INFORMATION PAMPHLET

The Use of PCE Based Superplasticizers for the Construction of Industrial Floors

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DEUTSCHE BAUCHEMIE

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1. INTRODUCTION

Industrial floors made of concrete are an integral part of industrial construction. Since these floors must withstand heavy mechanical loads over the long term, the concrete used must have especially high performance properties to meet these high requirements. In recent years there have been many reports concerning damage found on industrial floors that was traced to errors during their production. In some cases, the cause of damage was attributed to the use of PCE based superplasticizers when producing the concrete. However, PCE based superplasticizers have proved to be reliable products in practically all areas of concrete construction in the past years and they are also highly suitable for use when constructing industrial floors.

Industrial floor is the term used to describe floors made of concrete on which operational procedures in production buildings and warehouses take place. These floors consist of a compacted substrate, a base course made of gravel, broken stone or stabilised soil and then a concrete floor slab to which a hard aggregate topping is usually applied to achieve the desired mechanical properties.

Most of these concrete surfaces are smoothed by machine after they are placed and are therefore also referred to as „smoothed concrete". After floating, the surface is broadcast with hard aggregates. To ensure a reliable bond between the broadcast hard aggregate and the concrete, the surface of the concrete must permit foot traffic yet still be soft enough to bond to the hard aggregate. The time window between placing the concrete, smoothing and application of the hard aggregate topping is deemed critical for the entire building project and requires good coordination between the producer of the ready-mixed concrete, the company that places the concrete and the company that smoothes the concrete. When different companies are responsible for placing and smoothing the concrete, conflicts of interest may result. Since concrete can be placed within a short period of time without any great problems, a high concrete consistence is often selected. But a high consistence may increase the amount of time between post-placement work and standing time until it can be subjected to foot traffic and the right time for smoothing. The smoother, in turn, wants to be able to do his job within the defined time window and start smoothing as fast as possible but for this the concrete must quickly restiffen.

When using PCE based superplasticizers that retain consistency significantly longer, it is difficult to correctly estimate the time window within which the hard aggregate topping can be applied to the still soft concrete. In such cases, the consequences are insufficient bonding, the formation of cracks and delamination of the hard aggregate topping. Damage is then unavoidable and this leads to complaints. As a result, PCE based superplasticizers were strictly ruled out for use in industrial floors in many tenders.

The desired properties can be controlled by selecting a suitable superplasticizer when mixing the concrete.

Meanwhile there are numerous PCE based superplasticizers on the market which achieve high consistency for improved workability as well as targeted restiffening of the concrete. These properties are in the interest of both parties, the placer of the concrete and the smoother.

Since the introduction of DIN EN 206-1 and the application rules for this standard found in DIN 1045-2, the requirements on concrete technology have changed fundamentally. While concretes with high consistencies and a water-cement ratio of less than 0.5 were the exception 10 years ago, they are a standard product today. PCE based superplasticizers allow the production of concretes with low water-cement ratios and high consistencies which facilitates the placement of concrete. With this Information Pamphlet, the manufacturers of concrete admixtures represented by Deutsche Bauchemie would like to present the advantages and possible applications of PCE based superplasticizers as well as the requirements for their targeted use in industrial floors.

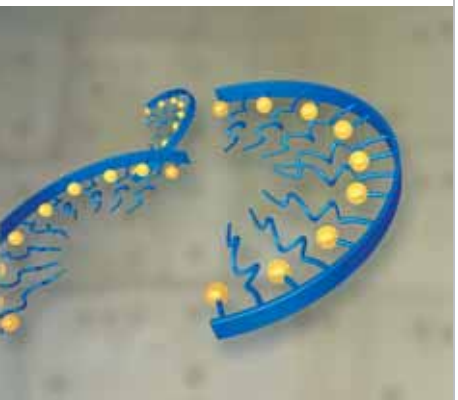
2. PCE BASED SUPERPLASTICIZERS

Superplasticizers are produced on a melamine, naphthalene or polycarboxylate ether (PCE) base. Compared to melamine and naphthalene sulphonates, the chemical structure of PCE provides manifold variation possibilities which allows superplasticizers to be produced that are targeted to different intended purposes. Decisive for the effect of PCE are adsorption onto the surface of the cement and the steric effect of the side chains. Adsorption can be controlled by the quantity of negative charges. This allows the development of quickly adsorbing superplasticizers with high initial plasticization or slowly adsorbing superplasticizers that retain consistency for a very long period. The viscosity of the cement paste and the development of the strength of the cement can be influenced through the structure of the side chains.

