Oryginalny artykuł naukowy (Original research paper)

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Influence of the resistance to concentrated mechanical loads on maintaining the water tightness of flexible sheets for roof waterproofing

Wpływ odporności na skupione obciążenia mechaniczne na zachowanie funkcji wodoszczelności pokryć dachowych wykonywanych z rolowych wyrobów hydroizolacyjnych

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Abstract. The article analyses the influence of concentrated mechanical loads on the durability of roofing materials as a function of roof waterproofing. The authors compared the influence of concentrated static, dynamic and hail loads on water tightness of coverings made of flexible roofing materials, i.e. bitumen sheet with reinforcement, PVC sheet and EPDM sheet. Mentioned materials were tested on concrete substrates and on the surface of mineral wool.

Keywords: roof coverings; resistance to concentrated loads; static; dynamic and hail loads; flexible sheets for waterproofing.

Streszczenie. W artykule przeanalizowano wpływ skupionych obciążeń mechanicznych na trwałość pokryć dachowych, określoną w funkcji wodoszczelności. Autorzy porównali wpływ skupionych obciążeń statycznych, dynamicznych i działanie gradu na wodoszczelność pokryć dachowych wykonywanych z wyrobów rolowych, tj. z papy, folii PVC i folii EPDM. Wspomniane wyroby badano na podłożach betonowych i z wełny mineralnej.

Słowa kluczowe: pokrycia dachowe; odporność na: skupione obciążenia mechaniczne; obciążenia statyczne; uderzenie i na działanie gradu; hydroizolacyjne wyroby rolowe.

In the Polish climate conditions, all destructive processes in building structures occur in the presence of water and moisture, at a simultaneous influence of variable temperatures with numerous transitions through 0°C [1 – 5]. Ensuring adequate protection of the building structures against the abovementioned impacts contributes significantly to the durability of building structures [3, 5].

The factors affecting the durability of waterproofing layers in buildings can be divide into:

- passing time and environmental factors;
- quality of building materials;
- structural solutions with design and implementation errors.

Taking into account the results of laboratory tests made in Building Research Institute and conclusions presented by other authors in the available technical literature it's possible to determine typical groups of faults that can potentially occur in the waterproofing layers, combined with the applied material type and the severity of the environmental impact.

Durable protection of a building against storm water, water accumulated in the ground and moisture entails the provision of two key components:

- materials whose properties are adequate to transfer the service loads in the building structure;
- correct embedding of the abovementioned materials.

The last fifty years saw significant development of waterproofing materials. Scientific research conducted at the Building Research Institute enabled contribution to refine the requirements concerning their performance, including durability. These works concerned the main groups of waterproofing products, e.g. reinforced bitumen sheets, plastic and rubber membranes, waterproofing mixtures (e.g. water- and solvent-based asphalt mixtures, cement-based waterproofing layers, polymer mixtures and polymer modified bituminous thick coatings), cement ceramic tiles and products intended for horizontal waterproofing layers made with injection methods. The determination of these values helped select the waterproofing products for specific service load conditions as an intrinsic component of the waterproofing solution durability. We supplemented the research on material's requirements with studies aimed to compare the durability of different groups of waterproofing products in specific service load conditions. Durability can be evaluated in two ways. The first method correlates the expected life in natural conditions with the results of laboratory ageing tests. The other method involves comparing resistance to the same service factors in reference to different product groups intended for the same functions in a building structure to determine which materials transfer the assumed loads best. For waterproofing so-

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lutions, we adopted the second durability evaluation method as the range of products in each product group intended for the same applications is highly diversified. That is why we decided that the potential correlation between the actual life and the results of laboratory tests would apply only to one group representative and not the entire group. From the scientific point of view, it is more interesting to compare the durability of different material groups to select the most favourable solution for the particular structure. Initially, the values were published only by the Building Research Institute, but to reach the broader public, we included them in subsequent publications [1 – 7].

In the article are presented the results of concentrated mechanical loads tests for flat roofs made in traditional systems and the influence of such properties on the durability of the protections made of them [8, 9]. Below are presented chosen comparative analyses of the durability of various systems of flexible roofing solutions in terms of three selected performance properties, determined on the basis of tests [1, 2], i.e.:

- resistance to static loading;
- resistance to impact;
- hail resistance.

