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Geosynthetics: versatility and variety in application in different geological profiles within the human construction cycle

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ABSTRACT
Throughout history, man was from the beginning of his existence the major responsible for the geological modification of the planet, which prehistoric man established as his place of residence, strategic geological points, where was easy access to water and food, Throughout the evolutionary cycle, it became the dominant species, being of vital importance for its survival, becoming common then its interaction with the natural geological cycle, in which it was able to handle different equipments, developing large circles which were established. whole civilizations. It is evident that the continuous interaction between man and the natural geological cycle, being such action directly implies the human survival, becoming a danger, where problems have been getting worse in the last decades, mainly involving slope stabilization, whose problem is constantly seen in the country, especially in the state of Rio de Janeiro where countless cataclysmic events are plaguing society. One solution to be effective is the use of geosynthetic blankets, material made of high strength fibers, has been a very widespread material within the construction, contributing directly to soil containment. This article aims to map different materials used in geotechnical works, which makes it really important to use effective systems that try to solve problems related to soil containment, where possible with the use of geosynthetic blankets, which presents a material very versatile that can be used in different works of Geotechnical Engineering with different purposes.

Keywords: Innovative Solutions, Geosynthetic Material;

1. INTRODUCTION

The versatility and variety presented by geosynthetics continue to drive its application in various Geotechnical Engineering projects. The idea of associating reinforcement, filtration, drainage and separation elements with geotechnical works started thousands of years ago. The reinforcements generally used for quality improvement were fibrous plant materials mixed with the ground, were used in the Ziggurats, the Great Wall of China, and various works of the Roman Empire, while fine bamboo and coconut-like fibers were commonly used. as a filtering element.

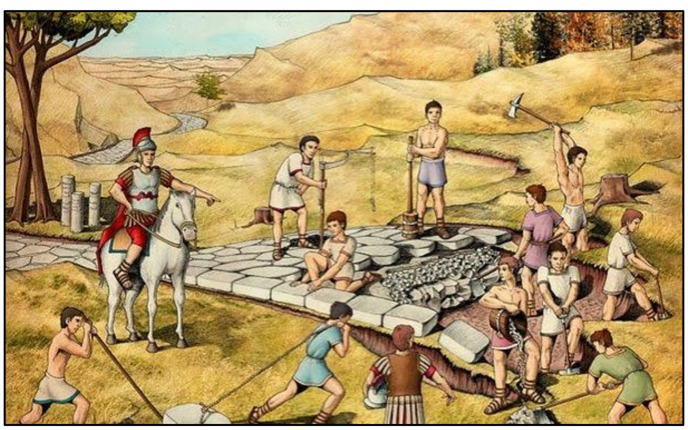

Figure1. Roman roads construction (NTC Brazil. 2019)

However, modern engineering did not give importance to the use of these techniques due, among other factors, to the poor durability of these materials, usually can not suffer cycles of saturation and drying, the difficulty in execution, practically craft constructive system. With the development of polymeric materials, which occurred after World War II, with the beginning of the petrochemical industry, began the Age of Gessynthetics, in recent decades has resolved the difficulties related to the durability of materials then existing. Its increasing evolution is accompanied by the use and standardization methods, thus defining new test methods that allow to better characterize them, regarding their properties correlating to the performance. The same type of geosynthetic can perform different functions related to mechanical properties such as confinement, erosion control, protection and reinforcement, as well as hydraulic characteristics, drainage, filtration and waterproofing. This class of material consisting of permeable polymeric products can be described as the most versatile soil stabilization product used in geotechnical engineering.

2. PRODUCT CHARACTERISTICS

Since its first uses in the early 1950's geosynthetics form a group of synthetic materials in geotechnics, the term derives from the combination of the words “geo” referring to geotechnics and “synthetic” related to the raw material used in geotechnics. Manufacturing, however not only solutions used in geotechnics, but also in other areas with Transport and Sanitation Engineering. Geosynthetics are characterized by flat and continuous blankets that separate the soil mass, in its broadest conception includes whether products from manufactured or natural polymers, although polymeric geotextiles predominate in most applications, only those requiring a long service life.

