A DESIGN METHOD FOR LIGHTLY TRAFFICKED AND PEDESTRIAN PAVEMENTS

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SUMMARY

In most regions of the world methods have been developed which allow pavements surfaced with paviors to be designed to accommodate loading of all types including highway traffic, industrial plant and aircraft. However, a significant omission has been the lack of design guidance for pavements where either no traffic, very little traffic, or traffic with low axle loading occurs. Pavements subjected to such light loading need careful design and specification since it is usually the case that such pavements are constructed at low cost, with little supervision and using materials which require particularly good workmanship to ensure their stability.

This paper presents a design method which is directed towards lightly trafficked pavements and which provides cost-effective durable solutions in these situations. New concepts are introduced such as the merging of pavement layers and the need for minimum specified traffic levels in the case of relatively few cumulative standard axles contributed by heavy vehicles.

The paper presents design charts which can be used to proportion lightly trafficked pavements and shows how material conversion factors can be used to broaden the scope of pavements to be designed. Examples are presented illustrating the design procedures.

INTRODUCTION

Since 1992 highway pavements in the U.K surfaced with clay or concrete block paviors have been designed in accordance with the recommendations of BS7533:1992 [1]. This gives guidance on the design of pavements trafficked by upto 12 million standard 8000kg axles, (i.e. for quite heavily trafficked roads).

Whilst BS7533 has proved successful in providing a basis for the design of many categories of highway pavements, it has failed to deal with lightly trafficked roads or principally pedestrian areas in a way which permits the achievement of cost effective design solutions. In particular the first loading category in BS7533 of 0 - 0.5 million standard axles (m.s.a), means that pavements subjected to very light trafficking have previously been designed uneconomically to accommodate greater loads than they will be required to sustain during their service life.

Many paved areas are required to withstand less than 1000 cumulative standard axles (c.s.a) during their design lives. Such areas include car parks, private drives, footways and principally pedestrian areas. The Authors consider that a design method is required which categorises low frequency traffic more precisely so as to permit more appropriate design solutions.

In some ways the design of lightly trafficked areas demands more skill and judgement than that required for heavily trafficked pavements. Often they need to cost less and may be expected to receive little or no maintenance throughout their design lives. They may also be built from weaker construction materials, be subjected to reduced levels of supervision during construction and may not be engineered to the same degree as a more heavily trafficked pavement.

The design methods presented in this paper take all of these factors into account and permit cost effective lightly trafficked pavements to be designed.

BEHAVIOUR OF PAVIORS ON LIGHTLY TRAFFICKED ROADS

In the case of heavily trafficked roads, it is common for the pavement construction to include a cement or bitumen bound road base. Traditional flexible pavement design methods have been modified on the basis that the paviors and the bedding sand equivalence with a similar thickness of bituminous material. For example, in BS 7533 the design method follows the U.K flexible pavement design procedure set out in the Transport Research Laboratory publication LR. 1132 [2] with the exception that instead of pavements being surfaced with typically a 100mm thickness of bituminous material they are surfaced with, say, 65mm thick chamfered clay paviors on 35mm of a suitable compacted sand bedding course.

In recent years this equivalence substitution has been found to produce cost effective, durable pavements enabling research to be focused on other issues; such as bedding course sand stability.[3]. However in the case of lightly trafficked pavements, many design solutions will omit a stabilised base such that clay paviors and the associated compacted bedding sand course will be supported by granular highway construction materials such as crushed rock. Some recent research [4] has suggested that in this situation, paviors do not equivalence to the same degree with bituminous materials as they do in pavements with stabilised bases. It has been found that when paviors are laid over granular material, levels of rutting have been measured which are upto two times the values measured in bituminous surfaced pavements in similar circumstances.

