Full Scale Laboratory Tests on Geosynthetics Reinforced Roads on Soft Soil

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ABSTRACT: The bearing capacity of geosynthetics reinforced unpaved roads over soft soil has been investigated by the mean of extensive full scale laboratory testing consisting in measuring the settlements distribution in a reinforced section when stressed cyclically with a load simulating a truck wheel. The ruts depths were measured as a function of the numbers of cycles, of the aggregate thickness, of the subgrade shear strength and of the reinforcement type and location. The ability of the reinforcement to distribute the load over a wider subgrade surface area was monitored and analysed. The results of the reinforced sections have been compared with the corresponding unreinforced sections showing the advantages of the use of the geosynthetics in increasing the road service life and savings in aggregate thickness. Due to the large dimensions of the reinforced sections and the number of tests performed this paper is a valuable tool for empirical design and verification of the theoretical assumptions.

1 INTRODUCTION

It has been well established that the inclusion of a geosynthetic reinforcement layer within the base can substantially improve the overall strength and life of a road section. Laboratory models of the reinforcing behaviour of the geosynthetics have been made by several authors, however most of them were performed in small boxes thus they can not be considered as full scale test. The aim of this work was to perform tests, simulating as close as possible the reality.

2 TEST ARRANGEMENT

To simulate the cross section of a road a very large metal box has been filled in the lower half with loose sandy soil. Above it, a reinforcement layer was placed and then the remaining part of the box was filled with well graded and compacted gravel. The dimensions of this box were 1.8 m x 0.9 m x 0.9 m and, vertically in the middle, there was a removable metal plate to divide it in two halves. Usually a geosynthetic layer was placed only in half of the area of the box, while the other half was left unreinforced to be used for comparison purposes. This technique allows a greater precision in determining absolute and relative reinforcement effects since all the properties of the soils were exactly the same because the two parts of the box were filled at the same time using the same soil handling procedures.

When testing the geogrids, the reinforcement layer was placed flat above 500 mm of loose soil and then folded at 90 deg at the box side and connected to it by a metal frame composed of bars and bolts as shown in Fig. 1.

The bolts were tightened only after the gravel has been compacted onto the geogrid. The reinforcement was connected to the metal box to model the anchoring behaviour of a geogrid in a typical road base reinforcement and thus preventing failure due to the still relative small dimensions of the box.

