PEDESTRIAN WALKWAYS – THE WALKING SURFACE

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ABSTRACT

Footways are a major part of our urban highway and are intended to segregate the different forms of traffic and provide unobstructive, safe, clean and easy to maintain areas for use by pedestrians only.

The Romans understood the need to move unhindered and layed many pavements. It took 1400 years for people to realise the need to segregate carriageways and footways and the need to walk on a hard surface and not the earth.

This paper explains the objective of the footway and will identify the causes of failure in all types of paving materials, it discusses a flexibly laid design method for vehicle overrun and methods of construction of flagged pavements.

The design method was developed following a survey of pavement failures of large plan area flags and the development of the small element paving. The fundamental principle of this design procedure is the evaluation of the thickness, the type of sub-base to be used to ensure the allowable stresses not to be exceeded and for the pavement to remain serviceable without major maintenance during its design life. The different modes of failure between flag plan areas will be discussed. This method forms the basis of a new British Standard published earlier this year.

1. INTRODUCTION

Precast concrete paving flags have been in existence for over 100 years and this paper demonstrates the author's involvement in paving for the last 40 years in the application, research and the development of the standards to determine performance and in the design to provide longevity of use. To understand the development of footways and materials we should examine the way the product has developed over a long period of time. As the product developed, the need for standards to be written giving 'good practice' information was established. With the advent of vehicular over-run, design criteria was written to minimise failure and maintenance costs and recently published as a British Standard. All these aspects are discussed in this paper.

The use of segmental paving is older than recorded history, but, its outcome and later history is worth study as this can do much to help the modern pavement designer, whether he is an architect or engineer. An examination of the requirements and performance of different forms of segmental paving in different historical situations can yield much of value in the writing of modern specifications for both materials and construction methods, and in developing layout details. Perhaps the only aspect where history cannot help is concerned with structural design, because man, his animals or his vehicles, could pull far in excess of those loads carried on modern axles. In most modern situations the needs for very high abrasion resistance are much less than were required a century or more ago, the pneumatic rubber tyre causing far less wear than steel-tyred wheels or steel-shod horses. An exception to this is the pedestrian pavements, probably, where the most abrasive traffic on modern pavements is caused by the stiletto heel.

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In some industrial situations the demands for high abrasion resistance can be as great as for the roads of yesteryear, for example in areas used by track-laying vehicles and where products, such as ingots of heavy metal are dragged over pavement surfaces. Footways are a major part of our Urban Highway and are intended to segregate different forms of traffic and provide unobstructed safe, clean, and easy to maintain areas for use by pedestrians only.

2. DEVELOPMENT OF MATERIALS USED IN FOOTWAYS

It is certain that prehistoric man would have used boulders that had fallen into rivers as a simple method of crossing the water and it would not have taken long before he thought of making fording places at convenient points by placing stones, ideally those with flat tops, in shallow waters. This may well have been the origin of segmental paving. Presumably, he next learned that the same concept could be used to form pathways across soft ground, giving better passage for both man and his animals during poor weather.

The next stage in paving development probably arose when man started to change from a nomadic existence to an agricultural and later an urban society, living in communities and keeping animals rather than hunting them. These changes would have brought about a need to pave the floors of buildings, external stockyards and, to a limited degree, roads within the immediate neighborhood of the community. The only possible paving materials available at the time were either compacted soil or stones closely placed together.

Some 5000 years ago, the Minoans had developed to a high level of civilization, where essentially the roads were made of large, flat-topped boulders, with very wide joints. Although by today's standards these roads offer a poor ride, in their day they served their purpose well, providing an all weather surface allowing the passage of man, animals and carts.

The roads of the Greek empire have much in common with those of the Minoans, obviously the Greek engineers were willing to learn from their predecessors and the paved areas outside major buildings, such as the Parthenon in Athens, demonstrate the potential longevity of segmental construction.

