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# THE BEHAVIOUR OF GEOTEXTILES UNDER ARID WEATHER CONDITIONS KWAIT AS A CASE OF STUDY

سلوك المنسوجات المستخدمه فى تحسين خواص التربه فى الاجواء القاريــــــه...

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الملخص

تهدف هذه الورقه الى دراسه مدى تاثر المنسوجات البوليميريه - المستخدمه في اغراض تحسين خواص الاتربه - نتيجه التعرض للظروف الجويه و بالذات التغيير فى درجات الحراره و الاشعه فوق البنفسجيه و كذلك التاثير نتيجه لدفن المواد فى التربه على عمقي ٠٫٥م و ١٫٥م

هذا و قد تم اختيار منطقه الشويخ بدوله الكويت لاجراء هذا البحث نظرا لتعرضها لتغير كبير فى درجات الحرار(صفر - ٥٥ درجه مئويه) بالاضافه الى طول فتره التعرض للاشعه فوق البنفسجيه(التي تمتد الي ١٦ ساعه في اليوم دون اي سحابات في معظم الاحيان). و قد تم اختيار احد المنتجات المنسوجه واخر من المنتجات الغير منسوجه لهذا البحث لما لهذه المنتجات من استعمالات متعدده .

و قد تم استخراج العينات بعد فترات زمنيه ٣ و ٦ و ١٢ شهرا حيث تم اجراء عدد من الاختبارات و مقارنتها بالقيم الاصليه. و تشمل هذه التجارب الوزن لوحده المساحات-السمك-المخروط الساقط - التمزق-الشد. و قد بينت النتائج ان بعض العينات قد تاثرت كثيرا عند التعرض لفترات طويله بينما لم تتاثر العينات الاخرى تاثيرا واضحا.

## 1- ABSTRACT

This paper investigates the behaviour of geotextiles at exposure, storage and burial in soil in a hot dry climate. Kuwait was chosen as it experiences a wide range of annual temperature throughout the year, with air temperature rising to 55°C in summer and dropping to 0°C in winter. It also has an extremely high UV radiation level with long hours of uninterrupted sunshine on most of the days of the years. Two geotextiles presently used for separation and reinforcement applications, were fully exposed, stored out of sunlight and buried in soil at the depth of 0.5 m and 1.5 m. The geotextile were woven polyproplene product and non-woven polyester/polyproplene needle punched product.

The samples of the material provided by the manufacturers were tested on delivery, then after sustaining exposure, storage and burial in soil for 3, 6 and 12 months. The tests carried out include six index tests: mass per unit area, thickness, cone drop, tear and wide width tensile test. Results are described, revealing some remarkably different responses from the two products, ranging from total degradation to no measured effects.

## 2. Introduction and History of Use of Geotextile:

Geotextiles are permeable textile material (usually synthetic) used with soil or rock to enhance the performance or to reduce the cost of a man-made products. They include textiles in a traditional sense, by standard weaving machinery or they may be melted or needled together. They consist of synthetic polymers, thus biodegradation is not a serious problem. They are porous to water flow across their manufactured plane and also along their plane. Geotextiles are often classified as "Woven or Non-woven".

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It is reported that jute fabric was used in military supply routes in India and Burma during the Second World War. Natural fabric (cotton) was used to reinforce roads by South Carolina Highway Department in 1936. Results showed a reduction in cracking, ravelling and localized road failures,but the cotton fabric lacked durability [1].

The first use of the synthetic materials, in the form of woven geotextile was by Agerschou (1961) as a filter in a coastal protection works [1].

Terzaghi and Lacroix (1957-1960) are known to have used a continuous polyvinyl chloride (PVC) plastic sheet as a "water tight stretchable membrane" to control cracking in the construction of the Mission Dam in British Columbia, Canada [6].

Barrett (1966) reported that geosynthetics were first used in connection with erosion control applications and were intended to be an alternative for granular soil filters. He described how effective woven geotextiles were in a variety of coastal structures.