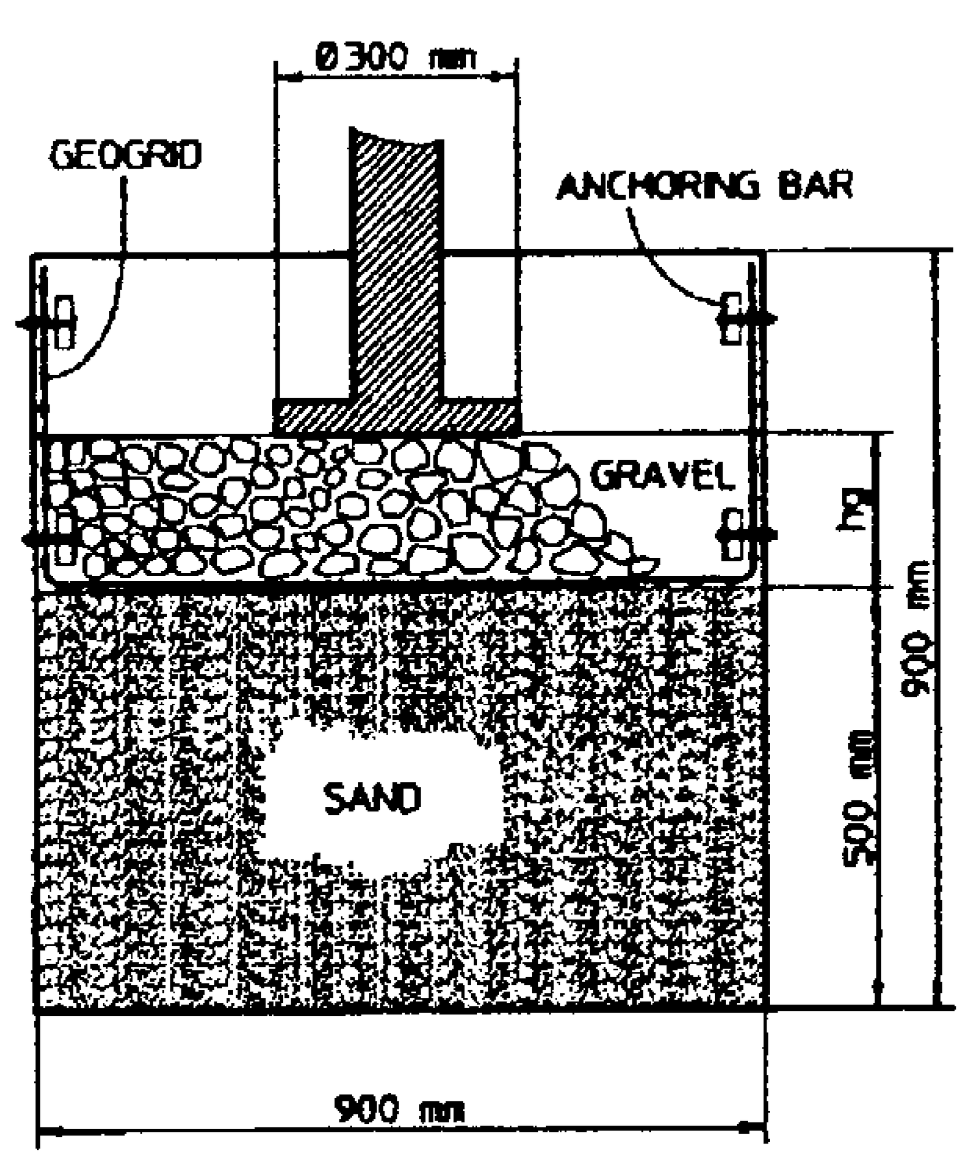

Figure 1 - Cross section of the testing box.

Up to 20,000 cycles of loading from 0 to 40 kN, equivalent to a maximum pressure of 570 kPa, have been applied at a frequency of 1 Hz through a circular loading plate having 300 mm diameter. The vertical settlements (ruts) have been recorded as function of the number of cycles together with the deformation in the road section. The applied load, contact pressure and the loading plate dimension were selected as typical conditions for truck tyre pressure and contact area. In fact, typically, 40 kN is the semi-axle load, 570 kPa is the inflating tyre pressure and 300 mm diameter can be assumed as the deformed tyre contact area.

The sinusoidal cycle loading were applied through a servohydraulic actuator controlled by an Instron 8580 digital multi-axis closed-loop controller and the rut depths were measured by a transducer inside the piston. The distribution of the deformation inside the subgrade was recorded at the end of the tests by measuring the displacements of several layers of a network composed of flat nylon fibres.

3 TYPES OF SOIL

Crushed sandy gravel with trace of silt aggregate was selected for the road aggregate. The gravel gradation is shown in Table 1.

Table 1 - Sandy gravel, U = 75.

SIEVE SIZE, mm	PERCENT PASSING, %
30	100
20	96
7.5	60
2	28
0.1	10
0.06	8.5

The soft and compressible subgrade was simulated by the mean of 500 mm thickness of loose sand having a low uniformity coefficient (U≈2), dry density γ_d=16.35 kN/m^3 and an optimum moisture content w = 17%. The sand grain distribution is shown in Table 2.

Table 2 - Subgrade sand, U = 2.3.

SIEVE SIZE, mm	PERCENT PASSING, %
4.76	3.5
2	96.5
0.35	60
0.15	10
0.06	1.5

A constant moisture content of 11% was selected and an empirical relationship between the CBR and the soil dry density was determined using the test procedure outlined in ASTM D 1883-87 standard, as shown in Fig. 2.

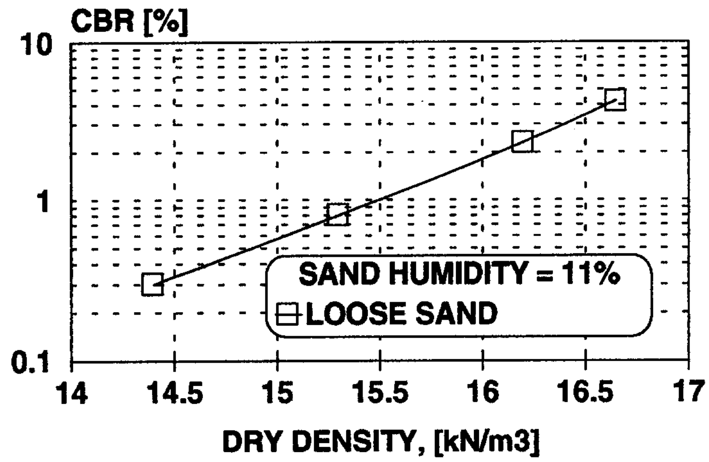

Figure 2 - CBR versus sand density curve.

