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ORIGINAL ARTICLE

Laboratory Evaluation of CMA impact on the Slipping resistance of the roads surface

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ABSTRACT
Generally, salt (which is an inexpensive and stable solution for De-icing) is used to prevent icing the road surface. However, salt has disadvantages which most of them are related to impose heavy costs associated with road pavement and increase the risk of road accidents in the winter.In the meantime, one of the ideal materials for road surface de-icing which can be used as a substitute for salt is calcium magnesium acetate (CMA). In this study, based on a laboratory study and performing British pendulum test in accordance with Standard BS118 for different samples of pavement, including asphalt pavement, typical concrete pavement, self-compacting concrete and pavement by aggregate materials, the effect of the use of the calcium magnesium acetate on sliding resistance of road surface in the winter's maintenance road has been investigated, and are compared to the salt.According to the test results on all types of pavement samples, CMA, rather than salt, increases slip resistance. Accordingly, the use of CMA reduces road accidents in winter by increasing the slip resistance of the road surfaces and use it instead of salt in the winter's maintenance road is recommended.

Keywords: *Calcium Magnesium Acetate (CMA), Slipping Resistance, Salt, Road Pavement*

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INTRODUCTION

Pavement is considered as the capital of each country and a major part of the development budget is spent on repair and maintenance of road pavements. Among problems in this regard can be noted to the negative effectof the pavement icing in prone areas, mainly in mountainous on the sliding resistance of the road surface, which, besides loss of abundant financial resources, it is followed by loss of life due to the increased risk of road accidents in winter[1].For many years, for melting snow of passages, removing de-icing and prevention of creating slippery surface in the streets and urban passages, the mixture of sand and salt is used. Meanwhile, annually a lot of money is spent on the construction and development of asphalt and concrete pavements in the country, which because of spraying salt on the roads, when snow and ice, pavement life is reduced.This means that given the high concentration of salt on the environment, it is harmful and cause corrosion and damage to vehicles, bridges and roads [2, 3, 4].Meanwhile, other de-icing materials which are used in the winter maintenance road services have disadvantages and shortcomings, and they broadcast the fine dust particles in the air, which should be removed from the surface of the roads at the end of winter.Thus, in addition to air pollution, the more money is spent to remove them [5]. Also, because of the use of the salt on winter's maintenance roads, the sliding resistance of the road surface is reduced, which increases the likelihood of accidents.In this context, the use of a substitute material of salt for de-icing the roads seems necessary, which in addition to preserve environmentally, economically and technically standards, also increases safety of road pavement and reduces road accidents in the winter.In the meantime, calcium magnesium acetate is considered as one of the known safest anti-freeze and it has been tested, and can be considered as a safe alternative to salt.CMA is a simple combination of dolomite lime and acetic acid (the main component of vinegar) which has been produced in Fort Madison lava [2].Ever, the damages to the environment due to use ice chloride anti-freezes and to structures such as bridges, has always been a concern. In 1970, the Federal Highway Administration America (FHWA), introduced calcium magnesium acetate as the only chemical material

that with much less wear than road salt, which also protects the environment [3]. Laboratory studies show that whatever the CMA in the combination is more the level of protection of concrete scaling and erosion is better [3]. During 1970, the Federal Highway Administration America (FHWA) began an integrated research program aimed at reducing the overall cost of de-icing highways America.An important part of this program is investigation of anti-ice chemical materials as possible alternatives to salt.In the first survey, more chemical materials considered due to high production costs, lack of easy access, improper chemical or physical characteristics (e.g. carbonated or non soluble in water) or harm to the environment, flammable, toxic or harmfulness, were eliminated. Finally, experimental studies were limited to two chemicals, methanol and CMA. Although both chemical materials, in terms of defrosting some criteria were considered as proper materials, CMA because of greater compatibility with the environment, and having the same features of salt has been taken into consideration by most countries. Initial laboratory tests showed that the CMA is harmless to plants and animals [4,5].Also, for concrete and other materials for highway, it has nondestructive properties, and for metals or corrosive properties has stainless. The main advantages of using calcium magnesium acetate instead of salt (NACL) have already been demonstrated in previous research, are its environmental aspects and corrosive factors.In addition, calcium magnesium acetate is an important adhesive and bonding factor for fine dust particles after drying roads and completing maintenance road operations against wind and other storms which prevents suspended particles in the air. If you use timely, this chemical material can be combined with snow and prevents from formation lump of snow and ice adhesion to the surface and thus, provides the safe movement of vehicles on the roads in seasonal frost[5].Also, has been prevented from concrete and asphalt pavement stripping after melting ice, and the crisp snow by snow removal machines is removed easily [4].

