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Effect of the compressibility of polymer-modified bituminous thick coatings on the durability of their waterproofing layers

Wpływ ściśliwości asfaltowych grubowarstwowych powłok modyfikowanych polimerami na trwałość wykonywanych z nich warstw hydroizolacyjnych

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Abstract. Polymer modified bituminous thick coatings are increasingly used in the construction industry as waterproofing of underground parts of buildings. One of the important application problems in assessing their durability is the susceptibility of the above-mentioned coatings to mechanical damage, including long-term compressive loads acting on their entire surface. As part of the research work, the resistance to compression of two randomly selected products was assessed, in accordance with the research methodology included in the PN-EN 15815:2011 standard. The research found that the phenomenon of changing the thickness of coatings without reinforcement leads to a more than 50 per cent reduction in the thickness of the tested coatings at loads specific to damp-proofing, i.e. 0.06 MN/m^2 after approximately 14 days of testing. A similar level of change in thickness occurs under the load assumed for waterproofing, i.e. 0.3 N/m^2 after just 3 days of testing, for the same coatings but reinforced with an internal reinforcing fibreglass insert. The results obtained indicate the lack of suitability of the above products for use in waterproofing of terraces, balconies and roof coverings

Keywords: bitumen-polymer thick coatings compounds; resistance to compression

Streszczenie. Grubowarstwowe powłoki bitumiczno-polimerowe znajdują coraz szersze zastosowanie w budownictwie do wykonywania izolacji części podziemnych budynków. Jednym z istotnych problemów użytkowych przy ocenie trwałości tych powłok jest podatność na uszkodzenia mechaniczne, w tym na długotrwałe obciążenia ściskające działające na całą ich powierzchnię. W ramach prac badawczych oceniono odporność na ściskanie dwóch losowo wybranych wyrobów, zgodnie z metodą badawczą ujętą w normie PN-EN 15815:2011. Po czternastu dniach badania stwierdzono, że przy obciążeniach właściwych dla izolacji przeciwwilgociowych, czyli 0,06 MN/m^2, następuje zmniejszenie grubości do ponad 50% w przypadku powłok bez zbrojenia. Podobny poziom zmiany grubości tych samych powłok, lecz wzmocnionych wewnętrzną wkładką zbrojącą z włókniny szklanej, następuje już po trzech dniach badania pod obciążeniem przyjmowanym w przypadku izolacji wodochronnych, czyli 0,3 N/m^2. Uzyskane wyniki wskazują na brak przydatności omawianych powłok do stosowania jako izolacji tarasów, balkonów oraz w pokryciach dachowych.

Słowa kluczowe: masy bitumiczno-polimerowe przeznaczone do wykonywania powłok grubowarstwowych; odporność na ściskanie.

Underground parts of buildings are exposed to the constant action of water and moisture stored in the surrounding soil and to ground pressure. The combined pressure varies from 30 MPa to 60 MPa for each 0.3 m depth [1 – 5]. Naturally, these values are lower for dry and permeable soils, increasing for cohesive soils. For this reason, parts of the structure in the underground parts must be protected against the negative effects of water and moisture, e.g. by waterproofing. These layers should form a continuous and tight system separating buildings or parts of them from water or water vapour. For these, both flexible sheets and coating products [1 – 4] are used, including polymer-modified bituminous thick coatings [1, 6 – 8].

Polymer-modified bituminous thick coatings are either single-component or two-component products. The single-component products are packed as a bitumen paste suitable for filling or spraying. Two-component products, on the other hand, consist of both a liquid component, also in the form of a bitumen paste, and a powder component. Both of the above-mentioned components are most often packed in a single container, with the liquid component separated by a spacer at the bottom from the powder component, secured in a watrtight bag, stacked above. Bitumen pastes, which are the main component of the products in question, are factory-prepared mixtures consisting of asphalts in the form of anionic or cationic asphalt emulsions, plastic additives and fillers. These mixtures may also contain added fibres. Fillers can include polystyrene granules, rubber granules or mineral components. The second component in two-component products

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is usually a powder – it contains cement, e.g. aluminium cement, and powdered highly hygroscopic substances. The suitability for use of the two-component product is achieved when the two components are mixed. The hardening process of both one-component and two-component products occurs as a result of a physical reaction involving the evaporation of water. In two-component products, the drying is further accelerated by the binding of excess water by the powder component, which, however, does not act as a hardening agent.

