CMA+

Instruction Manual 1.1

for the reduction of fine-dust (PM) pollution
through the application of a liquid "fine-dust glue"
(Calcium-Magnesium-Acetate)

www.life-cma.at

FINE! Dust-Free.

CMA+

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Introduction

This Instruction Manual (Version 1.1) provides municipalities with a method for significantly reducing fine-dust (PM) pollution (by up to 30% relative to the daily average value) along heavy-traffic routes. It is based on the results of the EU Project CMA+ and should provide guidance for users, but serves only as a recommendation.

The CMA+ Project was financially supported via the funding programme LIFE+ and extended over a period of four years (2009-2012). The goal of this EU project was to optimise, demonstrate and evaluate the application of CMA (Calcium Magnesium Acetate) as a "fine-dust glue" in Klagenfurt on Lake Wörthersee and in the project partner towns of Bruneck and Lienz both in winter and in summer. Apart from questions related to the quantity to be applied as well as when and how often, the issue of traffic safety was addressed. To this end, the Austrian Automobile Club (ÖAMTC), the Austrian Traffic Safety Committee (KfV) and Vienna University of Technology (Institute of Transportation) were commissioned with carrying out measuring campaigns. Scientific monitoring of air quality was performed by Graz University of Technology (Institute of Internal Combustion Engines and Thermodynamics). The Swedish Road and Transport Research Institute VTI performed tests in the road simulator. CMA as well as CMA:KF (a mixture of CMA and potassium formiate/KF), a product which was developed in the course of the Project and has better dust binding properties, is produced by the Danish partner to the Project, the company Nordisk Aluminat.

Any liability issues that may arise from the use of CMA or mixtures of CMA and KF shall be settled between the buyer or user and the manufacturer of these products.

If new findings are obtained from further applications, this Instruction Manual will be updated and complemented with this information.

List of abbreviations

NO_x	nitrogen oxide
PM_{10}	Particulate Matter, Fine-dust; those particles whose diameter are smaller than 10 micro-meters (10 microns = 0.01 mm)
CMA	Calcium-Magnesium-Acetat
FSZ	Driver training centre
KfV	Austrian Traffic Safety Committee
KF	potassium formiate
LCA	Life Cycle Assessment
CBA	Cost Benefit Analysis
IBC	Intermediate Bulk Container
WDS	Wet Dust Sampler
DTV	average daily traffic

Fine-Dust (PM_{10})

pollution, sources, health effects, legal background, abatement strategies

Dust (PM, particulate matter) is a complex mixture of solid and liquid particles. They differ in size, shape, colour, chemical composition, physical properties and origin or pathways. Basically, a differentiation is made between primary and secondary particles. Whereas the former are emitted directly into the atmosphere as primary emissions, the latter are generated through air chemistry processes from precursor substances (e.g. ammonia, sulphur dioxide, nitrogen oxides) that are emitted in gaseous form.

In the dust fraction referred to as PM_{10} particles are smaller than 10 µm, simulating the fraction that can enter the lower airways. Particles of this size are able to make their way into the lungs via the larynx and are therefore particularly harmful. They are, at best, as big as a single cell and hence not visible to the naked eye. Clearly visible dust as produced at construction sites or the spreading of grit consists largely of coarse particles.
$PM_{2.5}$ is a sub-quantity of PM_{10} and accounts for particles smaller than 2.5 µm in diameter.

Fine dust may originate from natural as well as from anthropogenic sources. The main ources for natural fine-dust pollution are pollen, volcanoes, sea salt, forest fires, (desert) sand drifting and erosion. Anthropogenic sources include, in particular, domestic fuel combustion (individual stoves, wood-fired heating systems and open fireplaces), industry, district heating (power) plants, agriculture, bulk handling, road traffic (abrasion from tyres, brakes, asphalt, exhaust emissions such as diesel soot) as well as rail and air transport.

The correlation between the exposure to fine dust and the effects on health has been confirmed by numerous studies in recent years. The impacts range from temporary impairment of pulmonary function to traceable fatalities, particularly due to respiratory and cardiovascular diseases. According to a very recent WHO assessment [1], ambient air pollution is one of the environmental impacts that have the biggest effects on health in Western industrialized countries. There is no threshold value for PM_{10}.
WHO (2005) recommends 20 µg/m³ as an annual mean value and 50 µg/m³ as a daily mean value (max. 3 days on which the limits are exceeded).

To protect health, immission limit values were introduced for pollutants in Europe. With the daughter Directive 1999/30/EC of 22 April 1999 of the Air Quality Directive, limit values were defined for fine dust or particulate matter for the first time. Currently, Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on Ambient Air Quality and Clean Air for Europe (Air Quality Directive) is applicable.

Limit values for PM_{10} und $PM_{2,5}$

PM_{10}	50 µg/m³	Daily average: per calendar year limit values may be exceeded on 35 days.
PM_{10}	40 µg/m³	Annual average
$PM_{2,5}$	25 µg/m³	Annual average - effective from 1/1/2015
$PM_{2,5}$	20 µg/m³	AEI (Average Exposure Indicator), sliding 3-year average as a mean value from urban background measuring stations, effective from 31/12/2015 with the obligation for further reductions

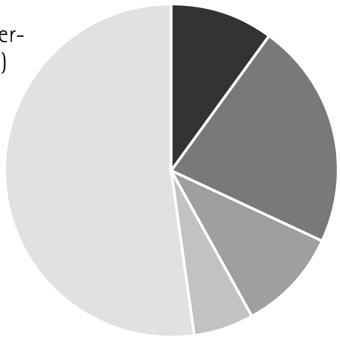
Where natural contributions to pollutants in ambient air can be determined with sufficient certainty, and where exceedances are due in whole or in part to these natural contributions, these may be subtracted when assessing compliance with air quality limit values. The same applies to contributions from sanding or salting of roads, provided that reasonable measures have been taken to lower concentrations [22].

If limit values are exceeded, clean air programmes and action plans have to be developed, with different strategies being pursued by the individual Member States [21].

The main contributor to PM_{10} pollution at traffic-oriented measuring stations in urban agglomerations is road traffic, with re-suspension of dust accounting for the biggest share.

Fig. 1 Contributors to PM_{10} in percentages at the measuring station Völker-markterstraße (23,000 DTV) in Klagenfurt, annual average 2005.

10% traffic exhaust
22% traffic non-exhaust
10% domestic fuels
6% industries
0% agriculture
52% background



One of the PM_{10} abatement measures in road traffic is to reduce exhaust emissions (electro-mobility, retrofitting of vehicles for compliance with Euro 5 or 6, creation of environmental zones, temporary and/or sectoral driving bans, city tolls, parking-space management, extension and promotion of local public transport, speed limits).

Road maintainers, too, are able to take effective measures to reduce re-suspension of road dust in urban areas in the course of their road maintenance service in winter and in summer, respectively, by appropriate road cleaning (sweepers that retain dust, wet cleaning of roads) as well as by applying the liquid fine-dust glue CMA or a mixture of CMA and KF.

Influences

of road cleaning and winter service on PM_{10}

Road cleaning

Re-suspension of road dust contributes significantly to the PM_{10} concentrations measured in many areas of traffic and transport. It is in particular in the Nordic countries that wear from studded tyres and the spreading of grit and salt produce high levels of road dust in winter. Road cleaning is considered to be an appropriate measure to control the re-suspension of dust.

Fig. 2 Road cleaning in Sweden

Fig. 3 This is road salting with brine in Denmark.

As summarised by Amato et al. (2010) [2], scientific studies dealing with this aspect are rather rare and have produced disappointing results regarding the reduction of PM_{10} emissions. It seems that road cleaning by conventional sweepers is ineffective in reducing overall PM_{10} in summer. On the contrary, some sweepers were reported to even increase local PM_{10} concentrations. While some few studies noted positive effects, the influence of meteorological conditions could not be excluded with certainty.

A recent study from Sweden on the other hand did show that modern sweepers are able to reduce local contributions to the PM_{10} concentration by up to 20 %, although the effect on total PM_{10} was fairly limited (Gustafsson et al., 2011) [4].

Winter road maintenance service

In regions where temperatures below 0°C are frequent, winter services are responsible for ensuring that sufficient friction is maintained on road surfaces so as to render them still passable. The most frequently employed method is salt spreading (sodium chloride) in solid or liquid form or the use of pre-wetted salt and grit (sand).

Grit may already contain very fine dust particles when being applied onto the road, where it is further crushed by traffic. Tests performed under laboratory conditions confirmed that grit contributes to high fractions of PM_{10} and is thus a major fine-dust source. The contribution to PM_{10} is probably high, but short in duration because it is carried away quickly by the tyres of passing vehicles. Kupiainen (2007) [5] demonstrated that the size distribution and the material properties of grit play a major role in PM_{10} emission.

He also discovered the so-called "sandpaper effect", which means that grit exacerbates road wear under the influence of traffic and thus contributes more to PM_{10} emissions. Based on these results, in Helsinki, for example, very fine particles were separated from grit by sieving or washing prior to its application and rock material, which is generally harder and more resistant to abrasion, was used.

