

REQUIREMENTS FOR GRITTING AGENTS FOR USE IN PRACTICAL WINTER ROAD MAINTENANCE

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1. Abstract

The central position in the middle of Europe has made Germany a transit country for traffic from the ports on the west coast of Europe to the eastern countries as well as from Scandinavia to the Mediterranean area. However, the major portion of Germany's domestic traffic also takes place on the highways. In order to accommodate this immense requirement, it is necessary to keep the highways safe and capable of carrying traffic even under winter weather conditions.

The basic requirements for winter road maintenance are contained in the Technical Rule (Merkblatt) for Highway Maintenance and Services, Winter Maintenance Section, published by the Road and Transportation Research Association (Forschungsgesellschaft für Strassen- und Verkehrswesen). The regulations in this rules are described more precisely in the so-called Requirement Level for Winter Maintenance (Anforderungsniveau fuer den Winterdienst) which defines the intensity for performing winter maintenance depending on the significance of a road for traffic.

One essential prerequisite for efficient winter maintenance is the use of effective de-icing agents. For this reason, the "Technical Delivery Specifications for Gritting Agents for Winter Road Maintenance" (Technische Lieferbedingungen fuer Streustoffe des Strassenwinterdienstes, TL Streu) in which the requirements for gritting agents are defined was worked out in Germany. Such requirements should be coordinated within the EU for reasons of competition equality. The suppliers of gritting agents should confirm observance of the requirements in a so-called product description. Tests are provided for checking the quality characteristics. The Technical Delivery Specifications are supplemented by recommendations for procurement of gritting agents containing additional explanations for the users.

2. Introduction

By far the major portion of personal and cargo traffic in the Federal Republic of Germany occurs on the motorways(Bundesautobahnen). In comparison to other means of transportation, over 90 % of the passenger traffic (man/kilometers) and nearly two thirds of the freight traffic (ton/kilometers) in land-bound freight transport occurs on the motorway. For this purpose, nearly 50 million vehicles drive on the roads, their total mileage has more than doubled during the last 30 years. It amounts to a total of approx.

630 billion kilometers per year. During the past years, industry has drastically reduced its stocks on hand for cost reasons in favor of just-in-time transport, meaning deliveries made directly to the production process. If such deliveries are not accomplished smoothly and punctually, machine standstill and significant production losses threaten. Here, as well, the major portion of transport is accomplished on the motorways. Moreover, due to its central location, Germany is an important European transit country as the connecting link between east and west as well as north and south.

The services and requirements mentioned assume provision of a continuously efficient and capable network of highways safe for driving the entire year around. The purpose of winter road maintenance is to ensure this even under winter weather conditions.

3. Weather

The winter weather in Germany is influenced decisively by the moist maritime climate in the west and cold dry inland climate in the east. Of basic significance is, moreover, the geographic altitude, which, beginning at the North and Baltic Seas in the north, increases continuously to the Alps in the south. Superimposition of these basic conditions leads to three basically different climatic regions. The north German lowland plane is distinguished by relatively mild winters with temperatures around freezing and frequent alternation between freezing and thawing with relatively low precipitation. In the eastern section, dry cold periods can also occur in corresponding major weather situations. The southern German area and Alpine region are distinguished by longer continuous winters with significantly lower temperatures and rich snow fall. The low mountain region located in between represents a transition between these extremes with lower average temperatures and higher rates of precipitation in comparison to the north German lowland plane.

These differing weather conditions also represent different requirements in performing winter maintenance and the gritting agents to be used. While in the Alps, the focal point is particularly removal of large quantities of snow, maintenance in the low lying areas of the north German lowland concentrates on eliminating rime ice and freezing rain. These are the significant basic conditions for working out the rules described below.