The development of the first non-woven geotextiles took place in 1968, by the Rhone-Poulenc company in France (Bidim, thick needle-punched polyester fabric) and by ICI in Britain (Terram, thin heat-bonded non woven fabric). In about 1971 three other geotextile or related product applications first appeared, namely "Fin drains, "Woven geotextile base reinforcements", and "Reinforced soil wall reinforcements" which opened new areas for geotextiles in civil engineering [2].

McGown and Ozelton (1973) identified the three basic functions of

"Separation", Filtration" and "Reinforcement" for geotextiles [10]. Leflaive and Puig (1974) also recognized these three functions and added "Drainage" as a fourth function [8].

### 3. Manufacturing and Functions of Geotextiles

**1)Woven geotextile**

Woven geotextiles were the first to be developed from synthetic fibers. They are manufactured using traditional or modified weaving techniques. The weaving process gives these geotextiles their characteristics appearance of two sets of parallel threads known as yarns,interlaced at right angles to each other. The term "Warp and Weft" are used to distinguish between the two different directions of yarn. The yarn running along the length of the loom and hence along the length of the geotextile roll is known as the "warp". The yarn running in the transverse direction, across the width of both the loom and the roll, is known as the "weft" [6].

**2)Non-woven geotextiles**

These are composed of elements bonded together by mechanical, melting or chemical methods to form a relatively smooth uniform mat. Each non-woven geotextile manufacturing system includes four basic steps: 1) fibre preparation; 2) web formation; 3) web bonding; and 4) post-bonding.

Non-woven geotextiles are formed from filaments or fibres arranged at random and bonded together into a planar structure. Common types of non-woven geotextile are [6]:

a) Needle Punched (Mechanical Bonding): A fibrous web is introduced into a machine equipped with a group of specially designed needles.

b) Melt-Bonded (Thermal Bonding): These materials are manufacturing by spraying continuous polymer filaments onto a moving belt which is then passed through heated rollers which cause partial melting leading to thermal bonding of the filament cross over points.

c) Resin-Bonding (Chemical Bonding): Acrylic or similar resins are sprayed onto a fibrous web. After cutting or rolling, strong bonds are formed between the filaments.

3)Functions of Geotextiles:

Geotextiles or related materials always perform at least one of the four basic functions [2]:

a)Separation; b)Filtration; c)Drainage;and d)Reinforcement.

a)Separation

A geotextile placed between two materials functions as a separator when it prevents the two materials from mixing under the action of applied loads.

b)Filtration

A geotextile functions as a filter when placed in contact with a soil or fine material. It allows water to pass through whilst retaining most particles.

c)Drainage

Drainage is the water or gas flow in the plane of the geotextile or related product. A product functions as a drain when it collects a liquid or a gas and conveys it towards an outlet [8].

d)Reinforcement

Geotextile reinforcement improves the strength of a soil in two different ways:

i) Membrane reinforcement when a vertical load is applied to a geotextile on a deformable soil.

ii)Shear reinforcement when geosynthetic placed on a soil loaded in a normal direction and then the two materials are sheared at their interface [2].

4. Testing Programme and Materials

4.1 Site Characteristics

The test site has the following characteristics:

1)Soil types

The soil profiles show that:

(i) The soil on the site is mostly yellow, fine to medium sand with very little coarse sand.

(ii) A little silt is present at a depth of 2 m.

(iii) Free silt particles are present only near the surface.

(iv) The soil conditions are uniform across the site.

**2)Particle size distribution**

Particle size distribution results show that:

(i) All samples contained particles passing BS Sieve No 4 (4.76 mm) and the percentage passing BS Sieve No 200 (0.074 mm) does not exceed 5% in any case.

(ii) There is no significant change in grain size distribution between any of the samples.

(iii) The coefficient of uniformity ($C_u$) ranges between 1.8 and 2.5 which means that the soil is poorly graded.

3)Water table and water content

No evidence of a water table was found down to a depth of 4 m. The water content increased with increasing depth, ranging from less than 2 per cent at a depth of 0.25 m to just over 12 percent at 1.5 m.

4)Soil consistency

The soil was found to be non-plastic. Liquid limit value ranged between 17.3% while no trial succeeded to determine plastic limit

5)CBR values

CBR values measured at the optimum dry density and were found to be in the range of 3.5 to 5%.

