AN EXPERIMENT WITH POROUS CONCRETE TOP LAYER ON J.C.P.

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SUMMARY

The application of porous asphalt is getting very popular in the Netherlands as it contributes substantially to road-safety and noise-reduction.
After laboratory tests and two small-scale experiments in the Netherlands it can be concluded that the results give support to the statement that porous concrete toplayers are a realistic concept.

INTRODUCTION.

Why there is a need for the development of porous concrete mixtures for road-construction?

Holland is the most densely populated country in Europe. This means that the roads in the west of the country (the urban agglomeration) have very heavy traffic. Traffic jams are the order of the day. The capacity of a road decreases sharply when the surface is wet or when rainwater is sprayed or splashed and moreover it has a negative influence on road-safety. It is for this reason that the decision was taken to provide many of the roads in this region with a top layer of porous asphalt. Another problem is the noise annoyance produced by traffic on roads in densely populated regions.

In addition to the construction of noise-barriers the application of a noise-absorbing top surface is a method to reduce the amount of noise produced by the traffic. Mainly for this reason porous asphalt is getting more popular.

The question arises if it will be possible to make a porous concrete top-layer with a sufficient porosity on a concrete pavement, in order to combine the advantages of cement concrete pavements and porous toplayers. In recent years research has been done in various areas of The Netherlands to discover the source of the noise resulting from the contact between the tyre and road surface. It was discovered that there are two different noise sources. At the first place there is what is called "tyre-rolling noise". This is caused by vibrations of the tyre, due to particular unevenness, especially with wave-lengthes of 40 to 80 mm.

The most important work in this area was carried out by Desconnet (B) who also introduced the idea of a "megatexture" in addition to a micro and macro texture (Fig. 1). It has been established that not only macrotexture causes the tyre to vibrate but also the megatexture which is not directly recognized as an uneveness of the road surface but more like a characteristic feauture due to the finisher.

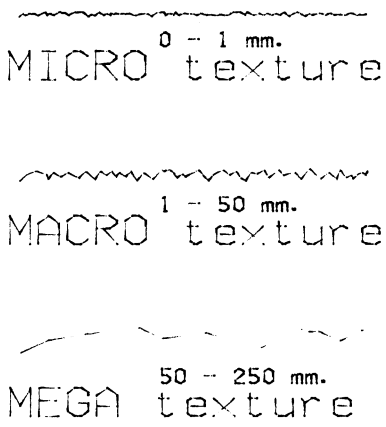

Fig. 1 different textures

The current modern finishing equipment produces a road surface with a smooth megatexture.

The other source of noise is the so called "air-pumping", the expulsion of air between the tyre and the road surface. Here also, the micro and macro textures play an important role. The shape of the texture and the direction in which it is applied may also cause different noise levels and frequencies. In experimental roadsections is has been shown that a texture applied longitudinally results in far less noise production. In additon, considerable noise-reduction is achieved by the application of a thin surface

treatment covered with fine and uniformly graded chips. The same result could also be achieved with a surface of washed-out concrete.

In order to achieve even greater noise reduction it would be necessary, in addition to good mega and macro textures, to make use of the noise-absorbing qualities of a porous road surface. For this reason research has been done into porous concrete mixtures with good durability so that these can be applied on concrete pavements without concessions to be made in the field of service-life, maintenance need, frost and de-icing salts resistance etc.

THE DEVELOPMENT OF POROUS CONCRETE MIXTURES.

After a long period of laboratory pilot research into possible mixtures for porous concrete, the first experimental sections with porous concrete were laid on roads in the Province of North Brabant and the City of Amsterdam in the early summer of 1988. These were areas where the behaviour of the concrete could be observed during varying weather conditions and traffic densities.

Laboratory research was directed towards finding a porous concrete with a void content of minimal 20% and with acceptable compressive as well as tensile strength.

In order to achieve an open structure of the concrete an aggregate skeleton was formed in two different mixtures, one with the use of 4 to 8 mm chips and another with 8 to 11 mm chips. This resulted in a mixture with a limited amount of fine sand 0 to 2 mm (50 to 150 kg/m^3), and cement contents of 300 to 400 kg/m^3.

In order to test the possibility of a raised level of compressive and tensile strength, by adding other materials, experiments were carried out with superplasticizers, silicafume, polymers and colloidal additives. However, all additives only gave a small increase of the compressive and tensile strength.