However, and as a general principle, grit should be used on secondary roads only, if at all.

It has also been shown that road salt contributes to PM_{10} (e.g. Furusjö et al., 2007) [3] and could thus be an important source of PM_{10} in winter in the proximity of roads.

According to the Air Quality Directive, PM_{10} pollution caused by the spreading of salt or grit can be subtracted retrospectively from annual pollution [22].

Fig. 4 Salt crystals on road asphalt

Analyses of fine-dust-filter samples performed so far in Klagenfurt suggest that up to 8 days per year on which the limit values were exceeded might be due to elevated NaCl concentrations.

Properties

of liquid CMA and of CMA:KF mixtures

CMA, which is marketed under the name ICE & DUST-AWAY, consists of a of 25 w/w % aqueous solution of Calcium Magnesium Acetate. It is produced by allowing acetic acid to react with caustic lime and magnesium oxide. ICE & DUST-AWAY is produced without additives and inhibitors.

A mixture of CMA and potassium formate (KF, produced from formic acid and potassium hydroxide) is available on the market under the name ICE & DUST-AWAY PLUS 50. This product (50 w/w % CMA and 50 w/w % KF) has a lower freezing point and a better melting capacity than CMA (see Fig. 31). Road simulator tests have shown both an improved dust-binding effect and a longer duration of action. Driving and friction tests performed by the Austrian Automobile Club (ÖAMTC) produced results for ICE & DUST-AWAY PLUS 50 that were comparable to or slightly superior to ICE & DUST-AWAY. However, ICE & DUST-AWAY PLUS 50 is considerably more expensive (1.8 times) than ICE & DUST-AWAY.

The products can be easily applied via a spray nozzle or by a spreader. Both products are easy to handle and completely stable even if stored over a longer period of time.

The products are used to bind dust on roads and as a de-icing agent on roads, pavements and in pedestrian zones.

The products are well suited for application near parks and green spaces because they have no detrimental effects on plants as well as in pedestrian zones to avoid corrosion and salt irritation to animal paws.

Classification

The product is not classified.

First aid

In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.

Manufacturer/supplier

Nordisk Aluminat A/S
Stejlhoej 16, DK-4400 Kalundborg
Email: tko@aluminat.dk (Ms. Klarskov)

Product properties

	ICE & DUST-AWAY	ICE & DUST-AWAY PLUS 50
Density at 20 °C	1.14 g/cm³	1.22 g/cm³
Viscosity at +5/0/-5/-10/-15 °C	32/37/44/53/- cP	-/28/32/36/43 cP
pH	8.8 ± 0.5	9.0 ± 0.5
Freezing point	-14 °C	-23 °C
Total chloride content	< 0.01 % by weight	
Apparence	transparent liquid	transparent liquid

Impact

of CMA on the environment

As a de-icing agent, ICE & DUST-AWAY bears the Nordic ECO-label, the Swan. So does the product containing KF. The environmental threshold values for the ECO-label are shown below. ICE & DUST-AWAY PLUS 50 has not been tested yet.

Environmental threshold values for the ECO label

Parameters	Threshold values	ICE & DUST–AWAY
Chloride content (Cl-)	1.0 % by weight	0.006 % by weight
Biodegradability	At least 70 % within 28 days (OECD 301 A)	70% was degraded in 3 days
Oxygen consumption	5 g O_2/m^2	1.2 g O_2/m^2
Ecotoxicity (Between 1-100 mg/l the substance must be readily degradable)		
Fish	LC50 > 1 mg/l	LD50 >11.4 g/l
Daphnia	EC50 > 1 mg/l	EC50 > 1.8 g/l
Algae	LC50 > 1 mg/l	EC50 = 13 g/l
Nutrients. total N	1 % by weight	0.00008 % by weight
Nutrients. total P	1 % by weight	0.002 % by weight
Heavy metals		
Arsenic (As)	10 mg/kg dry substance (DS)	7.5 mg/kg DS
Cadmium (Cd)	0.8 mg/kg DS	0.1 mg/kg DS
Mercury (Hg)	0.8 mg/kg DS	0.6 mg/kg DS
Nickel (Ni)	30 mg/kg DS	10 mg/kg DS
Lead (Pb)	40 mg/kg DS	16 mg/kg DS
Zinc (Zn)	30 mg/kg DS	9.3 mg/kg DS
Chromium (Cr)	40 mg/kg DS	9.1 mg/kg DS
Copper (Cu)	40 mg/kg DS	8.9 mg/kg DS

Test performed by Eurofins. Denmark for Nordisk Aluminat A/S

Material intensity and global warming potential (GWP) of CMA versus potassium formate (KF) and salt (sodium chloride)

	CMA 20g/m²	CMA 20g/m² (1x in 4 days)	KF 20g/m²	Brine 20g/m²	Salt 20g/m²
Abiotic material [g/m²]	15.3	3.8	70.8	25.0	27.2
Air [g/m²]	4.6	1.2	39.6	1.6	2.5
Water [g/m²]	385	96	3.978	162	356
GWP [g CO_2 equiv./m²]	5.77	1.35	25.73	0.46	0.58

Study performed by the Wuppertal Institute. Germany. as part of the Life CMA+ Project

Application

of CMA for fine-dust binding during the winter season

The application of CMA onto asphalted roads during the winter season (October – April) is based on a dynamically managed winter road maintenance service.

The following points have to be observed:

- The application of CMA may turn roads into wet surfaces when one would normally expect dry roadways. Road sections with reduced skid resistance or showing major wear or track grooves should not be treated. It is therefore recommended to perform grip tests on the roads which are intended for treatment prior to starting with the application.

- Sufficiently long before treatment is started, the respective road sections or areas have to be properly signposted (for examples of signposting see Figs. 11, 12, 29 and 30) and the population has to be informed through PR campaigns.

- The application is weather-dependent and should be done only under the following conditions: dry weather; air humidity below 80%; no precipitation expected; rising trend of PM pollution; limit values (> 50 µg/m3) have already been exceeded or are expected to be exceeded.

- The decision to go ahead with the application should be taken by a team of experts (air quality, meteorologist, winter service) on a daily basis. A daily updated planning and forecasting model serves as a basis for decision-making by the winter service staff (for the forecasting and interpretation model Lienz see Fig. 19 in the Annex).

- The dose for a single treatment should not be higher than 10 g/m^2 for traffic safety reasons. Intersections, pedestrian crossings, bends, roundabouts and bridges as well as road sections with reduced skid resistance must be excluded from treatment.

- Road sections with heavy traffic (more than 7500 DTV per lane) should be treated once a day, road sections with very heavy traffic (more than 15000 DTV per lane) twice a day. On less busy roads (< 5000 DTV), treatment on every other day is sufficient, below 2,500 DTV every third day. On roads with low traffic volumes (below 1000 DTV per lane) treatment does not make sense. If possible, the liquid de-icing agent should be applied before the onset of the morning rush hour (not later than at 7.00 a.m.).

- It is recommended to determine residual CMA quantities for checking purposes and for optimization of the spreading intervals.

- If the outside temperature has dropped below minus 10°C, treatment must be refrained from because of the danger of ice formation.

- As soon as weather conditions permit, the respective road sections should be cleaned and washed in between as often as possible (sweeper that is suited for PM and for operation up to minus 5°C, high-pressure washing vehicle).

- To make optimal use of CMA and to save resources and costs, the application may be done alternatingly, once across the entire road width and then only across the wheel track, provided the spreaders are equipped accordingly.

- Laboratory tests have shown the best dust-binding effect can be achieved by using the product CMA:KF at a 50:50 mixing ratio. However, this mixture has not undergone field-testing yet. While applying the same quantity, it might be possible to reduce the frequency of application.

- For the purpose of checking and documenting the quantity applied as well as for adhering to the recommended dose, detailed records have to be kept, and after each spreading journey a balance has to be drawn between the quantity applied and the distance covered (for the records see Annex, Figs. 27 and 28).

- Training and sensitising the road maintenance staff and, in particular, the operators of the sweepers as well as exchanging experiences with the winter service authorities of other local communities is an important key to success.

- If applied consistently, the curbside fine-dust reduction potential is up to 30 % relative to the daily average, 20 % relative to the monthly average and 10 % relative to the annual average.

CMA as a De-icing Agent

The de-icing effect of CMA was tested, in particular, in parks and on sensitive traffic routes close to flowing water bodies as well as on walkways in downtown areas.

Fig. 5 Application in the pedestrian area of Lienz: a de-icing effect can be clearly observed up to a new-snow depth of approx. 3 cm.

- In case of larger quantities of new snow, subsequent complete snow removal all the way down to the road surface becomes easier. The snow does not adhere to the road surface as tightly, which results in improved clearing.

- The effect as a de-icing agent is a preventive one, and the dosage to be applied is between 10 and 40 g/m², depending on the expected amount of snowfall. As the effect of CMA lasts for a considerably shorter period of time compared to road salt, using CMA alone in road traffic is not recommended (see Fig. 25). The simultaneous application of CMA and road salt does not pose any problems.

