Superficial Characteristics and Mechanical Strength Assessment of a Wearing Course made of New Porous Concrete

Agostinacchio M.
Full Professor in the Department of Architecture, Planning and Transportation Infrastructures (University of Basilicata)

Cuomo G.
BEng, MSc, PhD in Road Infrastructures and Transportation (University of Basilicata)

SYNOPSIS

The use of concrete for road pavements in Italy is still relegated to few applications, especially for those situations where a significant bearing capacity as well as high mechanical characteristics are required.
On the contrary, bituminous binders are widely employed for such pavement structures for which excellent performances from the standpoint of smoothness and both drainage and noise reduction are expected.
As a matter of fact, this research tried to study a *porous concrete* wearing course which would guarantee a good behaviour from the point of view of rainfall water drainage, the outstanding mechanical performances of rigid pavements being in any case not jeopardised.
Therefore, the authors made an effort in verifying how, for concrete pavements, both micro and macro texture could be manipulated, starting from the mix design, in order to achieve the above mentioned superficial characteristics.
For this purpose, different measurements were performed on several self-made laboratory porous concrete pavements assessing micro and macro roughness of the surface, and the results were compared to the outcomes of similar structural elements made of stone mastic asphalt SMA, and of draining flexible pavements; furthermore, porosity and permeability of the new material were investigated also.
Last but not least, as a porous concrete could tend to crumble because of the reduced compactness of the matrix, compared to ordinary concrete, the mechanical properties of such structural elements were assessed also.
In particular, compressive strength and impact resistance tests were performed on some porous concrete, plain concrete and SMA specimens, so that any decrease or increase in the performances could be monitored.
The outcomes were impressive, and they gave the proof of the fact that both knowledge and techniques on concrete pavements matters are increasing more and more, most of the prejudices about these structural elements being now anachronistic; the more researchers get into this matter, the higher the safety for users, and the large use of concrete pavement structures in many foreign countries is the evidence of the outstanding performances of this material.

Superficial Characteristics and Mechanical Strength Assessment of a Wearing Course made of New Porous Concrete

INTRODUCTION

The lack of a specific knowledge on concrete roads in Italy for both designers and enterprises have not allowed the development of rigid pavements so far; this tendency does not tally with some advanced countries such as the USA or the Anglo-Saxon world(12) where, on the contrary, these *environmentally friendly* structural elements are widely utilized(7).
The main idea of this research was therefore concentrated on the analysis of a concrete pavement which would well combine the typical features of this typology from the viewpoint of mechanical strength(8) with the classic characteristics of a draining and noise reducing asphalt pavement.
As a matter of fact, the authors decided to pay attention to the mechanical properties of the concrete structure, but also to superficial characteristics such as permeability, with a special interest in both environmental issues and drivers safety.
The first part of the study concerned the analysis of the grading curves which were to be used for the so-called *porous concrete;* after that, several laboratory tests were performed in order to assess both compressive and impact strength (after 7 and 28 days), the outcomes being weighed against the results of an ordinary concrete.
In addition, the superficial characteristics were determined by means of micro and macro-texture tests and porosity analysis for the draining performances assessment.
The effects were compared with both the stone mastic asphalt (SMA) and draining and noise-reducing asphalt pavements values suggested by the Italian Standards, so that an objective evaluation of the real performances would be possible.

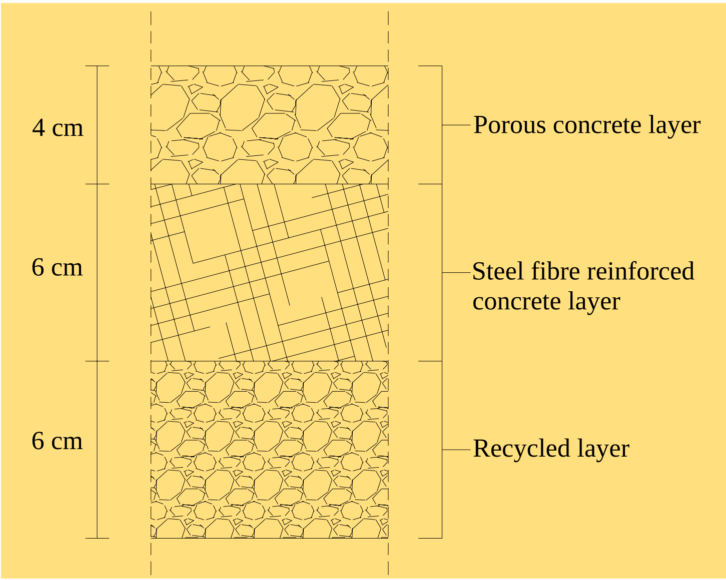


Figure 1: Sketch of the concrete pavement analysed during the research

LABORATORY ANALYSIS

The concrete pavement selected for the above mentioned analysis consisted of three layers (Figure 1) made of different materials, as explicitly mentioned below (from the bottom to the top):

- a concrete admixture lower layer, useful for the levelling of the surface: the aggregates were recycled from the milling of existing asphalt pavements, in order to manufacture an *environmentally friendly* road. Some steel fibres were added into the mix in order to improve the overall mechanical characteristics;

- an intermediate stratum made up of steel fibre reinforce concrete, which was basically the toughest part of the structure[14];
- a cortical layer which would drain rainfalls and, in case, reduce noise propagation: three different mixes were studied for this purpose in order to select the one which would best suit the above mentioned requirements.

In addition, several ordinary concrete specimens were manufactured so as to have some reference values for the mechanical strength results.
As for the mechanical strength, in accordance with the *UNI EN 12390-3/03* Standards, some compressive tests were carried out after 7 and 28 days of seasoning, with the intention of having an understanding of the way the mechanical properties could cope with such a porous material.
Furthermore, following the ACI 544 prescriptions, the impact resistance of the new material was assessed after 7 and 28 days.
The superficial characteristics of the porous pavement were measured by means of micro and macro-texture tests and through investigations with a permeameter on the draining performances of the material itself; besides, some specific trials were carried out to facilitate the overall assessment of the void ratio of the new porous concrete.
Eventually, the outcomes were compared with the results found for stone mastic asphalt specimens, so as to have a clear overview of the overall performances of the new rigid pavement itself.

Materials adopted for the tests

Aggregates
As for the upper draining layer, according to previous experiences on bituminous draining pavements[10], large amounts of basalt were used (76%) for sizes from 4 to 12,7 mm in order to achieve good mechanical properties; for the smaller sizes, calcareous materials were utilized.
The grading curves accomplished for the three different mixes of the cortical layer, named “mix 1” “mix 2” and “mix 3”, showed a highly discontinuous tendency (Figure 2): this characteristic was determined on purpose because of the high porosity expected, the coarse aggregate quantity being therefore larger than the small one.
In addition, one can notice the complete superposition of the three curves for sizes smaller than 4 mm.