The maximum compressive strength attainable appeared to be about 30 MPa after 28 days. However, the maximum tensile strength was about 5 MPa after 28 days, which is almost the same value as achieved by normal dense concrete with a characteristic compressive strength over 35 MPa.

This gives rise to the impression that in compressive tests on cubes of porous concrete, different splitting, flexural, tensile and compressive strength values are achieved than in tests on "normal" dense concrete.

This can be observed for instance in the yielding pattern of the test cubes. While in case of a dense concrete a sand-glass shaped crack pattern is seen, in the case of porous concrete there is a highly furcated vertical crack pattern.

It seems obvious that the tensile strength for the assessment of quality can be used for the time being. By observing the practical behaviour it can then be established if this can also be a standard for durability. In addition to the laboratory tests directed towards an optimal quality of concrete, further research was done into the mixtures with the best workability properties.

This additional research made clear that only mixtures with a colloidal additive showed adequate workability. The particular feature of this additive namely is the improvement of the adhesion between the cement/sand mortar and the coarse aggregate so that segregation and leaking is avoided.

TRIAL SECTIONS.

After extensive laboratory tests, it seemed necessary to test the mixtures which came out best in the pilot tests in practice.

Small trial sections had to be made to be anle to observe the workability of the selected mixtures. After that, once the porous concrete was applied to the road, its behaviour under traffic, the draining capacity and the noise-absorption capacity could be observed. At that time Cobeton v.o.f. was carrying out a project for the the Province of North Brabant in the southern part of the Netherlands. In this project a number of cracked and faulted slabs in the old concrete road needed to be replaced.

A location was found where five adjoining slabs over the whole width of the road needed replacement. This gave the opportunity to try out next to each other two different porous concrete mixtures, namely with 4 to 8 mm and 8 to 11 mm aggregates.

EXECUTION.

The length of the trial sections (2 * 30 m) was too short to carry out mechanical processing with a slipformpaver. Therefore this trial section was constructed manually (Fig. 2). As a consequence forms had to be placed and concrete had to be compacted by hand guided vibratory needles and finishing beams.

Since there was no previous experience to use as an example, at least as far as the manual processing of porous concrete was concerned, a trial was carried out at a ready mix plant in the neighbourhood. In this trial, the frequency of the finishing beams could be adjusted to the optimum in order to compact sufficiently.

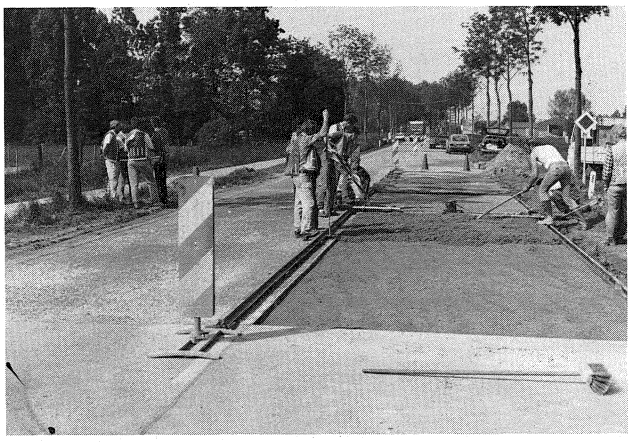

Fig. 2 placing the concrete by hand

In the preceding laboratory tests it had been established that a layer of aproximately 30 to 40 mm porous concrete would be sufficient for optimal drainage and noise absorption. For this reason, it was decided in the first trial section to use an underlayer of normal concrete of 200 mm topped, wet in wet, with a 40 mm layer of porous concrete (Fig. 3). Since first the normal concrete had to be placed over the full 30 meters and after that the porous concrete, it was decided to add a retarding superplasticizer to the normal concrete. This was to avoid the danger of the lower layer of concrete setting before the porous concrete could be placed on top. The drying out of the lower layer of concrete was prevented by covering it temporarily with wet jute after placing.

On the first section the 8 to 11 mm material was applied. The concrete was supplied from a readymix plant at a 30 km distance. Due to distance and rather high air temperature the concrete was setting already by the time it arrived at the site. This caused some troubles because of poor workability. It could be established also that it is not possible to improve the workability by just adding water because the colloidal additive obstructs the mixing of water with the mortar.

