GEOSYNTHETICS IN SOIL IMPROVEMENT. TYPES, FUNCTIONS AND PRINCIPAL USES.

استخدام المنسوجات البولميرية فى الهندسة المدنية

By

N. El-Shabrawy F. El-Shibini H. Al Mudhaf
Faculty of Teehnolofical Studies, Kuwait.

الملخص :-

من المعروف أن انشاء الطرق والمطارات يحتاج الى طبقة جيدة وقوية من الأتربة تتحمل الاوزان الثقيلة الناتجة من السيارات والشاحنات والطائرات وفى احيان كثيرة لاتوجد مثل هذه التربة بالطبيعة مما يستدعى التدخل العلمى لتحسين خواص هذه التربة . هذا وقد استعمل المهندسون والباحثون طرقا عديدة لتحسين مثل هذه التربة منها على سبيل المثال اضافة الجير والأسمنت والكلوريدات والبيتومين والراتنجات وغيرها مما اعطى نتائج جيدة فى احيان وغير كافية فى احيان أخرى .

وفى عام ١٩٦٢ اقترح فيدال استخدام الشرائح الحديدية بسمك ٥ مم وتثبيتها فى الحوائط الساندة للردم الضعيف وذلك لمنع انزلاق طبقات التربة - ثم استعمل كومير ١٩٧٦ بعد ذلك الأسياخ الحديدية التى تم تثبيتها رأسيا فى الأرض .

وقد كان أول استعمال للمنسوجات البولمرية لمحاربة التآكل فى عام ١٩٦٦ وتدرج الاستعمال بعد ذلك لتحسين خواص مقاومة الأتربة للقص وتحسين ظروف الصرف والترشيح وكذلك لفصل مواد طبقات الرصف عن بعضها حتى لاتسيطر الخواص الرديئة على الجيدة .

وقد كانت الحاجة لانشاء طرق ومطارات فوق أتربة ضعيفة دافعا لاستمرار الأبحاث والتعاون بين الهندسة المدنية والكيمائية ومهندس النسيج حتى أصبح استعمال البوليمرات المختلفة من البولى ايثلين والبولى بروبلين استير لانتاج خيوط صناعية ثم نسجها بطريقة معينة لانتاج منتجات تؤدى الى تحسين كبير فى خواص الأتربة من أهم سمات عقد الثمانينات حتى وصل استعمال هذه المنسوجات فى عام ١٩٩٠ الى حوالى بليون متر مربع فى أوربا فقط .

وتهدف هذه الورقة الى توضيح وتقديم منتجات الألياف الصناعية من البوليمرات للسادة المهندسين والمهتمين بموضوعات تحسين خواص التربة لاغراض البناء وانشاء الطرق وذلك بتوضيح انواع الألياف المستخدمة ووظائفها الرئيسية فى التربة ثم التطبيقات والاستعمالات الأساسية لهذه المنتجات فى مجالى البناء والطرق .

1. ABSTRACT- More recently, the soil is improved by introducing locally separated reinforcing elements. These include: the placing of metallic strips into the soil (reinforced earth), the introduction of steel rods or grouted needle piles (soil nailing) or the use of geosynthetic.

Geosynthetics were first used in connection with erosion cootrol applications and were intended to be an alternative for granular soil filters. (Barrett, 1966). Synthetic reinforcement is being increasingly used for temporary and permanent structures to improve the shear strength of soil. The fact that an increasing number of structures must be built on poor soils, has speeded up the development of soil reinforcement techniques. The basic principle of soil reinforcement, as described by Jewell (1982), is that when an oriented reinforcement is included, a higher shear strength is developed in the soil. Credit for early work in the use of geosynthetics should be given to the ICI fabrics in England. Their work and others such as Chemie Linz in Austria and Du pont and Micafi in the States has continued. Today many manufactures are involved in the production, sales, and distribution of geosythetics. McGown and others (1988) expected that sales of geosythetics may reach one billion square meters by the end of 1990.

2. INTRODUCTION

Soil improvement for highway and building purposes is probably the oldest but still the most interesting technique of all common execution methods in civil engineering. It ranges from simple soil compaction to elegant techniques of grouting systems.

