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BACK-TO-BASICS - MEASURING THE PROGRESS OF UNDERSTANDING OF OVER 35 YEARS OF THE USE OF CONCRETE BLOCK PAVING IN THE UK

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Note: The following is the notation used in this paper: (.) for decimals and ( ) for thousands.

Summary

In the early 1970s, few firms in the United Kingdom (UK) were equipped to manufacture paving blocks and sales were insignificant, as they lacked the background knowledge to take their product much beyond the use by the private householder and into the public highway centre. Although, concrete block paving was being used mainly in the Netherlands and in Germany, it was viewed in the UK as a non-starter.

In the early 1970's the Cement and Concrete Association (C&CA), became interested in the potential application of concrete block paving in the UK. There was little published research available, no design methods or quality standards, so the process began. The British Standards Institution "Glossary of building and civil engineering terms: Highway Engineering", did not include concrete block paving, so a glossary of terms was developed. Those terms are used today.

In 1976, to promote the product, the first design, construction and requirements Manual was written, followed in 1978, by the heavy traffic roads and paved areas publication. Publicity was provided by the C&CA with leaflets and a 20 minute, 16 mm film. To assist clients, a specification was agreed between the C&CA and INTERPAVE, published in 1978. A tripartite paper was presented at the First International Conference on Concrete Block Paving in 1980 in Newcastle upon Tyne, in the UK. This formed the basis of the British Standard BS 6717 : Part 1, 1986, followed by the European harmonization in 2002 with CEN 1338.

To assist layers, a booklet on "How to lay concrete block paving" was produced by the C&CA in 1976. The C&CA, County Surveyors Society and INTERPAVE produced a "Code of practice for laying", in 1983, and this formed the basis of the British Standard BS 6717 : Part 3, and lately the BS 7533 : Part 3.

The principles are the same now as then, for laying the product. Research has been undertaken for materials specification, especially bedding sands and jointing sands. Much of the earlier designs for roadways are still relevant today.

Moving forward, the concepts are the same, as in the 70's. Further research has been undertaken, but, if it were not for engineers, like Lilley and Knapton, our knowledge base would not be as comprehensive as it is today.

1. INTRODUCTION

Before the times of recorded history, segmental paving, in the form of natural stone, provided the only practical means of forming hard surfaces for pathways. Its use continued throughout different civilisations, although the construction differed, depending on the type of stones available, soil types and the form of traffic. Some 900 years ago, in parts of the world that lack an ample supply of a suitable natural stone, paving with bricks made of burnt clay became common.

It's not until the early part the 20th century that the use of segmental paving declined, mainly as a result of the development of bituminous and cementitious binders, allowing the creation to have continuous pavement 'in situ'. With only a few exceptions, the use a segmental paving continued to decline until the invention, in the latter half of the 20th century, of machines capable of making high quality, precision dimensioned concrete blocks, economically. The invention of these machines resulted in the creation of a major new form of the precast concrete industry, which has spread worldwide. In addition, the introduction of block paving resulted in the re-awakening, in the older forms, of segmental paving and, as a result, of growth in its use.

In the early 1970s, Alan Lilley became interested in the potential application of paving blocks in the UK, mainly in the belief that it could be an ideal solution for the surfacing of roads in residential areas. He was responsible for the early research and promotion of the concept in the UK, also advising designers and site staff and from time to time, for investigations of pavement and failures.

In the early 1970s, few firms in the UK were equipped to manufacture paving blocks and their sales were insignificant, as they lacked the background knowledge to take their products much beyond that used by private householders and into the public highway sector. The manufacturers quickly saw the main commercial potential of supporting research to extend markets into public paving works. The research work required the development of a credible paving design system, which local government engineers could use, and a specification for blocks that would be sure to be resistant to frost damage and would not polish and so lack adequate resistance to skidding. At the same time it was necessary to study simple construction methods that would allow potential contractors to undertake work economically and submit competitive tenders.

The work on the basic requirements for blocks, after a while, led to the formation of the Concrete Block Paving Association, which is now known as INTERPAVE, the trade association with the objective of unifying manufacture extending and promoting the market.

The fundamental decision was made by the C&CA and its engineers Lilley and Knapton developed a pavement design concept, specifically applicable to block paving. It was felt that this would be treated with suspicion by highway engineers, who used a standard document evolved by the government sponsored Transport and Road Research Laboratory (TRRL). For the TRRL document to be used, research had to determine the thickness of concrete block paving so that it had the same load spreading ability as hot rolled asphalt. This approach has, over its use, suffered criticism, some aimed at the official document, but, it has allowed many pavements to be designed and perform satisfactorily. Although, at the time, it was not to say that better design methods were not possible and would not be developed.

