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EVALUATION OF THE EFFICIENCY OF USE OF AGGREGATES AND CHEMICAL COMPOUNDS FOR WINTER ROAD MAINTENANCE

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The purpose of this article is to indicate the most effective chemical agents used for winter road maintenance. The research included the examination of melting speeds of snow and ice under various chemical agents, such as: calcium chloride, sodium chloride, potassium chloride and potassium formate. The research done proved that aggregate mixed with calcium chloride is the most efficient compound for removing winter road slipperiness. However, in view of the necessity of environmental protection, the use of chemical agents for maintaining roads during winter must be strictly controlled in practice.

1. INTRODUCTION

Road surfaces should meet appropriate safety conditions regardless of atmospheric conditions, which is especially important during wintertime. As a result of adverse weather factors it is necessary to perform efficient operations which aim at limiting traffic disturbance caused, among other things, by road slipperiness. This is possible by introducing up to date road maintenance techniques, more operational and effective methods of the removal of snow and winter slipperiness from road surfaces as well as earlier prevention measures against negative effects of natural phenomena on road and traffic conditions.

The following are the most frequently road maintenance operations performed during wintertime [Stypułkowski 2000, Ząbczyk 2006]:

- snow removal – removing snow from roadways, berms and accompanying objects, such as bus bays, parking areas and passenger service areas, etc.,
- passive protection of roads – preventing snow from being blown onto the road structure by means of plastic meshes or wooden fences, as well as by natural screens (hedges, vegetated buffer strips) or specially formed snow walls,

- preparation, collection and storage of materials that prevent from and remove winter slipperiness,
- removing winter slipperiness, i.e. preventing against and eliminating the slipperiness of roadways, squares and sidewalks based on the use of chemical agents and sanding materials.

The use of mechanical operations during winter roads maintenance does not produce satisfactory results. This is because of a thin and very slippery layer of snow that remains on a road surface. Complete removal of slipperiness is achieved only after the application of sanding materials [Wytyczne…2006] which include:

- sand of maximum graining up to 2 mm,
- natural aggregate of maximum graining up to 4 mm,
- crushed stone aggregate of maximum graining from 2 to 4 mm,
- blast furnace lump slag,
- ungraded aggregate of maximum graining up to 4 mm,
- boiler slag (furnace),
- ungraded aggregate of maximum graining up to 8 mm,
- homogenous aggregate mixed with salt whose gravimetric composition is 95-97% of aggregate + 5 - 3% of salt.

It seems that, in spite of the fact that Poland is the country with large resources of aggregate [Bilans zasobów…2005], using only aggregate to eliminate slipperiness of roadways is insufficient. High traffic density and strong wind make aggregate blown off roadways or form irregular windrows [Dębski 1974, Fortuna 1981]. Thereby, apart from aggregate, chemical compounds are commonly used, which allow aggregate grains to be incorporated into ice, and consequently, prevent grains from being blown off roadways.

The following chemical compounds are used for eliminating and easing the side-effects of winter slipperiness:

a) sodium chloride - NaCl,
b) road salt - ca. 97 % NaCI + 2,5 % $CaCl_2$ + 0,2 % $K_4Fe(CN_6)$,
c) brine – a solution of NaCI or $CaCl_2$ of concentration from 20 to 25%,
d) moistened salt: 30 % of brine (a solution of NaCl or $CaCl_2$ of concentration from 20 to 25% + 70 % of dry NaCl),
e) technical grade calcium chloride (77 – 80 % $CaCl_2$),
f) magnesium chloride $MgCl_2$,
g) a mixture of NaCl and $CaCl_2$ or $MgCl_2$.

2. RESEARCH METHODOLOGY

The research done by the authors concerned the effects of selected chemical agents on the speed of snow or ice melting: sodium chloride (NaCl), calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$), potassium formate (HCOOK) and a mixture of sodium chloride (NaCl) and calcium chloride ($CaCl_2$). Each of the mentioned chemical compounds was used in the dose of 5g per 75 ml of snow or ice. The study of each reacting substance was done in three identical tests in order to obtain the most reliable experiment results. The time of the test was 90 minutes, and the intensity of melting under each reacting substance was noted down in periodic time intervals of 5, 10, 15, 20, 30, 45, 60 and 75 minutes.