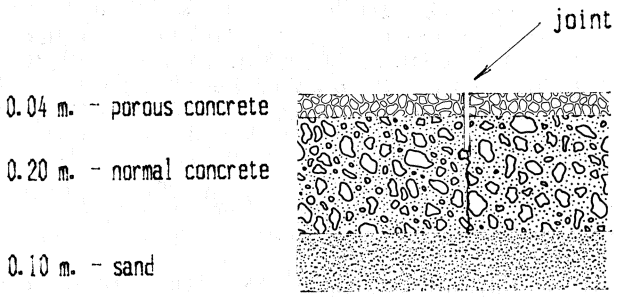

Fig. 3 construction in North Brabant

On the second day it was decided to supply the concrete from a plant in the immediate vicinity of the job and this decision solved the problems above. It has to be remarked that the processing of thin layers like this demands so little quantities of concrete per m² that the volume of the batches has to be adjusted to the progress.

CONCLUSIONS FROM THE NORTH BRABANT SECTIONS.

This trial section provided a lot of information on the processing of porous concrete mixtures. Comparing the two porous concrete mixtures used, it can be said that the mixture with 8 to 11 mm aggregate was more difficult to process than the mixture with 4 to 8 mm. One must take into consideration of course that it is the intention to process these kind of mixtures mechanically with a slipformpaver and that processing will be less critical. The surfacings as constructed were too coarse partly due to the manual processing, especially in the case of the mixture with 8 to 11 mm aggregate and as a result there is assumed to be less noise reduction. A less coarse surface is expected when the work is done mechanically by a slipformpaver.

The drainage effect of the 8 to 11 mm mixture is better than of the 4 to 8 mm. This was expected since the voids in the 8 to 11 mixture are more accessible than those in the 4 to 8 mm mix.

No skid resistance measurements or noise measurements have yet been made on this section as it was only meant for workability tests and performance monitoring.

TRIAL SECTIONS (continued).

The results of this trial section can be described as satisfactory. However, the trial section is situated on a road which is not subjected to high volume traffic and there is a limited amount of truck traffic. This is why it seemed a good idea to make use of these experiences in a second trial section where the porous concrete mixtures, improved slightly, could be exposed to heavy traffic conditions.

An opportunity to do this came at the same time that the sub-committee of PIARC on noise-reducing concrete road surfaces, would meet in the Netherlands on June 2, 1988.

Since it became clear that the Netherlands are pioneering in this field, several authorities, institutions and companies (*) cooperated in order to make it possible to have a trial section under construction by that day. To the great pleasure of the members of the PIARC-committee, who were most impressed by this idea, a suitable location was found in the western habour area of Amsterdam.

TRIAL SECTION IN AMSTERDAM.

The roads in the western habour area of Amsterdam are very busy asphalt roads with a high percentage of heavy truck traffic.

A 60 m long section was found on the right lane of one of a dual carriageway. This lane carries a daily average of about 9,000 axle loads of which 24 % over 2 tons equivalent with 3,500 of 80 kN e.a.l.

Here it was possible to build two adjoining sections of 30 m each with different types of porous concrete. The location was also suited to carry out noise measurements.

CONSTRUCTION.

The existing road surface was broken out. The underlayer of cement treated base did not remain completely intact during the demolition work and therefore the underlayer was filled in with crushed asphalt and compacted thoroughly.

For the traffic loads in this area, a concrete slab thickness of 260 mm was selected for the underlayer with a characteristic compressive strength of 45 MPa and 40 mm porous concrete surfacing. As it was not the aim of the experiment to check design methods the slab thickness was overdesigned deliberately and the contribution of the porous concrete to the bearing capacity was neglected (Fig. 4).

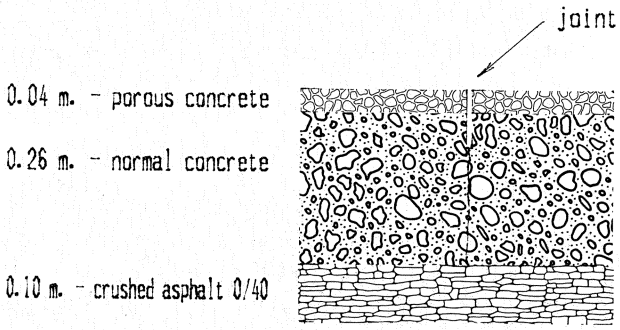

Fig. 4 construction in Amsterdam

Just as in the first trial a retarding superplasticizer was added to the mix for the underlayer in order to achieve proper adhesion between the underlayer and the porous concrete top layer.

