Concrete paving blocks in industrial construction in West Germany

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Introduction

THE USE of concrete paving blocks for floor finishing in industry has been common practice in the German Federal Republic for 30 years. Certainly, the successful use of concrete block paving in road construction (the beginnings of which go back 80 years) has contributed towards the discovery that the special properties of concrete paving blocks have in a short space of time also proved suitable for special applications in industrial construction.

Although the rectangular paving block measuring 16×16×14 cm was initially used in most cases (according to the paving designs then used for roads carrying heavy traffic), we find today numerous applications involving composite paving blocks 10 or 8 cm thick, for different branches of industry and types of loading.

About half of the production of the rectangular paving mentioned is now used for industrial applications, and it is also used, for example, for track paving on railways, urban roads carrying very heavy traffic, for port installations and in hydraulic structures. Even today, the preference for composite paving blocks for industrial construction applications is still considerable in German industry, but varies from one branch to another. It depends not only on the infrastructure of the industrial field, in which the concrete paving is to be installed, but also on regional building practices, on the flexibility of planners and builders, and on the experiences gained already in the use of concrete paving block.

The upward development experienced in the production of paving blocks in the Federal Republic (particularly in the years 1960 to 1973)—much envied particularly in neighbouring countries and at present approx. 7 million tonnes per annum—may be explained wholly on the basis of common building practice, whereby good is self-generating according to the motto "Better is the enemy of good."

Consistent scientific investigations by road building engineers into the optimum use of concrete block paving have been just as unsuccessful as expensive advertising campaigns in industry. Only in the last few years has it been increasingly realised that something else can possibly be gained here. I am therefore able to approach the subject from the German viewpoint not so much with scientific knowledge, but rather on the basis of practical experience. This applies especially to the use of paving blocks; on the other hand, it must naturally be emphasised, with regard to their manufacture, that the present quality level would be inconceivable without the high standard of mechanical engineering and present knowledge in concrete technology.

In any case, the assumption has so far not been refuted that the upward (increasing) development in the use of paving blocks of concrete has also been uninterrupted because the quality standardised in DIN 18 501 has prevented reversals as far as applications are concerned. A comprehensive strength of approx. 60N/mm^2 has been required for 20 years. This is a strength which at that time represented the absolute limit to what was mechanically possible, and even today requires the utmost care in the manufacturing process. Of course there are clients who for particular reasons prescribe strengths of 90 N/mm^2, with natural block paving made from granite or basalt serving as the strength "model."

Industrial floors

If we look at the factors contributing to the selection of an industrial floor, these include, among other things, its compressive strength, bending strength, elasticity, flexibility, impact resistance, wear (friction) resistance and surface hardness; in addition, thermal conductivity, heat dissipation (foot heat), noise insulation or acoustic absorption, electrical insulation, electrostatic dischargability, weather resistance, frost and thawing salt resistance, resistance to temperature changes, resistance to

Table 1: *Floor types*

Cement floor Terrazzo (Venetian mosaic) floor Hard concrete floor	Floors, cement-bonded
Concrete slabs (rough shuttering) Concrete freestone slabs (ground) Hard concrete slabs (with special facing) Reinforced concrete slabs (large-sized)	Concrete and reinforced concrete slabs
Concrete block paving Natural block slabs Natural block paving Slag block paving	Paving
Sheet steel floors Sheet steel panels Cast metal panels Grating	Metal floors
Ceramic floor tiles Brick and clinker paving Clinker and split clinker slabs	Ceramic floor coverings
Magnesia floors (block-wood (xylolite) floors)	
High pressure asphalt slabs (paving) Poured asphalt flooring Cold bitumen composite flooring	Floors on a bitumen base
Wood pavement Facing wood panels Deal floor Parquet (inlaid floor)	Wooden floors
Floor coverings of linoleum, rubber, PVC etc. Plastic floors Coatings and paints (sealing)	Floor coverings on a plastic base

fire and heat, inflammability, behaviour towards glowing tobacco products, chemical resistance, colour and light fastness, slip resistance, and finally behaviour towards bacteria and mould fungi.

