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Performance Of Drainage Geotextiles For Sustainable Development Of Soil And Water Resources In Egypt

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Abstract - Drainage, filtration, separation and reinforcement are the principle functions of geotextile products. In addition to these basic functions, geotextiles have unique properties that can provide effective solutions to many problems in civil engineering. For drainage applications, filtration occurs when a liquid passes through the plane of a geotextile while retaining soil particles on the upstream side of the fabric, providing a soil filter system similar to the traditional graded aggregate structure. Considering the great importance of environmental hazard mitigation, caused by unsuitable applications of modern textile technology in major Egyptian projects, this paper concerns with establishing the technological bases in drainage projects in Egypt. Local synthetic geotextiles, manufactured with different non-woven structural parameters, commonly used for drainage projects in Egypt, have analytically investigated. Effect of different structural parameters on drainage performance efficiency of different geosynthetic samples has studied. Also, time effect on the durability and properties stability of drainage network was investigated. Optimum samples structural parameters for draining some Egyptian soil., with specific structure, was successfully determined.

INTRODUCTION

Geotextiles form one of the two largest group of geosynthetics. Their rise in growth during the past fifteen years has been nothing short of awesome. They are indeed textiles in the traditional sense, but consist of synthetic fibers rather than natural ones such as cotton, wool, or silk. Thus biodegradation is not a problem. These synthetic fibers are made into a flexible, porous fabric by standard weaving machinery or are matted together in random, or nonwoven, manner. Some are also knit. The major point is that they are porous to water flow across their manufactured plane and also within their plane, but to a widely varying degree. There are at least eighty specific applications area for geotextiles that have been developed; however, the fabric always performs at least one of five discrete functions: speration, reinforcement, filtration, drainage or moisture barrier “when impregnated”.

The range of woven and nonwoven geotextile applications is extensive. The yarn “or fibre” chosen depends on cost and on the physical properties, especially thickness per mass, mechanical properties, in particular, strength and deformation, and hydraulic properties, i.e permeability. One use in temporary road construction is to separate the granular fill material involved in the road surface from the soft ground beneath. In instances where wear on the ground surface is severe, a geotextile can be used to provide soil separation as well as some physical support. The role of geotextiles is more extensive in permanent road construction. Here, they are used on their own, or combined with geogrids for reinforcement. Individually or combined, these materials can provide sub-structure support, ground drainage and erosion control, and prevent reflective cracking.

Retaining walls allow property owners to maximize their land use. However, building a concrete gravity or crib wall is often impractical because of their high construction cost. Geotextiles are used for a wide assortment of reinforcement applications, including embankments over soft soils, levees and retaining walls. Geotextiles are well suited to construction of walls with timber, precast panel and segmental block facing.(Sarah, E, 1999).

Geotextiles make retaining walls financially feasible. In fact, a geotextile retaining wall can be built for less than half the cost of a conventional wall. Woven geotextiles offer other significant advantages over conventional methods, such as simplified installation, construction, and the ability to use on-site backfill material.(Hearle, 1971). Owners and builders like the fact that polypropylene geotextiles cost approximately half the amount of polyster and polyethylene geogrids, and they require considerably less labor to install.

Land fill and waste disposal sites create a number of difficult problems which are now being tackled by the industry. Methane gas is generated by decomposing natural materials, as well as in industrial environments. Gases can also migrate upwards from worked coal seams and even undisturbed rock formations. The geotextile used in this instance will absorb the gas, allowing it to continue upwards, selectively releasing it to ground drains which remove the gas rapidly and prevent it from accumulating. An impermeable geomembrance can be fitted below the geotextile if the hazard is waste, or above if the problem is likely to come from below ground. (Ingold, S. 1988)

Geotextiles have replaced graded soil filters for drainage of virtually all structures, including groundwater, intercept systems, pavements, building foundations, dams and walls. Compared to conventional soil filters, geotextiles offer advantages by providing a consistent and continuous filter, reduced excavation, reduced environmental impact, and simplified higher quality construction and a substantial reduction in material costs. Geotextiles have replaced graded granular filters used beneath riprap or other armor materials in revetments.

Applications include drainage channels, shorelines, and bridge and pier scour protection systems. Without a geotextile filter, wave action and water movement erode subgrade soils from beneath the riprap or armor. Degradation of the subgrade negates the benefit of the riprap or armor, resulting in extensive repair and replacement. The selection of geotextiles for permanent erosion control is similar to subsurface drainage. However, permanent erosion control applications usually require higher geotextile strength properties. The geotextile must survive placement of possibly very large, angular ripap, plus be able to endure severe wave action.

Filtration occurs when a liquid passes through the plane of a geotextile while retaining soil particles on the upstream side of the fabric. In time, a graded filter cake develops adjacent to the fabric, providing a soil filter system similar to the traditional graded aggregate structure.

For this application, a geotextile high in “percent open area” should be selected, with a controlled opening size to suit the soil being filtered. Most non-woven fabrics and some woven fabrics will suit this application. Filtration is the key function in virtually all drainage applications, and the use of an appropriate geotextile in drainage is very effective, both technically and economically.

The inclusion of a geotextile fabric in any drainage system adds only a small fraction of the drain’s overall cost but greatly enhances the system’s performance and life expectancy. (Radko Krcma, 1971)

The objective of this work is to study the relationship between some geotextile fabric parameters and their drainage performance efficiency, for sustainable development of soil and water resources in Egypt.

