A new Manual for Concrete Block Pavement Design

Juan Miguel Abril, Prefabricados Uniland, Spain
Sergio Carrascón, Spanish Institute of Cement (IECA), Spain
Luis Irastorza, Uniland Cementera, Spain
Alejandro Josa, Technical University of Catalonia, Spain

SUMMARY
The contents of a new manual for concrete block pavement design, which will soon be published by the Spanish Institute of Cement and its Applications (IECA), are summarized in this paper. The main topics considered in it are, the current situation of Spanish pavement regulations, a brief description of the chapters of the manual, the method used for the pavement structural design, the different materials considered for it and an economic evaluation of the different solutions proposed.

1. INTRODUCTION

The use of concrete block pavements has, over the last ten years, evolved very favourably in Spain. Their most common use has been in pedestrian areas (refurbishment of old town centers, new urban development areas such as the Olympic Village of Barcelona'92), industrial areas (ports, exterior patios of industrial sheds), service stations, motorway tollbooth areas and, to a lesser extent, streets.

2. CURRENT SITUATION OF SPANISH REGULATIONS

Up until the publication in 1987 of the "Concrete Block Pavement Manual" (1) by the Technological Institute of Catalonia (ITEC) and the Spanish Institute of Cement and its Applications (IECA), no kind of regulations applicable to this type of pavement existed. The projects constructed before then were based on earlier experiments carried out in Spain and on the standards in force in other countries, that were not suited to Spanish conditions (kind of standard axle load, climatic conditions, etc.). This was the reason why some of the works carried out at that time did not produce the expected results.
The appearance of the ITEC-IECA Manual managed only partially to cover this lack of regulations, since it only gave recommendations for the design and construction of pedestrian and light traffic areas, while the other applications for medium and heavy traffic remained unchanged.

3. POINTS DEALT WITH IN THE MANUAL

The new Manual published by IECA has, as its objective, that of serving as a guide for those architects and engineers who wish to use this paving technique and have no prior experience of its utilisation. The normal situation in small towns is that the municipal architects and engineers, entrusted with the drafting of the project and with managing the job, are not paving specialists.
For this reason, the IECA Manual includes a number of introductory chapters, aimed at architects and engineers who are not paving specialists, before tackling specific questions of design, construction and preservation.
The Manual's index is as follows:

- Advantages and limitations of concrete block pavements, compared with other solutions.
- Main applications (pedestrian areas, streets in residential areas, streets with medium traffic, industrial areas).
- Shapes and colours of blocks and the possibilities for combinations.
- Brief description of the block manufacturing process.
- Physical and mechanical properties the blocks should comply with.
- General aspects of the pavements (behaviour of different types of pavements, layers of which they are made up, etc.)
- Concrete block pavement design for:
    - pedestrian areas
    - low traffic density streets
    - medium traffic pavements

- industrial areas.
- Construction.
- Maintenance.
- Estimating construction costs.
- Current regulations.

The new aspects included in this manual are:

- Description of the block manufacturing process.
- Catalogue of solutions for pavement structures for traffic design of up to 800 daily heavy vehicles the standard 13 ton axle load.
- Recommendations for the maintenance of concrete block pavements.
- Estimation of costs for the construction of concrete block pavements.
- Summary of standards in force.

4. BASIC DESIGN CONSIDERATIONS

In order to be able to design a CBP, as with any other kind of pavement, it is basically necessary to k the follow two parameters: the subgrade quality and the total traffic the pavement will have to bea The quality of the subgrade is a factor of supreme importance that substantially affects the behaviour durability of a pavement. All other factors being equal, the worse the quality of the subgrade, i.e., softer and more deformable it becomes when wet, the more quickly the pavement will be degrade As far as traffic is concerned, this will consist of different vehicles, each, generally speaking, with a dist load. The effect produced by the traffic on the pavement depends partly on the weight of the vehicle question and partly on the frequency of their passage. This means to say that, when a pavement reac the end of its useful life, this is not because of the effect of the most heavily loaded vehicle but of accumulated effect of all the vehicles that have passed over it.

4.1. SUBGRADE

The Manual takes into consideration a classic subgrade classification (Table 1) of four types (S0, S1, and S3), depending on the CBR (California Bearing Ratio) index or on the vertical deformation modu This classification is in accordance with that used for the Spanish roadway regulations (2) but with addition of a lower category (S0) that can be applied in the cases of pedestrian and light traffic ar Some directives are also included, indicating how a knowledgeable approximation of its quality can got from the type of tracks produced by a vehicle passing over the damp subgrade.