King Cheops, about 3000 years before the birth of Christ, is credited with having constructed the first stone-paved road in Egypt, to facilitate the movement of the large stone blocks used in the construction of the Great Pyramid. This road, built as a causeway, was undoubtedly a major undertaking and covered a distance of some 1000 metres long, height, up to 15 metres and its width, over 18 metres. It is probable that joints between the paving stones were grouted with bitumen, this jointing serving two functions, to make a smoother surface, more comfortable to walk on and easier for wheels to roll over and also to prevent rain water entering the embankment.



Photograph 1. Roman road construction.

The growth of the essentially military Roman Empire and its rapid spread from Rome, through Italy, to northern Europe and parts of Asia and Africa, led the Romans to develop a sophisticated road-building system, with a surfacing suitable for the speedy movement of both chariots and infantry; the Minoan and Greek roads were far from ideal in these respects. The basic difference between the Roman roads and those of the Greeks was that the Romans generally used smaller stones, more in the form of setts, as the surfacing. Probably the other major change of attitude brought about by the Romans was the realization that a paved road is essentially a structure that must be designed to take into account not just the weight and volume of traffic, but also the strength of the underlying soil, Photograph 1. They perceived that the strength of many soils could be influenced by the presence of water. Most, if not all-Roman roads had edge abutments or restraints, formed of large stones on each side of the carriageway to retain the unbound layers of the pavement construction, the origin of the modern kerb and edge restraint. Records of paving of very similar constructions to those in the northern hemisphere can also be found in China and in South America, but little is known of their history. After the fall of the Roman Empire, their roads also fell into disuse as few people had any need to travel from the villages where they were born and as a result the art of road construction was forgotten. Although the old roads became overgrown many still exist today, some providing foundations for more modern constructions.

Centuries after the demise of the Roman Empire, many European countries attempted to rebuild national road systems. One way to finance the construction and maintenance of these modern roads was by means of tolls, using the philosophy that the user pays. In today's society, a highway provides an economic and rapid means of transporting mail and goods for all people.

In medieval times travel, even by the nobility, was unusual and certainly torturous. This resulted in larger towns being constructed on river banks at points as far inland as possible, but still having adequate draught for the boats of the time. Within these towns and larger villages the provision of hard paving was important, even if it were limited to the quay sides, market squares and pavements, giving access to major buildings. The main forms of land transport were the horse and ox. These animals, in large numbers, would have been very damaging to any surface other than those paved with stone cobbles or setts. The remains of some of these medieval pavements still exist today.

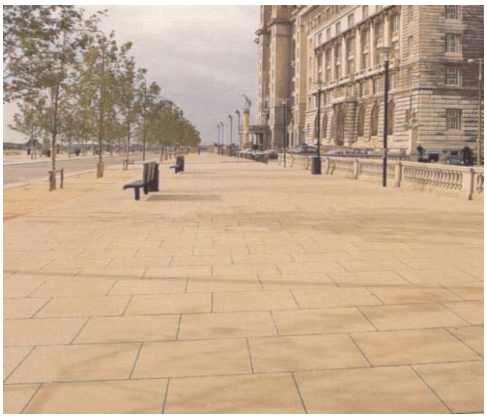
In Britain, in the 1600's, segregation between carriageways and footways was considered particularly in towns. In 1765, in the City of Westminster, raised paved footways were introduced. In Europe, Paris, for example there were no pavements until 1811. In the 19th century, natural stone usually referred to as Yorkstone since it originated from Yorkshire and North Lancashire, was used in many of our cities and towns. The use of this robust material declined in the mid 50’s, largely due to the demise of laying skills, doubtless affected by the prime cost of the material. Only in prestige locations is natural stone used today.

What we call "tarmac", a mixture of tar and stones mixed hot, then spread and consolidated after cooling, with a final coat of sand on top, was first made in Nottinghamshire in the 1830's. The use of tar and latterly bitumen macadam has increased from about 1900. In rural and lightly trafficked areas, due to its low construction cost, it is largely without competition. In suburban areas, the progressive removal of stone flags, from all but prestige locations, has been accomplished generally using bituminous macadam.

