THE USE OF GEOSYNTHETICS IN ROAD CONSTRUCTION GERMAN REGULATIONS AND THE PHILOSOPHY BEHIND

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In road construction in Germany geosynthetics are used in all types of earth works. For these applications we have regulations. Their aim is, to find for the user the product, which fits best for his application and to give the producer or deliverer a chance, to go into the market in a fair contest. To define the properties necessary for a given purpose, we calculate where possible and we classify where a calculation method is not available or not practical. The classification of the robustness, for instance, is a pragmatic approach, based on the experience and on tests in lab- and site-scale. For quality assurance we have a system in three steps with basic tests by an approved body to prove the main properties, with the production control by the producer and with control tests by the client or an approved body to guarantee, that the right product has been delivered.

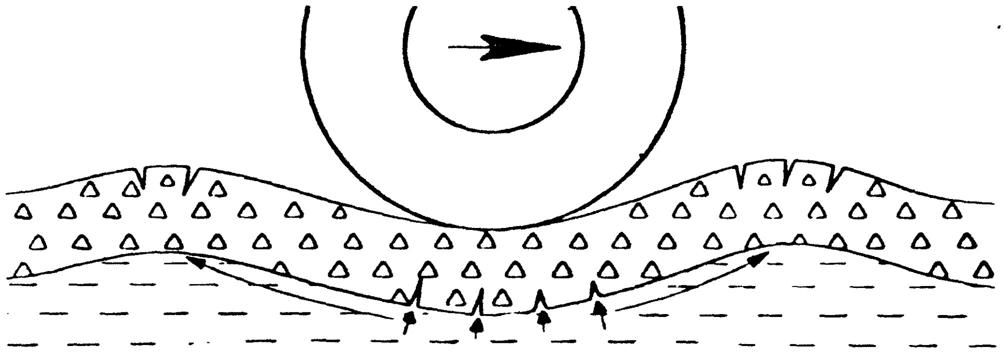
REGULATIONS IN GERMANY

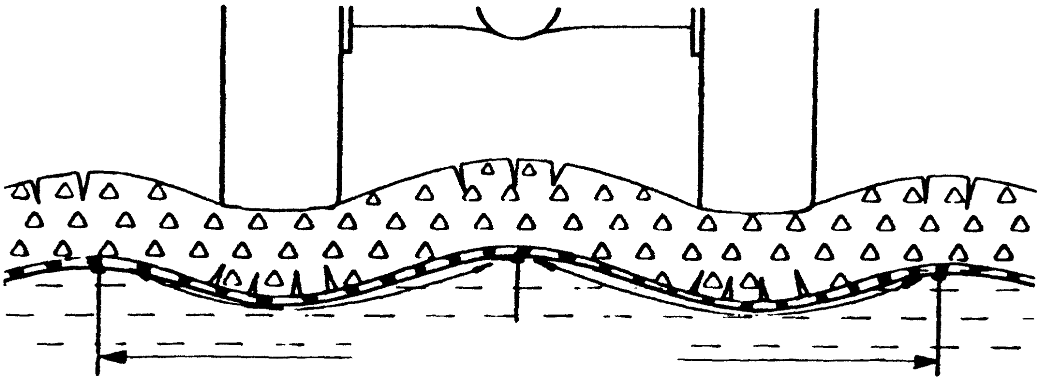
For the use of geotextiles and geogrids in road construction in Germany we have three papers, which are supplementing each other:

- Additional terms for technical contracts and guidelines for earthwork in road construction: ZTVE StB 94 [1]
- Technical terms of delivery of geotextiles and geogrids in earthwork in road construction TL Geotex E-StB 95 [2]
- Notes on the use of geotextiles and geogrids in earthwork in road construction 1994 [3]

FIRST STEPS TO THE USE OF GEOTEXTILES

In the beginning of the use of textiles in geotechnics in road construction in Germany in the early 70th, the function and the conditions for the function of these sheets where not fully understood. So we started with large-scale tests on site, laid in different nonwoven - products under the same conditions [4] [5]. By this we have seen, that the most important function was the separation of soils. This means, that soils of different behaviour keep their possibility to act under their properties by the laws of soilmechanics: fine grained soils in the ground consolidate under the loading, without destruction of their texture, while the coarse-grained fill stay in their behaviour of a soil with high internal friction. Without separator there will be a mix of ascending fines with the coarse grained fill. The fines separate the aggregates from each other until they „swim“ in the paste of water/soil mixture. Then the internal friction will break down to the friction properties of totally disturbed fine grained soil [6].
The separator must separate the soils, but allow the water to penetrate. It is better if it allows passing the very fines than to keep them back, which gives the danger to block the separator. The separator must be strong enough to withstand the mechanical damage by fill, by compaction and by site traffic. But it must not act as an reinforcement. The bearing capacity of the system is given by the addition of the bearing capacity of the fill and the subsoil.





