Materials and specifications in West Germany

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Development in Germany

THE first concrete paving stones were manufactured in Germany at the end of the last century. Even before the First World War a number of patents for concrete paving stones demonstrate the preference shown for this product. In 1920, Klinkmiiller[1] wrote of the concrete paving stone:

> "By mixing and pressing the stones in the machine, greater safety and reliability is guaranteed in the uniformity of texture. The remaking of a road presents no difficulties, since the stones are supplied ready for use. After laying, the road can be immediately opened to traffic, thereby avoiding protracted closure and interruption of traffic.. In the case of openings for pipe laying and repairs, the pavement can easily be taken up and remade."

In the 1930s reports were already being published on concrete paving stones which were providing compressive strengths of up to 1,000 kp/cm^2. Rectangular concrete paving stones 240 x 120 x 80 mm were being incorporated in 1936 in a road with heavy traffic at Neuss. This experimental road has proved excellent for decades. 20 years later, in 1956, the production of composite paving stones was begun in Germany. The versatile concrete paving was accepted by imaginative planners. In the period from 1970 to the present-day alone approximately 250 million m^2 of concrete paving stones have been laid in Germany. The following reasons were decisive in this development:

1. Concrete paving stones are durable, non skidding (provide good grip), are dimensionally accurate and provide great variety with regard to format (shape), surface structure and colour.
2. Concrete paving stones have risen very little in price in the last 10 years.
3. Concrete paving stones can be laid by untrained labour, even in the unfavourable season.
4. Concrete paving stones can be taken up without any noise nuisance and can be re-used on the same site or elsewhere.

Guidelines and standards

The Forschungsgesellschaft für das Strassenwesen e.V. (Road Construction Research Association) supported the manufacture and use of concrete paving stones at a very early stage by issuing guidelines and instruction sheets. As early as 1958 the first issue appeared of the "Guidelines for the manufacture and use of concrete paving stones in road construction". These guidelines were revised in 1961.

Concrete paving stones were standardised in Germany in 1964. Standard sheet DIN 18501, "Paving stones of concrete" will shortly be published in a revised form. For the engineer or architect entrusted with the planning and tendering for footpaths, paths, carparks etc., the "Guidelines for pedestrian traffic installations" were issued by the Forschungsgesellschaft für das Strassenwesen e.V. in 1972, and the "Guidelines for stationary traffic (RAR)" in 1975, together with the "Instruction sheet for the installation of parking areas" in 1977.

TABLE 1: Reference values for the thickness of concrete paving stones

Traffic load	*Minimum thickness (cm)*		*Application*
	Paving stone to DIN 18501	*Composite paving stone*	
Light (not stressed or stressed only occassionally by passenger cars)	8	6	Footpaths, cycle paths passsenger car carparks
Medium heavy (occasional truck and bus traffic)	10	8	Urban roads, passenger car carparks, entrances, pedestrian precincts, yard or bay fixtures etc.
Heavy (truck and bus traffic)	12	10	All roads, bus stops and lanes, industrial areas, armoured roads etc.

Stresses and quality requirements

Concrete paving stones in the installed condition are stressed by traffic, and additionally by weathering in the open air.

The traffic load will produce vertical and horizontal forces in the pavement covering, which lead to compressive and bending stresses of the paving stones. These stones must not fracture under the stress applied, nor must they move or come loose from the joint. The edges must not chip. The concrete paving stones must absorb the forces from the traffic without damage and transmit them to the bearing course or the subgrade. The traffic may also result in wearing of the surface. The amount of abrasion may vary according to the type of traffic present. Relatively small, highly-loaded wheels and tracked vehicles represent a particularly unfavourable stress.

Weathering leads to shrinkage and temperature expansions, but these are absorbed in the joints between the concrete paving stones. In winter, concrete paving stones may also be stressed by frost and thawing salts.

As a result of the stressing of the concrete paving stones by traffic and weathering, quality requirements have been developed for these stones. Concrete paving stones to DIN 18501 must, on delivery, have an average compressive strength of 60 N/mm^2. Concrete paving stones which meet this requirement are, as experience has shown, sufficiently resistant to frost and thawing salt attack if they are manufactured from standard cement and frost-resistant aggregates to DIN 4226, Part 3. Because of this the additional testing for frost and thawing salt resistance