Although many researches for replacing chemical materials instead of salt to protect roads in the winter are done, still, in many countries, salt is used as an anti-freeze material.Also, despite studies in the literature on the subject of the use of CMA in the winter maintenance road, no study in the field of comparison CMA with salt from the point of view of sliding resistance has been performed.Given the enormous costs arising from the use of salt in de-icing of roads on the road pavement, the use of alternative materials such as calcium magnesium acetate could reduce road pavement maintenance costs, and thus can be increased the useful life of the pavement. This study aimed to investigate the use of alternative materials such as calcium magnesium acetate on the increase of sliding resistance of the road surface, investigates and assesses this issue in the point of view of technical and in a laboratory study.

RESEARCH METHODOLOGHY

In this study, the British pendulum test (English pendulum) to determine the slip resistance of pavement samples is used. Considering that the aim of the present study based on investigation of the effect of CMA on the sliding resistance of the road surface, and comparing it with the salt, a series of laboratory experiments were organized in February 2014. In order to prepare laboratory samples for testing the effect ofCMA on slippingresistance of the roads surface, asphalt samples under road traffic load, concrete samples, aggregates samples and self-compacting concrete samples were used (figure 1). The desired asphalt samples from different parts of the road in the length and width of roads and arches were obtained (Figure 1).

Figure 2 - Concrete samples which were cut in stone cutting factory

Figure 1 - Preparation of asphalt samples by digging the road surface

Samples of asphalt obtained from the roads in order to cut and prepare laboratory specimens were moved to the stone cutting factory.In the stone cutting factory, asphalt samples with dimensions 10 × 20 cm were cut.Also, concrete samples with dimensions of 15 × 15 cm, aggregatessamples having stone broken in more than two dimensions in the dimensions 20 × 10 cm, and self-compacting concrete samples in the dimensions 20 × 10 cm, for preparation Laboratory samples were prepared. In Figure 2, aggregates samples with more than two broken dimensions and concrete samples cut in stone cutting factory, is

shown. British pendulum device, as shown in Figure 3, was stationed at the laboratory level.Due to the thickness of the pavement samples, the foundations of the device have been balance. For holding device as tight, a screw at the back of the device was tough. Samples on the ground, and in the location of samples in the British pendulum device, were placed according to the Figures 3 to 7.Shoe of machine is part of the British pendulum device that has length 12.6 cm and width 7.6 cm. Samples to be transported until to beginning and end of the passage shoe, is placed on the sample.This work was performed in accordance with BS118 standard. In this respect, a ruler with length of 12.6 cm was used.

Figure 7 - placing the self-compacting concrete samples in device of British Pendulum

Figure 6 - placing the concrete samples in device of British Pendulum

Figure 5 - placing the Asphalt samples in device of British Pendulum

Figure 4 - placing the aggregates samples in device of British Pendulum

Figure 3 - View of the British pendulum device (pendulum friction) in the pavement laboratory

It is should be noted that the effective width of slipping in the mentioned length and width are achieved, otherwise the numbers are invalid. Then, against sample, a heavy metal plate with a weight was placed on it to prevent to move horizontally the shoes which are passing the sample.Then, the index or black pointer is brought the machine to where the arm is fixed and it placed in parallel with the arm.After ensuring the above steps, first some water poured in the sample and the sample must become completely soaked, this amount should be enough and some water must be on the sample.Then, toggle of the pendulum arm, which is located on the right and top side and black indicators also is located in this area is hit, arm with its characteristic speed passes sample, the black pointer also moves and moves toward dial of the device (which slippery numbers are written on it).At the same time, the pointer on the screen shows the number of slip. However, after passing the arm through the sample, the arm is held to prevent to return, which otherwise black pointer is moved back, and it will not show the correct numbers.These procedures 5 times and in the two phases were performed for each sample. Thenumbers are presented in a table and average values are obtained, the number of slipfor solution is used and in the next section,the results of the experiments are discussed. After water, the same procedure was performed for the salt, and the slip number is obtained. Then, each sample was thoroughly washed with water until no trace of salt on the sample. Also, rubber shoes machine washed, so there was no trace of salt on it.Again, the previous stages have been done by with, and the slip number was read and was recorded. The CMA solution was poured onto the sample, and the steps were repeated, the slip number was recorded. Also, inserting metal sheet for the lack of movement of the sample when the shoe is passing samples, are shown. In Figures 8 and 9, salt-water Solution and CMA on pavement samples, is shown.