LITERATURE REVIEW

Over the years geotextiles have been used in hydraulic engineering. Mainly four different types are used: Mechanical bonded non-wovens, thermal bonded non-wovens, wovens and more recently knitted. For the majority of the projects their primary task is to act as erosion protection, alternative for, or part of a mineral filter. Whereas during the last years their affectivity has been discussed, today there is a tendency to create criteria, which enables the responsible engineer to choose the material best suitable for certain condition. Basis for such criterias is the knowledge, what kind of forces are acting on the geotextile in a project. Mostly there are five stages five effecting the drainage performance efficiency:

1- Designing and manufacturing the geotextile fabric, i.e. design and production parameters.
2- Wrapping parameters, i.e wrapping yarns for the drain pipe, wrapping machines, wrapping stress and mechanism.
3- Transportation, handling, and storage conditions , i.e. effect of transportation, handling and storage in the open air climatic Egyptian parameters, especially effect of UV radiation in-corporation with high temperature and humidity.
4- During and after soil excavation, for inserting drainpipes wrapped with geotextile envelopes.
5- After completion of the drainage system.

As a matter of fact, every one of the above-mentioned stages considerably affects the geotextile material, itself, i.e. all its structural parameters. In its turn, it strongly affects its behavior or performance efficiency.

Several researches have been carried-out for revealling the behavior of soil-water agricultural drainage system by using different geotextile envelope materials. Most of these works have emphasized on studying some criteria, for determination the need of an envelope material, for selection of the envelope material type. However, principals for establishing those studies has based on comprehensive studies of soil characteristics, especially soil particle sizes and size distribution, i.e. soil grading characteristics. For example, different criteria has been suggested and used to evaluate definite types of soils in Egypt (Omara, M. A. and Vlot man, W.F., at DRI(*) (1996-2000). These criteria includes: (clay content < 30%); (clay/silt < 0.50); (plasticity index (P_I)<6.0); (coefficient of uniformity (C_u)<5.0); and (Boundraies Voltman/ Omara 1996).

Most of the above-mentioned studies was not sufficiently interested in interpreting their results on geotextile structural parameters, such as fibre characteristics, yarn structure, density, mass per unit area, thickness, … etc.

METHODOLOGY

Geotextile specification

Three Egyptian manufacturers provided samples (N_1, N_2, N_3) from needle punched nonwoven polypropylene material in which their structural specification were different (fibre linear density (d, tex), fibre linear density distribution (d_{90}). Two imported samples (n_4, k) with thermal-bonded, and weft knitted structures respectively. Geometrical factors such as cover factor (i.e density of component fibres or yarns in related to their linear density (d)), specific structural parameters (for knitted, loop length, coarses/ in, wales/in .. etc) are different. Depending on the variation of structural parameters, main physical properties, involving drainage process, of geotextile fabrics are considerably affected. Main physical properties of drainage geotextile are thickness, mass/area, and pore size distribution).

MEASUREMENTS

For determining most of structural parameters, a relatively new optical technique" Image-Analysis Computer system" was used. Mass per unit area, thickness and pore size distribution were measured.Using the standard methods of (A.S.T.M) (1996). Five envelope geotextile samples were used in each measurement. Then the average of these samples were calculated.

RESULTS AND DISCUSSION

Table (1), Figs (From (1-a, 1-b and 1-c) to (5-a, 5-b, and 5-c) and figs (6-11), display the whole results, where mass/area (g/m_2), thickness (mm), porosity (%), fibre linear density (d_{tex}) and O_{90} for virgin samples and exhumed (6 months after construction) were determined. Using a relatively new optical

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[*] DRI- Drainage Research Institute, National Water Research Center, Ministry of Water Resources and Irrigation; Egypt.

technique "Image Analysis computer system", microphotographs (Figs 1-11) have obtained, where (a) indicates virgin sample, (b) indicates exhumed sample (microphotograph, taken from the drainpipe interface, and (c) taken from the soil interface.

Table (1): Performance properties of geotextile drain-envelopes

Symbol of each sample	Geotextile Fibrics	O_{90} (µm) T		Mass/area (g/m^2)	Thickness (mm)	D_{tex}	Binding points frequency
		Virgin	Virgin exhumed				
N_1	Polypropylene 360 "PP 360"	360	520	396	4.5	11- 183	16
N_2	Polypropylene 310 "PP 310"	310	358	324	4.5	11-826	28
N_3	Polypropylene 290 "Pp 290"	290	530	620	6.2	6-378	36
K	Knitted Socks ("O" Socks)	100	170	184	1.2	----	---
N_4	Typar	90	480	90	1.1	----	65

Effect of Fabric Structure:

Nonwoven geotextile samples N_1, N_2 and N_3 produced by needle punched technique, exhibit higher performance drainage efficiency (less blocking and higher hydraulic quality and more deformation resistance), in comparison with other samples (N_4 and k). This mainly due to the fact that relative fibre movement within the structure of (N_1, N_2 and N_3) is greater than in (N_4 and k) which is, in its turn, allows the fibres to slip on their contact surfaces and behaves better in the drainage site. This behavior is obviously shown in the course of comparing samples (N_1, N_2 and N_3) after construction, i,e exhumed geotextile fabrics. Exhumed (N_1, N_2 and N_3) samples are more durable and dimensionally stable after six months construction, especially in their side of drainpipe interface, shown in the microphotographs Fig (1-b), (2-b) and (3-b).