This Figure shows the function of a separation layer under a base course over a soft soil with vehicles passing. above: under the load the aggregates on the lower side of the base course open the spacing and the fines of soil can penetrate. low: The textile hinders this, but not the rutting under the vehicles load [6].

The first tests with nonwovens made clear, that by the use of a rock-fill or by big stones, it was good to use separators with high elongation, which can follow the very intense and irregular interface between the subsoil and the fill. Even the strongest nonwovens had been destroyed, when penetrated by a larger stone, but this seemed to be not a problem, because he stone stuck in the hole, the filaments surrounded it and so the hole was closed. That's why the typical separator by our experience is an nonwoven.

The Static Puncture Test and the Geotextile-Robustness-Classification

All the products tested worked well, but there where differences and we needed a system to evaluate the behaviour and the differences. And we needed a system to compare the different products, to give every producer the chance, to enter our market in a fair contest and to give the user the assurance to get always a good product. In the first International Conference on the Use of Fabrics in Geotechnics, held in Paris 1977 Alfheim & Soerlie reported about the system, developed in the Norwegian Road Research Laboratory [7]: They tested the mechanical strength of the textiles by a so called CBR-tensile-test and in addition by a cone-drop-test and used the results to define the suitability for the use under 4 different classes of fill over soft soil. We adapted the CBR-tensile-test in Germany as „Plunger-Puncture-Test" to measure the push-trough-force (the Plunger-Puncture- or so called CBR-Test is now defined as „Static Puncture" in ISO 12236). By this we then classified the nonwovens in four classes and defined the fill and the acceptable aggressivity of site conditions to it. This system is in practise since 1980 [6]. Based on this experience and on a lot of site tests [8], this system was changed in 1994 [3][9]. With the static puncture test, we classify now the nonwovens in five Geotextile-Robustness-Classes (GRC). For wovens we use the tensile - force. To find out the necessary GRC for a given site, we classify the fill in 5 classes on the bases of the diameter and the coarseness/sharpness of aggregates. In addition we classify the loads resulting from installation and construction works.

Table 1: Geotextil - robustness - classes of different geotextile - product - groups [2][3]

Product - group	Nonwovens		Wovens and Knitted (foil strips/ splice yarns)		Wovens (multifilament yarns)	
Geotextile - Robustness - Classes	Plunger - puncture - force (x*-s) [kN]	Mass per unit area (x*) [g/m²]	Tensile strength (x*-s) [kN/m]	Mass per unit area (x*) [g/m²]	Tensile strength (x*-s) [kN/m]	Mass per unit area (x*) [g/m²]
GRC 1	≥ 0.5	≥ 80	≥ 20	≥ 100	≥ 60	≥ 230
GRC 2	≥ 1.0	≥ 100	≥ 30	≥ 160	≥ 90	≥ 280
GRC 3	≥ 1.5	≥ 150	≥ 35	≥ 180	≥ 150	≥ 320
GRC 4	≥ 2.5	≥ 250	≥ 45	≥ 220	≥ 180	≥ 400
GRC 5	≥ 3.5	≥ 300	≥ 50	≥ 250	≥ 250	≥ 550

Table 2: Classification of cover - material (fine-grained subsoil): classes AS 1 to AS 5 [2][3]

Classes	Type of Cover Material	
AS 1	Without influence on selection	Without influence on selection
	round shaped grains	*sharp edged, crushed aggregates*
	coarse grained or mixed grained material	coarse grained or mixed grained material
AS 2	‘’ ‘’ without stones	---
AS 3	‘’ ‘’ with 5 ≤ 40 % stones	‘’ ‘’ without stones
AS 4	‘’ ‘’ with ≥ 40 % stones	‘’ ‘’ with 5 ≤ 40 % stones
AS 5	---	‘’ ‘’ with ≥ 40 % stones

