INNOVATIVE WATER PROOFING OF EXPLOITABLE ROOFS IN HIGH-RISE CONSTRUCTION

Vitaliy O. Chulkov¹, Ruben R. Kazaryan², Anastasya I. Shatrova³

¹Professor of the “Construction Process Organization and Technology” Department, Moscow State University Of Civil Engineering (National Research University), 26, Yaroslavskoeshosse, Moscow, Russian Federation
²Professor of the “Construction Process Organization and Technology” Department, Moscow State University Of Civil Engineering (National Research University), 26, Yaroslavskoeshosse, Moscow, Russian Federation
³Master's Degree Student of the “Construction Process Organization and Technology” Department, Moscow State University Of Civil Engineering (National Research University), 26, Yaroslavskoeshosse, Moscow, Russian Federation

¹vitolch@gmail.com, ²r.kazarian@mail.ru, ³shatrovaan@mail.ru

Corresponding Author: Vitaly O. Chulkov

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Abstract

High-rise construction requires scientific and technical support, which the authors of the paper suggest to comprehend as a “Man-Technology-Environment” system. With reference to this system, it is expedient to adapt the models, methods and means of anthropo technics management. It can serve as an effective means of improving the quality of innovative process-organizational and technological solutions for high-rise construction, taking into account some specific conditions of the Russian Federation environment. One of the examples examines the problems and possibilities of arrangement (design, erection, reorganization, and in particular - building reconstruction) of different roof types. In the Russian Federation, there are significant amounts of construction of high-rise buildings with different number of floors, on the roofs of which it is possible to create architectural and landscape objects with lawns and greenery. Such roofs are called exploitable; they are also implemented as “green roofs” or “hanging gardens”. With the use of traditional building and roofing materials, traditional technologies and organizational solutions for waterproofing (so-called “screeds”), it is difficult, and sometimes practically impossible to prevent leaks and provide sustainable protection from the root systems of green plantations. A horizontal screed made of cement and sand, vertical screeds
made of bricks, concrete blocks or flat asbestos-cement sheets are very laborious; when using them, “wet” processes are necessary, and asbestos-cement sheets fixing also reduces the reliability and water-resisting properties of the hydro insulation. An innovative solution to these problems is the TEFOND hydro-insulation (waterproofing) system based on a flexible polyethylene membrane. The system exhibits high density, strength, ductility and flexibility at negative temperatures, low water absorption and resistance to plant roots, reliability of roofing carpet underlay during service.

**Keywords:** Scientific and technical support / erection and reconstruction / exploitable roofs / screeds / TEFOND waterproofing system.

### I. Introduction

In Russia, there are many multistoried high-rise buildings intensively erected, on the roofs of those buildings it is possible to create architectural and landscape objects with lawns and greenery. Such roofs are called **exploitable**; they are also implemented as “green roofs” or “hanging gardens”.

These roofs are sophisticated in service, as traditional building and roofing materials practically do not provide waterproofing. It is very difficult to ensure the absence of leaks and sustainable protection from the root systems of green plantations. Regular waterproofing provides: **on horizontal sections**- 30 mm thick cement-sand screed, made of grade 100 cement grout; **on vertical sections** a screed made of M75 bricks on M50 cement grout with a thickness of 120 mm, and of concrete blocks of about 300 mm thick or of flat asbestos-cement sheets of 8 mm thick.

For the waterproofing of flat roofs made of concrete slabs, different treatments (repellents) and Penetron materials are used in the USA and Europe; such materials are changing the structure and properties of concrete almost on the entire thickness of the plate. The plate becomes practically impenetrable to moisture, but it is also additionally coated with mastic using Bikrost laminating rolls (or similar in characteristics). To eliminate leaks in joints and cracks in existing flat roofs, the Waterplug, Peneplag and Penecret materials are used.