Commercially available blocks were subjected to various tests, the strain in compression and bending, absorption, and resistance to damage by freezing and thawing. As a result, a tentative specification was produced and accepted by the manufacturers.

In 1978 the C&CA, in conjunction with manufacturers, produced a specification for concrete block paving, giving the requirements for the concrete block paving of rectangular and propriety shapes, manufactured for the construction of paver surfaces used by vehicular and pedestrian traffic.

Architects and engineers responsible for the planning and construction of the, then new, city of Milton Keynes, used block paving, not just in residential roads but for many other roads and paved areas in the commercial and industrial part of the city. At this time one of the early problems encountered was one of language and new terminology, not just between countries within the UK vocabulary. Long history and wide range of materials used in the construction of segmental pavements, has resulted in a mixed and often conflicting terminology and the "British Standards Institute glossary of Building and Civil Engineering terms: Highway Engineering", did not include all those needed for the writing of the standards.

It was hoped that in time, the terminology would have gained wide acceptance and reduced the confusion that often arose at meetings when reading documents written by different authors and in different parts of the industry. Because concrete blocks and clay pavers were often used in a similar way, the term "block" has been used for both in order to avoid a necessary repetition. Likewise, base has been used to meet the situation where a layer may either be a "roadbase" or a "sub-base".

In the UK, the renaissance of segmental paving began with the introduction of concrete blocks and in northern Europe in the late 1970s. The development of the use of the paving was partly because of its practicality, but also as a result of its attractive appearance and probably aided by nostalgia for the older paving forms of the previous century.

Pavement Design, particularly for block pavements, has generated a great deal of research. The design of pavements is complex because of the large number of variables concerned in any analysis. It is unlikely that a wholly reliable method will ever be developed, even using the present computer technology, which is more advanced than that of the early Seventies.

Footways were often treated as the least important part of any highway. In recent years footways have suffered greatly, being used for the parking of heavy vehicles, resulting in displacement of the flags and serious deformation. These faults may often lead to what could be serious accidents to pedestrians.

2. THE HISTORY OF PAVING

2.1 Concrete block paving

Roman roads have been a subject of many papers in previous conferences. It wasn't until 1838 that the modern form of paving was used in the front forecourt of New Street railway station, Birmingham. Later it was used to pave the area in front of one of London's main terminals, Euston Station at the southern end of the same railway line.

Taylor called this form of paving the "Euston pavement" (see Figure 1). At this time, stone setts were roughly 220 mm deep, 200 mm to 300 mm long, by 150 mm to 200 mm wide, much larger than segments been promoted by Taylor. However, joints in between the setts were wide and filled with either pitch or mortar, while Taylor required that the stone should be cut more accurately and joints between them should be filled with fine sand. With the major reconstruction and modernisation of Euston station, in 1978, the area originally paved by Taylor was replaced using a similar construction with concrete block paving in place of stone blocks.

To develop the market in the UK, the Cement and Concrete Association produced several documents including "Concrete block paving for road" by Lilley and Knapton in 1976, price £1 (see Figure 2).

To compliment and develop the heavy duty market and not lightly trafficked roads, another document for "Heavy-duty areas" by Lilley and Walker in 1978, "Concrete Block paving takes the load" was produced in the same year (see Figure 3). Prior to this move to combat the housing estate roads, concrete block paving was use as a decorative product mainly as a feature.

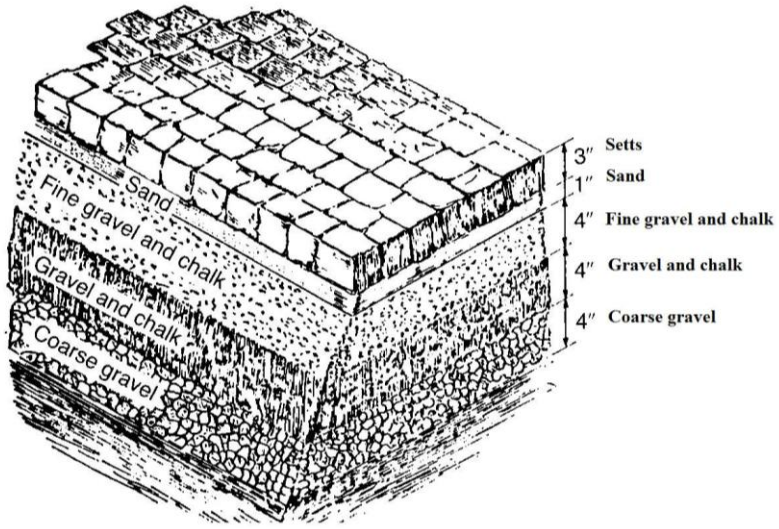

Figure 1. Taylor´s Pavement.

