INTERLOCKING CONCRETE ROAD PAVEMENTS - UPDATED DESIGN AND CONSTRUCTION INFORMATION - AUGUST 1986

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ABSTRACT

This paper summarises the steps taken to update the design and construction guides for interlocking concrete paving produced by the Cement and Concrete Association of Australia. Since the previous guides were published in 1982, information has become available from the Australian Road Research Board and other industry-sponsored studies. Also, much practical experience has been gained by the industry over the last few years. Computer-aided design methods have been developed and generally the use of mechanistic design procedures utilising elastic layer pavement models has become more widespread. The changes to the guides are discussed, particularly with respect to traffic estimation, design CBR, the quality of base and sub-base materials, construction tolerances - including the thickness of the bedding sand layer, and the use of cement-bound materials. A design flowchart is included to indicate the key steps and sequence in the design procedure. It is stressed that the guides are not specifications and that advice should also be sought as required and engineering judgement should still be exercised in the design and construction processes.

THE NEED FOR NEW DOCUMENTATION

Interlocking concrete paving has now been in use in road pavements in Australia for a decade. Concurrently with an extensive research and development program in Australia and Soutth Africa between 1977-1981, two interim guide documents were produced in the middle of 1980: Technical Note 34 'Design' and Technical Note 35 'Construction Specification'. These were updated with minor amendments in 1982 by Technical Notes TN40 and TN41 dealing with the same respective topics. Interlocking paving is still a relatively new technology in the pavement world. Since 1982, many developments have occurred of direct interest and relevance to interlocking paving. Some of these include:

(a) information from ARRB Project 363 - Concrete Block Pavements (see Sharp and Armstrong 1985);

(b) the development of computer-aided design methods and the general emergence of mechanistic design procedures utilising elastic layer pavement models;

(c) the need to emphasise the use of good-quality materials in the construction of the basecourse layer;

(d) the performance benefits which are likely to accrue from the use of cement-bound basecourses; and

(e) research by ARRB (Project 392 - Design and Maintenance of Residential Street Pavements) into many general aspects of the design of residential-type street pavements which are of direct application to interlocking concrete paving (e.g. see Mulholland, Schofield and Armstrong 1986).

Even in more established pavement types such as flexible pavements, NAASRA, for example, has recently engaged in two major rewrites of design information commencing in 1979. Interlocking concrete paving is therefore not alone in undergoing regular updating.

On the construction scene, many interesting developments have occurred since 1982 in areas such as the control of the thickness and preparation of the sand bedding layer and the introduction of heavy duty plate compactors which together have caused a re-evaluation of some previously held beliefs, and various techniques for mechanical laying of the paving units. It is appropriate that documentation issued by the Cement and Concrete Association of Australia (CACA) for the guidance of users and constructors of interlocking concrete paving should keep as up-to-date as possible and provide for future implementation of these recent developments.

UNDERLYING PRINCIPLES AND DOCUMENTATION FORMAT

In addition to generally improving the design methodology, the progressive feedback of information from those involved in the practice of designing and building these pavements, has given rise to the need to reinforce some of the important general principles which affect the success or otherwise of these pavements, and to emphasise them in information documentation. These key principles can be summarised as follows.

(a) Pavement thickness design, materials and construction procedures need to be integrated and not evaluated or approached as independent factors.

(b) The performance of the pavement will only be as good as the suitability of the thickness, materials and construction practice employed.

(c) The surface of the interlocking concrete paving units will not compensate for deficiencies in what lies beneath - the premise that "she'll be right, mate" most certainly does not apply.

(d) Drainage is as important to these pavements as it is to all pavements. There is nothing different about interlocking concrete pavements in this regard.

The documentation approach adopted for the updated publications includes the following three principles.

(a) The text provides detailed information and guidance based on the best available information and lessons learned from experience. However, they are not intended to serve as a 'standard' or a 'specification' and it is inappropriate to refer to them as such. They are a guide to good practice which needs to be assessed and adapted to each project.