Among the variety of roofing materials on the European construction market, the emphasis is made on:

- Reinforced rolled materials from oxidized bitumen, bitumen-polymeric materials, modified thermoplastic elastomer and modified thermoplastic polymer;
- Polymeric rolled materials: chlorinatated cellophane (polyethylene copolymer), terpolymer of ethylene and vinyl acetate, plastic polyolefin, polyisobutylene, polyvinyl chloride and a number of others;
- Elastomeric rolled materials: ethylene-propylene-terpolymercaoutchouc (rubber), butyl rubber, chlorosulfate cellophane, thermoplastic elastomers and others;
- mastic, waterproofing plastic material made of unsaturated polyester resins, polyurethane plastic, Poly(methyl methacrylate) (PMMA), bitumen rolls with iron foil and a number of others.

The optimal version of the exploitable roof waterproofing is currently a multilayered “pie” of different in characteristics, purpose, design and functioning principles layers, the number of which reaches ten. One of these layers of the “pie” is necessarily a membrane that provides collection and diversion (drainage) of water and condensate, as well as counteracting the spread of plant roots. The range (nomenclature), materials and form of the membranes are diverse, and the advantages from their utilization are sufficiently studied and published.

Developers of original innovative membranes protect their copyrights by patents, including - registering them not only in national patent organizations, but also in the World Intellectual Property Organization (WIPO). The patents examined are presented in our interpretation.

II. Materials and Methods

The range of roofing and waterproofing materials used in the Russian Federation is expanded by foreign thermo-plastic materials that appear on the Russian market; such materials have high strength, ductility, and flexibility at low temperatures, low water absorption and resistance to plant roots, which ensures the reliability of roofing carpet underlay during its service time.

First of all mention-worthy among such materials is the TEFOND waterproofing system based on High-density polyethylene (HDPE).

During the design and installation of roofs and waterproofing based on the materials of the TEFOND system, it is necessary to take into account the requirements of the official standards for:

● Erection and reconstruction of residential and public buildings and structures, and industrial and administrative buildings;

● Technologies and calculations of heat engineering parameters, fire safety of buildings and structures, erection and reconstruction of roofing and floors;

● Insulating and finishing coatings used to protect building structures from corrosion.

The TEFOND system is based upon waterproofing sheeting materials (membranes) of honeycomb structure made of High-density polyethylene (HDPE). They are equipped with target stabilizing coatings (reinforcing mesh made of fiberglass or polypropylene cloth – “Geotextiles”), which are produced according to the TU 5774-003-45940433-99 (technical specifications); and supplied in rolls of 20 m in length and 2.07 m in width.

HDPE-membranes of the TEFOND system, except for TEFOND PLASTER, are used as a protective waterproofing, additional hydro-insulation, self-contained hydro-insulation and a drainage layer. TEFOND PLUS, TEFOND DRAIN and TEFOND DRAIN PLUS membranes are used in exploitable (including of inversion type) roofs.
as a protective and drainage layer. For protective aprons, expansion joints compensators, elements of external gutters and finishing eaves on cornices, curly profiles of galvanized steel with a thickness of at least 0.8 mm are applied.

The joints of the longitudinal edges of the TEFOND HDPE-membrane can be of three types (Fig. 1):

- Single mechanical lock with a width of 70 mm (Fig. 1a);
- Double mechanical lock with a width of 170 mm (Fig. 1b);
- Double mechanical lock with two strips of SBS bituminous sealant applied. The sealant is applied in the factory and is protected with silicone sheeting. The presence of a sealant in the lock ensures tightness (waterproofing) of the connection (Fig. 1c).

The distance between the edge joints of the HDPE-membranes cross joints in the longitudinal direction should be at least 500 mm. The joint is sealed with self-adhesive ELOTENE tape.

III. Results

The waterproofing layer of the TEFOND system on the exploitable roofs of high-rise buildings is laid from top to bottom and from left to right, starting from the edge of the wall or retreating 1 m from any angle, to subsequently cover it with a

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*Fig. 1: Joint of longitudinal edges of TEFOND HDPE-membrane:*

- a) a single mechanical lock; b) double mechanical lock; c) a double mechanical lock with two applied strips of bituminous sealant; 1 - TEFOND membrane; 2 - bituminous sealant; 3 - supporting protrusions.

- Single mechanical lock with a width of 70 mm (Fig. 1a);
- Double mechanical lock with a width of 170 mm (Fig. 1b);
- Double mechanical lock with two strips of SBS bituminous sealant applied. The sealant is applied in the factory and is protected with silicone sheeting. The presence of a sealant in the lock ensures tightness (waterproofing) of the connection (Fig. 1c).