As precast concrete flags became available from about 1900, they presented an alternative to bituminous material due to their appearance. All major cities and towns used flags in the street and also on railway platforms. There are still examples all over the UK of areas paved with original flags for they were designed only to carry foot traffic and the sizes were similar to those of natural stone. The first standard for their manufacture and strength was produced in 1929 by the British Standards Institution[1] and today apart from using metric values the standard has not changed. Flags

were used extensively in residential development from 1945 and currently in many areas, moves to replace them have been vigorously resisted by local residents. Flags were the excepted surfacing material for footpaths in all areas of applications. Urban shopping area developments of the post war period have, almost exclusively, used flags, which have been developed in a range of colour, size and texture to meet demand, Photograph 2.

The volume and size of commercial vehicular traffic has increased, particularly since 1965, and the footway, supposedly an area of the highway exclusively for pedestrians, has now, in most areas, become subject to vehicle overrunning, in some cases, almost becoming a car park, Photograph 3. The industry was aware of the situation and in the early 80's worked in conjunction with the Greater London Council, and the Cement and Concrete Association to produce a suitable flag and at the same time commissioned work with The University of Newcastle to produce a Design Guide for Vehicular Over-run. This design[2] has proved to reduce damage to footways from vehicular over run. Not only were smaller sizes of flags introduced but a new method of construction and laying developed. The amount of traffic on an urban footway can be extensive and if pedestrians are to maximize it's use and as a result, shops gain business, the footway must be clean in all weathers. This in turn, means that the pavement surface must be hard, drain readily, resist wear by abrasion and be durable in all conditions. User comfort must also be considered, Photograph 2. Some urban footways are paved with flags, blocks, sometimes alone or in conjunction with each other.



Photograph 2. Pedestrian street



Photograph 3. Example of vehicle overrun

3. SPECIFICATION FOR LAYING FLAGS

The specification of many local authorities for laying flags included the use of boiler ashes from local town gas works pre 1950. In 1960, the cement-stabilized bed was developed and in 1980 there was a move away from a stabilized bed and since 1990 the exclusive use of an unstabilised sand bed has been the used with small element paving. This change in specification has resulted in a major reduction in flag failure. The results of this work were proven in the trial in 1983, where comparison of the two methods of construction was evaluated. In this evaluation, the number of broken flags when laid traditionally, of sizes of 600 x 600mm or larger, on a cementitious base, compared with the smaller sizes of 450 x 450mm or less when laid on designed construction and a sand laying course, was reduced from 80% to less than 2%. The National Paving and Kerb Association now Interpave commissioned research work and published the result in the form of a ‘design guide’ and the British Standard reflected this laying method by producing a standard.

4. MAINTENANCE

The maintenance of footways presents it's own peculiar problems. To reduce the need to dig up carriageways, it is common practice to assign services beneath footways that result in a frequent need to lift and relay the surfacing. Flags and blocks have proved ideal in this respect. They can be lifted, cleaned and re-used relatively easily after the trench has been reinstated without leaving that scar between new and old materials. One North Eastern Authority has a policy of replacing the tarmacadam with flags in footways, especially for Cable Television installers to lay their cables.

It was demonstrated some 20 years ago that footway maintenance consumed some 15 to 20% of urban highway costs. The basic problem was that footways were never designed for vehicular over run and those pavements were often (and still are) overrun by vehicles stressing the flags beyond their tensile strength. If the footway has to carry vehicles then it is necessary not just to use the right flags or blocks, but also provide them with an adequate foundation. British Standards addressed these issues by using Interpave's Design Guide to produce a British Standard BS 7533 – 8 Design Guide and to produce a laying guide for all British Standard sizes of flags.

5. OBJECTIVES OF A FOOTWAY

- To provide a safe walking path for pedestrians.
- Laid to plane and even gradients
- Segregated from traffic.
- Free from obstructions, depressions, trips, standing water loose surface.
- Surface should be non-slip in wet and dry weather.
- Surface well lit.
- No gaps, which will trap small wheels, canes or shoe heels.
- Compatible with immediate surroundings to enhance the environment.
- The need for maintenance should be minimized and consistent with achieving the lowest whole life cycle cost.
- Should be easily reinstated if disturbed.
- Should be capable of resisting the loading from foreseeable vehicle overrunning.

