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Original Research Paper

Concrete block pavements in urban and local roads: Analysis of stress-strain condition and proposal for a catalogue

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HIGHLIGHTS

- A stress-strain analysis of concrete block pavements was conducted.
- Various load positions, blocks patterns, bedding sand thicknesses and joint gaps have been modeled.
- Stretcher or running bond scheme provides the shortest service life.
- Herringbone bond schemes imply an increase by at least 10%–15% of allowable load repetitions.
- Nine pavement sets for urban and local pavements with concrete pavers are proposed.

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ABSTRACT

Although the construction of block pavements has grown fast in the last decades, there is still a need for simple tools that could be applied to design them. This paper analyzed and verified concrete block pavements for urban and local roads composed of rectangular concrete pavers with plane side surfaces (no interlocking effect). The examined blocks were laid on a bedding sand layer, a cement treated base layer and a granular unbound foundation layer. The commercial finite element (FE) software ANSYS® was used to calculate the response of the pavement when subjected to different loading, construction configurations. Three wheel positions, five blocks patterns, three bedding sand thicknesses and joints gaps have been considered to evaluate stress-strain condition on pavement materials. Fatigue and rutting verification was performed respectively for bound and unbound pavement materials using analytical curves available in the literature. At the end of this study, a proposal for a catalogue is presented. It has nine pavement sets, because it takes into account three values of subgrade capacity (30, 90, and 150 MPa of resilient modulus) and three levels of traffic (400,000, 1,500,000, and 4,000,000 passages of commercial vehicles during the service life). The obtained results provide an inexpensive procedure for the preliminary design of concrete block pavements.

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1. Introduction

The concept of block pavements dates to the period of the Roman Empire. In that period, stone blocks tightly interlocked between them formed the upper layer of the roads, whose bottom layers had mechanical and physical characteristics similar to those we have today (Di Mascio and Ranzo, 2005). Historical events (e.g., the end of the Empire, Barbarian raids), functional requirements (e.g., regularity of tire-pavement interaction) (Zoccali et al., 2017), logistic and economic needs (e.g., need for simple blocks producing, fast placing, and reducing of workforce) caused the abandonment of this technology.

Starting in the 80s, the industrial production of innovative materials (e.g., high strength cement concrete, composite or low-impact materials) gave a boost to the use of modular pavements, which could represent a viable alternative and sustainable to most common continuous solutions (i.e., bituminous and concrete pavements). Today, pavers are often used for the construction of sidewalks, cycle paths, residential driveways, parking lots, industrial spaces (Miccoli et al., 2014, 2015) and for special applications such as port and airport areas (Pradena and Houben, 2016; Richard, 2017) and permeable areas (Moretti et al., 2018; Lee et al., 2018; Lin et al., 2016). In the last decades, the use of concrete pavers strongly increased in Europe because under extreme weather conditions they proved to be more durable and versatile than ordinary asphalt pavements (Gunatilake and Mampearachchi, 2017). Moreover, the presence on the market of multiple technical and architectural possibilities increased the interest in these pavements (Hettiarachchi and Mampearachchi, 2016). Pavers' materials and their production techniques are various, and they offer to users different applications.

However, materials of the bottom layers are those commonly used for continuous road pavements, and design methods do not differ substantially from those used for bituminous pavements. Indeed, modular pavements are usually composed of a wearing layer (the blocks), a binder (the bedding sand course), a base layer and a sub-base layer (Shan et al., 2015). The positive experiences gathered during the last decades around the world extended their use to urban and local road pavements.

However, the design is more complex of traditional pavements due to the structural discontinuities of joints between pavers. Numerical simulations and/or FEM software packages are used to predict the stress-strain performances of block pavements, with serious computational complexity (Füssl et al., 2016). At this purpose, some public administrations added this type of pavements between solutions proposed in their catalogues for pavement design. Catalogues are tools widely used because they are easy to read and, at the same time, their contents derive from rigorous methods (Zoccali et al., 2018). Mechanistic modelling, laboratory testing, and field observations are used to validate the cross-sections in the design catalogues (FHWA, 2007). Road pavement catalogues have national coverage: they reflect long-term experience gained in a State about traffic loading, climatic data, material and soil properties. In Europe, Germany, Austria, Italy and recently Poland (Road and Transportation Research Association, 2001, 2015; Austrian Association for Research on Road, Rail, and Transport, 2006; CNR - Consiglio Nazionale delle Ricerche, 1995; Rys et al., 2016) developed pavement catalogues. However, not all of them offer solutions for modular pavements. For example, the Italian catalogue of road pavements (CNR - Consiglio Nazionale delle Ricerche, 1995) offers solutions only for asphalt, semirigid, jointed plain concrete and continuously reinforced concrete pavements to be laid according to the Italian standards about functional and geometric design of roads.

