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PROTOCOL #4 – 2005
Laboratory testing of the “Flexigum” compound
to evaluate the durability of bituminous-polymeric waterproofing
of inundated underground structures

Kiev – 2005

1. Reference for testing: Agreement #226 from 14.07.2004 with the company "BITUM" Ltd. on the subject: performance of laboratory tests to determine the durability of the bitumen-latex mastic "Flexigum" used for waterproofing inundated underground structures. License YK 02539.

2. Goal of the tests: Determination of the durability of waterproofing of inundated underground structures using the bitumen-latex water emulsion mastic "Flexigum".

3. Standard references: A list of the standards referenced in the present protocol is given in table 1.

Table 1

Code of Standard	Name of standard
ДСТУ Б В.2.7.-84-99 (GOST 26589-94)	Roofing and waterproofing mastics. Testing methods.
GOST 166-89	Vernier calipers. Technical requirements.
GOST 427-75	Measuring metal rules. Technical requirements.
GOST 450-77	Calcium chloride for industrial use. Technical requirements.
GOST 2405-88	Pressure gages, vacuum gages, pressure and vacuum gages, draught gages. General technical requirements.
GOST 6613-86	Square meshed woven wire cloths. Technical requirements.
GOST 6709-72	Distilled water. Technical requirements.
GOST 23683-89	Hard block petroleum paraffin. Technical requirements.
GOST 23732-79	Water for concretes and mortar. Technical requirements.
GOST 25336-82	Laboratory glassware and equipment. Types, major parameters and dimensions.
GOST 24104-88	General purpose laboratory balances and comparison balances. General technical requirements.
PCT YCCP 5027-89	Bituminous paste and mastic on solid emulsifiers. Technical requirements.

4. The tests were conducted from July 20th, 2004 until January 20th, 2005 in accordance with the requirements of the Ukraine national standard ДСТУ Б В.2.7.-84.

5. Preparation of samples was performed by the client – the company “BITUM” Ltd. and consisted in the application of a 4 mm layer of the bitumen-latex mastic “Flexigum” on one of the larger faces of 20 mm × 30 mm × 15 mm concrete plates, which were delivered to the NIISP laboratory of construction chemistry. The laboratory performed the final part of the preparation of the plates, which consisted in application of molten paraffin wax in accordance with GOST 23683 over the other faces of the plates. A total of 12 samples was prepared.

The composition of the concrete mix, mass %:

Portland cement mark 400 manufactured by the Kamenetz-Podolsky cement factory	5
Dniepr sand	20
Crushed granite stone, 5-10 mm fraction	59
Water in accordance with GOST 23732	6

The composition of the concrete mix corresponds to concrete of class B20.

The client also supplied 12 units of 200 mm × 200 mm × 4 mm sheets of the “Flexigum” mastic.

6. Features of the samples

For water resistance tests: concrete plates, covered on one larger face with the bitumen-latex mastic “Flexigum”, and on the other faces – by molten paraffin wax.

For water absorption and swelling tests: 50 mm × 50 mm × 4 mm sheets from the bitumen-latex mastic “Flexigum”.

For water impermeability tests: 150 mm × 150 mm × 4 mm sheets from the bitumen-latex mastic “Flexigum”.

7. Type and features of the testing equipment and measurement devices: a list of the equipment and measurement devices is given in table 2.

Table 2.

Equipment and measurement devices	Factory number	Date of certification and inspection		Certificate number
		last	next	
2 nd class vernier calipers according to GOST 166	450485	21.12.04	21.12.05	23-18/1816
Measuring metal rule according to GOST 427	none	31.03.04	31.03.05	certification mark
ВЛА-200-М balance	980	06.08.04	06.08.05	35-1/9381
СОСпр-26-2-000 stopwatch	8250	06.09.04	06.09.05	35-01/9942
Pressure gage according to GOST 2405	135954	27.12.04	27.12.05	certification mark

8. Test results

8.1. Water resistance test of the waterproofing layer.

For the purpose of testing the water resistance of the waterproofing layer in accordance with item 3.8 in ДСТУ Б В.2.7.-84 the samples were placed in glass jars in accordance with GOST 25336 and flooded with distilled water in accordance with GOST 6709 so that the level of water above the samples was at least 50 mm. After 24 hours, and subsequently after every 7 days, up until 70 days, the samples were taken out of the water and kept in the air for at least 2 hours. This was followed by visual inspection of the mastic layer for the presence of bubbles, blisters and flaking. During the entire period of 70 days during the samples were maintained in distilled water, no blisters, flaking or other waterproofing defects were found in the tested coating samples.