Effect of Binding points frequency:

Comparing the different microphotographs of the five samples, it is obviously shown that they are totally different in the number (frequency) of the binding points. Results of counting binding points in (cm^2) were: (16, 28, 36, 65) for samples (N_1, N_2, N_3 and N_4) respectively. The increasing trend in those samples proved the decressing ability of movement freedom of fibres within every non-woven structure. Typar (N_4), produced by thermal-bonded technique exhibited the most bonded geotextile, in comparison with the other three ones. At the same time PP 360 (N_1), which exhibited the best within other samples in hydraulic properties, has the lowest frequency of biding points. This is easily approved by comparing the clogging and blocking effects in microphotographs, (1-b,c), (2-b,c), (3-b,c), (4-b,c)-Big "O" socks sample, produced by knitted technique, exhibited bad hydraulic trend (more clogging and blocking). This is easily shown in microphotographs (5-b,c).

Effect of binding element type:

Binding elements in fabric structures could be single fibres, fibre strands, or binding threads. Thermal-boded is one example of non-woven fabrics consisted of single fibre (filament) binding element by fusing fibres at their cross-over points. Needle-punched is a typical example of non-woven geotextile, produced by fibre strands binding element. In its production the fibre web is interlaced with fibre strands pulled through by the barbs of the needles of a needle punching machine. Binding threads are used as the binding element in the production of nonwoven fabrics in which the web is reinforced by stitch bonding woven. Warp knitted or weft-knitted, are also typical representative of the binding threads geotextile fabrics.

For Egyptian silty, weak structured soils (fine textured soil), the coarser the geotextile surface texture, the more appropriate it would be, for drainage [DRI (1989 - 1996)]. This fact was approved by this work, where coarser nonwoven samples "made form fibre strands" (Samples N_1, N_2 and N_3) exhibited better draining quality than other fabric "made from fused single fibres" (sample N_4). For knitted structured sample (K), the realtively bad pore size grading, and relatively thinner thickness has led to bad draining hydraulic performance. All this analysis approved by microphotographs (Figs 1-5).

Effect of structural geometrical arrangement "i.e. Structure Orientation":

As a matter of fact, structural geometrical arrangement plays a great role in determining the drainage hydraulic behaviour of some geotextile drain-envelopes. The more regular geometrical arrangement; either planar, or spatial; the bad the grading characteristic of drainage geotextile fabric. Fibre, fibre strands, or yarns grading, as well as, pore size grading of geotextile fabrics are considered the main criteria of good drainage grading characteristics. The relationship between fabric pore size grading (O_{90}) and soil particle size grading is, for many drain scientists, the typical representive criteria of drainage efficiency.

Analysing the microphotographs of the five virgin samples (1-a, 2-a, 3-a, 4-a, and 5-a), it could be concluded that, the relatively bad oriented fabrics (N_1, N_2, N_3), where spatial dis arrangement occurred between fibres, composing the fabric. Typar (N_4) exhibited relatively better arrangement, or less dis arrangement", where fibre disarrangement occurred only in a plane Figs. 6,7 show the appearace of magnified (X 1000) fibres, protruded from "Typar" geotextile fabric, where virgin (Fig. 6) and exhumed (Fig. 7) display the planer arrangement of fibres. (Fig. 7) also shows the soil particles hanged clearly on the fibres surfaces.

Comparing that effect in its respective appearance, for both (PP 360) fibres of virigin sample (Fig. 8) and exhumed (Fig.9); and (PP 290) fibres of virgin sample (Fig. 10), and exhumed (Fig. 11), the spatial arrangement of fibres is obviously clear. Both (PP 360), Figs. 8,9, and (PP 290), Figs. 10,11 microphotograph proturded fibres (X 1000), shows the different relationships of soil particles with fibres [where sticking cohesively on fibre in (Fig. 9) and spreading on fibre surface in (Fig. 11)]. The worst geotextile sample was knitted socks (K), because of its relatively highest "yarn arrangements" within the structure. Results of changing of (O_{90}) and stability of other fabric physical properties after six months were shown in (table. 1) and Figs (1-b,c , 2- b,c ---- 5- b,c) of exhumed geotextiles for their both side interfaces (with soil and water drain).

Effect of fabric Thickness

Thickness of geotextile drain-envelopes considered as one of the major structural-physical characteristics, playing a great role in drain hydraulic mechanism "Kineticism" over the soil-geotextile system. As general, the thicker and bulkier the fabric, the better drainage it performs. This fact, could be approved by the results, displayed in table (1) and microphotographs of exhumed fabrics (Figs. 1-5).

Effect of Fabric Mass/area "g/m^2

Results, shown in table (1) display a clear variation in different geotextile mass/area. Those results could be proportional with the results of thicknss (mm) for the same fabrics. Needle-punched samples (N_1, N_2, N_3) exhibited the maximum values and (N_4) exhibits the lowest. Here, mass per/unit area is just a representative indicator of some important factors such as (d_{tex}, density, cover factor, thickness .. etc). So mass/area could not be solely a fair criterion for predicting the performance of geotextile envelope. Using mass/area incorporated with its thickness may be more fair criterion for drainage performance of geotextiles.

