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Investigation of the resistance of profiled membranes to root-proof and aggressive chemicals

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The article considers the use of profiled membranes in construction as a substitute of concrete preparation for foundation systems, floors on grade and drainage systems (e.g. multipurpose flat roofing, wall drainage). The article discusses the main properties of profiled membranes in terms of their ability to be used in such systems. The article gives examples of sites and construction site conditions. According to them the paper recommends the use of profiled membranes in various systems. The article describes the laboratory tests performed to determine the root-proof of PLANTER profiled membranes. According to the tests of CEN/TS 14416-2014, we placed the profiled membrane samples in special test clay pots with lupine (Lupinus albus) seeds for a period of 8 weeks. It is an ordinary time of roof-proof assessment of the material. In order to assess the chemical resistance, we placed PLANTER profiled membrane samples into 15% solutions of H_2SO_4, Na_2SO_4, NaOH.
We found that PLANTER polymer profiled membranes are root-proof (do not allow plant roots to germinate) as well as chemically resistant. This allows us to recommend their using for drainage systems, as waterproofing protection, to replace concrete preparation in foundation systems (or floors on grade).

Key words: concrete, reinforced concrete, corrosion, chlorides, concrete preparation, floors on grade, drainage, polyethylene, profiled membranes, reagents

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НАУЧНАЯ СТАТЬЯ
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Исследование стойкости профилированных мембран к прорастанию корней и агрессивным химическим веществам

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Статья рассматривает применение профилированных мембран в строительстве в качестве замены бетонной подготовки в системах фундаментов, полов по грунту и в дренажных системах (например, дренаж в эксплуатируемых кровлях, пристенный дренаж). Рассмотрены основные свойства профилированных мембран, которые характеризуют возможность их использования в таких системах. Приведены примеры объектов и условий строительных площадок, на которых рекомендуется использование профилированных мембран в различных системах. Проведены лабораторные исследования по определению корнестойкости профилированных мембран PLANTER, по результатам которых получено заключение. В данных испытаниях согласно CEN/TS 14416-2014 образцы профилированной мембраны помещались в специальные испытательные глиняные горшочки с семенами люпина (Lupinus albus) на период 8 недель, в течение которых оценивалась корнестойкость материала. Для оценки химической стойкости образцы профилированной мембраны PLANTER помещали в 15%-ные растворы химических веществ (H_2SO_4, Na_2SO_4, NaOH).
По результатам проведенных испытаний выявлено, что полимерные профилированные мембраны PLANTER обладают корнестойкостью (не позволяют прорастать корням растений), а также химической стойкостью. Это позволяет рекомендовать их для использования в дренажных системах, в качестве защиты гидроизоляции, для замены бетонной подготовки в системах фундаментов (или полах по грунту).

Ключевые слова: бетон, железобетон, коррозия, хлориды, бетонная подготовка, полы по грунту, дренаж, полиэтилен, профилированные мембраны, реагенты

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INTRODUCTION

The selection of quality materials at the design stage is an important aspect of any construction project. Construction of ordinary buildings and buildings for special purposes (e.g. construction class KS-3, according to GOST 27751-2014) [1, 2] requires the use of modern waterproofing materials such as polymeric membranes (PVC or Thermoplastic Polyolefin Reinforced Membrane (TPRM) [3, 4], BRM (Bitumen Roll Materials) [5], mastic, etc. The backfill soil often contains various rubbish, including sharp objects (broken bricks, concrete scrap, etc., Fig. 1, *a*), which can damage the aterproofing during backfilling. In order to avoid these consequences, according to SP 45.13330.2017 [8], item 11.30, the waterproofing must be protected with sheet or roll-fed materials, such as profiled membranes (Fig. 1, *b*) [6, 7]. If protection is not provided, there is a high probability of damaging the waterproofing layer [8] with further penetration of moisture into the structure, which can initiate the process of corrosion of concrete and reinforcement [9-11].

