CONCRETE BLOCK PAVEMENTS IN ISRAEL - STATE OF THE ART

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ABSTRACT

Concrete block pavers were first manufactured in Israel in 1975. Since then, production has increased rapidly to a total area of about 10 million square metres, half of this in the last three years. This rapid growth necessitated the development of a design method suited to local conditions. This paper reviews the progress in the development of an interim design procedure, which was a modification of an existing flexible pavement design method, using the concept of materials equivalencies. Lack of time and financial resources meant that the procedure had to be derived without experimental investigation and validation. However, the interim designs were compared with overseas designs and found to be suitably conservative. Proposals for future investigation and/or validation of the interim design method are outlined.

GENERAL INFORMATION

The use of concrete block pavements in Israel is relatively new. Industrial moulds for manufacturing the concrete blocks were first brought to the country in 1975. The first large-scale paving project - 5000 square metres of the Tel Aviv beach promenade - was constructed a year later. Since then, the process of production and construction has grown rapidly to a total area of about 10 million square metres, half of it within the last three years.

The special uses of concrete block paving and its distribution are as follows.

(a) walkways, sidewalks, roads, urban streets - 70%;

(b) sport, recreation, parks - 12%;

(c) industry, airports, military facilities - 8%;

(d) general developments - housing complexes, public facilities and miscellaneous - 10%.

DESIGN GENERAL BACKGROUND

The rapid growth of concrete block pavements in Israel in the last three years has raised the need for developing a design method for this type of pavement suited to local conditions. This need was shared both by designers who were not acquainted with concrete block pavements (CBP), and by block manufacturers who have been trying to compete with more 'conventional' types of pavements mainly the bituminous concrete pavement.

In this respect, the current situation in Israel resembles past situations in other countries (e.g. Britain and Australia in the late 1970s; Holland in the early 1980s), in such a way that the production and use of blocks are well ahead of the design-method-development stage. This part of the paper briefly reviews the interim design procedure which has been developed at the Transportation Research Institute of the Technion - Israel Institute of Technology.

INTERIM DESIGN PROCEDURE DEVELOPMENT BASIC CONSIDERATIONS

A thorough review of existing CBP design methods, presented at the First and Second International Conferences on Concrete Block Paving, revealed considerable differences in pavement structures yielded by these methods with regard to layer thicknesses as well as material properties (Livneh, Ishai and Nesichi 1985). These differences excluded the possibility of a direct adoption of any of these methods for Israeli conditions.

However, as a result of the pressing need for a local design method, it was decided that its development would follow the same lines that had been previously adopted by other researchers and organisations (e.g. U.S. Army Corps of Engineers (COE) (Rollings 1984), the U.K. Cement and Concrete Association (Lilley and Walker 1978); and in Japan (Miura, Takaura and Tsuda 1984)). These organisations developed their design procedures by relying on well-established flexible pavement design methods, and by modifying these methods for CBP's through the use of some form of layer equivalency. However, since no time was available for laboratory or field studies, the need for a very conservative design method was dictated.

The flexible pavement design method which was modified for use in CBP design was the current Israel Public Works Department (PWD) design method for inter-urban highways (Nedavia 1969). The layer equivalency values used for the modification were derived as a result of a comprehensive literature review (Livneh et al. 1985). The development of the design procedure and the method's main features are described in more detail in the following section of the paper.

REVIEW OF THE DESIGN METHOD DEVELOPMENT AND ITS MAIN FEATURES

The Israel PWD flexible pavement design method has been developed as a synthesis of the Peltier formula for flexible pavement design thickness of an earlier version of Road Note 29 (TRRL 1970) and of local experience with pavement materials (Nedavia 1969).

A pavement structure is determined readily by using design charts (e.g. Fig. 1), where the only input parameters needed are the design subgrade CBR value and the traffic category. Five traffic categories, varying from light (up to 150 commercial vehicles (CV) per day) to very heavy (up to 15,000 CV per day) were recognised within the method.

Recent analyses (Livneh et al. 1985) have shown that the method yields very conservative designs compared with the current COE CBR design method (U.S. Department of the Army 1980). This conservatism was in line with the pre-determined aim of achieving conservative designs for CBP as well.