Sodium chloride NaCl is the most common substance used to fight winter slipperiness. Therefore, an attempt was made to compare the efficiency of this compound with other chemical agents. The obtained research results were also compared with a blank test, i.e. with the decrease in ice thickness after a fixed period of time without having used chemical agents.

3. RESEARCH FINDINGS ANALYSIS

The conducted research showed that the efficiency of NaCl and $CaCl_2$ on the layer of snow depends on time and is higher along with the prolonged time of reaction (Fig. 1).

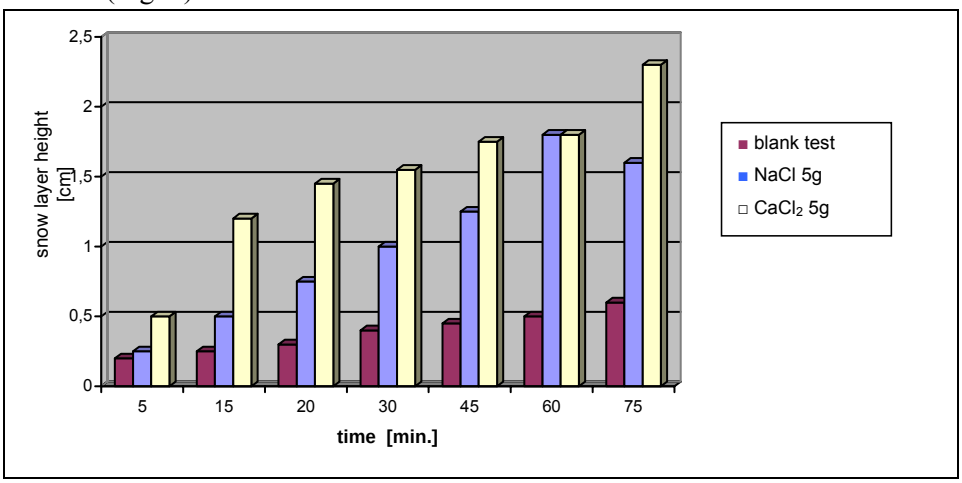

Fig. 1. The impact of NaCl and $CaCl_2$ on the effectiveness of snow melting

According to the research findings, calcium chloride proves to be more effective than sodium chloride, i.e. after only 15 minutes. The difference in the snow layer height decrease caused by the action of the two compounds was 0.63 cm, and 0.74 cm after 75 minutes.

The activity of sodium chloride (NaCl) as well as of calcium chloride ($CaCl_2$) is more effective in higher concentrations of each of these compounds (Fig. 2 and Fig. 3). Furthermore, the differences in the efficiency of action of other compounds in given concentrations increase along with the time elapsed. Thus, calcium chloride is a more effective, i.e. a faster acting, agent used for melting snow.

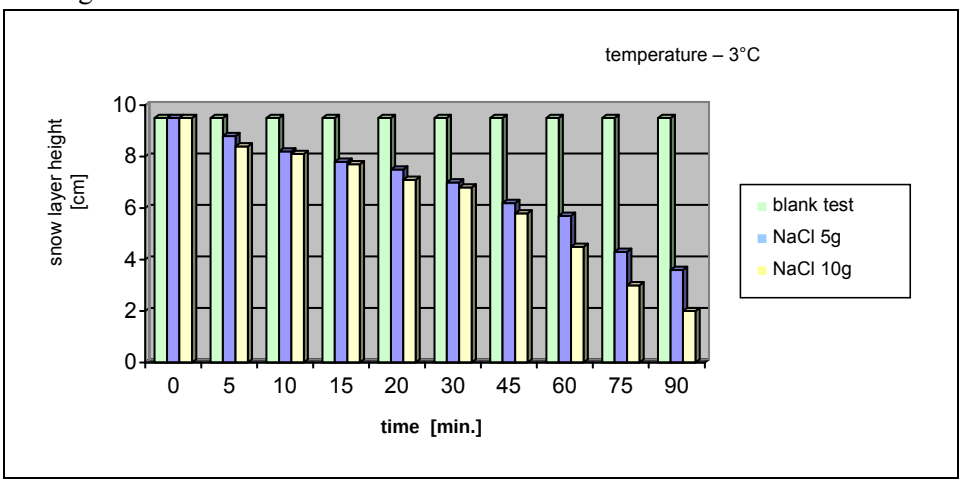

Fig. 2. The impact of NaCl on the effectiveness of snow melting in the temperature of -3^0C