Another reason to retard the concrete for the underlayer was the need to cut joints without the risk of spalling and cracking as it was expected that porous concrete would need a far longer curing time before the joints could be sawn. This avoided any risk of cracks in the underlayer appearing before a joint could be sawn without spalling in the upper layer of porous concrete.

In practice it turned out that a joint could be sawn in the porous concrete after approximately 22 hours.

In these trial sections a deliberate choice was made of jointed non-reinforced concrete pavemant in order to be able to observe the behaviour of joints in porous concrete.

Both in North Brabant and in Amsterdam the joints were sawn through the porous concrete and into the concrete underlayer as deep as 1/3 of the total thickness of the concrete underlayer. After the concrete had cured, the joints were filled with a bituminous joint filler.

EXECUTION.

The execution of the trial section in Amsterdam was carried out in the same way as in North Brabant. The concrete underlayer was compacted with vibratory needles

and finished by a twin finishing beam, whilst the top layer of porous concrete was finished with a twin beam only (Fig. 5). The freshly made concrete was treated with a curing compound and covered with wet jute afterwards.



Fig. 5 execution of the trial section in Amsterdam

The composition of the two mixtures in the Amsterdam trial sections was adjusted to some degree following the results of the first test.

	coarse	semi-coarse
aggregate 8-11 mm	1350 kg	
aggregate 4- 8 mm		1350 kg
mortar sand 0-2 mm	50 kg	85 kg
Portland Cement	375 kg	350 kg
colloidal additive	1.3 kg	1.3 kg
water	145 kg	140 kg

Table 1. composition of the two mixtures

Both mixtures showed improved behaviour during processing. But it had to be concluded once again that the surface texture does not show the desired smoothness (Fig. 6). Probably this will be achieved with the use of a slipformpaver, especially when the paver is equiped with a so called supersmoother.

INTERIM RESULTS/CONCLUSIONS SECOND TRIAL SECTION.

The conclusion can be drawn that this test has been very useful in obtaining insight into the application and processing of porous concrete mixtures. The sawing of joints went far quicker than could be expected.

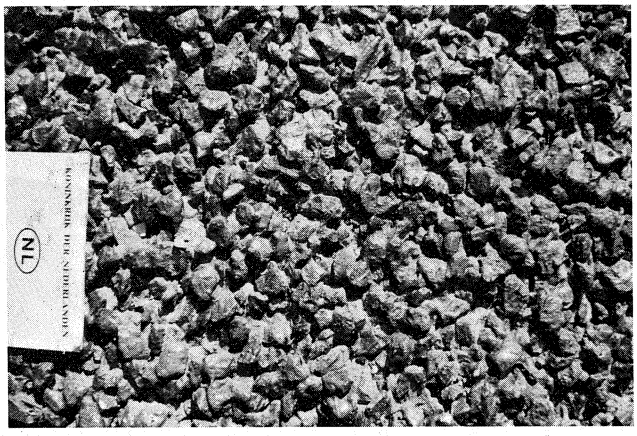

Fig. 6 the porous concrete surfacing

Opening to traffic, as soon as one week after the placing of the concrete caused no problems. No material loss of the surface could be observed so far. This is still the case after several months of use by heavy traffic.

As a matter of fact the coarse surface didn't contribute to noise-reduction. On the contrary. The noise level was measured as 3 to 5 dB(A) higher for a private car and 0 to 2.5 lower for a lorry than on the adjoining dense asphalt surfacing. (see attachment).

The following measurements have been done:

on the porous concrete surfacing:	
-noise-levels (see attachment)	
-eveness	± 3 mm
-skid resistance * (average)	0.77
-porosity	20.5 %
-draining capacity **	11.4 s

* SAAB Friction Tester with 17 % slip
** the maximum for draining surfacings is 80 s. The low value is caused by poor sealing of the rubber gasket of device on the roadsurface.

Table 2. Measured data on surfacing.

on porous concrete samples:	
-compressive strength of porous concrete (average)	30.0 MPa
-flexural strength of porous concrete (average0	4.8 MPa
-adhesive strength of porous concrete (average)	2.3 MPa

Table 3. Measured data on samples.

In the next years will be monitored:

- the drainage capacity over a long period (deposition)
- material loss of porous concrete layer after a long period of use.
- resistance to frost and de-icing salt.
- the long term performance of joints.
- the long term performance of the total construction.

ATTEMPT FOR IMPROVEMENT.