Also on the initiative of the German construction chemicals industry, the EN 15814 standard [10] was developed and adopted as a product standard in the EU in the following years. For this reason, the EN 15814 standard was modelled on the German DIN 18195 series of standards when developing the performance characteristics of the above-mentioned products, adopting the following pressure resistance values for protection [8, 9]:

● ≥ 0.06 MN/m² – of foundation slabs and walls against ground moisture and of floor surfaces and wet rooms against non-pressurised water (according to DIN 18195, parts: fourth and fifth);

● ≥ 0.3 MN/m² – against externally acting, pressurised water and pressure water (according to DIN 18195-6).

These products have been adopted fairly quickly throughout Europe and, due to their origin, are often referred to by the abbreviation KMB (German abbreviation for Kunststoffmodifizierte Bitumendickbeschichtungen).

According to the provisions of EN 15814+A2:2015-02 [10], polymer-modified bituminous thick coatings are only intended for waterproofing layers in underground parts of buildings. These coatings are at least 3 mm thick and have several unusual properties. One of these is significant compressibility as a result of prolonged loads acting perpendicular to the surface of the completed coating.

The aim of the research discussed in this article was to determine whether long-term compressive stress can affect the durability of the above-mentioned coatings under service conditions and whether any reduction in their thickness as a result of such loads occurs immediately after the load is applied or whether the process is a slow one. According to the provisions of EN 15814+A2:2015-02 [10], the compressive strength is divided into three classes that can be declared by the manufacturer in the declaration of performance, of course, after a positive test result, i.e:

a) Class C0 – no requirement;

b) Class C1 – stabilization at ≤ 50% (change maximum 3% within 3 subsequent days) under load 0.06 MN/m^2; for coatings with dry layer thickness ≥ 3 mm;

c) Class C2A – stabilization at ≤ 50% (change maximum 3% within 3 subsequent days) under load of 0.3 MN/m^2; for coatings with dry layer thickness ≥ 4 mm with inlay;

d) Class C2B – stabilization at ≤ 50% (change maximum 3% within 3 subsequent days) under load of 0.3 MN/m^2; for coatings with dry layer thickness ≥ 4 mm without inlay.

In their technical sheets, the manufacturers of the above products recommend additional protection for such coatings, presumably also due to their increased compressibility and susceptibility to mechanical damage. Insulating boards, drainage sheets, e.g. mottled membranes, are recommended as protective layers.

Materials and Methods

Materials. Two randomly selected polymer-modified bituminous thick coatings, purchased from building supply stores, were used in the research. The products selected for testing have the following similar performance characteristics:

■ **product No. I** – a two-component, solvent-free coating based on asphalt, plastic additives and fillers, with a mix density of 1.07 g/cm^3, water tightness in class W2A (i.e. at a pressure of 0.075 N/mm^2 over 72 hours – in a test with inlay), crack bridging ability in class CB2 (i.e. no damage at a crack width ≥ 2 mm);

■ **product No. II** – two-component, solvent-free waterproofing coating based on asphalt, plastic additives and fillers, liquid component with a pH of 9.0 – 9.5 and a density of 1.0 – 1.1 g/cm^3, density of the powder component 1.5 – 1.6 g/cm^3, waterproofing of the coating in class W2A (i.e. at a pressure of 0,075 N/mm^2 at 72 hours, in a test with inlay), crack-bridging ability of the coating in class CB2 (i.e. no damage at crack width ≥ 2 mm), rain resistance in class R2 (i.e. at ≤ 8 h), dry film thickness reduction ≤ 50%.

