PAVEMENT REHABILITATION USING CONCRETE BLOCKS

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SUMMARY

The paper deals with the design and construction of pavement rehabilitation schemes in which existing pavements are overlain with concrete block paving. The British Ports Association heavy duty pavement overlay method is described and examples are given. This method allows advantage to be taken of existing pavement courses, even if they are in substantially delapidated condition. Each course in the existing pavement is converted to an equivalent thickness of a standard material. Reduction factors are used to take into account cracking and rutting in existing materials and the derivation of these factors is explained in the paper.

The paper also deals with detailing of overlay schenes and describes the particular problems associated with overlaying concrete pavements. Details for preventing the loss of sand through joints are presented and the problem of trapping water in the laying course sand is discussed. Drainage details are described and methods for removing water frem the laying course sand are shown.

1. INTRODUCTION

This paper provides structural design and detailing information for existing pavements which are to be overlain with concrete block paving. The British Ports Association heavy duty pavement overlay design method is presented in relation to concrete block overlaying. This method allows the residual strength of existing pavements to be assessed. This residual strength can be added to the strength inherent in the concrete block overlay so that the strength of the overlain pavement can be compared with the strength required for a specified loading regime. This provides the basis for assessing whether or not an existing pavement can be overlain directly or whether the existing pavement needs to be strengthened prior to overlaying.

The British Ports Association method allows both good condition and delapidated pavements to be considered. This is particularly relevant to concrete block paving since concrete blocks can be used to overlay severely deteriorated pavements. This is not the case for other overlay materials which usually require a stiffer base than concrete blocks. The Author has been responsible for several overlaying projects in which the only alternative to a concrete block overlay would have been to remove the existing pavement and build a totally new one. The cost saving inherent in concrete block overlaying is considerable. For example, the final cost of overlaying a 16,000m2 delapidated concrete pavement in the UK in 1985 was £345,000. The cost of removing the existing concrete and sub-base material and of rebuilding would have been £590,000. In the Author's experience, overlaying with concrete block paving costs between £15/m2 and £24/m2 depending on the complexity of the site. A major element of these costs -is the supply and laying of the blocks which is approximately £12/m2. The removal and reconstruction of an industrial concrete pavement costs approximately £32/m2, of which £10/m2 is the cost of breaking out and carting away. All of these costs are taken from an analysis of contractors quoted prices, taking into account site establishment costs but not Value Added Tax (a purchase tax levied in ECC countries).

Between 25% and 60% of the total overlay cost is usually accounted for in detailing. For this reason, this paper considers detailing in relation to four schemes. Three of these schemes are industrial areas in which existing concrete paving required remedial work. The forth is a town centre street in which an asphalt surface was planed prior to overlaying.

2. OVERLAY STRUCTURAL DESIGN TECHNIQUE

Three techniques are generally used to assess the strength of existing highway pavements: (1) Deflection Beam method; (2) Falling Weight Pulse Load (Shell) method; and (3) Corponent Analysis method (U.S. Asphalt Institute).

The deflection beam (or Benkelman beam) method is widely used in the UK for the design of pavement overlays (Reference No. 1.) The falling weight pulse load method is based on measuring the elastic deflection in a pavement beneath a 150kg mass which is dropped 400mm onto the surface of the pavement. An arrangement of springs converts the impact load into an equivalent load of 600kg acting for a short time on the pavement. The deflection is recorded electronically.

3. COMPONENT ANALYSIS METHOD

During the 1960's the American Association of State Highway Officials (AASHO) emphasised the need for the rehabilitation of thousands of kilometres of sub-standard roads in the U.S.. To make this possible, the Asphalt Institute devised a method of evaluating the structural adequacy of pavements and hence a method of designing overlays. As the Asphalt Institute had already developed a design method for the design of new highways, the overlay design method was developed to work in conjunction with this existing method.

