DELIVERABLE D3.27 (ALSO D3.21 INCORPORATED)

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Work Package 3.5	**Refine and optimize the road surface** **Road test sections paved with poroelastic road surfaces**
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0 EXECUTIVE SUMMARY

0.1 OBJECTIVE OF THE DELIVERABLE

A recipe for a poroelastic road surface has been developed partly through modelling and simulations in the FEM Software "Comsol Multiphysics" and partly by laboratory studies (including measurements of dynamic stiffness, sound absorption as well as various strength, durability and stability tests etc.). A method has also been developed for impregnating the crumb rubber grains, used in the poroelastic road surface, with bitumen in order that the grains would be saturated with bitumen to prevent the rubber to soak up the binder that keeps the mix together.

A test section 80 m long at Tagenevägen in Gothenburg has been paved with the poro-elastic road surface according to the developed recipe on the 26th of September 2006. The purpose with this test section was twofold:

1) To test the production technique and
2) To measure and characterise the noise benefits from the poroelastic road surface

The measurements were performed on the 26th of October 2006. This delivery presents the composition of the poro-elastic road surface and its production.

0.2 STRATEGY USED AND/OR A DESCRIPTION OF THE METHODS (TECHNIQUES) USED WITH THE JUSTIFICATION THEREOF

Parallel with more theoretical studies the influence of amount and characteristics of components on acoustical and mechanical behaviour of the poroelastic road surface concept are basically studied in a lab scale on plates because of the many variants involved.

An interesting composition has be tested on a small test site.

The work to optimize the composition of the poroelastic road surface will be continued and further small tests may be done before a full scale test road will be made in 2007.

0.3 PARTNERS INVOLVED AND THEIR CONTRIBUTION

Acoustic Control (ACL)

Development of poroelastic road surfaces together with NCC and TRAF. Responsible for measurement of acoustical and mechanical impedances as well as FEM-analysis of binder strain and selection of rubber grain size. Measurements of acoustical characteristics on tests sites of poroelastic road surfaces.

NCC Roads AB (NCC)

WP-leader for WP 3.5. Development of poroelastic road surface together with TRAF and ACL. Responsible for lab tests of road surfaces. Responsible for paving of test surfaces in connection to field tests.

Trafikkontoret Göteborgs Stad (TRAF)

Development of poroelastic road surfaces together with NCC and ACL. Responsible for selection of test sites for field testing of poroelastic road surfaces.

0.4 CONCLUSIONS

A basic design for a poroelastic asphalt pavement, presented in Deliverable D3.18, has been further studied and optimized.

A method in which the rubber grains can be pre-treated with bitumen in order to get better adhesion and wear life has been developed. The method has been tested in full scale with good results.

0.5 RELATION WITH THE OTHER DELIVERABLES (INPUT/OUTPUT/TIMING)

This deliverable in a continuation of Deliverable D3.18.

The results from the noise measurements on the test site of poroelastic road surface presented in this Deliverable is presented in Deliverable D3.26.

1 OBJECTIVES AND SCOPE OF WORK

A recipe for a poroelastic1 road surface has been developed partly through modelling and simulations in the FEM Software "Comsol Multiphysics" and partly by laboratory studies (including measurements of dynamic stiffness, sound absorption as well as various strength, durability and stability tests etc.). A method has also been developed for impregnating the crumb rubber grains, used in the poroelastic road surface, with bitumen in order that the grains would be saturated with bitumen to prevent the rubber to soak up the binder that keeps the mix together. A test section 80 m long at Tagenevägen in Gothenburg has been paved with the poro-elastic road surface according to the developed recipe on the 26th of September 2006. The purpose with this test section was twofold:

3) To test the production technique and
4) To measure and characterise the noise benefits from the poroelastic road surface

The measurements were performed on the 26th of October 2006.

2 RECIPE FOR FIELD TEST

2.1 BASIC DESIGN

A basic design with characteristics as in table 1, has been presented in Delivery 3.18.

Table 1 Basic design.

Aggregate, %		Pre-treated rubber, %, with added bitumen in brackets		Binder PmB20, %
0/4 mm	4/8 mm	0/0,5 mm	0,5/2 mm	
14,5	77	3,8 (35 %)	4,7 (25 %)	7,8

The rubber granulates were pre-treated with emulsion, with the Swedish designation BE50R, which stands for 50 % of bitumen (160/220) content. PmB20 is a SBS-highly modified bitumen from Nynas Bitumen.

2.2 DEVELOPMENT OF RECIPE / INFLUENCE OF PARAMETERS

As there is a sensitive balance between the effect on sound absorption and resistance against wear some more laboratory tests have been performed to further optimize the composition.

