Formation mechanism and prevention analysis in plateau damp environment

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Abstract. This paper analyses and researches road condensation ice formation mechanism, so as to find out the effective and economical method to prevent road frozen ice and govern it. The method of prevention can be divided into passive inhibition technology and proactive inhibition technology. Passive inhibition technology cannot inhibit the formation of condensation. In the process of research of prevention condensation, early warning system for snow and ice research also should not ignore. To establish early warning systems and take it into implementation will greatly reduce the extent of the ice and snow disasters.

1. Introduction
Most of the Southwest China belongs to the plateau damp mountains areas. In the winter, roads are susceptible to condensation ice, which is characterized by hardness, thinness and wideness. After the road surface condensation ice formed, it not only has a serious influence on road traffic safety, but also poses a serious threat to the people's lives and property safety. Having recognized the threat the road surface condensation ice may bring about, it is necessary to have a systematic study on condensation ice formation mechanism in damp environment on the plateau. On the basis of this analysis, the road condensation ice prevention was conducted in order to solve or reduce the danges road condensation.

2. The formation mechanism of condensation ice

2.1 Condensation ice
Condensation ice is a state of water condensing on the road surface. In a broad sense, condensation ice can be divided into condensation ice of snow melting, condensation ice on road surface and frozen condensation ice. Condensation ice of snow melting often occurs in the northern area, which are mainly caused by temperature difference during the day melting and at night producing condensation ice with lower temperature and traffic influences. It is characterized by lasting for a long time but easily getting removed. Condensation ice on road surface is formed when the water falling on the road during the day encountered the below zero temperature at night. It is characterized by lasting for a short time, being thin and hard removing. Frozen condensation ice which is different from the former
two condensation ice is a kind of natural disaster in the country’s plateau damp mountains areas in the southwest.

To find out the formation mechanism of the country’s plateau damp mountains areas in the southwest. The formation mechanism of the freezing rain must first be made clear. By studying the spatial and temporal distribution and structure characteristics of temperature and humidity of freezing rain in our country, and according to the two kinds of freezing rain formation mechanism, it can be concluded that winter freezing rain formation mechanism in our country is mainly divided into two kinds-- the north (> 30° N) is mainly ice phase mechanism of freezing rain, and the south (< 30° N) is given priority to warm rain mechanism of freezing rain [1].

According to the temperature, the clouds can be divided into warm and cold cloud, warm cloud temperature being above 0°C and the cold cloud below 0°C. When the cloud droplets grow to a certain size, it can't stay in the sky, which finally landed and produce precipitation. According to the different altitude of the clouds temperature and the thickness of the cloud, precipitation pattern can be divided into snow, sleet, freezing rain and rain, etc. Usually in winter, the surface above 3000m is the snow condensation layer with the temperature below 0 °C. Ranging 1500m to 3000m, this layer usually is warmer layer which the temperature is slightly higher than the snow condensation layer. Close to the ground within 1500m is the air layer. The water, ice and snow in the slightly below 0°C snow condensation layer transformed into liquid droplets when entering the 1-4 ℃ atmosphere, a comparatively warmer layer. When liquid droplets enter the surface air layer which temperature is slightly lower than 0°C, it becomes super-cooled water droplets. Super-cooled water droplets come into contact with the ground which the temperature is lower than 0°C to form the so-called freezing rain. When landing on the surface of road, thus, it forms the condensation ice. Figure 1 is a schematic diagram of the formation of condensation ice.

Therefore, we can draw that the ice formation of southwest plateau damp area should have three necessary conditions: ①the formation of precipitation conditions; ②special structure of "cold-warm-cold" layer in the atmosphere; ③the ground temperature below 0°C.

![Figure 1. Schematic diagram of the formation of condensation ice.](image)

3. The hazard of road condensate ice and prevention analysis

3.1 The hazard of road condensate ice

It is easy for the plateau damp mountains areas in southwest to form condensation ice in winter. Thus, it reduces the pavement skid resistance ability, which lowers road traffic capacity seriously. According to relevant data analysis [2-3], the existence of road condensation ice greatly reduces the adhesion coefficient of road surface, thus worsening the adhesion to the vehicle's braking stability and operation stability. It will finally cause the brake failure, loss of direction control, vehicle easily skidding and
wandering and braking distance being prolonged. Road condensation ice not only poses a serious threat to people's lives and property, but also hindered the local economic development and social construction. Therefore, it is very necessary for pavement condensation prevention and governance.

3.2 Prevention analysis

3.2.1 Passive inhibition condensation ice technology. Passive inhibition condensation technology is a kind of passive way to remove snow, when snow is coming or already came. As shown in table 1, it is the classification of the advantages and disadvantages of passive inhibition condensation ice technology.

| Snow-melting agent | Sprinkle sand and gravel | Manual removal | Mechanical removal | Heart removal |
|--------------------|--------------------------|----------------|--------------------|--------------|
| convenient, deicing effect | convenient and fast for the early ice and snow, economic and environment-friendly. | low efficiency, cost highly, suitable for small amount of snow and the difficult sections of ice and snow. | fast, suitable for the large amount of snow and ice, but affected by the ice thickness. | need for corresponding equipment, cost highly, limited application and promotion. |

Sprinkling snow-melting agent mainly sprinkles to the pavement a certain amount of anti-freezing chemical materials. It can make snow and ice on the pavement melting or reduce pavement freezing degree. Commonly used snow-melting agents are in solid and liquid forms, mainly concluding the edible salt, calcium chloride, potassium slag, acetate etc.