2.1 Terminology and Classification

We currently have a wide variety of geosynthetic products, whose terminology based on the revision of the Brazilian standard (NBR 10318/20018), are named and characterized basically as follows:

- **Geotextile:** Permeable two-dimensional textile product, predominantly used in Geotechnical Engineering, composed of cut fibers, continuous filaments, monofilaments, laminates, forming structures, whose mechanical and hydraulic properties allow it to perform various functions, and the manufacturing process can be classified as :

- **Nonwoven Geotextile**: Product composed of cut fibers or continuous filaments, especially randomly distributed, which are interconnected by mechanical, thermal or chemical processes.

- **Knitted geotextile:** Geotextile produced by knitting multiple threads.

- **Woven geotextile:** Produced from the generally right-angled interweaving of two or more yarns, monofilaments or laminates (ribbons) among other elements, following directions preferably in the transverse and longitudinal directions

- **Geogrid:** Flat polymeric structure, with structure formed by an open mesh or grid with predominant reinforcement function, whose openings allow interaction of the environment in which they are confined, consisting of tensile elements. Depending on the manufacturing process, can be joined by extrusion, welding or woven

- **Georrede:** Consists of a set of parallel elements, with the grid structure, made to present a large volume of voids, with the predominant function in drainage systems.

- **Geomantic:** Product with permeable three-dimensional structure, made of polymeric, synthetic or natural monofilaments, used to control soil erosion, also known as bio mantle if it is a biodegradable blanket

- **Geocells:** Produced with an open, permeable and polymeric three-dimensional structure (natural or synthetic) or similar cellular structure, then consisting of interconnected cells, with a predominant function of reinforcement and erosion control.

- **Geotira:** Product with strip-shaped polymeric material, less than 200 mm wide, with the predominant function of soil reinforcement, used in Civil and Geotechnical Engineering applications.

- **Geospace:** Product with three-dimensional structure with interconnected air spaces, thus constituting a large volume of voids, used predominantly as a draining medium.

- **Geocomposite:** Industrialized material assembled by overlapping or associating at least one geosynthetic product with one another, generally designed to perform a specific function within Geotechnical Engineering.

- **Clay geocomposite for waterproofing barrier:** Structure consisting of the association of geosynthetics with a clayey material, industrially produced in the form of a blade, which has been developed to function essentially as a waterproofing barrier.

- **Geocomposite for drainage:** Produced and developed for drainage, generally composed of a Geotextile acting as a filter element and a geo-network or a geospace acting as a drainage element in Geotechnical structure.

2.2 Functions Performed by Geosynthetics

In the manufacture of geosynthetics, covering a variety of polymeric materials manufactured especially for use in various applications, the raw material gives the Geotextile all its characteristics and properties, which in turn combine to create the functions that the product is capable of. to perform, where the following stand out, separation, filtration, drainage, reinforcement, containment and control of erosive processes, in some cases the geosynthetic layer can perform more than one of the following functions.

- **Separation:** Geotextile acts on the interposition between two materials that have different particles, preventing their mixing and interpenetration between the layers, preserving their original characteristics.

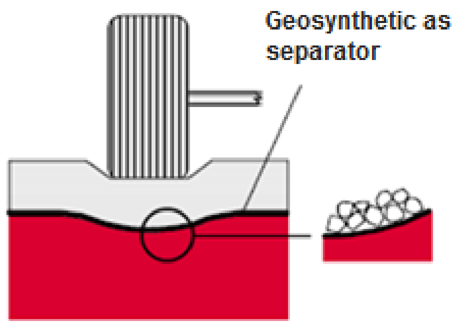

Figure 2. Geosynthetic as separator (International Geosynthetics Society-IGS. 2005)

- **Filtration**: Geosynthetic acts as a filter, similar to a sand filter, allowing fluids to pass freely through the soil while trapping solid particles from a draining system. It can also be used as a filter element for reducing the potential for leaching pollutant residues.

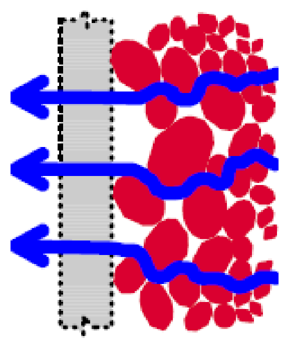

Figure 3. Geosynthetic filtering agent (International Geosynthetics Society-IGS. 2005)

- **Drainage:** The geosynthetic works as a drain that collects and carries the fluid in its plane through the less permeable soil, used in Geotechnical and Geoenvironmental works, similar to conventional granular filters.