6. PAVEMENT MANAGEMENT

Pavement management is a complete subject by itself but in basic terms we should consider the three areas independently and then combine them to provide the most cost effective solution.

Design life is an area where we have available facts. For blacktop the expected life before intervention is about seven years with major replacement about twenty years. Flag pavements, when laid correctly, will last for over eighty years although normally concrete products are designed to have a forty-year life. Maintenance records are limited and to my knowledge there are several local authorities that do not bother now to keep records for maintenance when they use small element paving.

7. PREFERRED SURFACE MATERIALS

In an attempt to find out the users' preferred surface to walk on, the Precast Flag Industry conducted a survey in one area of Southern England.

The primary objectives were: -

- To investigate public attitudes and levels of awareness in respect of existing Paving Materials in Suburban Street Schemes - identifying both positive and negative factors.
- To gauge levels of awareness of Concrete Paving and Concrete Block Paving as materials in general and their appeal as Suburban Street Paving in particular.
- To identify levels of consumer satisfaction in respect of Suburban Street Paving Schemes in terms of maintenance standards, aesthetics and practicality.

7.1 Summary of main findings

Two - thirds think the visual appearance of paving makes an important contribution to the local environment. Town centre pavement schemes are held in higher regard than those in residential roads. Solid concrete and black tarmac are least preferred material for suburban schemes. Concrete block paving/small concrete slabs are seen as the most preferred materials for residential paving schemes. Over 80% see a case for increased expenditure to upgrade pavements. Today's pavements are seen as more attractive, better coloured, made from better materials but less well maintained, safe or clean. Overwhelmingly, the majority of people were happy with a recently new town centre-paving scheme. Highest levels of dissatisfaction were with suburban pavements in old scheme.

8. SUMMARY OF CAUSES OF FOOTWAY DAMAGE

The Tables 1,2 and 3 list the defects, causes and remedies to damaged of the paving surfaces.

Table 1. Bituminous footways.

Defects	*Likely causes*	*Remedial work*
Trip or pothole	Action of water and frost	Fill cavity and patch
Fretting or aggregate Loss	Due to binder drying out lack of compaction	Seal surface
Disintegration or crumbling	Binder failure, inadequate tack coat or dirty base course	Resurface
Polishing	Heavy wear at concentrated usage points	Textured slurry seal or overlay
Cracking general	Debonding from base course differential thermal movement	Seal surface, patch as necessary
Crack parallel to kerb	Frost heave, crack left when surface settles	Seal surface
Surface deformation	Vehicle damage, subsidence Upward deformation- roots or weed growth. Inadequate excavation	Local or general reinstatement
Edge spalling or crumbling	Lack of edge restraint weed growth	Provide edge and patch.

Table 2. Rigid footways.

Defects	*Likely causes*	*Remedial work*
Fine cracking	faulty curing at installation	Patch or reconstruct
Trip	Slab settling due to water poor sub base compaction	Relay or reconstruct
Spalling	Surface deterioration and frost action	Possible patch or reconstruct
Cracking	Excess point loads	Reconstruct
Polishing	Heavy wear at concentrated usage points	Possible patch or reconstruct

Table 3. Paved footways.

Defects	*Likely causes*	*Remedial works*
Trips	Water in sub base vehicle over run, frost.	Repair
Broken or cracked flag,	insufficient base, wrong size excess point load, hard spot in bedding, vehicle over run	Replace after base
Polishing	Heavy wear at concentrated usage point	Retexture if necessary
Rocking flags	Badly laid, water in bedding	Relay
Rutting	Heavy wear at concentrated usage points	Repair sub base and relay flags
Surface deformation	Vehicle damage, water in formation, tree roots, weed growth, inadequate reinstatement	Reconstruct, remove weed growth
Joint widening	Lack of edge restraint	Reconstruct

9. STRUCTURAL DESIGN

Many new pedestrian schemes are designed with a paved surface, which has to support both pedestrians and delivery vehicles. In other urban streets, vehicular overrun of pedestrian surfaces has become more common as traffic volume has increased. Photograph 3.