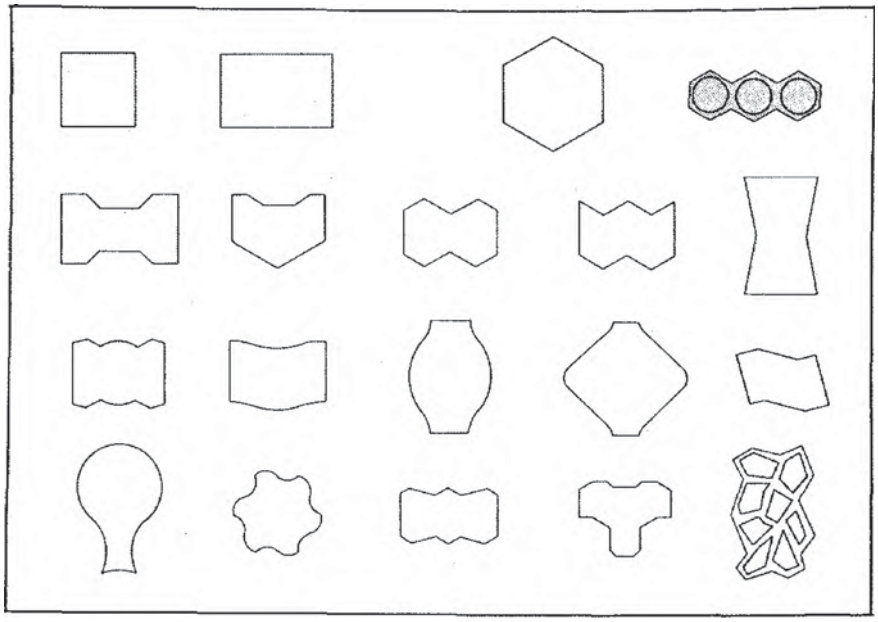


Figure 1. Types of concrete paving stone.

of concrete paving stones is dispensed with. The earlier requirement regarding wear is also dispensed with because it has been shown that all concrete paving stones with a compressive strength of over 60 N/mm^2 are sufficiently wear resistant.

Testing for the compressive strength of concrete paving stones is carried out to DIN 18501 on the whole stone, of approximately cube-shaped form. Stones with relatively long lateral lengths in relation to the stone height are loaded by placing steel plates on a partial area only, one side of the loaded partial area corresponding roughly to the height of the paving stone, and the other not deviating much from it. The pressure stressed partial areas are ground parallel and smoothly. As part of internal monitoring, grinding (smoothing) of the pressure faces may also be replaced by levelling with cement mortar. Cushioning intermediate layers leads to major test variations, particularly in paving stones with rough surfaces, and should not therefore be used.

The thickness of the concrete paving stones is determined from the traffic load and stone shape. Reference values for the thickness of paving stones of concrete are given in Table 1.

Types of concrete paving stones

The recognised advantages of the building material include the possibility of shaping and forming it arbitrarily. Considerable use of this possibility is also made in the manufacture of concrete paving stones, as shown by the wide variety of concrete stone paving that can be supplied, with regard to stone shape, surface structure and colouring. The shape of the stones is intended to permit the manufacture of closed or sealed surfaces, even round bends, and to permit a good distribution of the vertical and horizontal forces. Stone shapes which simplify and facilitate production, transport and laying are suitable.

Concrete paving stones may be divided into:

(a) paving stones without composite effect, and

(b) composite paving stones.

Paving stones without composite effect include square and rectangular paving stones, and certain special shapes. These have proved satisfactory for decades, even under heavy traffic. Paving stones without composite effect require a lateral edge limit such as an abutment in the form of kerbstones. Like natural stones - they transmit the pressure load to the subgrade without load distributing effect.

Composite paving stones can transmit not only compressive but also tensile forces in the horizontal direction. A composite pavement is capable of distributing point traffic loads over a larger area. Lateral limitation using kerbstones may generally be avoided.

Shapes of concrete paving stones are shown in Figure 1.

By selecting suitable lining courses, almost all requirements regarding surface structure and colouring can be met. The visible edges of the concrete paving stones are now almost always bevelled. This is advantageous in production and laying. Bevelled stones tend far less towards edge chipping than fully square stones.

Surface fixtures with composite paving stones do indeed require no kerbstones, but they do require special starting, edge and bend (curve) stones generally for this purpose.

Production

Concrete paving stones are now produced mainly on stationary automatic block making machines, which compress the concrete with the largest grain from 8 to 16 mm by vibration and/or pressing. In addition to pallet finishers, multi-layer finishers have also attained importance. The production area is generally 70 x 140 cm, and in special

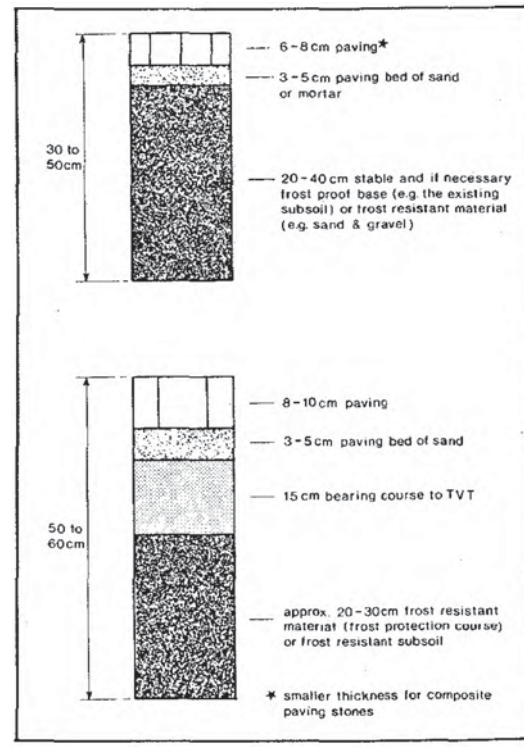


Figure 2: Examples of the strengthening of road surfaces with concrete paving stones; (above) carpark surfaces, footpath and cycle path; (below) parking area for trucks, industrial road.

cases 140 x 140 cm. By large-scale automation in production, wage costs have been considerably reduced in the course of time. In 1936 the production of 100 m^2 of concrete paving stones required about 15 wage hours. Today this figure is approximately 1.5 wage hours, i.e. only 10%. Similar savings of wage costs have been achieved in the meantime in internal transport and in loading using suitable equipment.