This paper analyses and verifies modular pavements for urban and local roads. The pavements consist of rectangular concrete pavers with plane side surfaces (no interlocking effect) because it is a typical shape for pedestrian and urban low-volume traffic pavements. Commercial and heavy loads considered in the study comply with those provided for in the Italian catalogue for road pavements design. The study consists of two parts: the first one presents the influence of blocks pattern on fatigue strength, horizontal displacements, and vertical deformations. Mechanical performances of examined pavements were calculated using the FEM commercial software ANSYS®; rutting and fatigue verification of the pavement was carried out using empirical curves available in the literature. Moreover, it analyses the pavement service life as consequence of currently used block thicknesses, joint gaps, and bedding sand thicknesses. The second part of the paper proposes nine pavement sets to constitute a catalogue considering three traffic volumes and three subgrade capacities. The results of this study answer to the need of a faster and easier analysis procedure than the FEM approach that could be used to design block pavements.

2. Modeling method and process

A common method to analyse a block pavement consists on using a finite element model to represent modular blocks laid on the bottom layers of the pavement. In the analysis of road pavements, it is common to model wheel loads applying a pressure (i.e., the tire pressure) uniformly distributed within a rectangular or circular area on the top surface of the pavement (Zheng et al., 2012). In presence of little blocks, the load is applied over more than a single block.

Different types of FEM analysis could be performed to calculate the stress-strain condition: static, quasi-static and dynamic approaches are possible. The first ones are simpler and easier than the former (Zoccali et al., 2015), but require the assumption of a dynamic amplification factor (DAF) to account for the dynamic effects induced by traffic loads (Knapton, 2007). In the present study, a static analysis has been carried out having a DAF equal to 10%: this value complies with the characteristic speed of traffic in urban and local roads (i.e., 40 km/h) (Cantisani et al., 2012). Indeed, at this operative speed the pavement discontinuities are not dangerous unevennesses in terms of road safety (Di Mascio et al., 2017) and noise generation (Cantisani et al., 2013).

The design traffic complies with the traffic mix for urban and local roads (Table 1) defined in the Italian catalogue of

Table 1 – Design traffic.

Vehicle type	Vehicle code	Gross vehicle load (kN)	Axle load (kN)	Wheel load (kN)	Dynamic wheel load (kN)	Wheel load code
Bus	V_1	30	10	5	5.5	P_1
			20	10	11	P_2
Light truck	V_2	120	80	40	44	P_3
			40	20	22	P_4

Road Pavement (CNR - Consiglio Nazionale delle Ricerche, 1995). Therefore, two types of vehicle (i.e., a light truck with a maximum load of 30 kN and a bus with a maximum load of 120 kN) and four axle loads (their static values are: 10, 20, 40 and 80 kN) were considered. All axles listed in Table 1 had single wheels whose operating pressure was 0.750 MPa.

As regard as the traffic distribution, V_1 represents 80% of total passages and V_2 represents 20% of them.

In this study, the tire pressure was uniformly distributed within a rectangular area whose shape factor S (i.e., the ratio between the longer and the shortest plan dimensions of the rectangle) was 1.5.

This choice does not affect the results of the analysis (Korunović et al., 2012), but allows simplification of meshes in the FEM models created with the software ANSYS® (ANSYS, Inc., Canonsburg, PA, USA). Several models representing concrete blocks laid on "flexible" pavement layers permitted to calculate stresses and strains induced by the traffic loads. Each model was 1.5 m × 1.5 m in plan, while its thickness varied according to the thickness of pavement layers. The modelling area was defined after a sensitivity analysis. The model size is big enough to have almost zero stress and strain values near the edges.

Solid hexahedral elements with 8-point of integrations composed the model; the shape function was quadratic. Their dimension was 20 mm under the applied load, and gradually increased to the edges of the model until reaching the maximum value of 40 mm. All materials were linear elastic, homogenous and isotropic, with the exception of the sand filled joints, whose behavior was elastic-plastic.

Flat frictional boundaries were assumed between the joint sand and blocks, based on the Coulomb friction formulation with a constant static friction coefficient equal to 0.7. This assumption complies with the experimental results obtained by Füssl et al. (2015) on concrete blocks with sand-filled joints. All other contacts between pavement materials were modelled as bonded. With respect to the boundary conditions adopted in the model, the horizontal displacements on the sides of the model were laterally constrained to represent the confinement due to the surrounding ground, while the bottom layer (i.e. subgrade) was fully constrained.

In the study, hand-sized concrete pavers with overall plan dimensions of 10 cm × 20 cm have been considered. Their dimensions comply with the studies of Knapton about concrete block pavements (Knapton, 2007). Their thickness varies according to the input data: 8 cm are usually adopted, 10 cm are recommended for heavy use, and 6 cm are considered for low-traffic areas. Fig. 1 represents a FEM model created with ANSYS® for this study.