CONCLUDION AND RECOMMENDATIONS

- Fabric parameters, in general, play the most important role in determining the performance efficiency of geotextiles, used for drainage applications, in specific soil parameters.
- Type of fabric structure (needle-punched, thermal bonded nonwovens, wovens, or knitted) dramatically affects the drainage behaviour of such geotextile drain-envelopes, either hydraulical or mechanical.
- The orientation of Fabric structure, i.e. the geometrical arrangement of its main component "particles" (fibres, fibre strands, yarns, .. etc) has a great influence on the kinetic behaviour of soil-water drainage system through fabric plane.
- Interlacing force represented by binding points frequency, is one of the most important parameters of the geotextile "non-woven" fabric, which considerably affects the drainage performance.
- Porosity, pore size distribution (O_{90}), binding element distribution (d_{90}), and their grading characteristics, in relation with similar soil grading characteristics, are still of major importance in controlling the drainage geotextile designing and producing parameters.
- Based on the previous results, the following recommendations can be made :
- An intensive research work should be carried out for widening the range of design parameters for drainage geotextiles.
- Kinetic movement of soil-water drainage system in situ, through different geotextile drain pipes envelopes, should be carried out for proper designs of new appropriate fabric parameters.
- Microscopically scanning, and other modern photographic methods, should be used for recording static or dynamic water flowing processes, from saturated irrigated soils,through geosynthetic fabrics.
- More in-depth and wide-range co-operation between DRI and textile scientists is recommended for best solutions of geotextile drainage problems.

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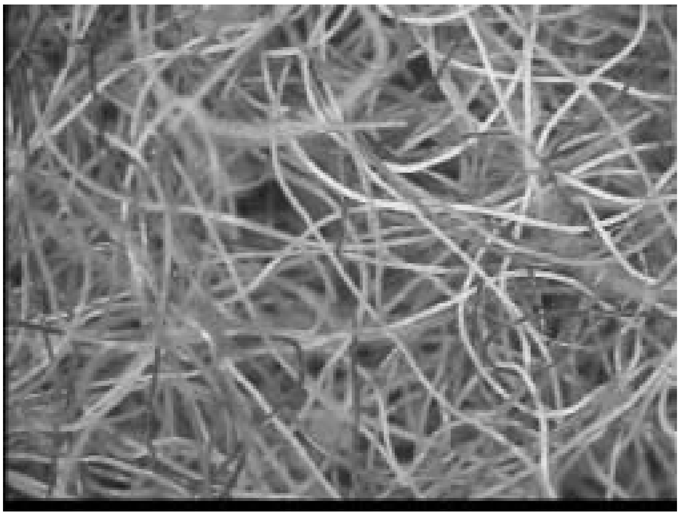