Table 2: Classification of load resulting from installation and construction process [2][3]

Classes	Types of Loading
AB 1	Manual installation and covering and no significant loading on the geotextile resulting from compaction
AB 2	Mechanical installation and compaction without significant stress resulting from construction vehicles
AB 3	Mechanical installation and compaction and increasing stress resulting from permitted rutting with depths from 5 to 15 cm
AB 4	Mechanical installation and extreme stress resulting from permitted rutting with depths of more than 15 cm

Table 3: Determination of the geotextile-robustness-class, necessary for a special site [2][3]

Classes of Cover Material	Loading Classes			
	AB 1	AB 2	AB 3	AB 4
AS 1	GRC 1			
AS 2	GRC 2	GRC 2	GRC 3	GRC 4
AS 3	GRC 3	GRC 3	GRC 4	GRC 5
AS 4	GRC 4	GRC 4	GRC 5	(*)
AS 5	GRC 5	GRC 5	(*)	(*)

(*) = site test necessary or increasing of the thickness of the cover layer required

NEW APPLICATIONS - NEW PRODUCTS: PRODUCT-SPECIFICATIONS

In the run of time a lot of new products with very different and very special properties are invented and allow very special applications. To find out their properties a lot of different test are developed. But how to find out the suitable product for a given application? In Germany we have a very open marked. We cannot really demand a product by brand name. To find the product, which fits best in a special application, we must define the properties, which the product must have or the technical demand, which it must fulfil. We calculate where calculation is possible and classify, where we have no basis to calculate or where calculation does not fit (see table 4) [1][2][3].

Table 4: Functions and related properties: calculation or classification

PROPERTY	Strength	Elongation	Installation-Damage	Friction	Durability		Filter - behaviour
FUNCTION					weather	chemical	
Separation	GRClas	GRClas	GRClas	n-n	clas	f-s	clas
Protection	GRClas	GRClas	GRClas	calc	clas	f-s	clas
Filtration	n-n	n-n	GRClas	n-n	clas	f-s	calc
reinforcement	calc	calc	f-s /s-t	calc	clas	f-s	clas

Explanations: calc: calculation; clas: classification; GRClas: Geotextile-Robustness-Classes; f-s: factor of safety; s-t: site test; n-n: not needed

Strength and elongation for the most functions is covered by the GRC, only for reinforcement there is a calculation, based on data from tensile test. For wovens and grids we normally use ISO 13934-1 and not use the wide-with-tensile test ISO 10319, because it is not really adapted to these products. The wide-with-tensile we prefer for nonwovens.

Installation damage is covered by GRC. But in case of reinforcements we demand performance-tests and in special cases site-tests, where the product is tested under the condition of the given site, concerning material for the fill and method of installation and compaction.

Friction is necessary for slope protection and for reinforcement. Slopes are simulated by an inclined plane test (ISO 12957); for reinforcements the results of a direct shear test are used (ISO 12957).

Durability:
Durability is demanded for the design life:

- Separator as construction-aid 1/2 to 1 year
- Filter in a drainage easy reparable: 10 to 25 years
- Filter in a drainage under a construction: 80 - 100 years
- Reinforcement under a dam against slipform-failure: time for consolidation: 1 to 5 years
- Reinforcement of a steep slope for long-term: 80 - 100 years.

Factors concerning durability:

Tensile creep and creep rupture of reinforcements is investigated by long-term tests. A short-term index creep test (ISO 13431) gives the chance to find out the basic creep properties of a product and to compare the creep-properties with those of a long-term tested product.

Compressive creep and creep collapse of drain elements: is tested by a short-term index test (ENV 1897)

The resistance against weathering conditions (UV-rays and washing out of protective inhibitors) is classified by the results of weathering tests in the Global-UV-tester (ENV 12224), see table 5. For installations, where the products can be unprotected for longer periods, for instance in slope-protection, only products with high resistance are allowed. In all other cases the time to protection is limited by the weather-resistance of the product. This is a question for the organisation of the work on site. The given periods are valid only for the conditions of the climate in Germany. In sunny regions the periods must be shorter.