In 1963 Vidàl proposed a soil improvement technique for fills using "reinforcement" (Fig.1). Flexible, about 5 mm thick strips of galvanized steel are laid in the layers of the fill bolted to the retaining wall at the facing of the fill. The main idea is that when sliding starts to occur in the soil, the anchored metallic strips will provide a complementary shear strength and therefore will stop further deformation.

Root piles were initially installed according to a patent of the Italian firm FONDEDILE (Lizzi, 1978). piles are inserted by means of a high speed rotary drill (Fig.2) in a way not to cause any collapse of the borehole walls or loosing the soil itself.

"Soil nailing" means the soil improvement by means of driving steel rods into the soil. This technique has been proposed by kocmer 1976 who used a combination of this technique with the use of a surface protection of geotextile (Fig.2). The fiber is stretched over the surface of the slope to be stabilized. Fig(3)

Soil improvement using geosynthetic is related primarily to their tensile strength. The term geosynthetic means that materials used in soils and are synthetic in nature. The first use of fabrics made from natural fibers to reinforce roads was attempted by South Carolina Highway Department in 1926. They use a heavy cotton fabric on a primed earth base and then applied hot asphalt mix. Results showed a reduction in cracking, ravelling and localized road failures.

This state of-the-art paper deals with geosythetics in highway engineering It describes types and manufacturing of geotextiles, geogrids, geomembranes and geocomposites as they are the famous types in use in soil improvement. Moreover the paper explains the function of different geosynthetics, and their principle uses to improve soil properties for highway purposes.

3. TYPES AND MANUFACTURING OF GEOSYNTHETICS

Geosynthetics means that materials used in soils and are synthetic in nature. They are usually hydrocarbons. The specific families of geosynthetics on which this paper will focus are the following: (Fig.4.)

- Geotextiles;
- Geogrids;
- Geomembranes; and
- Geocomposites.

3.1 Geotextiles

Geotextiles are permeable textile material (usually synthetic) used with soil, rock or any geotechnical engineering related material to enhance the performance or cost of a human made product, structure or system. They are indeed textiles in a traditional sense, but consist of synthetic fibers rather than natural ones like cotton, wool or silk. Thus biodegradation is not a serious problem. The fibersare made into a flexible, porous fabric by standard weaving machinery or are melted together. The major point that they are porous to water flow across their manufactured plane and also with their plane.

3.1.1. Geotextile Manufacturing

The fibers used in geotextile manufacturing are made from any of the following materials (ordered in decreasing order of use) :

- Polypropylene ;
- Polyester;
- Polyamide (nylon); or
- Polyethylene.

All are hydrocarbons derived from oil. The basic polymers are made into fibers by melting them and forcing the product through a spinnert similar in principle to a bathroom shower head. The resulting fiber filaments are then hardened or solidified by wet, dry or melt.

3.1.1.1. Woven Geotextiles

Modern industrial textiles are created by textile engineers using preeise scientific methods to produce fabrics that will properly perform specific tasks. The textile engineer works with five basie elements : (1) fibers; (2) yarn; (3) weave (4) count; and (5) finish. All of these elements must be accurately evaluated and controlled. The fabrics produeed in this way are ealled "woven Geotextiles" (Fig. 5).

3.1.1.2 Non-woven Geotextiles

Many construction fabrics are non-woven where the elements of yarn and weave are completely lacking. These fabrics are composed of textile fibers bonded together by resins, other bonding agents, or mechanical methods to form a smooth, uniform mat. Each non woven geotextile manufacturing system generally includes four basic steps : 1) fiber preparation; 2) web formation; 3) web bonding; and 4) post-treatment. The known types of non-woven geotextiles are :

- Needle punched where a fibrous web is introduced into a machine equipped with a group of specially designed needles (Fig. 6a).
- Spun-Bonded where a continuous process is performed to produce a finished fabric from a polymer (Fig. 6b)
- Melt-Bonded consists of long staple fiber melted together at fiber crossover points. Products are tough and compact.
- Resin-Bonding where acrylic resin is sprayed into a fibrous web.

3.2 Geogrids

Geogrids are relatively stiff, netlike materials with large open spaces (typically 12.5 to 50.8 mm) between the ribs that make up the structure. The ribs can be of three varieties as shown in Fig. (7).

1. Non-deformed nets
2. Deformed grids that have been work hardened to enhance properties.
3. Strips of polymeric materials laid in a grid fashion and bonded or joined at their intersections.