6)Soil Chemistry

Chemical analysis of soil was carried out on samples taken at 1.5 m. Results of the chemical analysis showed that:

(i) Chloride content in the soil 'C1', ranging between 0.007 and 0.176%.

(ii) Sulphate content as $SO_4$ content, ranges between 1.0 and 4.1%. The amount of $SO_3$ ranges between 0.9 and 1.47%.

(iii) Organic matter content in the soil ranges between 0.003 and 0.056%.

4.2 Types of Geotextiles Used:

**a)Woven geotextile (Lotrak 35/30)**

Lotrak 35/30 is produced by a conventional weaving processing, using a mechanical loom. The type of weaving used is known as plain weaving. The elements used are flat slit tapes from flat extruded film. The polymer type is 100% polypropylene with 10% carbon black, and the product is a general purpose geotextile.

**b)Non-woven geotextile (601-S Netlon)**

It is a needle punched product obtained by using continuous monofilaments which have been cut into short staple fibers. The bonding process is achieved by passing the loose web beneath a bank of reciprocating barbed needles which penetrate the full thickness of the web, causing them to interlace with other filaments.

### 4.3 Site Testing Programme

Samples of each type of geotextile were cut from undamaged rolls provided by the manufacturers. The size of the samples were 1.0 m in the machine direction of and 4.0 m in the cross machine direction. All samples were checked to ensure they did not contain any unusual irregular spots, grease, or any other damage. The number of samples were as follows:

a) One sample of each type of material was tested immediately to obtain the basic "Control" set of data.

b) Four samples of each type were left to all weathering conditions at the site, including direct sunlight to obtain exposed samples.

c) Four samples of each type of material were kept in the opened sided wooden room where they were subjected to all weathering conditions except direct sunlight.These samples were called Storage.

d) Four samples of each type of material embedded in soil at the depth of 0.5 m from ground level.

e) Four samples of each type were embedded in soil at the depth of 1.5 m from ground level.

### 4.4 Laboratory Testing Programme (Index and Performance tests)

Six types of tests were carried out [7],[9],[10]:

(i) **Mass per unit area**

To identify the variability of the control test specimens of the geotextiles.

(ii) **Nominal thickness**

To identify the variability of the samples studied.

(iii) Puncture resistance

To assess the resistance of the geotextiles studied to aggregate penetration and as an indirect indication of tensile strength.

(iv) Cone drop test

To assess the resistance of the geotextiles studied to damage by sharp stones during placement fill.

(v) Tear resistance

To assess the resistance of the geotextiles studied to tear propagation damage during and after installation.

(vi) Tensile strength and strain

To determine the variations in the short term stress/strain relationship and ultimate (breaking) strength and strain of both the geotextiles and the geogrids.

## 5. RESULTS and DISCUSSION

The test procedures used conformed with British Standard. All the Index and performance testing was conducted in-isolation, using dry specimens conditioned at 20 ± 1°C for at least 24 hrs prior to testing.

**1)Mass Per Unit Area Test**

The tests were conducted in accordance with BS 9864. The number of specimens tested from each sample was ten, each having an area of 100 $cm^2$. The test data obtained from all the mass per unit area tests showed no significance change.

**2)Thickness Test**

This test was conducted on the two geotextiles in accordance with ISO/DIS 9863. The thicknesses of the two geotextiles were measured at specified pressures of 2, 20 and 200 kPa. A comparison of geotextile performance due to the effects of thickness over the period of 12 months compared to their control values are shown in Table (1).

3)Puncture Resistance Test (CBR Puncture Test)

This test was conducted on the two geotextiles in accordance with BS 6906 (Part 1). The Puncture test method measures the force required to push the flat ended CBR plunger through a geotextile. A J-J tensile test machine was used to apply the puncture force. Attached plotters recorded the relationship between the applied force and the plunger displacement. Results were recorded as follows:

a)The push-through forces for both geotextiles.

b)The push-through displacements for both geotextiles.

The results can be summarized for the whole period of exposure as compared to the control values in Tables (2) and (3).