Table 5: Classification of weather resistance by remaining tensile strength after weathering in the Global-UV-Tester (ENV 12224) [2][3]

Weather resistance class	remaining tensile strength (x*-s)	Protection by covering with fill or topsoil
low	< 60%	within 1 week
medium	60 - 80%	within 2 weeks
high	> 80%	within 2 months

Resistance against chemical attack: For PE and PP the oxidative, for PA and PET the hydrolytic resistance has to be observed and in case of permanent applications to be improved, if the product is decisive for the life of the structure. Hydrolyses of polyesters (PET): the chains of the polyethilen-therephthalat can be split by water. The shorter the molecules, the lower the strength of the fibre (inner hydrolyses, acting in all pH-conditions, but accelerated by acids). The outer hydrolyses means corrosion of the surface of the fibre. This type is acting under high pH - values, especially under presence of calcium (for instance. limestone or gypsum). In long-term constructions PET must not be used in contact with soils with pH ≥ 9,5. In all cases PET is not to be used in direct contact to cement-concrete and to soils, mixed with cement or lime [3].

For constructions, where the fabric is very important for the safety, it is recommended, to install test specimen under realistic conditions and to test some of them every 6 year, to see if ever there is a change with time and to have the opportunity to act early, if a lack of safety is developing [2].

Blocking and clogging of a filter: a calculation, based on the opening size O_{90} tested by a wet sieving test with natural sand, gives the safety for the long-term function of the filter [2].

EXAMPLES OF APPLICATIONS

Geotextiles and related products are used in geotechnics for road construction for the functions [1][3]:

- Separation of different soils, mostly under loads
- Protection of slopes and of geomembranes and other waterproofing systems
- Filtration in drainage systems
- Reinforcement of earth constructions like dams and steep slopes.

Some typical examples out of the practice:

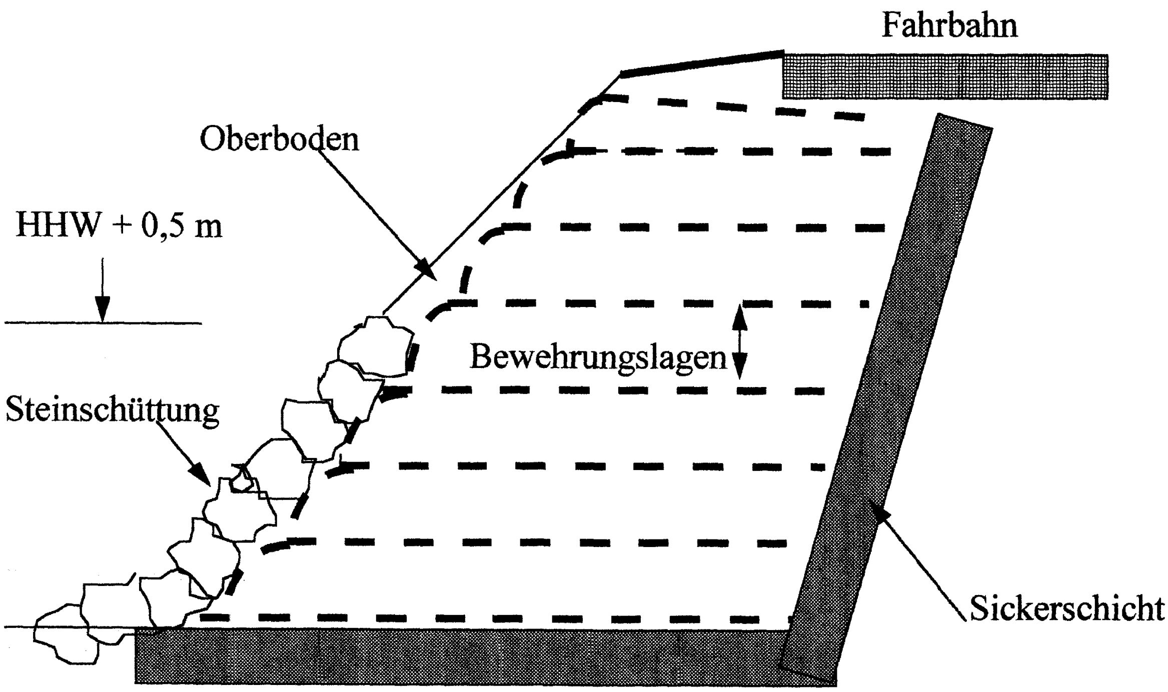
Separation under Road-Embankment

Where slip-form-failure under an embankment is not the main problem, a separation layer between the fine-grained soil - often with low bearing capacity - in the ground and the first layer of the embankment is a good solution. We demand a first layer out of stones or gravel with a high bearing capacity, > 50 cm thick, to allow the circulation of site traffic. The fill must have a good waterflow-capacity and the aggregates must be weather-proof. The fabric must be laid out across to the length of the embankment.