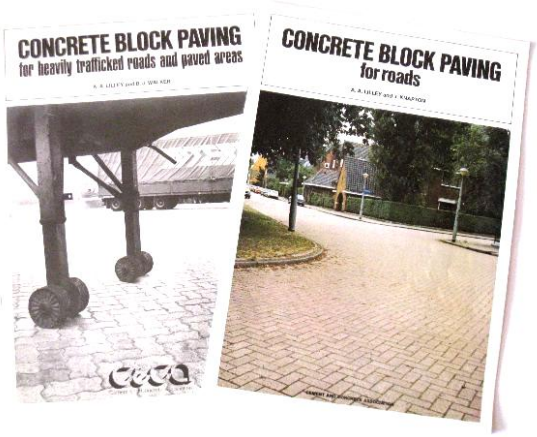

Figure 2.

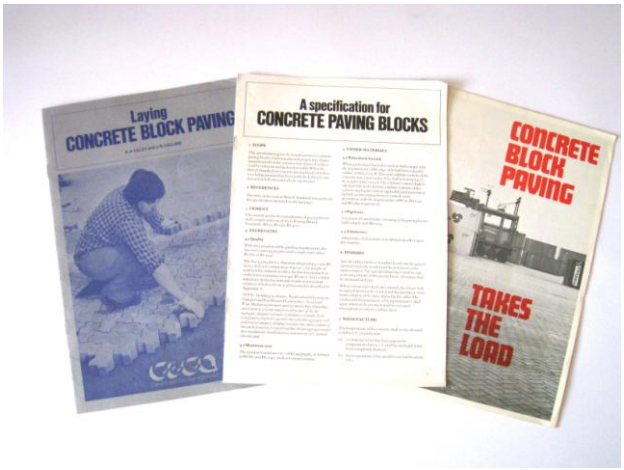

Figure 3.

To assist them with the laying of concrete block paving, Lilley and Collins produced a booklet in 1976 and that reproduced, with minor amendments in 1980 and 1981.

In February 1983 C&CA, County Surveyors Society and INTERPAVE drew up a "Code of practice for laying precast concrete block paving" (see Figure 4). Using this document, it formed the British Standard laying code for concrete block paving and is the current BS 7533-3. Soon after the specification for concrete block paving was printed in 1978, the C&CA, County Surveyors and INTER-

PAVE produced a specification, which was the forerunner to the British Standard for concrete block pavers, BS 6717 and more recently with European harmonisation to BS EN 1338. The tripartite specification, as it was known, was presented at the First Conference on Concrete Block Paving held in the Newcastle University (Newcastle upon Tyne, UK), organised by John Knapton.

Figure 4.

Figure 5.

To help promote the use of concrete block paving in the UK, the C&CA produced a 16 millimetre 20 minutes long film which demonstrated all aspects of concrete block paving.

In the late 1970's, the C&CA brought together manufacturers, who worked and helped in the development of concrete block paving. At this time, the National Precast Concrete Kerb Association (NPKA), was a separate trade association and many members were also members of the British Precast Concrete Federation (BPCF). To reduce costs for meetings and to reduce duplication, the NPKA joined with the Paving Group of BPCF. Manufacturers met and as most of this adhoc group were members of BPCF, negotiation were instigated with those outside the membership encouraged to join and this resulted in the formation of the INTERPAVE, "The Precast Concrete Paving and Kerb Association", as a trade association within BPCF.

To promote this product in the early days, lectures and mini seminars were arranged for all users of block paving. Since this time, INTERPAVE has been active in the development of the market by producing a wide variety of brochures on all aspects of concrete block paving. Using modern technology all their latest brochures can be viewed and downloaded from their website.

From a very low sales base of less than 400 000 m^2 in the late 70's, the market today is more than 23 million m^2 in the UK.