4. Performing Winter Maintenance

The basis for performing winter maintenance is given in the Technical Rule for Highway Maintenance and Services, Winter Maintenance Section published by the Road and Transportation Research Association. Within the last few years, it was revised fundamentally according to the newest research results and the two previous guide lines for winter maintenance on motorways and municipal winter maintenance were consolidated. Here, it was specified particularly that responsible use of thawing substances is preferable to treating slippery roads with grit for economical as well as ecological reasons. This specification has led to a significant amount of criticism from the Federal Environmental Office as well as from environmental societies and the public. It was lamented that the new rule promotes unreflected use of thawing salt instead of the environmentally friendly use of abrasive materials. The fact is that the technical rule does not recommend replacement of spreading grit with ice elimination by thawing. On the contrary, it was made clear that in many areas of the road network, for example on residential streets, the use of thawing salt is not recommended. Simultaneously, it was indicated that at points at which it is possible to eliminate the use of salt based on the significance for traffic and the topography, it is better for economical as well as ecological reasons to only clear the streets and completely eliminate the use of de-icing agents regardless of whether they provide an abrasive or thawing effect. On federal highways and freeways, thawing-type de-icing agents are used almost exclusively. The Technical Delivery Specifications for Gritting Agents for Winter Road Maintenance do, however, contain

requirements regarding abrasives, because these are still used in many municipalities to a significant extent for political reasons in spite of the recommendations mentioned previously.

5. Organization of Winter Maintenance

In contrast to the sector for waterways and shipping, the Federal Ministry for Traffic, Construction and Housing does not have its own administration for federal motorways. The responsibility for planning, construction and operation of the federal motorways is realized by the Federal States acting as agents for the Federal Government according to Section 90 of the Constitution. In addition to the Road and Transportation Research Association Committee already mentioned, the operational representatives of the States cooperate in the State Committee (LFA) "Road Maintenance and Operating Services" and in a corresponding Federal/State Committee. The primary objective of the State Committee is coordination of all activities going beyond state boundaries so that motor vehicle drivers will have a common level of ice clearing under winter road conditions. The guidelines for performing winter maintenance worked out by the Research Association are supplemented and given more precision in the "Winter Maintenance Requirement Level (Anforderungsniveau fuer den Winterdienst)" which goes beyond the explanations in the technical rules to describe when, where and to what extent winter maintenance is to be performed in consideration of the weather situation. For example, winter maintenance is intended to ensure that the federal freeways are capable of being driven on around the clock, i.e. 24 hours a day, with the only possible exception of extreme weather conditions such as long-lasting, rich snow fall. Here, the first priority is to clear and spread de-icing agents on the continuous main driving lanes, then the ramps at junction points and finally the parking locations and rest facilities. Federal motorways and other roads important for traffic such as roads with high traffic volumes or roads with a large share of public traffic, are generally kept free of snow and ice during rush hour traffic. Less important roads with lower significance or traffic and parking places have the lowest priority and can therefore only be cleared and de-icing agents spread when allowed by the vehicle and equipment fleet available and the weather.

6. Requirements for De-icing Agents for Winter Road Maintenance

As a matter of principle, winter road maintenance should first remove the snow to the extent possible and eliminate only the remaining snow residues with thawing substances. On the other hand, freezing rain and hoar frost can only be eliminated with thawing agents. In spite of the extremely restrictive use of thawing agents for economical as well as ecological reasons, approximately 75 million DM per year was spent during the past, relatively mild winters on federal highways and freeways alone. No corresponding statistics on quantities and costs are available for the abrasive de-icing agents used primarily by the municipalities. The "Technical Delivery Specifications for De-icing Agents for Winter Road Maintenance" are intended to ensure that the gritting agents used do not contain additives which are damaging to the environment or constituents which are not effective or have a negative effect.

According to the present state of knowledge, de-icing agents are the most effective gritting agents, because they are capable of completely eliminating the slippery conditions. Abrasive materials can, on the other hand, only reduce the slipperiness present by increasing the traction of the slippery layer on a short-term basis. However, they are pressed into the slippery surface quickly by traffic or thrown to the side thereby losing their effect. For this reason, it is necessary to respread them more frequently. Therefore, and because abrasive materials require expensive measures for removal and cleaning, spreading of grit is approx. 5 - 6 times as expensive as eliminating the slippery conditions with thawing salt.