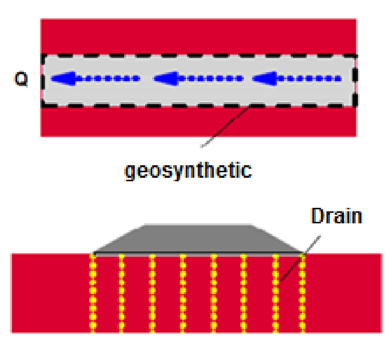

Figure 4. Geosynthetic as a drainage agent (International Geosynthetics Society-IGS. 2005)

- **Reinforcement**: The presence of the geosynthetic reinforcement layer through its mechanical properties, inserted into the soil has the purpose of reinforcing the soil massif, giving it greater mechanical resistance and less deformation of the natural soil.

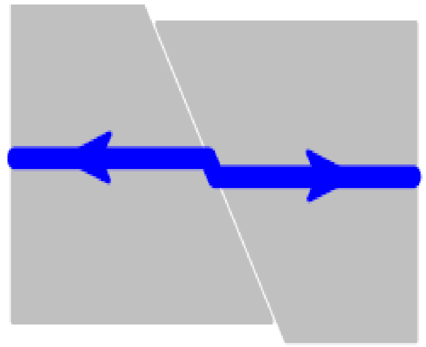

Figure 5. Geosynthetic as a reinforcing element (International Geosynthetics Society-IGS. 2005)

- **Containment (barrier):** In this case, the geosynthetic layer acts as a relatively impermeable barrier, having the function of blocking and minimizing the passage of fluids or gases. Such application is of particular importance in hydraulic and environmental protection works. Geosynthetics may also function as sediment barriers in erosion control works or to retard mass movement of the soil.

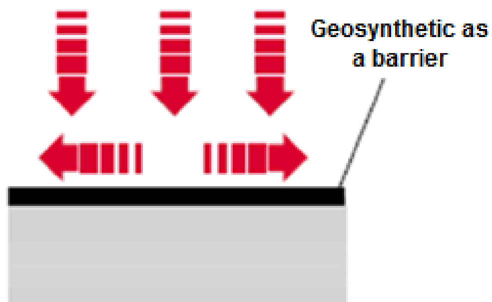

Figure 6. Geosynthetic as a barrier (International Geosynthetics Society-IGS. 2005)

- **Erosive process control:** The geotextile layer works to minimize the effects of soil erosion, caused by rain impact and runoff, geosynthetic barriers that are also used to retain displaced sediment during runoff, or geosynthetic blankets. are arranged permanently or temporarily along the slope.

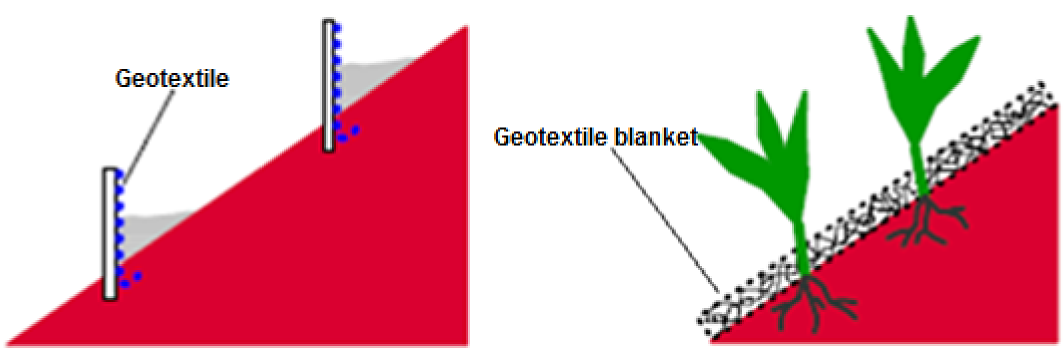

Figure 7. Geosynthetic as and controller of erosive processes (International Geosynthetics Society-IGS. 2005)

3. GEOSYNTHETIC APPLICATIONS AND TECHNOLOGY

The main fields of use of geosynthetics are highlighted below:

- **Agricultural applications:** geosynthetic utilization is increasing worldwide, early applications include trenching, minimizing the amount of water seeping into the soil, so water storage reservoir lining has become common on farms. , mainly in arid regions of the country. Its application in this sector has grown significantly in recent years, especially because of stricter environmental legislation and public awareness through programs developed by government agencies.
  Drinking water sources are becoming increasingly rare, the need to provide barriers that ensure less water loss and pollution is already a reality in many places.

