis and then spreading of the mixture on road, at the desired concentration and desired intervals. The truck required to apply the warm wetted sanding method.

**Chemicals:** This method much uses the fight against snow and ice like other methods. Studies on the effects of chemicals on the road have been carried out. Chemical substances can be applied in a solid or liquid state. The type and amount of chemicals to be applied varies depending on the amount of snow or ice, the ambient temperature, and the application area. Because they are cheap and effective, the most used chemicals are; sodium chloride (NaCl), magnesium chloride (MgCl2), calcium chloride (CaCl2), calcium magnesium acetate (CMA) and potassium acetate (KAc). However, some of these chemicals can damage the asphalt and concrete coating surface, concrete equipment, ecological system, and metal components. Especially because of acetate contains carcinogenic substances, it is limited preferred in the World to fight against snow and ice.

**Electrically conductive pavement:** The system is a layout to prevent snow and ice accumulation by using the automation related to the heating cable. Heating cables are used as a precaution in places where icing threatens life and property safety. The heating cables used are special cables that convert electrical energy into heat energy. In addition, depending on loads of passing vehicles, these cables must be resistant to pressure resistance. They can be used heating of lawns in open sports areas, heating of ground concretes and to prevent icing of pavement on critical roads. With the heating cables applied to the pavement, the heat rises upwards evenly from every point of the furnace and a homogeneous heat distribution occurs in the spaces. Heating cables are used to ensure seed growth in greenhouses and gardens. Norway, Canada, Denmark and some cities in Turkey use heating cables to melt snow and bubbles. For example, it was used in the protocol road in Ankara. Electric heating cables can be applied to almost all underground roads. Electric heating cables are used in the areas where snow and ice exist and traffic environment is prepared in terms of traffic safety. It is less costly in the long run, despite the cost of electricity consumption, which is not related to any chemicals that will overcome road coating. Furthermore, alternative energy is being studied for consumed by this system.

**Anti-icing spray method:** Frost, ice formation and adhesion of the snow to the surface of the road are prevented by the anti-icing and solvent solution. This solution is able to prevent and solve frost on the snowy and icy surface. This solution is usually liquid, light yellow and odorless. It is applied to the surface of the coating before snowing so that the thin film layer formed by the solution prevents adhesion of the snow to the road surface. This solution is environmentally friendly; it is a general advantage that it is applied very quickly and saving labor and time. It is also the most important advantage that this solution is not corrosive and does not damage the asphalt and concrete roads.

**Detecting and preventing icing system:** A new method is created by combining the anti-icing and solvent solution with technological developments and this method is called auto-icing spraying method or detecting and preventing icing system. The automatic anti-icing system is applied to areas where icing occurs frequently.

This system is also called auto-icing spraying method. It is developed by combining the anti-icing spraying system with technology and the components of this system are the nozzles, the sensor, the tank, and the control unit. The nozzles are located on the road surface and are used to spray the chemicals onto the road surface. The sensor unit is used in weather forecasting, which includes detectors for air temperature and humidity and the sensors are used to be informed about snowfall and icing on the road surface. Road and Weather Information System (RWIS) can be used as a sensor in this system.
Chemicals are stored in the tank unit and chemical pumping to the nozzles is carried out from this tank unit. The task of the control unit is to activate the system actively. As mentioned, this system is fully automatic. In other words, it is not a system based on human power. Only if there is a technical problem, an external intervention may be necessary. The system was applied at the entrance of the Bolu Tunnel.

Results and Discussion

The defroster mainly used for snow and ice control is salt in the World and Turkey. That’s why salt can be easily available and low cost. There are three main objectives of using salt for icing in winter cities. These objectives are to melt snow and ice on the road surface, lower the freezing point of water on the road surface and reduce the connection between snowflakes. With the reduction of connection between snowflakes, hardening of snow and sticking on road surface get difficult.

The amount of salt used for protection roads from snow and icing especially depends on snowfall and winter temperatures. Until this time, many studies have been done on the effect of salt on asphalt and some limits have been found. There are significant limits for the use of salt at heavy precipitation and extremely low temperatures. There is no doubt that the salt effect has a validity period. A salt having high impact at temperatures below -10 degrees with light snowfall (equivalent to 1 mm water per hour), loses its effectiveness at lower temperatures and with heavy snowfall and becomes dangerous for traffic flow. If the hourly precipitation is 1 mm or less and the temperature is above -10 °C, salt may be effective. If the temperature is above -10 °C and the hourly precipitation is above 1 mm, the salt should be used with caution. But if the temperature is below -10 °C, salt usage should be avoided regardless of precipitation.