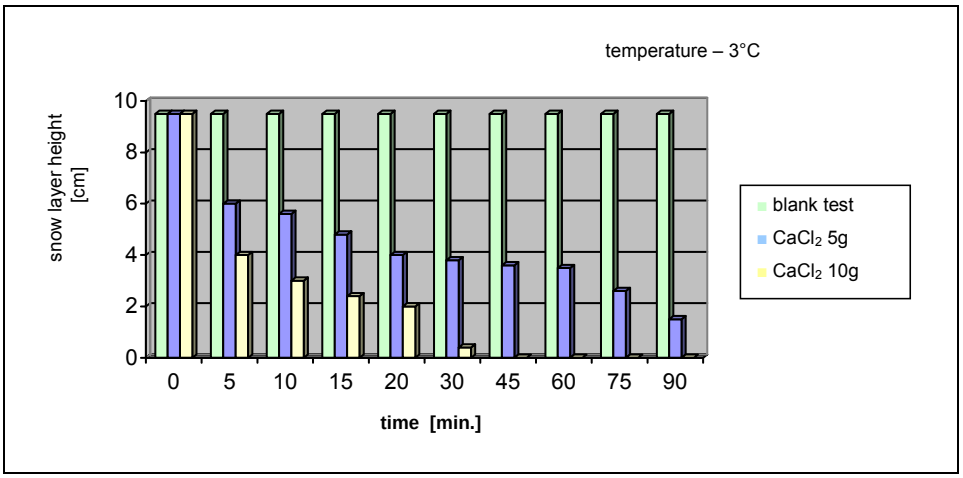

Fig. 3. The impact of CaCl2 on the efficiency of snow melting in the temperature of -30C

Similar tests were carried out in the case of ice layers. When comparing the effectiveness of snow and ice melting with the use of NaCl (Fig. 4) and $CaCl_2$ (Fig. 5), it may be concluded that much better results are obtained when

applying the above mentioned compounds to a layer of snow; both NaCl and $CaCl_2$ acted faster in the case of removing snow from roadways than in the case of removing ice. Calcium chloride ($CaCl_2$) proved to have been a much more effective compound which completely melted a 9.5 cm thick layer of snow after 75 minutes (Fig. 5), whereas sodium chloride (NaCl) melted only a 5.0 cm thick layer of snow in the same period of time (Fig. 4).

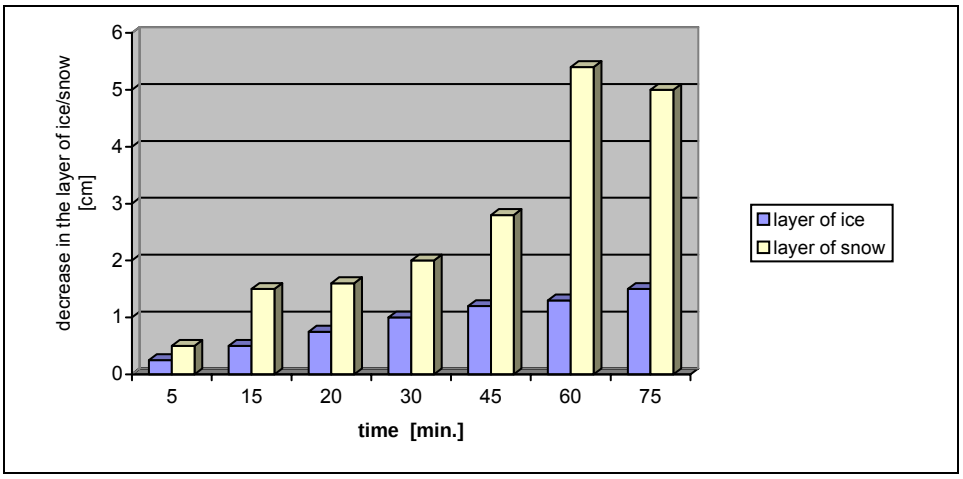

Fig. 4. The comparison of activity of NaCl (in the dose of 5g) on the effectiveness of snow and ice melting