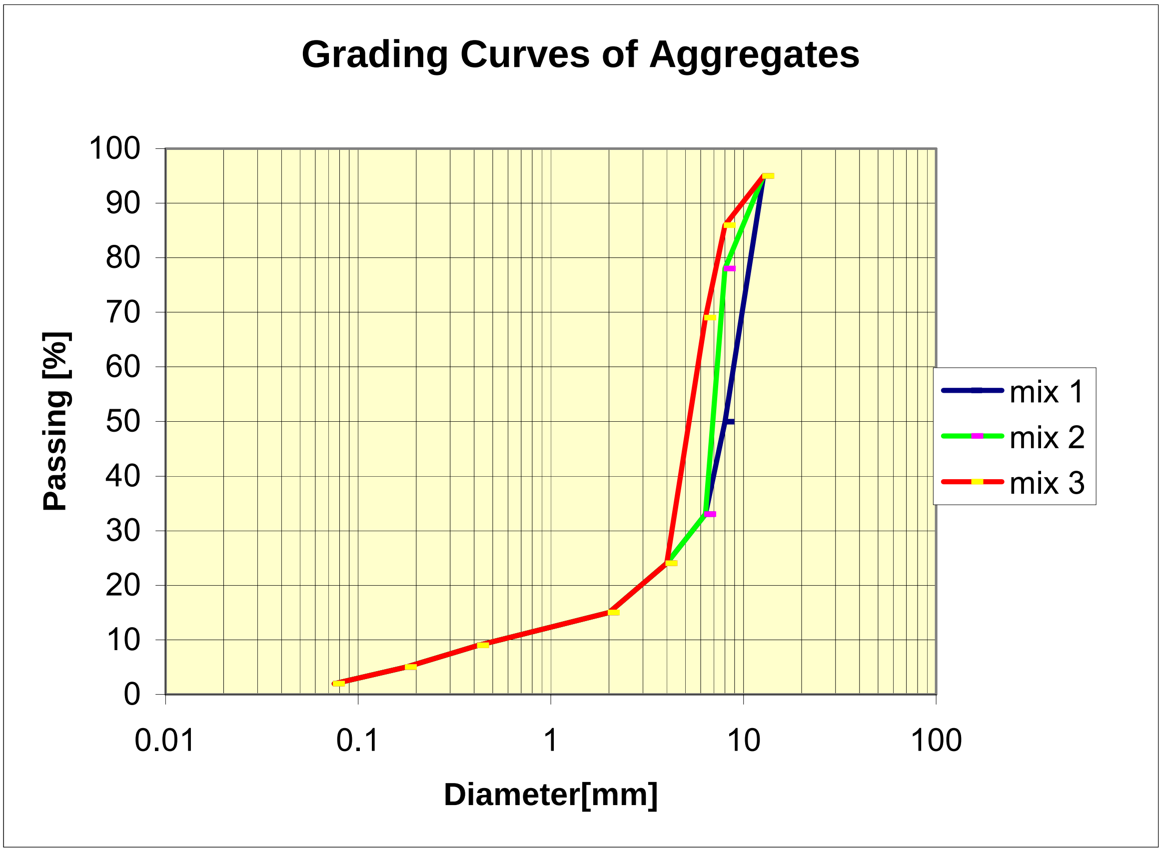


Figure 2: Grading curves of the aggregates for the three mixes used for the draining concrete layer

Table 1: Particle size of the three mixes used for the draining concrete layer

Sieve	mm	MIX 1		MIX 2		MIX 3	
		Passing	Retained	Passing	Retained	Passing	Retained
½"	12,70	95%	5%	95%	5%	95%	5%
10	8,00	50%	45%	78%	17%	86%	9%
¼"	6,35	33%	17%	33%	45%	69%	17%
5	4,00	24%	9%	24%	9%	24%	45%
10	2,00	15%	9%	15%	9%	15%	9%
40	0,42	9%	6%	9%	6%	9%	6%
80	0,177	5%	4%	5%	4%	5%	4%
200	0,075	2%	3%	2%	3%	2%	3%
	filler		2%		2%		2%

Table 2: Aggregates characteristics

	Basalt	Limestone
Absolute gravity [t/m^3]	2,89	2,70
Los Angeles Index	13,5	25

Table 2 shows the characteristic values for the two kinds of materials selected for the mixes:
Furthermore, as already stated, the lower layer of the pavement was made of recycled aggregates coming from the milling of existing bituminous roads.

Concrete
Referring to previous experiences[(1),(3)] and to the British prescriptions of the *Highway Agency Design Manual for Roads and Bridges HD38 ch3*, a 42,5 Portland concrete (Table 3) was employed for the mixes of all the pavement layers: the concrete choice and its dosage were seen as primary for the sake of the research, the role of the binder being fundamental in such a high voids structural element.

Table 3: general features of the cement adopted for every layer

	Property	Mean value
Chemical features	Cl^-	0,04%
	SO_3	2,54%
Physical features	Setting start	105 min
	Expansion	1 mm
Mechanical features	R_{ck} 2 gg	27,9 N/mm^2
	R_{ck} 28 gg	48,3 N/mm^2

Additive
A fluid polymer-based super-plasticizer additive was used in order to ease the concrete workability in presence of such a low water-cement ratio.
Generally speaking, the use of this product drives the hardened concrete to high strength for every seasoning time as well as significant durability, with respect to the *ASTM C-494/86 type "F"* and to the *UNI EN 934-2/02* Standards.
The suggested dosage varies within 0.75 and 2% on the cement weight (0,75÷2,00 litres every 100 kg of cement).
The addition of this product involves also significant improvements for the just poured concrete, and in particular:

- enhancement of workability;
- reduction of the water-cement ratio (up to 20%), the workability being unaltered;

- reduction of bleeding;
- delivery and placing easiness;
- reduction of the cement content, the mechanical strength being the same.

Steel fibres features

Rounded and hocked-end steel fibres were added into the lower recycled layer so as to improve the overall performances of this material[(6), (9)]. The aspect of these micro-elements is represented in Figure 3, while their general characteristics are condensed in Table 4.

