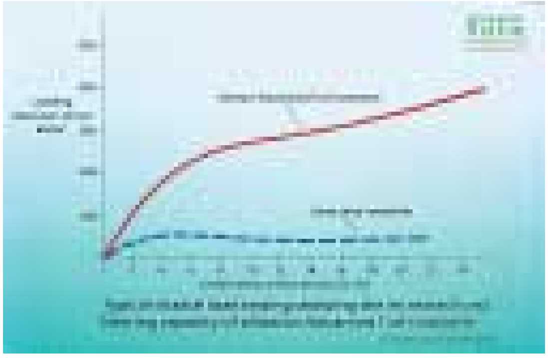
California Bearing Ratio testing showed that CBR values improved steadily as mesh content increased. A series of plane strain model footing tests were conducted to ensure that the strength improvements observed were not limited to the above test methods.



Axial Strain a (%)

Fig. 10. Results of triaxial testing of Leighton Buzzard sand increased strength due to inclusion of mesh elements.

These tests indicated that with a layer of mesh element stabilised soil present, the bearing pressure increased for any given settlement and that deep treatment of soils in not necessary. Furthermore, the mesh inclusions increased the ductility of the soil, a factor previously noted in the triaxial data.

Another significant factor noted was that when unloading the footing tests, almost 20% of the imposed settlement was recovered, which was four times that of the soil alone. This improved recovery of the system is important, particularly where repeated loading occurs. (fig. 11)

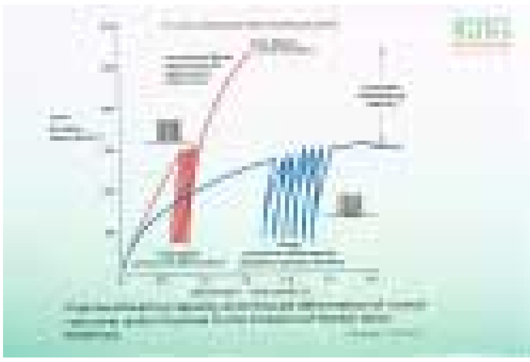


Fig.11. Tri- axial testing with repeated loading (6 cycles) Improved bearing capacity and reduced deformation of a sand rootzone under load. (University of Strathclyde)

A Heavyweight Test

To assess the system's load bearing characteristics,Warwickshire Fire and Rescue Service was invited to operate a 16-ton rescue platform and a 10-ton fire tender on an area previously laid with Netlon Advanced Turf.The rescue platform was positioned and all four jacks were extended to raise the rear axle off the ground. The hydraulic arm was raised and then rotated to place the maximum pressure on the jacks.

Approximately 2,000 litres of water were pumped from the tender over a five minute period around the base of the front jacks and rear off side jack. The saturated area was then trafficked by both vehicles.

After examining the areas, it was found that the maximum wheel deformation was 7mm, with an average of 4mm in the saturated area. The jacks had made virtually no impression. The average deformation was just 5mm.

The Divisional Commander in charge concluded that the demonstration had successfully confirmed Netlon Advanced Turf's stability under heavy loading even when the surface had become saturated.

"Netlon Advanced Turf has great potential for greener, friendlier fire access to buildings. It could save our lives."
Divisional Commander Warwickshire Fire Service

"No arena event has been cancelled winter or summer, since Netlon Advanced Turf was installed. Despite heavy rain, all events on the Grand Ring still go ahead as scheduled."
Gary Attwood, Head Groundsman, Royal Agricultural Showground

"Since the installation of the ATS in the Grand Ring, we have had sufficient confidence in the product and its performance to never say No. Its resilience and speed of recovery coupled with the correct care and attention has provided us with an asset to be proud of."
Mike Thompson, Head of Facilities Management, The Grand Ring, Stoneleigh.
November 2000

References Mercer, F B Andrawes, K Z McGowan, A and Hytiris, N (1984) "A New Method of Soil Stabilisation". Proc Conference on Polymer Grid Reinforcement. Thomas Telford, London, p224-249. McGowan, A (1990) "Static and Dynamic Interlock". Report to Netlon Ltd.AASHTO (1986) Guide for Design of Pavement Structure. Published by the American Association of State Highway & Transportation Officials.Beard, J B and Sifers, S I (1993) "Stabilisation and Enhancement of Sand-Modified Root Zones for High Traffic Sport Turfs with Mesh Elements". Texas Agriculture Experiment Station, Texas A & M University Research Report B-1710. Hytiris, N (1986) "A New Soil Stabilisation Technique". A Thesis submitted for the degree of Doctor of Philosophy in the Department of Civil Engineering, University of Strathclyde, Glasgow.