Fig 1a

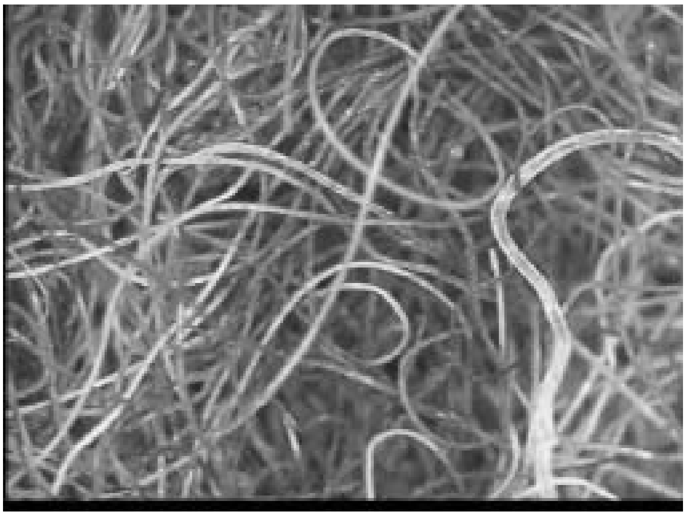


Fig 1b

Fig 1c

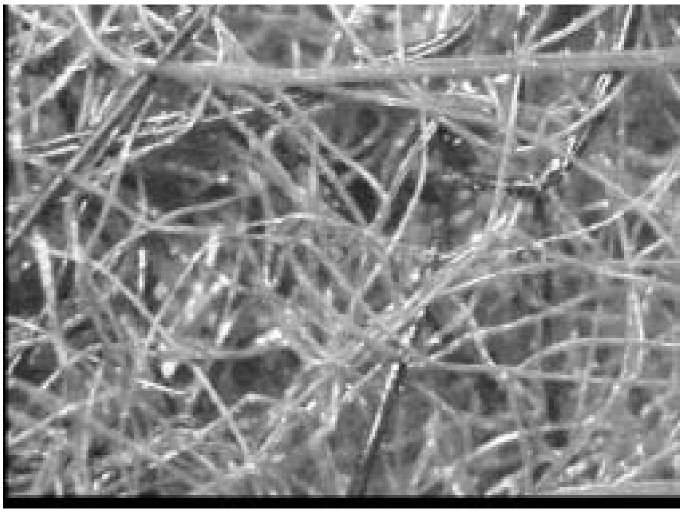


Fig 2a

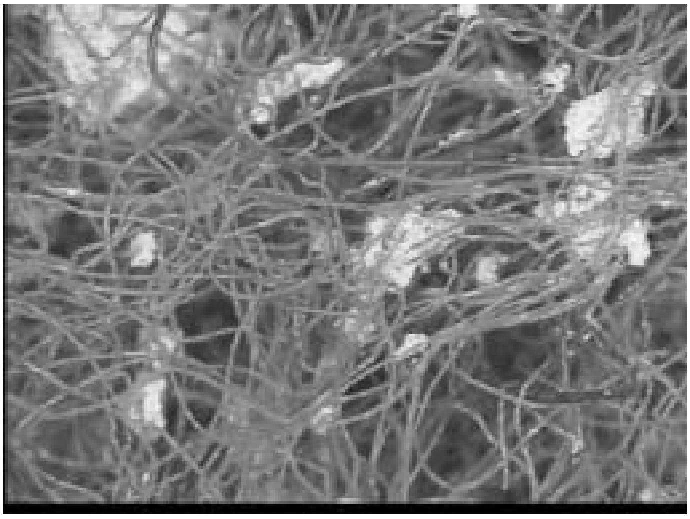


Fig 2b

Fig 2c

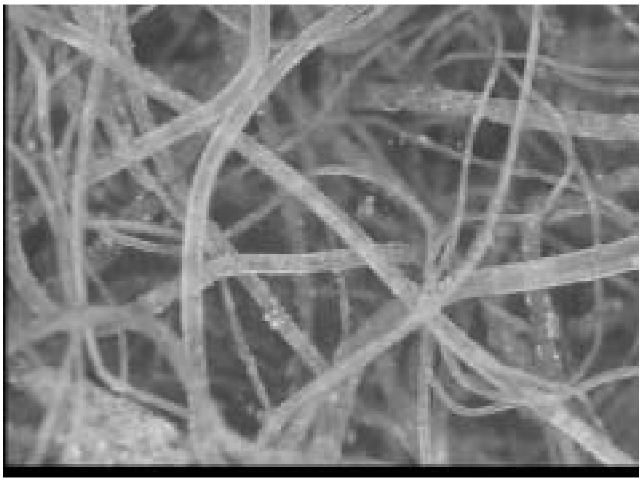


Fig 3a

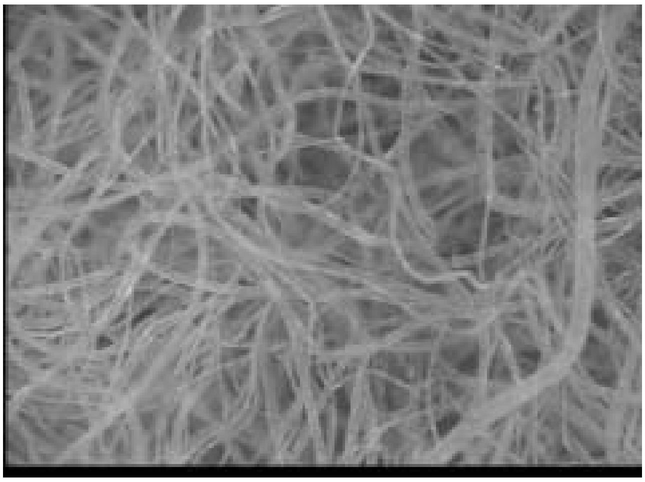


Fig 3b

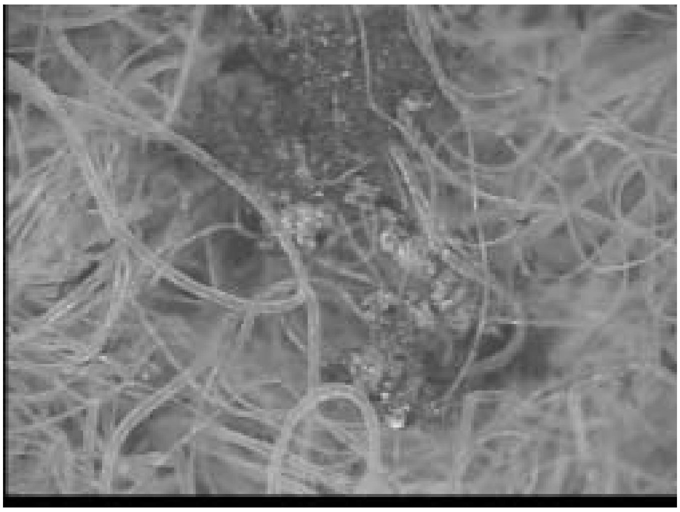
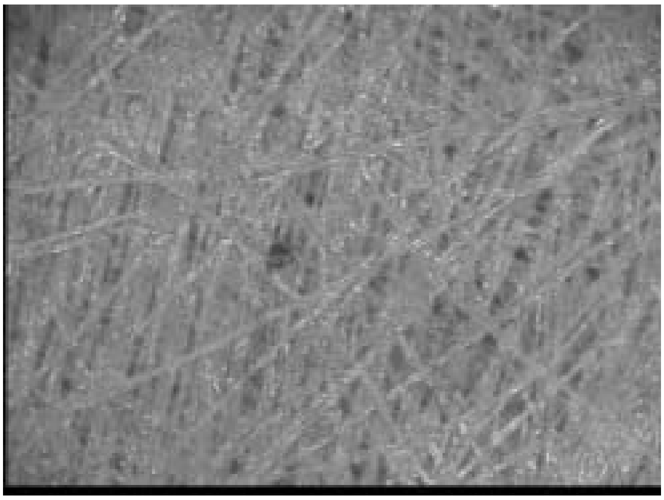