To accommodate these changes, three small element-paving flags were developed:

Type E 450 x 450 x 70mm
Type F 400 x 400 x 65mm
Type G 300 x 300 x 60mm

These British Standard flags are capable of accepting loads imposed by vehicles in the following areas:

- footways with frequent car and occasional commercial vehicle overrun
- pedestrian precincts with up to 25 commercial vehicles per day each way

There are two modes of failure of pavements constructed with small element paving flags. Type G (300 x 300 x 60mm) flags can fail due to the subgrade becoming overstressed. Type E (450 x 450 x 70mm) and Type F (400 x 400 x 65mm) flags, can fail due to increased concrete stress (i.e. flag strength) is the critical factor.

9.1 Method

This design method evaluates the thickness and type of sub-base or roadbase to be used beneath paving flags to ensure that the allowable stresses in the paving flag and subgrade are not exceeded, and the pavement remains serviceable, without major reconstruction during its design life. The design proceeds as follows:

9.1.1 Establish the CBR of the subgrade

Where any doubt exists the lower of the CBR values should be assumed. If the site investigation was undertaken during a dry period, due allowance for a substantial reduction in CBR during wetter periods must be made.

9.1.2 Assess the total number of commercial vehicles
Vehicles having an unladen weight exceeding 1.5t, to be carried during the design life of the pavement. In the absence of more reliable information, an estimate may be made based on Table 4.

Table 4. Number of commercial vehicles.

Location	Commercial vehicles per day
Residential areas	1
Small shopping areas	5
Large shopping areas	10
Precincts and pedestrian areas	More than 20

From knowledge of the mix of commercial vehicles using the pavement an estimate of the number of standard axles per day can be obtained from the conversion factors in Table 5.

Table 5. Conversion factors.