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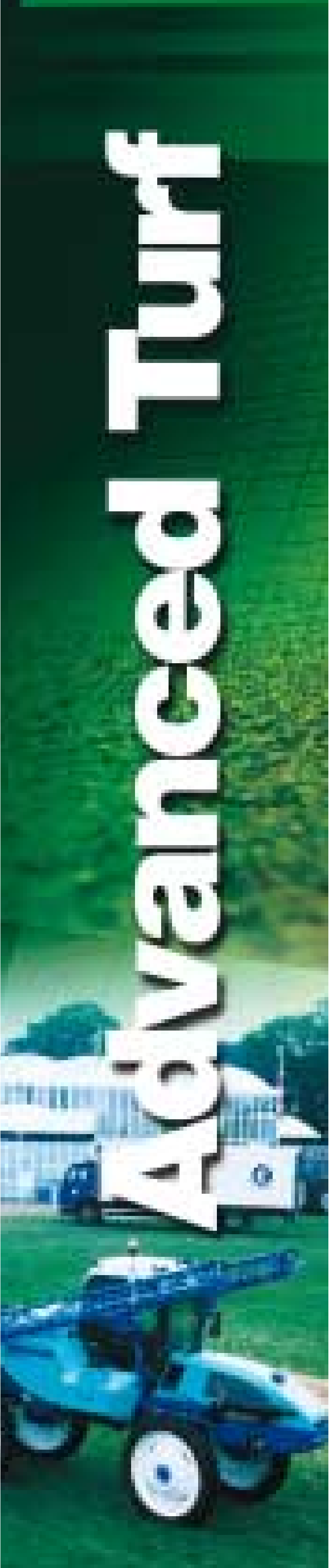
NETLON®
TURF SYSTEMS



Netlon Advanced Turf

Technical Research Data

Netlon Advanced Turf is a patented rootzone system which brings unrivalled resilience, durability and health to natural grass surfaces.

Netlon Advanced Turf is a new solution to the problem of trafficked or load bearing grass areas. It has been developed in the UK following extensive research carried out by the Civil Engineering Department at Strathclyde University and the Turfgrass Science Department at Texas A&M University, USA, in conjunction with Netlon Ltd.

The result is an engineered natural grass surface with high load bearing characteristics, improved damage resistance and a unique cultivation property which overcomes the problem of soil compaction.

The system known as Advanced Turf consists of conventional grass grown on a selected rootzone material which is reinforced with randomly oriented polypropylene mesh elements. (fig.1)

The small mesh elements, each 50mm x 100mm in size, are blended uniformly with a selected high sand content rootzone medium. The mesh elements reinforce the rootzone medium, increasing strength, maintaining permeability and conserving suitability for cultivation.

When the grass is established the roots penetrate and entwine with the mesh elements, further stabilising the system and providing positive anchorage for the grass plants. (fig. 2)

The principle involved is that the polymeric mesh elements interlock with groups of soil particles, thereby providing tensile resistance to the soil matrix. The random arrangement of the mesh elements produces a highly isotropic reinforced soil mass. Most importantly, this increase in strength is achieved without any reduction in permeability or ductility. (Hytiris, 1986).

This unique combination of soil reinforcement and improved agronomical properties offers specifiers an environmentally attractive solution to the problems of trafficked grass areas where grass has been deemed unsuitable or the existing grass surfaces have failed due to misuse.

Fig. 1. Netlon mesh elements

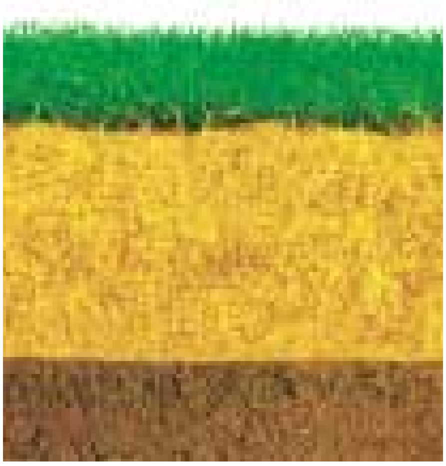


Fig. 2. The secret of Nelton Advanced Turf is the inclusion of Nelton mesh elements in a selected rootzone medium.