The Authors have reviewed the findings of other researchers involved in this field of activity and have concluded as follows. The development of peak transient vertical stresses when rolling 'patch' loads are applied to paviors leads to rapidly changing high levels of stress in the materials directly beneath the paviors. [5]. Where such material is crushed rock, present highway specifications [6] permit less than 100% relative compaction. The Authors have concluded that in such pavements the high levels of rutting measured have resulted from further compaction of the granular material by traffic during the early life of the road. As research and experience have shown that lightly trafficked pavements do perform well when granular material is fully compacted, the Authors consider it is appropriate to use a 1:1 equivalence figure between clay paviors and bituminous material. Therefore, in the sections which follow, the design recommendations are based on the assumption that granular material is compacted to at least 99% of theoretical dry density. This can often be achieved using the method as described in CL.802 of reference [6] but in some cases it may be necessary to specify a heavier roller, more passes of the roller, thinner layer thicknesses or combinations of some or all of these.

The work undertaken by the Authors in relation to the stability of bedding sands [3] has led to sands being categorised principally according to the proportion of material passing the 75 micron sieve and their geological origin. It is recommended that for all the applications covered in this Paper, Category 3 sands or a higher Category (i.e. 1 or 2) should be used except in conditions where channelised flow of vehicular traffic may cause destabilisation of Category 3 sands. In such cases the recommendations given in reference [3] should be followed.

When constructing lightly trafficked pavements, it is imperative that established good practice guidelines for the construction of flexible pavements are followed. These are well documented [7], [8] and proven in practice.

In lightly trafficked pavements where the specification for the roadbase and sub-base is for a similar material (i.e. crushed rock), the design procedure allows for the separate courses to be merged into one combined course for the purposes of construction. In the merged course construction tolerances should be those that would have been applied to the higher of the two separate courses. Construction can then take place in increments which are governed by construction efficiency rather than by design output. For example, the design procedure may generate a 175mm thick base over a 225mm sub-base each comprising Department of Transport (D.O.T) Type 1 granular material [6]. In this case the pavement can be constructed in two layers each with a thickness of 200mm. The maximum thickness usually constructed in a single layer is 225mm but for the reasons explained above in relation to levels of compaction it is recommended that this figure be reduced to 200mm for all pavements where only granular unstabilized materials are used.

DETAILED DESIGN GUIDANCE FOR LIGHTLY TRAFFICKED ROADS

There are two distinct categories of lightly trafficked pavement. The first category comprises those pavements trafficked by relatively few heavy vehicles and the second pavements trafficked by vehicles no heavier than cars. The Authors consider that these two cases should be treated separately and a design chart is therefore presented for each case.

Consider the design of pavements trafficked by cars and similar light vehicles. A simple design procedure is illustrated in Figure 1. This allows the thickness of granular sub-base material to be proportioned according to local ground conditions. In many such pavements it would be impractical to require that engineering tests are undertaken in order to characterise the ground conditions. Therefore a simple ad hoc test is proposed whereby the impression made in the subgrade by someone walking or pressing their heel into the ground can be used as a basis for design. Whilst there are obviously opportunities for error in this approach, it is preferable to either ignoring the ground conditions or specifying detailed engineering tests which would rarely be undertaken. Some U.K researchers have developed similar guidance but have failed to take into consideration subgrade strength at all. It is important that the 'ad hoc' test detailed in Figure 1. is undertaken when the soil is in a similar condition to that which will persist during the design life of the pavement.

Perhaps the most difficult category of pavement to design is that receiving a significant number of commercial vehicles but which nevertheless total less than 1.5 m.s.a during the projected design life. The design chart shown in Figure 2 has been developed for such pavements. It is similar in structure to the design chart for heavily trafficked roads [1] and indeed there is some overlap between the levels of loading considered in BS7533 and those detailed in Figure 2. However whereas the least trafficked category in BS7533 is 'upto 0.5m.s.a', the design method presented in this paper includes the following categories:

Table 1: **Categories of Traffic To Be Used In Lightly Trafficked Pavement Design Method**

Category	Cumulative Number of Standard Axles (c.s.a)
A	Upto 100
B	100 - 1000
C	1000 - 10,000
D	10,000 - 100,000
E	100,000 - 500,000
F	500,000 - 1,000,000

As an example of the use of Figure 2, consider a pedestrian area to be trafficked by three heavy refuse disposal vehicles per week. Assume that the pavement will be constructed over a soil with a California Bearing Ratio (C.B.R) of 7% and that a design life of 15 years is required. Simple multiplication shows that there will be 2340 vehicle passes during the design life. Assuming that each pass of the vehicles applies 2 No. 8000kg standard axles, then the pavement receives a total loading of 4680 standard axles. A feature of the design method is that in cases where the pavement is trafficked by axle loads in excess of 7000kg, the calculated number of standard axles must be increased by a factor of 3. If, even with this factor applied, the cumulative number of standard axles is less than 100,000, then 100,000 standard axles should be used as the basis for the design. The purpose of the two changes detailed above is to ensure that when relatively thin pavements are designed there will be no instances where a single pass of a heavy vehicle causes premature pavement failure.