One of the reasons for this expansion has been the development and publicity of using thinner blocks than was originally suggested by Lilley. The 50 mm block has transformed the decorative market and has begun to penetrate the lower end of the roads market. The concrete mix is similar to the original mix designs; the only change is that the base on which they are laid has been increased by the difference in thickness between the blocks.

The design concept, which originally was based on Road Note 29, the early design from Lilley and Knapton, is still functioning in pavements.

As the market increased, new areas of application was sought leading to their use in very heavy duty application with the development of the British Ports Authority Design Guide in hard copy. In 1978 a design was published for heavy duty pavements. The current design for industrial areas can be downloaded from INTERPAVE's web site (see Figure 6).

Figure 6.

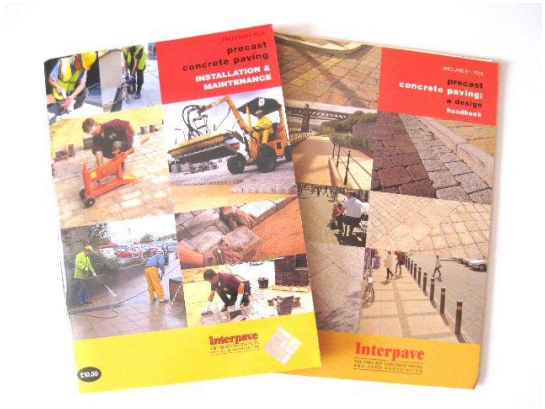

Figure 7.

Concrete blocks have been used in all types of construction of heavy duty port areas, airports, military establishment, roads, pedestrian areas and private roads. The latest development is the use of blocks in permeable pavements.

Permeable paving systems have been introduced in the UK in the last 10 years, with the base designed to hold water, before discharging it back into the ground, under controlled discharge rates. This has been produced as a British Standard document BS 7533-13 using the information used by INTERPAVE to promote its use.

More recently, concrete block paving has been laid using rigid bases, rigid bedding methods and rigid joints, mimicking the laying of natural setts, slabs and flags. Using the design and construction for setts, concrete blocks have been substituted for the natural stone product and are covered by amendments to BS 7533-7 and BS 7533-10.

2.2 Concrete paving flags

Concrete paving slabs have a long history, dating back to the 1890's when local authorities began to replace natural stone slabs. Concrete paving were produced then and still are, using the Fielding Wet Press method. Examples of this paving are still in evidence today. In 1929, the first British Standard was introduced with test methods for strength and water absorption, BS 368, being updated to BS 7263-1 and currently BS EN 1339.

Over many decades concrete paving flags overtook and replaced natural stone, mainly due to the accuracy of manufacture and cost until the 1990's when stone, particularly in town and city centres, was being used.

This method of manufacture has proved to be very practical and the end, durable. The concept has not been very widely used outside the UK.

The same process is used to produce kerbs of different sections and in 1928 the British Standard produced BS 340 for the product to be updated, in 1990, by BS 7263- 3 and currently BS EN 1340.

The voice of the industry in the 1960's was the NPKA who promoted the use of flag and kerbs. Forming INTERPAVE increased the promotion level, to enlarge both the flag and block markets.

In the early 80's, paving flags were having a bad press, due to the high number of insurance claims from the general public falling or tripping on broken flags. The traditional way of laying flags was to lay them on a weak sand cement mixture using the 5-spot method as had been the norm for 100 years. As vehicles became larger and heavier, traffic increased. Vehicles overran the footpaths that were designed for foot traffic only, so it was inevitable that the unsupported flag would crack and

break. The flag industry reacted in conjunction with the C&CA and produced a much smaller plan size of flags. Rejecting the old method of fixing the flags, these were laid in a similar construction method to concrete block paving using a properly designed base and bedded on sand. This, immediately, reduced the incidence of flags breaking and has continued to be successful on footpath and precincts. The design for flexible laying of flags is BS 7533-8 and BS 7533-4 is used for the method of laying all categories of flag applications.

It is recognized in the UK that there is little difference between natural stone and concrete flags and design procedures have now been published by British Standards in BS 7533-12. The method employed for laying flags and natural stone has been added to British Standards BS 7533-4

INTERPAVE continues to produce helpful guides on the use, design and laying methods for paving flags.