(b) Due to the range of climatic and particularly soil conditions in Australia, the documentation provides, where appropriate, a range of design options. The options need to be evaluated based on local conditions and experience and the judgement of engineers involved with the pavement.

(c) Where appropriate, users of the information are advised to consult those masonry manufacturers who are members of the Concrete Masonry Association of Australia (CMAA) regarding the design and construction of pavements incorporating specific products. This will hopefully provide greater input and liaison by these manufacturers at the inceptiion of a project to 'design out' and avoid some of the site problems that might ottherwise occur.

THE PUBLICATIONS

Two new publications have been issued:

(a) Interlocking Concrete Road Pavements - A Guide to Design and Construction (T35): a combined guide for design, materials selection and construction planning/practice of about 20 pages in length.

(b) Guide Specification for Construction of Interlocking Concrete Road Pavements (TN56): a guide construction specification in the established model clause/commentary format or six to eight pages in length.

It should be noted that the publications are intended for, but limited to, pavements subjected to trafficking by road vehicles. Separate information in the form of computer software is being developed by others for pavements to be used for industrial vehicles.

PAVEMENT STRUCTURE

The term 'surface' has been introduced to collectively include the concrete paving units, bedding and jointing sand, and edge restraints. A key difference in new pavement nomenclature is that the layer previously designated 'sub-base' is now designated 'basecourse' to introduce conformity between the name of the layer and the material quality to be used in its construction. This needs to be of a suitably high standard. This derives directly from the recommendations arising out of ARRB Project 363.

A sub-base/working platform layer is introduced to provide some design options for low-strength subgrade soils where conventional techniques may no longer be economical or feasible in achieving a firm, stable platform on which to construct the pavement.

DESIGN PROCEDURE

The design procedure is divided into five steps: traffic estimation; surface design; subgrade investigation; basecourse design; and design for low-CBR soils. A design flowchart is included in the documentation to indicate the key steps and sequence in the design procedure.

TRAFFIC ESTIMATION

Traffic is to be estimated in terms of the number of commercial vehicles exceeding 3 t gross. To account for the distribution of vehicles and loads, the measured distribution of actual traffic into different axle groups, and within each axle group the distribution of actual loads which is likely to have a significant impact on the new NAASRA Guide to Pavement Design, is adopted. This traffic distribution leads to the direct application of computer-aided design methods which do not mind the complex repetitive calculations required - a procedure which would in all probability be unacceptable to manual methods of design.

The document makes no actual recommendations as to design traffic loads for particular road types, or even the design period over which the traffic is estimated. These are matters for the designer.

Reference is made to NAASRA documents and recent ARRB research into traffic in residential streets to assist designers in preparing traffic estimates. In the absence of any local traffic data, designers are referred to the street hierarchy used by local government in N.S.W. as a preliminary estimating tool only (e.g. Local Government and Shires Association of N.S.W. 1982). This procedure also eliminates the cause for some critical comment on the traffic classifications in earlier documents, which invariably arose because users of the information read only the traffic data and not the accompanying text notes and limitations on their usage.

Reference is also made to the high early intensity of building traffic which can occur in narrow residential streets and their effect on design as a result of ARRB research into general aspects of residential street pavement design (e.g. see Schofield 1985).

The traffic axis on the design chart is for the design lane only, not necessarily for the whole carriageway or formation.

SURFACE DESIGN

There is no significant change from the previous documents. The document includes a reference to the Shape X paving unit classification which covers the development and introduction of paving units with special interlocking characteristics, particularly those specially designed to facilitate mechanised laying but which do not conform to present shape classifications. In relation to thickness design, little information is currently available and the designer is referred to CMAA members for advise on these particular units, whilst providing no specific recommendations in the new document.

SUBGRADE INVESTIGATION

Experience has confirmed the need for the use of a soaked subgarde CBR as the appropriate papameter for thickness design purposes. As to methods and procedures, designers are referred to the design manuals published by the State Road Authorities for advice relevant to regional considerations. This is a key design decision and should be taken by a suitably qualified and experienced engineer.