Fig 3c



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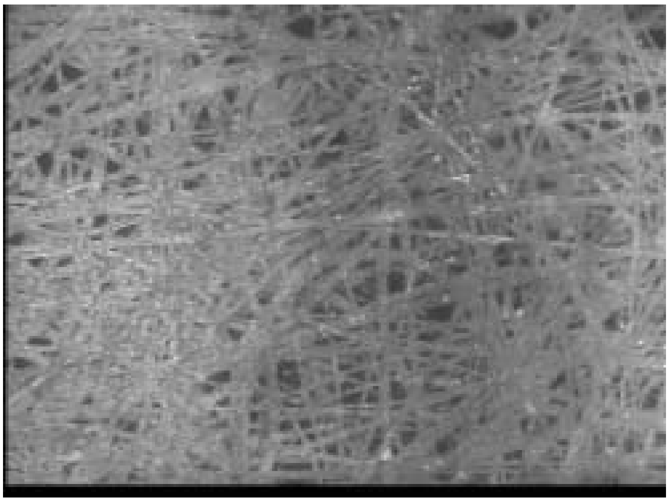

Fig 4b

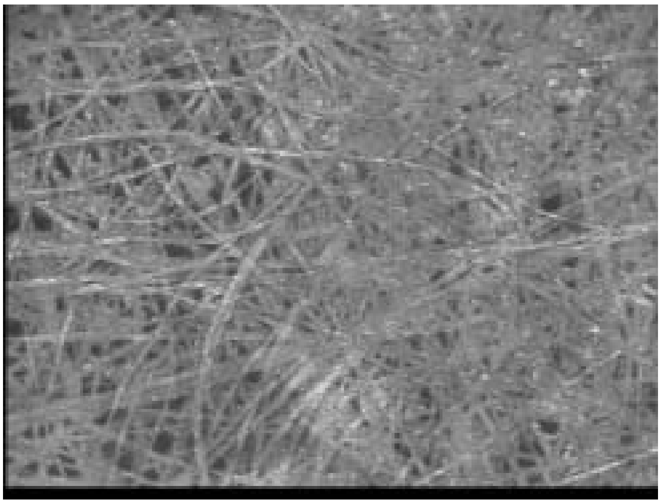

Fig 4c