The structure of the concrete, the compaction achieved, the storage of the fresh stones and their subsequent treatment are of considerable importance to the quality of the stone. The supply of heat to accelerate concrete setting is generally only normally practised in winter. In summer the moistening of the stones aged approximately 1 day should not be dispensed with if sanding of the surface is to be avoided. The concrete, with a low water cement ratio, used for concrete paving stones, is sensitive to premature drying.

During production, the initial or raw materials used, particularly the concrete aggregate, and the proportioning systems for the cement, aggregate and water, the mixing action and the compaction must be continuously monitored.

Installation

Like all traffic surfaces (road surfaces), paved surfaces require expert treatment of the subgrade, a substructure and sufficient drainage. Outcropping soil may already be sufficiently stable for low traffic loading. When loaded with a truck having a wheel load of 2.5 t, at walking speed, no permanent or clearly visible elastic deformations must be produced. If the stability of the subsoil or subgrade is insufficient, it must be improved; e.g., by hydraulically bound bearing courses. In the case of a sandy subsoil, good compaction is sufficient for the surfaces over which traffic does not travel. In the case of the surfaces over which traffic does travel, on the otherhand, a bearing course is generally necessary.

In the case of a wet, coherent subsoil, the increase in moisture must be prevented by the incorporation of suitable courses. The frost-proof superstructure on a frost-sensitive subsoil should be 30 to 50 cm, according to the traffic load. Examples of the strengthening of traffic (road) surfaces with concrete paving stones are indicated in Figure 2.

Concrete paving is normally laid on a *pavement bed* of sand. A mortar bed is only suitable for stone heights of < 6 cm. For heavily loaded surfaces, e.g. works entrances and bus-stops, a bed of concrete, strength class B5, with a thickness of at least 10cm, should be provided. Well graded natural sand, or a crushed sand/broken stone (grit) mixture, with a maximum grain size of 8 mm, is well suited as a sand for the paving bed. Cavities existing in the substructure must be filled in before applying the paving bed, either by shaking in or washing in, so that the bedding material does not seep into the substructure. The sand bed should be 3 to 5 cm thick in the compacted condition. The pavement bedding is drawn off to the exact height between centerings, with the required longitudinal and transverse gradients. In doing so, consideration must be given to subsequent compacting of the pavement bedding. The sand must be introduced with suitable banking. The drawn off pavement bedding must neither be driven nor walked on.

Concrete paving stones, because of their high degree of dimensional accuracy, are not individually set with the hammer, like natural stones, but are laid on the prepared pavement bed. The laying of the concrete paving stones may also be carried out by untrained labour after brief instruction. Only about one third of the time required to set natural stones is expended per unit of area. Laying machines are no longer used in practice. Larger coherent paving slabs with joints are only laid mechanically in the upper half. It is difficult to remove such pavement coverings, because the fractures produced under traffic load are interlocked.

After laying, sand is swept or washed into the joints, and the paving is shaken uniformly from the edges to the centre, until stability is achieved. Pouring bituminous or cement-bound compounds into the joints is the exception.

Paved surfaces require a sufficient longitudinal and transverse gradient. The transverse inclination should not be below 3%, in the case of footpaths 2%, and should not exceed 4%. The surface water must be drained off. Because rainwater is able to penetrate the covering, the substructure must also be thoroughly drained.

In paved surfaces increasing importance is attached to edge design. If composite paving stones are laid without a kerb, special kerbstones must be used, and the bearing course must be extended a sufficient distance beyond the edge. Otherwise, the normal edging and kerb stones are suitable as edging for paved surfaces. Concrete paving stones may be taken up and re-used without difficulty.

Applications

Technical and economic reasons, but also nostalgia and environment protection, have led to a renaissance of paving in recent years. Justifiably, concrete paving is being increasingly appreciated as an architectural building medium in an otherwise extremely sombre road construction landscape. Traffic areas and surfaces of concrete paving are characterised by constant wheel-grip (non-skidding) and a long service life. They adapt to the movements of the subsoil. Because of this they are used particularly where changes in the subsoil are feared. Concrete paving is now found in pedestrian precincts, in parks and gardens, on banks and slopes, market places and carparks, on station platforms, in track beddings and as bus lanes, yard and road fixtures, in factory shops and other buildings, in short, in almost all areas of modern transportation, path and road construction.

1. KLINKMÜLLER, Kunststeinstrassenpflaster, *Tomndustrie-Zeitung*, Berlin, 1920.