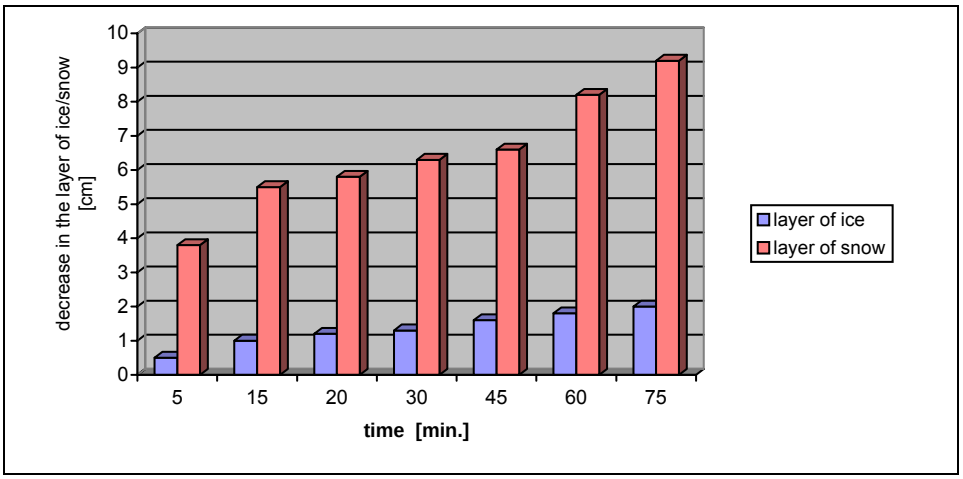

Fig. 5. The comparison of activity of $CaCl_2$ (the dose of 5g) on the effectiveness of now and ice melting

Hence, a univocal implication is made that $CaCl_2$ is a more effective (faster acting) agent which can be used in winter operations regardless of whether a road is covered with snow or ice.

Comparing the impact of each chemical compound on the melting of ice, including sodium chloride (NaCl) and potassium formate ($KHCO_2$) – Fig. 6, and sodium chloride (NaCl), potassium formate ($KHCO_2$) and calcium chloride ($CaCl_2$) – Fig. 7, it may be noticed that there is a significant difference in the effectiveness of each of these agents. Calcium chloride seems to be the most effective substance, while sodium chloride – the least effective one.