The basic polymer materials used in the manufacture of geogrids are either polypropylene or high density polyethylene. Initially, they are of a heavy gauge and in sheet form. Holes are then punched into the sheeting on a regular pattern, and the sheet is theo drawn uniaxially or biaxially. Drawing is done under controlled temperatures and strain rates so as to avoid fracture but allow free flow of the molecules into elongated and isotropic conditions. Key variables in this process are the drawn, ratio molecular weight, molecular weight distribution, and degree of branehing or cross linking.

4.1 Separation

The major point in geosynthetic (all types) manufacturing is the introduction of a flexible synthetic harrier placed between dissimilar materials such that the integrity and functioning of both materials can remain intact or be improved.

When placing stone on a soil there are two simultaneously mechanisms that tend to occur; one is that the soil fines attempt to enter into the voids of the stone ruining its drainage capability, while the other is that the stone attempts to intrude into the soil thereby ruining the stones strength. Geosynthetics may stop the two mechanisms and improve the properties of each layer as designed.

4.2 Reinforcement

Geosynthetic reinforcement (all types) is the synergistic effect on system strength created by the introduction of geosynthetics (which are good in tension) into the soil (which is poor in tension but relatively good in compression). Geosynthetics improve the strength of soil in three different ways: (Fig. 9)

1. Membrane reinforcement when a vertical load is applied to a geosynthetic on a deformable soil. It depends upon the depth that the geosynthetic is placed from the surface of load application.
2. Shear reinforcement when geosynthetic placed on a soil loaded in a normal direction and then the two materials are sheared at their interface. Geocomposite sections may prove excellent performance in this case.
3. Anchorage reinforcement when the soil acts on both sides of the geotextile as a tensile force tends to pull it out of the soil. Again gecomposite in the eggshell form or box-form may be quite efficient.

4.3 Filtration

Filtration is the equilibrium fabric-to-soil system which allows for free water flow (but not soil loss) across the plane of the fabric over an indefinitely long time period. The geosynthetic concept (geomembranes) function of filtration involves the movement of water through the fabric itself (ie. across its manufactured plane). At the same time, the fabric serves the purpose of retaining the soil on its upstream side. The selection of geosynthetic type is very important since permeability requires open fabric structure while soil retention requires a tight fabric structure. Moreover, the long term soil-to-fabric compatibility which will not allow the geosynthetic clogged during the lifetime of the system is important. Geotextiles should be avoided in cases of cohesionless sand and silts, gap graded particle distribution or high hydraulie gradient. The large open mesh structure of the geogrid ensures the rapid dissipation of excess pore water pressure from over-burden loading. This provides a rapid increase in shear strength in the underlying subgrade.

4.4 Drainage

Drainage is the equilibrium fabric-to-soil system which allows for free flow (but not soil loss) in the plane of the fabrics over an indefinitely long time period.

All fabrics (except geogrids) can provide such a function but to widely varying degrees. It is important to note that there is a considerable overlap of drainage and filtration and except for the consideration of direetion of flow, the soil retention and long-term compatibility concepts remain the same. Fabrie thickness will decrease with increasing normal stress on it which increases the inplane permeability.

4.5 Moisture Barrier

A moisture barrier can be created by rendering the fabric relatively impermeable to both cross-plane and in-plane flow. The impermeability is generally obtained by spraying bituminous, rubber-bitumen or polymeric mixes into a properly deployed geotextile to create the in situ moisture barrier. Geomembranes can do this fuction perfectly.

Geogrids are not used in filtration or as a moisture barrier due to their large opening size. Also, when used as a drainage core they are generally protected by a geotextile acting as a filter.

4.6 Combined Function.

Although geosynthetics are used for a single function, but they often serve multiple or combined function. Some examples are:

1. Prevention of crack reflection in asphalt pavement overlays where both reinforcement and moisture barrier functions are involved.
2. Beneath railroad ballast where separation, reinforcement, filtration and drainage can all be involved.