In industrial construction, over 30 different floor coverings are commonly used, whose selection is determined by the above criteria and which, because of the industrially determined varying conditions, are only interchangeable to a limited degree.

The distinctions listed in Table 1 are made.

Concrete block paving in industrial construction.

The range of industrial floors represented, and the above-mentioned selection criteria, clearly show that applications for concrete block paving in industrial construction have quite natural limitations. These limitations to the use of concrete paving blocks in industrial construction are not generally marked by industrial types of stress, for which the paving would not be suitable, but by other factors, such as requirements regarding cleanliness and hygiene, required flexibility and elasticity of the floor covering (e.g., in relation to any delicate workpieces falling down onto it) or by comfort criteria (e.g., foot heat for personnel). In the extremely wide range of construction methods for industrial purposes, the possibility of using concrete paving blocks really only exists in the case of production and processing workshops where work is carried out at ground level, in the open air or in single storey shops. These may, for example, be:

(a) Production shops or warehouses (stores) in the block and terracotta industry (e.g., concrete and precast unit industry, cement industry, ready-mix concrete industry etc.)

(b) Metallurgical works and rolling mills of all kinds.

(c) Production shops and stores in heavy industry (works in the metal and metal processing industry and, with limitations, also the engineering industry).

(d) Plants for energy production (power stations of all kinds).

(e) Agricultural operations (farms).

(f) Industrial roads, access roads, courtyards and open areas for industrial plants, container storage areas, ramps etc.

For the industrial areas just mentioned, which may generally be provided with concrete block paving regardless of the branch of industry, the principles of road construction engineering, which are not the subject of this special report, will largely apply.

As is well known, a concrete block pavement cannot be kept clean (in the sense of dust-free) since, when it is swept, sand and dust are always whirled up out of the joints and are swept back into the joints. For this very reason numerous production factories in the metal processing and engineering industry (e.g., the automotive industry) cannot lay down this sort of paving for their production shops.

Conditions are similar in (for example) market halls, particularly where fish and meat are sold, and in numerous farms where the floor must be kept clean with the water hose. For hygienic reasons the use of concrete block paving is not possible here, because of the risk of trapping pathogens in the joints).

On the other hand, paving blocks are preferred in large market halls for flowers, at trans-shipment points in rail and road traffic, in port installations or in the market places of urban pedestrian zones; i.e., pedestrian pecincts and shopping centres.

Types of industrial loading

As far as the mechanical stressing of concrete block paving in industrial construction is concerned, essentially similar factors apply as on public transport routes. In the majority of applications, they are mainly stresses resulting from heavy and very heavy truck traffic, and from internal transport vehicles, such as fork- and side-lift trucks, front loaders, etc. From the technical data for the vehicles used, the stresses may be determined for the pavement covering. The unladen load and payload of the vehicles are essential for dimensioning the substructure, whilst the wheel loads, tyre pressure and wheelbases are also important in selecting the paving.

However, there are a number of additional special stresses to be considered, according to the branch of industry, which result from the peculiarities of the production method and require from the floor covering, extreme wear resistance, or very high compressive strength or crack resistance, for example.

This is the case, for instance, with locally very high surface pressures, such as those which occur in the depositing of heavy loads on relatively narrow supports (container loads). Special abrasive wearing stresses must then be expected if metal materials, semi-finished products, etc. are stored temporarily on the floor.

Dynamic loads, impact and impact loads are produced when transporting and depositing containers, workpieces etc.; extreme impact loads may occur as a result of accidental dropping or tipping of metal materials.

In metallurgical works and foundries there are additional heating effects which occur as a result of transport and intermediate storage of red hot metal parts and which, with their pressure and temperature stressing, represent the absolute loading peak for an industrial floor.

Planning and stress criteria

The stresses of an industrial paved floor are generally many times higher than those found in normal road construction. This also means that special requirements must be imposed on industrial paved areas, which apply not only to the quality of the substructure, but also to the selection and quality of the blocks themselves.