Table 2 lists the geometrical, physical and mechanical characteristics of the examined concrete pavers.

Table 3 lists the main mechanical characteristics of the examined road materials.

In the first part of the study, the wheel load P_3 has been applied to the pavement represented in Fig. 2 to investigate the role of the block pattern respect to vertical displacements under the load. In the reference block pavement (Fig. 2) the subgrade had a resilient modulus measured according to the AASHTO T274-82 standard (AASHTO, 1982) equal to 150 MPa and it was assumed 40 cm-thick for the stress-strain analysis.

Five different patterns of the concrete blocks have been compared (Fig. 3):

- Stretcher or running bond;
- 90° stretcher or running bond;
- Basket weave or parquet bond;
- Herringbone bond;
- 45° herringbone bond.

For each pattern, three different load positions (red areas) respect to the blocks have been considered (Fig. 4); the motion directions comply with Fig. 3. Three criteria have been defined for choosing the loading positions. The first two are geometrical, the last one is mechanical.

- to have the loading position tangent at least to a joint;
- to minimize the number of blocks included in the load imprint in order to have the maximum stress on a single block;

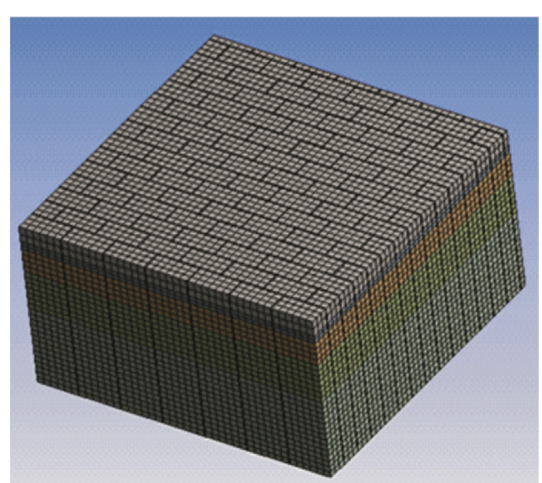

Fig. 1 – Example of a finite element model developed using ANSYS®.

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Table 2 – Geometrical, physical and mechanical characteristics of the examined blocks.

Characteristic	Value
Length (cm)	10
Width (cm)	20
Thickness (cm)	6-8-10
Ultimate load (N/mm)	250
Density (kg/m^3)	2200
Flexural strength (MPa)	>4.6

- to maximize the vertical displacements.

Stresses and strains calculated with FEM for most severe pattern permitted to verify several pavement sets. Thus, fatigue verification of bonded materials and rutting verification of granular materials were performed.

The fatigue verification considered tensile stresses at the bottom of each bound layer (Fig. 5(a), while the rutting verification took into account vertical stresses or displacement induced on the top surface of an unbound layer (Fig. 5(b)).

In this study, both analyses comply with the Miner's law (Eq. (1)) (Miner, 1945).

$$\Sigma n/N < 1 \tag{1}$$

where n is the number of load repetitions during the service life, N is the number of allowable load repetitions.

For the cement treated base layer, N was evaluated according to Eq. (2) (Ferrari and Giannini, 1991).

$$\sigma_N = \sigma_R (1 - K \log N) \tag{2}$$

where K is a regression coefficient equal to 0.04; σ_R is the tensile strength of cement treated base layer; σ_N is the tensile stress.

For the unbound granular materials and the subgrade (Ferrari and Giannini, 1991), Eq. (3) allowed the calculation of N respect to the rutting damage.

$$\log N = -7.21 - 395 \log \epsilon_z \tag{3}$$

where ϵ_z is the vertical strain.

However, the pattern also affects horizontal displacements: if the gaps among adjacent paving blocks form a continuous connecting line parallel to the drive direction (for example pattern 2), greater displacements can occur respect to other patterns. Therefore, horizontal stresses induced by vehicle accelerating, braking or steering cannot be overlooked in the design of block pavements. Horizontal stresses can cause misalignment of the blocks with consequent variation

Table 3 – Mechanical characteristics of the pavement materials.

Material	Young's modulus (MPa)	Poisson ratio	Tensile strength σ_t (MPa)
Bedding and joint sand	100	0.30	
Cement treated	400	0.25	0.25
Granular course	250	0.35	

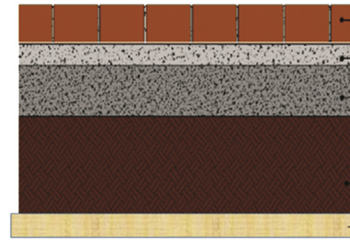

Fig. 2 – Reference block pavement.

of the joints thickness, which affects pavers self-blocking and therefore the transmission of stresses to each other.