An overlapping of 50 cm is demanded to guarantee that even when the sheets are deformed, there is a closed blanket. The overlapping must be made in the direction of filling (like roof-tiles).

Embankments in this way constructed, can be built up safely. Under the control of the settlement it is possible to accelerate the settlement by over-compaction with heavy vibration-rollers. After the consolidation a bearing thickness of 1,5 m to 2,0 m of a road embankment is enough for a safe road over silty soils [1]; swamps and peats need special investigations.

Slope Protection against Erosion by Rain or by a Flood

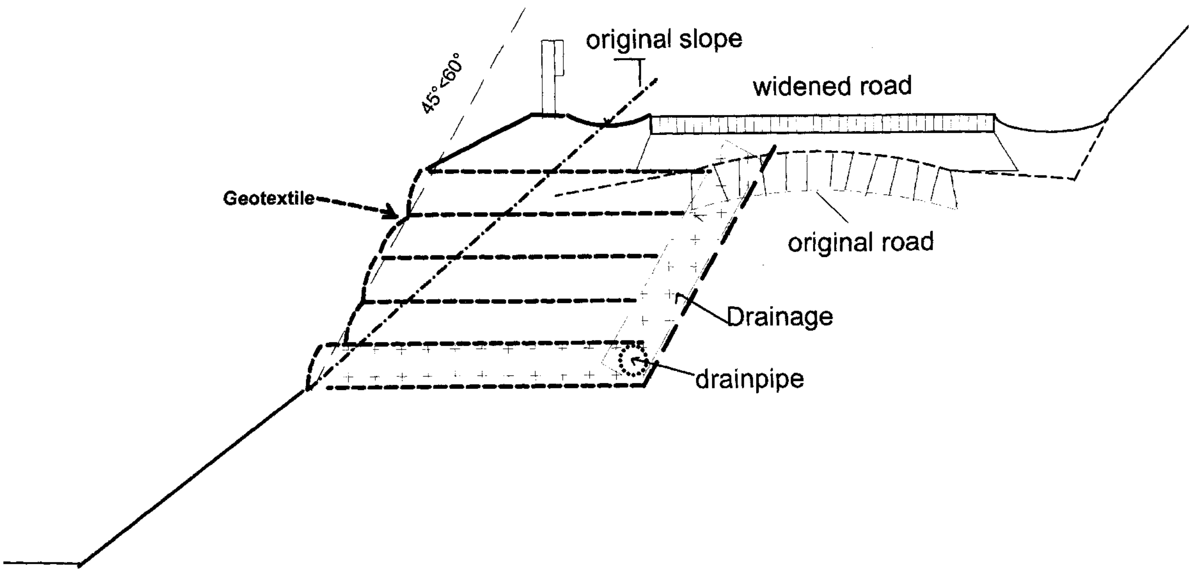


Embankments over riverbanks or in sometimes flooded areas can be protected against erosion by a fill of big stones. If the embankment itself is made of finer grained soils than the stones, there is the danger that the dam can be washed through the stone protection layer. Geotextiles can protect the core of the dam [3].

Reinforcement: Embankment over a Subsoil with low Bearing Capacity

On swamps and peats a deficit of the bearing capacity during construction and later on, can be covered by a reinforcement. The needed strength and the allowable deformation must be calculated. In the examples in Germany only high-strength PET - wovens could fulfil the demand. Large-scale site test have shown the efficiency [10].