6.1 Requirements Placed on Thawing Salts

In Germany only

- sodium chloride
- calcium chloride and
- magnesium chloride

are used in winter road maintenance. As a rule, sodium chloride is used as a solid thawing agent, calcium chloride is used in solid form at particularly low temperatures and dispersion is accomplished in the form of thawing salt solutions only in exceptional cases. Solid sodium chloride is used primarily as pre-wetted salt, moistening is accomplished with aqueous solutions of all three substances specified. Sodium chloride comes primarily from domestic production from natural deposits of rock salt or boiled salt, however, is also obtained from foreign countries. To an increasing degree, the specified chlorides are also offered as industrial byproducts, for example from flue gas purification at garbage incineration plants. Particularly the latter could contain pollutants relevant for the environment.

Requirements Placed on Sodium Chloride:

- Additives: In order to allow uniform application, it is necessary for the sodium chloride to remain pourable. For this reason, it may contain additives which ensure its pourability. Generally, potassium ferricyanide $K_3[Fe(CN)_6]$ or potassium ferrocyanide $K_4[Fe(CN)_6]$ are added to the thawing agents to maintain the pourability. The percentage should not exceed 200 mg/kg (calculated as $Fe(CN)_6^{4-}$ anions). For other additives such as agents to color the salt, it is necessary for the supplier to provide proof that the additives do not pose a hazard for the environment and do not have a negative effect on the thawing procedure. As a matter of principle, thawing salts should not contain substances which have a water repelling (hydrophobic) effect, because this delays the thawing procedure. Additives which reduce the corrosion resulting from chlorides (inhibitors), have not proven to be effective according to present knowledge. It is also necessary to ensure that the inhibitors do not damage the environment or reduce the effect of the thawing agent.
- Chemical composition: Thawing agents from natural deposits and waste salts from industrial processes contain extraneous constituents which are not effective in the thawing process or even impede or delay the thawing process. The effective thawing substance calculated as NaCl must be at least 96 %.

Water-soluble sulfates attack concrete. In view of the aggressiveness to concrete structures, the maximum quantity of water-soluble sulfates should not exceed 2 % by weight (calculated as SO_4^{2-} anions). Determination of the sulfate content is accomplished according to ISO 2480.

- Water-content: Salt with a high water content leads to formation of lumps, which makes the loading operation and uniform application more difficult. Since calculation of the delivery quantity is accomplished according to weight, a high water content would also reduce the percentage of the effective thawing substance. For this reason, a maximum water content of 2 % by weight is prescribed for the adherent moisture at the time of delivery. This calculation is accomplished according to ISO 2483.
- Grain size: The particle size distribution curve is of particular significance for application as well as the effect of thawing salt. In comparison to salt with coarse grain distribution, fine grain salt has a large specific surface and can be distributed more evenly. For this reason, the thawing procedure begins at a large number of points and quicker implementation of the thawing operation is achieved all totaled. It is therefore particularly suitable for use on rime ice or as a precautionary measure in the

face of freezing rain. On the other hand, salt with a large grain distribution tends to be better for use in falling snow to keep it capable of being cleared as well as for post-salting of thick layers of ice, because a salt solution is produced in the thawing crater resulting around the individual grain of salt, which freezes later in comparison to finer salt grain due to its concentration and therefore provides for better thawing of the layer of ice down to the surface of the road.

On the other hand, fine salt drifts when spread while coarse salt grains hit against the road when spread and bounce to the edge of the road where they are then no longer available for thawing the driving lane. Both properties can be counteracted by pre-wetting the salt.

In order to obtain salt which is as uniform as possible without either too many large or too many small grains, a particle size distribution curve is required from the suppliers which is required to contain information on the following grain size ranges:

- less than 0.16 mm
- from 0.16 mm to 0.8 mm
- from 0.8 mm to 1.6 mm
- from 1.6 mm to 3.15 mm
- from 3.15 mm to 5 mm
- from 5 mm to 8 mm
- greater than 8 mm

The grain fraction less than 0.16 mm should not exceed 5 % by weight and no grains larger than 5 mm should be present. Suppliers are allowed production-related tolerances of up to + 2 % by weight. Whereby the tolerance is based on the maximum grain size of the limit grain up to 8 mm, i.e. the fraction from 5 to 8 mm may not be greater than a maximum of 2 % by weight, grains larger than 8 mm are not permissible.