As regard as braking forces, the authors examined the maximum adherence force F induced on the pavement (Eq. (4)).

$$F = f_a(s)\, P_a \tag{4}$$

where $f_a(s)$ is the adherence coefficient depending on the pavement condition and the vehicle speed s, and P_a is the vertical tire force on the braking wheels.

The input data for calculation of horizontal displacements are listed in Table 4.

Finally, the authors examined the influence of block thickness, joint gap and bedding sand thickness on the pavement service life.

In the second part of the study, the authors defined nine block pavements solutions for three levels of traffic (Table 5) and three levels of subgrade load bearing capacity (i.e., 30, 90 and 150 N/mm^2 of resilient modulus Mr). All input variables are compliant with those defined by the Italian catalogue of Road Pavements (CNR - Consiglio Nazionale delle Ricerche, 1995).

The proposed pavements have been calculated according to the exposed FEM approach and verified according to the fatigue and rutting equations.

3. Results and discussion

Fig. 6 shows the layout of vertical displacement obtained for each examined combination of pattern and wheel load position. Images show only the most significant area where vertical displacements are appreciable in order to highlight the blue areas.

The legend of Fig. 6 shows that the red color means no vertical displacement, while the blue color means the maximum vertical displacement Δ_z for each examined configuration. Table 6 lists the values of Δ_z for each examined configuration.

Pattern 1 implies the most severe results which has the maximum vertical displacement obtained (i.e., −1.93 mm) between the 15-examined combinations. On the other hand, pattern 5 has the less vertical displacement (i.e., −1.58 mm).

The most severe configuration of each pattern has been considered to verify the fatigue and rutting damage of pavement materials. Table 7 lists the maximum tensile stress (σ_N) in the cement treated base layer, and the vertical deformation (δ_z) of the unbound foundation and the subgrade having reference the pavement shown in Fig. 2. For each input data,

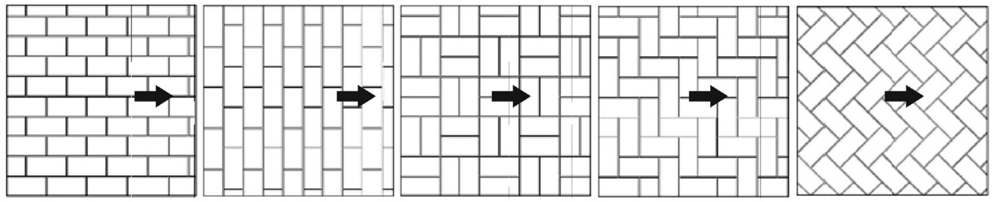

Fig. 3 – Examined patterns (the black arrows indicate the direction of motion).