Several subgrade shear strengths have been used during the tests, with CBR ranging between 1 and 3%. Different aggregate thicknesses, ranging from 130 to 420 mm, have been tested with several types of subgrade shear strengths and geosynthetics.

4 TYPES OF GEOSYNTHETICS

The geosynthetics tested have been: 1) biaxially oriented polypropylene geogrids, manufactured both by continuos extrusion and orientation processing, and by punching and drawing a sheet; 2) honeycomb polyethylene geocells manufactured both by continuos extrusion and by welding of polymeric strips. The characteristics of the geosynthetics tested are highlighted in Table 3.

Table 3 - Geosynthetic type.

GEOGRID TYPE	NOMINAL TENSILE STRENGTH (MD x TD), kN/m
A-TENAX LBO301 SAMP	19.5 x 31.6
B-TENSAR SS2	17.5 x 31.5
GEOCELL TYPE	CELL DIMENSIONS, mm
C-TENAX TENWEB 4/100	Φ = 100, Depth = 100
D-PRESTO GEOWEB 8"	Φ = 100, Depth = 200

The performances of the geogrid layers have been investigated at the subgrade-aggregate interface and in the centre of the aggregate layer, showing better results at the base-subgrade interface.

5 TEST RESULTS

The tests results are plotted in Fig. 3, 4 and 5.

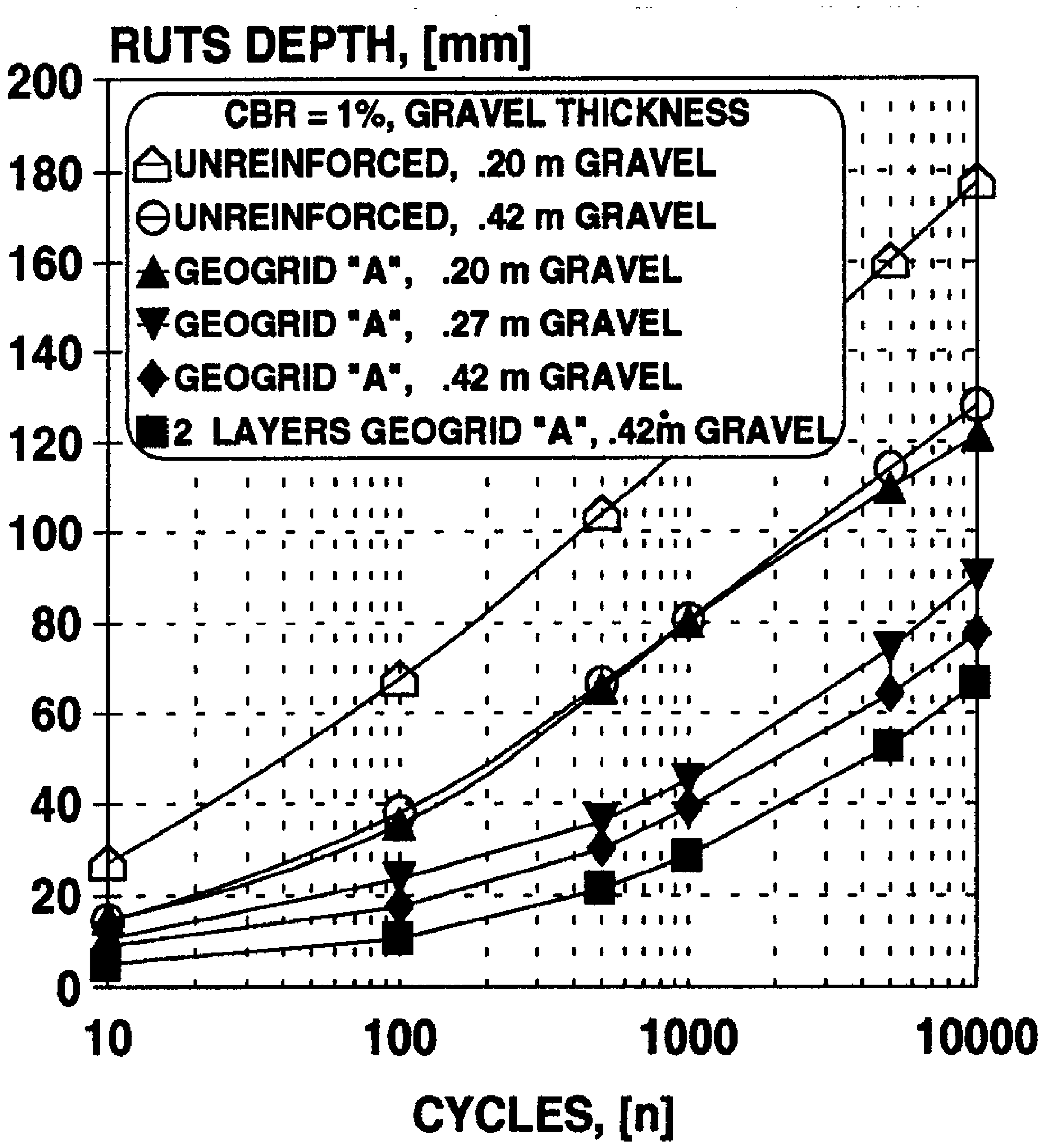

Figure 3 - Comparison between reinforced and unreinforced sections and between reinforced sections at several gravel thicknesses.