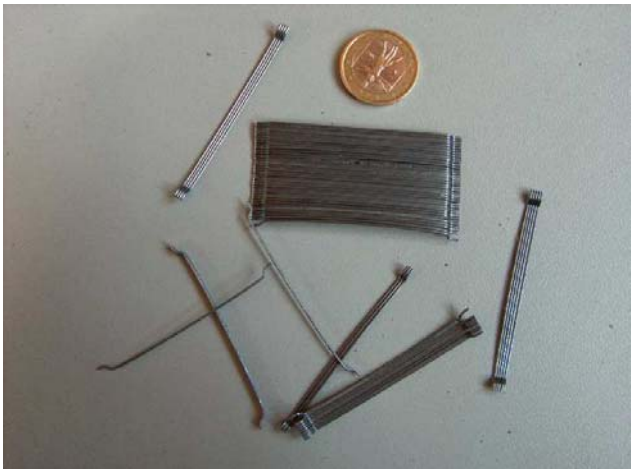


Figure 3: Steel fibres added to the recycled layer

Table 4: Characteristics of the steel fibres

Length	60 mm
Equivalent diameter	0,75 mm
Aspect ratio	80
Section	0,44 mm^2
Tensile strength	1050 MPa
Dosage	30 Kg/m^3

Polymer-modified fibres features

Following some recent studies on the matter[(5)], these fibres (Figure 4), from now on called PMF, were used to strengthen the intermediate layer; in addition, they were also employed into one of the cortical layer mixes, with the intention of having an understanding on how the micro-fibres can influence both the uniformity of the porous mix and the general mechanical characteristics of the specimens.
Table 5 contains all the information on PMF fibres.

Figure 4: Copolymer and polypropylene fibres

Table 5: PMF fibres characteristics

Material	Copolymer/polypropylene
Shape	Monofilament / fibrillated
Acids/salts resistance	Complete
Absolute gravity	0,91 kg/dm^3
Tensile strength	620-758 MPa
Length	54 mm
Equivalent diameter	0,069 mm
Aspect ratio	782
Dosage	20 kg/m^3

Mix Design

The mixes prepared for the different layers were numbered from the top to the bottom, for the sake of the readers understanding, as indicated in the following Figure 5.
In addition, Table 6 includes the dosages adopted for each of the mixes already pointed out:

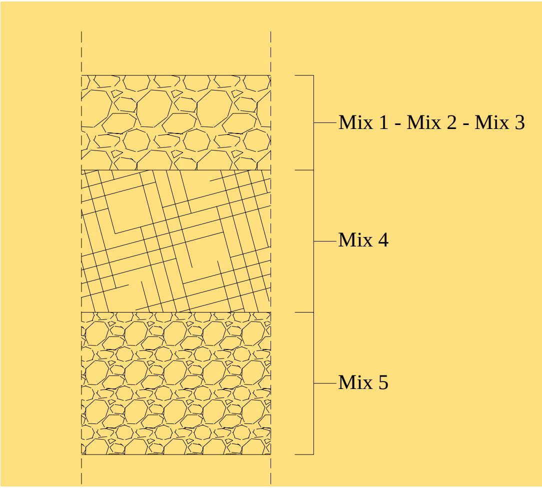


Figure 5: Numbering of the mixes for the different layers of the pavements

Table 6: Dosage of each mix

	MIX 1	**MIX 2**	**MIX 3**	**MIX 4**	**MIX 5**
Cement 42.5 [kg/m^3]	350 (20% on aggregates weight)	350 (20% on aggregates weight)	350 (20% on aggregates weight)	350 (20% on aggregates weight)	350 (20% on aggregates weight)
W/C	0,4	0,4	0,4	0,4	0,4
Additive [on cement weight]	0,75%	1,5%	0,75%	1,5%	1,5%
Fibres [kg/m^3]	-	20 (PMF)	-	20 (PMF)	20 (steel)

Concrete specimens manufacture

Some important considerations were made on the superficial characteristics of the conglomerates manufactured following the above mentioned dosages: the very first impression was that the grading curve of the first mix drove to a too rough surface, the overall compactness of the layer being dramatically jeopardised, as illustrated in Figure 6; moreover, the presence of fibres into the second mix irrecoverably stopped the aggregates from binding to each other, with the consequence of getting to a crumbling material (see Figure 7).

As for the last mix, it showed up as being the best amongst the three, because of the high compactness of the layer, the overall porosity being not reduced. The general aspect of this layer is illustrated in Figure 8.

Figure 6: The aspect of the first mix

Figure 7: The lack of compactness of the second mix

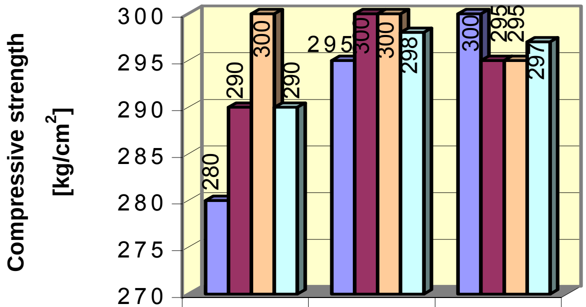
Figure 8: Mix 3 showed the best superficial aspect and compactness

Compressive Strength Tests

Some compressive tests were performed on concrete specimens representing all the three layers (for each of the three pavements), in order to assess the real strength of the structural element in a whole.
As a matter of fact, after 7 and 28 days seasoning at moisture controlled conditions, several cubic concrete samples were tested, whose outcomes, for the sake of brevity, are summarised in Figure 9 and Figure 10.
As one would expect, because of the objective higher weakness of the three cortical layers, compared to the lower ones, all the specimens experienced cracks mostly in the porous concrete layers.
The first, the second and the third sample were obviously based on, respectively, mix 1, mix 2 and mix 3 (upper stratum), the lower layers being the same for each of the structural element.

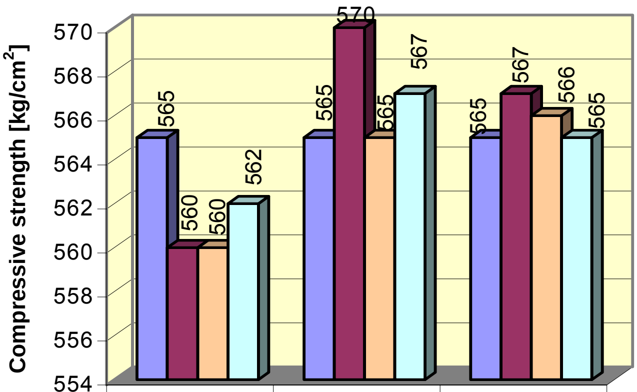
Impact Resistance Tests

The aim of this investigation was the assessment of the elements behaviour against impact, at different seasoning times: these outcomes are interesting because they give an idea of the performances of road pavements when they are exposed to impact loads during their life cycle[(2)].
The *American Concrete Institute ACI 544* prescriptions were followed for the investigation: as a matter of fact, the Marshall hammer was used, a slight change in its framework being needed for the purpose, as illustrated in Figure 11.