Based upon the above and in this example the calculated number of standard axles is adjusted to 100,000 giving a design section based on Figure 2 as follows:-

Wearing Surface:	(200 x 100 x 65)mm chamfered clay paviors
Bedding Course:	50mm thickness of bedding course sand [3]
Road Base:	250mm Type 1 granular material
Sub-Base:	200mm Type 1 granular material

As the same material is used for the road base and the sub-base, these two courses could be merged into one course giving the following pavement section:-

Wearing Surface:	(200 x 100 x 65)mm chamfered clay paviors
Bedding Course:	50mm thickness of bedding course sand [3]
Merged Road Base and Sub-Base:	450mm Type 1 granular material

The pavement section determined above could be used as it stands or modified further. Recent research and development in pavement construction materials has indicated, for example, that the incorporation of some categories of 'geogrid' material into the pavement section permits the sub-base thickness to be reduced by 30%. This would give rise to the following section:-

Wearing Surface: (200 x 100 x 65)mm chamfered clay paviors

Bedding Course: 50mm of bedding course sand [3]

Merged Road Base and Sub-Base: 390mm Type 1 granular material

Geogrid: Incorporated immediately beneath the sub-base

Material conversion factors for evaluating highway pavement materials are shown in Table 2.

Table 2.

CATEGORY OF MATERIAL	MATERIAL CONVERSION FACTOR
Cement bound material 1 (CBM1)	2
Cement bound material 2 (CBM2)	2
Cement bound material 3 (CBM3)	3
Cement bound material 4 (CBM4)	3
Pavement quality concrete	4
Dense bitumen macadam	3
Hot rolled asphalt	3.5
Type 2 granular sub-base material	0.7
Subgrade improvement material	0.5

The use of this Table allows materials included in the design process to be exchanged for alternative materials on a weighted basis assuming Type 1 granular material has a value of 1. For example cement bound material 2 (CBM2) has a material conversion factor of 2 which means that the 450mm of Type 1 material selected in the previous example could be replaced by $450 \div 2 = 225$mm of CBM2. Alternatively 300mm of granular sub-base material could be replaced with 150mm CBM2 and the remanding 150mm reduced to 105mm (say 100mm) if a geogrid material is used immediately below the sub-base. This would produce the following section:-

Wearing Surface:	(200 x 100 x 65)mm chamfered clay paviors
Bedding Course:	30mm of bedding course sand [3]
Road Base:	150mm of CBM2
Sub-Base:	100mm of Type 1 granular material
Geogrid:	Incorporated immediately below the sub-base.

In order to assess which of the alternative designs is preferred, a costing exercise would normally be undertaken based on the unit costs of materials and their associated laying costs. Additionally the reduction in excavation depth consequent upon a thinner pavement could prove a significant factor in the cost analysis. The existence of statutory undertakers services close to ground level might also be a factor in the selection of a thinner pavement. In one instance the Authors were involved in the design of a pavement where construction thickness had to be minimised to preserve mediaeval skeletons in an 'historic' English town centre.

CONCLUSIONS

Whereas design procedures for heavy duty pavements have been used successfully for many years, designers have frequently been using inappropriate design procedures for lightly trafficked pavements. This paper presents design methods to cope with the design of these pavements. There are essentially two categories of lightly trafficked pavement viz pavements trafficked by motor cars and vehicles of similar weight and pavements trafficked infrequently by heavy commercial vehicles. These two categories of pavement require an entirely different design approach and this paper has developed and demonstrated two appropriate design methods. In the former case, design is simplified such that the only testing required can be undertaken by a layman. For the more heavily trafficked pavements it is necessary to make an assessment of the C.B.R value of the subgrade and the cumulative number of standard axles likely to be imposed on the pavement during the design life.