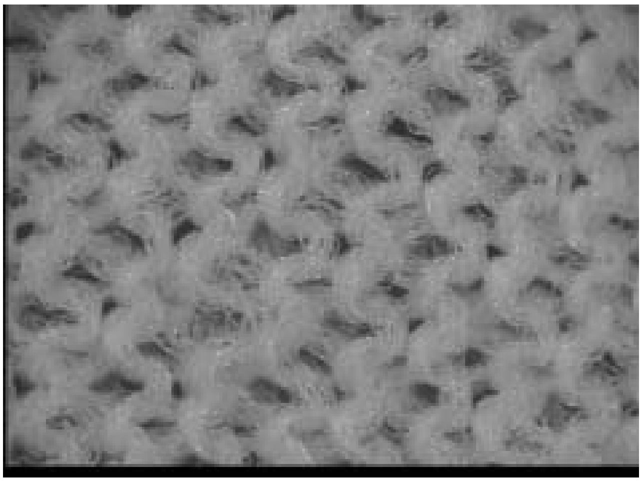

Fig 5a

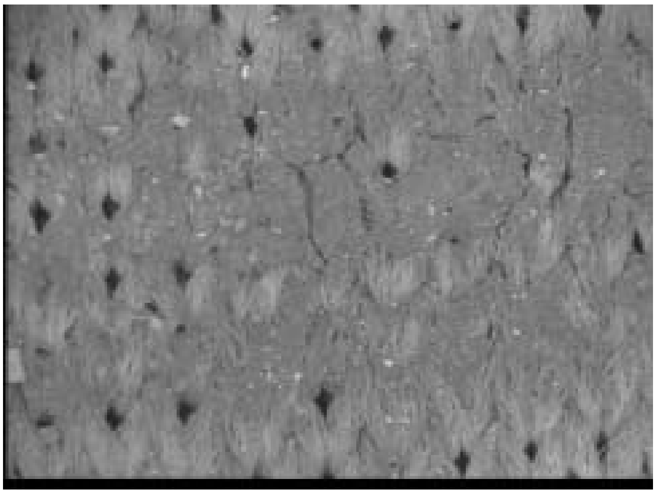

Fig 5b

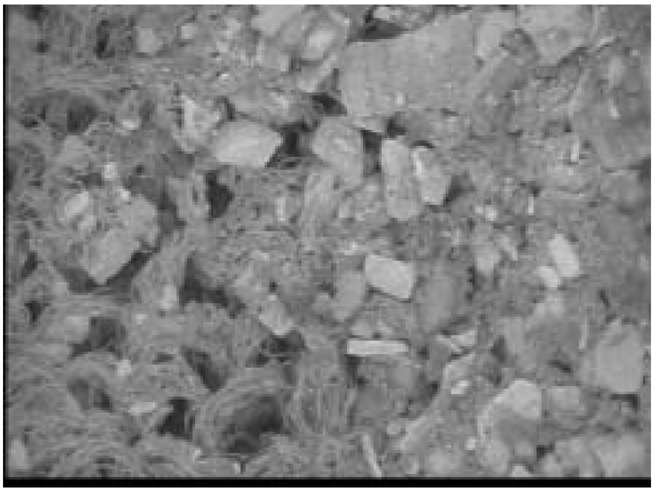

Fig 5c

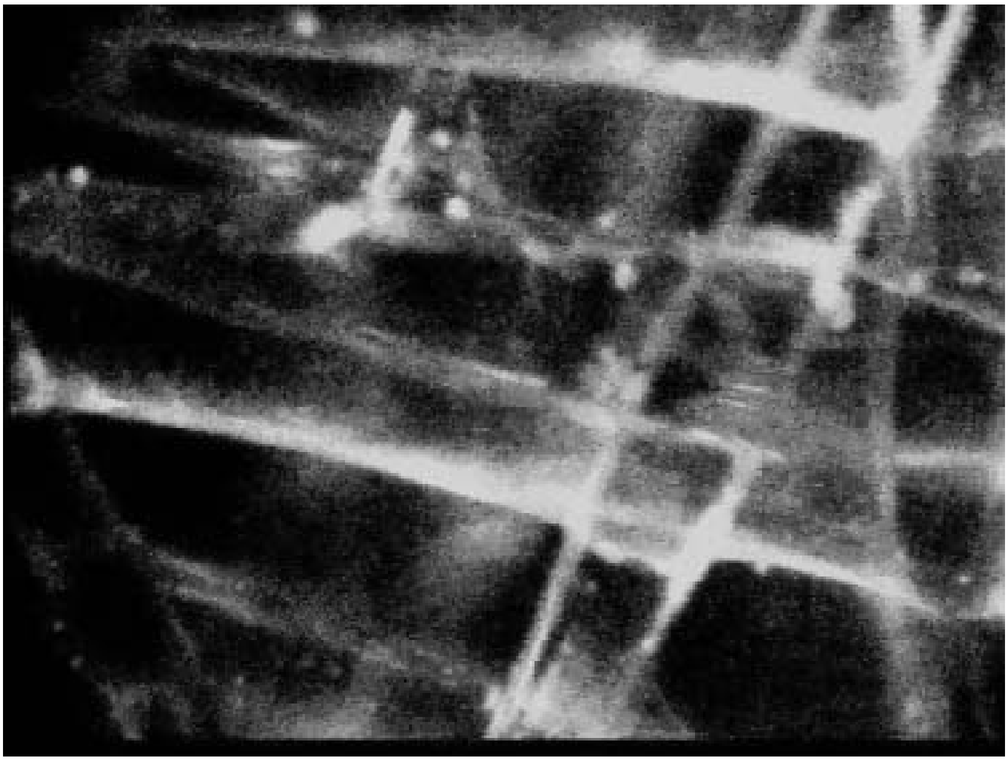