The distance between the edge joints of the HDPE-membranes cross joints in the longitudinal direction should be at least 500 mm. The joint is sealed with self-adhesive ELOTENE tape.
whole sheet. With the help of a level or a plumb, the insulated surface is marked out; a sheet of the necessary length is cut off from the roll. After making sure that the supporting protrusions located in the center of the mechanical lock are on the right side, HDPE-membrane have to be fixed to the insulated surface with nails and washers, inserting them into the second row of sockets every 300 mm and receding from the edge by at least 30 mm.

In the exploitable roofs of the traditional version, rock wool board thermal insulation is used - with a compressive strength of at least 0.06 MPa (Dachoterm, Isover, etc.); and in places loaded by moving vehicles of different weights - extruded polystyrene with compressive strength not less than 0.15 MPa (TU 2244-001-47547616-00) or non-pressing expanded polystyrene plates (GOST 15588-86) may be utilized.

In coatings on inverted roofs, it is recommended to provide only extrusion foam plates heat insulation, such as Pemoplex (TU 5767-002-46261013-99), Styrofoam/Styrodur, etc.

Bitumen and bitumen-polymeric materials on a glass or synthetic basis, as well as elastomeric vulcanized sheeting materials are used for the construction of a waterproofing carpet. In the cement-sand screed, thermal shrinkage joints of 5-10 mm are made, dividing the screed into sections of not more than 6 × 6 m; and for the length of bearing plates of 6 m - on the sections not exceeding 3 × 3m. The joints are arranged over the end seams of the bearing plates and filled with mastic, followed by a one-sided sticker to the seam of the roofing material strips with a width of 150-200 mm.

To ensure the adhesion of rolled roofing materials, all the surfaces of the cement-sand grout and concrete base are covered with priming cold compositions (primers) prepared from bitumen and kerosene in a ratio of 1: 2 or 1: 3 (by weight), or from adhesive mastics (butyl rubber and similar) diluted with a solvent in a ratio of 1: 2. Before the installation of waterproofing layers, the base surface must be dry, dust-free, without ledges, furrows and other irregularities.

TEFOND PLUS and TEFOND DRAIN PLUS membranes are laid with ledges upwards along the waterproofing carpet or along the slabs of the insulation. The edges of the membranes are mechanically combined by superimposing them on each other, providing an additional waterproofing of the coating due to the sealant in the “lock” (Fig. 2).

In the spots where the roof adherence the parapets, layers of additional bituminous carpet and the TEFOND layer are set on the upper edge of the parapet,onto which the parapet plates are laid, and the seams between them are sealed.

The locations of pipes passing through the roof are refined using steel pipes with flanges (or reinforced concrete cups) and sealing the roof in this location (Fig. 3). The design of the roof adherence to the parapet of the inverted exploitable roof and the skip variant are shown in Figures 3 and 4.
Fig. 2: Adherence of the exploitable roof to the parapet:
1 - additional layers of waterproof carpet; 2 – the up stand of the cement-sand grout; 3 - parapet plate; 4 - fencing of the roof; 5 - TEFOND PLUS membrane.

Fig. 3: Adherence of the inverted exploitable roof to the parapet:
1 - inclined up stand; 2 - concrete tiles; 3 - parapet wall; 4 - DG 3.7 × 70 fired pin (dowel); 5 - 4 × 40 mm steel strip; 6, 7 - a protective apron from the zinced steel; 8 - additional layers of waterproof carpet; 9 - TEFOND DRAIN PLUS membrane.

Fig. 4: the pipe passing through the roof:
1 - a protective zinced steel apron; 2 - a collar; 3 - steel pipe sleeve with flange; 4 - mineral wool insulation; 5 - pipe to be passed; 6 - sealing mastic; 7 - TEFOND PLUS membrane.

In the transitional areas of waterproofing layers from the vertical surface to the horizontal, joint of vertical and horizontal waterproofing is produced on a horizontal surface at a width of not less than 150 mm. On the top, the waterproofing layers are protected with a TEFOND PROTECT or TEFOND PLUS membranes.