- Good results could be demonstrated in pedestrian zones and parking areas, albeit of a preventive nature only. In case of heavy snowfall, the additional spreading of sodium chloride or of skid-proofing material is recommended.

- In private areas, CMA, which is supplied in 5-litre cans, can be applied with manual spraying devices as used for gardening. Here, too, a slight smell of vinegar may be perceived carried along on shoe soles into indoor areas. However, this is unproblematic and harmless.

- For the optimal time of application, the general experiences gained by winter services should be relied upon.

- The most efficient de-icing agent is the mixture between CMA and KF. The higher the share of KF, the better the thawing effect will be.

CMA for Dust Binding

on unpaved roads and at construction sites

Dust binding on unpaved roads requires less effort but a higher dosage of 100-200 g/m² compared to the application during winter road maintenance.

Non-asphalted roads should be treated with a dose of up to 200 g/m² to minimize the local re-suspension and air transport of dust particles into sensitive neighbouring areas (residential areas, etc.).

In principle, CMA can be applied onto gravel roads in open land or in gravel pits with equipment as used in winter or with a conventional spray lance and a water barrel.

The frequency of application depends on weather conditions, surface characteristics and traffic volume. According to previous experience, the effect may last for several weeks and is observable on site since increased dust formation becomes visible immediately.

The ground to be treated should be wet before application to improve wetting of the soil matrix by the CMA droplets. Wetting of the ground may either occur naturally (morning dew, rain) or it may be achieved mechanically (spraying with water).

Due to the product itself and the high dosage, a slight smell of vinegar may be perceived close to the site of application, which, however, is not harmful to the environment.

Fig. 6 Test track on Druckerweg with air-quality measuring station, Klagenfurt.

Application at construction sites is possible, too, to reduce local dust formation from construction site traffic. However, it must be considered that dirt may be carried over from unpaved areas to paved public road sections by vehicle tyres due to the strong dust-binding effect. To avoid soiling of public traffic routes, construction sites where the use of CMA is intended should therefore ideally be equipped with a wheel-washing facility.

Fig. 7 Application on Stegener Marktplatz, Bruneck

Limiting factors

1. Centimetre-thick dry dust layers prevent the liquid droplets from being wetted due to the high surface tension of water. This effect is particularly obvious on hot mid-summer days.

Fig. 8 CMA on a dry dust layer

2. In case of strong wind, drifting of dry dust from large unpaved opencast mining areas (opencast extraction of mineral resources, gravel pits) cannot be prevented by this method.

Fig. 9 Dirt road gravel pit, Hörtendorf near Klagenfurt

Air-Quality Measurements

to evaluate the effects of CMA

General

Given the specific meteorological conditions in Alpine basins in the winter months (inversion weather conditions, low wind velocities, ...), the measuring concept of campaigns to measure air quality has to be adjusted accordingly. The approach has been changed insofar as 2 appropriate measuring stations are chosen in proximity to the road and another one to determine local background pollution. On this basis, the differences in pollution from PM_{10} (delta PM_{10}) and from NO_x (delta NO_x) are calculated as, contrary to PM_{10}, NO_x emissions are hardly subject to major variations and can be predicted very reliably by computation. This allows the best-possible determination of traffic-induced immission. For the sake of better understanding, the approach is shown schematically in the graph below.

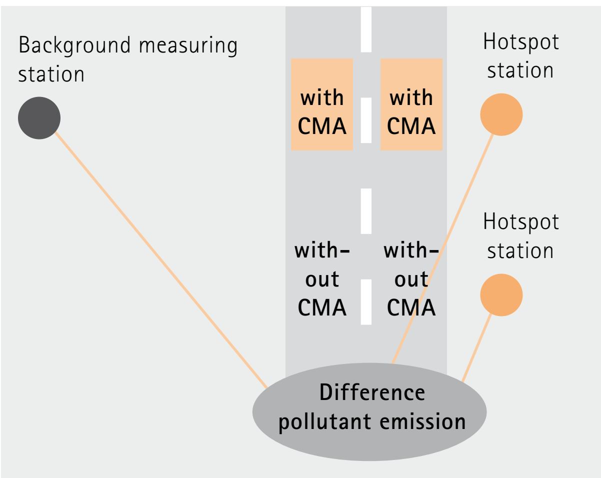


Fig. 10 Scheme of measuring set-up – air-quality measuring station of Graz University of Technology

The calculated road-induced contributions to immissions and traffic sensing for the precise capturing of the respective shares of passenger cars and of heavy-duty vehicles are the basis for the next step of calculation. Using the individual traffic proportions and the NO_x emission factors calculated via the NEMO model, the fleet-averaged emission factor can be determined for NO_x in g/km*vehicle. This fleet-averaged emission factor for NO_x is now multiplied by the ratio between delta PM_{10} and delta NO_x. As a result, the flee-averaged emission factor is obtained for PM_{10} in g/km*vehicle, which is higher at hotspot stations without CMA compared to those with CMA.

$$EF\ PM_{10}\ [g/km * vehicle] = EF\ NO_x * \frac{delta\ PM_{10}}{delta\ NO_x}$$

The result can then be assigned back to the PM_{10} reduction potential.

Days with precipitation and high air humidity must be excluded in the evaluation.

If there is only one curbside measuring station available, episodes with and without CMA application may be compared with each other, provided that there are similar meteorological conditions. An example of an evaluation is given in Figs. 20 and 21 in the Annex.

Instrumentation

For determining the pollutant load in the course of the air-quality measuring campaigns, the following components are measured: PM_{10} ($PM_{2.5}$, PM_1), NO, NO_2, NO_x as well as the meteorological parameters temperature, air humidity, wind veloocity and wind direction. At the curbside measuring stations, traffic figures are recorded additionally via lateral radar units. If possible, measuring devices of the same type and operating according to the same principle should be used for ease of comparison.

Winter measuring campaigns

Apart from traffic, domestic heating systems and industry are among the big contributors to local PM_{10} pollution in urban areas. To provide the best possible information of the impact of traffic on air quality, it is crucial to select the appropriate site for the background measuring station.

The following aspects should be considered:
- low building density
- low influence of single sources (domestic heating, industry, ...)
- low traffic volume on the nearest road

In order to allow for the influence of traffic and of CMA, respectively, on current air quality to be determined also on the basis of short-term averages, it is important to ensure that the diurnal variations in the concentration of air pollutants do not differ too much between the background station and the curbside measuring stations. Ideally, the curbside measuring set-up should comprise at least two measuring stations. In proximity to a measuring station, CMA is applied on a length of + 200 m The area of the next curbside measuring station remains untreated. The distance from the end of the test track should be at least 500 m (trailing effect!). Based on this, it should be possible to determine the reduction potential of CMA as regards current air quality by comparing pollutant concentrations with the background measuring station.

Summer measuring campaigns

Summer measuring campaigns are carried out in a similar manner to winter ones.

The following aspects should be considered:
- low building density
- low influence of single sources (construction site, manipulation processes, ...)
- sufficiently high traffic volume (~ 300 vehicles per day)
- grit/gravel road

In order to allow the influence of traffic and of CMA, respectively, on current air quality to be determined, it is important to ensure that the road surface be largely the same (grit, gravel) and that the traffic volume be sufficiently high. As described above, the curbside measuring set-up should comprise two measuring stations. The background measuring station should be positioned at a sufficient distance (> 500 m) from the unpaved road to avoid influences of road traffic on the level of air pollution.

Influence

of CMA on friction behaviour and traffic safety

In the course of the Project, numerous tests were performed to study the influence on friction behaviour and on traffic safety:

- braking tests and comparative test rides on the circular track at the driver training centre of the Austrian Automobile Club (ÖAMTC) in Mödling and in Carinthia in 2009 and 2011
- grip tests by Vienna University of Technology, Institute of Transportation, in Klagenfurt, Lienz and Bruneck in 2010 [6]
- laboratory tests at the ACCT
- accident scene investigations, conflict studies in Klagenfurt, Lienz and Bruneck by the Austrian Traffic Safety Committee (2009-2012)

As soon as a dry and clean road surface has been soiled with an intermediary material (water, humidity, dirt, oil, sand, salt, grit, CMA, etc.), grip between the road and the tyres deteriorates.

GripTester studies, braking tests and test rides on a circular track have shown that skid resistance is up to 25% lower immediately after the application of CMA or CMA:KF (versus a dry road). Depending on the road surface, grip is reduced to the level of a wet surface or slightly below [6]. The reduction in grip is higher at a dose of 20 g/m² than at a dose of 10 g/m².

However, when outside temperatures are mild and combined with solar radiation and wind, the asphalt road dries up very quickly and becomes "more skid-proof" again, i.e. adhesion between the tyres and the road is improved again. The spreading agents remaining on the road do not influence the frictional coefficient of the road surface. After 5 minutes to approx. 2 hours (depending on the weather conditions), the treated road surface has reached its initial dry state (partly even dryer). After three successive applications of 10 g/m² no accumulation has been observed.