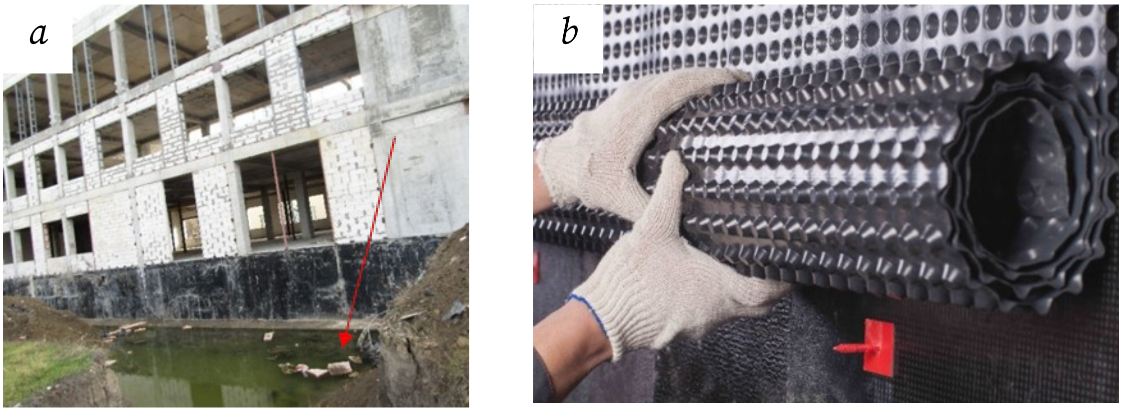

Fig. 1: *a* - building rubbish in the backfill soil at various construction sites; *b* - waterproofing protection with profiled membrane

We strongly recommend against allowing moisture to penetrate, as groundwater contains various salts (e.g. chlorides) which can lead to corrosion of the steel reinforcement inside the concrete body and cause the failure of the concrete protective layer [9-11]. According to GOST 31937-2011, Appendix E, Table E.1, item 6, such a defect (as well as preceding defects in item 2, item 5, Table E.1) reduces the bearing capacity and durability of reinforced concrete structures [11, 12]. Repair of reinforced concrete structures in case of such defects is difficult and expensive one [12-15], because it is necessary to completely remove the corroded protective layer of concrete, perform mechanical cleaning and treatment (with corrosion converters) of steel reinforcement surface and restore the protective layer with special repair compositions [12-15]. Large construction projects require the extra Scientific and Technical Construction Support Activities (STSS) [16], which can be performed in order to monitor the quality of work in progress and prevent concrete corrosion/damage of the waterproofing.

In addition to protecting waterproofing, profiled membranes can be used in drainage systems (e.g., double-layer profiled membranes with a layer of filtering geotextile (Fig. 2, *a*, 3, *b*), and as a replacement for concrete floors on grade (see Fig. 2, *b*, 3, *a*), in landscaping, etc.

The profiled membranes based on High-Density Polyethylene (HDPE, PVP, LPP) are the most common ones. Polyethylene is produced on a large-scale; the polymer is chemically resistant and has great physical and mechanical properties allowing it implementation in many areas of construction [17, 18].

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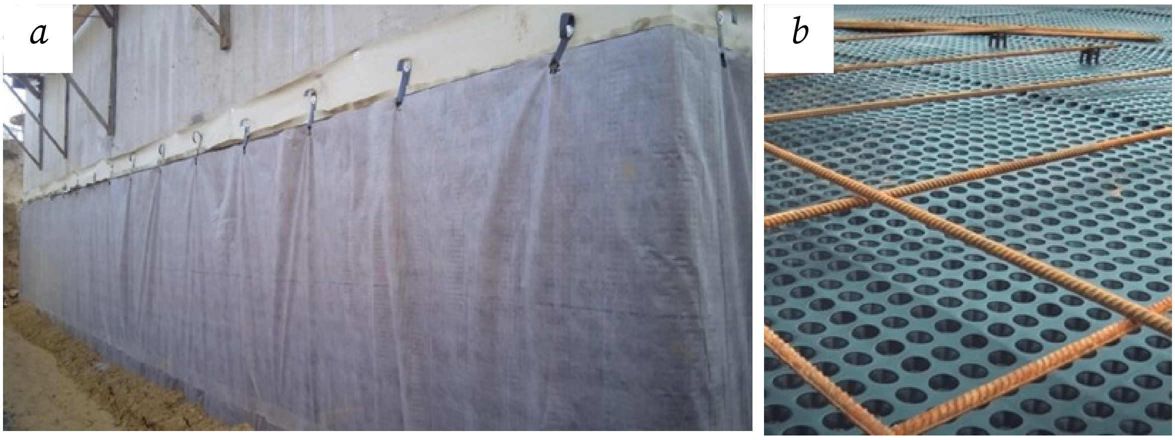