Layer equivalency values which enable the replacement of the PWD flexible pavement component layers (bituminous concrete, granular base and sub-base) by equivalent layers of the CBP (blocks and bedding sand) were derived from a comprehensive literature survey (Livneh et al. 1985) . In this survey, an attempt was made to gather all the information regarding specific layer equivalency values as given by Shackel (1979), Knapton (1984), Miura et al. (1984), etc*. However, layer equivalencies were also calculated by comparing flexible and concrete block pavement structures designed for similar input conditions by various organisations who had developed design methods for both pavement types. For example, comparisons were carried out on flexible versus CBP structures designed both by the COE relevant design methods (Rollings 1984; U.S. Department of the Army 1980); by the NITRR methods (Clifford 1984; NITRR 1980); etc.

Based on the above-mentioned survey and comparisons, the following layer equivalency values were adopted:

concrete blocks/bituminous concrete - 1.5 (1.45 for heavy industrial loading;

concrete blocks/granular base - 2.3 (2.0 for heavy industrial loading; and

sand bedding/granular base - 0.5.

These layer equivalencies were superimposed on the PWD flexible pavement design charts, and design charts for CBPs thus developed. A typical example is shown in Fig. 2, which was derived from the flexible pavement design chart in Fig. 1.

Equivalent components of the CBP and the flexible pavement, derived through the use of layer equivalencies, are compared in Table 1. This comparison leads to the following inferences.

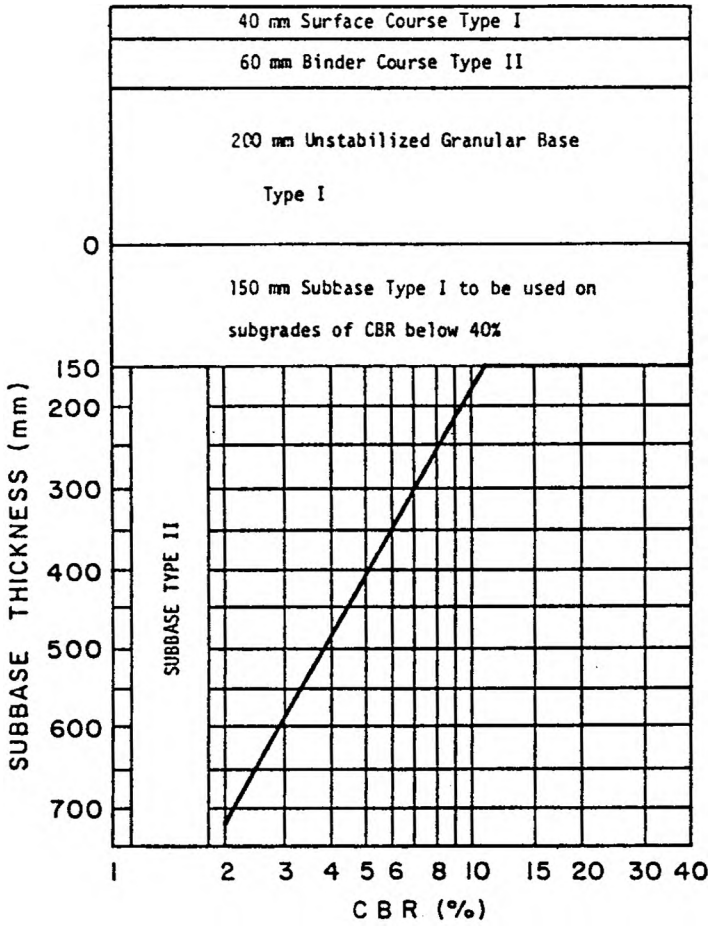

Fig. 1 - Flexible pavement design chart for very heavy traffic category (more than 4500 CV per day) - Israel PWD design method (Nedavia 1969)