Trailing effect

Fine-dust glue is taken up from the asphalt surface by vehicle tyres and "dragged along" in the direction of driving. Depending on the weather conditions, this may reduce the CMA content in the contact zones between the tyres and the asphalt (track width) by up to one third compared to the middle of the road and the edge of the road, respectively (see Fig. 26). However, this trailing effect does not impair the skid resistance of untreated road sections significantly.

Traffic safety

The Austrian Traffic Safety Committee could not establish a relationship between any of the traffic accidents or conflict situations observed on site and the application of the fine-dust glue. There have been no indications that CMA might compromise safety [8].

However, practice shows that every driver, no matter whether more or less experienced, adjusts his or her driving speed to the current weather conditions. "Good", i.e. "dry and mild weather" suggests good driving conditions. Based on this visual impression and on subjective judgement, the driver will adjust his or her driving style and speed accordingly.

Statistically, every fourth accident happening in urban areas is caused by skidding, and most of them occur during adverse weather conditions. Bends and roundabouts, in particular, tend to give rise to critical situations in terms of driving dynamics, which drivers are unable to manage. The phase in which the driver turns into the bend or into the roundabout is particularly critical. Drivers of two-wheeled motorised vehicles are especially at risk.

Bearing this in mind, preventive accompanying measures have been derived for the application of CMA:

- Precise and uniform spreading of a dose not to exceed 10 g/m^2.
- Bends, roundabouts, intersections, pedestrian crossings, slippery road surfaces or roads in a bad state of repair must be excluded from treatment. Application must be stopped at a distance of approx. 20 m from the critical road sections mentioned above.
- The roads treated with CMA must be clearly and visibly signposted for road users.
- As a preventive measure, desolate road sections may be marked with appropriate traffic signs (e.g. "danger of swerving", "other dangers") or be subject to speed limits.

For signposting examples in the test area of Klagenfurt and Bruneck see Figs. 11, 12, 29 and 30.

Fig. 11 Signposting of the fine-dust test track Druckerweg, Klagenfurt

Fig. 12 Opening of the test track in Bruneck

Determination of Residual Amounts

The SOBO-20 measurements should be timed depending on the local conditions and should allow for flexibility (according to experience, at 30-minute intervals or every hour) until CMA is no longer detectable on the road.

Duration of measurements

Measuring the cross section of a road section, which has been closed for a short time (with 1 lane in each direction), takes only a few minutes.

Measuring conditions

The road section selected for the measurements should be even, homogenous and in a good state of repair.

As the SOBO-20 measuring principle is based on the conductivity of a saline solution, the instrument is cross-sensitive to alkali salts and earth alkali salts (NaCl, $CaCl_2$, $MgCl_2$), i.e. it measures de facto the aggregate conductivity of the sampled road section.

A reliable measurement of the residual content of CMA or CMA:KF is only possible if the instrument has been calibrated for the substance to be analysed and if it can be ensured that the road is free from de-icing salt.

Measurements performed in Klagenfurt demonstrated that CMA could not be detected any more after 4 hours on a road passed by 500 vehicles/h. The reduction was considerably higher in the track grooves than in the centre or on the edge of the road (see Fig. 26 in the Annex).

Fig. 13 Sobo measuring procedure

Fig. 14 Measuring image cross section

Equipment

for CMA users (storage, spreading system)

3 different substances in one vehicle

Fig. 15 Gritting vehicle Lienz

CMA disk mode

When operating in disk mode, CMA is spread at a dose of 10 grams per m² across a constant width of 3 m. To prevent unintended operating errors, the dispensing quantity cannot be changed manually in this mode. The driver may only actuate a button for switching CMA spreading on and off – particularly at intersections and roundabouts. Spreading is fully automated and depends on the distance travelled, which means that the dosage is adjusted automatically to the driving speed, thus generating a constant CMA film of 10 grams per m² behind the gritter (for control panel and operating instructions of the spreading system by Springer see Figs. 23 and 24.).

If not in use for more than 2 days, the pipes leading from the pump to the spray disk must be cleaned with water (valves may become clogged).

Fig. 16 Spray disk

CMA nozzle mode

The nozzle mode enables the targeted application of CMA onto the wheel track, the rationale being that the road often appears in different shades of grey. Areas where CMA is still present from the last spreading operation are darker in appearance (usually on the edge and in the middle of the road) while areas through which car tyres have passed are lighter because there is hardly any CMA left to adhere to the road and to bind particles. In this case, it makes sense to apply CMA only to the lighter sections. At a roadway width of 3 m, the light areas account for about 1/3 and the dark ones for about 2/3 of application. By switching to the nozzle mode, the automatic spreader is now able to limit treatment to the light area, thus reducing the amount of CMA spread over the same distance by 2/3.

Fig. 17 Spray nozzle

For this kind of operation, a spray bar has been mounted in addition to the spray disk and provided with nozzles, which are positioned precisely where the lighter wheel tracks tend to be (position can be set as required). Each nozzle produces a spray cone of about 50 cm in width on the roadway, which results in 2 CMA strips of 50 cm each. As in the disk mode, the quantity dispensed is 10 grams per m^2.

Storage of CMA

CMA can either be stored in an open depot in stackable intermediate bulk containers (IBCs) of 1000 litres each or in larger tanks. As an alternative, the producer delivers CMA by tanker trucks for refilling, which, ultimately, is also a question of price.

In Klagenfurt, the city's municipal service has provided a roofed storage yard for the stacking of IBCs.

Fig. 18 CMA storage yard, Klagenfurt

Calculation of Costs

General (applies to both winter and summer service): At an estimated basic price of € 51/h for lorries and of € 10/h for CMA spreaders and assuming a spreading speed of 20 km/h (1 km in approx 3 minutes), the costs incurred for lorries and CMA spreaders amount to € 3.05 in total per kilometre.

Material costs

When using CMA for the winter service the material costs amount to € 13.50 per kilometre. At 10 g/m^2 and a spreading width of 3 m, 1 kilometre of road corresponds to 3,000m^2 of treated surface or a consumption of 30 kg of CMA solution.

If CMA:KF mixtures are used, the material price is higher, depending on the product price (the gross price for 1 t of CMA incl. freight is about € 520 and for 1 t of CMA:KF about € 880), but this can be compensated by the lower frequency of application in the disk mode. Operation in the nozzle mode (i.e. treatment of the wheel tracks) may reduce the material costs by 2/3.

In Klagenfurt, the costs for the large-scale application on 30 days and on a length of 164 km amounted to approx. € 84,000 in the winter season 2012.

The material costs for the application on unpaved roads amount to € 270 per kilometre.

At 200 g/m^2 and a spreading width of 3 m, 1 kilometre of road corresponds to 3,000 m^2 of treated surface or a consumption of 600 kg of CMA solution.

Case Studies

Town	Start Application Year	Application test track [km]	Results Reduction PM_{10}	Results Traffic safety	Refer-ences
Klagenfurt (A)	2006	up to 164 km	-10% (episode)	No impairment	8
Lienz (A)	2010	up to 12 km	-30% (24h)	No impairment	8
Bruneck (I)	2010	up to 12 km		No negative impact	8
Wolfsberg (A)	2010	25 km		No impairment	9
London (U.K.)	2010	City of London, 3 km	-14% (Episode)	No impairment	10
Stockholm (S)	2005-2008, 2011-2012	Certain streets in city centre and highways	-20-50% (24h)	Reduced skid resistance at high CMA dosage. Not at 10-15 g/m^2.	11-14
Goteborg (S)	2005-2008	Certain streets in city centre	-20-40% (24h)	Reduced skid resistance at high CMA dosage.	15
Norrkoping (S)	2006-2010	Certain streets in city centre		Reduced skid resistance at high CMA dosage	
Linkoping (S)	2006	Rural road	-35-40% (24h)		16
Stuttgart (D)	2010-2011	1.2 km B14 Neckartor	No reduction observed	No impairment	7, 17-19

Summary

and recommendations

The CMA+ Instruction Manual provides guidance on the use of CMA, which, if applied consistently as a fine-dust suppressant, is able to achieve a clearly measurable PM_{10} reduction in the ambient air at curb-side measuring stations (up to 30 % relative to the daily average, 10–20 % in the winter months, 5–10 % on an annual average).

Provided that the dose of 10 g/m² is not exceeded and spread evenly and provided that bends, round-abouts, intersections, pedestrian crossings, slippery roads or roads in a bad state of repair remain unt-reated, negative impacts on traffic or consequential damage are not to be expected on public roads.

Roads to be treated with CMA must be signposted accordingly and the population must be informed.

The time when CMA should ideally be applied depends on factors such as the level of PM pollution, air humidity, temperature, precipitation and traffic volume. If PM pollution is clearly below the limit values, in case of high air humidity (above 80 %) or if precipitation is to be expected, there is no need to apply the fine-dust glue.

CMA is very effective as a de-icing agent, albeit only as a preventive measure. The combined use as a fine-dust glue and as a de-icing agent is therefore possible and so is its combined use with road salt.