Materials and methods

Typical groups of flexible sheets applied in roofing were used in the research. After initial elimination tests performed on different flexible sheets which are common for the represented material groups. We chose four materials for further tests, i.e.:

- bitumen sheet with woven glass reinforcement, surface mass of 211 g/m^2, with a double-sided coating made of oxidized bitumen, surface mass of 1900 g/m^2. The top side is covered with mineral granules, the bottom side is protected with a plastic sheet;
- polymer modified bitumen sheet with polyester reinforcement, surface mass of 250 g/m^2, with a double-sided coating made of bitumen modified with SBS elastomer, surface mass of 2700 g/m^2. The top side is covered with mineral granules, the bottom side is protected with a plastic sheet;
- PVC sheet, thickness of 1,2 mm, inside reinforced with a glass fiber mesh;
- EPDM sheet, thickness of 1,4 mm inside reinforced with a polyester mesh.

The tests were performed in accordance with the test methods specified in the following standards, i.e.:

- resistance to static loading, according to PN-EN 12730:2015-06 [10];
- resistance to impact, according to PN-EN 12691:2018-05 [11];
- hail resistance, according to PN-EN 13583:2012 [12].

The test equipment is shown in figure 1. In all discussed tests resistance to mechanical loading is expressed as a load which has not caused leakage of the flexible sheet under the pressure of 15 kPa applied to the area where the load has been applied, during 60 s.

cover materials were reinforced bitumen sheets with a polyester and glass reinforcement, PVC and EPDM sheets. In single-layer systems, the variant of roofing made of reinforced bitumen sheet with glass woven reinforcement was not taken into account. It's very difficult to produce such product with properties which meet the requirements for single-layer roofing. The analysed solutions also did not take into account the reinforced bitumen sheets with non-woven glass reinforcement because such material shows very low tensile properties. The provisions indicating the limited usability of the product in question were already functioning in Polish regulations at the end of the last century [13]. The aforementioned national standard recommended the use of reinforced bitumen sheets with non-woven glass reinforcement only as one of the layers in multi-layer roofing. That indirectly indicates its limited usability.

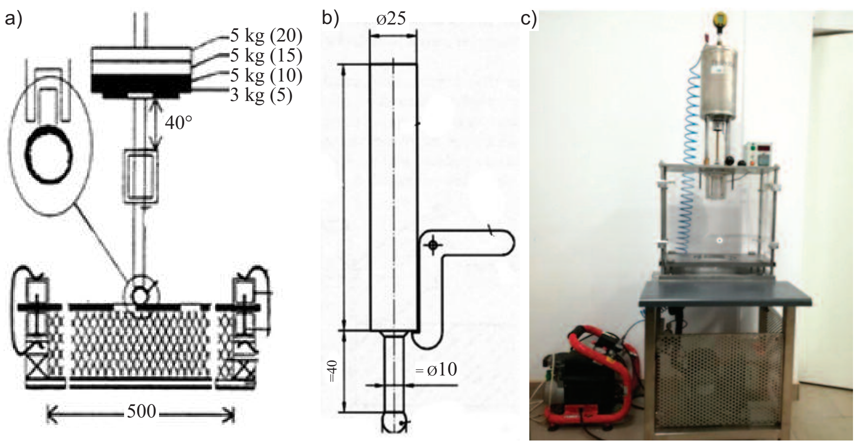

Fig. 1. Test equipment for mechanical tests: a) for static loading resistance; b) for impact resistance; c) for hail resistance
Rys. 1. Wyposażenie badawcze do badań mechanicznych: a) odporności na obciążenie statyczne; b) odporności na uderzenie; c) odporności na działanie gradu

Results and discussion

Below are presented comparative analyses of the durability of various systems of flexible roofing solutions in terms of three selected performance properties connected with concentrated loads acting on the surface of covering [1, 2]. The results of tests are shown in Figure 2.

The comparisons were made of typical covering materials used in single and multi-layer systems, laid on the following substrates: concrete or surface of thermal insulation, glued to the substrate and mechanically fastened. In the analysed solutions, the thermal insulation material was mineral wool placed on the surface of the metal sheet. The

The resistance to mechanical damage as a result of point loads depends on the type of substrates on which the products are placed. Bitumen sheet with polyester reinforcement on a concrete substrate have the highest resistance to concentrated mechanical loads acting in a long-term manner (i.e. static load – without damage under load at 20 kg) or temporarily, with different impact energy (i.e. impact resistance – without damage at the punch drop height of 1250 mm and hail resistance – no penetration by tested ball at the speed of 34 m/s) in the case