5. PRINCIPLE APPLICATIONS OF GEOSYNTHETICS

The choice of a proper geosynthetic is dependent upon many factors such as the primary required functions, secondary functions, and the environmental conditions. Within the functions mentioned before, there are large number of applications or use areas for each type of geosynthetics. Some of these uses (principle ones) which can be located in the literature are shown in table 1. Obviously it is an all-inclusive list because the field of geosynthetic application is constantly growing. (Fig. 10)

6. CONCLUDING REMARKS

1. There are many applications where geosynthetics are used for improving earth structures. There is a large number of results on the performance of these materials. However only in few cases has this evaluation been scientifically examined on the basis of the physical and chemical laws that govern the long term behaviour of polymer products.

2. Certainly new products will appear and existing ones may disappear in the future. It is upto the designer to understand the application, evaluate the function or functions, and compare these requirement to that of the candidate geocomposite's properties.

3. While geosynthetics by themselves can be made very strong, the combined use of polymeric fibers with other materials can be made considerably stronger and sometimes less expensively.

4. There is one characteristic which the many different types of geosynthetics have in common: the basic products are manufactured under strict and carefully controlled conditions. The properties of the material, which are required in order to fulfill certain functions and which have been defined by the designer, can be best obtained by checking the criteria continuously throughout the production process.

5. The quality of the product, as a component of the complete structure, will depend not only on the product itself, as it leaves the plant, but also on the way in which it is handled during transport and construction. Careful supervision will increase the quality and reliability of the final product and performance.

7. REFERENCES

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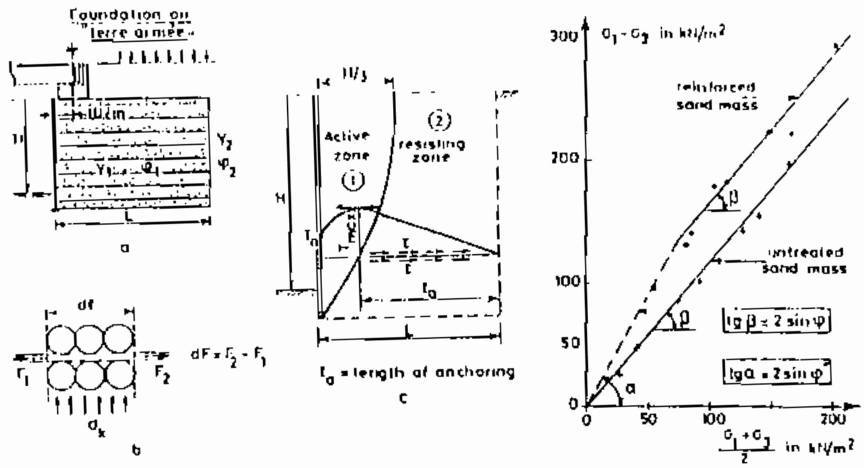
TABLE (1) FUNCTIONS AND PRINCIPLE APPLICATIONS OF GEOSYNTHETICS

KEY
5,4,3,2,1 Decreasing order of efficiency.

a,b,c,d Decreasing order of use.

		Functions					Type of geosynthetic			
	Application	Separation	Drainage	Reinforcement	Filtration	Moisture barrior	Geotextile	Geogrids	Geomembranes	Geocomposites
1.	Unpaved roads	5	1	4	3	0	a	a	d	c
2.	Paved roads	5	2	5	2	0	a	a	b	c
3.	Embankment fills	4	2	5	2	0	a	a	b	a
4.	Ballast in railroads	5	3	5	2	0	a	a	b	a
5.	Retaining walls	3	4	5	4	2	a	a	b	a
6.	Erosion control	2	2	2	5	1	a	b	c	c
7.	Trench drains	3	2	1	5	1	a	d	a	b
8.	Asphalt reinforcement	1	1	5	5	1	b	a	d	d
9.	Sheet anchors	1	1	5	1	0	c	a	d	b
10.	Repair of slope failures	2	4	4	3	1	a	a	c	c
11.	Soft soils for airfields	5	3	5	3	0	a	a	d	a
12.	Oversoft soils in sports fields	3	4	5	4	0	a	a	d	b
13.	Improving bearing capacity	2	4	5	4	2	a	a	c	a
14.	To filter hydraulic fills	3	4	2	5	0	b	d	d	a
15.	Drain beneath geome...	0	5	1	4	2	a	d	a	a
16.	Drain beneath railroad ballast	2	5	3	3	2	a	d	a	a
17.	Drain for roof gardens	0	5	0	2	3	b	0	b	b
18.	Pore water dissipator in fill	2	5	2	2	2	b	0	c	c
19.	Porous tips for wells	2	3	1	5	1	b	0	0	a
20.	Filter beneath store	2	3	1	5	0	b	d	0	a
21.	Linears for potable and reserve water	1	1	1	1	4	d	0	a	b
22.	Water proofing within tunnels	1	0	1	0	5	d	0	a	a
23.	Controlling odours in land fills	2	0	0	0	5	0	0	a	a
24.	Reflection cracking	2	1	4	1	0	b	a	0	b
25.	Decreasing pavement thickness	2	0	5	0	0	b	a	0	d