The Simple Facts

Netlon Advanced rootzone technology provides:

- a natural turf surface with unrivalled load bearing characteristics and resistance to rutting
- rapid surface drainage - the turf is never saturated
- built-in resistance to soil compaction
- a safe, attractive surface which is environmentally friendly
- accelerated recovery of damaged turf
- an economical alternative to hard paving

The mesh elements which give Netlon Advanced Turf its unique toughness have been specially developed by Netlon Limited, the manufacturers of Tensar geogirds used extensively in civil engineering. They are made from polypropylene, selected for its durability and flexural stiffness - the vital characteristics which give Netlon Advanced Turf its unique, springy strength.

Polypropylene is non-toxic, insoluble, non absorbent and inert to any of the chemicals likely to be found in a turf rootzone.

The surface is stable, but not hard, and the mesh elements present no danger to people or animals.

Turfgrass research

To establish the agronomical properties of ATS rootzone, research was undertaken at Texas Agricultural Experimental Station. Based on eight major field plot investigations Beard, (1993) established a number of significant effects due to the inclusion of mesh elements, which are relevant to areas subjected to vehicle or pedestrian trafficking:

1. Improved damage resistance and recovery rate (50% reduction in recovery time)

2. Improved drainage performance (increased infiltration rate and percolation rate) (fig. 3)

3. Increased soil moisture (up to 50% increase in available soil moisture) (fig. 4)

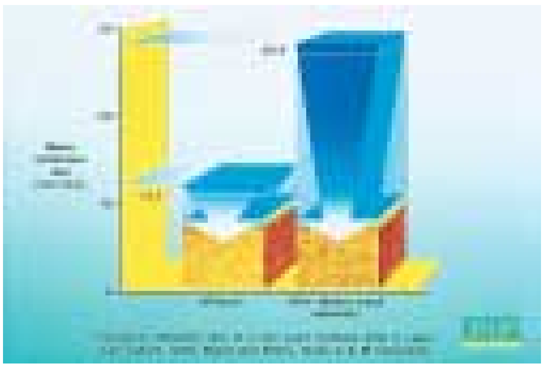


Fig. 3. Increased infiltration rate of a fine sand rootzone after 3 years' turf culture. (after Beard and Sifers, Texas A & M University)

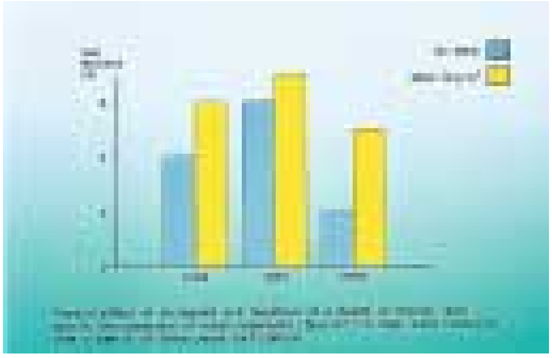


Fig. 4. The inclusion of Netlon's mesh elements increases the moisture retention of a sand rootzone (after Beard and Sifers).

Fig. 5. Self Cultivation

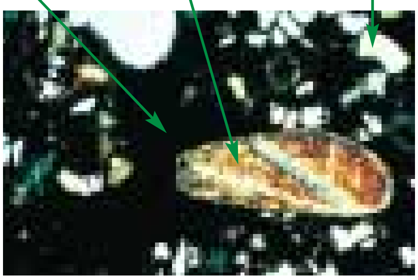
When the turf rootzone is compressed by people or vehicles, the mesh elements act as thousands of springs.

The flexing action creates and maintains voids along the length of the mesh filaments.

This "self-cultivation" action ensures that Netlon Advanced Turf rootzones are healthier than those associated with ordinary turf with a built in resistance to soil compaction.

Microscopic examination shows interconnected voids created by the Netlon mesh elements, which maintain an adequate supply of oxygen deep into the rootzone and vent waste gases.

Void **Mesh filament (section)** **Sand rootzone particles**



Water can pass more rapidly throughout the rootzone, whilst at the same time the confinement of soil particles within the mesh apertures enhances capillary water retention.

Source: Department of Soil and Crop Sciences, Texas A & M University (Dr.J. B. Beard and Mr. M. De Pew)

Self-cultivation

After four years of grass cultivation on the research plots, substantial differences in water infiltration rate, root depth and the general health of the grass indicated that the plots containing mesh elements were not exhibiting soil compaction problems, whereas the control plots were severely affected. (Beard, 1993)

Study of thinly sectioned undisturbed samples of rootzone under the microscope revealed the presence of air voids around the mesh element ribs in almost every case.