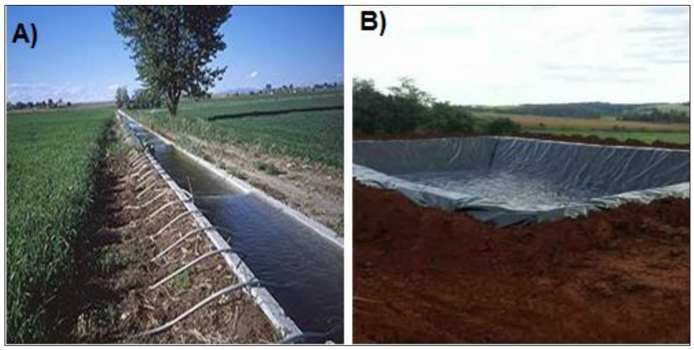

Figure 8. **A)** Irrigation canal. **B)** Anaerobic digesters for waste ponds (LJS-Environmental Solutions. 2019).

- **Slopes on stable foundations:** The reinforcement layer used in the stabilization of rupture slopes consists of horizontal reinforcement layers. The reinforcement layer allows steeper construction than in cases where reinforcement layers are not used. In most cases the face of the slope should be protected against erosion, requiring relatively light materials such as thin soil-filled geocells to help fix the vegetation.

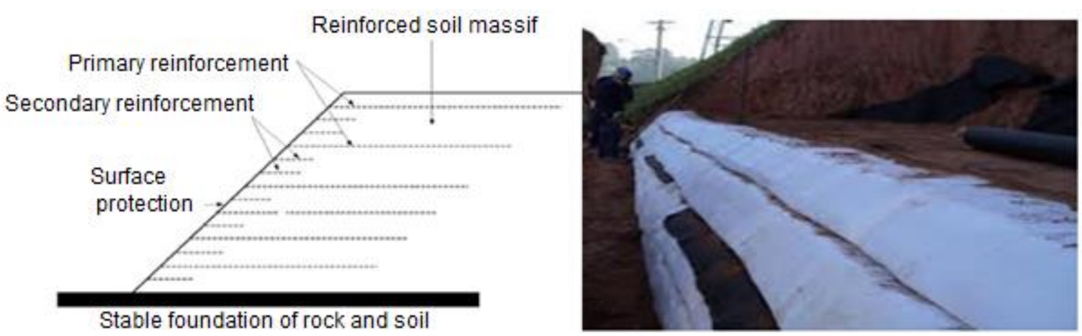

Figure 9. Slope of reinforced soil on stable foundation (REGEO-Geosynthetics. 2011)

- **Hydraulic Projects:** comprise the geosynthetic market segment with significant growth potential, frequently used in order to limit the interaction between structure and water, increasing its stability. Reducing water infiltration, avoiding channel erosion, promoting drainage and reinforcing the entire hydraulic structure.

Figure 10. Upstream facing of a dam (Dam Geology. 2011)

- **Retaining Walls:** In order to obtain a reinforced soil mass, it can incorporate horizontal layers of geosynthetics in landfills, the structure now behaves as a gravity structure resisting the pressures, promoted by the non-reinforced soil massif. The geotextiles commonly used in this type of construction are geogrids, woven geotextiles and polyester strips.

Figure 11. Armed earth retaining wall (ECO SALIX-Ecological Systems of Natural Engineering. 2019)

- **Roads:** Geosynthetics can be effectively used for road reinforcements.

Unpaved roads built on soft ground, if well defined, the geosynthetic can perform the following functions, separation, reinforcement and drainage, the materials commonly used in such applications are geogrids and geotextiles. Compared to unpaved roads the presence of geosynthetic contributes the following advantages: (reduced landfill thickness, lateral deformation, periodic maintenance, road operating cost, increased load capacity, service life, separation between aggregate and soft soil and generation of a more favorable stress distribution).