3. GLOSSARY OF TERMS

This part of the paper lists the terminology that was developed at the inception of block paving and which continues to be used today. The long history of segmental paving and its development of commercial interest has led to a proliferation of terms, or worse, the use of similar terms with very different meaning. It is intended to assist the readers, who are less familiar with the technology, especially the new engineers, who are being currently educated in our universities and educational establishments. It will also remind those experienced people, in both block paving and paving flags markets, that the majority of definitions were produced 30 years ago and are now being used throughout the world and are internationally recognised.

3.1 Concrete block paving and flags

Concrete paving block: A precast concrete unit, used as the surfacing material, in which, at a distance of 50 mm from any edge, any cross section has not a horizontal dimension less than 50 mm and with an overall length which when divided by its thickness is less than or equal to four (4).
Flag: A precast concrete unit, and used as the surfacing material, with an overall length that does not exceed one metre (1 m) and an overall length which when divided by sickness is greater than four (4).
Permeable pavements: A pavement consisting of a surface course of paving units laid with wide joints, voids or openings, that allow water to pass through into the pavement construction.
Conventional pavement: A pavement consisting of a surface course of paving units laid with narrowed joints and filled jointing material that has low permeability.
Spacer nibs. A small protruding profile on a side face of unit.
Bed face. A surface intended to be seen when in use.
Facing layer. A layer of concrete on the upper face of a block of different materials and/ or properties to the main body or backing layer.
Arris: A part of the block with two faces meet. Can be bevelled, surrounded, chamfered, radiussed to splayed.
Work dimensions: Any dimension of a unit specified for its manufacture at which the actual dimensions should conform within specified permissible deviation.
Secondary processing: A manufacturing process to texture of the whole unit or any surface, carried out after basic manufacture before or after hardening.
Skid resistance: The ability to resist the relative movement between a vehicle tyre and the traffic to concrete paving surface.
Slip resistance: The ability to resist relative movement between a pedestrian's foot and a trafficked concrete paving blocks surface**.**

Wipe: A fine cement mortar or slurry applied to the surface of the unit, maximum thickness 1 mm.
Work dimension: Any dimension of a unit specified in order of overall length, overall width and thickness.
Tactile paving surface indicator: A profiled paving finish used to convey information to visually impaired pedestrians about hazards and amenities.
Visually impaired: Blind or partially sighted person.
Profile feature: A single component of a tactile paving surface indicator.
Blister surface: A profile paving finish comprising raised rows of domes, flat top domes, flat top pyramids or cylinders, arrays of offset rows of domes, flat top domes or cylinders shape with rounded edges, or raise lozenges
Rib surface: A profile paving finish by using parallel rounded bars running full width or diagonally on the unit, flat top bars running full width or diagonally on the unit, trapezoid shapes, continuous sine like waves, trapezoidal intermittent ribs
Grooved surface: A profiled paving finish comprising flat grooves running full width of the units, flat trapezoidal grooves running full width of units

3.2 Construction

Laying course: The layer of material which pavers are bedded.
Subgrade: The upper part of the soil, natural or constructed, that supports the load transmitted by the overlying pavement.
Subgrade improvement layer: The layer of granular or treated material at the top of the subgrade should provide an improved foundation for the pavement.
Sub-base: One or more layers of material placed immediately above the subgrade.
Roadbase: One or more layers of material placed above the sub-base that constitutes the main structural element of the pavement.
Cement bound material [CBM]: Granular material to which cement has been added.
Channelized traffic: Traffic where the vehicle track wit and the traffic lane widths are virtually the same.
Dynamic loading: Spectrum of loads normally occurring on highway pavement and vehicle speeds exceeding 30 mile an hour [50 km/h].
Standard axle: An axle carrying a load of 8 200 kg.
Cumulative traffic: Number of standard axles of pavement is designed to carry, measured in millions standard axles [msa].
Commercial vehicle: Vehicle having an unladen weight exceeding 1.5 t.
Flexible pavements: Pavement, constructed with pavers jointed with sand laid on a laying course, which is assumed to behave in a flexible manner.
Lightly trafficked pavements: A pavement which receives a limited number of heavy vehicles.
Surface course: Layer paving units that acts as a wearing surface and forms part to the structure of the pavement.
Pavement: Paved area subject pedestrian and stroke off vehicular traffic.
Bound construction: Paving units laid on and jointed with hydraulic mortar.
Unbound construction: Paving units laid on a jointed with sand.
Kerb race: Foundation on which the units are laid.
Mortar joint: Joint between two units filled with the sand/cement mixture.
Movement joint: Joint constructed to allow units to expand and contract.
Restraints: A device that so as to prevent lateral movement of paving units and to prevent loss or have the laying course material.
Edge restraint: Restraint used at the edges of an area been paying.