As a de-icing agent, application is recommended in pedestrian zones and sensitive areas to avoid environmental damage associated with the use of conventional road salt.

CMA:KF mixtures are more efficient as regards both their de-icing and their fine-dust-binding effect, which also lasts longer compared to the pure CMA product. Due to test in the road simulator the optimal effect is achieved if CMA and KF are mixed at a ratio of 50:50.

A very good and long-lasting dust-binding effect (at least -50 %) is achievable on unpaved surfaces at a CMA dose of at least 100-200 g/m².

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Annex

	FRIDAY 24/02/2012	SATURDAY 25/02/2012	SUNDAY 26/02/202	MONDAY 27/02/2012
Weather conditions				
Precipitation	☐ yes ☐ rain ☒ no ☐ snow	☐ yes ☐ rain ☒ no ☐ snow	☐ yes ☐ rain ☒ no ☐ snow	☐ yes ☐ rain ☒ no ☐ snow
Air humidity (noon)	45%	50%	60%	40%
Temperature (max./min.)	Min/Max -1/14°	Min/Max 0/14°	Min/Max 1/11°	Min/Max -1/13°
Wind	moderate to strong	moderate to strong	moderate to strong	moderate to strong
Important information	-	-	-	-

Fig. 19 Forecast and interpretation model Lienz (graph: Meteo Experts, Lienz, 2012)

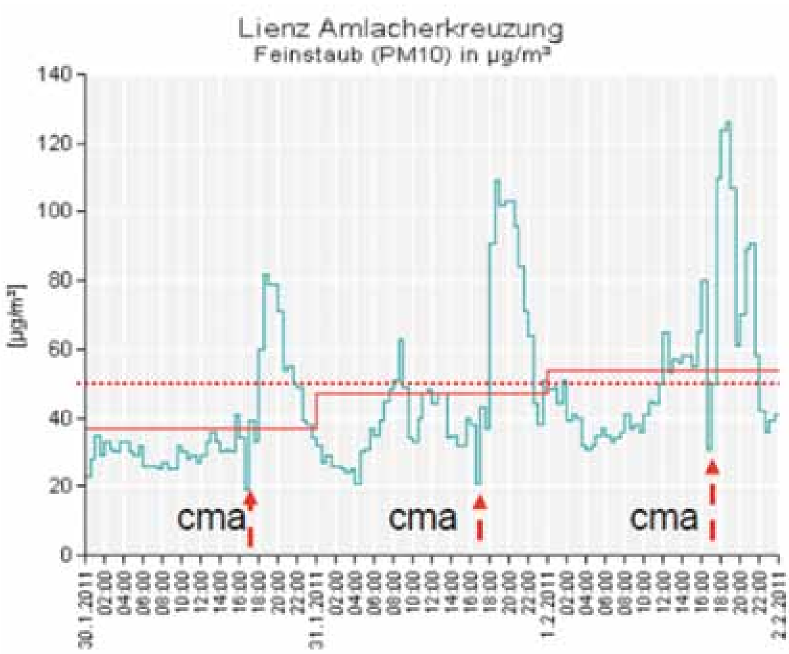


Fig. 20 Correlation between CMA application and PM formation, source: Federal Environmental Agency, air quality, time curve, 2011

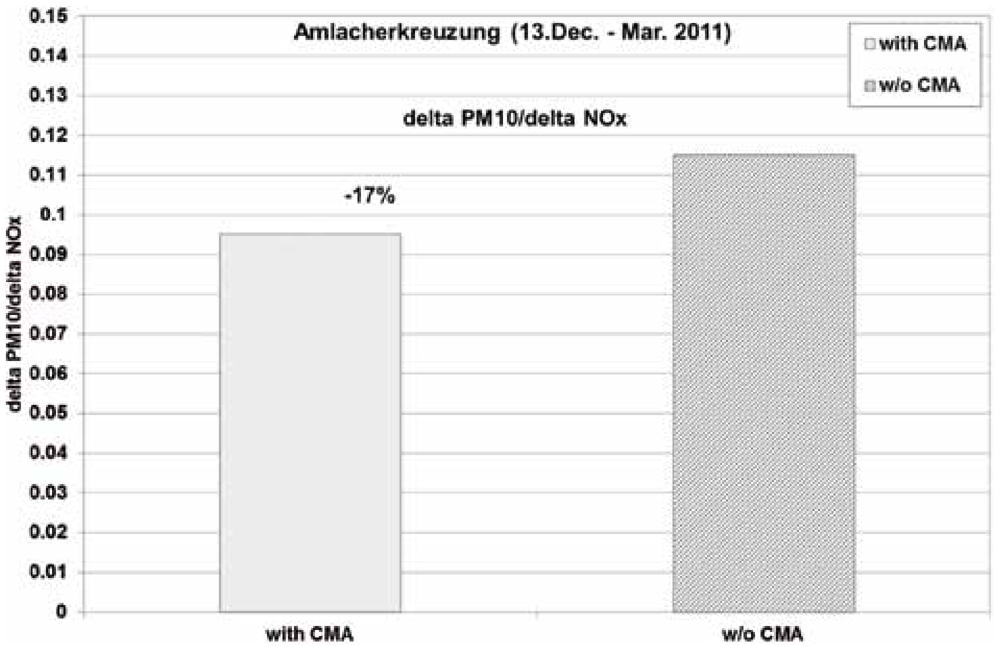


Fig. 21 Reduction potential of CMA related to the average PM_{10} emission factor of traffic at the Amlacher crossroads in Lienz (winter 2011)