Two parameters are being kept fixed from the basic design:

- The maximum aggregate size is 8 mm. This is a compromise between noise reduction effect, which would be better with a smaller size, and wear, resistance, which would be better with a bigger size
- The total amount of rubber is 8,5 %.

The variables that have been tested at this stage are rubber granulate grading/size, pre-treatment of rubber, binder type, binder content and aggregate grading.

The tools for this have been mainly the same as presented in Delivery 3.18, namely acoustic and mechanical tests on plates. The tests methods used for evaluating wear resistance and referred to in the following are presented in chapter 2.4. The results from the analysis are presented under respective heading below and a summary of the composition of the different mixtures/plates is presented in chapter 2.4.1.

2.2.1 Rubber granulate grading/size

If the rubber grain size is bigger than the average binder film thickness, then it is believed that the binder film would not completely cover the aggregate, resulting in poor adhesion.

The basic design contained maximum rubber granulates of 2 mm, but results from FEM-calcutions (see D3.18) shows that stresses will be less if the maximum size is lessened, and e.g. for a mix with aggregate maximum size of 8 mm and a bitumen content of 8

%, the rubber grain size should be about 1 mm. Some plates have now been made with this finer grading to validate the calculations.

Table 1 Influence of rubber granulate maximum size on wear resistance

Plate	Rubber granulate maximum size mm	Cantabro test – Wear cm^3	
		Dry	Wet
10	2	7,5	14,3
14	1	5,8	11,7

Decreasing the rubber granulate maximum size from 2 to 1 mm seems to give a better resistance to wear, but at the same it can be seen that the void content is decreased as well, which will have a decremental effect on noise reduction. The void content should be increased to the wanted 20 % by a change in the aggregate grading (see chapter 2.2.4).

2.2.2 Pre-treatment of rubber granulates

It has been found that rubber can absorb large quantities of bitumen. This process is very slow in normal outdoor temperatures, but will be clearly visible after some months. The amount of binder left "free" in the mix is then not enough to provide the necessary strength.

That a high bitumen content in the pre-treatment of the rubber is important is shown in a comparison in a wear test (Cantabro test and). The only difference between plate 8 (se Delivery 3.18) and 10 is the pre-treatment of the rubber granulates, which in average is doubled from about 7 to 15 % bitumen content.

Table 3 Influence of bitumen content in pre-treatment on wear resistance

Plate	Total binder content in the rubber %	Cantabro test – Wear cm^3	
		Dry	Wet
8	7	12,0	17,2
10	15	7,5	14,3

A high bitumen content in the pre-treatment process has an disadvantage in the following process of adding the rubber/bitumen mix. This problem seems to have been solved by shredding with an ALU-loader (see chapter 3.2), why the bitumen added to the rubber in the field test will be increased to about 17 %.

2.2.3 Binder content

It is understood that the binder content has a great influence on the durability and wear resistance of the pavement. A comparison for wear resistance, the Cantabro test, between a mix with the 7,8 % of binder as in the basic design and a mix with lower binder content 7,4 %, everything else the same, gives results as shown in table 4.

Table 4 Influence of binder content on wear resistance

Plate	Binder content %	Cantabro test – Wear cm^3	
		Dry	Wet
10	7,8	7,5	14,3
11	7,4	16,7	39,6

This shows very clearly the importantance of using a high bitumen content in the mix, but at the same time earlier experience has shown that a still higher binder content does not seem to be beneficial as this makes the mix too soft and sticky. This means that the binder content for the field test recipe is set at 7,8 %.

Note. The bitumen added to the rubber in the pre-treatment process is not included in the binder content in the final asphalt mix mentioned above.

2.2.4 Aggregate grading

Changing the maximum rubber grain size from 2 mm to 1 mm has an influence on the void content of the compacted mix. The void content will be lower, which is the reason why the plates 12 and 13 had to be cancelled as the mass in the plate form became to small to give a good enough compaction. This means also that some of the noise reduction effect will be lost. To compensate for this the aggregate grading will have to be more open as the aim still is to have a void content of about 20 % (accordiing to EN 12697-29 Determination of the dimensions of a bituminous specimen).

A comparision has been made with a rubber granulate maximum size of 2 mm (see table 5) and different aggregate gradings (see chapter 2.4.1). The tests on plate 16 and 17 show that opening the aggregate grading too much (plate 17 and 18) will have a negative effect on the wear resistance. The wear of the mix is very sensitive of the void content.

As a compromise the mix-recipe for plate 16 will be used for the field test.

Table 5 Influence of aggregate grading (void content) on wear resistance

Plate	Void content % EN 12697-29	Cantabro test – Wear cm³	
		Dry	Wet
10	19	7,5	14,3
16	18,5	7,1	12,8
17	21,1	12,7	22,4
18	21,5	16,1	28,5

2.2.5 Model used for determination of void content

The air voids content of a bituminous specimen is calculated using the maximum density of the mixture and the bulk density of the specimen.