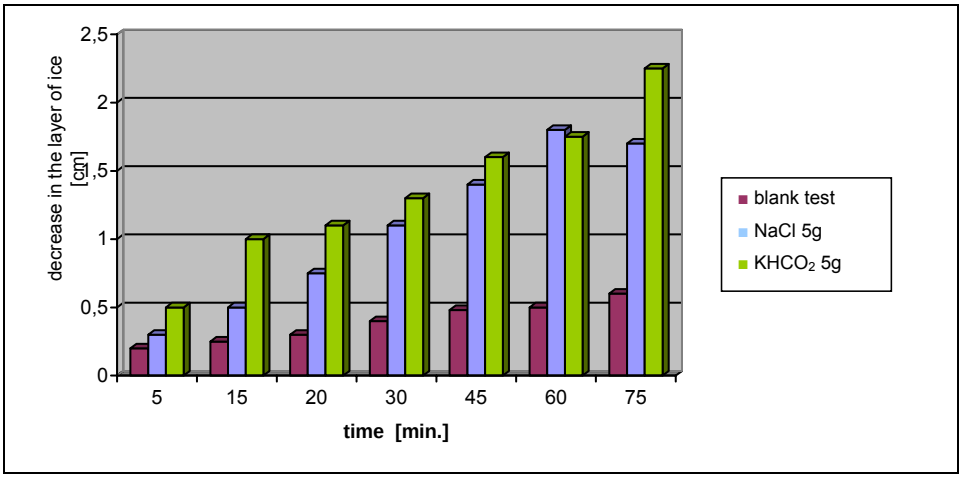

Fig. 6. The impact of NaCl and $KHCO_2$ on the effectiveness of ice melting

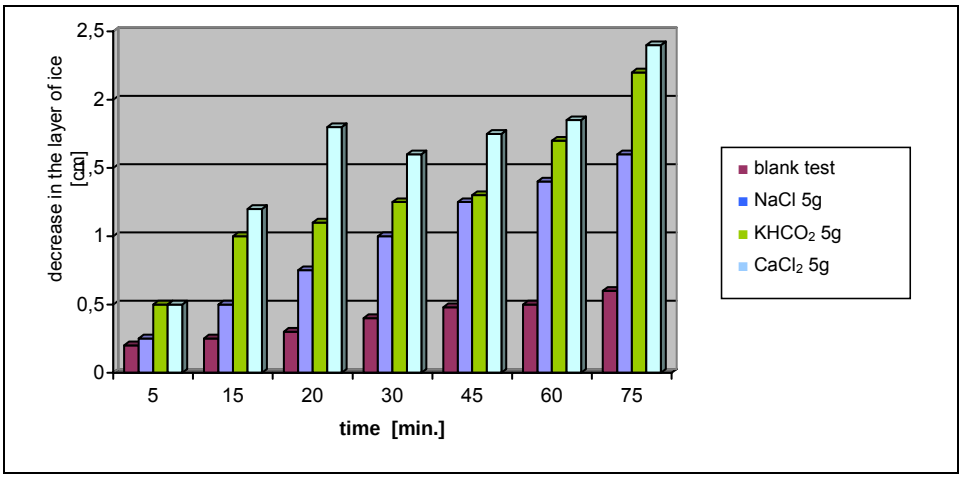

Fig. 7. The impact of NaCl, $KHCO_2$ and $CaCl_2$ on the efficiency of ice melting

Slightly different results were obtained after using the mixture of sodium chloride and calcium chloride (Fig. 8). After 15 minutes of the test, the decrease

in the layer of ice was 0.43 cm, after 45 minutes – 0.5 cm, and after 75 minutes – 0.94 cm.

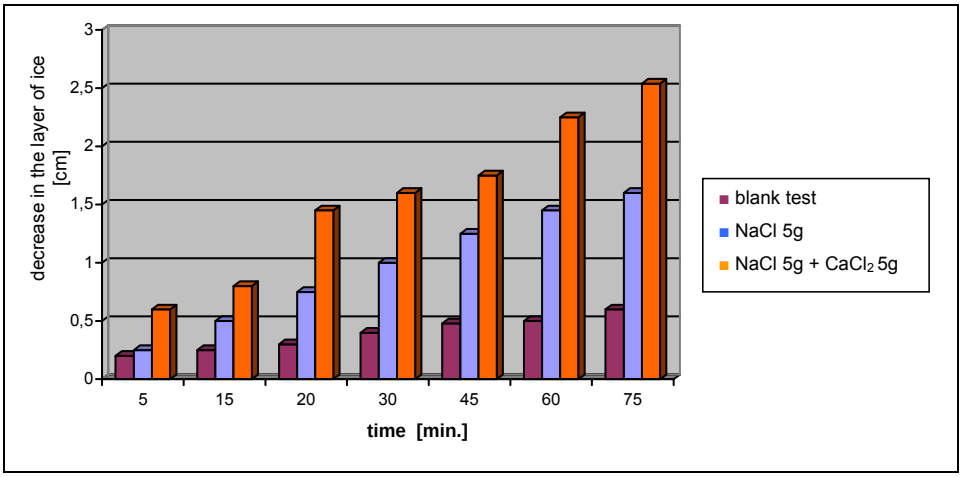

Fig. 8. The impact of NaCl and the mixture of NaCl + CaCl2 on the effectiveness of ice melting

Magnesium chloride also proved to be an effective means of eliminating slipperiness. The impact of time on the effectiveness of activity of this agent compared to sodium chloride is presented in Fig. 9.