Vehicle type	Conversion factor
2 axle rigid	0.34
3 axle rigid	1.7
4 axles	2.6

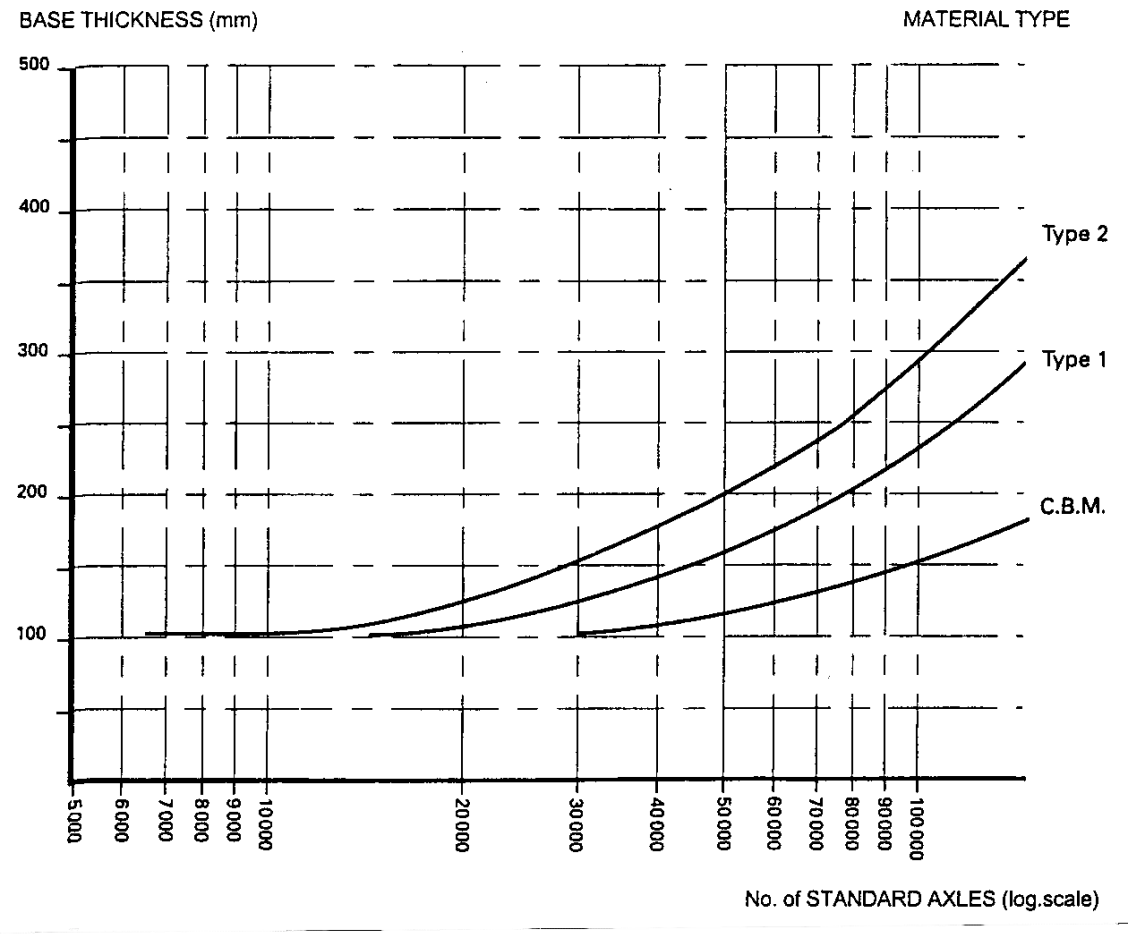
A conservative assumption of the type and number of heavy goods vehicles for a typical pavement is that one repetition of a HGV is equal to one standard axle. The design life for flag pavements is normally a minimum of 20 years. The number of standard axles using the pavement in its design life can be obtained by multiplying the number of standard axles per day by the required design life.

9.1.3 Determine the sub-base or roadbase thickness
Two thicknesses must be determined - one to prevent the paving flag cracking, and two to prevent overstressing the subgrade. The thicker of the two values is adopted to avoid premature pavement failure.

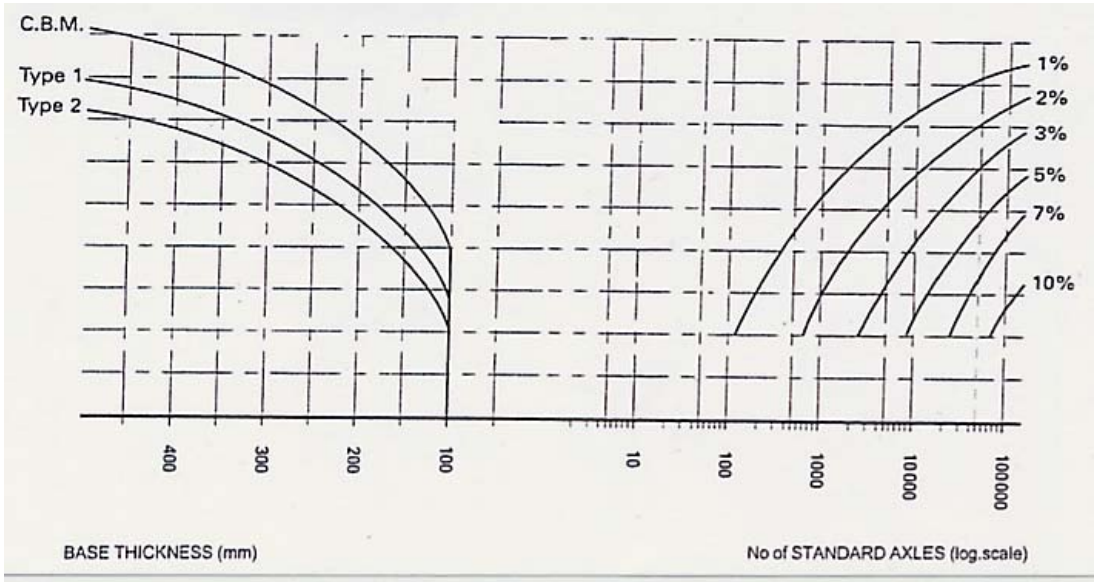
The procedure is as follows: -
- Select the type of flag to be employed: - Type E , Type F or Type G.
- Select which of the three types of recommended sub-base or roadbase is to be used:
  • Type 1, • Type 2 or • CBM (granular material to which cement has been added)