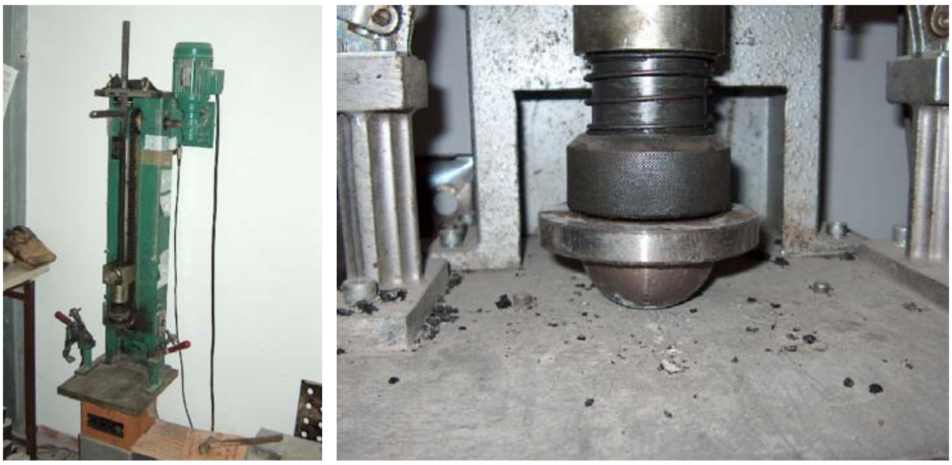
	first pavement	second pavement	third pavement
specimen 1/3	280	295	300
specimen 2/3	290	300	295
specimen 3/3	300	300	295
mean value	290	298	297

Figure 9: Compressive tests after 7 days



	first pavement	second pavement	third pavement
specimen 1/3	565	565	565
specimen 2/3	560	570	567
specimen 3/3	560	565	566
mean value	562	567	565

Figure 10: Compressive tests after 28 days



a) b)

Figure 11: (a) Marshall hammer; (b) Impact maul

After starting the analysis, the following characteristics were measured:

- first crack number of impacts;
- overall width of cracks;
- number of impact for collapse.

The test ended when the specimen broke up or, in case, when the cracks width exceeded 5 mm.

First crack number of impacts after 7 days of seasoning

At this stage, the mix 1 specimens were discarded because of the already mentioned considerations, the analysis being useless for them.

Table 7 embraces the first crack number of impacts after 7 days and the corresponding mean values for each specimen, and the outcomes are compared to the results obtained for ordinary concrete samples during another similar research at the University of Basilicata.

Table 7: First crack number of impacts after 7 days of seasoning

	First crack number of impacts after 7 days		
	Mix 2	Mix 3	Ordinary 42,5 concrete
Specimen 1/3	4	3	4
Specimen 2/3	4	5	5
Specimen 3/3	5	4	5
Mean value	4	4	4,67

From the results above included, one could notice that the presence of fibres did not involve any changes in the overall impact resistance of the draining concrete layer; furthermore, no significant worsening was experienced, from the same standpoint, moving from ordinary (42,5) to porous concrete (mix 2 and 3), and this was an outstanding result from the point of view of the mechanical resistance assessment of the new rigid pavements.

First crack number of impacts after 28 days of seasoning

The same pattern was followed for the long seasoning assessment of the impact resistance of the materials: Table 8 contains the results of the test session after 28 days.

Table 8: First crack number of impacts after 28 days of seasoning

	First crack number of impacts after 28 days		
	Mix 2	Mix 3	Ordinary 42,5 concrete
Specimen 1/3	8	9	10
Specimen 2/3	9	8	9
Specimen 3/3	9	9	9
Mean value	8,6	8,6	9,33

The conclusions are perfectly the same as the short term seasoning ones, the general good pattern of porous concrete from the viewpoint of first crack resistance being therefore confirmed.

Number of impacts for rupture after 7 days of seasoning

In this case a slight increase in the mechanical performances of the fibre-reinforced porous concrete is experienced, as the indicated in Table 9.

Table 9: number of impacts for rupture after 7 days of seasoning

	number of impacts for rupture after 7 days		
	Mix 2	Mix 3	Ordinary 42,5 concrete
Specimen 1/3	10	9	8
Specimen 2/3	8	5	8
Specimen 3/3	9	7	8
Mean value	9	7	8

Number of impacts for rupture after 28 days of seasoning

As for the long term seasoning, the general tendency of the material resistance reflected the effects of the previous case, with a predominance of fibre-reinforced porous concrete.

In any case, these good performances were thwarted by the expulsion of aggregates from the surface: the presence of fibres, indeed, did not allow the coarse aggregates to bind to each other properly, the material being, as a matter of fact, unusable.

Table 10: number of impacts for rupture after 28 days of seasoning

	number of impacts for rupture after 28 days		
	Mix 2	Mix 3	Ordinary 42,5 concrete
Specimen 1/3	18	15	16
Specimen 2/3	15	16	15
Specimen 3/3	15	14	15
Mean value	16	15	15,33

Superficial Micro and Macro Texture Assessment

After the thoughts above exposed, only the specimens belonging to mix 3 were considered for the superficial characteristics assessment of the new porous concrete road pavements.

Micro-texture assessment

This test was carried out following the Italian Standards prescribed by the *"Bollettino Ufficiale del C.N.R. - A. XIX – N.105"*, by means of the "*British portable skid resistance tester*" (see Figure 12).

The outcomes, expressed in BPN (*British Portable Tester Number*) are condensed into Table 11.

Figure 12: Skid resistance tester

Table 11: Micro-texture values

Trial	Swinging	BPN	mean BPN	Temperature	Corrective factor	final mean BPN	total BPN
1	1	78	77	19°C	+1	78	**78**
	2	77					
	3	77					
	4	77					
	5	76					
2	1	79	77	19°C	+1	78	
	2	77					
	3	77					
	4	76					
	5	75					
3	1	79	78	19°C	+1	79	
	2	78					
	3	78					
	4	77					
	5	76					

Macro-texture assessment

As for the macro-roughness measurement (Figure 13), the Italian Standards imposed by the *"Bollettino Ufficiale del C.N.R. - A. XIX – N.94"* were respected, the resulting values of HS being incorporated in Table 12.