The Technical Delivery Specifications provide that price discounts can be agreed upon between the ordering party and supplier for deliveries within these tolerance limits.

Determination of the particle size distribution curve is accomplished according to DIN 66 165, Parts 1 and 2 with the specimen dried according to ISO 2483.

In order to ensure that the specified tests are accomplished on a representative specimen from the delivery, the procedure for sampling is defined precisely in Appendix A of the Technical Delivery Specifications on the basis of DIN EN 932-1. Here, a differentiation is made between samples taken from a conveyor belt, samples taken from stockpiles and samples taken from silo vehicles. For such cases, it is defined in each instance how many individual samples are to be taken and how they are to be combined to form one specimen from which three individual samples are to be formed with a minimum quantity of 1 kg each.

Requirements Placed on Calcium and Magnesium Chloride:

The following specifications apply for calcium and magnesium chloride:

The minimum content of effective thawing substance is

- 77 % by weight for calcium chloride (calculated as CaCl_2)
- 47 % by weight for magnesium chloride (calculated as MgCl_2).

The sulfate content - in relation to the crystalline, water-free form - must not exceed a maximum of 2 % by weight. This is to be determined according to ISO 2480.

The grain size for goods stored in sheds should be between 0 and 20 mm. Here, a maximum of 25 % by weight should not be smaller than 2mm and the percentage of the fraction between 10 and 20 mm

should not exceed 5 % by weight. Here as well, determination of the particle size distribution curve is accomplished according to DIN 66 165, Parts 1 and 2 on the dried specimen.

Requirements Placed on Aqueous Solutions of Sodium, Calcium and Magnesium Chloride:

The following specifications apply for the three thawing agents specified: The pH value of a 10 % solution should be between 5 and 10 and the sulfate content should not exceed 0.6 % by weight.

Heavy Metal Contents:

Particularly stringent requirements are contained in the Technical Delivery Specifications in unison with the applicable guidelines for environment protection regarding the quantity of water-soluble heavy metals contained. The following limits are required for a 10 % aqueous solution at a pH value of 4 corresponding to the definitions in DIN 38 414-4:

Arsenic	(As)	≤ 0.25 mg/l
Lead	(Pb)	≤ 0.5 mg/l
Cadmium	(Cd)	≤ 0.2 mg/l
Chromium, total	(Cr)	≤ 0.5 mg/l
Copper	(Cu)	≤ 0.5 mg/l
Nickel	(Ni)	≤ 0.5 mg/l
Mercury	(Hg)	≤ 0.05 mg/l
Zinc	(Zn)	≤ 2 mg/l

6.2 Requirements Placed on Abrasive Materials

In Germany, primarily natural stone in the form of crushed gravel is used as an abrasive anti-icing agent. Crushed sand is used more rarely, particularly in inner-urban areas, i.e. in pedestrian zones and on sidewalks. In addition, a large variety of byproducts from industry are used such as slag from steel production or from garbage incineration facilities. These are also broken or granulated to the desired grain size depending on their origin.

- Grain size: The limits for the particle size distribution curve of abrasive materials are defined in a manner similar to those for thawing type de-icing agents. The lower limit is intended to prevent excessive development of dust during application. Moreover, a smeary and therefore slippery coating can form on the road surface if the percentage of the finest grain size is too high. For this reason, the permissible percentage of minimum grain size less than 0.063 mm is limited to 5 % by weight. The maximum grain size must not exceed 8 mm. This value is intended to eliminate damage to vehicles parked at the side of the road to the greatest possible extent. Determination of the particle size distribution curve is accomplished according to DIN 52 098.
- Grain shape: Abrasives can only be effective when they ensure sufficient interlocking with the slippery layer. Unbroken river gravel or sand, for example, does not fulfill this requirement, because it is rounded and flattened by transport in the water. Crushed rock is better suited because it has a cube shape and broken edges which ensure the required interlocking with the slippery layer. The Technical Delivery Specifications require that the percentage of cube-shaped grains be greater than 50 % by weight. Determination is accomplished according to DIN 52 114. The percentage of grains with a broken surface determined according to DIN EN 933-5 must be greater than 90 %. On the other hand,

the broken edges must not be sharp as in the case of glass to avoid injury to pedestrians and bicycle riders when they fall as well as eliminate damage to tires.