4)Cone Drop Test

The tests were conducted on the two geotextiles in accordance with BS 6906 (Part 6). They determined the resistance of the geotextiles to penetration. A standard cone having a mass of 1Kg was dropped from a height of 500 mm onto the centre of the specimen. The response of a geotextile to the falling cone was two-fold. First there was a penetration into the geotextile that was recorded by measuring the hole diameter. The second response was a deflection of the geotextile. The hole diameter, provides an indication of integrity, density and organization of the structure of the geotextile under test. The deflection is related to stiffness of the geotextile structure and polymer. The data obtained were recorded as follows:

a) The cone penetration for both kinds of geotextiles were recorded and compared to the control sample test data.

b) The Goetextiles deflection for both kinds of geotextile were recorded and compared to the control sample test data. Values are summerized in Tables Nos. (4) and (5).

**5)Tear Test**

This test was conducted on the two geotextiles in accordance with ISO TC.38/SC. It determines the tearing force, which is the force required to propagate a tear in a geotextile. A constant rate of extension tensile test machine (J-J Machine) was used. The machine is started and the tearing force recorded until the tear is completed, keeping the rate of extension constant at 75 mm/min. The test data were recorded as follows:

a) The tear force for both kinds of geotextiles tested.

b) Displacement for both kinds of geotextile tested. Values are summerized in Tables (6) and (7).

6) Tensile Test

The J-J tensile test machine was employed for the constant rate of strain tensile testing. Curves of load versus deformation were plotted automatically by the attached plotter and were then translated manually into the more useful form of load per metre versus average engineering strain. The principle of the test procedures was to grip a test specimen across its entire width in a tensile testing machine which operated at a specified rate of strain and to apply a tensile force to the test specimen until it ruptures.

The test specimens were mounted centrally in the jaws (where the distance between the jaws was 100 ± 3 mm.The test data were recorded as follows:

1) Effects on the average maximum load of geotextiles.

A comparison of the behaviour of average maximum load of geotextile over the period of 12 months based on the control values are in Table (8).

2) Effects on strain at maximum load of geotextiles.

A comparison of the performance of the strain at maximum load of geotextiles over the period of 12 months based on the control value can be summerized in Table (9).

3) Effects on the average break load of geotextile

A comparison of the performance of the average break load of geotextiles over the period of 12 months based on the control value can be summerized in Table (10).4)

4.Effects on strain at break load of geotextiles.

A comparison of the behaviour of the strain at break load of geotextile based on the control value can be summerized in Table (11).

## 6. CONCLUSIONS

Four of the Index Tests considered in this project relate to strength characteristics; namely wide width tensile test, puncture resistance, resistance to perforation and tear. The different strength test methods showed consistent and related pattern of behaviour which added confidence in the test results obtained. Conclusions can summarized as:

a) The test results reveal that thin woven polypropylene geotextile,in Kuwait (desert condition), should be limited vigoursly to UV exposure as it has very poor performance in exposure condition.

b) For storage sample of the material, the effect was less than the exposed sample. But the reduction in strengths caused by the cycling temperature and heat is significant.So, it is concluded that this material should not be stored in Kuwait's atmosperic conditions. The material be more brittle and it got more stiffer.

c) There is a very small reduction in the strength of the product which was buried at the depth of 1.5 and 0.5 m for a period ranging upto one year for undistributed soil exposure. But it is not a significant deterioration if it is compared with the other storing conditions.

d) the different strength test methods showed consistent and related patterns of behaviour of the non-woven geotextile. But the results showed that the non-woven suffer an increase in the variability of the property with time. It is obvious from the results that this product is much less effected than the woven one. Its thicknes (thicker than woven) is the major factor that played a considerable role in protecting the mass of the fibres from UV light and heat.

e) In the exposed and storage material there is a decrease in the strength but no significant change is observed in the buried material.

f) A substantial decrease in the displacement of geotextile deflection was noticed in the results in all the conditions over the whole year. It means that is although the strength does not undergo any changes, it does not reflect the behaviour of the material.

## 7. Recommendations for Use

Tables produced in this research work indicate that some changes can take place slowly and others very rapidly. Moreover, these changes vary from geosynthetic material to another. The main points obtained in this study relevant to the design approach are:

1. Method of handling, transporting and storing the material have significant effects on the material degradation. Contractors must take care in handling the material and the projects from weather effects by proper storing. It applies, generally, to all materials and woven geotextiles in particular.