The structural adequacy of a pavement is defined as its ability to carry its predicted traffic without suffering any structural distress. Once the current structural adequacy of a pavement has been determined, the future service life of the pavement may be found. If this is considered to be inadequate it also forms the basis for designing an overlay. This method is known as the Component Analysis Method. Firstly,the thickness and condition of each of the courses within a pavement are selected. Secondly, the effective thickness of the existing pavement in terms of full depth asphalt is calculated using conversion factors (Table 1). The overlay design method

Type of Material	Material Conversion Factors
130nm concrete block paving including 50irm sand	1.1
30 N/mm2 pavement quality concrete	1.7
12 N/mm2 lean concrete (CBM4)	1.0
18 N/mm2 lean concrete (CBM4)	1.3
Cement-bound granular material (CBM3)	0.7
4.5 N/mm2 soil-cement (CBM1)	0.5
7 N/mm2 soil cement (CBM2)	0.6
Open-textured bituminous material stiffened with latex slurry	1.5
Dense bituminous macadam	1.0
Rolled asphalt	0.8
Type 1 sub-base material over subgrades with CBR > 5%	0.3
Type 1 sub-base material over subgrades with CBR ⩽ 5%	0.2
Type 2 sub-base material over subgrades with CBR > 5%	0.2
Type 2 sub-base material over subgrades with CBR ⩽ 5%	0.1
Subgrade	0.0

TABLE 1: MATERIAL CONVERSION FACTORS FOR COMPONENT ANALYSIS METHOD

is dependent on whether the existing pavement is flexible or rigid, the difference being that, for rigid pavements, the condition after preparation is used to select the conversion factor whereas, for flexible pavements, where preparation work does not affect the stength, its observed condition is used. Thirdly, the total thickness of material required above the prepared subgrade for the measured subgrade strength and predicted traffic intensity is found from the U.S. Asphalt Institute's pavement design tables. The overlay thickness required is the difference between the total thickness required and the assessed effective existing thickness.

The British Ports Association Component Analysis Method is similar except that the pavement is transformed into an equivalent thickness of 12N/mm2 compressive strength lean concrete. The required 'new' pavement is designed using an existing concrete block pavement design method. The design used is that incorporated in the British Ports Association (BPA) design manual (Reference No.2), which can be applied to either highway or industrial pavements. However, the component overlay method can be linked to any design method. The reason for transforming all pavement courses to equivalent 12N/mm2 lean concrete is that the BPA manual includes design charts for that material. The overlay thickness is then determined by subtraction.

The method coirprises two stages: the transformation of the existing pavement into an equivalent thickness of lean concrete, and the determination of the thickness and material properties of the overlay.

The transformation to an equivalent thickness of lean concrete is accomplished using the conversion factors shown in Table 1.

The materials in Table 1 are defined in a way which is compatible with the U.K. Department of Transport's "Specification for Highway Works" (Reference No. 4), Note particularly that the document defines four categories of cement bound material. These are called CBM1, CBM2, CBM3 and CBM4 in ascending order of strength. Note also that granular materials are classified as either "Type 1" or "Type 2". Type 1 material is free draining and non-plastic. Type 2 is poorer quality, may have a plasticity index and often relies on a clay binder for a substantial part of its strength.

4. PAVEMENT TRANSFORMATION

When a condition survey or structural analysis of a pavement shows that the pavement is deteriorating or that it is insufficient to carry new expected loadings, it becomes essential to undertake strengthening measures to extend, or maintain, the serviceable life of the pavement. In some situations/ deterioration may have become so severe that the most practical solution is to remove the old pavement and design and construct a new one. Frequently it is more economical to

overlay the pavement before the deterioration becomes too servere. This is done using the Component Analysis Method already described, assuming that the old and new pavement courses form a composite pavement structure having the strength required to meet the new design criteria, i.e. the overlay forms an integral part of the total pavement so that the strengthened pavement will meet all the requirements of a new pavement in the same location. It is therefore necessary to evaluate the old pavement in terms of the structure and thickness of its components so that advantage may be taken of residual strength in the design process. As the existing pavement constitutes a part of the strengthened pavement, it is essential to determine accurately the thickness of each of the existing courses and the degree of degradation each has undergone.

If records of the original pavement design are unavailable, it will be necessary to either drill cores or dig holes to obtain the required information. Testing should be conducted on the basis of one test every 500m2 of pavement. There should be a minimum of three tests and a maximum of seven for larger pavements of uniform construction and condition. Where areas are subjected to different types of traffic, each location should be considered separately for analysis purposes. Similarly, if initial testing shows that certain areas of the pavement are stronger than others, it may be preferable to divide the area to be overlain into zones; at least three tests should be conducted in each zone.

In certain circumstances, the properties of existing materials may have changed since construction, e.g. by cementing action or the intrusion of materials from another pavement course, and it is essential to know if this has occurred. Sampling should also be used to determine the condition of each course so that the appropriate condition factors can be selected. It may be difficult to assess the condition of lower pavement courses, particularly with respect to cracking. In such situations, conservative assumptions should be made.