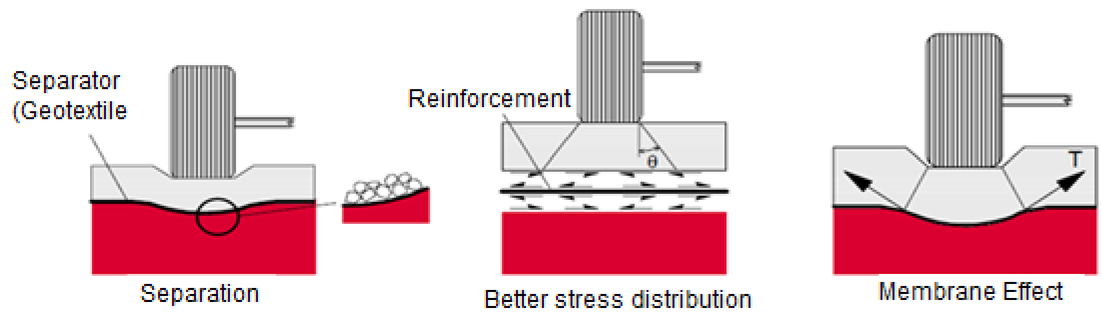

Figure 12. Geosynthetic Contribution on Soft Ground Roads (International Geosynthetics Society-IGS. 2005)

Paved stays are of utmost importance for development worldwide, asphalt paving can last considerably less than expected due to the constant flow of heavy vehicles, weather conditions and the quality of the material used in construction. If properly installed and specified geosynthetics can provide economically viable solutions by improving the final quality of the floor. In this context they can be effectively used to reduce crack reflection as a barrier avoiding fines pumping, reducing asphalt mat thickness and pavement thickness and increasing paving life.

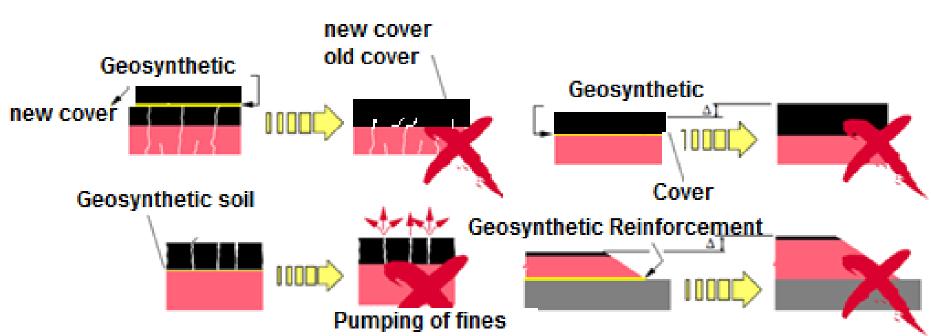

Figure 13. Geosynthetic Contribution to Paving (International Geosynthetics Society-IGS. 2005

- **Drainage and Filtration**: Geosynthetics can be used as drains and filters within construction. And environmental in the addition or complete replacement of traditional materials. The most used materials are geotextiles, georedes and geocomposites these can be used in constructions such as retaining walls, landfills, erosion control, in landfill areas, etc.

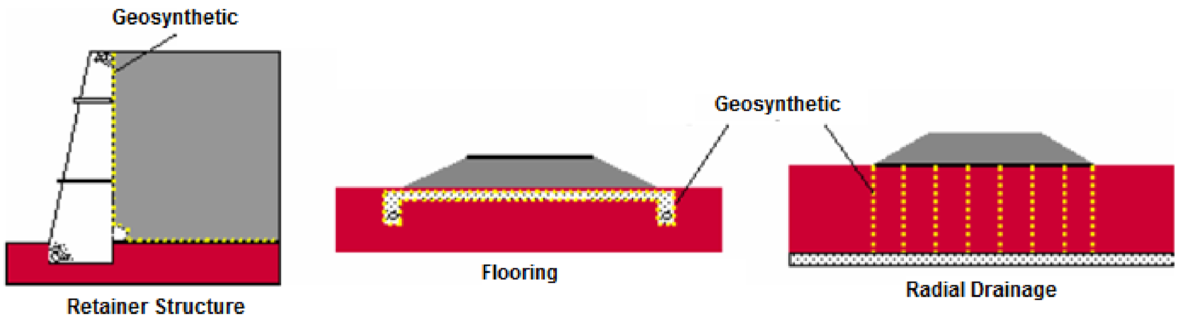

Figure 14. Geosynthetic applications as drain and filter (International Geosynthetics Society-IGS. 2005)