In the European Standard EN 12697-08 "Bituminous mixtures - Test methods for hot mix asphalt - Part 8: Determination of void characteristics of bituminous specimens" the following terms and definitions are used:

- *air void* = pocket of air between the bitumen-coated aggregate particles in a compacted bituminous specimen
- *air voids content* (Vm) = volume of the air voids in a bituminous specimen, expressed as a percentage of the total volume of that specimen
- *maximum density* (ρ_m) = mass per unit volume without air voids of a bituminous material at known test temperature

- *bulk density* (ρ_b) = mass per unit volume, including the air voids, of a specimen at known test temperature.

The air voids content is calculated as follows:

$$V_m = \frac{\rho_m - \rho_b}{\rho_m} \times 100 \quad \% \text{ (v/v)}$$

The maximum and the bulk density can be determined in three and five different manners respectively. The suitability of these procedures for a specific bituminous mixture is mixture-dependent, i.e. that especially the bulk density and the voids will be defined by respective method. Below the principle difference between methods are described.

Maximum density

The maximum density is determined by methods given in:

- EN 12697-05, "Bituminous mixtures - Test methods for hot mix asphalt - Part 5: Determination of the maximum Density".

According to this standard as described in Annex A (informative): "General guidance on selection of a test procedure to determine the maximum density of bituminous mixtures", there are three procedures for determining the maximum density of a bituminous mixture (voidless mass): a volumetric procedure, a hydrostatic procedure and a mathematical procedure.

The difference between the hydrostatic procedure using water and the volumetric method using solvent is described as follows:

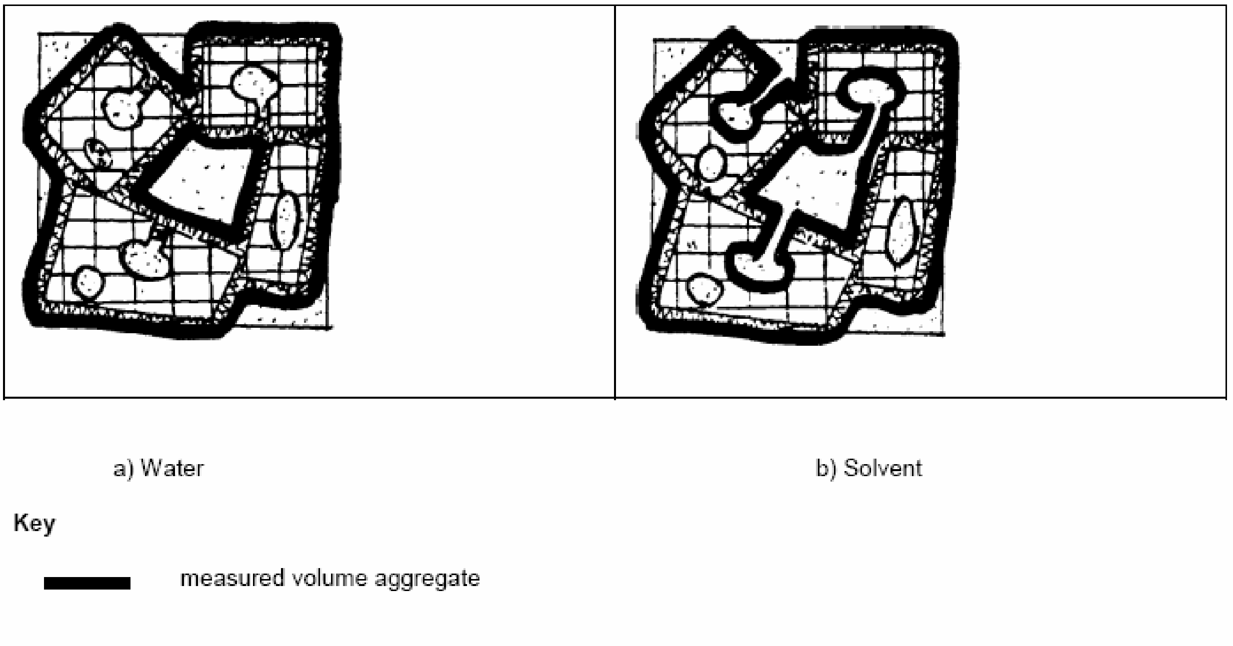


Figure A.1 — Aggregate voids in a bituminous mixture

In the volumetric and hydrostatic procedures de-aired water at ambient temperature should be used. One advantage of using water is that no hazardous mixtures are used.