Manual removal can remove ice and snow more thoroughly, but it is low in efficiency, time-consuming and labor-consuming. It will affect traffic and pose a threat to the personal safety of workers at the same time when being conducted. It cannot be applied to a wide range of operation for a long period of time, but for difficult small sections of ice and snow.

Adopting mechanical equipment to remove snow has been applied for dozens of years. This method can be divided into two categories-- mechanical shoveling snow and ice and mechanical blowing snow. Mechanical shoveling snow and ice is suitable for large area clearing with heavy snow and before ice freezing. Mechanical blowing snow is suitable for the thin pavement snow without crushed, and it usually only applies to the airport and other small scopes where snow removal is manageable.

Heat removal is the use of high temperature medium to be in contact with the snow. By the using of heat transmission generated by temperature difference, it can increase the temperature of snow to go above the melting point and transform into flowing water to drain off. This method requires a lot of heat and is not affordable. Heat removal can be also subdivided into the following three ways. Spraying water melting method is suitable for the area that is small and has a good drainage system so that the melting ice water can flow away quickly, otherwise, it is easy to freeze again, leading to more serious traffic accidents. Heat pipe method is that the pipe geothermal is transferred to the ground surface to melt snow and ice, but construction and installation of the heating pipe are complicated and take a long time. Fluid heating method is to use natural hot water or stored solar energy for heating. Taking the method of solar heating method for example, stores the solar energy in the summer, then heat energy storage is used to melt ice and snow in winter. Construction and installation price of it is high, and it is not applicable.

The methods above belong to the traditional methods of dealing with road condensation ice which can be divided into two major categories of removing and melting methods. The former is mainly by
means of artificial or mechanical equipment crushing snow and condensation ice and moving from the road to the other place to ensure road traffic safety. The latter is mainly through the adoption of a certain snow-melting agent or heating method to melt snow and ice to flowing water and discharge it.

3.2.2 Proactive inhibition condensation ice technology. Proactive inhibition condensation ice technology is the use of pavement mechanical characteristics or structural characteristics, through the vehicle repeatedly rolling, spontaneously to clear condensation ice or change the state of ice and snow so as to improve the traffic. Proactive inhibition condensation ice technology mainly has the following three ways.

(1) The road of storage salt

Germany first used a substance that is called "verglimi" and is a kind of a salt to deice [4]. This salt is covered by a hydrophobic substance. "Verglimit" has good temperature stability and it can be directly added to the asphalt mixture in the process of mixing. In order to make the pavement work, porosity of the mixture in engineering applications is about 3-4% (volume), the porosity of Marshall Specimen in the experiment is about 2-3% (volume). In order to improve the durability of the mixture, the mixture of the binder content should be improved.

Besides "verglimit", "mafilon" is the same type of material. Mafilon is a pale yellow powder, and the powder is made of sodium chloride which is a hydrophobic material on the surface. As a result of the existence of this kind of hydrophobic material, it can ensure that the salt can exist in the water for a long time and gradually release under the effect of wheel friction. And this kind of hydrophobic material has good high temperature performance, making the road surface to release less amount of salt in the heat than in a freezing point temperature. And it won't last a damp phenomenon on the road surface during the summer.

The road of storage salt technology isn’t applied widely. Japan mainly carried out some research about latest installation technology of inhibiting freeze. Its purpose is essentially to slow the progress of the pavement freezing by adding the sodium chloride and calcium chloride in the asphalt mixture to reduce the freezing point, so as to achieve anti-freezing effect.

(2) Elastic rubber asphalt pavement

The research for the technology of rubber particles in asphalt mixture began in the late 1980s. Rubber used in the research of elastic pavement is mainly rubber particle and rubber pieces.

Based on the rubber particles related study [5], it shows: (1) As the needle flake content in the rubberized concrete decreasing, the mixture’s compact ability, stability and durability is improved. The characteristic differences of rubber particle surface affect the performance of the mixture slightly. (2) The rubberized concrete concrete’s mixing molding temperature is 10 to 20 degrees higher than ordinary asphalt concrete. Mixing process should be controlled strictly. The step is to dry mix rubber particles and stone around 30s, and then adding asphalt to mix about 90s. When molding it should be twice compaction molding, and pavement construction also should use twice compaction technology. (3) The deicing effect of rubber particles asphalt pavement is affected by rubber particles content, distribution location, pavement thickness, ice thickness and ambient temperature. When the temperature is below -12℃ or the ice thickness is more than 9mm, deicing effect almost disappear.