8.2. Water absorption and swelling test of the waterproofing layer.

Water absorption testing of the samples of the waterproofing layer from the "Flexigum" bitumen-latex mastic was conducted in accordance with item 3.9 in ДСТУ Б В.2.7.-84. The tests were conducted on six samples which were first dried in a desiccator over calcinated potassium chloride in accordance with GOST 450, then weighed, placed in glass jars in accordance with GOST 25336 on a special wire gauze in accordance with GOST 6613 (to allow free access of distilled water from all sides) and flooded with distilled water in so that the level of water above the samples was at least 50 mm. After 24 hours, and subsequently after every 7 days, up until 70 days, the samples were taken out of the jars and weighed in accordance with ДСТУ Б В.2.7.-84 on an analytical balance in accordance with GOST 24104. Three of these samples were used to determine the swelling index in accordance with PCT YCCP 5027.

The obtained results of the tests are presented on figures 1-2 as graphs of the dependence of water absorption and swelling on time in days (appendices B and C).

8.3. Water impermeability test of the waterproofing layer.

The water impermeability was determined in accordance with item 3.10 in ДСТУ Б В.2.7.-84 on 150 mm × 150 mm × 4 mm sheet samples using the device, whose drawing is given in ДСТУ Б В.2.7.-84 (fig.10 on p.18). Impermeability tests were performed on the original sample and on soaked samples after 24 hours, and subsequently after every 7 days, up until 70 days, according to the procedure: the positive water pressure on one side of the sheet was held at 2 atm, exposure time – 2 hours. Water was not detected on the external side of the samples during inspections performed in the entire testing period.

9. Discussion of the test results

The durability of waterproofing coatings in underground and underwater conditions is mostly a function of their water resistance, i.e. by the change in their mass, volume and strength as a result of the prolonged influence of water.

The absorption of water is a very important parameter in materials with other applications as well, such as paint coatings. It is known that water absorption initiates another, quite undesirable process – swelling, which is accompanied by the development of stresses in the waterproofing layer and at its interface with the substrate (the support, for example, concrete surface).

It seems important to compare the water absorption and swelling parameters obtained for the “Flexigum” mastic with those of other aqueous emulsion mastics.

Thus, for bituminous emulsions based on solid emulsifying agents (clays) according to PCT YCCP 5027 the water absorption after 15 days for bituminous paste is 6 % by mass, for bituminous-latex paste – up to 3 % by mass and for bituminous mastic – up to 5 % by mass; the swelling by volume should not exceed 1.6%, 0.8% and 1.0% respectively. However, the values of these parameters increase after further soaking in an aqueous medium, which causes the insulating sheet to lose its integrity, and as a result these materials can not be used for waterproofing underground structures maintained in an inundated soil environment.

Waterproofing coatings from the bituminous emulsion mastic BAEM after 6 months of accelerated testing is characterized by water absorption of up to 15.7 % by mass and swelling of up to 1.5% (Popchenko S.N., Trofimov V.N., “Calculating the durability of waterproofing coatings from emulsion mastics”, in Russian, Collected works of the VNIIG Vedeneyev Institute, Vol.128, 1979). These data were corroborated by special tests made by the above researchers over 11 years, as well as full-scale tests.

Taking into account the processes of ageing, static fatigue and the effect of thermal stresses in the material the durability of waterproofing coatings based on BAEM mastics in the opinion of experts is at least 26 years.

The results of tests of the bituminous-polymeric compound “Flexigum” indicate that after 45 days an equilibrium condition is attained in the “waterproofing layer” system; the water absorption remains at a level of 0.94 % by mass, swelling – 0.75 % by volume.

The durability of “Flexigum” bituminous-polymeric compounds depends on several factors.