The state and province roads in which the GDH is responsible in 2018 is 64,278 km long. In 2018, GDH conducted snow and ice work in 94% of these roads. A total of 186,081 tons of salt was used in this struggle. The roads under the responsibility of 12th Regional Directorate are 3,342.78 km. In these roads used generally salt to fight against snow and ice. The amount of salt used is approximately 10,294.84 tons. The material costs of the materials used in the salting operations of the cities located in the task area of 12th Regional Directorate of Highways are shown in Figure 3. In 2018; 166,394.19 $ worth salt, 238,786.62 $ worth fuel oil were used and 13,219.19 $ worth other expenses (hardware, maintenance, and repair costs) were made and these are shown in Figure 4.

Salting which is appropriate and effective at certain temperatures causes serious costs damaging pavement as well as reducing traffic safety in Erzurum and other cities.

The material cost of 12th Regional Directorate of Highway yielded 418,422.22 $ for fighting against snow (salting method). On the other hand, as well as fighting against the snow is not limited to this cost, damage of salting method for pavement increases asphalt road maintenance costs. As shown in Figure 5, the major part of material costs is due to asphalt road maintenance. The method of fighting with snow selected correctly affects material costs directly thus providing it to reduce to a large extent.

Depending on the road situation, location and weather conditions, the conventional methods to be used in the fight against snow and ice may vary. The comparative costs of conventional methods based on tons are shown in Table 4. Wetted sanding method uses % 10 and warm wetted sanding method uses % 30 less sand than classic sanding method.
Salt and certain chemical mixtures have been used in many European countries and in Turkey for many years for fighting against snow and ice. Since Erzurum and Ağrı, which are among cities where these methods have most widely been used, receive heavy snowfall and have low temperatures, they have to struggle with winter conditions for 5 months of a year. It is obvious that salt and chemicals which have been used considering as low cost, damages to pavement and environment.

Regarding time of influence of methods on-road platform after being applied; while most conventional methods can be effective for 1 day on the road surface, the newest conventional method, warm wetted sanding method, can be effective on the road surface for 3 days. In this case, the amount of salt used for road surface will be decreased at least to the ratio of 1/3 using warm wetted sanding method thus creating an environment-friendly impact.

Apart from conventional methods of fighting against snow and ice, there are modern methods as well known. A comparison was made between the installation costs and the material expenditure electrically conductive pavement (ECP), spray system and detecting and preventing icing system (DPIS), which are considered to be modern methods. This comparison is given in Table 5. In this comparison, it is assumed that ECP runs for 10 minutes in the 1-hour period. The spray system and DPIS are assumed to use MgCl₂ solution once within 1 hour. MgCl₂ was taken as 6g/m².

The costs of modern methods seem to be higher than conventional methods. Although the impact rates are high under certain conditions, due to their conditions, GDH and local governments don’t use these modern methods to fight against snow and ice. However, these methods can be used at the points where the usage is intensive and weather conditions are heavy.

One of the world’s most talked-about problems in the 21st century is environmental pollution. Various efforts have been made to reduce this pollution in every area. There is no doubt that there are many factors that cause environmental pollution in transportation. One of the materials used in the transportation area and causing environmental pollution is salt used in the fight against snow and icing. Alternative methods are also being studied to fight against snow and icing to remove salt damage. These researches are divided into two parts as conventional and modern methods. The newest of conventional methods is the warm wetted sanding method. The newest of modern methods can be considered DPIS.

However, as mentioned in the paper, the use of modern methods remains at a very low rate due to their cost. Because if the modern methods of fighting against snow and ice are used, the cost will increase dramatically. Besides, it is very difficult to apply modern methods all the roads in the cities where winter is severe. Even in practice, if any technical malfunction occurs, it is very difficult to repair the fault due to weather conditions. It is logical to use it at more critical points as mentioned. Therefore, it would be more appropriate to compare conventional methods within themselves. For salt in conventional methods, it is not a logical option while considering the damage to the environment and road surface although advantages of salt. Despite the advantages of

Table 4 — Costs of materials used in Conventional methods

<table>
<thead>
<tr>
<th>Methods</th>
<th>Costs ($/Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt</td>
<td>13.47</td>
</tr>
<tr>
<td>Sand</td>
<td>3.872</td>
</tr>
<tr>
<td>Wetted sand (10 % less than sand)</td>
<td>3.485</td>
</tr>
<tr>
<td>Warm wetted sand (30 % less than sand)</td>
<td>2.710</td>
</tr>
</tbody>
</table>