In the case of the lightly trafficked design method to accommodate heavy commercial vehicles, material conversion factors permit a wide range of design solutions to be compared and evaluated so that a 'least cost' pavement can be specified.

It is concluded that the design methods presented in this paper fulfill an important function in dealing with an area of design which hitherto could only be addressed by the application of inappropriate design methods.

REFERENCES

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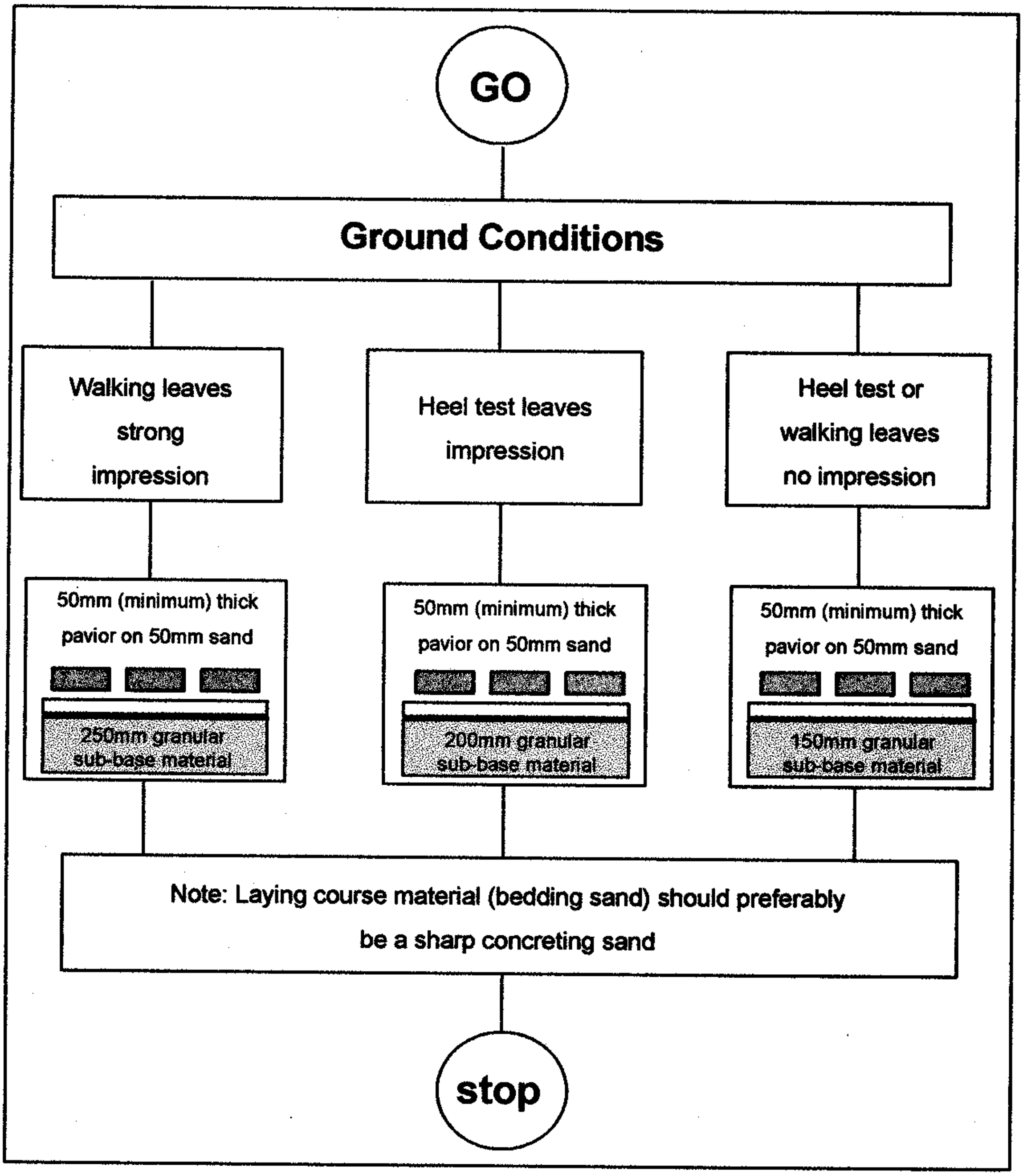