- **Erosion control:** Erosion is the process of natural degradation of soil by wind and especially water, factors such as soil type, topography and vegetation directly influence the erosion process, where this action can be accelerated due to activity. of land occupation. Out-of-control erosive processes can cause major disruptions to structure and the environment. Geosynthetics can be used to minimize erosion in such cases as: (Slope protection, Channels, Drainage ditches, Waterways, Coastal protection, Degradation recovery, Reforestation, Ravine protection, Soil block fall barriers, Dams , Dykes, Embankments, etc .;).
  Depending on the characteristics of the project site, erosion control construction may involve the application of more than one type of geosynthetic, such as georede, geogrids, geotextiles, geomantas, etc.

Figure 15. Erosion Control (Geosolutions. 2019)

- **Soft Landfill:** Building soft landfills can be a major challenge, as the use of geosynthetics to improve stability in this type of construction is one of the most effective and well-tested techniques for soil reinforcement.

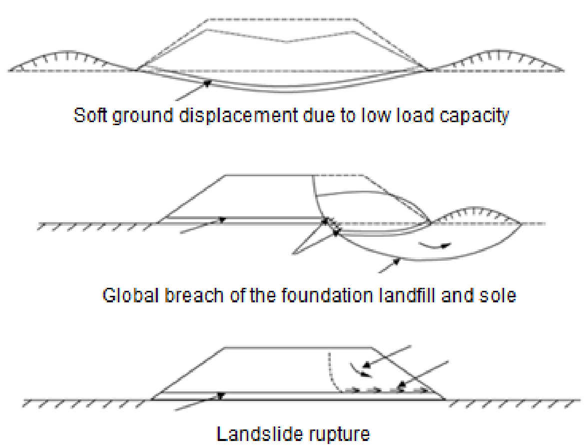

Figure 16. Typical ruptures in unreinforced soils (International Geosynthetics Society-IGS. 2005

The stability level of a landfill reinforced by safety factors (Fs):

- For overall stability:

$$Fs = \frac{Mr + \Delta Mr}{Md} \geq \text{typically } 1{,}2 \sim 1{,}3$$

Where: Md = unstable moment.
Mr = resistant moment.
ΔMr = moment due to the geosynthetic's contribution against the rupture.

- For slip stability:

$$Fs = \frac{Pr}{Pa} \geq \text{typically } 1{,}5$$

Where: Pa = active thrust in the landfill.
Pr = frictional force along the interface between the landfill and the reinforcement.

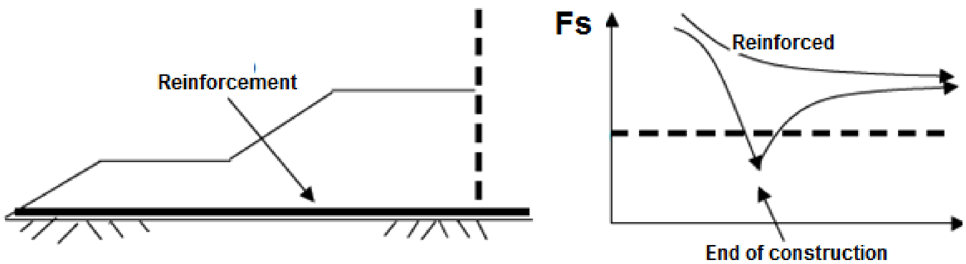

Figure 17. Efficiency of geosynthetics as reinforcement in soft landfills. (International Geosynthetics Society-IGS. 2005)

If the effect of geosynthetic on soil reinforcement is limited, reinforced landfill may be used on precast piles or improved soil piles may be applied.