FIG(1) PRINCIPLE OF SOIL REINFORCEMENT USING METALIC RODS

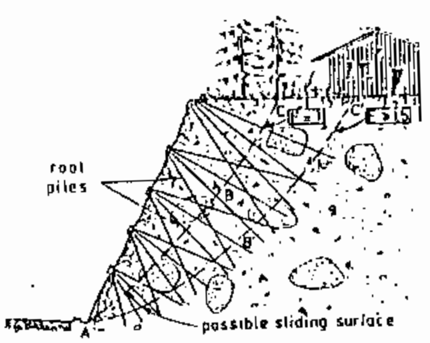


Fig. (2) Stabilization of slopes using roor piles

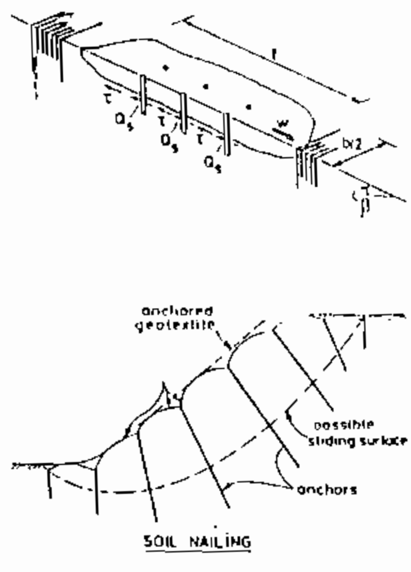


Fig. (3) Soil nailing with geotextiles.