Figure 13: macro-texture measurement

Table 12 macro-texture measurement

Trial	D [mm]	HS [mm]	mean HS [mm]	Superficial macro-texture
1	150	1,4	**1,4**	**Very coarse**
2	155	1,3		
3	150	1,4		

Permeability assessment

The assessment of the material porosity was one of the most important aspects of the research: therefore, a measurement of this parameter was performed by means of the water column permeameter represented in Figure 14.
After 5 measurements, the results included in Table 13 were found.

Figure 14: Water column permeameter for the permeability assessment

Table 13: Outcomes of the permeability test

Measurement	Water quantity drained in 5 sec	Water quantity drained in the time unit	Permeability (cm/sec)	Mean value
1	53,5 cl/5 sec	10,70 cl/sec	0,66 cm/sec	0,62 cm/sec
2	49,40 cl/5sec	9,88 cl/sec	0,60 cm/sec	
3	50,26 cl/5sec	10,05 cl/sec	0,62 cm/sec	
4	49,45 cl/5sec	9,89 cl/sec	0,61 cm/sec	
5	49,45 cl/5sec	9,89 cl/sec	0,61 cm/sec	

OVERALL CONSIDERATIONS AND LABORATORY ANALYSIS RESULTS COMPARISON

Grading Curves Comparison

In this section of the work the grading curves of the three different mixes designed for the porous concrete defined so far are compared with the SITEB prescriptions(13), for:

- draining and noise reducing asphalt pavements;
- *twin-layer* draining and noise reducing asphalt pavements;
- stone mastic asphalt pavements.

Comparison with the particle size of a draining and noise reducing asphalt pavement

From a general analysis of all the curves considered for the porous concrete layer, one could easily notice that there was no difference moving from filler to 4 mm aggregates; on the contrary, some changes were experienced for the coarser aggregates, as indicated in Figure 15.

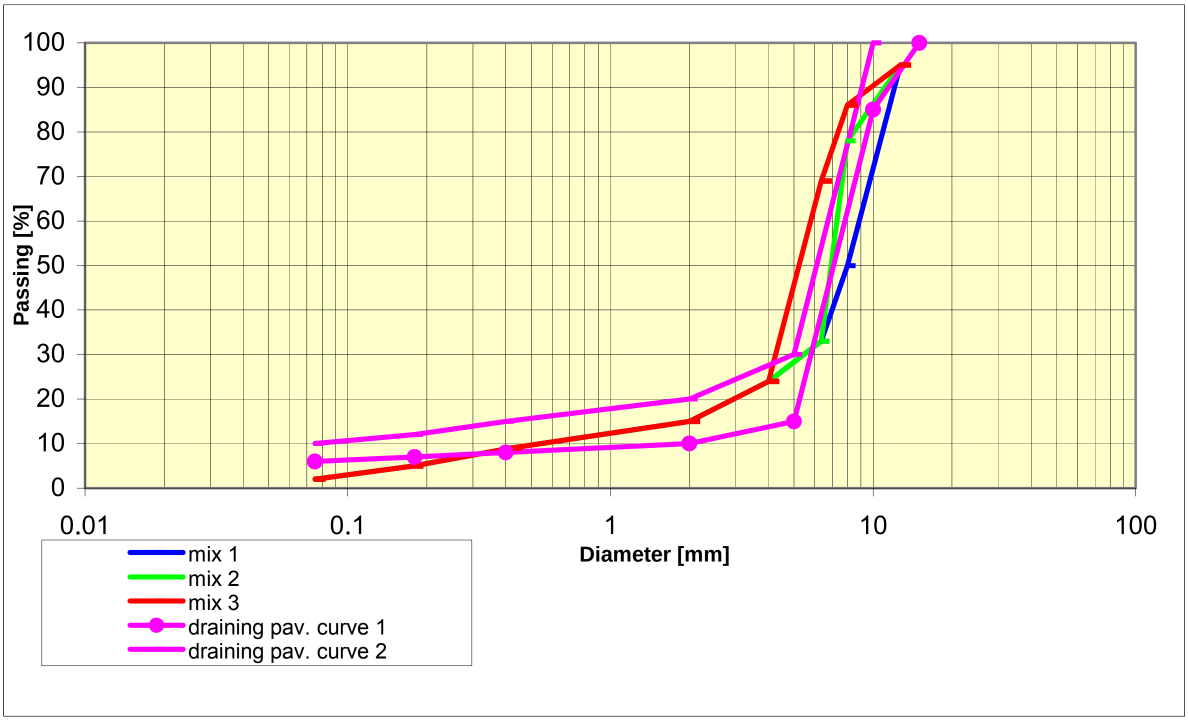


Figure 15: Comparison between the particle size of the three porous mixes and of a typical draining and noise reducing asphalt pavement

<u>*Comparison with the particle size of a twin-layer draining and noise reducing asphalt pavement*</u>

The *twin-layer* asphalt pavement is made of two levels, their particle size being different from each other; the upper layer performs the duty from the standpoint of noise reduction, acting as a filter, while the lower one works a the real draining mean(11).

In this case, as each layer refers to a specific grading curve, the comparison with the porous concrete layers particle sizes has been split in two different charts, as indicated in Figure 16 and 17.