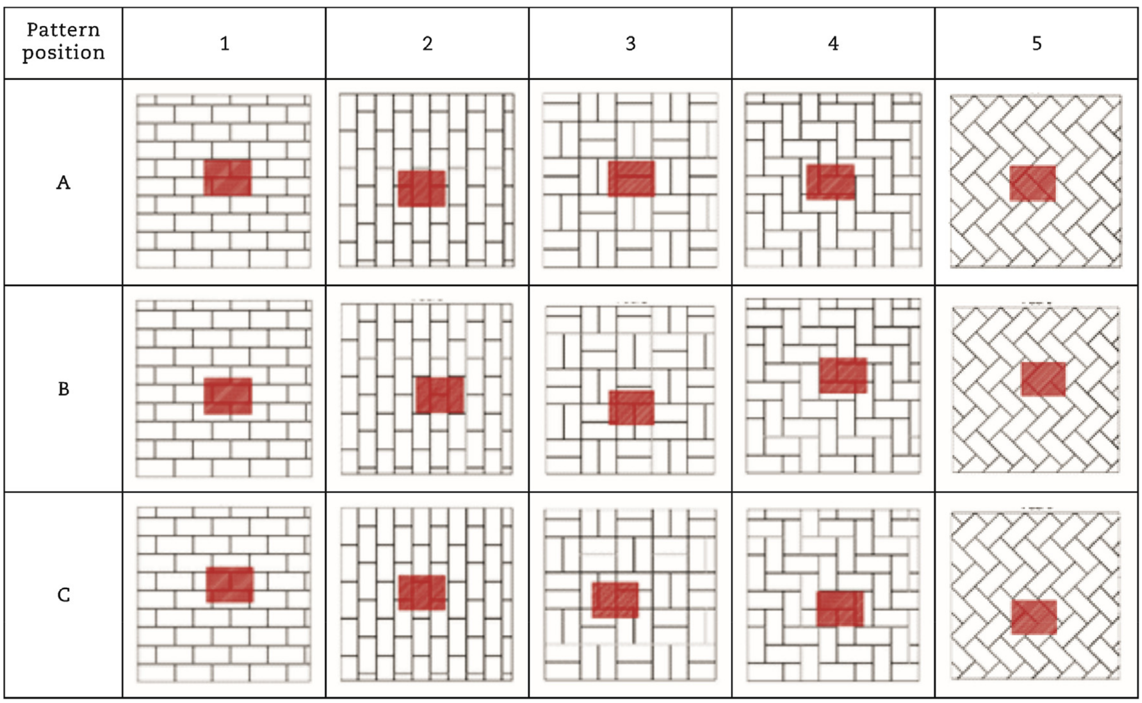

Fig. 4 – Wheel load positions for different patterns.

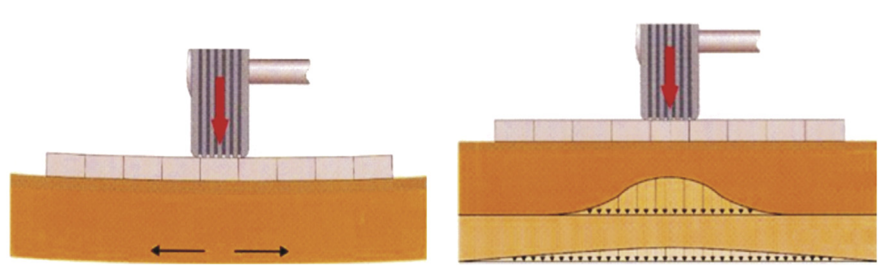

Fig. 5 – Stresses and strains. (a) Stresses for fatigue analysis. (b) Strains for rutting analysis.

Table 7 shows the maximum number of allowable repetitions N of the design load P_3.

Table 7 highlights that for each configuration the granular unbound foundation layer ensures the lowest value of N before the pavement crisis (i.e., the rutting). The most severe results in terms of pavement service life refer to the configuration 1A (stretcher or running bond), while both herringbone bond schemes imply an increase by at least 10%–15% of N than 1A (Fig. 7).

The herringbone patterns allow a greater number of passages because the wheel load area affects a greater number of blocks than the other configurations. Indeed, the more is the number of elements involved by the load, the greater is the stress distribution.

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Table 4 – Input data for calculation of horizontal displacements.

Input data	Value
Design vehicle	V_2
Design axle load	P_3
Inertial coefficient of blocks	1.2
Vertical tire force P_a (kN)	48
Adherence coefficient	0.8
Adherence force F (kN)	38.4

Table 5 – Design traffic levels.

Traffic level	Number of expected passes during the service life
I	400,000
II	1,500,000
III	4,000,000

As regard as the horizontal displacements of blocks induced by the traffic load P_3, Fig. 8 represents the most critical alignments of horizontal displacements obtained for the configurations listed in Table 7: the colors used to plot the results comply with those used in Figs. 6 and 7. It is possible to note that the horizontal displacements are equal to zero at the edges of the model (its in plant edges were 1.5 m long).

According to Fig. 8, Table 8 lists the maximum horizontal displacements of blocks δ_h induced by the traffic load P_3.

The results of both herringbone bond schemes comply with those obtained in the fatigue and rutting analyses: these patterns ensure the best stress-strain behavior of blocks, while the 90° stretcher or running bond gives the highest

Table 6 – Values of Δ_z for different patterns and load positions.

Position	Δ_z for different patterns (mm)				
	1	2	3	4	5
A	−1.93	−1.88	−1.84	−1.74	−1.73
B	−1.78	−1.87	−1.80	−1.69	−1.58
C	−1.87	−1.73	−1.72	−1.73	−1.61

maximum horizontal displacement. Fig. 9 shows the percentage increase of the maximum horizontal displacement of patterns less stable than the configuration 5B (45° herringbone bond).

In addition to blocks pattern, important aspects related to the mechanical performance of a modular pavement are: the pavers' thickness, the joints' thickness, and the bedding sand thickness. These factors affect the pavement behavior in terms of deflection, and therefore they effect its service life. Therefore, they have been varied from the reference solution (Fig. 2) to quantify their effects on deflection and number of allowable passes during the pavement service life. The design load, thicknesses of bottom layers, and mechanical performances of pavement materials coincide with those taken thus far. The pattern used in this analysis is the stretcher or running bond because it gave the worst results in terms of durability.