Fig. 2. Example of using profiled membranes «PLANTER» manufactured by TECHNONICOL Corp: *a* - at the wall drainage system in combination with waterproofing of PVC-polymer membranes; *b* - as a capillary cutoff for floors on grade

When used as a capillary moisture barrier in ground-supported floor structures and as a substitute for concrete preparation, profiled membranes can be classified as secondary concrete protection in terms of their characteristics (Fig. 2, *b*, 3, *a*). 3.6 GOST 31384-2017, item 4.4 of SP 229.1325800.2014, item 5.1.2 and item 5.3.4 of SP 28.13330.2017), to a subset of facing insulation coatings (item 9.3 GOST 31384-2017, item 5.1.2 and item 5.3.4 of SP 28.13330.2017), which make the contact of concrete with aggressive mediums difficult. These materials must be highly resistant to aggressive media (item 9.14 GOST 31384-2017) [19]. Flooring regulations, e.g. in SP 29.13330.2011 [20], item 10.4, recommend the use of capillary-retaining layers of geosynthetic materials in the construction of floors on grade.

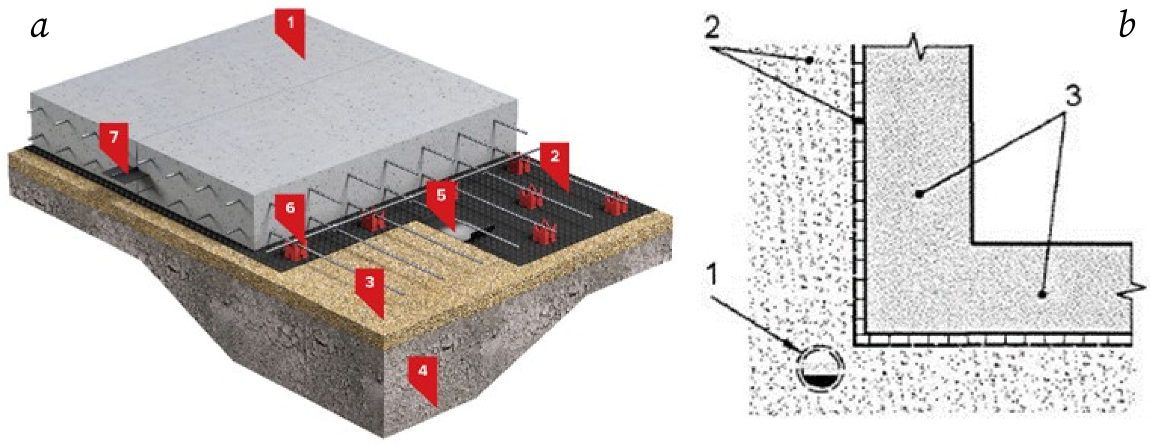

Fig. 3. Example of using profiled membranes: *a* - as a replacement for concrete preparation in a slab foundation; *b* — in a wall drainage system in combination with a drainage pipe, according to SP 250.1325800.2016

Design and construction of drains normative documents are one of the special protection measures, according to item 4.5 of GOST 31384-2017), in particular, SP 250.1325800.2016 item 4.2.5, item 7.6.2.8, provide for drainage membranes, which can be used in various systems (see Fig. 2, *a*, 3, *b*), for example for a wall drain [21]. Materials used in various types of soils should demonstrate high rates of physical and mechanical properties, in particular, for root - proof. (item 5.2 and item 5.3.5 of SP 28.13330.2017, item 6.4 of GOST 31384-2017), durability and resistance to various aggressive factors.

We examine these properties using as an example PLANTER profiled membranes (Table 1).