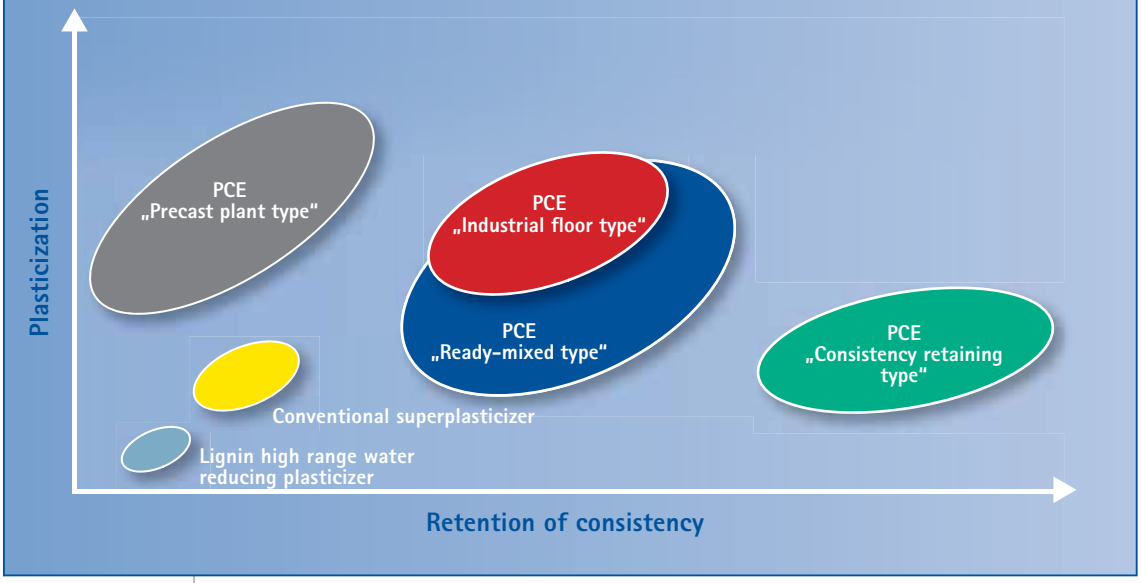
Among the PCE superplasticizers there are various categories and types of products depending on application which must be taken into account when selecting a suitable admixture for the construction of industrial floors. They are divided according to application area into two product categories, ready-mixed concrete and precast elements.

In the ready-mixed concrete area, superplasticizers are predominately used that significantly retain consistency for a longer period and thus increase the working time of the concrete. Superplasticizers that only moderately increase the „open time" of the concrete and begin to stiffen within the usual time frame are also found in this category.

In the precast area, the mechanism of action of the superplasticizers is coordinated to achieving good plasticization of the concrete and the development of high early strength.



OVERVIEW OF THE PERFORMANCE CHARACTER OF SUPERPLASTICIZERS



PCE superplasticizers that allow sufficient working time but only moderately increase the „open time" of the concrete and cause the concrete to restiffen after a short time are suitable in general for the construction of industrial floors. The period of time in which the concrete begins to stiffen is therefore in a range comparable to production with conventional superplasticizers. This can help to avoid incorrect assessments concerning sufficient strength for foot traffic, the time for smoothing and application of the hard aggregate topping. Weather conditions at the time the concrete is placed should also be taken into account when selecting a superplasticizer. Since the ambient temperature influences the hydration process, high temperatures can accelerate initial stiffening of the concrete while cold weather conditions tend to slow down this process. The properties of the superplasticizer should be coordinated to these influences (summer/winter PCE).

3. NOTES ON PLANNING AND TENDERING

The basis for planning and tendering is to compile exact data on intended utilisation and define the resulting requirements on the concrete to be used for the industrial floor in regard to exposure and utilisation class. To ensure the success of the construction measures, it is a good idea to specify basic requirements on execution, taking various technical parameters that influence the concrete into account such as the temperature of the fresh concrete, wind conditions at the site the concrete is placed, air pore content and the hard aggregate topping which have an impact on execution.