To investigate if a smoother surfacing would show a more satisfying noise-level, the surfacing was milled with a bumpcutter i.e. that about 3 to 4 mm were milled off. Thus the surface looks more or less like it is expected when finished by a slipformpaver. Thus a noise-reduction was obtained of 1 to 1.5 dB(A) compared with the adjoining dense asphalt. It has to be taken in consideration that bumpcutting only approximates the smoothness of the slipformpaver equiped with a supersmoother.

In order to draw definite conclusions that with regard to drainage capacity as well as noise-reduction porous concrete is a realistic concept, more extensive tests in practice are needed, especially concerning the use of equipment like slipformpavers with supersmoothers. But with view on the results of both described tests it can be concluded, that we may be optimistic about the possibilities of the application of porous concrete.

Moreover it is important in such future test sections to investigate the application of porous concrete on different types of cement concrete pavements.

(*) Public Works Department, Road and Hydraulic Engimeering Division; of the Netherlands;

Public Works Department of the Province of Noord Brabant;

Public Works of the City of Amsterdam;

Cobeton v.o.f.;

Mebin B.V.

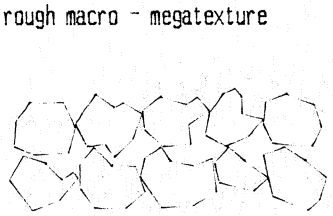

Fig. 7 Placed by hand.

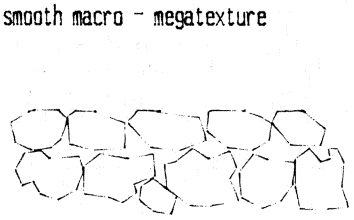

Fig. 8 Placed by slipformpaver



Fig. 9. bumpcut surface with joint.

ATTACHMENT

NOISE MEASUREMENTS ON EXPERIMENTAL PAVEMENTS WITH POROUS CEMENT CONCRETE TOPLAYER

ON THE NORTH SEA ROAD IN AMSTERDAM.
(First Interim Report)

by R.C. Muchall BSc.

Bureau of Sound Affairs
Public Works
City of Amsterdam
november 28, 1988.

(Abstract)

1. INTRODUCTION.

Instructed by the Road Department noise measurements have been carried out on two experimental pavements of which the surfaces consist of porous cement concrete. The purpose was to assess whether more or less noise is produced when either private cars or lorries pass these pavements.

2. EXPERIMENTAL SECTIONS.

Two sections were constructed with porous toplayers:

- one with 4/8 mm aggregate, here indicated as semi-coarse;
- one with 8/11 mm aggregate, indicated as coarse.

Both toplayers have a porosity between 20 and 25 %. As a referene measurements have also been made on the adjoining dense asphalt section of the same road.

3. VEHICLES.

The vehicles used for the measurements were:

P: a private car mark Mitsubishi Galant model 88;

L: a truck mark Mercedes type 1617, loaded with 5000 kg ballast. This vehicle has also been used for several noise measurements on porous asphalt sections.

Evidently it appeared not to be possible to reach higher speeds with the lorry than 60 km/h with engine working and 50 km/h with engine idling, caused by the limited running start length.

4. MEASURING METHOD.

4.1. Installation of apparatus.

At 7.5 m from the centreline of the right lane and about the centre of the measured section a measuring microphone mark B&K type 4165 was installed, connected to a real time analyzer mark Rion type SA 25, with which a number of octave bands were measured simultaneously.

4.2. Sound Exposure Level.

Measured was the average sound level (Leq) during the passage of the vehicle and the length of time of each measurement (T). The results were recalculated to total sound energy per passage, the so called Sound Exposure Level, expressed in dB, according to the formula:

$$SEL = Leq + 10*\log(T)$$

This was done for 8 octaves from 63 Hz to 8 kHz and for the total frequency spectre as well with the use of an A-weighing, expressed in dB(A).

4.3. Measured sections.

The measurements started at the moment the vehicle entered the section and finished when the vehicle left.

4.4. Meteorological conditions.

The weather was rather windy when measuring. It pointed out that the 63 Hz band was dominated too strongly by wind rumble so that no conclusions can be drawn from this frequency band measurements of the lorry. During the passage of the private car this rumble was far less so that for this vehicle there is no restriction.

4.5. Alternatives.

The following alternatives were measured.

P + E 80 km/h private car with engine working;
P - E 80 km/h private car with engine idling;
L + E 60 km/h lorry with engine working;
L - E 50 km/h lorry with engine idling.

5. RESULTS.

The differences of the measured results are given in the tables 1 and 2.