Coatings from the “Flexigum” bituminous emulsion mastic differ in the following significant aspects of their composition from known bituminous and bituminous-polymeric aqueous emulsion mastics:

- The bituminous mastic was prepared on the basis of liquid emulsifying agents, which make the size of the emulsified bitumen droplets comparable to the particle size of the modifying latex (which guarantees a uniform structure and stable material properties);
- The modifying latex used was synthetic rubber latex, which has good compatibility with bitumen;

- The ratio between the bituminous part and the latex part (the emulsion and the latex) is such that the sheet has high elasto-plastic properties which promote dissipation of stresses developing as a result of external physical influence or as a result of a drop in temperature and the associated changes in volume;

- The absence of a filler, whose presence in certain amounts could have an adverse effect on the water absorption and swelling parameters, impair adhesion, induce cracking, etc.

It should be stressed that the bituminous-polymeric mastic "Flexigum" is intended for waterproofing underground structures maintained in an inundated state, which indicates that such powerful ageing factors of bituminous materials as oxygen from surrounding air, ultraviolet solar radiation and high temperature (40°C) are not present in the operating conditions.

Therefore, the durability of coatings from the bituminous-polymeric mastic "Flexigum", which have a decisive advantage in their composition over known bituminous mastics, and operate in conditions ruling out oxidation, photodestruction and thermal ageing, should be at least twice as durable as the bituminous emulsion mastic BAEM, which is well-studied and tested in full-scale conditions on hydraulic facilities.

The bituminous-polymeric mastic "Flexigum" does not contain mineral fillers; therefore it would be correct to compare its properties to unfilled emulsions, such as bituminous emulsion obtained by high viscosity emulsification.

When a waterproofing coating from bituminous paste prepared using lime as a solid emulsifier is soaked in water, it reaches a stable water absorption state of 6.0 % by mass after 30 months, which gives the waterproofing coating a durability of 25 years.

Our tests have shown that under similar saturation conditions the waterproofing coating from the "Flexigum" compound reaches a stable water absorption condition of 0.94 % by mass in 1.4 months.

Introducing the expert coefficient K , which characterizes the temporal stability margin of the bituminous-polymeric material "Flexigum", the durability is calculated based on the following dependence:

$$T_{\Phi} = \frac{W_n}{W_{\Phi}} T_B K$$

where T_{Φ} is the durability of the "Flexigum" waterproofing, years;
 W_n is the water absorption of the bituminous paste on attaining the stable condition, % by mass;
 W_{Φ} is the water absorption of the "Flexigum" bituminous polymeric coating on attaining the stable condition, % by mass;
 T_B is the durability of the bituminous mastic BAEM, years;
 K is the expert coefficient, = 0.296

$$T_{\Phi} = \frac{6}{0.94} \cdot 25 \cdot 0.296 = 47.2$$

Conclusion:

The coating from the “Flexigum” compound has a durability of at least 47.2 years as a waterproofing for structures maintained in inundated conditions.

Notes:

1. The protocol of the tests pertains only to the coating samples and sheets from the bituminous emulsion mastic “Flexigum” submitted for testing to the NIISP laboratory of construction chemistry by the company “BITUM” Ltd..