Figure 9 - Sprinkle CMA solution on samples

Figure 8 - Sprinkle salt solution on samples

ANALYSIS AND INTERPRETATION OF RESULTS

According to tests performed, and because benefiting larger population (different pavement samples) the various pavements were used to compare.In Tables 1 to 5, the measurement slip values of asphalt concrete pavement by solution CMA, NACL and water are provided.For each anti-freeze solution and water (comparison measure in this experiment.), experiments in two stages and each stage of the experiment was repeated 5 times according to the standard BS118. The tables' numbers at each step

shouldn't have difference more than the ∓ 3 with each other. Otherwise, the test must be repeated again. Possible errors may be due to being low solution on sample, or lack of being balance of the device, or incorrect setting shoe on the sample.For this table, average of each of the 5 slip numbers obtained is determined and the desired number with average of the next step is averaged.The resulting number as the slip number for asphalt sample for that solution is recorded and reported.

Table 1 - Results of British pendulum test for asphalt concrete samples

Asphalt concrete samples of along the roadand without away	PN							
	1	2	3	4	5	Average	Total Average	Standard deviation
Water	63	64	64	63	63	63.4	63.7	0.55
	64	64	64	64	64	64		0
Salt	59	59	60	60	60	59.6	59.7	0.55
	60	60	59	60	60	59.8		0.45
Water	65	65	65	64	65	64.8	64.8	0.45
	65	65	65	65	65	65		0
CMA	65	64	65	64	65	64.6	64.6	0.55
	65	65	65	64	64	64.6		0.55
Water	64	64	64	65	64	64.2	64.3	0.45
	65	65	64	64	64	64.4		0.55

As can be seen in the column of standard deviations in Table 1, the sample of asphalt concrete of along the roadand without away, the sample with CMA has more organized standard deviation than the samples with salt.The reason for this is the nature of the CMA which prevents asphalt fine separation from each other, and prevents to reduce sliding resistance of the examples. Also, the reason for similar results with the results of asphalt samples with CMA and salt is that the British pendulum test device refines all cases alike, and therefore, in the statistical analysis comparing the standard deviation, it can be seen.In Table 1, values of slip with saltabout 5 units are declined, while the CMA is not reduced the slip values in any way.This result indicates the negative effect of salt solution on the slipping resistance of the road surface.In fact, CMA Slip resistance is greater than salt.

Figure 10 has been drawn and shown comparison of the slipping resistance of asphalt pavement of the road with anti-freeze solutions and water using the British pendulum test results. According to the figure 10, for asphalt pavement sample of the road, it can be seen that, NACL reduces slipping resistance of the road surface, whereas, calcium magnesium acetate on asphalt pavement samples doesn't decrease the slip resistance of the road surface. Therefore, CMA at reducing road accidents in asphalt pavement in Winter Maintenance road is effective.

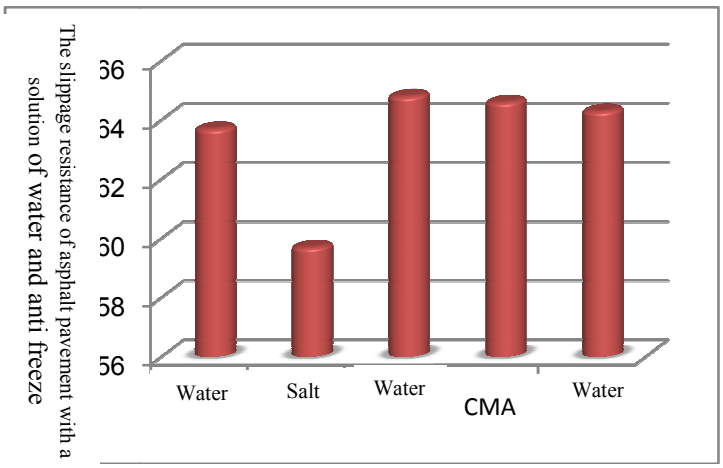

Figure 10 - Comparison of the slippage resistance of asphalt pavement along the road with water and anti freeze solutions