The transformed thickness is multiplied by two condition factors (CF) : CF1 takes into account the loss of strength of each course owing to cracking and spalling. CF1 values, which can be used for both rigid and flexible pavements, are given in Table 2. CF2 (Table 3) takes into account the reduction in strength of each course as a result of rutting and settlement in the surface of flexible pavements. This is measured as the difference in levels under a 3m straight edge. If a pavement has deformed, cores should be taken to determine which courses of the pavement are affected. When there is no deformation or cracking the CF values are taken as 1.0, i.e. the material is as new.

The transformation procedure is carried out for each course in the pavement and the sum of the transformed thicknesses is taken as the equivalent thickness of the pavement. The equivalent thickness is used in the design of the overlay.

Condition of Material	CF1
As new	1.0
Slight cracking	0.8
Substantial cracking	0.5
Fully cracked or crazed and spalled	0.2

TABLE 2: CONDITION FACTORS FOR CRACKING AND SPALLING

Degree of Localised Rutting or settlement (mm)	CF2
0 to 10	1.0
11 to 20	0.9
21 to 40	0.6
40+	0.3

TABLE 3: CONDITION FACTORS FOR MAXIMUM DEGREE RUTTING AND SETTLEMENT

5. PAVEMENT EVALUATION EXAMPLE

A cross-section of an existing 8m wide, 200m long road is shown in Figure 1. Settlement has taken place in the subgrade, resulting in local deformations of lOOnrn over much of the pavement.

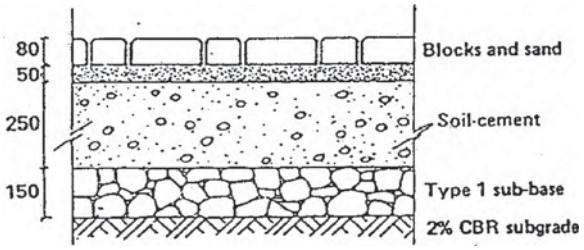


FIGURE 1: PAVEMENT EVALUATION EXAMPLE

Each course has settled. No cracking or spalling has taken place at the surface, though the soil-cement layer is substantially cracked. Using Tables 1, 2 and 3, each course is transformed into an equivalent thickness of lean concrete as shown in Table 4

Analysis shows this pavement to be equivalent to 71mn of lean concrete. Had the settlement not taken place, the pavement would have been equivalent to 235mm of lean

Course	Actual Thickness (mm)	Material Conversion Factor	Condition Factor CF1	Condition Factor CF2	Equivalent Thickness of lean Concrete (mm)
Concrete blocks and	130	1.1	1.0	0.3	43
Soil-Cement (CBM1)	250	0.5	0.5	0.3	19
Type 1 Sub-base	150	0.2	1.0	0.3	9
Subgrade CBR 5%	-	0.0	-	-	0
				Total:	71

TABLE 4: PAVEMENT EVALUATION EXAMPLE

concrete. In this case the pavement was either under-designed, or no account was taken of a compressible subgrade material. It is possible that the settlement was predicted when the pavement was originally designed; hence the use of concrete blocks.

6. DESIGN PROCEDURE

In order to derive the thickness of the overlay it is firstly essential to design a new paverrent structure for the required design criteria, using either the BPA or similar design method. The criteria are :

design life
subgrade CBR
LCI of traffic
type of overlay considered

(LCI is a term used in the BPA method to categorise vehicles according to the damage which they inflict on pavements. A highway vehicle with lit axles is LCI Category A).

When a lean concrete overlay option is to be used, the BPA chart for a canpressive strength of 12N/mm2 should be adopted..

The designed 'new' pavement consists of a lean concrete basecourse and concrete block surfacing over a granular sub-base. The equivalent thickness of the transformed pavement is then subtracted from the thickness of the lean concrete base determined from the BPA design charts. This gives the thickness of the overlay.

7. OVERLAY DESIGN EXAMPLE

An existing pavement carprises a substantially cracked concrete slab overlying 150mm of Type 2 granular sub-base (see Figure 2). The pavement has been trafficked by a terminal trailer system of LCI Category B. The most severely trafficked part of the pavement is subjected to 700 passes per day of a laden terminal trailer. There is no rutting.