Respect to the reference pavement (Fig. 2), two values of block thickness (6 and 10 cm), two values of bedding sand (3 and 5 cm), and two values of joint gaps (3 and 4 mm) have been considered. Fig. 10 summarizes the results of the sensitivity analysis: it represents the values of Δ_z under the load area for the examined conditions. The three points with

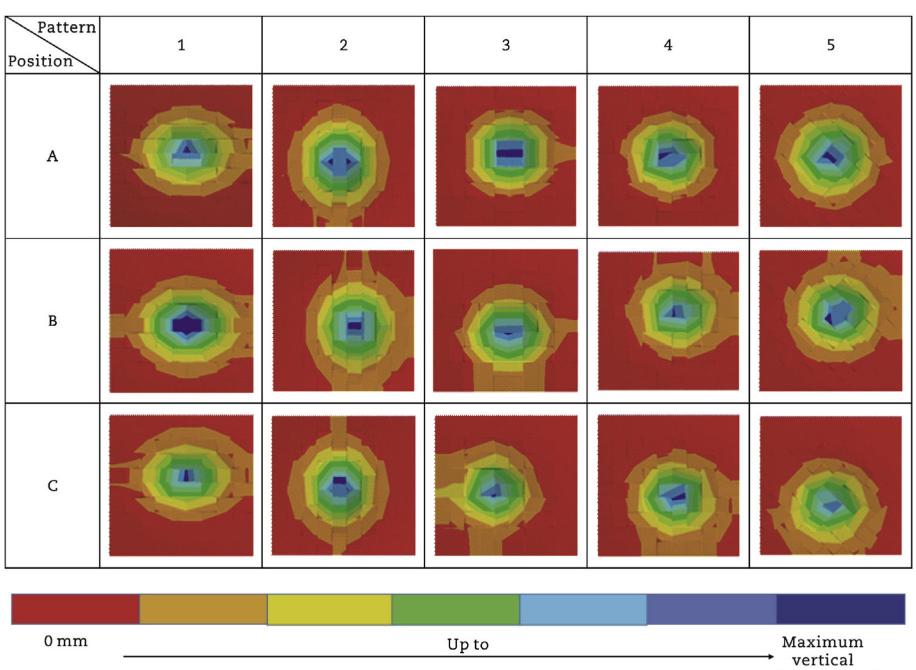

Fig. 6 – Layout of vertical displacements.

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Table 7 – Input data and results of fatigue and rutting verification.

Result	Pattern-position				
	1A	2B	3C	4B	5B
Base					
σ_N (MPa)	0.039	0.033	0.035	0.034	0.032
N	1.33E+20	7.50E+20	4.22E+20	5.62E+20	1.00E+21
Foundation					
δ_z (mm)	−0.345	−0.340	−0.341	−0.332	−0.333
N	2.92E+06	3.09E+06	3.06E+06	3.40E+06	3.36E+06
Subgrade					
δ_z (mm)	−0.247	−0.247	−0.239	−0.241	−0.239
N	10.93E+06	10.93E+06	12.45E+06	12.05E+06	12.45E+06

Δ_z equal to 1.8 mm refer to the maximum vertical displacement obtained for the reference pavement, which has 8 cm thick blocks, 5 mm thick joint gaps, and 4 mm thick bedding sand.

Table 9 summarizes the results of the sensitivity analysis. As for the configurations addressed above, the cement-bound foundation layer gave rise the pavement durability, because its number of N was the lowest one compared to other pavement materials in all cases. Therefore, the values of N listed in Table 9 refer to this layer.

Block thickness is the most critical variable between those examined. Having the 6 cm thick as reference solution, 8 cm and 10 cm thick blocks lead to an increase of respectively 7% and 15% to the current value of N. The maximum percentage increase of the service life for decreasing values of joints and bedding sand thicknesses is respectively 2.3% and 2.4%.

In the second part of the study, the results of the first part have been used to define a catalogue of urban block pavements with concrete blocks. Table 10 lists the geometrical properties common to all designed modular pavements.

Table 8 – Maximum horizontal displacements for different pattern and load configurations.

Result	Pattern-position				
	1A	2B	3C	4B	5B
δ_h (mm)	0.59	0.80	0.70	0.51	0.49

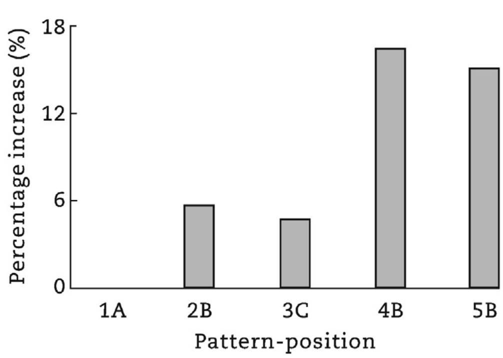

Fig. 7 – Percentage increase of N (1A is the reference pattern).