Methods. Resistance to compression tests were carried out in accordance with EN 15815:2011 [11]. The principle of the test was to subject a substrate coated with a polymer-modified bituminous thick coatings to compression at a constant pressure until a stabilization of the reduction of thickness is reached. The principle of the test is shown in Figure 1.

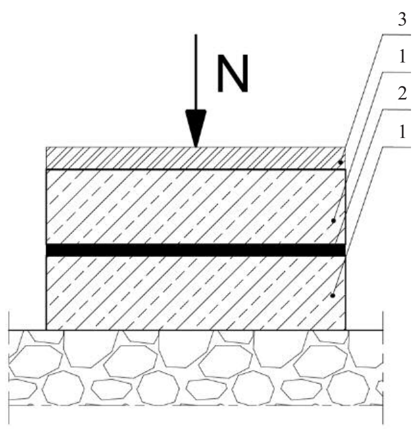


Fig. 1. Principle of the compression resistance test: 1 – concrete slab 20 x 20 cm, 4 cm thick; 2 – tested bitumen-polymer coating; 3 – metal pressure plate

Rys. 1. Zasada badania odporności na ściskanie: 1 – płyta betonowa o wymiarach 20 x 20 cm, grubości 4 cm; 2 – badana powłoka bitumiczno-polimerowa; 3 – metalowa płyta dociskowa

The polymer-modified bituminous thick coatings were applied on concrete slabs of min. 20 x 20 cm and 4 cm thick. The coating was laid according to the manufacturer's instructions, under laboratory conditions, at room temperature. The samples prepared in this way were stored for 28 days under standard conditions, i.e.: temperature (23 ±2)°C and humidity (50 ±5)%. After 28 days, the average dry sample thickness (S_v) was determined. The specimens were then placed in a compression testing machine, applying a preload of 0.01 MN/m^2 to determine the average change in thickness of each specimen (ΔS_0). Then, a main load was applied, depending on the class specified in EN 15814+A2:2015-02, i.e. respectively:

- 0.06 MN/m^2 in the test for class C1;
- 0.30 MN/m^2 in the test for class C2A.

The test was considered completed when:

- the average reduction in thickness of each specimen after 5 days (S_5) was less than 50% of the original layer thickness, and
- the difference between the observed thickness changes within the last 3 days of the test, e.g. between day 2 and day 5 of the test ($S_5 – S_2$), did not exceed 3%.

If the reduction in sample thickness over the next 3 test days was greater than 3%, the test was continued for a maximum of 40 days, ending when the change over the last 3 days did not exceed 3% ($S_n – S_{n-3}$).

The test result was the average of the results obtained by testing three samples. The average deviation of the thickness of each sample (ΔS_n) from the initial thickness (S_0) in each measurement n was calculated from equation (1) as the relative change in thickness of the S_n layer.

$$S_n = (\Delta S_n/S_0) \cdot 100 \qquad (1)$$

where:

S_n – the relative change in the thickness of the layer [%];

ΔS_n – the mean deviation of the thickness of each specimen [mm];

S_0 – the initial thickness [mm].

Test results of resistance to compression of polymer-modified bituminous thick coatings, performed according to the test method in PN-EN 15815:2011 [11]

Wyniki badań odporności na ściskanie asfaltowo-polimerowych powłok grubowarstwowych, wykonanych wg metodyki badawczej podanej w PN-EN 15815:2011 [11]

No of test sample	Results (summary of the average value of the three samples)	Class of resistance to compression	Additional information
Product No. I	negative, after 14 days of testing change in specimen thickness greater than 50%, i.e. 61.1% on average	C1	coating tested without inlay, average wet layer thickness 6.2 mm, dry layer thickness 4.2 mm
	negative, after 3 days of testing change in specimen thickness greater than 50%, i.e. 54.4% on average	C2A	tested coating with glass fleece inlay, average wet layer thickness 6.5 mm, dry layer thickness 4.5 mm
Product No. I	negative, after 20 days of testing change in specimen thickness greater than 50%, i.e. 65.2% on average	C1	coating tested without inlay, average wet layer thickness 6.2 mm, dry layer thickness 4.0 mm
	negative, after 3 days of testing change in specimen thickness greater than 50%, i.e. 55.4% on average	C2A	tested coating with glass fleece inlay, average wet layer thickness 6.5 mm, dry layer thickness 4.1 mm