Subgrade Category	CBR	Vertical Deformation Modulus EV_2(MPa)
S0	3-5	15-25
S1	5-10	25-50
S2	10-20	50-100
S3	>20	>100

Table 1

.2. TRAFFIC

he second essential factor in the design of any pavement is that of knowing the total traffic volume t to pass over it during its useful life. In order to know this factor, the designed pavement life must stablished, and the daily traffic volume to pass over it at the time of its opening must be known, as w a prediction of traffic growth.

he regulations in force in Spain (2) define five traffic categories, in terms of average annual daily hea ehicle traffic (AADTh), that are as follows (Table 2):

Traffic Category	Traffic Level
T0	AADTh > 2,000
T1	2,000 > AADTh > 800
T2	800 > AADTh > 200
T3	200 > AADTh > 50
T4	AADTh < 50

Table 2

This Manual covers the T2, T3 and T4 types of traffic envisaged in the current Spanish roadway regulations, dividing the traffic into sub-categories and taking into account the special applications for these pavements, such as those purely for pedestrians. A classification has been established that is summarised in Table 3.

Traffic Classification			
Traffic		AADTh	Traffic Category
Pedestrian	only pedestrian	0	TV2
	mixed with cars (no trucks)	<5	TV1
Low Volume Traffic		<5	TL3
		5-9	TL2
		10-19	TL1
Medium Traffic		20-49	TM3
		50-99	TM2
		100-199	TM1
Heavy Traffic		200-399	TP2
		400-800	TP1

Table 3

The design period considered is 30 years with an annual traffic growth rate of 2 %.

5. MATERIALS CONSIDERED

Of all the materials used in the various layers of pavements, those that are the most frequently used in Spain and are mentioned in current roadway regulations, have been selected for the catalogue of the manual sections. They, furthermore, are those that produce the best performance, at the structural level, when combined with a block pavement.

5.1. PAVING BLOCKS

The paving blocks considered in the Manual are of two types, depending on their thickness: 60 mm and 80 mm. It has been considered that the blocks are always placed on a layer of sand, of 30 mm thickness after compacting.

5.2. BASE

For the base layer, four materials have been considered, all of them with a hydraulic or bituminous

nder, i.e.:
sphalt concrete base;
an concrete;
ement-bound granular material;
ement stabilized soil.

3. SUB-BASE
r the substrate layer, only two materials have been considered, one of them stabilised (cement stabilize
il) and the other granular (natural graded aggregate).

CRITERIA FOR THE SELECTION OF THICKNESS.
e selection of the block to be placed is based on the widely accepted criterion (3,4) that, for pedestria
ffic, 60 mm blocks should be used and for the remaining applications 80 mm blocks should be laid

BASES FOR CALCULATION
the moment various methods exist for the design of concrete block pavements (3,5,6,7). All of ther
e as basic data for the design the bearing capacity of the existing subgrade, the mechanica
aracteristics of the materials that make up the various layers of the base, the environmental condition
the pavement in terms of drainage and freeze-thaw cycles and a prediction of the traffic that will pas
er the pavement during the period of the project.
order to check the available design methods, verifications have been carried out with a series o
amples of those that have obtained similar results using different methods for the same conditions o
bgrade bearing, traffic, materials, etc. The results of these verifications were positive and, except fo
nall differences of thicknesses, very similar cross-sections were obtained.

Type of Material	Symbol	Mechanical Characteristics	Thickness	
		Vertical Deformation Modulus EV_2(MPa)	Max (mm)	Min (mm)
CBP 80 mm	A80	2800	——	——
CBP 60 mm	A60	2600	——	——
ean Concrete	HM	20000	250	100
Cement-Bound Granular Material	GC	12000	250	150
Cement Stabilized Soil	SC	5000	200	150
sphalt Concrete Base	MBB	2500	300	80
latural Graded Aggregate	ZN	100	250	150

Table 4

ce the objective of the work was to obtain a catalogue of cross-sections suited to the Spanish
ulations in force, the first step was to adapt the various methods to the Spanish specifications (13 ton
load, materials, traffic volume) and to carry out a further comparison, this time with a classic multi-
r method.
mechanical characteristics adopted for the materials and maximum and minimum thicknesses
nitted for construction purposes are summarised in Table 4.
n the application of the above-mentioned criteria, the catalogue of cross-sections presented below has
n obtained.

ROSS-SECTION CATALOGUE
es 5, 6, 7 and 8 show the solutions proposed for the various traffic densities and gradings considered

ne project. The tables in question show the minimum thicknesses in mm of the various layers.

ubgrade ategory	Pedestrian Traffic Level	
	TV2	TV1
S0	A60+150 HM	A60+200 HM
S1	A60+200 ZN	A60+150 HM
S2	A60+150 ZN	A60+100 HM
S3	A60	A60

)+150 HM = CBP of 60 mm thick + 30 mm sand and a base of 150 mm HM

Table 5

ubgrade ategory	Low Volume Traffic		
	TL3	TL2	TL1
S0	A80+180 SC A80+120 MBB A80+80 MBB+150 ZN	A80+150 GC A80+160 MBB A80+80 MBB+250 ZN A80+150 SC+200 ZN A80+120 HM	A80+200 GC A80+150 GC+150 ZN A80+180 SC+250 ZN A80+180 MBB A80+120 MBB+200 ZN A80+80 MBB+150 SC A80+140 HM A80+100 HM+200 ZN
S1	A80+250 ZN A80+80 MBB	A80+200 SC A80+100 MBB	A80+200 SC A80+130 MBB A80+90 MBB+150 ZN A80+100 HM
S2	A80+150 ZN	A80+200 ZN	A80+250 ZN A80+80 MBB
S3	A80	A80+150 ZN	A80+150 ZN