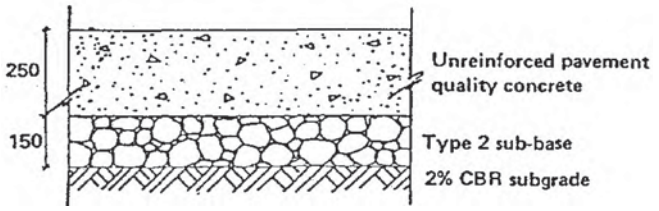


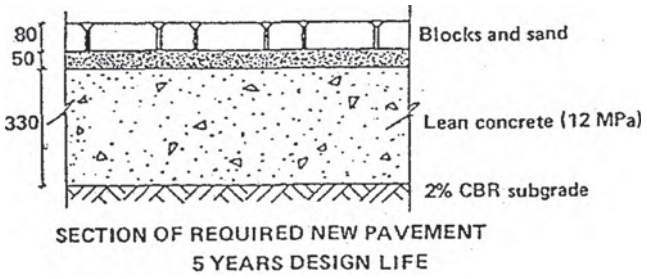
FIGURE 2 SECTION OF EXISTING PAVEMENT

It is proposed to continue with the same operation and two designs are required - one to last 5 years and one to last 25 years, each of 300 working days - so that an economic appraisal can be undertaken:

1) 5 years number of repetitions
= 700 x 300 x 5 = 1,050,000

2) 25 years number of repetitions
= 700 x 300 x 25 = 5,250,000

Using the BPA design chart for concrete block paving with no sub-base, the pavements shown in Figure 3



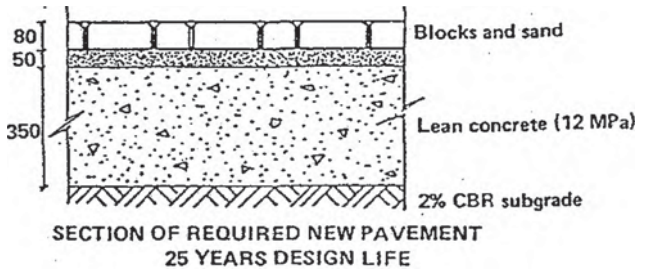


FIGURE 3 OVERLAY DESIGN EXAMPLE:
BLOCK PAVEMENTS REQUIRED

are required, with the appropriate calculations as shown in Table 5. Therefore, for each of the two alternative future design lives, the additional thickness of 12 N/mm2 lean concrete required is:

1) 5 years: 330mm - 227mm = 100mm

2) 25 years: 345mm - 227mn = 120mm

The two strengthened pavements are shown in Figure 4.

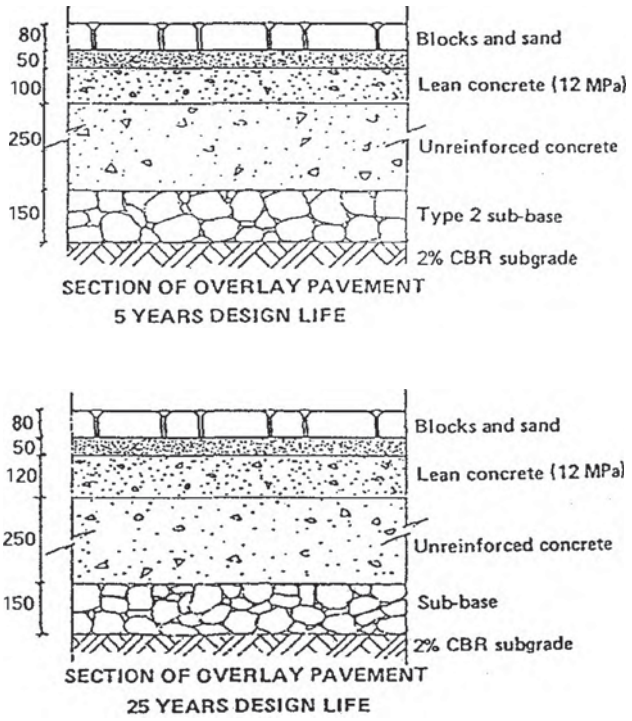


FIGURE 4 OVERLAY DESIGN EXAMPLES: STRENGTHENED PAVEMENTS.