TEFOND PLUS or TEFOND HP membranes with a mechanical seal, sensing part of the hydraulic pressure, can remove water entering the ground of the exploitable roof into drainage pipes and collector wells.

TEFOND HP membrane with special double-row bituminous mastic sealing of the mechanical lock allows restoring the broken waterproofing of the roof.

The membrane is fixed with anchor screws screwed into dowels with a diameter of 9 mm, which are inserted into the holes in the wall pre-drilled through the pock marks in the membrane. The spots of the screws passing through the membrane are then sealed with ELOTENE sealing tape, and the reinforcing mesh is fixed to the “ears” of the anchor screws.

IV. Discussion

TEFOND waterproofing system is known in the world construction market for several years, but for the construction industry in Russia it is still an innovation. Its application in our country began with the waterproofing of underground...
construction facilities, cellars and underground technical floors of buildings and structures, single- and multi-leveled parking lots, etc.

Attempts to utilize this system in the construction and reconstruction of the exploitable roofs of residential, public and administrative buildings are known only for the last 5-6 years. The operational experience of such roofs in Russia has not yet been investigated; system monitoring of the results of the TEFOND waterproofing systems utilizing in the country is not carried out. This is due not only to the lack of officially operating methods and technologies for such monitoring, but also to the “Trade secrets” of domestic market building companies engaged in the construction of exploited roofs in high-rise buildings.

In the high-rise construction, the TEFOND system and its Tefond Plus, Tefond Drain, Tefond Drain Plus and Tefond HP modifications can be successfully used in the basement and ground floors of erected or remodeled buildings - where premises for servicing equipment of a high-rise building are located, along with single- and multi-leveled parking lots, social service enterprises, clubs and other establishments of social orientation.

The TEFOND system and its modifications can be applied in the processes of “retracement” (construction or reconstruction of external collapsible hinged building finishing systems), as a waterproofing of the surfaces of the structure.

Based on high density polyethylene membrane - TEFOND waterproofing system has high strength, ductility, flexibility at negative temperatures, low water absorption and resistance to external physical and chemical influences, and sufficient vapor permeability.

Therefore, the above-mentioned innovative process-organizational and technological options (on the sample of exploitable roofs) are an actual modern component of scientific and technical support for high-rise construction.

V. Conclusion

TEFOND high-density polyethylene waterproofing membrane is a reliable and inexpensive rolled material for waterproofing and drainage works, which provides long-term reliable waterproofing from moistness and plant roots. These impacts are inherent in both the conditions for the erection and operation of roofs of high-rise buildings, and the conditions for the erection and operation of underground building.

A special lock (unique design feature of adherence of two membrane track beds) ensures fast and accurate positioning of the membrane both in the horizontal and vertical directions of its installation without the formation of separation seams. The TEFOND membrane in all its modifications is supplied in rolls of 20 m and 2.07 m wide, which ensures the convenience of placing the membrane on surfaces of any shape and any size: the excess part of the coating can be easily cut off; and when storing rolls, the storage areas are reduced by more than 50%.
The availability of spherical projections in the TEFOND drainage membrane provides ventilation for the insulated surfaces, and ensures a constant air circulation and condensate removal. The membrane allows, at its packing by vertical strips, to fasten a material only in the uppermost part, avoiding an additional necessity to pierce fixing holes in a wall.

TEFOND is the first material the parts of which are perfectly connected with each other simply by imposing their edges. This unique connection method (special lock with seal seam) ensures fast and easy laying of the coating; and also makes the whole system reliable and durable: the edges of the two parts of the coating do not separate even under strong pressure.

All materials of the TEFONDT system are certified for compliance with the ISO 9001 European quality standards.

VI. Recommendations

The variety of TEFOND waterproofing membranes (Tefond, Tefond Plus, Tefond Drain, Tefond Drain Plus and Tefond HP) is universal in its application. But in high-rise construction their application cannot be overestimated. Particular attention is drawn to the Tefond HP modification. This drainage membrane is made of increased strength high-density polyethylene with a thickness of 8.5 millimeters and bitumen sealant lock. It is used on large-scale construction sites for soil stabilization, waterproofing and even distribution of loads. The use of Tefond HP in the construction of roads can reduce the thickness of the roadway and lower the level of its deformation.

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