Intermediate restraint: Restraint used at intervals along an area has been paid to.
Temporary restraint: Restraint used when a partially paved area is to be trafficked or when it is necessary to preserve the integrity of the laying face at the end of a working period.
Interlock: Effects of frictional forces between paving units which prevent them moving in relation to each other.
Laying course: Layer of material on which paving units are bedded.
Laying face: Working edge of the surface course to which paving units are being placed.
Roadbase: One or more layers of material placed above the sub-base that constitutes a structural element of a flexible or composite paving.
Inboard cutting: Cutting to break the bond to allow the cut at the edge to be greater than one-third of a unit.
Laying pattern: Arrangement of paving units either for structural requirements or for visual effects.
Jointing material: Material applied to fill joints between paving units.
Joint width. Distance between adjacent paving units or units and restraints you.
Void: Between adjacent paving units, or units and restraints, formed by virtue of the shape of the units and how they fit together.
Mechanical laying: Laying of clusters or formation of paving units by mechanical means.
Creep: Horizontal movement of paving units resulting from the action of deceleration, cornering forces or gravity.
Regulating layer: Layer of compacted material upon which the laying course is laid, which ensures a laying course thickness is in tolerance.
Complimentary fittings: Using the end of alternative rows to break one to avoid the need to cut.
Bedding mortar: Blend of fine aggregate and cementitious binder.
Geo-cellular Box System: Storm water storage system comprising a series of modular plastic boxes clipped together to form avoid either for the storage or the attenuation of storm water.
Geo textile: Permeable textile, mesh, net or grid that allows water to flow through and prevents migration of particular between construction layers.
Impermeable membrane: Membrane which contains all the water entering the pavement and being contained within the structure.

4. CONCLUSIONS

The use of small stone elements to create a hard surface for roads and pavements can be traced back to ancient Babylon. The Romans, with their engineering ability, developed the system of using small units locked together with fine material, which preceded many present day concrete paving technology principles. In particular, the Romans had the accurate cutting of units and consistent joint widths, measured by attempting to insert a knife blade between the units, a principle we follow today in maintaining accurate joint widths.

Lilley and Knapton in 1976 wrote "...block roads are economically attractive; no special construction plant is needed. Some roads are softened by oil spillage but this cannot happen to blocks. This is probably a major reason for their choice for car and lorry parks and petrol stations".

Lilley and Walker wrote in 1978 "...that concrete block paving provides an ideal surfacing for many forms of pavements including roads, goods yards, storage areas, dockside paving, roll-on roll-off and container terminals".

Back to basics, measuring our progress over the last thirty years, raises the question have we made progress? The methods we employ to construct pavements have not changed in principle. The de-

sign of the structure still uses the principles of road design of all types. We have introduced a wider spectrum of applications. In the case of concrete block paving, the introduction of permeable paving, where water collection is important to combat the growing urbanisation, thus reduces the capacity for natural, sustainable drainage, but still provides an attractive load bearing surface, still laid in the traditional way. Paving flags, using the same construction methods, have been used to deliver messages to the partially sighted and the blind.

Moving forward, the concepts today are the same as in the 70's. Further research has been undertaken, but if it was not for engineers like Lilley and Knapton, our knowledge base would not be as comprehensive as it is today.

5. REFERENCES

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- Part 1: Guide for the structural design of heavy duty pavements constructed of clay pavers or precast concrete paving blocks.
- Part 2: Guide for the structural design of lightly trafficked pavements constructed of clay pavers or precast concrete paving blocks.
- Part 3: Code of practice for laying precast concrete paving blocks and clay pavers for flexible pavements.
- Part 4: Code of practice for the construction of pavements of precast concrete flags or natural stone slabs.
- Part 6: Code of practice for laying natural stone, precast concrete and clay kerb units.
- Part 7: Code of practice for the construction of pavements of natural stone setts and cobbles.
- Part 8: Guide for the structural design of lightly trafficked pavements of precast concrete flags and natural stone slabs.
- Part 10: Guide for the structural design of trafficked pavements constructed of natural stone setts.
- Part 12: Code of practice for the opening, maintenance and reinstatement of pavements of concrete, clay and natural stone.
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