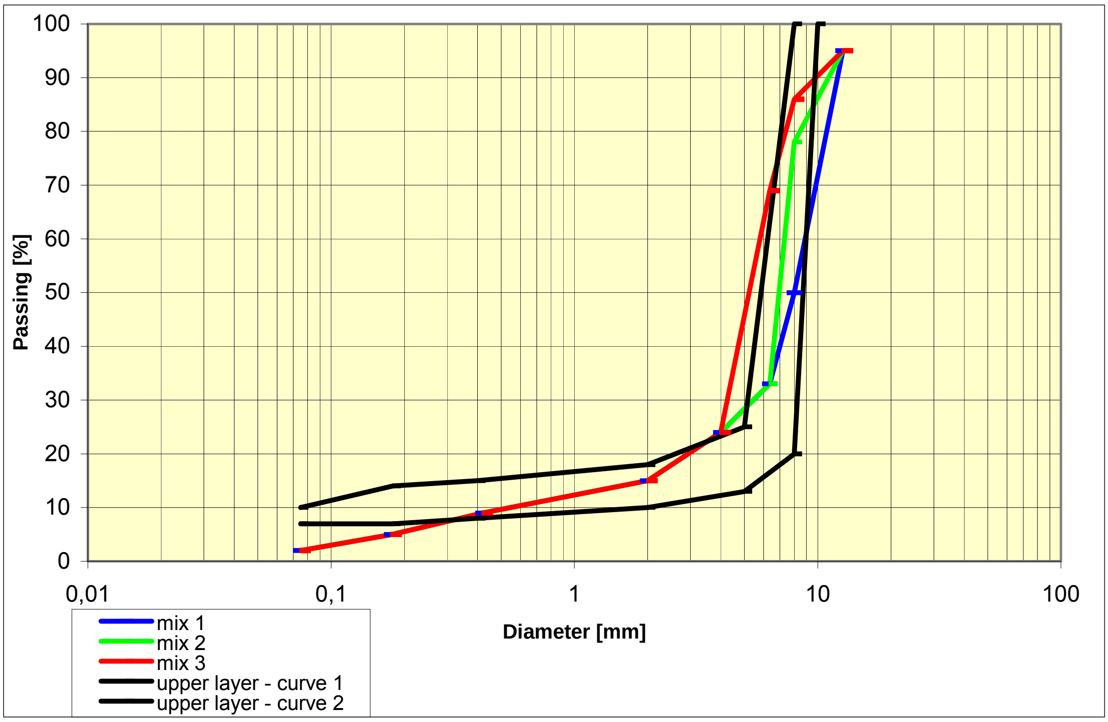


Figure 16: Comparison between the particle size of the three porous mixes and of the upper layer of a *twin-layer* draining and noise reducing asphalt pavement

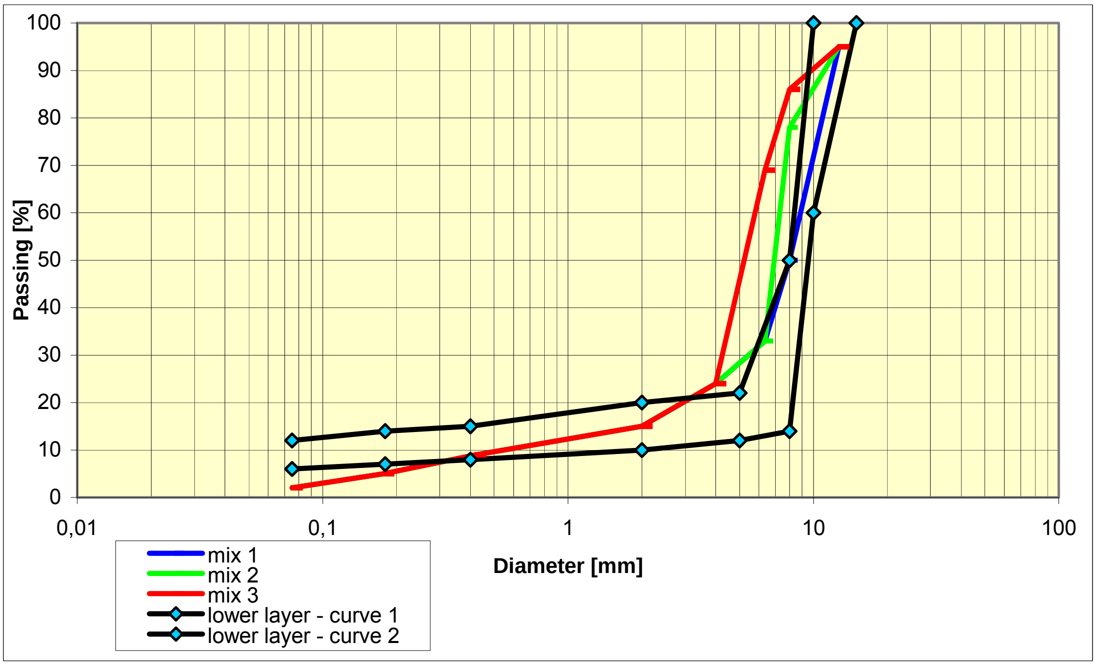


Figure 17: Comparison between the particle size of the three porous mixes and of the lower layer of a *twin-layer* draining and noise reducing asphalt pavement

Comparison with the particle size of a stone mastic asphalt pavement SMA

The differences noticed in Figure 18 belong to the fact that porous concrete and SMA are different materials, as the porosity values are unlike, no matter the similarity in the mechanical properties.