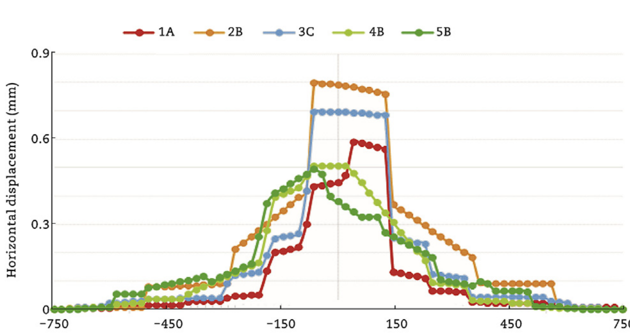

Fig. 8 – Horizontal displacements.

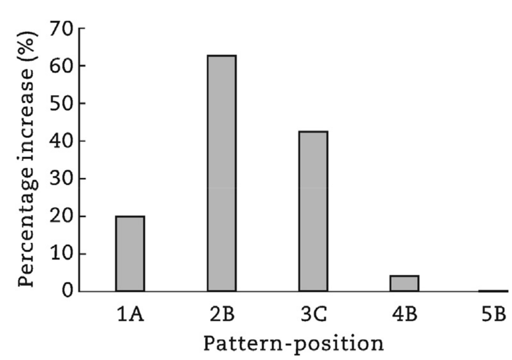

Fig. 9 – Percentage increase of δ_h (5B is the reference pattern).

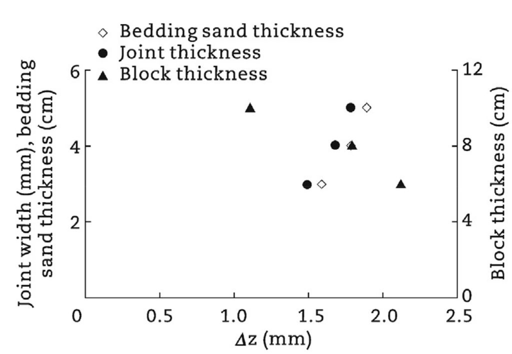

Fig. 10 – Maximum vertical displacement varying joint width.

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Table 9 – Verification results for different configurations.

Input data	Joint width: 5 mm, Bedding sand thickness: 4 cm, Block thickness (cm)			Block thickness: 8 cm, Bedding sand thickness: 4 cm, Joint width (mm)			Joint width: 5 mm, Block thickness: 8 cm, Bedding sand thickness (cm)		
	6	8	10	3	4	5	3	4	5
N (10^6)	2.76	2.92	3.13	2.99	2.95	2.92	2.97	2.92	2.90

Table 10 – Properties of modular pavements.

Property	Value or type
Pavers thickness (cm)	8
Joints thickness (mm)	5
Bedding sand thickness (cm)	4
Pattern configuration	Stretcher or running bond

Table 11 – Input data for pavement verification.

Wheel load code	Mechanical performance		
	σ_N (MPa) (Cement treated base)	δ_z (mm) (Granular foundation)	δ_z (mm) (Subgrade)
P_1	0.005	−0.048	−0.029
P_2	0.009	−0.097	−0.059
P_4	0.017	−0.187	−0.114
P_3	0.030	−0.438	−0.225

Table 12 – Results of pavement verification.

Wheel load code	Number of allowable passes N		
	Cement treated base	Granular foundation	Subgrade
P_1	4.10E+19	7.33E+09	5.17E+10
P_2	2.21E+19	4.23E+08	3.12E+09
P_4	4.13E+18	3.28E+08	2.32E+08
P_3	2.45E+18	1.03E+06	1.58E+07
Verification $\Sigma n/N$	4.27E-13	0.735	5.52E-02

They derive from the first part of the study: the pavers thickness answers to medium traffic volumes, the joint width is the maximum considered in the sensitivity analysis, while the bedding sand thickness is 4 cm. This thickness is the average of the values generally adopted worldwide (Di Mascio, 2002; Road and Transportation Research Association, 2001; Austrian Association for Research on Road, Rail, and Transport, 2006; Rys et al., 2016): to avoid excessive rutting during the pavement service life, the bedding sand thickness range between 3 and 5 cm. In the catalogue the average value is proposed because the variation in the service life of the overall pavement is only of 2.4%, as already said.

For each combination of traffic level and load bearing capacity of subgrade the authors verified a pavement solution. For the sake of brevity only the analytical results for Mr = 150 MPa and traffic level III are presented. The pavement is composed of: 8 cm thick concrete pavers; 4 cm thick bedding sand; 9 cm thick cement treated base; 15 cm thick granular foundation. The design traffic complies with data listed in Table 1 and presented in the section materials and methods.

Tables 11 and 12 respectively list the input and output data of verification process.

The exposed procedure has been applied to all other 8 examined combinations of traffic volume and subgrade load bearing capacity. Fig. 11 shows all the concrete block pavements verified for urban and local roads according to the Italian standards for road design and construction.