A second advantage is that the density of water is less temperature susceptible than that of organic solvent, which means that the temperature control during the test execution requires less effort. A third advantage is that the accessible air voids in the aggregate beneath the binder film occurring when porous aggregates are used are determined as part of the volume of the aggregate, see Figure A.1.

> NOTE 1 Figure A.1a): When using water the bitumen film on the particle surface remains intact, the accessible voids in the aggregate remain closed for the water.
>
> The accessible voids are incorporated in the volume of the aggregate. Technologically this is preferable as from that point of view only the voids between particles are relevant.
>
> NOTE 2 Figure A.1b): When using solvent the bitumen film on the particle surface is removed, the solvent will penetrate the accessible voids in the aggregate. These voids are now determined as being part of the voids between the particles, which results in unrealistic values for e.g. voids in the mixture, voids filled with binder etc.

One disadvantage of using water is that not all voids between coated particles can be accessed by the water and that voids that can occur beneath the binder film due to bad coating are also be included as part of the volume of the aggregate, see Figure A.2.

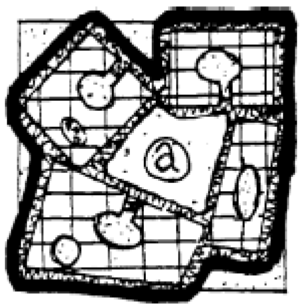


Figure A.2 — Voids between particles (a) to be accessed

In particular, this can occur with mixtures which readily cohere in loose form. In that case the evacuation of entrapped air can be facilitated by either applying a partial vacuum, by using boiling (hot) water or by using an organic solvent. Additionally evacuation can be facilitated by stirring, vibrating and/or rotating. A small amount of dispersion agent can be applied.

It should be noted that when using an organic solvent the volume of voids consisting of accessible pores in the aggregate is included in the volume of voids between the particles. Another disadvantage of using such a solvent is that the test result might be less accurate because of the relatively large temperature susceptibility of such a mixture. Furthermore, hazardous mixtures are being introduced.

Bulk density

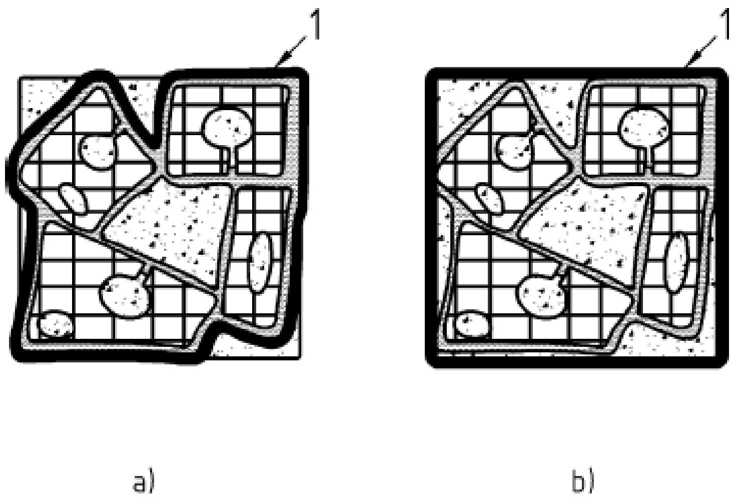
The bulk density is determined by methods given in:

- EN 12697-06, Bituminous mixtures - Test methods for hot mix asphalt - Part 6: Determination of bulk density of bituminous specimens. In this standard four alternatives are given: a) bulk density — dry (for specimens with a very closed surface); b) bulk density — saturated surface dry (SSD) (for specimens with a closed surface); c) bulk density — sealed specimen (for specimens with an open or coarse surface) and d) bulk density by dimensions (for specimens with a regular surface and with geometric shapes, i. e. squares).
    - The alternative d) refers to: EN 12697-29, Bituminous mixtures - Test methods for hot mix asphalt - Part 29: Determination of the dimensions of bituminous specimen.
- EN 12697-07, Bituminous mixtures - Test methods for hot mix asphalt - Part 7: Determination of bulk density of bituminous specimens by gamma rays.

According to the standard Part 6 as described in Annex A (informative): “General guidance on selection of a test procedure to determine the bulk density of compacted bituminous mixtures”, there are four procedures (besides by gamma rays) for determining the bulk density of compacted bituminous mixture: three hydrostatic procedures and one measuring procedure.

The difference between procedures is described as follows:

The main issue in selecting a procedure for the determination of the bulk density of bituminous materials is, whether the voids in the specimen surface are taken into account as a part of the specimen volume sufficiently precisely. The ideal procedure takes into account exactly those voids that are part of the volumetric material composition, but neglects those voids that occur as specimen irregularities due to the specimen preparation method.