It is hypothesised that these interconnected voids are created as the mesh elements flex in the soil under the action of traffic (fig 5). The presence of the voids explains the improved drainage and the better health of the grass plants.

This "self cultivation" property is believed to be unique to the use of mesh elements. The stiffness characteristics and dimensional stability of the mesh are critical to its performance in this respect.

The development of a natural grass surface based on an engineered rootzone provides an opportunity to design grass surfaces for vehicular traffic or frequent pedestrian use. (fig. 6). Areas of application include:

- roadside verges
- overspill car parking
- fire access roads and other occasional access roads
- airport verges
- pedestrian/ landscaping areas
- multi-use events/ sports areas

Soil Mesh Element Interaction Mechanism

When a soil mass is subjected to stress, tensile strains may develop within that soil mass. When mesh element inclusions are present in the zones of tensile strains, they are strained and develop tensile resistance. This leads to an increase in the overall load carrying capacity of the soil mass. (Mercer et al, 1984). (fig. 7).

The mechanism by which this stress takes place between soil and mesh elements depends upon the soil particles penetrating through and interlocking with the mesh structure. This mechanism is much more efficient than surface friction. During compaction the mesh structure deforms locally as the soil particles are packed into the mesh apertures. This deformation sets up tensile stresses in the mesh ribs. After compaction, the mesh attempts to return to it's original dimensions but its prevented from doing so by the soil particles packed within the mesh apertures referred to by McGowan (1990) as "dynamic interlock". The resilient properties of the mesh elements ensure that these tensile stresses are sustained in the long term. The additional confining stress imposed on the soil provides a further strengthening effect.

Interlock occurs at two levels, firstly with the soil particles interlocking into the mesh apertures as described above to form an aggregation of particles, then adjacent aggregations interlocking to form a coherent stable matrix. (fig 8).

Engineering Research

In order to understand the operational mechanisms and levels of soil improvement, investigations have been carried out including shear box, triaxial, CBR and footing tests.

A significant feature of the triaxial testing was the appearance of the stabilised samples compared to those of the soil alone. Triaxial testing of Leighton Buzzard sand (fig. 9) compared sand containing mesh elements and sand only samples. Bulging of the sand only sample is very clear. By comparison, the sample stabilised with mesh elements has an entirely different appearance at large strains. The 'lumpy' aggregations created by the sand/ mesh interlock mechanisms are clearly visible.

Inclusion of the mesh elements into the soil sample produced significant increases in strength. The degree of increase being influenced in the soil by the nature of the soil itself . (fig. 10)

Many sizes and varying stiffnesses of mesh were investigated in order to arrive at the optimum characteristics and dimensions. (Hytiris, 1986).

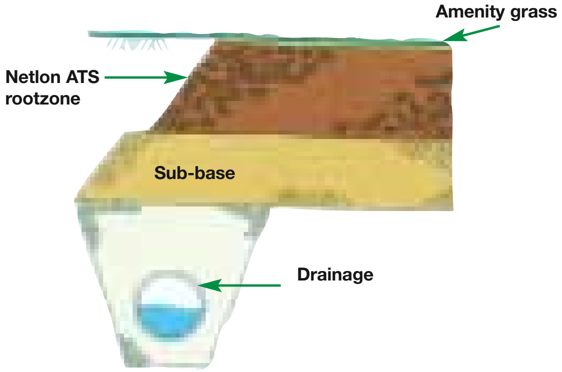


Fig. 6. A Typical Section

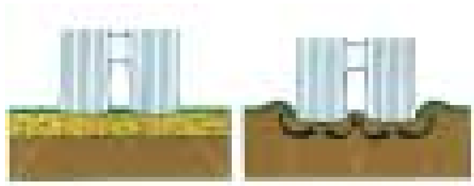


Fig. 7. Nelton Advanced Turf distributes loads more efficiently to resist rutting.

Fig. 8. Soil particles interlock within mesh apertures to form an aggregation. Adjacent soil/ mesh aggregations then inter lock to form a coherant stable matrix.

Fig. 9. Triaxial testing of sand samples. The interlocking aggregations are clearly visible as bulges in the sand sample on the left containing mesh element inclusions. The sand only sample on the right shows no evidence of aggregation at high strains.