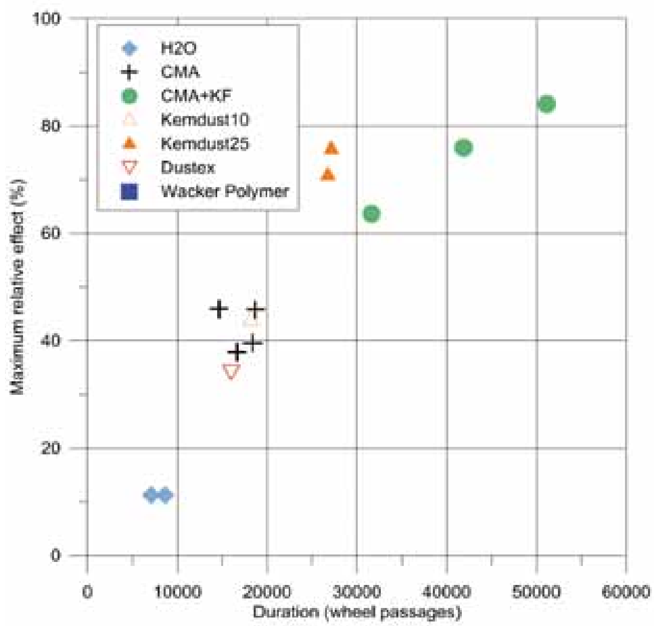


Fig. 22 Comparison of the effect of different dust suppressants

ELMR 150/60 digital for pre-wetted salt and CMA application

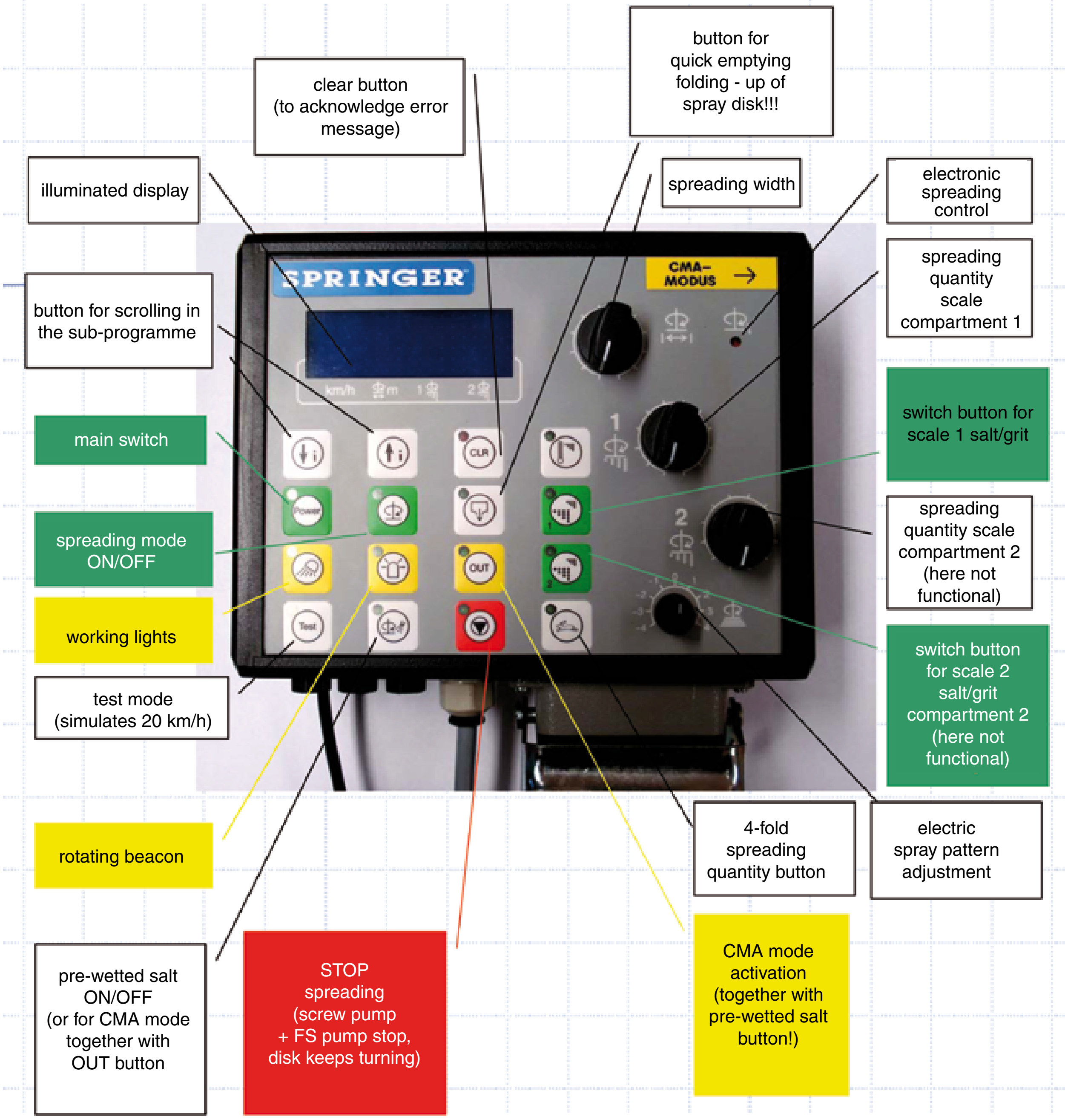


Fig. 23 Control panel, spreading system by the company Springer

Operation: Procedure in spreading mode

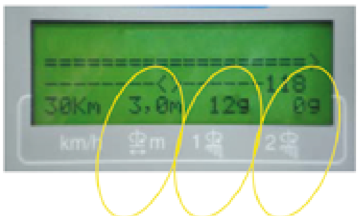
1. Spreading mode salt/pre-wetted salt

Actuate main switch – LED is on –control panel is ready (illuminated).

Which substance has been loaded into the compartment?
Salt – LED is not on (salt scale 0-40 g/m²).
Grit - Actuate grit button – LED is on (grit scale 0-240 g/m²).

If all preparations have been carried out properly and no defects have been noted, the spreading operation can start.

Spreading mode ON – LED is on (disk rotates and as soon as the vehicle starts to move, the set amount – i.e. g/m² – is applied depending on the vehicle speed). Spreading mode OFF – LED is off.



Spreading quantity compartment 1  can be set as required. The quantity set is indicated in the lower right part of the display (in this chart 12 g. Quantity 2 is non functional here). The spreading width can also be adjusted as required via a separate rotary switch and is shown on the display (cf. left) at the bottom.

For pre-wetted salt spreading, actuate pre-wetted salt button.

- LED on – pre-wetted salt spreading
- LED off – dry salt spreading

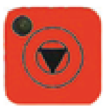
2. CMA spreading:

Actuate main switch – LED is on – control panel is ready (illuminated).

Actuate OUT button and then pre-wetted salt button – both LEDs are on (the bottom of the display indicates CMA) – now the set values for the spreading of CMA have been taken over and cannot be changed any more via the rotary switch (spreading width 3m / spreading quantity 10 g/m²).

(To deactivate, switch off OUT button. Both LEDs are no longer illuminated. CMA on the display is no longer illuminated. The gritter is in spreading mode for dry salt).

Spreading mode ON – LED is on (disk rotates and as soon as the vehicle starts to move, the set amount of CMA is applied depending on the vehicle speed). Spreading mode OFF – LED is off.



The button is actuated to interrupt the spreading mode/CMA mode for a short time (LED flashes and control peeps five times). To return to spreading mode, actuate the button again – LED is no longer illuminated.

Fig. 24 Operating instructions for Springer gritter

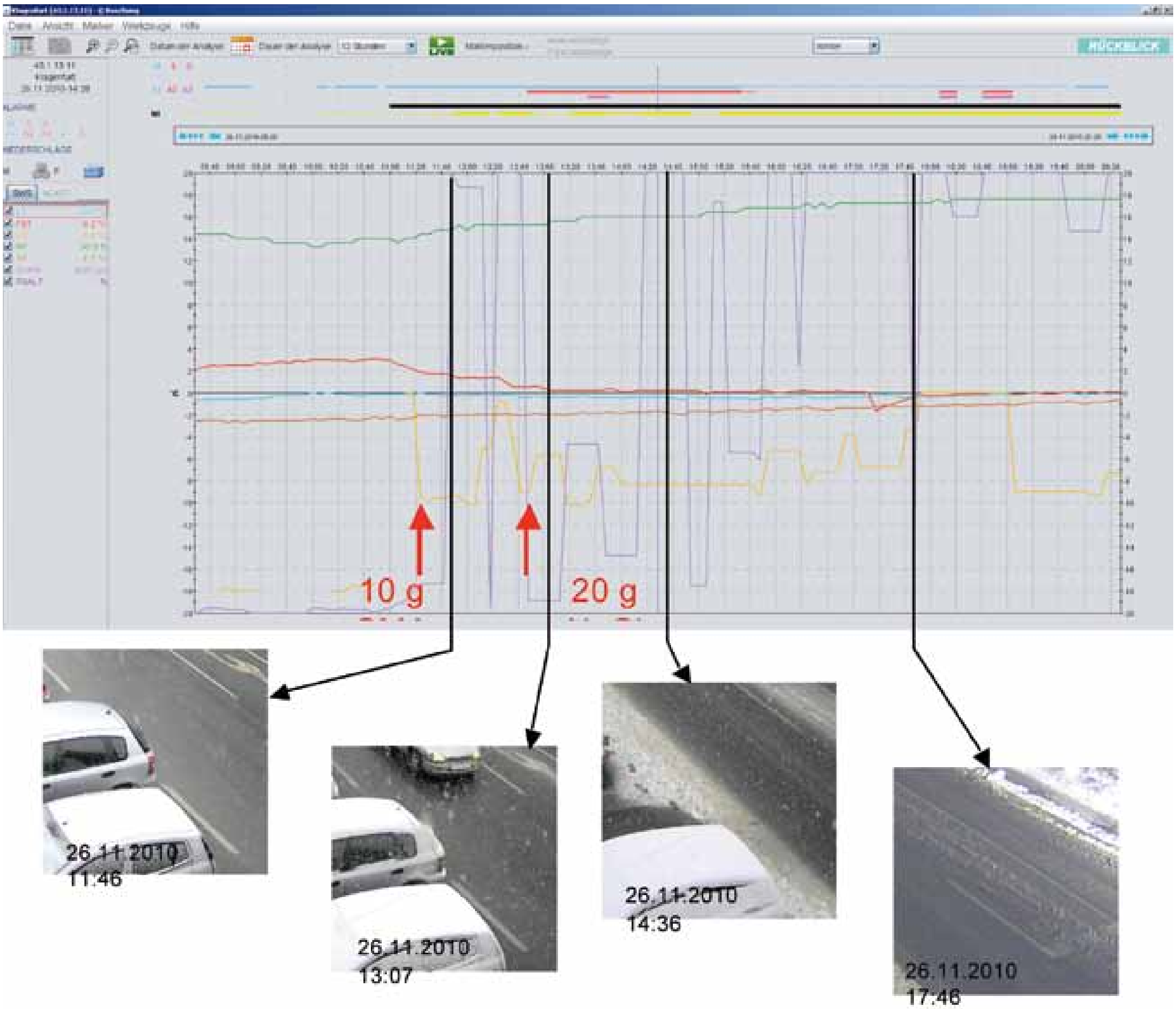


Fig. 25 Boschung's ground sensor online measuring system, test track, comparison of reduced freezing points of 10 g CMA and 20 g NaCl.