Key

1 ——— : Boarders of measured volume

Figure A.1 — Voids in the specimen

Figure A.1 a) shows the effect of procedures A and B: As the water penetrates the surface voids, they are not seen as a part of the volume of the specimen. In this case a relatively low volume a relatively high bulk density will be calculated. This is correct if the surface voids do occur e.g. due to the specimen preparation method or due to sampling defects. However this is not correct in the case of a coarse bituminous mixture with a high voids content: The voids being an intrinsic part of the mixture are not validated. In that case the obtained mixture density is not representative for the produced material.

NOTE When the pores are wide, the water will leave the specimen after taking it out of the water bath. The negative effect will be less severe; however in that case the accuracy of the procedure will be reduced as the handling of the specimen because the test operator activities will have an increased influence on the test result.

Figure A.1 b) shows the effect of procedure D: The volume is obtained via measuring the dimensions of the specimen which means that all surface voids are incorporated in the specimen volume. This thus leads to a relatively high specimen volume or a relatively low bulk density. This procedure will be correct if the surface voids are an intrinsic part of the bituminous material.

An intermediate result is obtained when the specimens are sealed (procedure C): Part of the surface voids will be measured as belonging to the specimen volume, part of the voids will be excluded from the specimen volume. This procedure theoretically will provide the most realistic results; however due to practical operational problems, the increased complexity of this procedure (which is not relevant to all materials) and costs, this procedure is not applied in all cases.

To select a procedure for a specific situation the following guidance is given:

a) Procedure A: Bulk density – Dry Procedure A is suitable for measuring the bulk density of very dense, practically non-absorptive bituminous specimens. It is a quick, easy method and is, for example, particularly convenient for many dense laboratory prepared specimens.

The applicability of the procedure is related to the specimen surface texture and the accessibility of internal voids of the specimen: the specimen should be smooth, the internal voids should be difficult to access.

This procedure is suitable e.g. for hot rolled asphalt (smooth specimen, relatively very fine pores) and for mastic asphalt (almost no accessible pores).

b) Procedure B: Bulk density – SSD Procedure B is suitable for measuring the bulk density of dense-graded bituminous specimens having a low water absorption level or a slow drainage of absorbed water.

Extreme care should be taken in achieving the saturated, surface dried state of the specimen. An excess film of moisture on the surface will lead to an under-estimation of the bulk density and thus to an over-estimation of the voids level in the specimen or an under-estimation of the level of voids filled with binder. Excessive drainage of water will lead to an over-estimation of the bulk density and thus to an under-estimation of the voids level of the specimen.

The applicability of this procedure is related to the voids level and the diameter of the pores: for continuously graded materials such as asphalt concrete (with relatively small pores) with voids contents up to approximately 5 % (v/v), for materials which give rise to large diameter voids in the specimen (e g. stone mastic asphalt) up to approximately 4 % (v/v).

c) Procedure C: Bulk density - sealed specimen Procedure C is suitable for measuring the bulk density of bituminous specimens with air voids levels up to 15 % (v/v). The method however is less convenient to conduct than either procedure A or B and is therefore rarely used.

In the case of testing laboratory prepared specimens with a rough surface texture, certain sealing materials (e. g. foils) cause observation of texture voids as internal specimen voids, which may cause an under-estimating of the specimen density or an over-estimating of the air voids level of the specimen. Other sealing materials (e. g. paraffin wax) might penetrate into the internal voids of the specimen, leading to an over-estimation of the bulk density and thus to an under-estimation of the air voids level of the specimen.

This procedure is not suitable for reclaimed asphalt because it cannot be excluded that it contains water.

d) Procedure D: Bulk density by dimensions Procedure D is suitable for measuring the bulk density of bituminous specimens whatever the voids content may be. Specimens should have a regular surface and a geometric shape to facilitate the measurement of their dimensions. Procedure D described in this European Standard is suitable for void contents greater than 15 % (v/v). Also in this procedure the surface texture voids are considered as part of the internal specimen voids, which may cause an under-estimating of the specimen density or an over-estimating of the air voids level of the specimen.

This is especially significant when laboratory prepared specimens (not sawn or cored) are being tested.

Procedure D is particularly applicable to porous asphalt.

Selected methods for definition of voids in a poroelastic asphalt pavement

Most suitable methods for defining the void contents of a poroelastic asphalt pavement will be

- Maximum density: EN 12697-05, "Bituminous mixtures - Test methods for hot mix asphalt - Part 5: Determination of the maximum Density" – the hydrostatic procedure.
- Bulk density: EN 12697-06, Bituminous mixtures - Test methods for hot mix asphalt - Part 6: Determination of bulk density of bituminous specimens. Alternative d) bulk density by dimensions (for specimens with a regular surface and with geometric shapes, i. e. squares).