Table 1. Coarse porous concrete - smooth asphalt:

	dB(A)	63	125	250	500	1000	2000	4000	8000
P+E	3.90	3.44	6.92	10.0	8.96	3.2	-2.1	-3.4	-3.7
P-E	4.08	5.58	6.50	10.9	9.68	3.06	-2.3	-4.1	-5.5
L+E	-0.2	1.41	0.36	0.62	0.97	-0.8	-0.6	-0.5	-0.8
L-E	-2.3	-10.0	-0.9	3.32	-0.6	-4.2	-5.4	-5.3	-4.2

Table 2. Semi coarse porous concrete - smooth asphalt:

	dB(A)	63	125	250	500	1000	2000	4000	8000
P+E	2.64	4.68	7.84	11.1	8.06	1.34	-2.7	-4.6	-3.9
P-E	3.26	4.55	7.03	11.8	8.93	1.83	-1.7	-3.7	-4.2
L+E	-0.4	0.53	-0.5	1.60	0.57	-1.0	-1.1	-0.9	-0.8
L-E	-1.6	4.50	4.40	-0.7	-4.1	-4.1	-4.1	-4.4	-2.5

6. ANALYSES.

The following facts can be noticed:

- the deviations of the measurements are rather small, with the exception of the 63 hz band;

- the differences in dB(A) compared to smooth asphalt are:

on coarse porous concrete:

P+E 80 km/h +3.9 dB(A)
P-E 80 km/h +4.0 dB(A)
L+E 60 km/h -0.2 dB(A)
L-E 50 km/h -2.3 dB(A)

on semi coarse porous concrete:

P+E 80 km/h +2.6 dB(A)
P-E 80 km/h +3.3 dB(A)
L+E 60 km/h -0.4 dB(A)
L-E 50 km/h -1.6 dB(A)

- semi coarse as well as coarse porous concrete give an increase of the noise below 1000 Hz. This is probably caused by the relatively strong hitting of the tyres due to the roughness of the surface. Above 1000 Hz there is a better sound absorption resulting in a decrease up to 5 dB(A).

- the influence of the surface on the noise caused by the lorry with working engine is neglectable. The noise of the engine is dominant. In the situation with idling engine the absorption above 500 Hz abolishes the increase of the volume in the lower frequencies. The breaking point of this phenomenon is probably depending of the driving speed and the size of the tyres.

7. CONCLUSIONS.

Coarse and semi coarse porous concrete as rough as it was on the experimental sections cause an increase of the rolling sound in the lower and a decrease in the higher frequencies. The breaking point is different per vehicle and depending of the driving speed. On balance the result in dB(A) can be an increase as well as a decrease of the rolling sound.

8. FURTHER IMPROVEMENTS.

Further decrease of the noise production could be thinkable as the result of closer analyses of the acoustical functions of the road surface and the practical consequences of that. A first step into this direction could be the intended milling of the coarse surface in order to reduce the strong hitting of the tyres to the surface.

FROM THE SECOND INTERIM REPORT.

After the surface of both experimental sections had been milled in order to imitate a surface like it is supposed to be obtained with the use of a slipformpaver with supersmoothers the whole series of measurements was repeated. The results are given in the tables 3 and 4.

Table 3. Milled coarse porous concrete - smooth asphalt:

	dB(A)	63	125	250	500	1000	2000	4000	8000
P+E	-0.5	2.17	1.76	2.89	0.59	0.20	-2.1	-1.4	-2.0
P-E	-1.0	-0.4	0.27	2.73	0.42	-0.0	-2.8	-3.9	-3.6
L+E	1.21	0.57	0.85	1.11	2.26	0.98	1.32	1.51	0.83
L-E	-1.6	1.01	3.50	3.14	0.00	-2.3	-4.0	-3.2	-1.5

Table 4. Milled semi coarse porous concrete - smooth asphalt:

	dB(A)	63	125	250	500	1000	2000	4000	8000
P+E	-1.2	2.66	2.31	1.76	-0.5	-0.5	-2.4	-2.2	-3.3
P-E	-0.6	3.24	0.75	2.67	0.51	0.15	-2.0	-2.9	-4.8
L+E	1.39	1.35	1.09	1.67	2.32	1.24	1.40	1.45	1.25
L-E	-2.3	3.20	3.68	1.89	-0.7	-2.5	-4.5	-4.0	-1.8

Obviously there is a considerable decrease in comparison with the original surface especially in the frequencies above 250 Hz.