Figure 1 : Untrafficked Footways and Driveways for car traffic only

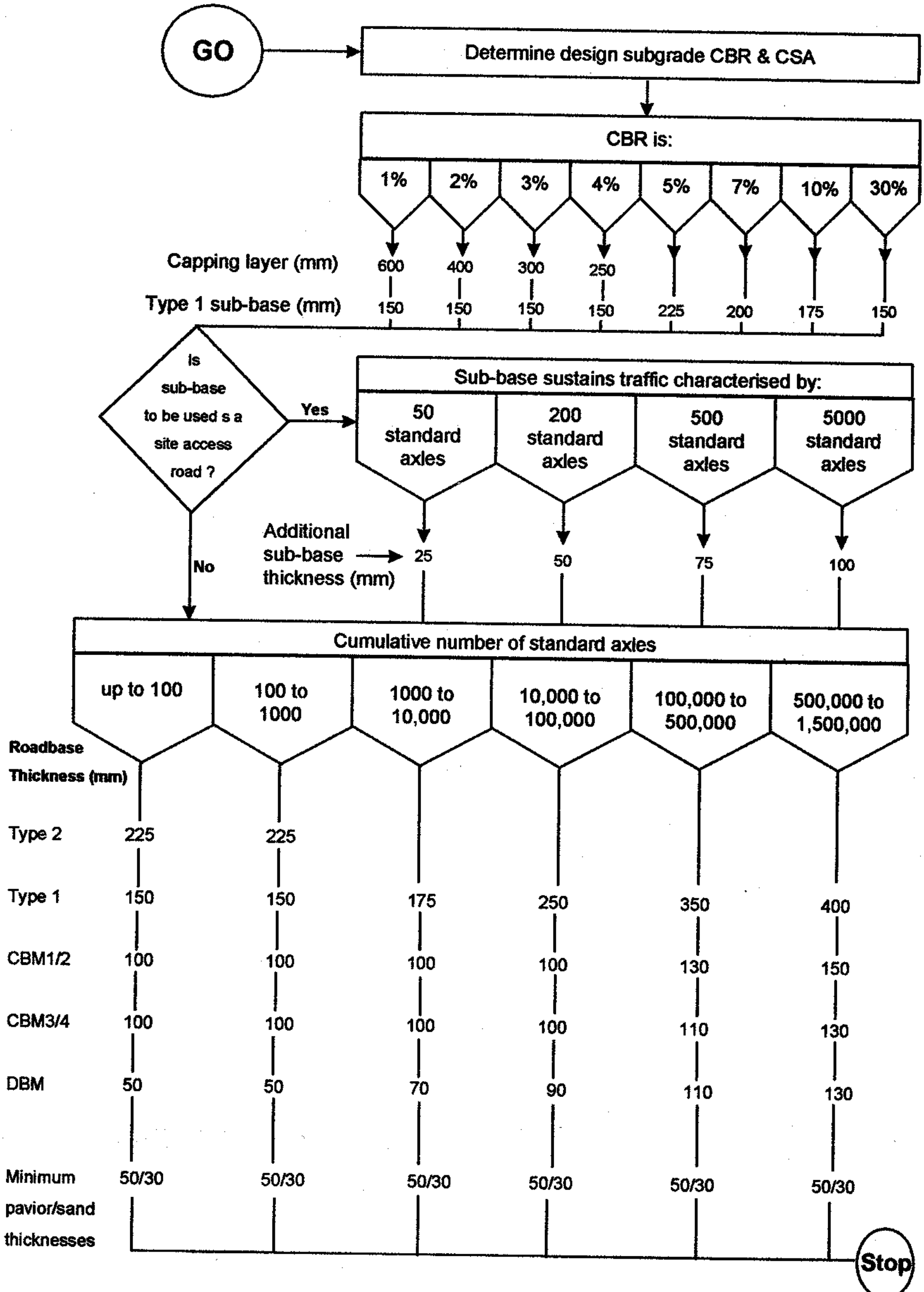

Figure 2 : Design chart for lightly trafficked pavements