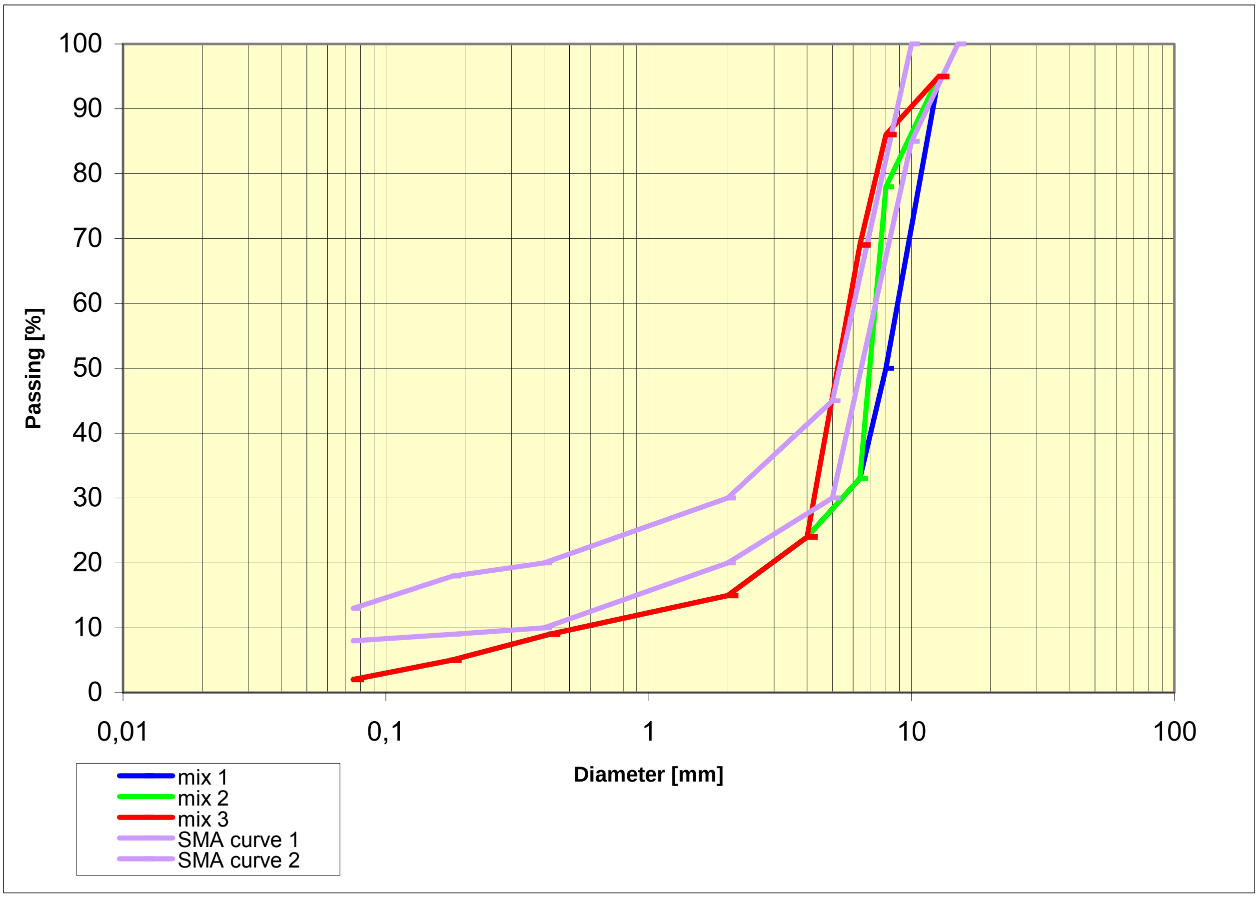


Figure 18: Comparison between the particle size of the three porous mixes and of the stone mastic asphalt pavements

Micro and Macro Texture Comparison

Roughness of a pavement is one of the most important superficial features from the standpoint of both surface regularity and users safety.
As a consequence, in this paragraph all the outcomes of sand height (HS) and British Portable Number (BPN) are included, respectively in Table 14 and 15, with a specific comparison to the SMA results found at the University of Basilicata for two diverse mixes with different quantities of modifier.

Table 14: Superficial macro-texture values for porous concrete and SMA pavements

Material	Sand height HS – mean value (mm)	Superficial macro-texture
SMA 6,5% modified	0,93	Coarse
SMA 7,5% modified	0,98	Coarse
Porous concrete	1,4	Very coarse

Table 15: Superficial micro-texture values for porous concrete and SMA pavements

Material	Temperature	BPN	Mean BPN after ageing
SMA 6,5% modified	>21 °C	40	56
SMA 7,5% modified	19-21 °C	43	58
Porous concrete	19 °C	78	78

Thus, the results of these tests stated that, from the point of view of roughness, the performances belonging to the new porous concrete are far better than those of a traditional stone mastic asphalt pavement.

Comparison with the Norms prescriptions

There are actually no Standards nowadays in Italy on porous concrete pavements which can be adopted in order to understand the validity of the project carried out.
For the sake of the research, therefore, the authors decided to compare the outcomes with the prescriptions of the *Infrastructures and Transportation Minister* regarding the SMA and the draining and noise-reducing concrete pavements.
As the superficial characteristics were the only aspects involved in this assessment, the writers believed this sort of comparison would be correct, a good reference guide for the overall assessment of both micro and macro-texture performances of the new material being for that reason, available.
Table 16 includes the minimum values asked for both HS and BPN for the already cited bituminous pavements, according to the above mentioned Standards, as well as the outcomes of the porous concrete pavement.

Table 16: HS and BPN comparison between porous concrete and the minimum values of prescriptions for SMA and draining asphalt

	SMA pavements	Draining and noise-reducing Pavement	Porous concrete tested
HS	> 0,5 mm	>0,8 mm	1,4
BPN	≥ 65	≥ 55	78

Permeability Values Comparison

Was the concrete pavement going to be permeable enough to be considered a porous material?
This was the hope, and actually some concerns arose during the whole research about the real draining possibility of the new road surface, with respect to mechanical properties.
At the end of the tests session, the outcomes were outstanding as one can understand from the results included in Figure 19, where the permeability values found for the porous concrete pavement are compared with the requirements of the *Infrastructures and Transportation Minister* regarding both the draining and noise-reducing concrete pavements and the superficial bituminous micro-layer.

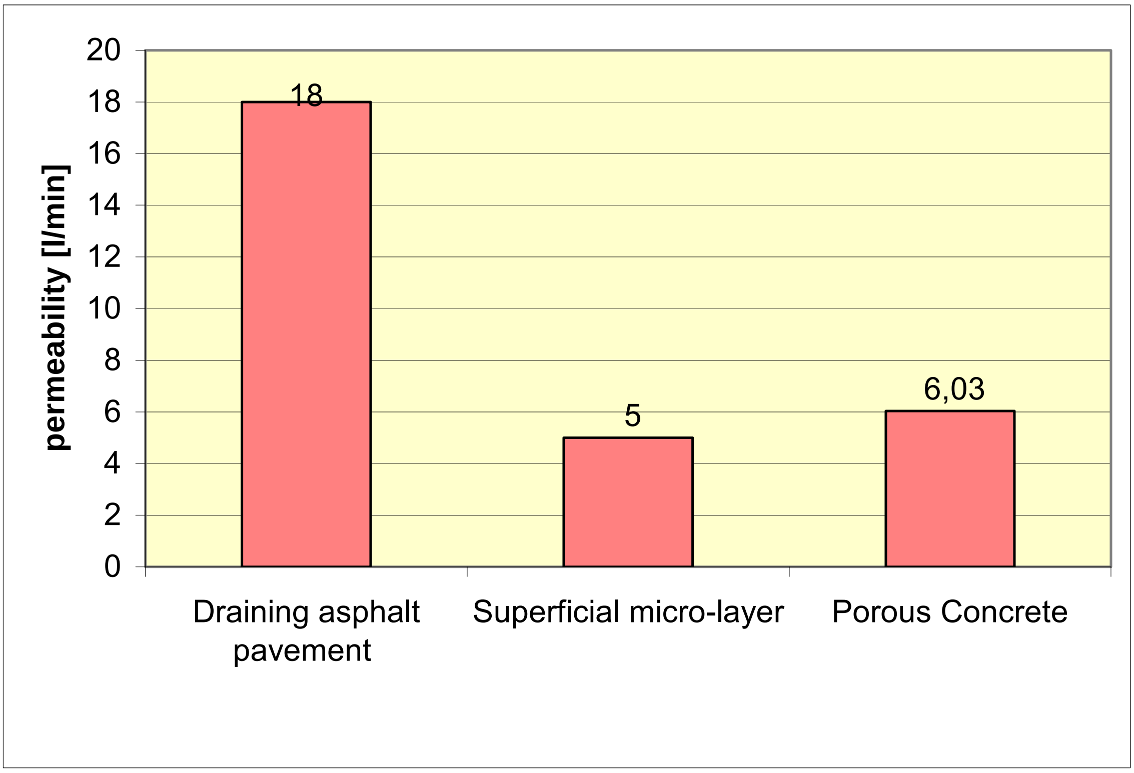


Figure 19: Permeability comparison between draining asphalt, superficial micro-layer and porous concrete pavements.