2.3 METHODS OF ANALYSIS

2.3.1 Samples / Lab plates

Lab plates are used for testing at one hand for dynamic stiffness and sound absorption and at other hand for resistance against wear.

The plates are produced by compacting laboratory mixed mixtures in a mold with a small roller (se figure 1). The plates are normally 40 mm thick and have a dimension of 500 x 500 mm.

Manufactured plates are listed in table 2.

When manufactoring plates with mixes composed of pre-treated rubber granulates and polymermodified binders sometimes there will be practical problems, e.g. the mix will stick to the roller. This means that some of the plates will have to be cancelled from further testing and therefore remade (see table 4). The rubber granulates have after pre-treatment been stored for at least 1 month at ambient temperature.

Table 4 Composition of lab plates.

Plate no	Aggregate grading [2)]	Binder type [1)]	Rubber granulates [3)]				Note
			0/0,5 mm		0,5/2 mm		
			Mix	%	Mix	%	
9	Basic design	*PmB20*	*7*	*3,8*	*5*	*4,7*	*Cancelled*
10	Basic design	PmB20	7	3,8	5	4,7	
11	Basic design	PmB20	7	3,8	5	4,7	
12	Basic design	*PmB20*	*7*	*3,8*	*11*	*4,7*	*Cancelled*
13	Basic design	*PmB20*	*7*	*3,8*	*11*	*4,7*	*Cancelled*
14	Basic design	PmB20	7	3,8	11	4,7	
15	Basic design	PmB20	7	3,8	11	4,7	
16	See below	PmB20	7	3,8	5	4,7	
17	See below	PmB20	7	3,8	5	4,7	
18	See below	PmB20	7	3,8	5	4,7	

1) The bitumen content is the same (7,8 %) with one exception, plate 11 (7,4 %).

2) The aggregate grading has been the same for plates 9 to 15 (basic design): 14,5 % 0-4 mm and 77,0 % 4-8 mm. Note that these figures stand for added fractions, i.e. including over- and undersized material. Plate 16 and 17 have another grading as follows (the rubber content is the same 8,5 %)

Plate	Aggregate %		
	Filler	0-4 mm	4-8 mm
16	6,5	3,5	81,5
17	7,0	0	84,5
18	6,6	1,8	83,1

3) Bitumen content of pre-treated rubber

Mix	Rubber granul. size mm	Bitumen residual %
5	0,5-2	13
7	0-0,5	17
11	0,5-1	13

The plates have been tested for wear (see chapters 2.2.1 to 2.2.4). Methods for wear resistance are presented in chapter 2.4.2.

2.3.2 Resistance against wear

A critical parameter for the poroelastic asphalt pavement is the resistance against wear. To evaluate this characteristic, three methods have been considered:

1) Wear resistance in accordance with EN 12697-17 Particle loss of porous asphalt specimen, the Cantabro test.

   Particle loss is assessed by the loss of mass of porous asphalt samples after turns in the Los Angeles machine.

   Even if it is not normally part of the test it will also be performed after conditioning in water in accordance with EN 12697-12 Water sensitivity.

2) Wheel tracking test (rutting test) run dry and in water.

   The susceptibility of bituminous materials to deform is assessed by the rut formed by repeated passes of a loaded wheel at constant temperature. Equipment: APA (Asphalt Pavement Analyzer).

3) Wear resistance in accordance with EN 12697-16 Abrasion by studded tyres - Part A, the Prall test.

   A cylindrical specimen having a diameter of 100 mm and a length of 30 mm is brought to a temperature of 5 °C. The specimen is worn by abrasive action during 15 min by 40 steel spheres. The loss of volume in millilitre is recorded and is reported as the abrasion value.

Samples for the tests are cored or sawed from lab plates (see 2.4.1).

Method 1, the Cantabro test, has been the main method used for testing for wear resistance.

Method 2, the wheel tracking test, is more a test for stability characteristics and has so far only been used in a limit extent.

Method 3, the Prall test has after some initial testing been cancelled as it is found to be not quite suitable for highly elastic mixes.

3 PRE-TREATMENT OF THE RUBBER GRANULATES WITH BITUMEN

With a high amount of rubber in an asphalt mix this will with time become very dry even if the added amount of bitumen is enlarged from normal content. The reason for this is an interreaction between rubber and bitumen which is not fully understood. It might be a transport of bitumen into cracks and pores in the rubber granules, a chemical reaction or a combination of both. To avoid this drying up of the mix a pretreatment of the rubber with bitumen might be a solution. This process involves several steps such as mixing, storing and disintergration of eventually built up clumps.