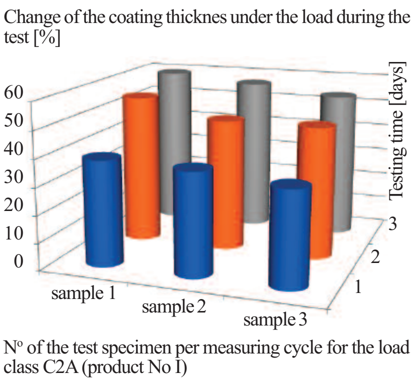


Fig. 2. Thickness variation of individual test specimens of product I under a load of 0.3 MN/m^2 (Class C2A) during 3 days of testing)

Rys. 2. Zmiana grubości badanych próbek wyrobu I pod obciążeniem 0,3 MN/m^2 (klasy C2A) podczas trzech dni badania

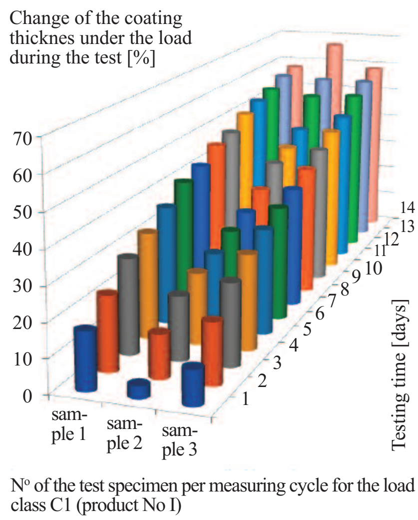


Fig. 3. Thickness variation of individual test specimens of product I under a load of 0.06 MN/m^2 (i.e. for class C1) during 14 days of testing)

Rys. 3. Zmiana grubości badanych próbek wyrobu I pod obciążeniem 0,06 MN/m^2 (klasa C1) podczas czternastu dni badania

Results and Discusion

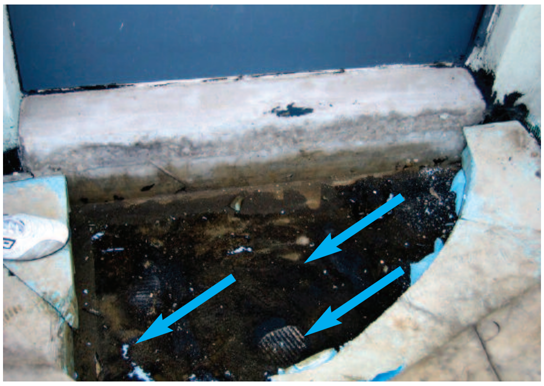
The results of resistance to compression of the tested products are presented in Table 1. The tests were performed for two load classes C1 and C2A, without continuing the determination in class CB2 due to the negative results obtained in the preceding classes. Figure 2 shows the changes in thickness of the individual test specimens of Product I under a load of 0.3 MN/m^2 (i.e. for Class C2A) during 3 days of testing, and Figure 3 under a load of 0.06MN/m^2 (i.e. for Class C1) during 14 days of testing. In both cases, the test was stopped when the change in thickness of the specimens exceeded the 50% value.

Tests performed indicate that the process of reducing the thickness of coatings unreinforced with additional inlays as a result of compressive stresses occurs much more slowly, even at very low loads of the order of 0.06 MN/m^2, than in the case of the same coatings reinforced with inlays subjected to 5 times higher loads. The initial deformation values of the unreinforced coatings differ considerably, even by a factor of 5, only to reach comparable values after 14 days. The results discussed also indicate that if the coating is deformable, reinforcing it with an inlay does not significantly increase the compressive strength and is not able to transfer the loads expected for reinforced products either. In the case of reinforced products, the deformation progresses even faster, as the limit values are already determined on the second day of loading.