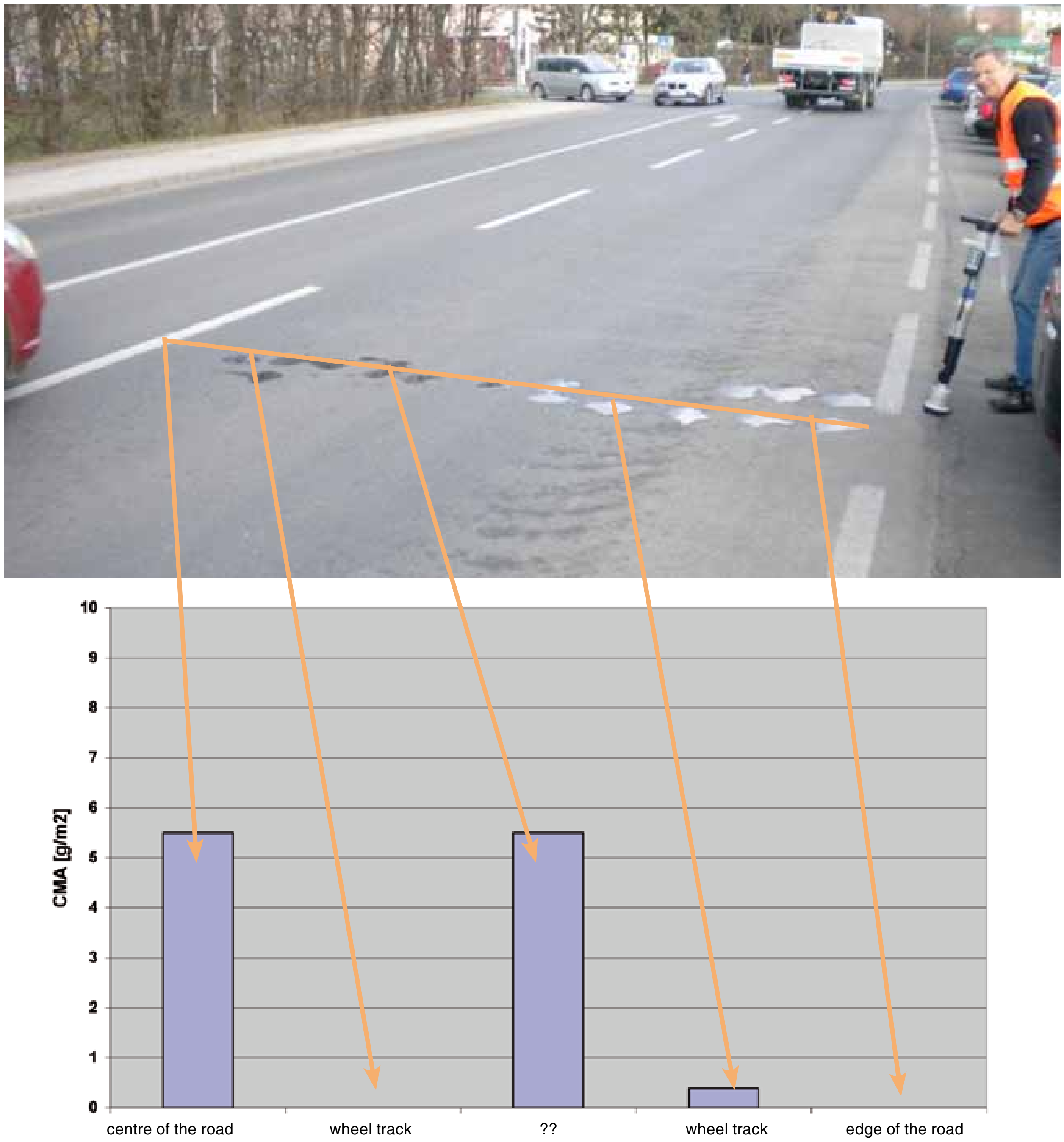


Fig. 26 Test track Rudolfsbahngürtel, cross section measurements (schematic) after 4 hours and 2,000 vehicles, average after 4 h application (10 g/m² CMA).

Bezeichnung	Auftrag-geber	FA. Privat	Neuer-Platz	Alter Platz + Fußgänger-zone	Div. Streu-aufträge	Drucker-weg 480 m	Testgebiet 92,000 Km	Menge	Lieferschein-nummer
	2012								
CMA	Auftrag Abt.US						2475,00	kg	10817
CMA	Auftrag Abt.US						500,00	kg	10818
CMA	Auftrag Abt.US						2600,00	kg	10819
CMA	Auftrag Abt.US						2500,00	kg	10820
CMA	Auftrag Abt.US						2500,00	kg	10821
CMA	Auftrag Abt.US					700,00		kg	10822
CMA	Auftrag Abt.US						500,00	kg	10823
CMA	Auftrag Abt.US	6000,00						kg	11177
CMA	Auftrag Abt.US			50,00				kg	11289
CMF	Auftrag Abt.US						2420,00	kg	10824
CMA	Auftrag Abt.US						2520,00	kg	10824
CMA	Auftrag Abt.US		25,00					kg	12505
CMA	Auftrag Abt.US						2600,00	kg	10833
CMA	Auftrag Abt.US	6000,00						kg	11191
CMA	Auftrag Abt.US		20,00	60,00				kg	12507
CMA	Auftrag Abt.US						2600,00	kg	10849
CMA	Auftrag Abt.US						800,00	kg	10850
CMA	Auftrag Abt.US						2650,00	kg	13351
CMA	Auftrag Abt.US						2630,00	kg	13352
CMA	Auftrag Abt.US		45,00	45,00				kg	12537
CMA	Auftrag Abt.US						890,00	kg	13353
CMA	Auftrag Abt.US						2600,00	kg	13354
CMA	Auftrag Abt.US						850,00	kg	13355
CMA	Auftrag Abt.US						1800,00	kg	13357
CMA	Auftrag Abt.US						1450,00	kg	13360
CMA	Auftrag Abt.US	5000,00						kg	13362
CMA	**Summe:**	**17000,00**	**90,00**	**155,00**	**0,00**	**700,00**	**34885,00**	**kg**	

Fig. 27 Winter road maintenance records, Klagenfurt

Fahrer	Baustelle	Datum	Abteilung	Partie/Firma	Bezeich-nung	KFZ	Zeit	KS	Bemerkung	Stunden
	2012								**2012**	
W. Z.	Testgebiet / 2012	11.01.2012	Straßenbau und Verkehr	Straßenreinigung	CMA	K 903 CZ	0.00 - 8.00	615	Streuteller	8,00
W. Z.	Testgebiet / 2012	12.01.2012	Straßenbau und Verkehr	Straßenreinigung	CMA	K 903 CZ	0.00 - 7.00	615	Sprühdüsen	7,00
W. Z.	Testgebiet / 2012	13.01.2012	Straßenbau und Verkehr	Straßenreinigung	CMA	K 903 CZ	0.00 - 7.00	615	Streuteller	7,00
W. Z.	Testgebiet / 2012	16.01.2012	Straßenbau und Verkehr	Straßenreinigung	CMA	K 903 CZ	0.00 - 7.00	615	Streuteller	7,00
W. Z.	Testgebiet / 2012	18.01.2012	Straßenbau und Verkehr	Straßenreinigung	CMA	K 903 CZ	0.00 - 8.00	615	Streuteller	8,00
W. Z.	Schotter-straßen	18.01.2012	Straßenbau und Verkehr	Straßenreinigung	CMA	K 903 CZ	9.00 - 12.00	615	Streuteller	3,00
W. Z.	Testgebiet / 2012	19.01.2012	Straßenbau und Verkehr	Straßenreinigung	CMA	K 903 CZ	0.00 - 7.00	615	Sprühdüsen	7,00
J. Z.	Lieferung Fa. Stark	18.01.2012	Straßenbau und Verkehr	Straßenreinigung	CMA	K 904 CZ	9.00 - 12.00	615	Lieferung	3,00
G. L.	Testgebiet / 2012	19.01.2012	Straßenbau und Verkehr	Straßenreinigung	CMA	K 149 EK	4.00 - 8.00	615	Streuteller	4,00
W. Z.	Testgebiet / 2012	20.01.2012	Straßenbau und Verkehr	Straßenreinigung	CMF	K 903 CZ	0.00 - 7.00	615	Streuteller	7,00
W. Z.	Testgebiet / 2012	26.01.2012	Straßenbau und Verkehr	Straßenreinigung	CMF	K 903 CZ	0.00 - 7.00	615	Streuteller	7,00
G. L.	Testgebiet / 2012	01.02.2012	Straßenbau und Verkehr	Straßenreinigung	CMA	K 149 EK	11.00 - 12.00	615	Streuteller	1,00
W. Z.	Testgebiet / 2012	02.02.2012	Straßenbau und Verkehr	Straßenreinigung	CMF	K 903 CZ	0.00 - 7.00	615	Streuteller	7,00
J. Z.	Lieferung Fa. Stark	03.02.2012	Straßenbau und Verkehr	Straßenreinigung	CMA	K 904 CZ	6.30 - 9.00	615	Lieferung	2,50
G. L.	Testgebiet / 2012	03.02.2012	Straßenbau und Verkehr	Straßenreinigung	CMF	K 149 EK	4.00 - 6.00	615	Streuteller	2,00
W. Z.	Testgebiet / 2012	22.02.2012	Straßenbau und Verkehr	Straßenreinigung	CMF	K 904 CZ	0.00 - 7.00	615	Streuteller	7,00
W. Z.	Testgebiet / 2012	23.02.2012	Straßenbau und Verkehr	Straßenreinigung	CMF	K 904 CZ	0.00 - 7.00	615	Sprühdüsen	7,00
W. Z.	Testgebiet / 2012	24.02.2012	Straßenbau und Verkehr	Straßenreinigung	CMF	K 904 CZ	0.00 - 7.00	615	Streuteller	7,00
W. Z.	Testgebiet / 2012	27.02.2012	Straßenbau und Verkehr	Straßenreinigung	CMF	K 904 CZ	0.00 - 7.00	615	Streuteller	7,00
P. D.	Testgebiet / 2012	27.02.2012	Straßenbau und Verkehr	Straßenreinigung	CMF	K 149 EK	4.00 - 12.00	615	Streuteller	8,00
W. Z.	Testgebiet / 2012	28.02.2012	Straßenbau und Verkehr	Straßenreinigung	CMF	K 904 CZ	0.00 - 7.00	615	Sprühdüsen	7,00
W. Z.	Testgebiet / 2012	29.02.2012	Straßenbau und Verkehr	Straßenreinigung	CMF	K 904 CZ	0.00 - 7.00	615	Streuteller	7,00
W. Z.	Testgebiet / 2012	01.03.2012	Straßenbau und Verkehr	Straßenreinigung	CMF	K 904 CZ	0.00 - 7.00	615	Sprühdüsen	7,00
W. Z.	Testgebiet / 2012	07.03.2012	Straßenbau und Verkehr	Straßenreinigung	CMF	K 904 CZ	0.00 - 5.00	615	Streuteller	5,00
W. Z.	Testgebiet / 2012	09.03.2012	Straßenbau und Verkehr	Straßenreinigung	CMF	K 904 CZ	0.00 - 5.00	615	Streuteller	5,00
W. Z.	Lieferung Fa. Stark	09.03.2012	Straßenbau und Verkehr	Straßenreinigung	CMA	Selbstab-holung				
Jahr	2012	52830,00							Stunden:	147,50
Jahr	2011	58049,00							Stunden:	186,00
Jahr	2010	11872,00							Stunden:	125,00
Jahr	2009	60680,00							Stunden:	350,00
Gesamt [kg]:		**183431,00**							**Gesamt [h]:**	**808,50**