Chemicals
- NaCl                                  | 36             |
- CaCl₂                                 | 120            |
- MgCl₂                                 | 95             |
- CMA                                   | 1,280          |
- KAc                                   | 800            |
- Urea                                  | 108            |

Table 5 — Costs of Modern Methods

<table>
<thead>
<tr>
<th>Methods</th>
<th>Cost Of Installation ($/100 M²)</th>
<th>Material Expenditure ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECP</td>
<td>9,547.2</td>
<td>0.54</td>
</tr>
<tr>
<td>Spray System</td>
<td>24,260</td>
<td>0.087</td>
</tr>
<tr>
<td>DPIS</td>
<td>36,660</td>
<td>0.097</td>
</tr>
</tbody>
</table>
the sanding method compared to the salt are less, but there is no damage to the environment in the sanding method. In chemical methods, the duration of chemicals on the road surface is not very long and for this reason, continuous reinforcement is required. This is very difficult in terms of implementation. At the same time, it is very difficult to apply chemicals on all roads, like modern methods. The wetted sanding method cannot produce the desired effect despite the decrease in the used sand ratio. The sand used in the warm wetted method is 30% to 50% less than the conventional sanding method. Unlike the wetted sanding method, this method can show the desired effect. Due to the sand used is very low, the cost is very convenient and it is easy to apply. Because of these advantages, it is the most logical method to implement.

In line with the reduction in the ratio of salt caused by the use of the method, because of that method consists of the water-sand mixture and is sprayed at regular intervals, substantial reductions have been provided in the amount of sands used in conventional methods, which substantially reduce countrywide sand usage cost.

In addition, since abrasive material has low grading (0 – 4 mm), it brings several advantages along. One of these advantages is to minimize financial losses preventing abrasives from jumping windshield glasses of moving vehicles. It's another advantage is that the probability of sewage-obstruction of remaining material on the roadside, causing environmental damage is lower as compared to the materials with high gradation.

By using these methods in Turkey and in other European countries, costs born due to adverse effects of severe winter conditions will be reduced and harmful effects of salt on pavement will be minimized. There will be a serious decline in the amount of salt using salt only during precipitation and accordingly budget allocated for road asphalt maintenance will be reduced. This method will provide a safe driving in adverse weather conditions and will create an environment-friendly impact in Erzurum and Ağrı provinces where snow cover duration is long. Due to the fact that warm wetted sanding method, which hasn’t been used in Turkey and in the most European countries, will reduce cost and create an environment-friendly impact, importantly should be started to be used.

Conclusion

One of the world’s most talked-about problems in the 21st century is environmental pollution. Various efforts have been made to reduce this pollution to every area. There is no doubt that there are many factors that cause environmental pollution in transportation. Some of the materials used in transportation area and causing environmental pollution are salt and chemicals used in the fight against snow and icing. Alternative methods are also being studied to fight against snow and icing to remove this damage.

By using these methods in Turkey and in other European countries, costs born due to adverse effects of severe winter conditions will be reduced and harmful effects of salt on pavement will be minimized. There will be a serious decline in the amount of salt using salt only during precipitation and accordingly budget allocated for road asphalt maintenance will be reduced. This method will provide a safe driving in adverse weather conditions and will create an environment-friendly impact in Erzurum and Ağrı provinces where snow cover duration is long. Due to the fact that warm wetted sanding method, which hasn’t been used in Turkey and in the most European countries, will reduce cost and create an environment-friendly impact, importantly should be started to be used. Through this paper, general information about this method is provided to readers and allow an opportunity for the implementation of this method in the future. Besides, the availability of more connective and low-cost alternative material which can be used instead of sand can be investigated in subsequent studies.

In this study, the ECP method, which is the most advantageous method in terms of cost, can be used in the way of the 12th Region General Directorate of Highways in the critical points where have intersections or more accidents in the city centers. In the other road sections, the use of warm wetted sanding methods is appropriate for this task.

Acknowledgments

I would like to thank the General of Directorate Highways and the Turkish Meteorological Service for the data used in this study.

Conflict of Interest

Author declares that there is no competing or conflict of interest in this research.
References
17. KGM, The general directorate of state highways and provincial roads maintenance and operating costs. Strategy development department, transportation costs and productivity branch manager, (in Turkish), 2016.