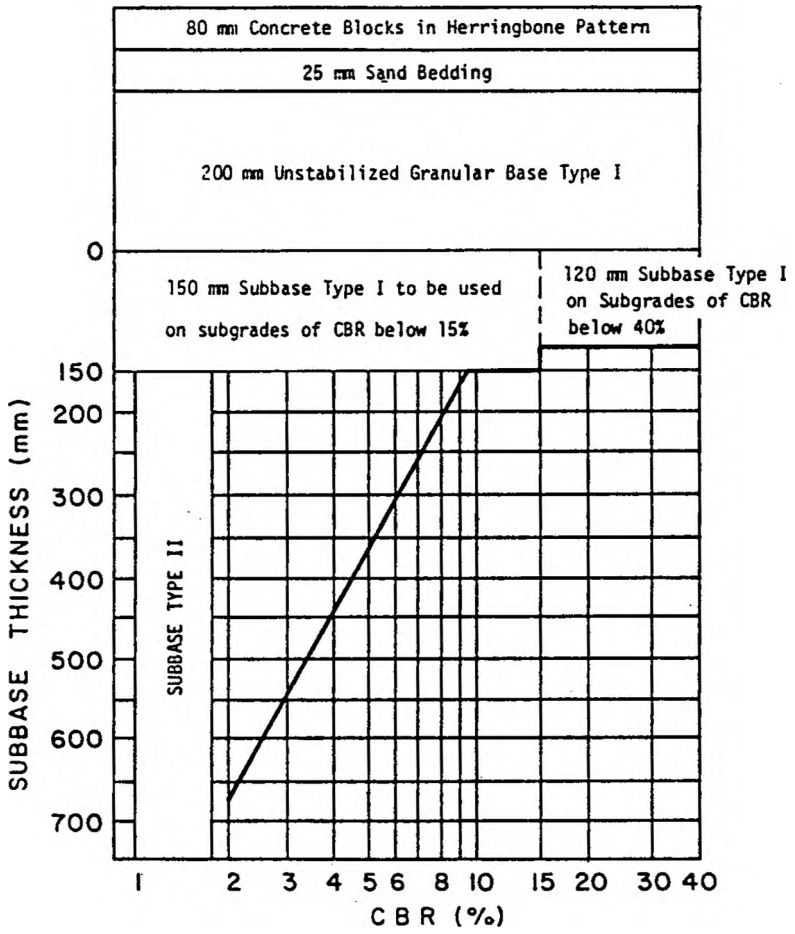

Fig. 2 - Concrete blocks pavement design chart for very heavy traffic category (more than 4500 CV per day)

TABLE 1

CONCRETE BLOCKS AND SAND BEDDING LAYER THICKNESSES: EQUIVALENCY TO FLEXIBLE PAVEMENT LAYERS

Traffic Category (CV/day)	Concrete Blocks & Sand Bedding Layer Thickness (mm)	Equivalent Flexible Pavement Layer Thickness (mm)
light (15-150)		BC: 50 GL: 120 Total: 170
light-moderate (150-450)		BC: 50 GL: 120 Total: 170
moderate-heavy (450-1500)	Cone. Block: 80 Sand Bedding: 25 Total: 105	BC: 80 GL: 70 Total: 150
heavy (1500-4500)		BC: 80 GL: 70 Total: 150
very heavy (> 4500)		BC: 100 GL: 40 Total: 140

(a) Generally, the layer equivalencies adopted yield designs close to the U.S. COE method - the concrete blocks and sand bedding are equal to the upper 140-170 mm (depending on the traffic category) of the flexible pavement, compared to 165 mm used in the development of the U.S. COE method.

(b) The Israeli method seems to be better suited to the local conditions since, unlike the COE flexible pavement design method, the quality requirements of the flexible pavement layers are reduced for the lower traffic categories (Nedavia 1969). Therefore, it is logical that the same CBP components may replace greater thicknesses of poorer materials.

The interim design method was further extended to traffic categories which are not dealt with in the current PWD flexible pavement design method: very light (10-15 CV per day), which are equivalent to 0-7 x 10 standard axles on the one hand, to heavy and extra-heavy industrial loads (up to 2 x 10 standard axles) on the other. This extension was carried out first by extrapolating the PWD designs for these categories, and then applying layer equivalencies in the same procedure described above. Further details are given in Livneh et al. (1985).

Other important features of the design method are as follows.

(a) Block thicknesses of 60, 80 and 100 mm are recommended for very light traffic, normal traffic, and heavy industrial loading respectively. No specific block shape is recommended following recent findings that block thickness has a much greater influence on performance than block shape (e.g. Rollings 1984; Sharp and Armstrong 1985). However, a herringbone laying pattern is a must in all traffic categories.

(b) Jointing and bedding sand: the NITRR recommendations (Clifford 1984) were adopted regarding gradation curves, plasticity limitations, etc. However, the recommended thickness of the sand bedding layer is somewhat higher than the NITRR guidelines (25 mm instead of 20 mm), since practical experience gained in Israel and other countries points out that it is very difficult to achieve a 20 mm thickness in the field.

VERIFICATION OF THE METHOD AND POSSIBLE MODIFICATIONS

The serious time limit and budgeting problems have so far prevented the undertaking of laboratory and field

studies to assure the reliability of the design method. However, in order to check whether the pre-determined aim of achieving a safe and conservative method was achieved, another approach was implemented: designs yielded by the method were compared with designs derived using existing methods from other countries for identical input conditions. Typical results are shown in Fig. 3. The designs using the interim method for two CBR values (5 and 20 per cent), and various traffic categories, are generally the most conservative.