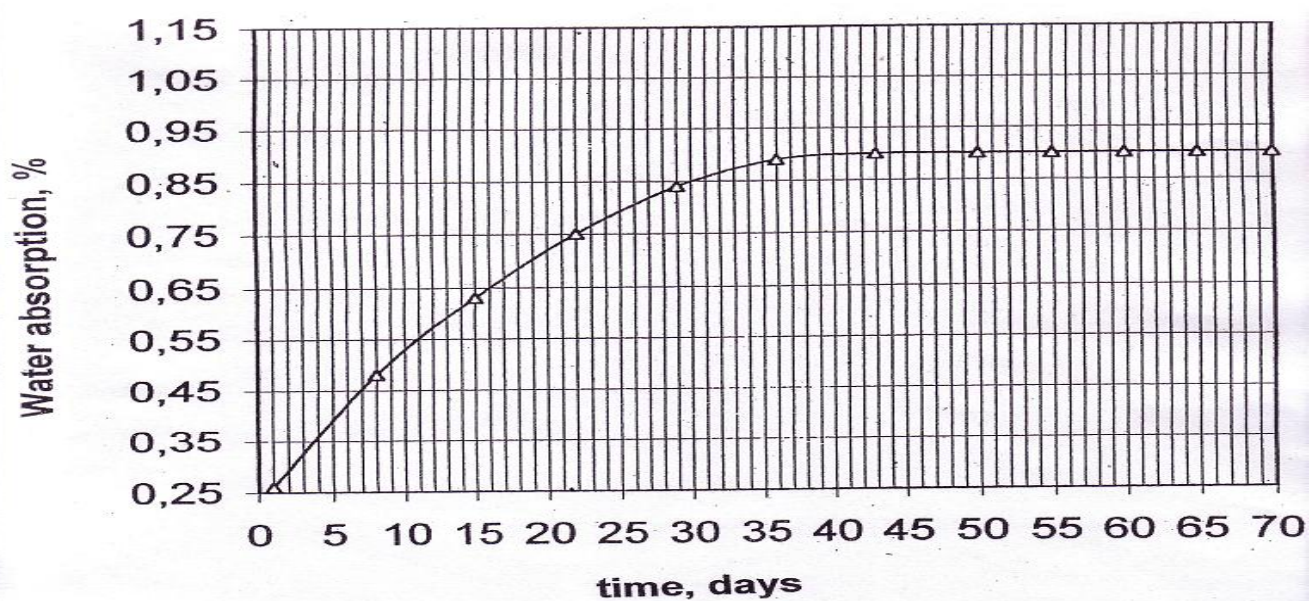
2. Full or partial reprinting of the protocol without the permission of the NIISP institute of the Ukraine State Construction Management is prohibited.

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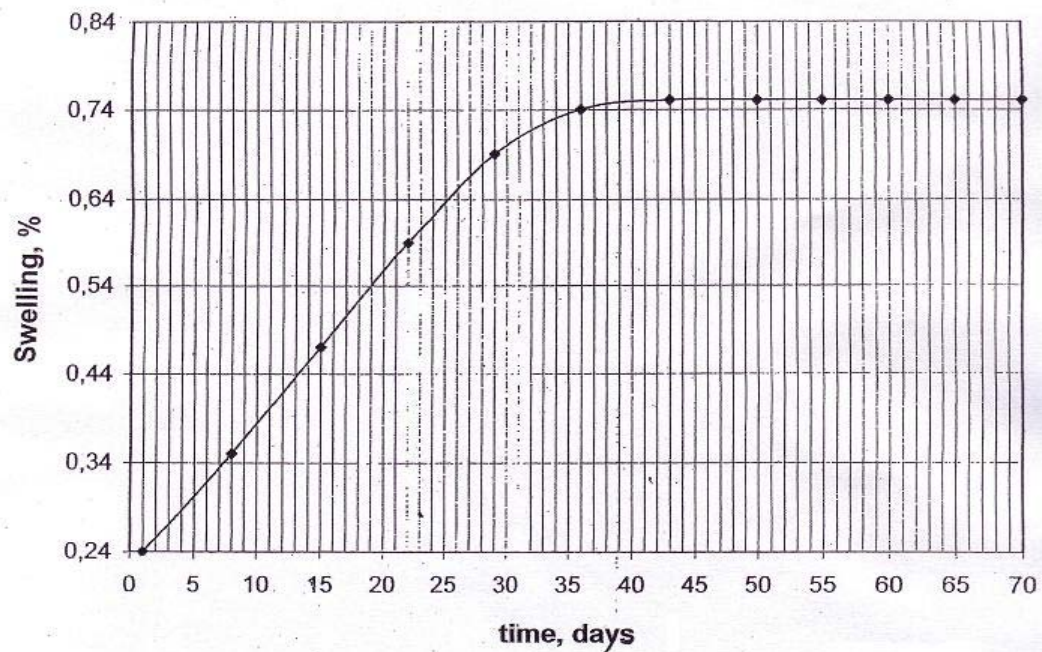
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**Fig.1 Water absorption vs. time of sheet samples
from the bituminous-latex mastic "Flexigum"**



**Fig.2 Swelling vs. time of sheet samples
from the bituminous-latex mastic "Flexigum"**