CONCLUSIONS

This research aimed at the analysis of a rigid pavement which would consider both the typical characteristics of this structural element, from the standpoint of the mechanical strength[(4)], and the distinctive features of draining and noise-reducing asphalt pavement.
Hence, the study of a road pavement with high draining properties was the main purpose, the *safety* and the *environmental* issues being combined in a whole.
In particular, the experimental analysis revealed that both *porosity* and *permeability* are positively influenced by a careful selection of the grading curve, the former getting to outcomes (17%) completely comparable to the corresponding values of a draining and noise-reducing asphalt pavement (18÷20%).
The latter gave positive effects also, the results being better than the similar ones obtained for a bituminous micro-layer normally used for cheap and quick interventions against water accumulation on the road surface.
Additionally, the *micro* and *macro-texture* comparative tests between porous concrete and stone mastic asphalt pavements told that the rigid material involves improvements in the HS values up to 40% compared to SMA , no matter the quantity of modifier used in the bitumen mix.
As for the micro-texture, the BPN results confirmed a similar pattern.
Furthermore, from the standpoint of mechanical strength, the results obtained for the draining concrete material were impressive: both compressive strength and impact resistance were outstanding, especially if compared with the outcomes of an ordinary 42,5 concrete.
As for the micro-fibres, differently from other applications, they revealed as being useless, the coarse aggregates of the concrete matrix finding strong difficulties in combining with them with such low water-cement ratios.
As a matter of fact, the laboratory trials showed that those characteristic which were peculiar of flexible pavements can nowadays be gained by rigid ones as well: in any case, for the success of this process, the careful choice of the draining layer particle size is fundamental, as a certain void ratio is to be achieved for the sake of rainfalls removal from the road pavement surface.
Amongst the others, the grading curve selected at the end of the tests showed up as being very similar to the corresponding one normally used for a draining bituminous pavement, the only diversity between them being made up only by the different binder: cement for rigid pavements, bitumen for flexible ones.
In any case, all that glitters is not gold, as a higher level of aggregates thickening would be desirable for the sake of the overall layer resistance against the friction belonging to vehicles tires.
At the very end of the research, the authors feel like considering the new porous concrete road surface as the link between splittmastixasphalt and draining bituminous pavements, as it could guarantee both safety (reduction of *splash, spray* and *aquaplaning* phenomena) and environmental compatibility, the use of oil products being dramatically cut down, with respect to mechanical strength; in addition, the aspects connected with the supposed reduced maintenance of rigid pavements should be taken into account also.
In any case, the conditional clause is *de rigueur* , as the new material mechanical performances ought to be tested *in situ*, under the real loads coming from the heavy vehicles movement along the road surface.
From this point of view, thanks to the financial support of the ANAS compartment of Basilicata, the authors are keeping on working on these matters, concentrating their efforts on an experimental laying of such a porous concrete pavement, following the most recent tendency of the road construction technique (Smart Road).

REFERENCES

1. Agostinacchio M., Cuomo G. (2004), *"Plastic shrinkage reduction in concrete pavements due to the addition of both steel and polymer modified fibers", CONCRETE Magazine* - Volume 38 – Number 2, Crowthorne, Berkshire, Great Britain.
2. Agostinacchio M., Cuomo G. (2004), *"Assessment of the impact resistance in concrete pavements reinforced with various kind of fibres: a comparison between common steel fibres and new polymer modified fibres", Transportation System 2004 Workshop - Supporting DOD operations Worldwide*, Fort Lauderdale, Florida.
3. Agostinacchio M., Cuomo G. (2004), *"De-icing salts resistance of plain and fibre reinforced concrete road pavements" , Sixth RILEM Symposium on Fibre Reinforced Concrete (FRC) BEFIB 2004*, Varenna (CO), Italy (forthcoming).
4 Agostinacchio M., Cuomo G., Olita S. (2004), *"Finite element and post-crack analysis of fiber reinforced concrete pavement structures" , 9th International Symposium on Concrete Roads*, Istanbul, Turkey.
5 Agostinacchio M., Cuomo G. (2003), *"Polymer modified and steel fiber reinforced concrete pavements : assessment of toughness and residual strength", CONCRETE Magazine* - Volume 37 – Number 8, Crowthorne, Berkshire, Great Britain.

6 Agostinacchio M., Cuomo G., Olita S. (2003), *“Pavimentazioni in calcestruzzo fibro-rinforzato: analisi agli elementi finiti e comportamento post-rottura“, L'Industria Italiana del Cemento* - Anno LXXIII – Numero 785, Roma, Italy.
7 British Cement Association and Britpave (1999), “*Highway Reconstruction: Whisper Concrete in Austria and UK*”, n° 61, Great Britain.
8 Cuomo G., (2003)*“ Utilizzo delle fibre di rinforzo all'interno delle pavimentazioni rigide: tecnologia, modello di calcolo ed analisi sperimentale*”, *PhD Thesis in Roads Infrastructures and Transportation*, Università degli Studi della Basilicata, Potenza, Italia.
9 Cuomo G., West R.P. (2002) , *“Pavimentazioni in calcestruzzo fibro-rinforzato: allineamento delle fibre in campo magnetico”, Enco Material Journal*, Anno VII – Numero 20, Spresiano (TV), Italy .
10 Diomedi M. (2000), “*Ottimizzazione delle miscele di Splittmastixasphalt con riferimento alle diverse normative internazionali*”, X Convegno S.I.I.V., Catania, Italy.
11 Domenichini L., La Torre F. (2002), “*Analisi ed ottimizzazione delle caratteristiche di fonoassorbenza dei manti drenanti doppio strato*”, *Giornata di studio sul bitume stradale*, Auditorium EniTecnologie, Italy.
12 Green J., Jones D. (2001), “Technical Guidance Sheet E2: Quieter Road Surfaces”, Britpave, Great Britain.
13 SITEB (2000), “*Suggerimenti e note tecniche per elaborare un Capitolato d'Appalto per Pavimentazioni Stradali con bitume modificato*”, Seconda edizione, I*taly*.
14 West R.P., Cuomo G. (2001), *“Strength Loss in the Wake of a Steel Cylinder Dragged through a Concrete Slab”, Concrete Reasearch in Ireland – Proceedings of the 2001 Colloquium*, Eamonn P. Cannon Editor, Galway, Ireland.