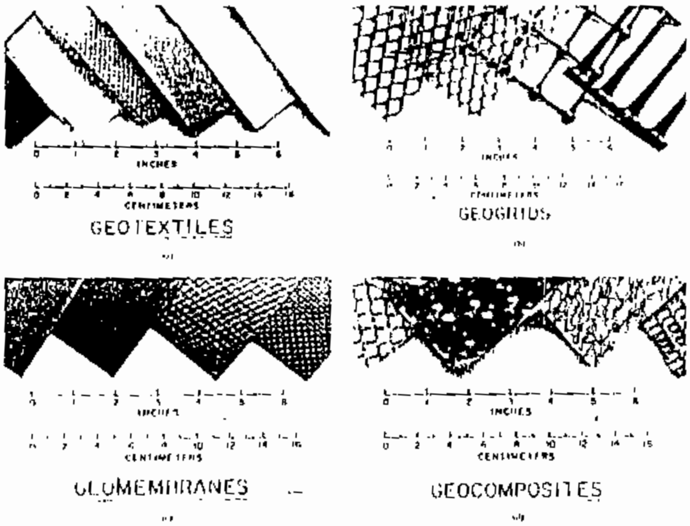


Fig. (4) Geosynthetic materials

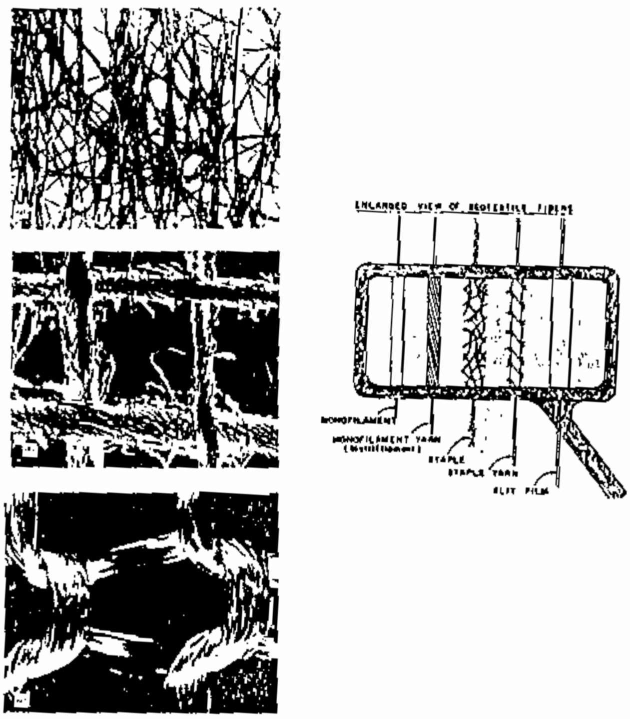
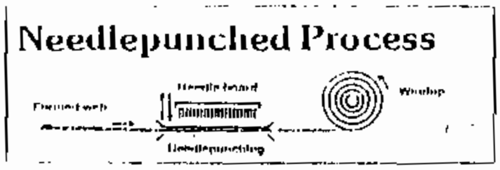
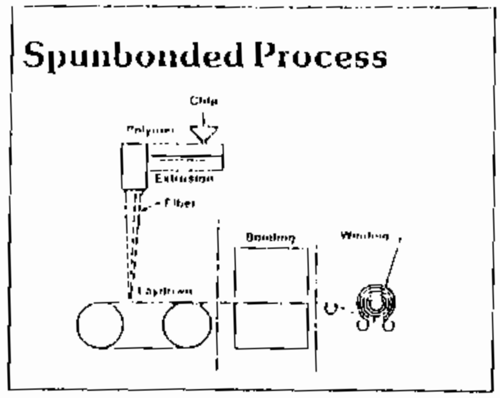


Fig. (5) Enlarged photographs of nonwoven, woven and knit fabrics