2. Non-woven geotextile needs a great care when it is used in civil engineering, since curves of load-strain relationships were vary from condition to another with no fixed relation. Moreover, the majority of strains were taken place very clearly (In the first 5 seconds) while strain rate decreased afterwards.

3. Designers must take into consideration the conditions and duration of storing since all curves of strain-time and load-strain relationships are effected by changing either storing conditions or storing duration or both.

4. Designers are requested to perform a testing programme for each lot of production after receiving it in site and not depending on manufacturers values. In many cases the tests showed that the actual values determined are quite different than the manufacturers specifications.

8.REFRENCES:


1. Agerschou, H.A. (1961) "Synthetic Material Filters in Coastal Protection." ASCE Journal(Waterways&Harbo),87.No.WW1.pp 111-124.
2. Andrawes, K.Z. & McGown, A. (1977) "Alteration of Soil Behaviour by inclusion of Materials with Different Properties." Proc. Symposium of Reinforced Earth, TRRL/Heriot-Watt University, Edinburah.
3. Baudonnel, J., Giroud J.D. (1982) "Experimental & Theoretical Study of Tensile Behaviour of Non-Woven Geotextile." Proc. 2nd International Conference on Geotextiles, Las Vegas. Vol. 3. pp 823-828.
4. B.S. 2576 (1977). "Methods of Test for Textiles - Woven Fabrics - Determination of Breaking Strength & Elongation (Strip Method)."
5. B.S. 4304 (1977). "Methods for The Determination of The Resistance to Tearing of Woven Fabrics by the Wing-Rip Technique." .
6. El-Shabrawy,Elshibini,and Al-mudhaf(1991)."An Introduction to the Use of Geosynthetics in Civil Engineering",MEJ,V ,No1.pp - .
7. Haliburton,T.A.,Anglin.C.C.,Lawnmaster,J.D.(1978)"TestingofGeotech Fabricforuse as Reinforcement."ASTM.Geotech Test.Vol.4.pp 203-212.
8. Leflaive, E. (1988). "Durability of Geotextiles: The French Experience" Geotextiles and Geomembranes. Vol. 7. pp 23-31.
9. Murray, R.T., and McGwon, A. (1982). "The Selection of Testing Procedures for the Specification of Geotextiles." Proc. 2nd Int. Conf. Las Vegas, USA. Vol.2.. pp 291-296.
10. Murray, R.T.&McGwon, A.(1987)"Geotextile Test Procedures: Background & Sustained Load Testing."TRRL Appl Guide No. 5.Uk.
11. McGown, A., Andrawes, K.Z. & Kabir, M.H.(1984)."Rapid Loading Creep Testing of Geotextiles and Related Materials."TRRL DGR 474/91.

**Table (1)**

Results of thickness compared to control values.

| Thickness | | Exposed | Storage | 1.5 m | 0.5 m |
|---|---|---|---|---|---|
| WOVEN | 2 kPa | +12% | +11% | +6% | +12% |
| | 20 kPa | +14% | +12% | +2% | +5% |
| | 200 kPa | +12% | +11% | +2% | +6% |
| NON WOVEN | 2 kPa | +11% | +1% | -10% | -6% |
| | 20 kPa | +7% | +2% | -9% | -7% |
| | 200 kPa | +3% | +2% | +2% | +1% |

**Table (2)**

Results of push through Force from CBR Puncture test as compared to control value

| Force | Exposed | Storage | 1.5 m | 0.5 m |
|---|---|---|---|---|
| Woven | Covex up decrease to 0 value | 25% Decrease | 6% Decrease | 4% Decrease |
| Non-Woven | 3% Decrease | 9% Decrease | 7% Decrease | 2% Decrease |

Table (3)

Results of push through Displacement from CBR Puncture test as compared to control value

| Displacement | Exposed | Storage | 1.5 m | 0.5 m |
|---|---|---|---|---|
| Woven | 50% Covex up decrease | 9% increased | 14% Increased | Constant |
| Non-Woven | 50% Convex down decrease | 26% Straigh line decrease | 15% Covex up decrease | 15% Straight line decrease |