According to the table 2 and figure 11 and for asphalt concrete in place away from the road, similar to the asphalt sample of along the road, slip resistance values obtained from the British pendulum tests have more organized standard deviation which regarding the nature of CMA, it is considered as a significant advantage over increase the life of pavement in Winter maintenance road.Accordingly, the mixed asphalt which is a combination of bitumen and mixtures, gravel, fines and as well as some materials (which modify asphalt properties) such as polymer, phosphoric acid and hydrated lime, in the use of the CMA solution in the winter maintenance road, fine separation of the compound does not occur to them, which it is a major problem and yet the public problem for asphalt pavement of the road due to the use of the salt.Since, asphalt pavement in the winter is subjected to extreme humidity and rain, the phenomenon of detachment fine from asphalt is faster, the salt will increase the speed of this process, but if the CMA instead of salt is used, the rate of degradation of asphalt pavement is decreased, and pavement life is increased.According to the Figure 11, the selected asphalt pavement away from the road, CMA than salt, increases slip resistance 4.5 units.

Table 2 - British pendulum test results for asphalt concrete samples away from the road

Asphalt concrete in a place away from the road	PN							
	1	**2**	**3**	**4**	**5**	**Average**	**Total Average**	**Standard deviation**
Water	63	64	64	64	64	63.8	64	0.45
	65	64	64	64	64	64.2		0.45
Salt	59	59	60	60	61	59.8	60	0.84
	60	60	60	61	60	60.2		0.45
Water	65	64	64	63	64	64	63.8	0.71
	64	64	63	63	64	63.6		0.55
CMA	65	64	65	65	65	64.8	64.6	0.45
	64	64	65	64	65	64.4		0.55
Water	64	63	63	64	64	63.6	64.2	0.55
	65	64	65	65	65	64.8		0.45

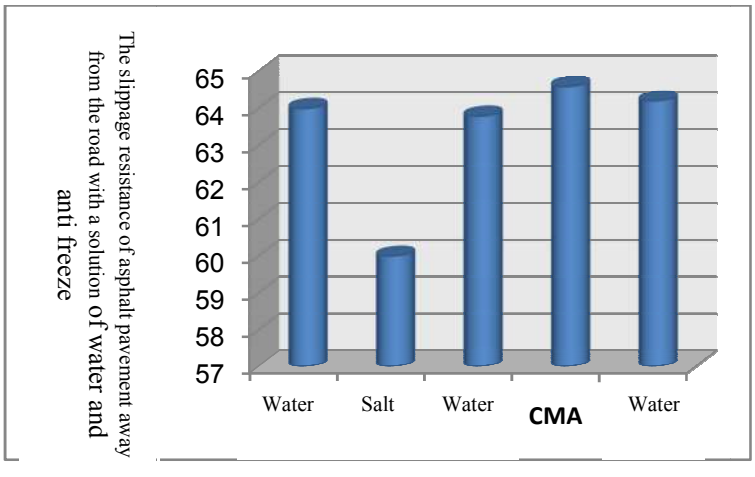

Figure 11 - Comparison of the slippage resistance of asphalt pavement away from the road with a water and anti freeze solutions

In Table 3, the British pendulum test results for concrete pavement samples are shown.According to the Table 3, for concrete pavement samples, British pendulum test results with CMA, has a more coherent SD

than the sample with salt.Concrete pavements due to more dense and continuous aggregation and high levels of contact with car tires havehigher dependence level, and slip resistance in these pavements is more than asphalt pavements.

For this reason, the CMA solution in the concrete pavement sample compared to asphalt pavement in terms of the slip resistance indicates higher numbers, and the use of CMA on Winter Maintenance Road in Concrete Pavement samples is recommended.