In this case the required compressive strength is not generally subject to any variation, since deviations from the standardised strength of 60 N/mm^2 are only necessary in exceptional cases. Special requirements may, however, be imposed with regard to the shape of the block, pavement height, the admixtures and binding agents used, abrasive wear resistance, heat resistance and, if applicable, special resistance to chemical attacks.

With regard to paving block shape, as compact a shape as possible is preferred. This means essentially square (possibly hexagonal) or rectangular, with a side ratio of 1:2, and a length/height ratio which is generally less than 2, with a maximum value of 2·5, but never exceeding this value. Of the paving block formats available in Germany, which number well over 50, the following are mainly found in industrial construction: square, rectangle, hexagon and only 3 to 4 types of composite paving block.

The wear resistance of standardised paving blocks is 15cm^3 per 50cm^2 in the abrasion test after Böhme. The blocks consist of broken, weather resistant, natural or artificial hard rock, in some cases with the addition of quartziferous natural sands, or of hard, weather resistant sand and gravel. Particularly wear resistant paving blocks are manufactured using suitable hard concrete linings. In this case both mineral wearing courses or layers, with abrasion values of below 10cm^3 per 50cm^2, and wearing courses or layers into which metal additives are introduced, are considered. These highly wear resistant paving blocks, with abrasion values of below 3cm^3 per 50^2, are used where there is primarily abrasive and impact traffic stress or in the case of vehicle traffic having wheels with steel tyres.

In the case of stressing from rubber-tyred vehicles, but with high loads and largely fixed storage goods, however, a wearing course on a mineral base, with abrasion values of below 10cm^3 per 50cm^2, is normally sufficient.

A special type of stress which occurs in foundries is the thermal or heating effect from red hot metals which must be transported and are subject to intermediate storage. Here paving blocks of heat resistant concrete are the only solution.

Because of the small size of the blocks, the temperature stresses in the material are not relieved by crack formation; the individual paving blocks, which are locally heated to high temperatures, may absorb the temperature (thermal) expansions, regardless of the neighbouring blocks, but on the other hand the firm in question may in many cases dispense with measures designed to protect the floor covering from too great a heating effect. This leads to greater planning freedom and operational flexibility.

As an example of this, mention is made of a wide strip works in which red hot rolls of steel strips (coils) must be conveyed from the strip line to an intermediate store. This was previously carried out by rail, but had the disadvantage that the coils—deposited on the rails—were damaged on the outermost layers of strip from the pressure of the rail sections. Today it is done wihout the use of tracks using heavy, rubber-tyred stacker vehicles which are only able to operate under the cooling effect of the wind produced by travel and must be quickly reversed as soon as they have deposited their red hot load onto the paving, otherwise the tyres will be damaged. The paving withstands the extreme thermal and compressive stresses under the temporarily stored coils without damage. The heat resistant paving blocks are produced from special compositions using blast furnace slag and slag cement.

One of the commonest justifications for using paving blocks in industrial construction is their reusability; i.e., the fact that paved areas can be taken up and relaid fairly easily. In the vicinity of industrial workshops and neighbouring bay areas a high degree of subsidence of supply and removal lines in the ground must be expected, causing repair or modification work at fairly short intervals. Concrete paving blocks are in this case considered to be the only logical floor fixture.

Choice of paving block thickness

The standard paving block sizes for use in industrial construction are the 16×16×14 cm square block and the 16×24×14 cm rectangular block (in some cases only 12 cm thick). Composite paving blocks are used in industrial construction in thickness of 8 and 10 cm. The choice of paving block thickness depends on the quality of the subgrade or base and on the loads to be expected.

For bays, storage areas, industrial collecting lines and industrial workshops 8 cm thick composite block paving is generally sufficient. 10 cm thick composite paving is used only for particularly heavy traffic and for extremely high point loads from vehicles or stacked goods, or under difficult subgrade conditions.

In foundries and other types of operation in heavy industry, however, many builders "swear" by the tried and tested rectangular 16×16×14 cm paving.