Fig 6

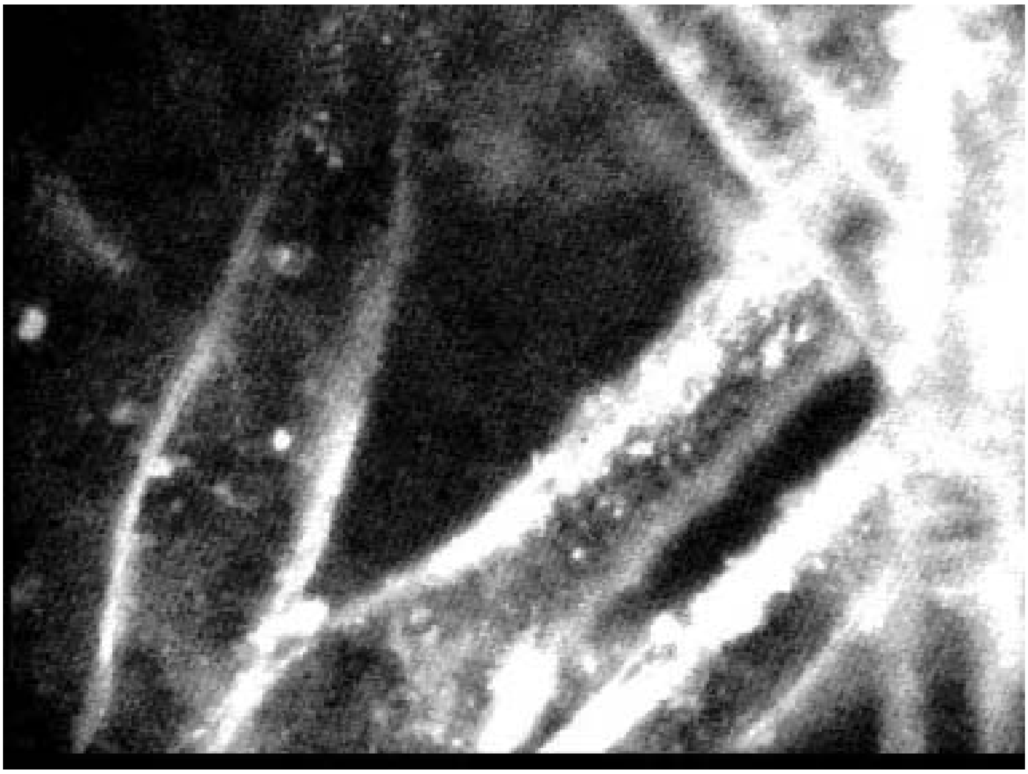

Fig 7

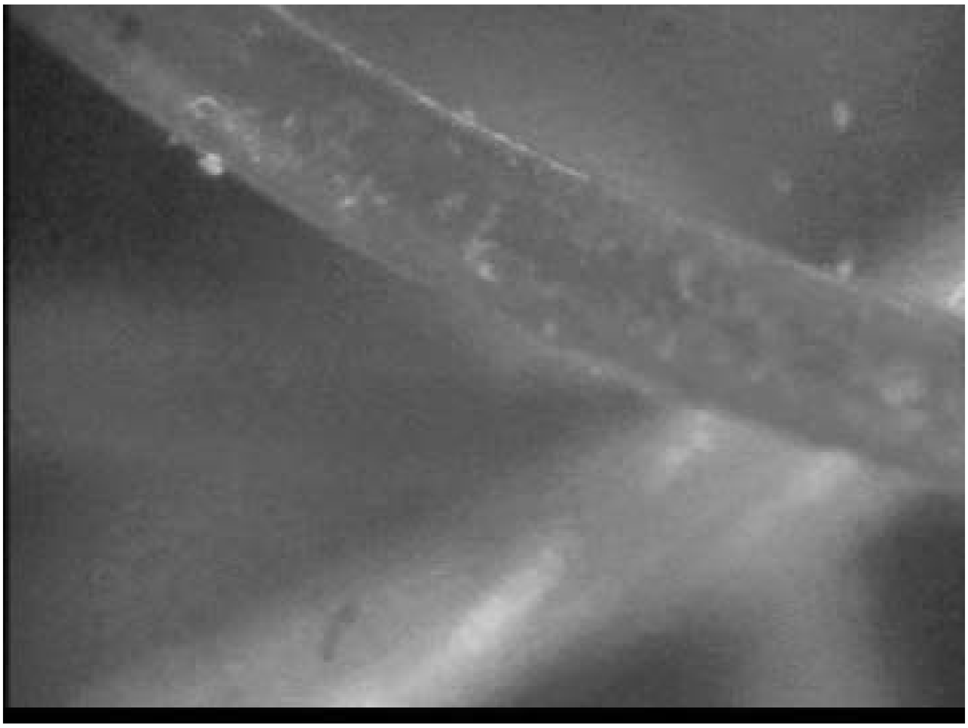

Fig 8

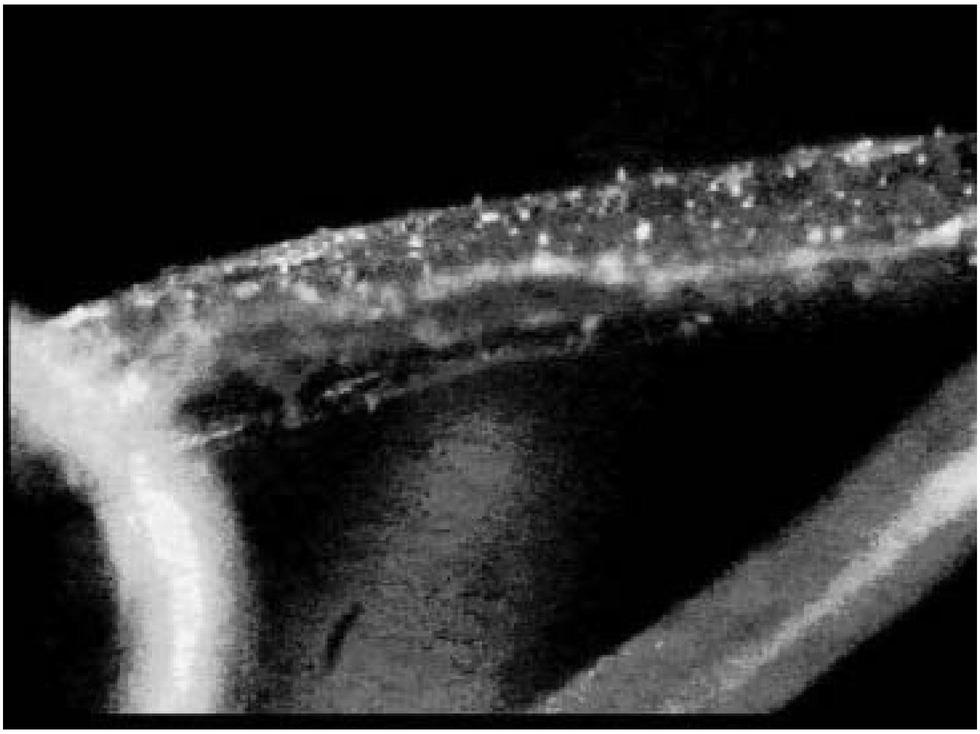

Fig. 9