BASECOURSE THICKNESS DESIGN

Subject to modification for aspects peculiar to residential street design, the basis for basecourse design thickness is the computer-aided design

procedure, which is dealt with elsewhere in this Workshop (Shackel 1986). The computer-aided approach is simply a more up-to-date and powerful design tool than the previous simple rut depth-based procedure. The software includes the particular performance characteristics of concrete paving units. The software enables the plotting of accurate ball-park basecourse thickness for all traffic loads. These thicknesses have been modified to take into account some of the particular aspects of residential streets as reported in ARRB Project 392 (e.g. see Mulholland et al. 1986).

Due to some peculiarities of residential streets, e.g. double trafficking, early intensity of traffic, and the unavailability of the full elastic modulus of the paving units shortly after construction, the minimum recommended compacted thicknesses are constant below design traffic loads of 10,000 commercial vehicles (a factor in common with the results of previous ARRB research not connected with interlocking paving). Accordingly, the design charts are considered adaptions of results from the computer software - not direct plotting of the results.

Correction factors are provided for car-park pavement design for either cars or commercial vehicles. This avoids the need to develop separate charts for this application.

The design charts provide for an absolute minimum basecourse thickness of 100 mm. Design charts are provided for either unbound or cement-bound basecourses only. The charts are set out in the NAASRA format to encourage similarity to design procedures for other types of pavement (see the Appendix).

It should be noted that, due to the different failure modes (rutting for unbound material, flexural cracking for cement-bound materials) and fatigue criteria applicable to either unbound or cement-bound materials combined with the modification for residential streets as already outlined, the cement-bound basecourses are not always thinner than the unbound basecourses. This generally applies to lightly-trafficked pavements where the minimum cement-bound thickness to provide fatigue resistance under a mixture of commercial vehicle loads is slightly thicker than the thickness required to meet unbound rutting-controlled criteria. As traffic loads increase and subgrade values are low, the thickness of a cement-bound basecourse becomes lower than that of an unbound (or cement-modified) material.

Should the designer wish to evaluate multi-layered basecourses using different materials or parameter values different to those assumed and nominated in the document, then the designer can utilise the computer software so that designs can be tailored to suit specific requirements or otherwise rapidly evaluate the thickness and costs of a range of candidate solutions.

DESIGN FOR LOW-STRENGTH SOILS

Specific design options are provided for low-strength soils, not for any reason directly associated with interlocking paving, but because some soils present real problems in achieving, in a reasonable time and at a reasonable cost, a firm layer on which to build the pavement. Without a firm, stable subgrade no pavement is likely to perform successfully. The design chart is endorsed accordingly.

For the purpose of these documents (individual engineers may have differing opinions) a low-strength soil is defined as one having a soaked CBR value of less than 4 per cent. Included is a 'do-nothing' solution if the engineer believes he can compact the subgrade by normal means; but this becomes his decision and he cannot fall back on the document if he is proven wrong.

Chemical subgrade stabilisation by lime, lime/flyash or lime/cement, including minimum suitable depths, is included as an option. Where a working platform is required, but where rollers are not suitable due to the condition of the soil, options including the use of lean-mix concrete or geotextiles are given. With the exception of geotextiles, for which little quantitative design data are available, adjusted design subgrade CBR values are suggested.

The choice of option, if any, is clearly spelled out as a matter for decision by the engineer based on his own experience and conditions prevailing at the site. This further underlines the role of the document as a guide rather than as a standard or specification, and the need for and benefits to future pavement performance arising from thorough subgrade investigation during the design phase.

It is axiomatic that the performance of any pavement, including interlocking concrete pavements, will be directly influenced by the quality

of materials used in their construction. A significant, and separate, section of the document is devoted to materials. The paving unit specification complies with the requirements of the new manufacturing specifications issued by CMAA and discussed in this Workshop (Rourke 1986). The requirements for the bedding sand are unchanges from the previous documents. The requirements of the joint-filling sand have been expanded to included a grading envelope, to point out that different sands are likely to be required for bedding and filling, and the benefits of including a small amount of clay or silt fines in the filling sand in realtion to early life pavement permeability and performance.