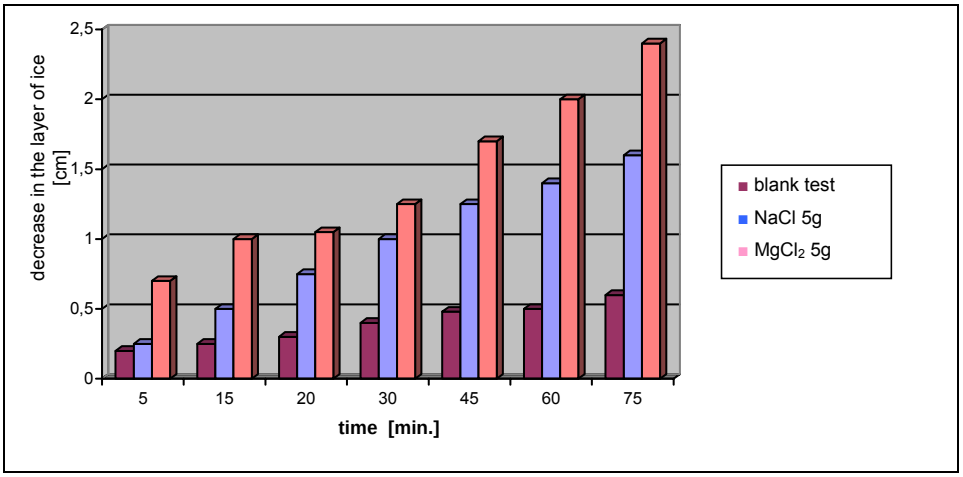

Fig. 9. The impact of NaCl + $MgCl_2$ on the efficiency of ice melting

A higher dose of magnesium chloride ($MgCl_2$) increased its effectiveness (Fig. 10), and like in the case of sodium chloride, the differences in the efficiency of the two doses increased along with the reaction time.

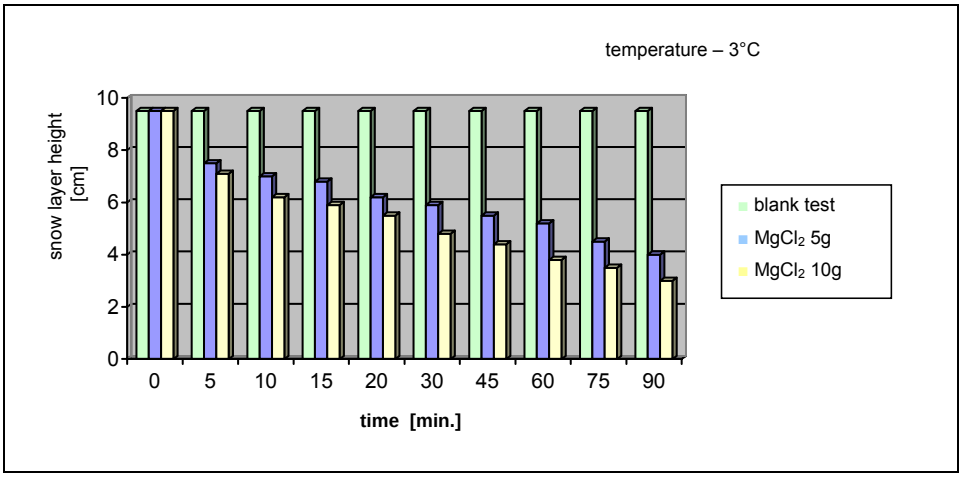

Fig. 10. The impact of $MgCl_2$ on the efficiency of snow melting in the temperature of -3^0C

A collective analysis of the findings obtained carried out with regard to a layer of ice (Fig. 11) shows that the highest efficiency in removing ice from road surface may be achieved with the use of calcium chloride, and then the mixture of sodium chloride and calcium chloride, whereas sodium chloride is the least effective.