Course	Actual Thickness (mm)	Material Conversion Factor	Condition Factor CF1	Condition Factor CF2	Equivalent Thickness of Lean (mn)
Concrete	250	1.7	0.5	1.0	212
Type 2 Sub-base	150	0.1	1.0	1.0	15
Subgrade CBR 5%	-	0.0	-	-	0
				Total:	227

TABLE 5: OVERLAY DESIGN EXAMPLE

8. DETAILS OF OVERLAIN PAVEMENTS

a) CONTAINER HANDLING FACILITY SOOTH EAST ENGLAND

Figure 5 shews a plan of part of the pavement at an 18,000m2 container handling facility. The concrete was four years old and poor detailing of the reinforcement had lead to longitudinal cracking of the slabs and in some places, severe spalling and loss of the concrete. Approximately 10% of the concrete has removed and reconstructed prior to overlaying the area with rectangular 200mm x 100mm concrete blocks laid in herringbone pattern. Mere the concrete blocks were laid over joints, a 600mm wide strip of filter fabric was laid over the joint in order to prevent sand from being washed into the joints. Filter fabric was also laid over wide cracks.

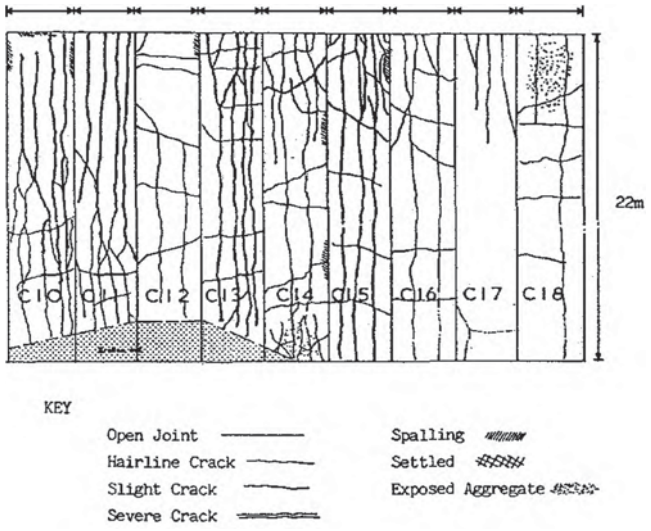


FIGURE 5 CONDITION OF A REINFORCED CONCRETE PAVEMENT PRIOR TO OVERLAYING WITH CONRETE BLOCKS. WITH CARE,CONCRETE IN A VERY POOR CONDITION CAN BE OVERLAIN SUCCESSFULLY.

Figure 6 shows details of a ramp between the overlain area and the access road. This ramp was designed to slow vehicles at a checking gate and is working satisfactorily. During the construction of the work temporary ramps comprising timber railway sleepers pinned to the existing concrete were formed between the newly constructed paving and the previous concrete paving. This allowed container handling operations to proceed normally.

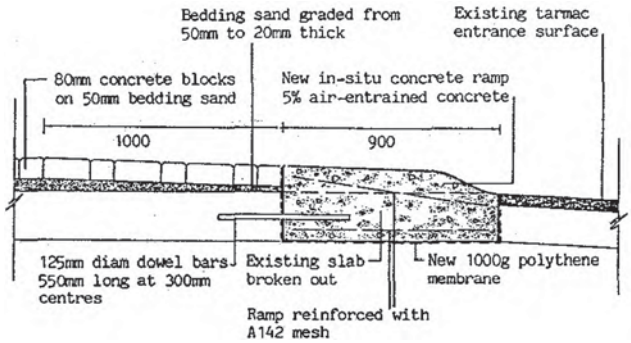


FIGURE 6 INDUSTRIAL YARD OVERLAY SHOWING CONCRETE RAMP DOWN TO ORIGINAL LEVEL.

At the perimeter of the area, an upstand concrete beam was constructed to restrain the concrete blocks and to form a raised kerb to restrain highway vehicles. TWo rows of string course blocks were laid adjacent to this kerb both to facilitate laying and to disguise the cut edge.

b). INLAND FREIGHT DEPOT MANCHESTER

The concrete road used by the haulage contractors had deteriorated when one of the contractors started to use a front lift truck to handle containers. Corner cracking and spalling had developed. Frost attack was also evident and a cost study showed that a concrete block overlay was the most cost effective remedial treatment. The major complication was that each of the haulage contractors used a hardstanding alongside the road so that effectively, over a length of 1000 metres, the road had no clearly definable edge along one side. It was necessary to provide a concrete block ramp along the length and Figure 7 shows details of the 3m long ramp provided over a length of 1000m. Concrete block speed humps were incorporated in the road and it was found that a height of 75mm was optimum. A height of 100mm was constructed initially, but this proved too severe, both for heavy vehicles and for private cars.