Depending on the parameters given above, the requirements on intermediate curing and curing of the surface should be given special attention in the Bill of Quantities, stating these as separate items. When describing these items, it should also be stated that curing measures must be coordinated to the expected weather conditions and adjusted correspondingly. Smooth concretes should not be placed when ambient and building element temperatures are extreme in summer or winter.

A hard aggregate topping can only be reliably executed with concrete up to strength class C30/37 because the water content of these concretes is sufficiently high to allow the hard aggregate to be rubbed into the surface without weakening the bond. If the required strength is higher, a hard aggregate screed should be placed instead of a topping.

The stipulated requirements on the state of the surface must be understood by all contractual partners and it is thus recommended to agree on reference surfaces or samples that show the texture of the surface to be produced. Such agreements have proved to be very useful, particularly for weathered, outdoor surfaces.

4. NOTES ON PRODUCING THE CONCRETE

General Planning Principles from a Concrete Technology Viewpoint

Special aspects in regard to concrete technology require considerable knowledge on the part of contractors, specifiers and executing companies.

All of the necessary requirements for planning and execution should be clarified in joint preconstruction meetings with the respectively responsible persons.

Principles to be examined:
■ Specification of the concrete according to properties or according to composition
■ Specification of the requirements and properties such as compressive strength, exposure classes, placement consistency and wear [hard aggregates]
■ Specification of the constituent materials such as type of cement, aggregates, mineral aggregates and admixtures
■ Limitation of air pore content and concrete temperature
■ Type and execution of intermediate curing
■ Type and execution of curing
■ Specification of type of placement and placement output
■ Limitation of ambient conditions such as drafts, frost or vibrations

Concrete (planning the formulation)

When formulating the concrete, restraint stresses in young and in hardened concrete should be kept as low as possible through concrete technology measures.

Placement consistencies in the range of F4 are recommended – with softer consistencies there is an increased risk of segregation and the formation of cracks in young concrete. If the consistence is too low, complete compaction cannot be guaranteed and when toppings are applied, problems with bonding are likely.
The content of fine grains (< 0.125 mm) should range between 360 and 370 kg/m³; the fine grains and ultra-fine sand content (< 0.25 mm) should not be more then 430 kg/m³.

CEM I and CEM II cements should be preferably used. At higher temperatures, a combination of fly ash or the use of CEM III/A may be a better choice. Cements with strength class CEM 32.5 are preferable.
Important: In these cases as well, the standing time (waiting time until the concrete can be finished) should be kept as short as possible.

Formulations that contain between 320 kg/m³ and 340 kg/m³ cement have proved to work well for the production of normal concrete floors.

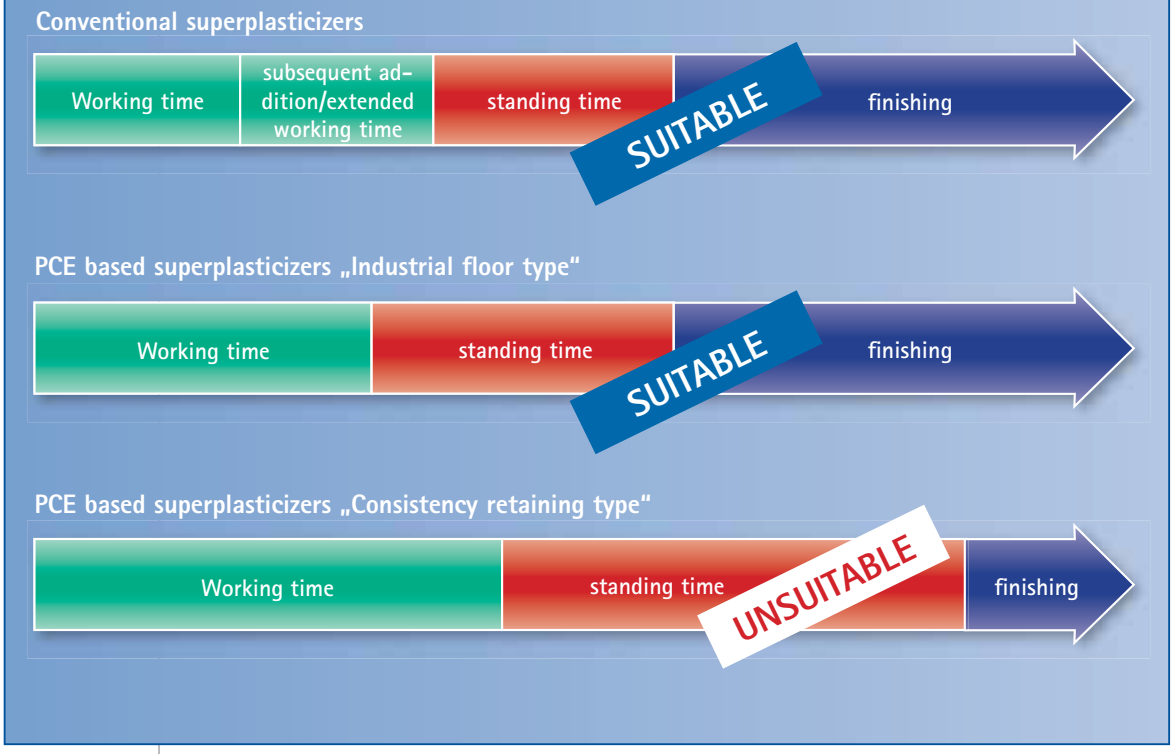
Fly ash can be used to reduce the development of hydration heat and improve workability. In special cases, the use of silica dust is useful for very dense concretes or for areas that will be subjected to heavy mechanical loads.