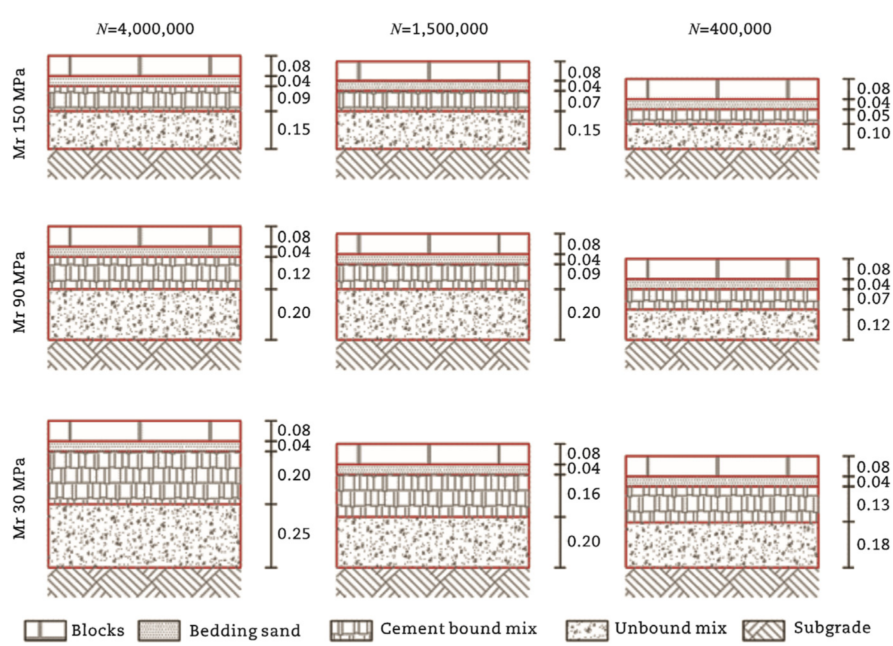

Fig. 11 – Catalogue of concrete pavers for urban roads (unit: cm).

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The obtained results comply with the Italian standards for road design and construction, but they could be taken as reference for preliminary designs, feasibility studies and pavement management systems in urban areas (Loprencipe et al., 2017). All proposed solutions refer to the stretcher or running bond, which is the most severe pattern in terms of pavement service life. Therefore, it implies that the use of other examined patterns, especially the 45° herringbone bond, will ensure performances better than the provided for.

4. Conclusions

Statistical data show that the use of block pavements is increasing in recent decades. These structures are often constructed in pedestrian areas, but it is increasing their use for urban and local roads where heavy vehicles are admitted and the average running speed is not over 40 km/h. However, a practical design tool for concrete block pavements lacks, and only FEM models could perform the analysis.

On that basis, the study presented a catalogue for urban or local road pavements composed of concrete blocks obtained from models implemented in the FEM software ANSYS®. All data input about materials and traffic characteristics comply with the Italian standards about road design and construction. Rectangular concrete pavers with shape factor of 1.5 and five patterns (i.e., running bond, 90° running bond, basket weave, herringbone bond, and 45° herringbone bond) have been examined in the first part of the study to highlight the most severe condition in terms of horizontal displacements, vertical strains, and flexural stresses. The stress-strain analysis of materials subjected to heavy traffic loads showed that the crisis of compared pavements starts from the granular foundation, whose rutting causes the pavement failure. Moreover, the results of rutting and fatigue verifications prove that the stretcher or running bond scheme provides the shortest service life, contrary to the best performances of herringbone bond schemes, which imply an increase by at least 10%–15% of allowable load repetitions. The same trend has been observed varying the blocks thickness, the joints gap, and the bedding sand thickness. The performances of the herringbone bond reflect the fact that the wheel load area affects a greater number of blocks than the other examined configurations: it contributes to a better stress-strain distribution. In the second part of the study, the rational method of FEM and the empirical curves available in the literature for rutting and fatigue calculation allowed the definition of a catalogue for three traffic volumes and three values of subgrade load bearing capacity.

The obtained results are interesting and useful, since they provide an inexpensive procedure for the preliminary design of concrete block pavements to be laid in urban or local roads. Indeed, catalogues are widely used by public administrations because they are easy to be used and, at the same time, their solutions are calculated with rigorous method. The proposed solution could be a valid instrument for design in the preliminary phases of the project, when the input parameters are not yet deeply investigated.

Conflict of interest

The authors do not have any conflict of interest with other entities or researchers.

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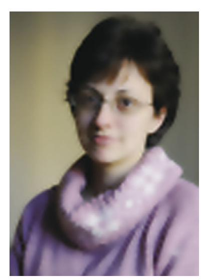

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