As to application studies of rubber block, a Japanese company sprinkled 2cm diameter rubber block and pressed it into the just finished asphalt road’s surface with roller. It showed that the method improves elasticity of the pavement and has superior performance in terms of deicing and anti-slipping etc, but durability and flatness is not ideal.

According to the research on frost-resisting pavement in recent years, it was found there are several deicing technology with rubber materials as following: (a) Using rubber granular mixtures, that is to add certain specifications of the waste rubber particles to the mixture to increase the flexibility of surface to curb freezing; (b) Cutting a diameter of 50mm, 25mm deep small hole in the surface of asphalt concrete according to a certain spacing and then pressuring into the same size of the rubber cylinder, and filling the gap with fiber at the same time. Depending on the rubber’s stress which generates by the effect of vehicle, ice will automatically break; (c) Soaking with polyurethane in the
groove of drainage pavement to pave, it can avoid ice adhesion through its elasticity and smoothness, thus to improve the ability to resist freeze; (d) filling the groove of the pavement surface with rubber particles to reduce the freeze.

(3) Rough pavement of anti-sliding

Rough pavement of anti-sliding is to make up the loss of structural depth which is brought about by condensation ice, provide enough road anti-sliding ability, and reduce the effect of condensation ice on road traffic safety by rebuilding pavement wearing layer of great structural depth, so as to reduce the influence of snow and ice on the road traffic capacity. Larger surface and the interstices of internal aggregate can smoothly provide drainage channel, and pavement anti-sliding function can be effectively maintained when producing condensation ice. Rough pavement has the application value in damp regions where the snow is not deep, and condensation ice is thinner.

As to rough pavement, the most often used thing is Open Graded Friction Course (OGFC) [6]. Because of the pore connectivity of the material, it has less condensation ice when compared to the conventional pavement and can improve anti-sliding performance. But with the increase of ice and snow, the internal space is filled and the pavement anti-sliding performance will gradually decline. At this time, using salt to deice costs about 20% more than conventional road. So it is not economical, and the technology is used too narrowly to apply widely.

From the above analysis, we can know that proactive deicing technology is the direction of future research of deicing. As to the research of proactive deicing technology, foreign countries studied earlier than china, but china began to research the technology widely in recently years. If the technology has a major breakthrough, I believe that it will be applied widely in the near future. It will greatly reduce the probability of traffic accidents, and ensure the safety of vehicles and pedestrians.

3.2.3 The early warning of pavement condensation ice.

From the study of material of paved roads, it is an important approach to solve pavement condensation ice. And this method is also the main solution of solving condensation ice, but before producing condensation ice, informing the drivers in time of the time of producing condensation ice and severity forecast will reduce traffic accidents to a certain extent. Condensation ice forecast has a lot relevance with the establishment of disaster warning system of snow and ice. The so-called disaster warning system of snow and ice is to establish Highway Meteorological Service System [7] or Road Weather Information System (RWIS) [8]. It can improve the intelligent level of traffic management and traffic safety of the public service ability through the accurate and timely meteorological Information.

Based on the traffic accidents caused by the complex weather and road conditions, developed countries are successively setting up different forms of highway meteorological service system. Traffic management institutions in some countries integrated the RWIS and Intelligent Transport System (ITS) and successively developed a series of Pavement Meteorological Monitoring System. While on the research of road traffic safety early warning, some foreign related research institutions are studying.

The research about this aspect started relatively late at home. In recent years, we have accumulated preliminary experience about analysis theory methods of climate effects on road traffic safety, but we have not formed systematic research results in the weather forecast service system and also failed to carry out large-scale highway meteorological service. The National Climate Center has analyzed and reviewed the effects of climate and severe weather on the traffic system and researched the severe weather and highway traffic, but not reach to the level of the public service yet.

As the increasing of the highway traffic meteorological service demand, some meteorological observatories in our country are beginning to build severe weather monitoring system along the highway. However, due to funding constraints, such progress is slow and focuses on monitoring a single meteorological phenomena. The early warning measures about disaster from snow and ice has not been studied systematically, it remains to be studied further.
4. Conclusion

According to the above analysis, it has to meet some conditions to form condensation ice. Condensation ice will greatly reduce the friction coefficient of pavement, seriously influence the traffic, and even lead to frequent occurrence of traffic accidents. In order to ensure safety, it is necessary to prevent and govern the pavement condensation ice. Some traditional methods mainly include the removal method and melting method. In view of the rapid development of our countries transport network system, these methods could not have a wide range of applications, it only applies to the city and highway in some key areas.

At present, china and other countries focus on proactive inhibition condensation ice technology, which has a variety of techniques to select. But each technology is not perfect. One technology can solve the problem of condensation ice, but it brings the durability of pavement and the stability of driving at the same time. One does not affect the durability of pavement, but deicing effect is not ideal. So this technology remains to be studied further. It not only can carry out from the perspective of road materials to prevent and govern condensation ice, but also the research of disaster warning system of snow and ice should not be neglect. Only by combining the two kinds of direction organically can we ensure the safety of driving to the maximum extent.

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