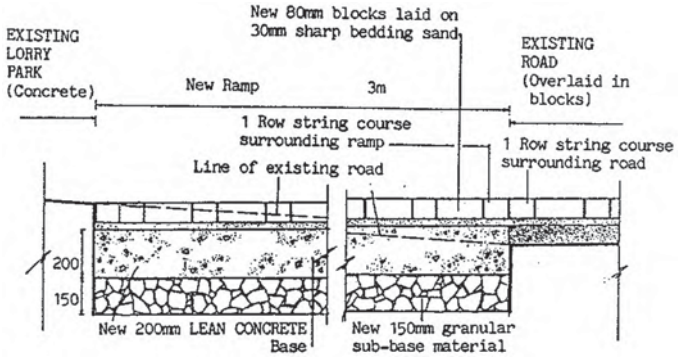


FIGURE 7 DETAILS OF 3 METRE WIDE CONCRETE BLOCK RAMP BETWEEN ORIGINAL CONCRETE ROAD AND NEW OVERLAIN CONCRETE BLOCK INDUSTRIAL AREA.

c). COAL HAUL ROAD, NORTH EAST ENGLAND

Earth movers had severely damaged a concrete road where they brought coal to a power station feed hopper. The existing road comprised 250mm thickness of reinforced concrete on 200nm granular sub-base material over a variable fill material with a California Bearing Ratio of 3%. The earth movers had wheel loads of 35,000kg and this had led to corner cracking and general cracking and spalling of the concrete slabs. Approximately 18% of the existing slabs were removed and replaced. The whole road was then overlain with concrete blocks.

Figure 8 shows two types of edge detail, one in which insitu flush kerbs were vertically dowelled to the existing slab and one where a substantial beam was constructed in the ground.

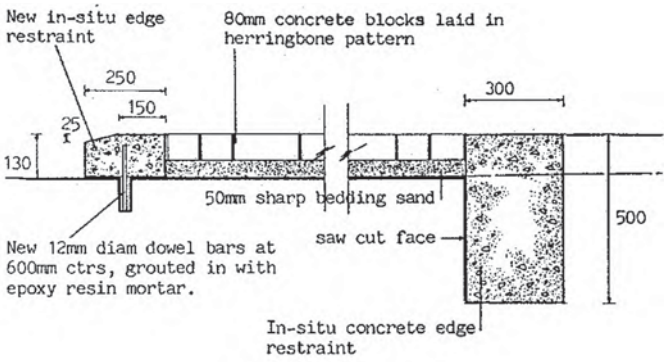


FIGURE 8 TWO TYPES OF IN-SITU CONCRETE EDGE RESTRAINT CONCRETE BLOCK OVERLAY ON ROAD TRAFFICKED BY 140,OOOKG EARTH MOVERS.

Prior to laying the concrete blocks, filter fabric was placed over the joints and over severe cracks. It is interesting to note that after one year, it was possible to discern the position of most of the joints in the underlying concrete since the concrete blocks had depressed by approximately Sum over the joints. An investigation showed that the filter fabric had stretched over the joints and had allowed sand to enter the joints partially. Although this was not a problem on this project, it could be elsewhere. Figure 9 shows a transition ramp at the end of the road.

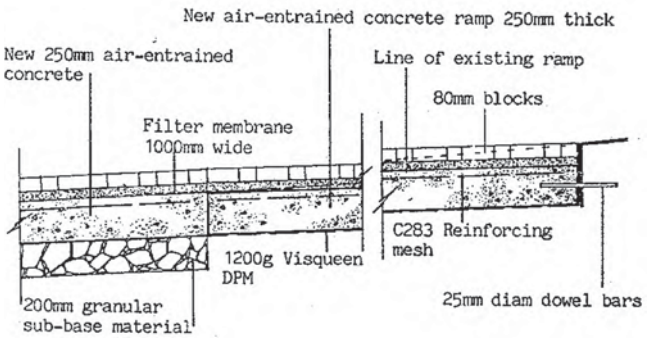


FIGURE 9 CONCRETE BLOCK TRANSITION RAMP AT END OF ROAD TRAFFICKED BY 140,000KG EARTH MOVERS

d). TOWN CENTRE STREET, EASTERN ENGLAND

In this project, a narrow asphalt shopping street was overlain. Both concrete blocks and clay bricks were considered as the overlaying material and bricks were chosen to match the surrounding buildings. The bricks were laid into sand and conventional concrete block paving technology was adopted throughout the project. The appearance of this project was enhanced by special bricks which were used