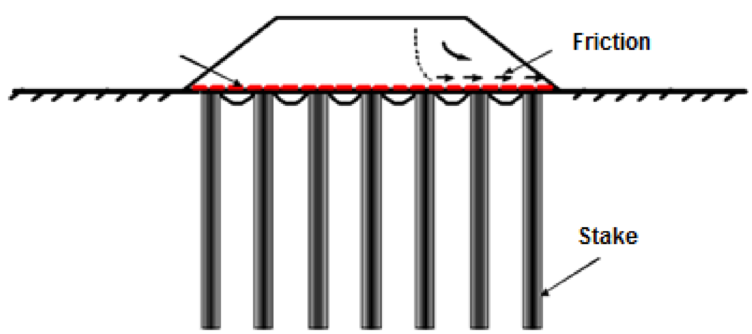

Figure 18. Reinforced piling embankment. (International Geosynthetics Society-IGS. 2005).

- **Landfills:** Widely applied in landfill projects, mainly to compose the structure, acting as a barrier against flow from the base and the roof. Being the geosynthetics that can be applied in landfill constructions:

  - Geogrids, which can be used to reinforce slopes below the debris as well as to reinforce the covering soil on the geomenbranch;
  - Georrede, used as draining mattress;
  - Geomenbrana, are relatively waterproof blankets made of polymeric materials and can be used as barriers for liquids and vapors;
  - Geocomposite, consists of the combination of two or more geosynthetics, being used for separation, filtration or drainage;
  - Clay geocomposite, geosynthetic benthic combinations, which can be used as hydraulic barrier and against infiltration;

- Geotubes, used in landfill to facilitate collection and quickly drain leachate, leading to a treatment system;
- Geotextiles, used for filtration or as a mattress to protect the geomenbrana from damage;

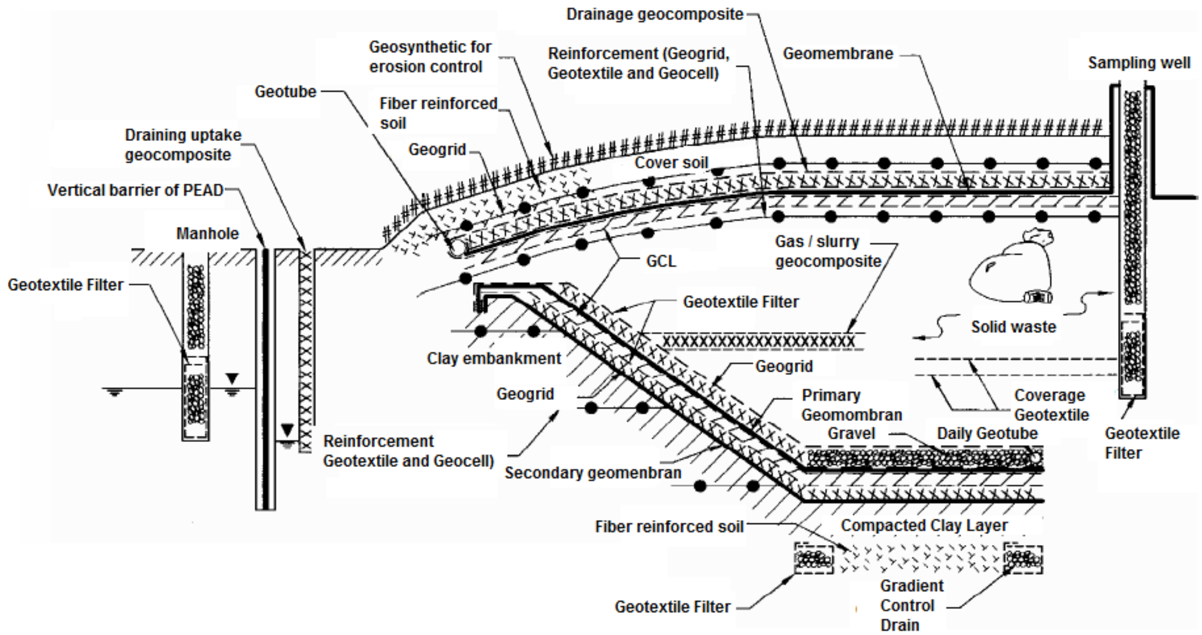

Figure 19. Multiple applications of geosynthetics in landfill projects (International Geosynthetics Society-IGS. 2005).