The following criteria should be fulfilled:

- The rubber granulates should be saturated with bitumen
- It must be possible to handle the mix and the required storage time and the time and effort for making powder of the pre-treated rubber granulates shall be short and as simple as possible
- The disintegration must be such that the rubber/bitumen mix can be exactly metered for the production of the asphalt mix

3.1 PRETREATMENT OF RUBBER GRANULATES

When freshly mixed the mixture of rubber and bitumen (e.g. added as emulsion) will stick together in clump that is very difficult to disintergrate. Even if it is worse with a high content of bitumen it is also difficult with low bitumen content. But as mentioned above with time the rubber will 'consume' the bitumen and the will get dry and more easy to disintergrate. With low bitumen content it seems to be a question of weeks, but with high content of bitumen it is a question of months.

As described in D3.18 two different possible ways of pretreatment have been tested: With bitumen emulsion or with foam. The performed tests have shown that mixing rubber granulates with emulsions works better with the tested bitumen qualities (penetration bitumens 70/100 or 160/220), in that the rubber/bitumen mix after pretreatment with the foam technique will give a harder more difficult to handle product.

It is important to find a good compromise between saturation, without surplus, and a realistic storage time. Practical studies give so for a good operational solution as

- Saturation of the rubber granulates by adding about 20 % of bitumen (40 % of bitumen emulsion with content of 50 % bitumen) if the grading is 0-0,5 mm. If the grading is 0,-1(2) mm the saturation point seems to be reach by adding about 15 % of bitumen.
- Storage time has been found to be about 4 weeks as a good compromise looking at it from the effect of the storage time and the pratical point of view.

Pretreatment of rubber granules gives a mix that when new, with even a rather low amount of bitumen, sticks together and is only with difficulties disintegrated. When stored this changes. The bitumen and the rubber interreacts and the mix gets to be dryer and more easily disintergrated.

3.2 DISINTEGRATION OF RUBBER/BITUMEN MIX

But even with storage the bitumen/rubber mix will have a tendency to stick together and already in the earlier tests (see D3.18) the conclusion was that perhaps even 17 % of bitumen (rubber grading 0-0,5 mm) was too much as the mix hardened and seemed difficult to handle.

Disintergration (pulverization) of the rubber/bitumen mixture during or after storage is then very important as it is necessary to be able to measure the correct amount when e.g. screw feeding the mixture into the plant mixer.

Different pulverization techniques have been studied and the requirements have been

- Able to handle big quantities
- Movable
- Robust
- Cost effective

A promising pulverization technique was found in a so called ALLU (see figure 1). The ALLU is an attachment which is installed in place of a bucket on a loader. In place of the bottom, the ALLU has rotating discs with hammers that pulverize and size material.

Figure 1. ALLU mounted on a loader.

To test this pulverization technique big samples (dimensions: 0,35x0,76x1,16m and weight about 180 kg, see figure 2) of rubber/bitumen mix were produced in laboratory.

The grading of the rubber granulates was 0,5-2 mm and the bitumen emulsion added was 32 % of the rubber weight, which gives a bitumen content of 12 % in the rubber/bitumen mix.

Figur 2. Blocks of rubber/bitumen mix in the ALLU.

Figure 3. The rubber/bitumen mix after processing in the ALLU.

The samples were tested with the ALLU as shown in figure 3 . The performance was quite satisfactory, so this technique was chosen for the field test (se chapter).

3.3 USING BITUMEN FOAM FOR PRETREATMENT

As mentioned above pretreatment with foam will give a somewhat harder bitumen/rubber mix than when using emulsion. This is anyway the case when using the same type of bitumen. A prelimary test has been made with a softer binder, a soft bitumen V6000, which gave interesting results, as the mix in this case ‘dried up’ quicker. It should also be a benefit for the fuctionality to have a softer binder together with the rubber.

Some further tests will be performed with soft bitumens, to study the potentiality of this technique.

4 FIELD TEST OF A POROELASTIC PAVEMENT

4.1 RECIPE FOR FIELD TEST

The studies carried out in 2005 as reported in D3.18 gave as a result a general outline for a recipe that can withstand passenger car traffic without fatigue cracks in the binder material, 10%(w) rubber grain and 8%(w) bitumen binder and 82%(w) aggregate.

After some more laboratory studies (see chapter 2) the recipe as follows has been chosen for a small field test.

- Aggregate: 6,5 % filler, 3,5 % 0-4 mm, 81,5 % 4-8 mm
- Pretreated rubber: 8,5 % (45 % 0-0,5 mm, with 20 % bitumen and 55 % 0,5-1 mm, with 15 % bitumen)
- Binder (PmB): 7,8 %

Aggregate and pretreated rubber make 100 % and the binder is in % of the total mix . The binder in the rubber is included in the total weight of the aggregate and the rubber.