Considerable detail is provided on basecourse materials, including quality, grading envelope and individual layer control. In terms of current road pavement terminology, the emphasis is on the use of 'basecourse quality' material. This new emphasis is one of the direct results of work conducted under ARRB Project 363.

Three types of materials are included:

(a) unbound fine crushed rock or basecourse-quality gravel;

(b) cement-modified unbound material where locally-available material may be slightly deficient in quality - usually plasticity; and

(c) cement-bound material based on good quality untreated material with sufficient cement to achieve a 7-day unconfined compressive strength of 3.5 MPa.

As the intention of the cement-modified material is not to achieve any particular strength or significant strength, but to make usable at a reasonable cost locally-available materials, no reduction in thickness is recommended for this type of basecourse material. In this sense the performance objectives and differences between cement-modified and cement-bound materials need to be clearly understood.

The overall performance of an interlocking concrete pavement would be expected to be improved by the specification of a cement-bound basecourse, particularly with regard to basecourse moisture susceptibility under wet subgrade soil conditions and long-term surface deformation. However, the new documentation points out that the decision as to what basecourse material to specify should be based on a combination of costs of alternatives based on relative thickness, local materials availability (and related costs) and a performance/cost comparison.

In noting that some leeway is provided in the quality of untreated material for the cement-bound basecourses, it does not necessarily follow that where the cement-bound basecourse is thicker than an unbound basecourse then it will be significantly more expensive.

CONSTRUCTION PRACTICE

There are many aspects of planning and execution of the construction of these pavements which are different to other pavements. They are not complex but need to be understood and implemented to ensure good results.

A section on general construction practice, planning and co-ordination is included in the main document in an attempt to encourage those involves with these pavements to include construction planning as part of the pavement sytem, particularly the prepositioning and placement of materials relative to the laying face and the actual development of the laying face. The progress and economy of some projects has been adversely affected by the failure to realise the necessity of minimising the transfer distance from the placed pallets of paving units to the laying face and to maintain an adequate supply at the laying face.

This section of the major document draws attention to current developments of complete paving systems involving mechanised screeding or paving of the bedding sand and the use of heavy duty road pavements. There needs to be flexibility in approaching construction methods, because the types of practices expounded even a few years ago are being supplemented and improved by new procedures. There is no longer one unique construction procedure suited to all types of interlocking concrete pavements.

GUIDE CONSTRUCTION SPECIFICATION

Much more emphasis is placed in the new guide specification on the fact that it is a guide only, and should not be used as a contract document. The model clauses and commentaries which make up the guide specification should be assessed and adapted as individual projects dictate.

New sections are included to cover the construction of the options provided for a working platform/sub-base for low-strength soils to complement the design document. Subgrade and basecourse tolerances have been revised to provide some acknowledgement of difficulties often encountered in accurately trimming subgrades, whilst ensuring that the basecourse thickness actually constructed is at least that specified. The subgrade should be trimmed to avoid ponding and be within +0, -50 mm of nominated levels. The basecourse should be trimmed to within -0, +10 mm of nominated levels.

In order to foster good service performance of these pavements, it is important that the basecourse be in proper firm condition when the units are laid. As responsibility for the contract may be split between the basecourse contractor and the pavior, a new note (rather than a model clause) is included in an attempt to ensure that a separate inspection and proof testing of the basecourse is undertaken before the paving units are laid, particularly when there is a reasonable time gap between the two operations.