More important, however, than the question of correct paving block thickness is the choice of correct sub-structure. Only in exceptional cases is the naturally occuring soil suitable as a substructure or base for the pavement covering to be laid. Generally speaking a compacted soil backfill is required as the substructure. This bearing course must, if necessary, be frost resistant, but in any case sufficiently and uniformly stable and flat. It is incorporated according to the technical regulations for bearing courses (TVT) and the Technical Regulations for Earthworks (ZTVE) in road construction. In this case, particular attention must be paid to careful, layer by layer compacting.

The typical structure of a heavy construction class in the industrial field is:

10 cm composite block paving,
3 – 5 cm sand bed,
30 – 60 cm (according to subsoil/base) hydraulically bound gravel or ballast (broken stone) bearing course on frost-proof subgrade or on a 30 cm thick frost protection course.

An example of a slightly lighter structure is:

8 cm composite block paving on a
3 – 5 cm sand bed, and
30 – 50 cm unbound gravel bearing courses on frost-proof subgrade or on approx. 30 cm frost protection course, but as protection against mineral oil derivatives, a fuel resistant plastic sheet may be inserted under the sand bed on a 3 cm fine sand course (e.g. close to filling stations).

On industrial surfaces where heavy traffic is mainly used—particularly where horizontal forces are simultaneously produced from brakes and driving round bends—the sand bed in which the paving lies tends to be squeezed out; track grooves are formed. Here it is recommended that the sand be stabilised by the addition of cement or a lime/trass lime mixture (earth moist installation in the approximate mixing ratio of 1:8).

Otherwise the same conditions apply to the manufacture of paving surfaces in industrial construction as in the use of concrete block paving in other fields.

Concluding this paper, I should like to discuss a product which has for the moment been almost forgotten, and which at first sight has little to do with the subject "Concrete paving blocks in industrial construction," but from the point of view of production engineering is closely related to paving block, and is increasing in importance, namely concrete block for pit lining.

As is well known, Germany, like Great Britain, is rich in pit coal deposits. In the wake of more expensive mineral oil, the "great pit death" of the 1960's has in the Federal Republic been followed by a revival of pit coal production. New beds are being developed, old mines lined and tubbed. In this process, not only working pits (hoist shafts) but also a large number of ventilation shafts are being constructed, for which shaft lining with concrete blocks provides an economical alternative to the use of in-situ concrete or wood. For example, the blocks have a depth of 30 cm, with a width which increases conically from 20 to 21·6 cm, and a thickness (height) of 20 cm, and they weigh approx. 300 kg. They are produced from a B 45 or B 55, and are mixed dry. The shaft sinking and soil stabilisation behind the pit lining blocks are carried out using normal mining methods.

Thus the energy crisis in the concrete and precast concrete industry has produced not only extremely light, thermally insulating building blocks, but has also contributed to the revival of an almost forgotten concrete product (see DIN 21 525).

In conclusion, a summary

Paving blocks—particularly in their cube-shaped form—are among the oldest mineral building materials, and pavement surfaces are among the oldest building structures anywhere. The fact that a World Congress is being devoted to this product in 1980 is at first sight difficult to understand even among building specialists. Undoubtedly paving constructions have literally experienced a renaissance in the last 2 decades (at any rate in the Federal Republic), a renaissance which might possibly be in store for many other countries. The reason for this is twofold:

(1) the high standard of production in the concrete block industry, and

(2) the change in thinking among all those connected with planning and construction of urban roads and areas (road construction today is again more than just the production of tracks for motor cars).

In industrial construction, the conditions are similar, but more differentiated, although they could be made simpler. Here there is in many cases—as I have tried to explain above—no sensible alternative to concrete block paving. This also applies to building material variants on a cement base (screeds, in-situ concretes, large-sized slabs), which are unable to offer the special advantages of concrete block paving, either because of the technical specification or because of the price.

Thus the decision on whether or not to use concrete paving blocks in industrial construction is often based purely on ignorance. To provide adequate information on the use of this material seems to me to be one of the most important tasks in our industry and also a beneficial side effect of this congress.