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THE MECHANISM OF BITUMEN ADHESION TO AGGREGATES
THE INFLUENCE OF MINERALOGIC NATURE

BY

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Abstract. The main function of bitumen is that of adhesive. It is necessary to realize either the linking of aggregate particles or the link between particles and surface. Although the occurrence of the premature break attributed to adhesives is relatively rare; the breaks can imply substantial expenses when they occur. The necessity of insuring a link between aggregate and bitumen is very important.

The mineralogic nature of aggregate is, also, very important because the bitumen „prefers” basic aggregates. However, in practice, the most used aggregates for hot (or cold) coating are acid. There is a continuous problem for specialists to find the optimal methods in increasing the percentage of bitumen capacity of coverage.

Key words: bitumen; aggregates; adhesiveness; aggregate.

1. Introduction

One of the most important properties of bitumen that makes it useful in the transport sector is its adherence to the natural aggregates. Due to these properties, the range of road work in which bitumen or its derivatives are used, is very large.

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The aggregate is slightly wet and the presence of water may cause unexpected problems. They can appear any moment as long as the asphalt is good, from the moment of the initial moulding of the aggregate during the mixing process, to keep an adequate link between bitumen and aggregate within the traffic.

Other factors that affect the initial adhesiveness and the new link are the surface texture of the aggregate, the presence of dust on the aggregate and, to some extent, the presence of water in contact with the interface. It is generally admitted that the rougher surfaces of the aggregate have better adhesiveness characteristics. A balance is necessary between the moisture of the aggregate (the plain surfaces are easier to moisture) and the rough surface that holds the bitumen better once the moisture process is finished.

2. Technical Request. The Mechanism of Bitumen Adhesion to Aggregates (Anderson *et al.*, 1992)

Normally, bitumen is absorbed on the surface of the aggregates. Fractions, parts of bitumen deeply absorbed, have been identified at the surface bitumen–aggregate, making up a "band" with the thickness of 180 Å. Cetone, dicarboxylic acid anhydride, etc. and various compounds of nitrogen have been discovered in that "band" (Ensley ,1973). It was discovered that these substances deeply absorbed components have the capacity to form some hydrogen links with the aggregates, even in the presence of water (turning into

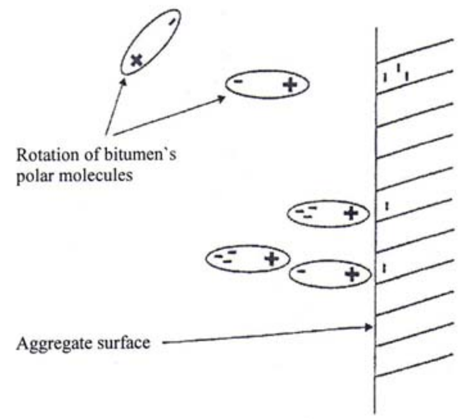

Fig. 1 – Bitumen's molecules are absorbed on the surface of the aggregates.

an "active water". The migration of some components of bitumen at the interface is a demonstrated fact but this phenomenon depends on the composition of mixture, on the temperature of mixture and viscosity. Fig. 1

illustrates the process, the bitumen molecules from the surface line up in the direction of the substratum (aggregate), sometimes this surface being negative (siliceous aggregates); they are considered main responsible for the break of the thin layer of bitumen from the surface of the area of molecule orientation stretches to some thousand molecules.

The majority of adhesive breaks have been associated with silicon such as granite, rhyolite, etc. The fact that the satisfactory results are obtained with these aggregates and the breaks take place together with the use of aggregates which resist well to breaks, such as limestone, outlines the complexity of the bitumen /aggregate and the possibility that other factors play a part in the break.

The break of the link between aggregate and bitumen usually refers to uncover the bitumen film. One of the main factors is the aggregate type. This has a considerable influence over the adhesiveness of bitumen, due to the difference of bitumen affinity. The majority of aggregates are classified as "hydrophilic"(water affinity) or "oil-proof" (which reject oil).The aggregates with a high content of silicon, oxides, for example, quartz and granite (acid rocks in general), are more difficult to cover with bitumen than basic rocks (which contain a high percentage of).