When using superplasticizers on a PCE base, attention should be given to the notes on character and performance properties given in chapter 2. It is a good idea to coordinate the superplasticizer to the circumstances in advance.

When using superplasticizers (FM) and air-entraining agents at the same time when producing concrete, their suitability must be proved by a test for effectiveness (determination of characteristic air pore values by the manufacturer of the admixture).

Recommendations for designing the concrete mix:
■ Limitation of the target value for placement consistency to max. 52 cm
■ Fine grain content 0/0.125 mm ≤ 370 kg/m³
■ Fine grain/ultra-fine sand content 0/0.250 mm ≤ 430 kg/m³
■ With water-cement ratios ≤ 0.45, hard aggregate toppings cannot be reliably produced. In this case, industrial screeds or a layer of subsequently bonded hard aggregates would be a better choice.
■ A combination of XF4 and XM3 cannot be executed from a technical standpoint.
■ When air-entrained concrete is used and a hard aggregate topping is applied, there may be problems with bonding between the concrete and hard aggregate topping (delamination of the wearing layer).
■ Practice has shown that the total air content in fresh concrete (with the exception of air-entrained concrete) should be limited to max. 3.5 % (control tests).
■ Evaluation of setting behaviour by suitable testing methods, e.g. „Knetbeutelverfahren" [kneading-pouch test] to estimate the expected standing time.
■ Evaluation of the bleeding behaviour of the concrete so that, if necessary, measures can be taken or intermediate curing taken into account when planning.
■ Limiting the quantity of PCE based superplasticizers to 1.0 % of the weight of the cement when formulating.
■ When fibres are used, taking the possible entrance of air into account.

SCHEMATIC OVERVIEW OF SELECTION CRITERIA FOR SUPERPLASTICIZERS



The duration of the working steps illustrated vary depending on constituent materials, environmental conditions and the quantity of PCE that must be added.

When selecting and determining a suitable superplasticizer on a polycarboxylate ether base, focus is not predominately on the best possible retention of consistency but a targeted restiffening that allows sufficient time for working but the shortest possible standing time until the concrete can be smoothed.

5. NOTES ON PLACING THE CONRETE

Acceptance of concrete

When the concrete is delivered to the construction site, the information on the delivery note should be compared with the order.

The concrete must have the specified consistency when it is delivered. Concretes of consistency class F4 have proved themselves in practice as a compromise between the desire of the user to easily place the concrete and the requirement to limit the consistency of the concrete for stability reasons (to avoid slurry concentrations on the surface). An additional agreement on a target value for consistency, e.g. 520 ± 20 mm after the pump, has a positive effect on the uniformity of the concrete consistency. A suitable superplasticizer should be added at the ready-mixed concrete works; subsequent addition of superplasticizers at the construction site should be avoided if possible. The addition of water at the construction site is prohibited.

To recognise an unintended air pore content in concrete which could have a negative effect when the surface is smoothed, random testing of air pore content is advisable. Air pore contents below 3.5 % are deemed uncritical.