One of the areas of subtle but significant change relates to the compacted depth of the sand bedding. Much field practice has confirmed that the compacted bedding thickness should be as thin as possible, preferably 20 mm. In the past, a thickness range of 20-40 mm was nominated as suitable to take into account field conditions. With more attention and emphasis on accurate basecourse trimming, and the development and use of longitudinal metal screed-rails, or the use of asphalt-type pavers, the recommended compacted thickness is now reduced to 20-25 mm. This reduced thickness will largely offset concern about precompaction and acknowledges the reality that with equipment on site, keeping either wheels or foot traffic out of the bedding sand, while desirable, will not always be feasible. With, say, 40-45 mm of loose sand these concerns would have some basis, but with 20-25 mm most problems are removed. The ban on using bedding sand as filler to correct localised basecourse low-spots remains. The effect of the reduced recommended bedding sand thickness will require, perhaps, more attention to basecourse preparation, but if this is so, that will be a positive move in the interests of the pavement in the final analysis.

In turn, the revised bedding sand recommendation will probably impose closer co-ordination of subsequent joint-filling operations, because the movement of bedding sand upwards into the pavement joints may be limited.

With the advent of the heavy-duty plate compactors, which can be up to three times as heavy as the normal plate compector, there is now a need to have some flexibility in construction specifications such that on small or light-duty projects specifiers do not rule out the normal plate compector. However, there is no doubt that as experience with the heavy-duty compactors spreads and their improved performance and efficiency is realised, there will probably be a greater move towards their general use, particularly on major or heavy-duty road pavements.

Another area which is outlined in both documents is the need to select the start line for paving to achieve the preferred orientation of rows of paving units when completed, the actual commencement of paving, and the development of the laying face to facilite accurate and quick laying. The use of stringlines to control laying bond within the pavement and when working near and around pits, etc. is a simple yet effective technique deserving of more mention when the general technology of laying segmental paving is discussed. A tolerance clause has been introduced to progressively check the accuracy of laying with a view to encouraging the use of stringlines or similar devices during the day, rather than waiting until the end of the day to discover faults in laying and the need for more time-consuming corrective action.

LIMITATIONS OF DOCUMENTS

It should be noted that these documents are related to the design and construction of pavements for road vehicles. The documentation is based on the performance under research and field conditions of pavements incorporating specific shapes and laying patterns of concrete segmental paving units and the accuracy in dimensional tolerance available in these products. A small uniform sand-filled joint is essential. Accordingly, the use of a surfacing consisting of tightly-butted units of indifferent dimensional accuracy is unlikely to lead to good performance. The use of these documents in relation to other than concrete segmental paving units is therefore inadvisable. There is some applicability to industrial pavements; however, the documents are not intended for general use on industrial pavements and separate advice should be obtained.

FUTURE DEVELOPMENTS

The new documentation represents the first major update of technical information on this subject in the ten years of experience in Australia. Much has been learned and there is little doubt that much more will be learned in due course. Given the rapid development that has occurred over the last three or so years and the variety of construction and detailing techniques now being employed, it is considered that if the currency and applicability of the information remains relevant for the remainder of the 1980s, then it would have achieved its objective.

The Cement and Concrete Association of Australia will continue to monitor progress on this subject and provide further information where relevant and appropriate.