Table 3 - British pendulum test results for concrete pavement sample

(Concrete Pavements)	PN							
	1	2	3	4	5	Average	Total Average	Standard deviation
Water	84	83	84	85	84	84	83.9	0.71
	84	84	83	84	84	83.8		0.45
Salt	73	74	74	72	72	73.4	73.4	0.75
	74	74	73	73	73	73.4		0.55
Water	81	80	80	81	79	80.2	80.3	0.84
	80	80	80	81	81	80.4		0.55
CMA	79	81	80	81	80	80.2	80.3	0.45
	80	80	80	81	81	80.4		0.45
Water	83	83	82	82	82	82.4	82	0.55
	82	82	81	81	82	81.6		0.55

According to Figure 12, the slip by the salt 9 units tan water is reduced, while the CMA has reduced 1.7 units slip than water. In fact, Slip resistance of CMA is higher than salt, and this issue in comparison with the asphalt pavement represents an increase of 2.3 units. The reason for this is that concrete pavements due to more dense and continuous aggregation and high levels of contact with car tires have higher dependence level, and slip resistance in these pavements is more than asphalt pavements.

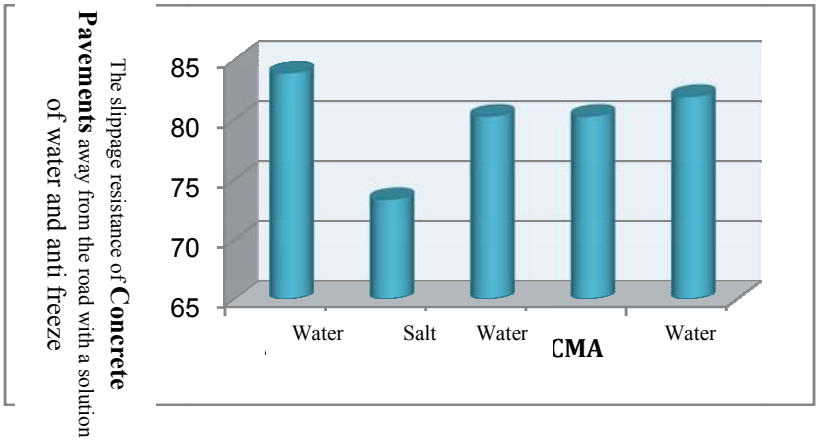

Figure 12 - Comparison of the slippage resistance of concrete pavement with water and anti freeze solutions

In Table 4, the British pendulum test results are shown for payments and parking that are made of self-compacting concrete.

For pavement sample by self-compacting concrete, slip resistance values reported based on the British pendulum test for salts and CMA solutions, the standard deviation of the data is almost the same. This issue can be sought in the structure of the self-compacting concrete and combined with itshigh resistance

against salt and CMA. In Figure 13, the slip resistance of self-compacting concrete pavement with antifreeze and water solutions is shown. According to Figure 13, the amount of slip is reduced by salt 8.93 units in comparison with water whereas CMA has increased the amount of slip 0.37 units in comparison with water. To be more precise, Slip resistance of CMA has been more than salt, and as well as in self-compacting concrete, CMA Slip resistance compared to other payments has increased.

Table 4 - British pendulum test results for the sample of self-compacting concrete pavements

Self-compacting concrete	PN							
	1	2	3	4	5	Average	Total Average	Standard deviation
Water	80	80	81	80	81	80.4	80.3	0.55
	81	80	80	79	81	80.2		0.84
Salt	73	73	72	73	72	72.6	71.8	0.55
	72	71	71	71	70	71		0.71
Water	82	82	81	82	83	82	81.8	0.71
	81	82	82	81	82	81.6		0.55
CMA	80	81	80	79	80	80	81.1	0.71
	81	81	81	82	81	81.2		0.45
Water	80	80	80	81	80	80.2	80.1	0.45
	79	80	80	81	80	80		0.71