FIGURE 10 DETAILS OF STREET OVERLAY
USE OF SPECIAL UNITS

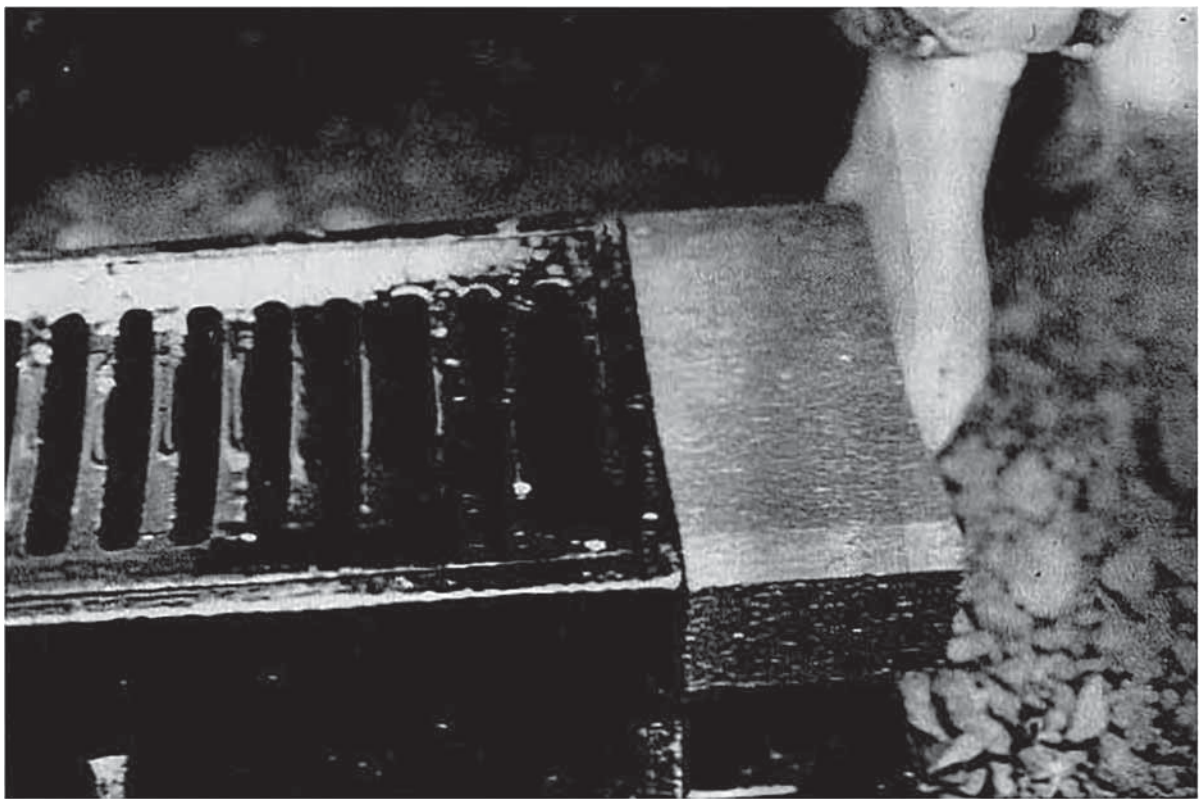


FIGURE 11 USE OF GULLEY GRATING AND
BLOCK OF SIMILAR PROFILE
TO AVOID AWKWARD DETAIL

to avoid awkward detailing around gullies.

Triangular units were used to avoid cutting and laying was undertaken with particular accuracy to ensure that all cutting was avoided where possible. Figures 10 and 11 show the result and it can be seen that attention to detail has resulted in a pleasing appearance.

CONCULSION

Overlaying with concrete blocks is a cost effective way of improving both the strength and appearance of delapidated pavements. Pavements rehabilitation is a major part of the UK concrete block paving market and is likely to grow in importance. The success of an overlay depends on both structural design and detailing. It is common for the detailing to cost as much as the straightforward blocklaying. The cost of overlaying is frequently half of the cost of removing and rebuilding a pavement.

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