Steep Slope on Top of a Dam



Roads on hilly sides often show cracks and faults parallel to the edge of the pavement. Reason is mostly, that over the years the road was stepwise widened to the edge of the slope, which has not enough bearing capacity. If rainwater enters the cracks, the soils may loose their strength and lateral slides may occur. The construction of a steeper slope in the upper side can be a solution. In Germany we have laws which demand to reuse as much material as possible. In several sites we had a good success by the construction of a reinforced earthwork. As fill we reused the soil out of the slope. The reinforcement - layers had been nonwovens, because the fill was a mixture of silty sand with a high amount of stones. Investigations of tensile behaviour and also of creep of wovens and nonwovens in-soil, by the Technical University of Munich, with an in-soil-tester Type McGown, have shown, that nonwovens can be calculated as reinforcements when regarding the small deformations during the phase of use, which are only small [1]. We prefer to calculate the phase of use and not only the phase of rupture.

Reinforcement of the Base Course of a Road Superstructure: test results.

A lot of tests are made in model - and site - scale, to proof the possibility to better the bearing capacity of a road superstructure over a soft ground by a reinforcement. They all show, that a reinforcement needs deformation to activate strength. The deformation under a superstructure, which is necessary to activate a deformation with a measurable effect of strength in the fabric, is too high for a superstructure with an asphalt overlay [12]. It can be possible for access-roads etc. where rutting is allowed. The highest effect on the bearing capacity of the road has the combination of the bearing capacity of the subsoil and the superstructure. That means by our conditions it is better, to have a thicker superstructure or to enhance the bearing capacity of the subsoil by a thicker layer of high internal friction. A good alternative is the stabilisation of soils by lime or cement.

Conditions for Contracts [2][3]

A product - datasheet is demanded as base of the contract (ENV 30230). It contains all the important data about the construction of the fabric and its properties, which are necessary for the recent application. The test data has to be guaranteed by the producer and must be assured by a basic test, executed by an approved institute (see table 6).

Label on the single roll (ENV 30320): On each roll of any fabric a label must be fixed, which contains the name of the producer, the product-name of the fabric, the product-type, the main polymer (PA/PE/PET/PP), the weight per unit-area and the production-number of the roll.

Labelling of the product: the product itself has to be labelled with the product-name by printing or by fixing of a mark (ENV 30320).

Quality Assurance

In Germany we have a three step system of quality-assurance-tests for all materials, used in road construction: Basic tests by an approved body, production control testing by the producer and controlled by an approved body and finally control tests on site or of specimens, taken from the site. In the technical terms of supply of geotextiles and geogrids in earth construction of road construction (TL Geotex E-StB 95) [2] is defined, which tests are to be made in relation to special fields of use (Table 6). The specimens for site control are taken by the client or an institute under contract with the client, together with a representative of the producer or/and of the contractor. The result decides the acceptance or rejection of the product. If the product is already installed the test-results gives the argument for a deduction from the price. This is a very efficient and very important mean to assure the quality of the products in a high level.

Table 6: Tests for Quality assurance.

Properties to be tested	Standards	Basic tests				Production control				Site control			
		S	P	F	R	S	P	F	R	S	P	F	R
mass per unit area	EN 965	+	+	+	+	+	+	+	+	+	+	+	+
thickness	EN 964 /1-2	+	+	+	+	+	+	+	+	+	+	+	+
tensile strength & elongation	ISO 10319 ENV 29073 /3	+	+	+	+	+	+	+	+	g	g	g	g
tensile creep & creep rupture	ISO 13421				+								
compressive creep	ENV 1897			d									
static puncture (CBR)	EN-ISO 12236	n	n	n	n	n	n	n	n	n	n	n	n
installation damage		+	+	+	+								
chemical resistance	ENV 12447	x	x	x	x								
weather resistance	ENV 12224	+	+	+	+								
friction soil/product	ISO 12957	x	x	x	+								
friction product/product	ISO 12957				+								
pullout force - anchorage	ISO 13430				+								
opening size $O_{90,w}$	ENV ISO 12956	+	+	+	x			+					
water permeability vertical k_V	ISO 11058	+	+	+	x			+					
water flow capacity in plane k_H	ISO 12958			d									

Explanations:
Standards: ISO: Standards of the International Standard Organisation / EN: European Standard / ENV: provisional European Standard
Functions: S = Separation / P = protection / F = filter & drainage / R = reinforcement
+ = test necessary / x = applicable in some cases - for some products / g = for wovens, grids and some knitted fabrics / d = for drains only / n = for nonwovens only

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