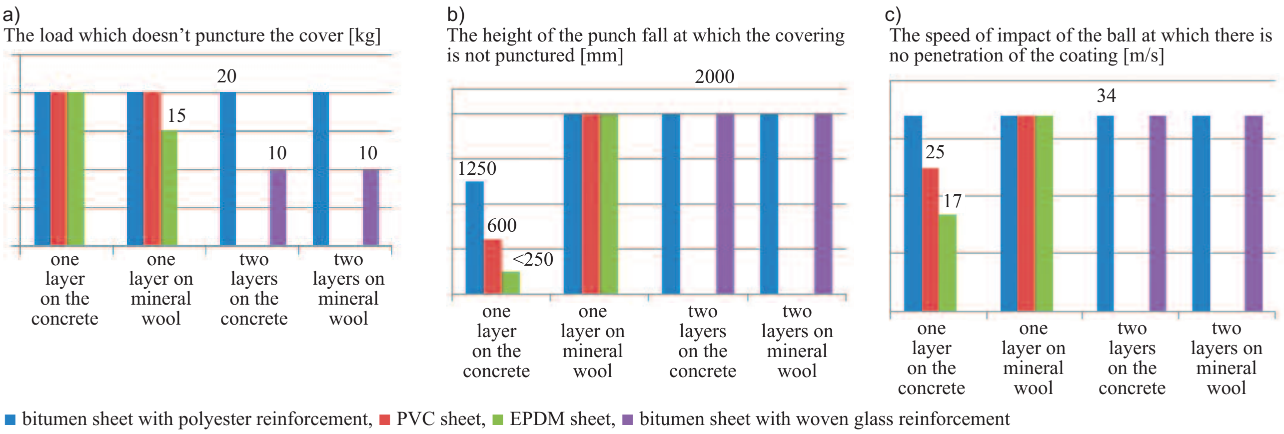

Fig. 2. Comparison for selected solution systems to: a) resistance to static loading, tested according to PN-EN 12730:2015-06 [1, 2, 10]; b) impact resistance, tested according to PN-EN 12691:2018-05 [1, 2, 11]; c) hail resistance, tested according to PN-EN 13583:2012 [1, 2, 12]
Rys. 2. Porównawcze zestawienie odporności wybranych układów rozwiązań pokrywczych na: a) obciążenie statyczne w badaniu wg PN-EN 12730:2015 [1, 2, 10]; b) uderzenie w badaniu wg PN-EN 12691:2018-05 [1, 2, 11]; c) działanie gradu, w badaniu wg PN-EN 13583:2012 [1, 2, 12]

of single-layer coverings. The EPDM sheets on a concrete substrate are definitely not impact-resistant, because they are damaged at the height of the punch drop below 250 mm. Among other things, for this reason, such solutions are rarely recommended for use in roofing. PVC sheets on concrete substrates show a higher impact resistance than EPDM sheets, without damage at the punch drop height of 600 mm, but they are still values lower than the resistance in this range of bitumen sheet with polyester reinforcement. The discussed situation changes when the above-mentioned coverings are assessed in single-layer systems, but on mineral wool substrates, i.e. substrates usually used in PVC and EPDM systems. In such solutions, all three products exhibit the same impact resistance as a result of concentrated loads, without damage at the punch drop height of 2000 mm and hail resistance – no penetration by tested ball at the speed of 34 m/s, with the lowest resistance to long-term concentrated loads in the case of EPDM sheet, without damage under load at 10 kg.

Two-layer coverings, in the discussed group of products, represented by two types of roofing reinforcements, i.e. polyester and woven glass, show the same impact resistance both in the case of laying on concrete and mineral wool substrates, without damage at the punch drop height of 2000 mm. Bitumen sheet with woven glass reinforcement shows a twice lower static resistance to long-term loads (i.e. 10 kg) than bitumen sheet with polyester reinforcement (i.e. 20 kg) placed on both of the above-mentioned types of substrates.

Conclusions

This article presents test results related to a functional property of flexible sheets i.e., concentrated mechanical loads which has a significant impact on water tightness of flexible roofing. Based on the obtained results, the following conclusions can be drawn:

- resistance to mechanical damage of flexible sheets depends on the type of substrate on which they are laid and the number of cover layers;
- on a concrete substrate, the highest resistance to mechanical damage as a result of concentrated loads is demonstrated by the bitumen sheets with polyester reinforcement, used both in one-layer and two-layers systems;
- on substrates made of mineral wool, all tested flexible products, i.e., bitumen sheets with polyester reinforcement, and woven glass reinforcement, PVC sheets and EPDM sheets, used in a single-layer system, show the same level of resistance to concentrated loads.

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