Placement conditions

The speed at which the surface of a freshly placed industrial floor dries is determined by air velocity and surface temperature. From the time the concrete is placed until curing begins, there should be no drafts and the floor slab should not be exposed, even partially, to direct sunlight.

Concrete placement

The concrete placement concept plays an essential role in the successful production of an industrial floor. This includes planning the sequence of work and required personnel as well as coordination of interfaces. Especially important are:

- **Coordination of concrete placement output, topping and smoothing output**
  It is of essential importance that the surface of the placed concrete areas can be finished within the available time window. With a daily output of more than 1,000 m², additional measures will be necessary as a rule, e.g. a second work crew.

- **Determination of the sequence for placing the concrete**
  The surface of the concrete must be worked in the same order that it was placed and there should be no great differences in age when concrete surfaces are placed next to each other.

- **Interface coordination**
  Documentation and information along the chain consisting of concrete ordering party → concrete placer → concrete smoother must be complete. The information required for each of these works (e.g. concrete properties, placement time) must be available.

Concrete compaction

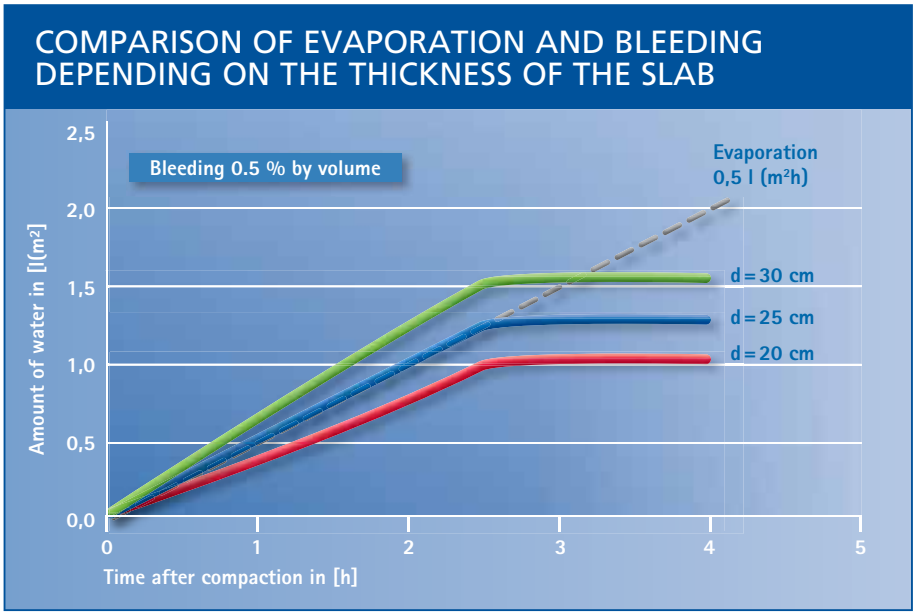
Concrete of consistency class F4 must always be thoroughly compacted. This is done either with internal vibrators or surface compactors (vibrating beam or power screed). When internal vibrators are used, the distance between the immersed vibrators should be as close as possible so that there will be no areas that are not compacted in between. When surface compactors are used, you must make sure that the concrete is completely compacted over the entire placement area.

Intermediate curing

In the period of time between levelling the surface of the concrete after compaction and broadcasting the hard aggregates or smoothing, which is referred to standing time (see section 4), the surface of the concrete should not be allowed to dry out. If the surface dries, this can cause the layer of cement paste/fine mortar on the surface to strengthen which results in what is sometimes called „elephant skin" in practice which makes the concrete appear to be load-bearing when in fact it is not. If hard aggregates are to be broadcast or the concrete is to be smoothed, a matt damp concrete surface is absolutely essential.

The results of research on the phenomenon of elephant skin formation confirm that this can be reliably avoided by intermediate curing. The longer the standing time, the greater the risk that elephant skin will form if the surface of the concrete dries, regardless of the superplasticizer used [5].

According to Krell [3], whether the surface of the concrete will dry depends on the ratio between the loss of water on the surface through evaporation and the water that rises to the surface when the concrete bleeds.



Source: Krell [3]

If the expected evaporation is greater than the expected bleeding, intermediate curing must be carried out. The expected evaporation can be estimated with an evaporation diagram [6]. The supplier of the ready-mixed concrete should be able to provide information on expected bleeding.