From the number of standard axles evaluated above and the sub-base or roadbase selected, use Graph 1 to obtain the sub-base thickness required to prevent overstressing of the paving flag. Using the number of standard axles evaluated above, the CBR of the subgrade and the sub-base or roadbase selected, use either Graphs 2 for 400 mm x 400 mm and 450 mm x 450 mm flags or Graph 3 for 300 mm x 300 mm flags, to obtain the sub-base thickness required to prevent overstressing the subgrade.

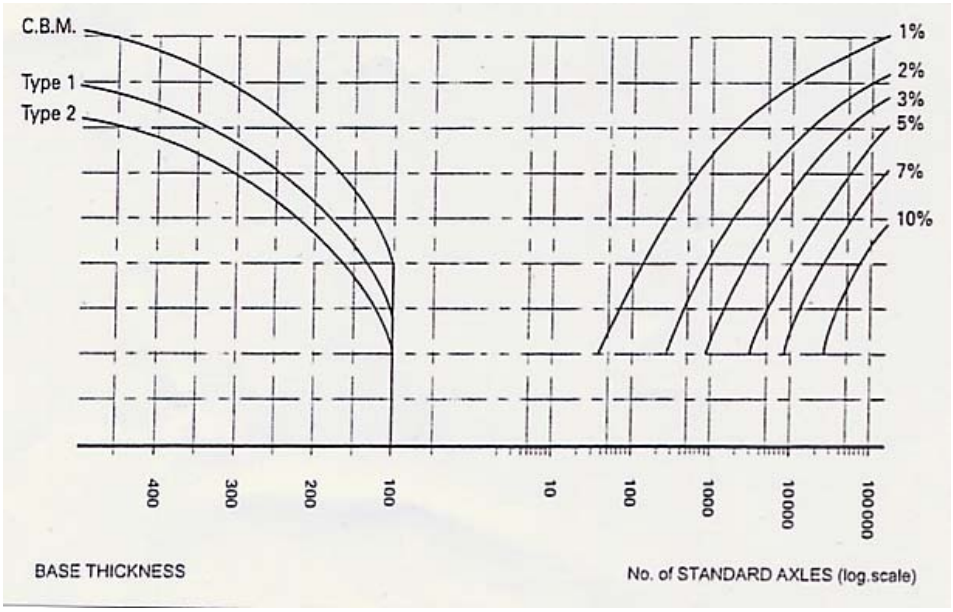
The greater of the two sub-base thickness obtained is adopted as the design thickness. The minimum thickness of any sub-base or roadbase material required is 100mm. When using Type 2 material, care should be taken in the selection, as some Type 2 materials are frost susceptible. Construction complies with the procedures outlined in BS 7533 - Part 4. The laying course sand complies with BS 7533-Part 4, the nominal sand thickness is 25mm with sand moisture content approximately 5% - 7%. The joint widths are between 2 mm and 4mm and are filled with sand complying with BS 7533: Part 4.



Graph 1. Base design for paving flag overstressing.



Graph 2. Base design for subgrade overstressing.
(400 mm x 400 mm and 450 mm x 450 mm paving units)



Graph 3. Base design for subgrade overstressing.
(300 mm x 300 mm only)

9.2 Sand requirements
The sand grading for the laying course sand and the jointing sand are shown in Table 6.

Table 6. Grading limits.