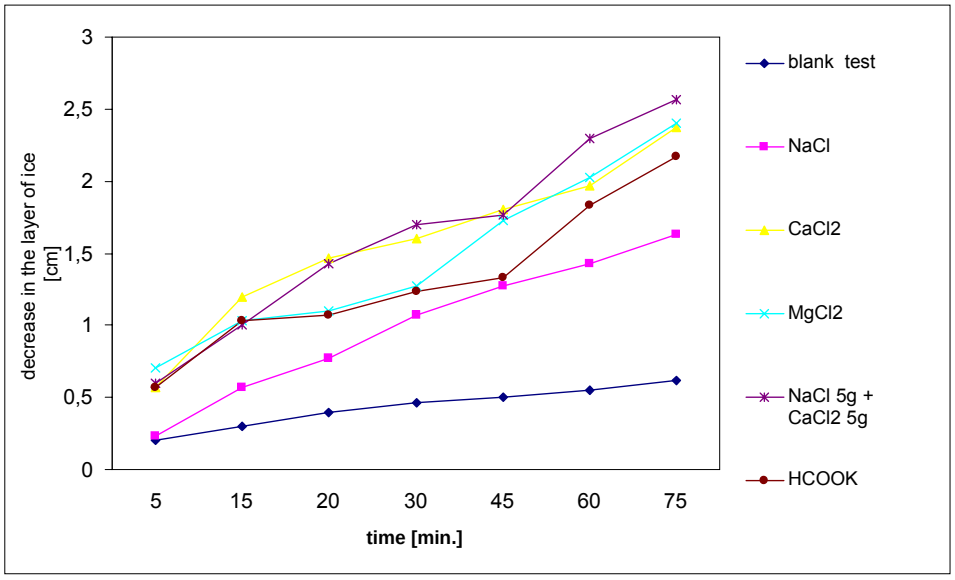

Fig. 11. A collective comparison of the impact of chemical agents on the speed of ice melting

In the case of the layer of snow, however, it was proven that calcium chloride is the most effective in winter operations compared to calcium chloride, magnesium chloride and sodium chloride (Fig. 12).

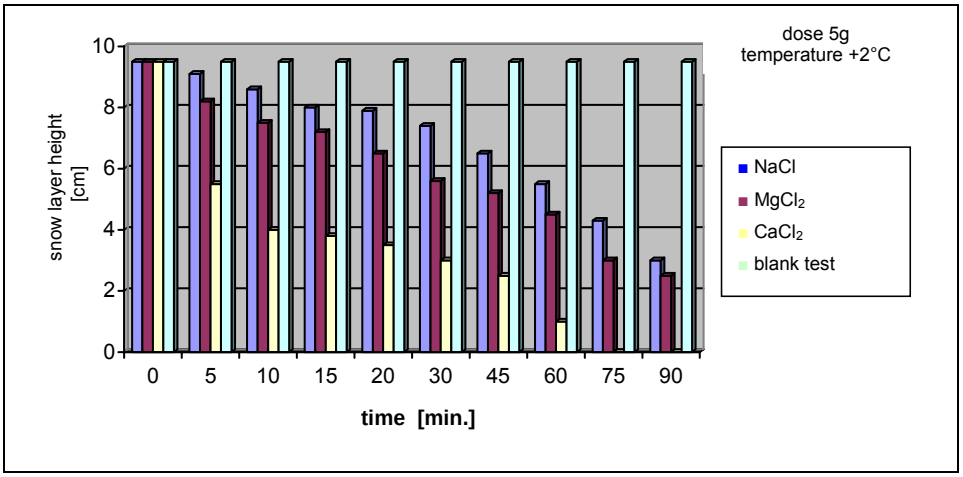

Fig. 12. The efficiency of activity of chemical compounds used in the dose of 5g in the temperature of +2 ^{0}C

4. CONCLUSIONS

Many years of experience of individual countries, Poland included, indicate that the use of a chemical method is the most effective and the most economical one during wintertime road maintenance. The research done by the authors of this thesis showed that the effectiveness of using aggregates that increase the roughness of road surfaces is strengthened by using appropriate chemical compounds which make mineral grains set into ice. Calcium chloride ($CaCl_2$) proved to be the most effective chemical agent that should be used for removing road slipperiness, followed by magnesium chloride ($MgCl_2$), and finally – sodium chloride (NaCl).

Sodium chloride (NaCl), which is commonly used in Poland, is the most economical agent due to its general availability and price and still, however, this is the slowest agent of all. It causes a decrease in a 1.63 cm thick ice layer only after 75 minutes, whereas magnesium chloride, within the same period of time, causes a decrease in a 2.4 cm thick ice layer and of a 6.5 cm snow layer, while calcium chloride causes a decrease in a 2.37 cm thick ice layer and of a 4.3 cm thick snow layer.

Unfortunately, beside many advantages, such as speed, effectiveness and lower costs of winter road maintenance, chemical compounds have a disadvantageous impact on natural environment [Kołodziejczyk 2004, Pečenik

1981]. The basement or nearby soils, plants, and surface waters and underground waters are subject to negative activity of each chemical compound.

Environment protection cannot be forgotten when thinking about effective means that can be used during winter road maintenance – and consequently – when thinking about the safety of all road traffic participants. Using chemical agents must be strictly controlled.

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