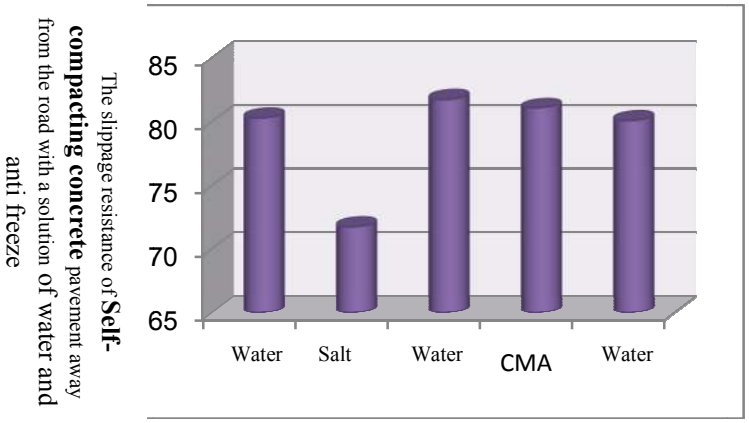

Figure 13 - Slip resistance of self-compacting concrete pavement with antifreeze and water solutions

In Table 5, values of slippery are shown according to the British pendulum test results for aggregates pavement and parking. For a pavement sample by aggregate materials, the numbers of slip resistance are similar to the standard deviation, and it is mostly due to non-uniform aggregate crushing operations after they are extracted from the mines.It should be noted that, the best shape of aggregates is cube-shaped for use on the surface, as well as in terms of slip resistance, while we know that stones of payment are not similar to cube, and because of the shape dissimilarity of these samples, these statistical differences compared with other samples in the pavement appear in aggregates pavement.In Figure 14, the comparison of slip resistance of aggregates pavement with water and antifreeze solutions is shown. Figure 14 in the aggregates pavement or materials, CMA increases Slip resistance by5.7 units than salt compared with water.

Table 5 - British pendulum test results for an aggregate pavement sample

An aggregate floor	PN							
	1	2	3	4	5	Average	Total Average	Standard deviation
Water	60	61	61	61	61	60.8	60.8	0.45
	61	61	61	60	61	60.8		0.45
Salt	55	54	55	55	55	54.8	54.3	0.45
	54	54	53	54	54	53.8		0.45
Water	60	61	60	61	61	60.6	60.3	0.55
	60	60	60	61	59	60		0.71
CMA	60	60	60	61	60	60.2	60	0.45
	59	60	60	60	60	59.8		0.45
Water	61	61	61	60	59	60.4	60.4	0.89
	60	60	60	61	61	60.4		0.55

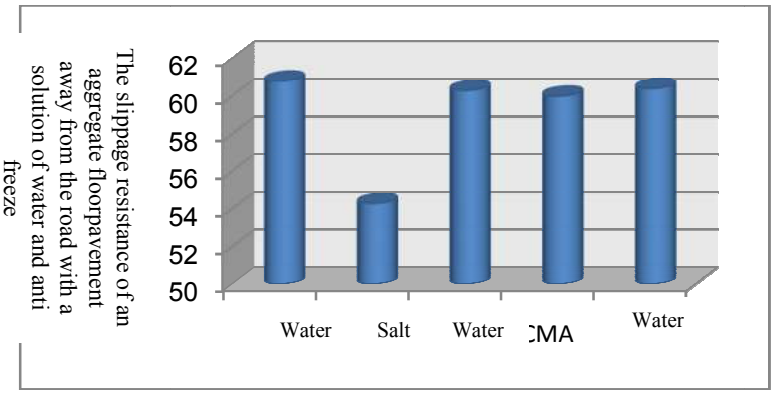

Figure 14 - Comparison of slip resistance of aggregates pavement with water and antifreeze solutions

Finally, in Figure 15, a comparison is made between different types of pavement materials tested in terms of slip resistance with antifreeze and water.