Since the design method has become available to local engineers (about one year ago), it has been implemented in most of the projects under construction, with no problems so far. Since the method is very conservative on the one hand, and the reliance on layer equivalencies for its development is basically scientifically questionable (e.g. see Mackenzie and Fletcher 1980; Rollings 1985) on the other, further modifications, and later its replacement with a more rational method, are planned. These modifications and possible replacement will be carried out, subject to budgetting and research constraints, in the following stages.

(a) Checking designs yielded by the current method for their factor of safety against subgrade shear and critical rutting through the use of multi-layered programs and comparisons with strain criteria suggested in the literature (e.g. Uzan, Livneh and Ishai 1980). A high factor of safety may allow some thickness reductions in the current designs.

(b) Carrying out a comprehensive field study for the purpose of arriving at reliable values for the assumed elastic parameters of the concrete block layer, and evaluating the strengthening phenomenon ('lock up') reported by various researchers (e.g. Shackel 1984; Molenaar, Moll and Houben 1984), etc. The field data will be used as input to the development of a new design procedure which will rely on multi-layered models.

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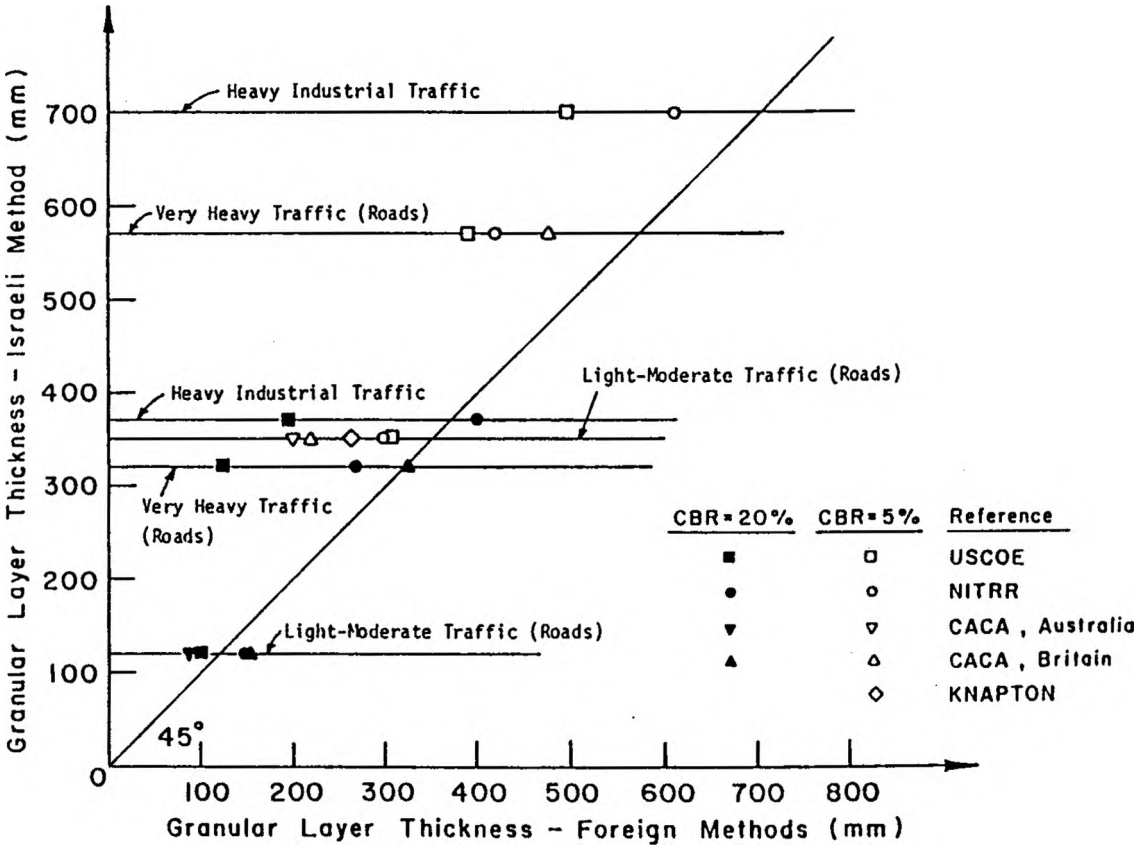

Fig. 3 - Comparison of granular layers (base plus sub-base) thickness required by Israeli design method v. thickness requirements according to other methods