4.2 SITE

The test has been performed in Gothenburg on Tagenevägen at Kärra in the northern parts of the city. Tagenevägen at the site is a industrial road with heavy traffic. The average daily traffic is 4 200 with about 20 % of heavy traffic (1999) and the speed is limited to 50 km/h.

The mixing and laying of the test pavement was done at the 26th of September 2006. The weather conditions were favourably with clear skies and a temperature between 10-15°C.

4.3 PREPARATION OF RUBBER

The pre-treatment of the rubber granulates was performed on the 7th of August at Spannarp about 200 km south of Gothenburg. For the pre-treatment a cold-mixing plant was used. This type of asphalt plant (see figure 4) is otherwise used for production of cold-mixes with emulsion or soft bitumens as binders and with no heating of the aggregate, which may be juvenile or recycled (RAP).

The rubber granulates were delivered in two seperate fractions and each was blended with emulsion BE50R 160-220 as follows

Table 5 Pre-treatment of rubber granulates

Rubber granulate fraction mm	Emulsion added %	Bitumen residue %
0 – 0,5	40	20
0,5 – 1	30	15

Figure 4. Cold mix asphalt plant used for blending rubber/bitumen mix.

Nafta can solve out about 10 % of bitumen (of a total of about 17-18 %) from the rubber/bitumen mix, which means that the rest (about 7-8 %) has somewhat reacted with the rubber. This is tested on a sample taken after storage at the time of production of the asphalt mix (see below).

Figure 5. Rubber/bitumen mix in lumps before processing in ALLU (the biggest lump in picture is about 25 cm across.

The rubber-bitumen mixtures were directly after blending put on a lorry in separate piles and transported to the asphalt plant at Kärra in Gothenburg. Here the mixes were stored on a hard made surface under a roof shelter in waiting for use. As can bee seen in figure 5, the rubber/bitumen mix is still rather lumpy.

The day before the production of the poroelastic asphalt mix the piles of pre-treated rubber granulates were mixed and pulverized with the ALLU. The rubber granulates were passed through the ALLU once and directly on to a lorry on which the whole batch were stored during the night for use next day (see figure 6).

Figure 6. The ALLU at work and the rubber/bitumen mix falls directly onto the lorry.

4.4 MIXING AND LAYING

The production of the mix was made very early in the morning of the 26th of September as the first mix of the day.

The pre-treated rubber granulates were added into the asphalt plant in the same manner as RAP is normally added. This way normal mixing procedures may be used for production of a poroelastic asphalt mix.

Note worthy is that the process with sheddering the rubber/bitumen mix, which after storage still sticked together in rather big lumps, into rather small balls onto the lorry, after handling and weighing in the recyling bin made the mix behave like a easy flowing matter, well suited to be added and mixed with the other ingredients into a homogenous mix.

The mix was then installed on the road with ordinary paving and compaction equipment (see figure 6). The paving went very well, but it was noted that the mix was stickier than normal, which especially made it difficult to lay manually.

Figure 7. Installment of the poroelastic asphalt pavement.

4.5 ANALYSIS OF MIX AND PAVEMENT

The produced mix has been analysed for composition (table 4) and the finished pavement for void content (table 5).

Table 4 Aggregate grading (Weight-% passing)

Weight-% passing	Sieve mm					
	0,063	1	2	4	5,6	8
Test sample	6,0	8	12	15	31	90

Table 5 Voids content volume-% 1).

Voids content %	Bulk density	
	EN 12697-06 2)	EN 12697-29 3)
Average (n=4)	9	15

1) Compact density measured according to EN 12697-05 Determination of Maximum density.

2) Determination of bulk density (hydrostatic) of bituminous specimens.

3) Determination of the dimensions of a bituminous specimen.

The results show that the void content is a little lower than expected and aimed for (about 15 compared to 20 %, according to method EN 12697-29). This might be due to:

- There are a little more fines in the mix than the recipe votes for

- It is known that there is always a difference in lab and field compaction (no restraints) and even if this has been calculated with it is quite possible that the difference is greater in this case, when the rubber content is very high

These abbreviations can be rectified.

Figure 8. Poroelastic asphalt pavement at Tagenevägen in Gothenburg.

5 QUESTIONS STILL TO BE CONSIDERED

There are still some questions to be answered considering the recipe and the production of a poroelastic asphalt pavement, such as:

- Binder type for pre-treatment of rubber granulates
- Aggregate grading in combination with rubber grading to achieve void content of 20%
- Type of polymermodified binder for the poroelastic mixture

Work on this topics will be continued in the next stage, before the test sections planned in SP5.5 are performed.