a) Needle punched process .



b)Spun bonded process

FIG(6) PRODUCTION OF NON-WOVEN GEOTEXTILE

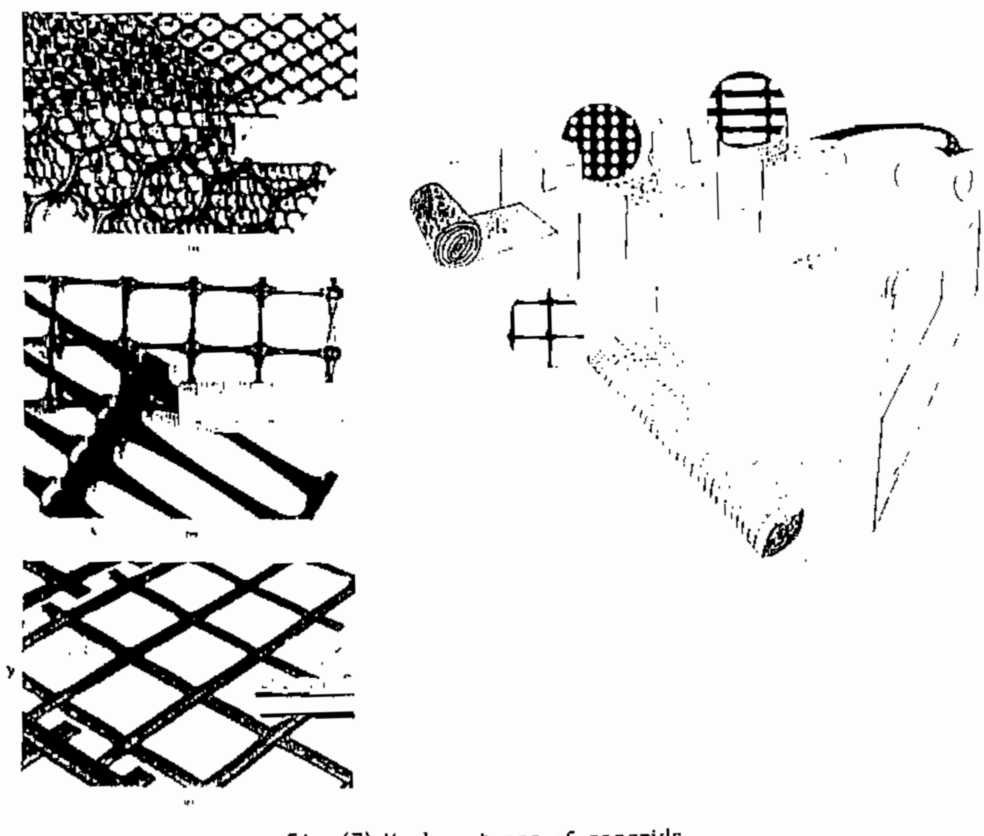
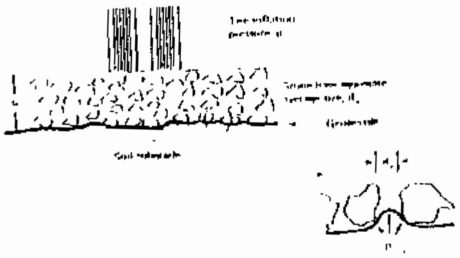
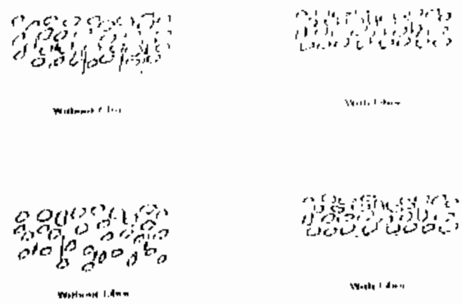