Table (4)

Results of Penetration of Geotextile compared to control values

| Penetration | Exposed | Storage | 1.5 m | 0.5 m |
|---|---|---|---|---|
| Woven | Increased to ∞ after 12 months | Constant | Constant | Constant |
| Non-Woven | 6% increase | 4% increase | 2% increase | 4% increase |

Table (5)

Results of Geotextile Deflection compared to Control Value

| Displacement | Exposed | Storage | 1.5 m | 0.5 m |
|---|---|---|---|---|
| Woven | Covex down decrease to 0 value | 25% Decrease | 20% Decrease | Constant |
| Non-Woven | 20% Convex down decrease | 20% Straigh line decrease | 15% Decrease | 5% decrease |

Table (6)

Results of Tearing Force compared to control values

| Penetration | Exposed | Storage | 1.5 m | 0.5 m |
|---|---|---|---|---|
| Woven | Convex down decrease to 0 value | 50% Straight line decrease | Constant | Constant |
| Non-Woven | 30% Straight line decrease | 7% decrease | Constant | Constant |

Table (7)

Results of Tearing Displacement compared to Control Value

| Displacement | Exposed | Storage | 1.5 m | 0.5 m |
|---|---|---|---|---|
| Woven | 60% Covex down decrease | 60% Straigh line decrease | Constant | Constant |
| Non-Woven | 80% Straigh line decrease | 70% Straigh line decrease | 20% Decrease | 20% Straight line decrease |

Table (8)

Maximum loads from wide width strip test results compared to control values

| Maximum Force | | Exposed | Storage | 1.5 m | 0.5 m |
|---|---|---|---|---|---|
| WOVEN | MD | Convex up decrease to 0 value | 25% Convex up decrease | 11% decrease | 12% decrease |
| | XMD | 50% Convex up decrease | 20% Straight line decrease | 20% decrease | 8% decrease |
| NON WOVEN | MD | Constant | Constant | Constant | Constant |
| | XMD | 12% decrease | Slight Convex up decrease 20% | 9% decrease | Constant |

Table (9)

Strain maximum loads from wide width strip test results compared to control values

| Strain at Maximum Load | | Exposed | Storage | 1.5 m | 0.5 m |
|---|---|---|---|---|---|
| WOVEN | MD | Convex down decrease to 0 value | 40% Convex up decrease | 25% Straight line decrease | 15% Convex up decrease |
| | XMD | Straight line decrease to 0 value | 40% Straight line decrease | 25% Decrease | 25% Convex up decrease |
| NON WOVEN | MD | 20% Decrease | 40% Straight line decrease | 6% decrease | 25% Decrease |
| | XMD | 30% Straight line decrease | 35% Straight line decrease | 5% decrease | 25% decrease |

Table (10)

Break Load from wide width trip test results compared to control value.

| Average Break Load | | Exposed | Storage | 1.5 m | 0.5 m |
|---|---|---|---|---|---|
| WOVEN | MD | Straight line decrease to 0 value | 40% Straight line decrease | 9% decrease | Constant |
| | XMD | 70% Convex up decrease | 35% Straight line decrease | 20% Decrease | 7% decrease |
| NON WOVEN | MD | Constant | Constant | Constant | Constant |
| | XMD | 20% decrease | 20% decrease | 8% decrease | Constant |

Table (11)

Strain at break Load from wide width trip test results compared to control value

| Strain at Maximum Load | | Exposed | Storage | 1.5 m | 0.5 m |
|---|---|---|---|---|---|
| WOVEN | MD | Convex down decrease to 0 value | 30% Convex down decrease | 15% Convex up decrease | 20% Convex up decrease |
| | XMD | Straight line decrease to 0 value | 30% Straight line decrease | 15% Convex up decrease | 15% Convex up decrease |
| NON WOVEN | MD | 20% Decrease | 45% Straight line decrease | 25% Decrease | 20 % Decrease |
| | XMD | 20% Decrease | 40% Straight line decrease | 25% Decrease | 25% Decrease |