The residual valence or the superficial charge of an aggregate is important. The aggregates with unsymmetrical charges have a surface energy. If the surface of the aggregate is "covered" with a liquid of opposed polarity, the surface energy will tend to be balanced and thus an adhesive layer will result where the two components in a liquid state are present, for instance bitumen and water. The liquid which can best satisfy the energetic requirements will stick the aggregate. The phenomenon of uncover the bitumen film in the presence of water can be reported to superficial charges.

The physical and mechanical absorption between bitumen and the aggregate surface depends on some factors, including the total volume of the permeating area (space, the opening poles, viscosity and the surface tension of bitumen. It was demonstrated that the bitumen particles are deeply absorbed into the surface of the aggregate at approximately 180 Å (18×10^{-9} m) deep. It was suggested that the good mechanical link made on a rough aggregate can be more important than the mineralogical composition of the aggregate in order to maintain the bitumen/aggregate adhesiveness. The properties of bitumen are also more important in reaching the bitumen/aggregate link and the later retention.

The nature of the aggregate seems to be the dominant factor that influences the bitumen/aggregate adhesiveness.

If the surface of aggregates is covered by a thin layer of water, the bitumen can cover the aggregate particle but it won't adhere on its surface. Bitumen can get in contact with the aggregates covered with a thin dust layer but it won't manage to adhere to their surface. The thin water and/or dust layer prevents the contact between bitumen and aggregate surface (Fig. 2).

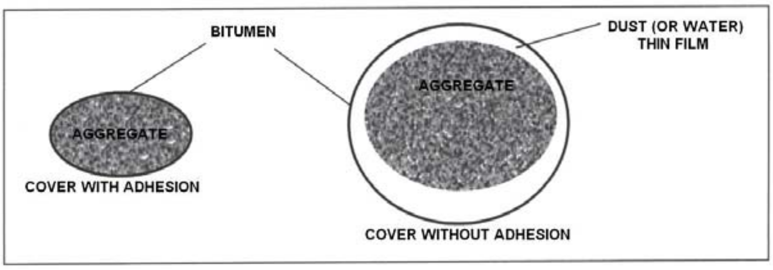

Fig. 2 – The thin water and/or dust layer prevents the contact between bitumen and aggregate surface.

It is well-known that bitumen is a hydrocarbonate adhesive and has much smaller superficial tension than water. This means that it will damp the aggregates easier than bitumen.

In order to ensure a good contact between bitumen and the surface of aggregates the bitumen must be liquid, a fact that can be achieved by heating or using solvent mixture. The liquid bitumen makes the contact of aggregates and this characteristic is called *damping capacity*. It is very much influenced by the viscosity of bitumen : the smaller the viscosity of bitumen, the bigger the damping capacity.

3. Experimental

The used laboratory method was that of the adhesiveness of bitumens for roads to natural aggregates, the so called *quantitative determination method*.

The samples was processed effectively according to STAS 10969/3-83. The sampled colouring solutions are separately analysed by spectrophotometer. The extinctions and the value of the C_1 and C_2 concentrations of the solutions are determined from the calibration plot. The adhesiveness (S_n) is calculated according to the relation

$$S_n = 100 - \frac{C - C_2}{C - C_1} \cdot 100, [\%], \qquad (1)$$

where: C is the initial solution concentration, [%]; C_1 – the solution concentration after recirculation on the natural aggregate *per se*, [%]; C_2 – the solution concentration after recirculation on the bitumen-filmed natural aggregate, [%].

In the event no other technical conditions are specified, the adhesiveness of the bitumen/emulsion to natural aggregates is deemed corresponding if its value – determined by means of the most unfavourable method – is of 80% at least. If it does not reach this value, additives must be introduced in order to improve the adhesiveness value (Mustață, 2004).

The used aggregates come from diverse quarries (which are named Quarry1, Quarry2 and Quarry3) and possess a structural diversity of composition rocks. Mineral aggregates build up the crystal skeleton which provide the resistance and stability of the structure and influence the physical-mechanical properties of the compound.

a) *Quarry1* (characterization of rocks)

The rock type: quartz-porphyry; the rock nature: magmatic, metamorphic; structure: porphyric; texture: massif; mineralogic composition: feldspars (50%); quartz (40%); biotite (5%); others minerals (5%); apparent density: 2,650 kg/m^3.