- **Strength:** The strength of the gravel is of particular importance for spread grit. Gravel without sufficient resistance to crushing can be ground up when rolled over by vehicles thereby quickly losing its interlocking effect. The strength is of great interest particularly when the abrasives are to be picked up following the winter period, treated and used again the next winter. For this reason, the Technical Delivery Specifications require an impact shatter value SZ_{sp} of less than 30 % according to DIN-EN 1092-2. This value means that a maximum of 30 % of broken material may be present after application of a defined impact force. A special value applies for use of lava slag. When it is used, a shatter value Z_L of less than 15 % must be maintained according to the "Data Sheet on Lava Slag in Street and Road Construction (MLS)".
- **Heavy metal contents:** For abrasive materials, the same stringent requirements apply regarding the heavy metal contents as for the thawing agents.

Arsenic	(As)	≤ 0.25 mg/l
Lead	(Pb)	≤ 0.5 mg/l
Cadmium	(Cd)	≤ 0.2 mg/l
Chromium, total	(Cr)	≤ 0.5 mg/l
Copper	(Cu)	≤ 0.5 mg/l
Nickel	(Ni)	≤ 0.5 mg/l
Mercury	(Hg)	≤ 0.05 mg/l
Zinc	(Zn)	≤ 2 mg/l

- Determination of the heavy metal contents is accomplished according to the uniform German procedure for water, waste water and sludge testing using the ph4-stat method with which it is necessary to maintain a constant pH value of 4 during analysis.
- **Special properties:** Abrasive materials must remain pourable during dry storage. They must not contain any coarse matter of organic origin such as wood or plant residues nor finely distributed humus materials.

7. Supervision of Quality Characteristics and Tests

The suppliers of gritting agents are required to prove observance of the specified requirements in so-called product descriptions. The product descriptions must be submitted when a contract is concluded or on delivery and must not be more than one year old.

If the ordering party for a delivery has doubts regarding observance of the agreed standard, it is entitled to perform control tests according to the terms of the Technical Delivery Specifications. The costs for such control tests are borne initially by the ordering party. However, if the control test confirms the doubts, the supplier is required to bear the costs.

8. Recommendations

The Technical Delivery Specifications are intended to contain only specifications regarding the characteristics of a delivery for legal contract reasons. For this reason the document "Commentary and Recommendations for Handling the Technical Delivery Specifications for Gritting Agents" was worked out as a supplement particularly for the road construction administrations as the ordering parties for de-

icing agents. As the title already indicates, it includes additional explanations on the individual requirements in the Technical Delivery Specifications for gritting agents and notes on handling the deliveries.

In particular the commentary describes how to handle deliveries which do not possess the properties specified in the product description. When this is proven during a control test, the ordering party is entitled to return the delivery as a matter of principle. However, in practical situations, this often represents an unreasonable hardship and is also not practical particularly when the deficiency is noted for the first time during the winter period and the gritting agents are required for use. It is therefore recommended to agree upon price deductions for such situations.

9. Perspectives

The Technical Delivery Specifications still require ratification by the European Union. They contain the usual clause whereby products from other member countries in the European Union and goods originating from other member countries in the European Economic Community, which do not fulfil the delivery specifications, including tests and surveillance performed in the producing country, are to be treated as equivalent when the required level of protection - safety, health and suitability for use - are equal and permanently achieved. This clause is intended to counteract the development of any type of commercial barriers.

The "Technical Delivery Specifications for Grittings for Winter Road Maintenance" (Technische Lieferbedingungen fuer Streustoffe des Straßenwinterdienstes, TL Streu) are intended to ensure the use of only effective and economical gritting agents, which do not contain extraneous constituents which are either ineffective or hinder or delay their effect and no additives which damage the environment. They are the indispensable basis for effective and efficient winter maintenance services.