Sieve Size	Bedding Sand % passing	Jointing Sand % passing
10 mm	100	100
5 mm	89 to 100	100
2.36 mm	65 to 100	100
1.18 mm	45 to 100	90 to 100
600 µm	25 to 80	50 to 100
300 µm	5 to 48	15 to 60
150 µm	0 to 15	0 to 15
75 µm	0 to 3	0 to 3

10. CONCLUSIONS

All material when correctly designed and laid, provides a suitable walking surface, whether it is bituminous, insitu concrete or flags. However, from the survey, we know that two thirds of the respondents think the visual appearance of paving makes an important contribution to the local environment. Nearly half the respondents were dissatisfied with suburban pavements. Small element concrete paving and concrete block paving are seen as the most preferred materials for residential schemes. Solid concrete and Black Tarmac are the least preferred materials for suburban schemes and concrete paving flags provide a hard, durable, safe walking surface, compatible with the immediate surrounding areas, enhances the environment, be non slip in wet and dry weather, with minimum of maintenance, that can be easily reinstated.

Almost all of us are pedestrians, even if we own a car. Walking costs nothing and is one of the best forms of exercise. Half the UK population walks for pleasure, while almost half of children walk to school. A quarter of all journeys by foot are to and from shops.

The majority of defects reported by highway authorities are vertical defects in flagged footway (trips), plus potholes and cracked and surface raveling in bituminous footways. There is evidence to suggest that a large proportion of footway surface defects are caused by under design, vehicle overrun or faulty reinstatement of utility work.

Measures that can improve and encourage walking include setting standards for design, construction and quality audits, providing for the needs of people with disabilities, identifying areas where pedestrians should be given priority and to develop strategies for a footway network.

11. REFERENCES

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Biography

Dr Allan J. Dowson began his career in 1956, working for the British Precast Concrete Federation at their laboratories located at the Cement and Concrete Association at Wexham Springs, Stoke Poges. Among the research areas was the developments of waterproof cements, freeze thaw testing, crazing of Cast Stone and the development of the ISAT test method.

After eight years, was appointed as Head of Technical Research and Development with Marshalls PLC, the largest producer of these products in the UK, a position held for 36 years. During this time was responsible for all quality aspects of concrete products, the development of new products including the introduction of concrete block paving and vehicle over-run flags and the technical advice given to all types of customers for the complete range of the company's products. Also, he specialising in concrete block paving and paving flags design, construction and maintenance.

Throughout this period has been involved with several national working parties related to concrete block paving and paving flags. Has been President of the British Precast Concrete Federation, Chairman of Interpave Main committee and Technical committee, National Paving and Kerb Association and a member of Stone Federation Technical Committee, Concrete Society Technical Executive Committee and Chairman of the Joint Concrete and Clay Industry Committee.

Currently a member of B507 Precast Concrete, Stone and Clay Products, Chairman of B507/1 Precast concrete products, Chairman of B507/2 Natural Stone, Secretary to B507/4 Slip/skid group and B507/5 Tactile paving. Responsible for writing standards on concrete block paving, concrete flags and natural stone.

Is a UK expert on European Committees CEN 178 (main committee), CEN 178/WG1 Concrete products, TC 178/WG2 Natural Stone, TC 178/WG4 Slip/Skid Group, and was a member of TC 229/WG3/TG4 Linear Drainage and the European Standards committee for Pigments.

Is the Chairman of TC178/WG5 -Tactile paving committee.

Obtained Doctor of Philosophy Degree at Newcastle by researching construction methods and laying course and jointing sands for use in block paving construction.

In September 2001, he established 'Allan Dowson Consulting' as an organisation to provide a service to producers and users in all aspects of design, construction and maintenance of precast, clay and natural stone pavements. He is also a Consultant to Interpave and a Visiting Industrial Lecturer at the University of Leeds, where he lectures on concrete block paving to MSc students.

Has presented over forty papers at different international conferences, ranging from mix design, construction methods, materials and product standards, pigmentation, development of urban areas, designing for the disabled, bedding sand quality, maintenance to slid skid properties. Also made many company and trade association presentations.