Fig. (7) Various types of geogrids



Geotextile under traffic loading



Geotextile in seperation function

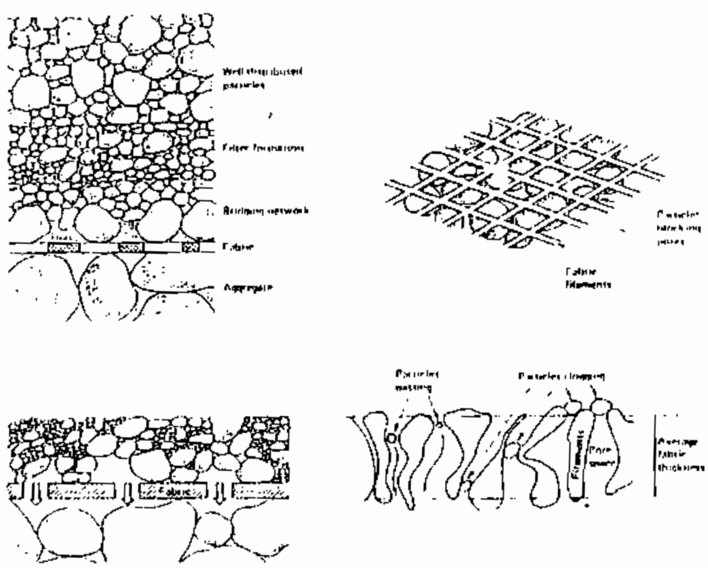
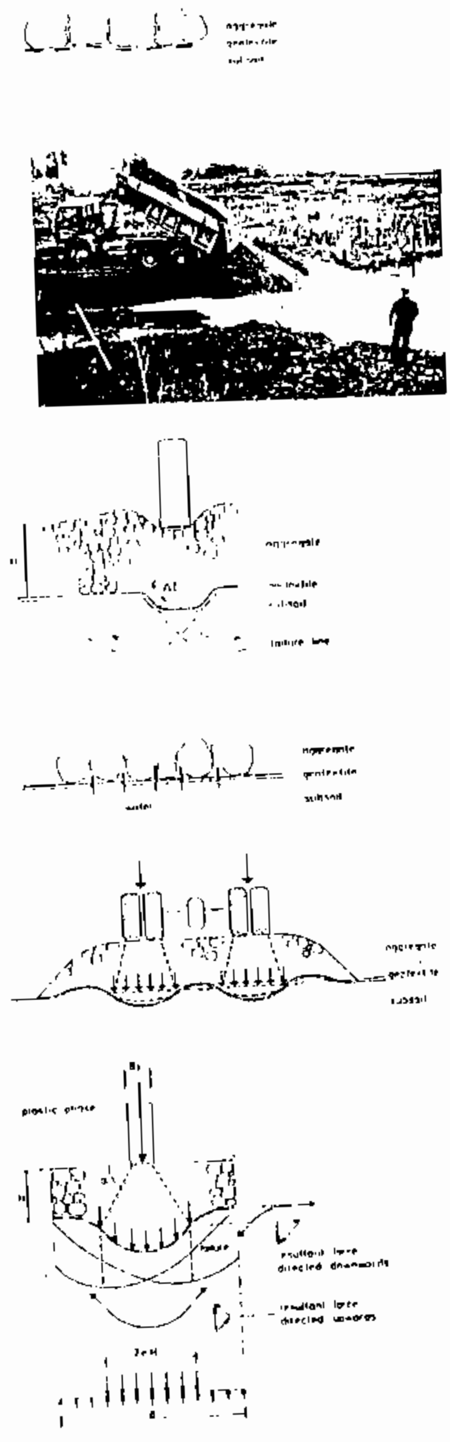
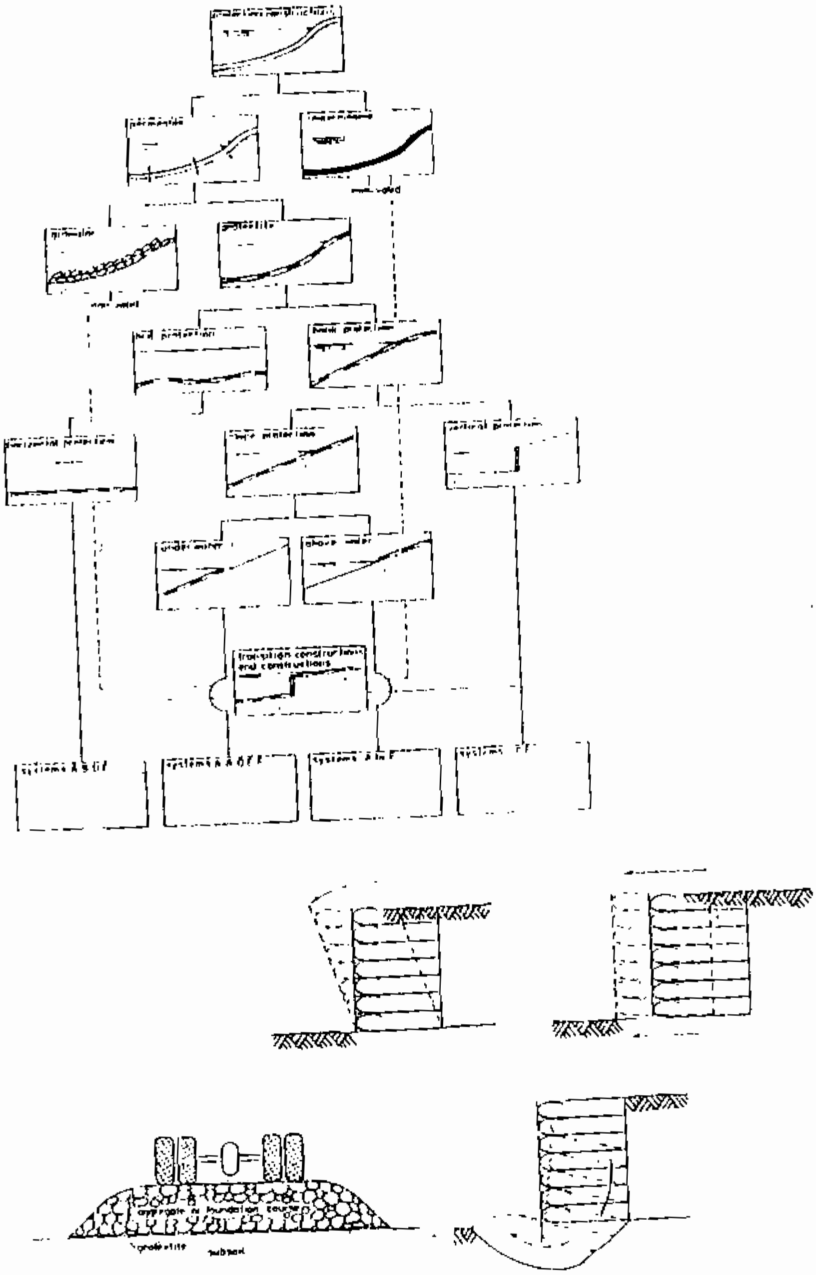


Fig. (8) Principle of seperation and soil-to-fabric flow compatibility.



FIG(9) PRINCIPLE OF SOIL REINFORCEMENT



FIG(10) SOME APPLICATIONS OF GEOSYNTHETICS