Quartz-porphyries belong to volcanic rocks above ground. They are *acid* rocks, older then rhiolites and dark coloured.

b) *Quarry2* (caracterisation of rocks)

The rock type: dacite; the rock nature: magmatic (hypoabyssal); structure: porphyric; texture: massif; mineralogic composition: feldspars (20…30%); quartz (5…10%); hornblende (2…10%); biotite (2…5%); magnetite (~1%); ground-mass build up from feldspar microlite, quartz and glass (40%); apparent density: 2600 kg/m^3.

Dacites are neovolcanic rocks proper of granodiorites. The colour alternates between grey and brown. They are *weak acid* or *neutral*.

c) *Quarry3* (caracterisation of rocks)

The rock type: diabase (basaltic); the rock nature: magmatic; structure: inequigranular; texture: massif- compact; mineralogic composition: olivine - phenocryst (15%); calcosoda feldspar (20%); pyroxene (7%); ground-mass build up from augite, olivine and glass (60%); apparent density: 2,800 kg/m^3.

Basalts are *basic* neovolcanic rocks proper of granodiorites. The colour alternates between grey-brown and black.

4. Results and Discussions

The obtained results of quantitative determination proper of each aggregate (for the same kind of bitumen, which was named B50/70, after its penetration class) are noted in Table 1.

The obtained results show that the adhesiveness of basics aggregates (Quarry3) is higher than adhesiveness of acid (Quarry1) or neutral aggregates (Quarry2). So, the bitumen "prefers" indeed basic aggregates and for an acceptable adhesiveness (S_n > 80%) the bitumen need to be doped with additives (when are used acid aggregates).

Table 1
Qualitative Determinations

Nr.	Quantitative adhesiveness, S_n %	Bitumen 50/70	Aggregate 5/8
1	63.8	B50/70	Quarry1
2	68	B50/70	Quarry1
3	74.4	B50/70	Quarry2
4	79.4	B50/70	Quarry2
5	78.4	B50/70	Quarry3
6	82.2	B50/70	Quarry3

5. Conclusions

1. The adhesiveness between aggregates bitumen is a surface phenomenon which depends upon the contact between the two materials.

2. Adhesiveness is the property of the bitumen and its derivatives to adhere to the aggregate surface. The adhesiveness is efficient if it is made on any kind of rock and it is maintained in the presence of water. A bitumen adheres better on a mineral granule if it damps its surface.

3. The adhesiveness between bitumen and natural aggregates is a decisive factor for the resistance of the road. Very often, because of the problems appeared on the road surface, may be attributed to the inadequate adhesiveness between bitumen and natural aggregates.

REFERENCES

Anderson D.A., Dukatz E.L., Petersen J.C., *Adhesion Agents*. *Asphalt Paving Tehnology*. Pennsylvania State Univ., Univ. Park, PA, USA, **51,** 298-302, 1992.

Mustață M., *Research Topics* (in Romanian). Pollchimic Laboratory of Giurgiu, 2004.

Nösler I., Beckedahl H., *Adhesion between Aggregates and Bitumen – Performance Testing of Compacted Asphalt Specimens by Means of the Dynamic Indirect Tensile Test*. Euroasphalt & Eurobitume Congress, Barcelona, 2000.

* * * *Adhesiveness of Bitumens for Roads to Natural Aggregates – Quantitative Determination Method* (in Romanian). STAS 10969/3, 1983.

MECANISMUL ADEZIVITĂȚII BITUMULUI LA AGREGATE
Influența naturii mineralogice

(Rezumat)

Principala funcție a bitumului este considerată a fi aceea de *a acționa ca un adeziv*. Este necesară fie legarea particulelor de agregat, fie asigurarea legăturii dintre

particule şi suprafaţa existentă. Deşi incidenţa ruperii premature atribuite adezivităţii este relativ rară, ruperile pot implica cheltuieli substanţiale în momentul în care apar. Necesitatea asigurării unei legături între agregat şi bitum este foarte importantă.

Natura mineralogică a agregatului este, de asemenea, foarte importantă deoarece bitumul „preferă" agregatele bazice. Însă, în practică, cele mai multe agregate folosite pentru prepararea mixturii asfaltice la cald (sau la rece) sunt acide. Pentru specialişti, găsirea soluţiilor optime pentru creşterea gradului de acoperire a bitumului reprezintă o problemă continuă.