4. GEOSYNTHETICS IN BRAZIL

The use of geosynthetics in Brazil originated in the early 1970s, more rapidly used in much of the country since the 1990. In the 1970s, geotextiles were known to a limited minority compared to the number of geotechnical professionals in the country. The lack of information about hitherto was associated to some extent, the reluctance to accept plastics as quality materials in the community's construction, such a product compromised technical reliability as components of geotechnical works. In this respect, besides the situation was totally different, in the late 1970s, the Institute of Road Research of the National Department of Roads, began the construction of experimental landfills instrumented on soft soils in the Baixada Fluminense, Rio de Janeiro, increasing the early 1980s interest in its use, involving not only use in drainage and filtration systems, but also as soil reinforcement.

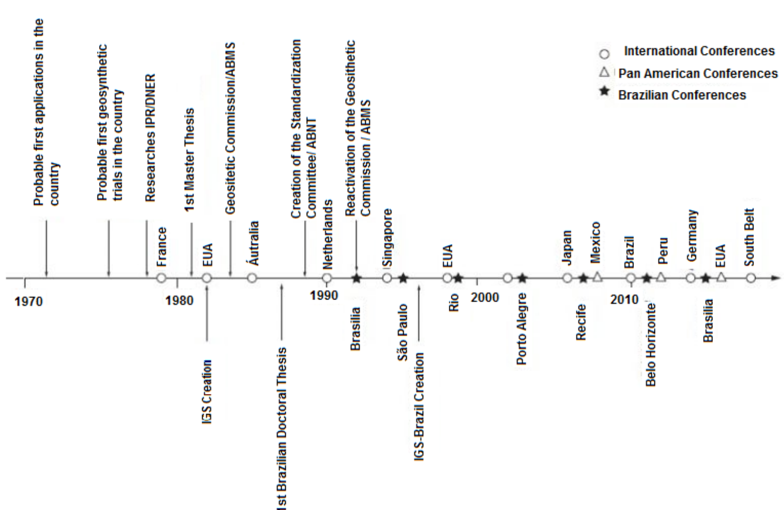

Figure 20. National, international and Brazilian milestones in the evolution of geosynthetics (Geosynthetics in Geotechnics and Environment- 2015)

It can be observed that most of the relevant facts in Brazil occurred after the 1980s. Important steps were taken for the development of these materials, and the Geosynthetics Commission of the Brazilian Association of Soil Mechanics and Geotechnical Engineering (ABMS) was created.), in the early 1980s, and with this the first realization of a national event on geosynthetics. Another important milestone was the creation of the IGS-Brazil (International Geosynthetics Society) section in 1996. Since then, IGS-Brazil together with the ABMS Geosynthetics Commission have been promoting the dissemination and knowledge of geosynthetics through events. scientific studies, courses, lectures, symposiums, newsletters, etc., with significant support from geosynthetic manufacturers.
There are currently no official and reliable documents, which makes it very difficult to know the size of our market. Certainly the Brazilian market grew a lot, consolidating solutions with geomembranes, geotextiles, geogrids, geocells and clay geocomposites, among other materials. However, the size of the Brazilian market is still small compared to the size of the global market, showing that there is still much room for growth. However, with the fall in the pace of construction, due to the current political and economic scenario, the advance of geosynthetics has stabilized. Brazil's current scenario results in very little investment in infrastructure projects. Even though the country is going through a difficult time, both politically and economically, the prospects for the future are very good, there are still opportunities for innovative solutions when it comes to using geosynthetics.

5. CONCLUSION

The present work shows the use of geosynthetics as elements used in different constructions, both geotechnical and civil construction. Aspects related to the technological mechanisms involved in the application of this material were discussed.
As geosynthetics is a material of increasing application in Engineering, and particularly in geotechnical works, the ease of application brings with it the low cost and versatility of these materials when compared to previously used methodologies and traditional materials, making it an extremely attractive material. in construction, thus providing the progressive increase of its use. Citing examples such as the minimization of environmental and financial impacts due to the high effectiveness of the solutions, the reversibility of the structures to which geosynthetic materials are applied and their high degree of use at different times within the construction.
Given the above, it is clear that there are several examples of success in the application of geosynthetics in environmental, social and financial protection, and that the choice of systems that employ (Geotextiles, Geogrids, Georedes, Geocells, Geotiras, Geospaces, Geocomposite, etc.) has grown a lot in recent years. However, Brazil needs routinely innovative products, thus always having room for opportunities for new solutions within Engineering.

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