)+180 SC = CBP of 80 mm thick + 30 mm sand and a base of 180 mm SC

Table 6

Subgrade Category	Medium Traffic		
	TM3	TM2	TM1
S1	A80+200 GC A80+180 SC+200 ZN A80+180 MBB A80+100 MBB+250 ZN A80+140 HM	A80+220 GC A80+200 SC+250 ZN A80+210 MBB A80+140 MBB+250 ZN A80+110 MBB+150 SC A80+160 HM A80+100 HM+250 ZN	A80+200 GC+250 ZN A80+260 MBB A80+190 MBB+250 ZN A80+130 MBB+200 SC A80+140 HM+250 ZN A80+140 HM+200 SC
S2	A80+110 MBB A80+160 SC	A80+200 SC A80+140 MBB A80+80 MBB+ 200 ZN A80+110 HM	A80+160 SC+200 ZN A80+180 GC A80+180 MBB A80+110 MBB+250 ZN A80+140 HM A80+100 HM+150 ZN
S3	A80+150 ZN	A80+80 MBB	A80+110 MBB A80+160 SC

A80+200 GC = CBP of 80 mm thick + 30 mm sand and a base of 200 mm GC

Table 7

Subgrade Category	Heavy Traffic	
	TP2	TP1
S1	A80+250 GC+250 ZN A80+180 GC+180 SC A80+240 MBB+250 ZN A80+180 MBB+200 SC A80+240 HM A80+180 HM+250 ZN A80+140 HM+200 SC	A80+230 GC+200 SC A80+280 MBB+250 ZN A80+220 MBB+200 SC A80+220 HM+250 ZN A80+170 HM+200 SC
S2	A80+230 GC A80+230 MBB A80+150 MBB+250 ZN A80+90 MBB+200 SC A80+170 HM A80+120 HM+250 ZN	A80+ +190 GC+250 ZN A80+260 MBB A80+190 MBB +250 ZN A80+130 MBB+200 SC A80+200 HM A80+140 HM+250 ZN A80+120 HM+150 SC
S3	A80+160 GC A80+160 MBB A80+80 MBB+250 ZN A80+110 HM	A80+150 SC+150 ZN A80+190 GC A80+190 MBB A80+110 MBB+250 ZN A80+140 HM A80+100 HM+150 ZN

A80+140 HM+200 SC = CBP of 80 mm thick + 30 mm sand, a base of 140 mm HM and a sub-ba of 200 mm SC

Table 8

9. ECONOMIC EVALUATION

In tables 9 and 10, the economic evaluation of the different cross section (per square meter, cubic meter or ton) and prices of the different materials are shown. It can be seen that the most expensive cross sections are those which contain asphalt concrete layers.

Type of Material	Price
CBP 80 mm	14$/m^2 (1960 Pta/m^2)
CBP 60 mm	13$/m^2 (1820 Pta/m^2)
Lean Concrete	30$/m^3 (4200 Pta/m^3)
Cement-Bound Granular Material	28$/m^3 (3920 Pta/m^3)
Cement Stabilized Soil	20$/m^3 (2800 Pta/m^3)
Asphalt Concrete Base	27$/ton (3780 Pta/ton)
Natural Graded Aggregate	9$/m^3 (1260 Pta/m^3)

Table 9

	Type of Subgrade			
Traffic Level	S0	S1	S2	S3
TV2	17$/m^2	15$/m^2	14$/m^2	13$/m^2
TV1	19$/m^2	14$/m^2	16$/m^2	13$/m^2
TL3	18-22/m^2	17-19/m^2	16$/m^2	16$/m^2
TL2	18-24/m^2	17-20/m^2	16$/m^2	16$/m^2
TL1	18-25/m^2	17-22/m^2	17-19/m^2	16$/m^2
TM3	——	18-25/m^2	18-21/m^2	16$/m^2
TM2	——	19-27/m^2	18-23/m^2	19$/m^2
TM1	——	20-30/m^2	18-25/m^2	17-21/m^2
TP2	——	21-32/m^2	19-29/m^2	18-24/m^2
TP1	——	23-34/m^2	20-30/m^2	18-25/m^2

1US$ = 140 Pta

Table 10

10. CONCLUSIONS

A new manual for CBP design has been presented. The target of this work hasn' t been to develop a new design method, but to adapt to the Spanish regulations in force, one of the existing methods.

A cross section catalogue has been presented, using the most common materials utilized in Spain. Also, an economic estimation of the construction cost has been included.

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Mr. Sergio Carrascón
Instituto Español del Cemento y sus Aplicaciones
Josep Tarradellas 123 4A
08029 Barcelona (Spain)
Fax: 343-4052502