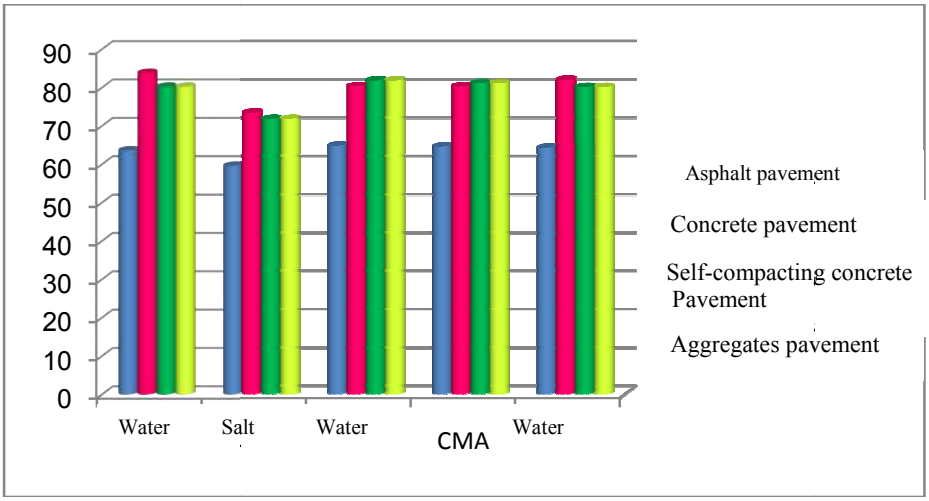

Figure 15 - Comparison of slip resistance for different pavement types with water and antifreeze solutions

As shown in Figure 15, in all the pavements, CMA than salt increases the slip resistance, and the reason for increase of resistance in concrete pavements in comparison with asphalt and aggregates is that concrete pavement surface is dense, which in this case, the reliance level of the tires with pavement is increased, and slip resistance increases. Accordingly, in accordance with what explained in the tables of the British pendulum test results for different samples of pavement, the value of slip of water and CMA as the average is 83 units, and salt 74 units in self-compacting concrete pavement sample and asphalt pavement sample were obtained respectively 65 and 55.Thus, CMA is slippery like water, while the salt has reduced slip resistance by 10 units, and because of that, the likelihood of road accidents is increased and road safety for passengers is reduced. Pavement samples which were prepared from more continuous and denser gradation, due to greater reliance on the tires, showed a better number in comparison with samples with discrete aggregation. Also, the solution CMA sticks on pavement samples, and remains on the sample surface that salt doesn't have this property, and like dust is distributed in the air. Consequently, the CMA can be used for de-icing of roads and because it does not distribute in the air, it does not harm the environment. While the distribution of salt in the air, causing environmental degradation and will cause the decay of facilities related to the roads and their corrosion.

CONCLUSION

For many years, for melting snow of passages, removing de-icing and prevention of creating slippery surface in the streets and urban passages, the mixture of sand and salt is used. However, experts and activists in the urban environment, in recent years, have repeatedly warned about the devastating consequences of the salt spray method for de-icing and the impact that the salt spray method will has on the urban environment, however, because other methods which is now used in many countries are costly, so this issue cause that the application of the salt spray method between other de-icing methods of streets and city streets in the winter is considered as the best solution. In the meantime, calcium magnesium acetate is considered as one of the known safest anti-freeze and it has been tested, and can be considered as a safe alternative to salt.In this paper, based on laboratory study and performing pendulum British test according to the Standard BS118, for different samples of pavement consisting of asphalt pavement, typical concrete pavement, self-compacting concrete pavement and pavement by aggregate materials, the effect of the use of calcium magnesium acetate on slip resistance of the road surface in the winter maintenance road, has been investigated, and the results have been compared to the salt. The main results of the study are briefly as follows.

1. In all the pavements (asphalt pavement, typical concrete pavement, self-compacting concrete pavement and aggregates pavement), CMA increases slip resistance than salt.
2. The use of salt in all types of pavements is associated with reduction of slippery road surface resistance.
3. In accordance with what explained in the tables of the British pendulum test results for different samples of pavement, the value of slip of water and CMA as the average is 83 units, and salt 74 units in self-compacting concrete pavement sample and asphalt pavement sample were obtained respectively 65 and 55. Thus, CMA is slippery like water, while the salt has reduced slip resistance by 10 units, and because of that, the likelihood of road accidents is increased and road safety for passengers is reduced.
4. Pavement samples which were prepared from more continuous and denser gradation, due to greater reliance on the tires, showed a better number in comparison with samples with discrete aggregation in the British pendulum device. On this basis, given the weakness of asphalt pavements in the heavy themes which often have rough, long and continuous wave and sometimes fractures, the use of concrete slab as a strong and stable surface, causing solving mentioned problems and decrease the maintenance period.
5. The solution CMA sticks on pavement samples, and remains on the sample surface that salt doesn't have this property, and like dust is distributed in the air. Consequently, the CMA can be used for de-icing of roads and because it does not distribute in the air, it does not harm the environment. While the distribution of salt in the air, causing environmental degradation and will cause the decay of facilities related to the roads and their corrosion.

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