Table 1. Physical and mechanical characteristics of PLANTER profiled membranes

Name of parameter	Unit of measure	Criterion	Value (for the brand)			Test method
			Standard	Eco	Extra	
Thickness of sheet	mm	-	0.55	0.5	0.8	GOST EN 1849-2-2011
Protrusion height	mm	-	8.5	8.5	8.5	GOST EN 1849-2-2011
Weight	g/m^2	at least	550	450	800	GOST EN 1849-2-2011
Compressive strength (at deformation >75%)	kPa (kN/m^2)	-	280	200	550	STO 72746455-3.4.2-2014 (item 7.3)
Compressive strength (determined at maximum load in the deformation zone of the sample up to 50 %)	kPa (kN/m^2)	-	130	80	310	STO 72746455-3.4.2-2014 (item 7.3)
Maximum tensile force, method A:	N/50 mm					GOST 31899-2-2011 (EN 12311-2:2000)
alongside the roll		at least	280	200	450	
across the roll			270	190	430	
Relative elongation at maximum tensile force	%	at least	20	20	18	GOST 31899-2-2011 (EN 12311-2:2000)
Static crushing resistance, method B	kg	at least	20			GOST EN 12730-2011
Flexibility on a 5 mm radius bar at low temperature	°C	maximum	- 45			GOST 2678-94
Water absorption by mass	%	maximum	1			GOST 2678-94
Water resistance at a pressure of at least 0.001 MPa for 24 hours	-	at least	no sign of water penetration			GOST 2678-94
Dimensional changes at 80 °C	%					GOST EN 1107-2-2011
alongside the roll		maximum	2.0			
across the roll			2.0			

Depending on the brand, the strength tests of PLANTER profiled membranes (see Table 1, Fig. 4) show that, they can withstand loads (in terms of tensile strength) from 200 to 550 kPa (Fig. 5). Due to this, the use of profiled membranes as a waterproofing protection and substitute for concrete underfloor cavity preparation (floors on grade) is reasonable and recommended in various normative documents (e.g. in SP 29.13330.2011).

Application for profiled membranes

The main objects for the application of profiled membranes are: large residential complexes (replacement of concrete preparation, drainage on stylobates/roofs (Fig. 6, *a*) and wall drainage/waterproofing protection in foundation structures (see Fig. 2, *a*)), transport tunnels (waterproofing protection and drainage), large industrial and agricultural facilities (ground-supported floors, Fig. 6, *b*). Various fasteners and accessories are used to fix the profiled membranes (Fig. 7).

It is important to remember that, although profiled membranes are similar to waterproofing coatings, they are not a completely waterproofing membranes, but can only protect against capillary moisture penetration.

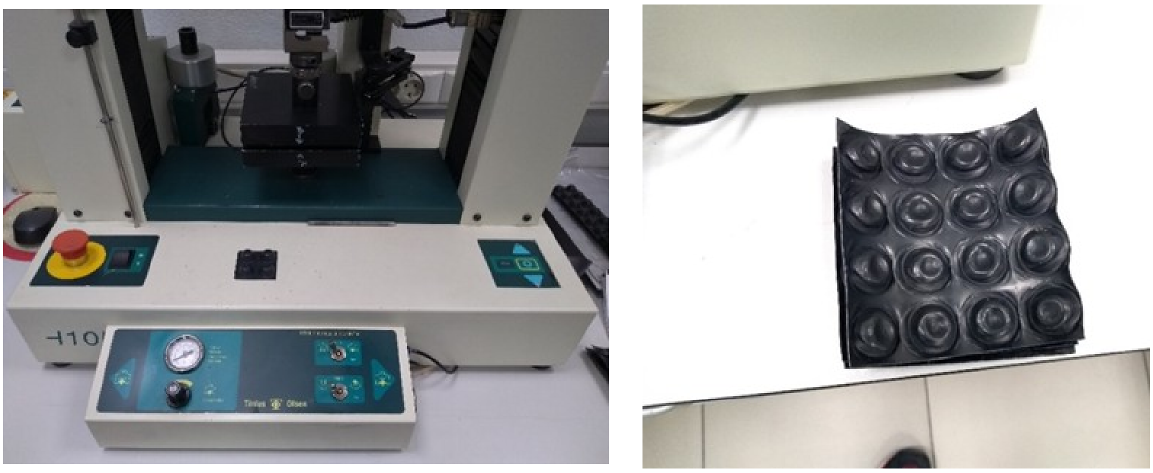

Fig. 4. Example of testing a sample of a profiled membrane with a size of 10x10 cm for compression