CMA+

Partnerstadt: Wolfsberg
Ansprechperson: Hr. Vallant

Datum	Ausbringung		Teststrecke	Fahrweglänge	Maßnahme	Menge	Straßenzustand
	Beginn	Ende		[m]		[l/d] bzw. [kg/d]	bei Aufbringung
29.11.2011	11:45	12:45	Frantschach - St. Gertraud	1900/1900	CMA	48/42	nebelig
29.11.2011	11:00	12:38	Wolfsbg. Süd - Wolfsbg. Nord	3800/3800	CMA	144/118	nebelig
11.01.2012	12:46	12:54	Frantschach - St. Gertraud	1900/1900	CMA	34/38	sonnig
11.01.2012	12:36	13:20	Wolfsbg. Süd - Wolfsbg. Nord	3800/3800	CMA	127/160	sonnig
12.01.2012	06:07	06:24	Frantschach - St. Gertraud	1900/1900	CMA	29/28	klar
12.01.2012	06:35	07:15	Wolfsbg. Süd - Wolfsbg. Nord	3800/3800	CMA	82/100	klar
13.01.2012	06:06	06:35	Frantschach - St. Gertraud	1900/1900	CMA	79/37	heiter
13.01.2012	06:04	06:50	Wolfsbg. Süd - Wolfsbg. Nord	3800/3800	CMA	82/78	heiter
16.01.2012	07:42	07:54	Frantschach - St. Gertraud	1900/1900	CMA	37/37	klar
16.01.2012	07:57	08:22	Wolfsbg. Süd - Wolfsbg. Nord	3800/3800	CMA	119/93	klar
17.01.2012	07:51	08:05	Frantschach - St. Gertraud	1900/1900	CMA	40/38	bewölkt
17.01.2012	08:08	08:25	Wolfsbg. Süd - Wolfsbg. Nord	3800/3800	CMA	86/75	bewölkt
26.01.2012	10:27	10:35	Frantschach - St. Gertraud	1900/1900	CMA	46/51	sonnig
26.01.2012	10:37	10:50	Wolfsbg. Süd - Wolfsbg. Nord	3800/3800	CMA	110/95	sonnig
31.01.2012	08:04	08:15	Frantschach - St. Gertraud	1900/1900	CMA	60/44	heiter
31.01.2012	08:20	08:40	Wolfsbg. Süd - Wolfsbg. Nord	3800/3800	CMA	60/55	heiter
01.02.2012	09:20	09:30	Frantschach - St. Gertraud	1900/1900	CMA	48/44	bewölkt
01.02.2012	09:25	09:40	Wolfsbg. Süd - Wolfsbg. Nord	3800/3800	CMA	112/90	bewölkt
23.02.2012	09:45	09:55	Frantschach - St. Gertraud	1900/1900	CMA	38/39	bewölkt
23.02.2012	09:20	10:15	Wolfsbg. Süd - Wolfsbg. Nord	3800/3800	CMA	74/101	bewölkt
27.02.2012	10:10	10:30	Frantschach - St. Gertraud	1900/1900	CMA	45/45	wolkenlos
27.02.2012	10:35	10:55	Wolfsbg. Süd - Wolfsbg. Nord	3800/3800	CMA	90/90	wolkenlos
29.02.2012	11:06	11:16	Frantschach - St. Gertraud	1900/1900	CMA	46/46	sonnig
29.02.2012	10:45	11:38	Wolfsbg. Süd - Wolfsbg. Nord	3800/3800	CMA	154/104	sonnig
07.03.2012	10:05	10:13	Frantschach - St. Gertraud	1900/1900	CMA	38/40	sonnig
07.03.2012	10:02	10:32	Wolfsbg. Süd - Wolfsbg. Nord	3800/3800	CMA	128/108	sonnig

Fig. 28 Winter road maintenance records, Wolfsberg

Fig. 29 Signposting of test areas

Fig. 30 CMA test area (164 km), Klagenfurt on Lake Wörthersee with the locations of the identification signs

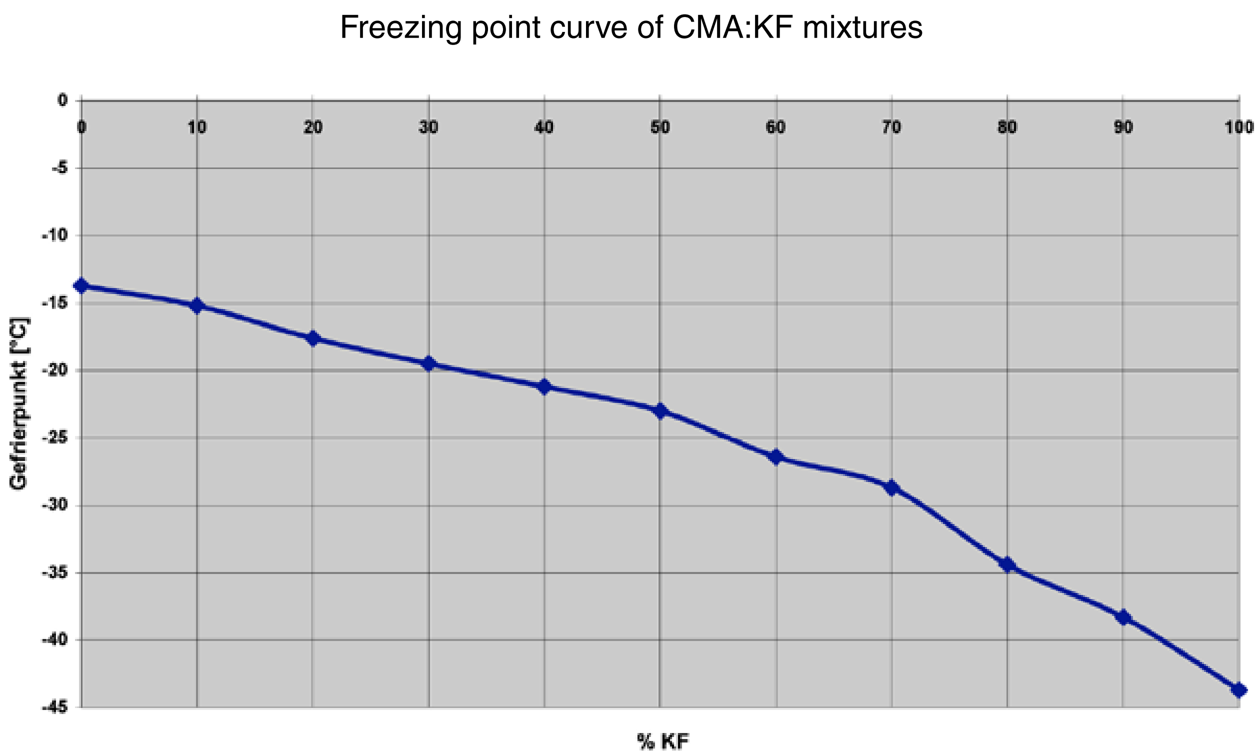


Fig. 31 Freezing point of CMA, CMA:KF mixtures (w/w %) and KF in an aqueous solution; determined as per the ASTM D 1177 method by Saybolt, Denmark, analysis report no. 102/11639-0/11, of 19.9.2011, commissioned by Nordisk Aluminat, DK.

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