Unfortunately, the presented test results do not give definitive values for the reduction in thickness of the coatings, but only indicate the time after which it can be considered that the coating no longer guarantees effective protection of the structure against the effects of water and moisture. The limit value for disqualifying a product is a reduction in thickness under pressure by more than 50% of the initial thickness. It should also be borne in mind that this is not a definitive value and that this process may continue under further stress, leading to even greater degradation of the thickness.

The obtainedtest results were compared with the manufacturers' declarations in the aforementioned assessment area. In both cases, the manufacturers declared class C0, i.e. no requirements, in their declarations of product performance with regard to compressive strength. This prompted the authors of the article to carry out the above-mentioned tests to see what values of deformation could be associated with such a declaration. Unfortunately, these test results indicate that in such cases, the coating is expected to be susceptible to prolonged compressive loads, which may lead to a localised reduction in thickness in the areas exposed to the above-mentioned exposures. These results confirm the validity of the restriction on the serviceability of the above-mentioned products in EN 15814, sanctioning their use only in underground parts of buildings, where the coatings are exposed to increased compressive loads to a limited extent. However, there are known cases of the use of the products in question in waterproofing of terraces and balconies, leading to a localised reduction in thickness in areas exposed to repeated loads, such as pedestrian walkways. In extreme cases, there is a risk of localised loss of waterproofing of such waterproofing layers.

An example of such damage to a thick polymer-modified asphalt coating laid on a terrace slab is shown in Photo 1. The photo shows the surface of the above-mentioned coating after removal of the thermal insulation and surface layers. The area shown is the area next to the threshold in the doorway leading to the terrace, i.e. the area exposed to repeated use loads. Within the coating, localised reductions in layer thickness are visible. At individual points, even the surface of the substrate is exposed, indicating that the coating in this area has lost its waterproofing function.



View of the of the polymer-modified asphalt thick coating at the threshold of the door leading to the terrace, with traces of local thickness reduction. The arrows show examples of areas of coating thickness reduction in the region of increased local, pressure

Widok grubowarstwowej powłoki asfaltowej modyfikowanej polimerami przy progu drzwi prowadzących na taras, ze śladami miejscowego ograniczenia grubości warstwy. Strzałkami pokazano przykładowe miejsca obniżenia grubości powłoki w rejonie zwiększonych miejscowych nacisków

Conclusions

This paper presents the results of a study of the compressive strength of two randomly selected polymer-modified bituminous thick coatings. Due to the small population of test objects, the results cannot be generalised, but should be regarded as important symptoms requiring further research. Considering the above, the results obtained allow the following preliminary conclusions:

- the compressive strength of the coatings has a significant impact on the durability of the waterproofing layers made of them, due to the threat of a local reduction in their thickness in areas where the stresses are of a cyclic/repetitive nature;
- the susceptibility to deformation due to compressive loads precludes the use of such products in areas other than waterproofing of underground parts of buildings. Also in the underground parts of buildings, it is recommended that the surface of the completed coating is covered with, for example, a slab of thermal insulation material with low water absorption, e.g. XPS. This will both contribute to an even load distribution on the surface of the coating and protect it from possible mechanical damage during backfilling;
- the declaration of class C0 with regard to the compressive strength of polymer-modified bituminous thick coatingsmay suggest the possibility of a more than 50% reduction in thickness when working in areas exposed to cyclic compressive loads;
- the thickness reduction process of unreinforced coatings under a load of 0.06 MN/m^2 (i.e. for Class C1) is prolonged in time compared to the deformation of coatings reinforced with inlayers under a load of 0.3 MN/m^2 (i.e. for Class C2A);
- it may be presumed that the negative result obtained for unreinforced coatings under a load of 0.06 MN/m^2 may be taken as a preliminary prediction of the deformability under a load of 0.3 MN/m^2 of reinforced coatings made of the same product.

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