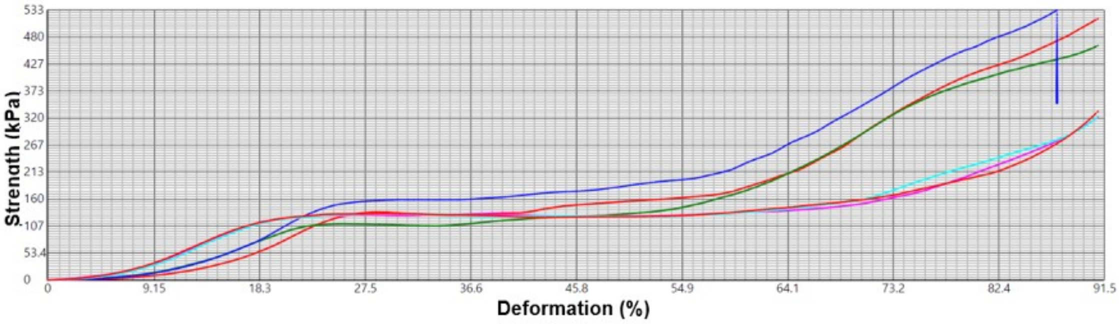

Fig. 5. Example of a graph for determining the compressive strength when testing various samples of PLANTER profiled membranes

Fig. 6. Application of profiled membranes at real construction objects: *a* – the green roof of the museum complex; *b* – installation of floors on grade for a large agricultural complex

It is the result of the membrane are usually joined by using bitumen-polymer tapes (see Fig. 7), which cannot fully replace a polymer membrane welder. Thus, the main condition for using a profiled membrane as a substitute for concrete preparation is a low groundwater level at the construction site. If there is a high level of groundwater, the use of profiled membranes is not recommended and it is necessary to arrange concrete preparation.

The use of drainage membranes as part of the drainage system is recommended for facilities located in the area with high groundwater level (see SP 250.1325800.2016 item 4.2.5 and SP 104.13330.2016 item 4.9), floodplains, etc. [22]. Drainage membranes enable the drainage of groundwater and surface water on construction sites, landscaping elements (e.g. soft screeds or pavements), multipurpose flat roofing, etc.

Fig. 7. Accessories for profiled membranes «PLANTER»

As drainage systems, concrete preparations and ground-supported floors are used in groundwater and soil conditions, they should have root - proof and chemical/biological stability in order to ensure an extended effective operation life for the structures. The experimental part of the article deals with tests of PLANTER profiled membranes for chemical resistance and to root – proof, which are of high relevance and directly relate to the durability of buildings and structures.

EXPERIMENTAL PART AND RESULTS

PART 1. Selected samples of PLANTER profiled membranes with a pre-fixed weight were immersed for chemical resistance tests (according to GOST R 56910-2016/EN 1847:2009) in a test liquid and incubated for a defined period (28 days) at a given temperature. Membrane characteristics were determined before immersing the samples into chemical reagents and the same parameters were subsequently measured after exposure to the corrosive medium.

In the laboratory conditions, we complied with the requirements for standard test:

- temperature - 23 °C;
- atmosphere pressure - 740 mm Hg;
- relative humidity - 65%.

Samples of the profiled PLANTER membrane were placed into solutions of aggressive substances:

- 15% sulphuric acid solution (H_2SO_4);
- 15% sodium hydroxide (NaOH) solution;
- 15% sodium sulphate solution (Na_2SO_4).

Depending on site conditions, the list of reagents can be modified according to EN ISO 175:2000, e.g. instead of sodium hydroxide (NaOH) a calcium hydroxide ($Ca(OH)_2$) solution can be used to simulate curing concrete conditions.

After removing the samples (Fig. 8, *a*) from the test fluids, we recorded the presence of visual defects on the samples:

- change of colour;
- appearance of spots;
- appearance of gloss or mattness;
- occurrence of cracks/microcracks;
- appearance of bubbles/deepening/flatting etc.