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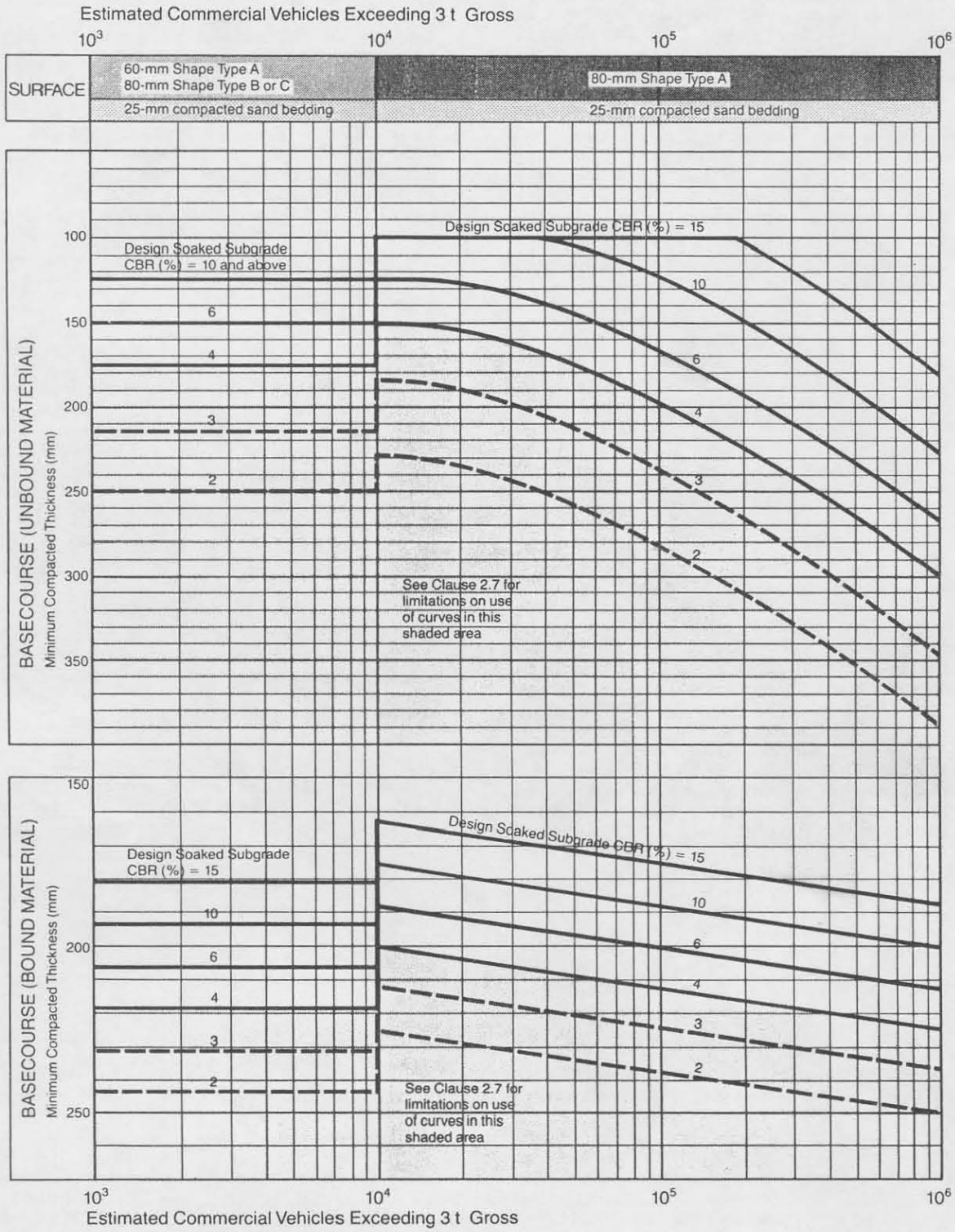
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APPENDIX

BASECOURSE THICKNESS DESIGN GUIDE FOR INTERLOCKING CONCRETE ROAD PAVEMENTS



NOTES ON USE OF DESIGN CHARTS

1 For parking areas designated for use by family cars and station-wagons only, basecourse thickness indicated for traffic loads below 10^4 commercial vehicles may be reduced by up to 50 mm, subject to an absolute minimum of 100 mm for unbound material or 125 mm for cement-bound material

2 For those parts of parking areas which serve as access driveways, loading docks & other areas regularly used by commercial vehicles exceeding 3t, the basecourse thickness should be appropriate for the estimated traffic loads

3 For pedestrian-mall pavements expected to be subject to occasional construction traffic or heavy service vehicles, the basecourse thickness should not be less than that for traffic loads up to 10^4 commercial vehicles

4 Basecourse thickness may be reduced by 20 mm where 80-mm Shape Type A paving units, laid in herringbone bond only, are selected for a pavement subject to traffic loads up to 10^4 commercial vehicles