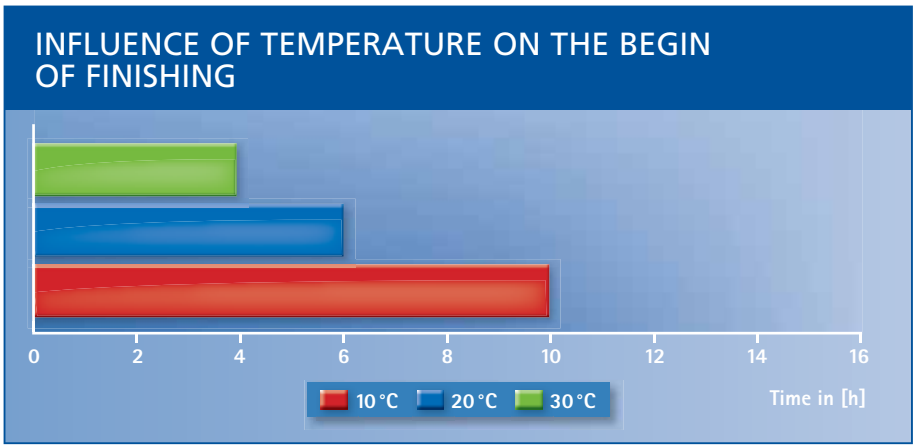
Suitable measures for intermediate curing are either finely misted water (which can be created with, e.g. high pressure cleaning equipment) or the use of a curing agent on a plastic dispersion base. Conventional curing agents on a paraffin wax base are not suitable.

Broadcasting hard aggregates and smoothing

If the surface strength of an industrial floor is to be improved by working in a hard aggregate, the concrete must correspond to at least strength class C25/30 and maximum C30/37. Hard aggregate toppings on concretes of strength classes C35/45 cannot be reliably produced.

The hard aggregates should be broadcast as early as possible, either directly after the concrete surface has been levelled, using machine-guided broadcasting equipment, or as soon as the concrete can be subjected to foot traffic, using a hand-guided topping material cart. If the aggregates are broadcast too late, there may be voids and delamination.

The point in time at which the concrete can be subjected to foot traffic and finishing can begin is usually determined at the construction site by a „boot test". The supplier of the ready-mixed concrete should be able to give reference values. The time when finishing can begin for a certain type of concrete is especially dependent on temperature (see illustration on the following page).



Hard aggregates are usually worked in with a power disc trowel and the surface then finished in several passes with a power blade trowel. Smoothing work must have been concluded before final set of the concrete. Here as well, the supplier of the ready-mixed concrete should be able to provide reference values on final set.

6. SUMMARY

The various influences and resulting measures to be taken presented in this Information Pamphlet, which decisively influence the success of producing industrial floors, prove how necessary it is for all parties involved to cooperate right from the beginning and throughout all stages of production.

As with all concrete placement jobs, formulation of the concrete should be coordinated to meet all of the requirements placed on the fresh and hardened concrete. This has an affect on the suitability of all starting materials.

Research work [5] on this subject is presently underway that focuses on selecting PCE plasticizers that are particularly suitable. During this research work it was determined that controlling the loss of water through the surface is decisive for preventing the formation of elephant skin. This applies regardless of the type of plasticizing admixture used. It was also determined that superplasticizers with a moderate retarding time in summer and a shorter retarding time in winter are most suitable for this application. If superplasticizers are used that extend the workability of the concrete too long, longer curing times are necessary which cause delays and errors in the sequence of construction that are not acceptable, especially in winter.

The factors described apply on principle to all industrial floors, regardless of the type of concrete admixture used. If the notes on the selection of the right formulation in regard to ingredients are observed, there is no justified reason to exclude the use of certain concrete admixture raw materials which was occasionally the case in regard to the use of PCE based plasticizing raw materials.

EPILOGUE

This Information Pamphlet was prepared by a project group appointed by Deutsche Bauchemie's Special Committee 2 „Concrete Technology". It is intended to provide information for all member companies as well as the specialised public.

Deutsche Bauchemie e. V. invites you to share your experience and make comments regarding the information in this Information Pamphlet which should be directed to the main office in Frankfurt.

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