The change of weight in compare with their original weight and the change in strain and strength characteristics (e.g. tensile/compression strength, Fig. 8, *b*) are also recorded.

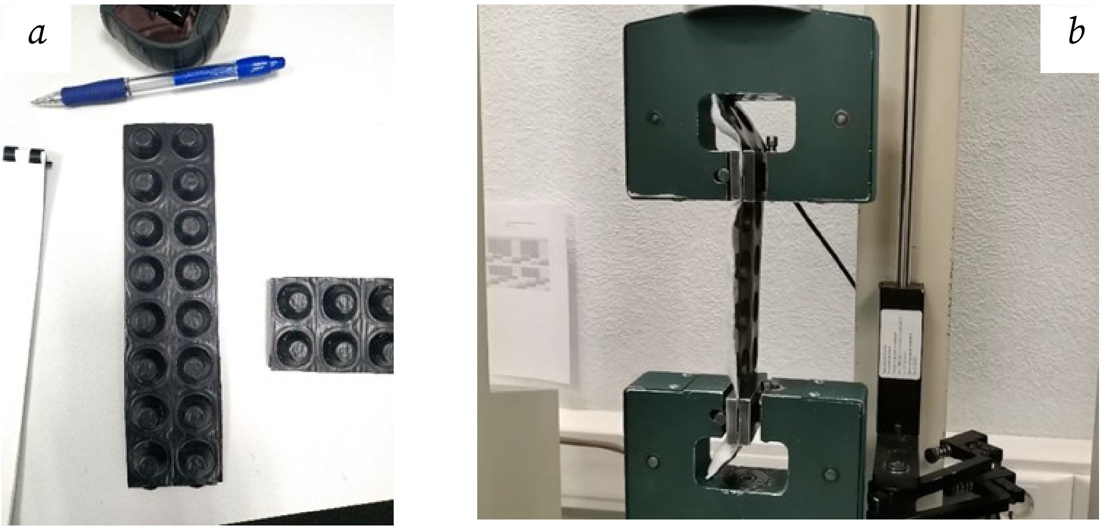

Fig. 8: *a* – selected sample of profiled membrane for testing; *b* – determination of tensile strength for profiled membrane sample (200x50 mm)

According to the tests, the physical and mechanical properties of the profiled membrane samples before and after the tests (tensile/compressive strength of the samples) did not change by more than 5%. The change in weight was not more than ±3.5%. This suggests the high chemical resistance of PLANTER profiled membranes when exposed to aggressive chemicals over a given period.

PART 2. We placed selected samples of PLANTER profiled membranes Ø200 mm into special clay test pots for root - proof tests according to CEN/TS 14416-2014. We piled soil with white lupine (Lupinus albus) seeds on top for a period of 8 weeks. Both conventional and enriched soil mixes can be used to speed up flowering of seeds (the substrate is premixed with nodules, grinded roots of old plants, etc.). Early sprouts can appear as early as 7–19 days with the enriched potting soil mixture, so a period of 8 weeks is sufficient to evaluate the root - proof of the materials.

At the time of completion of the tests, we dug up the samples and assessed the extent of root damage (whether the roots had germinated through the material). Root - proof materials can prevent roots germinating completely (Fig. 9, *a*, *b*).

Fig. 9. Testing of profiled membranes for resistance to root – proof: *a*, *b* – the sample of the profiled membrane did not allow the roots to germinate

Based on the results of the tests, Table 2 shows the root germination through the test material and its chemical resistance values.

Table 2. Test results of PLANTER profiled membranes for root resistance and resistance to aggressive chemicals

Material/polymer	**Root - proof according to 8-week results**	**Chemical resistance according to 28-day test results**		
		Solutions		
		15% H_2SO_4	**15% Na_2SO_4**	**15% NaOH**
PLANTER profiled membrane (HDPE)	The roots have **NOT** penetrated the material	Withstands the effects of	Withstands the effects of	Withstands the effects of

CONCLUSIONS

Thus, by the experimental results, we can conclude the synthetic materials, in particular of PLANTER profiled membranes, are root – proof and chemical resistant. On the basis of the results named above the test reports were issued.

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