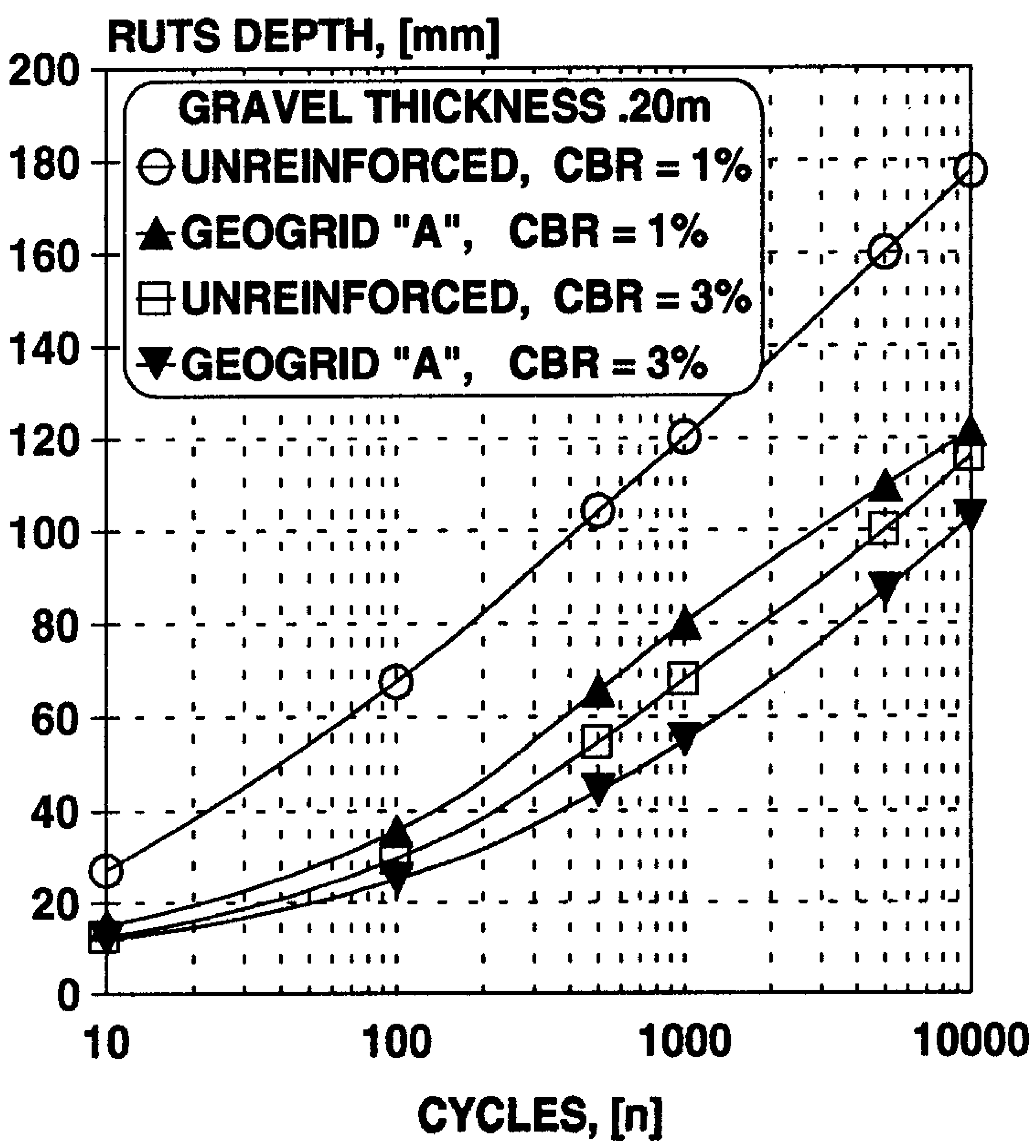

Figure 4 - Comparison between reinforced and unreinforced sections at CBR equals to 1 and 3%.

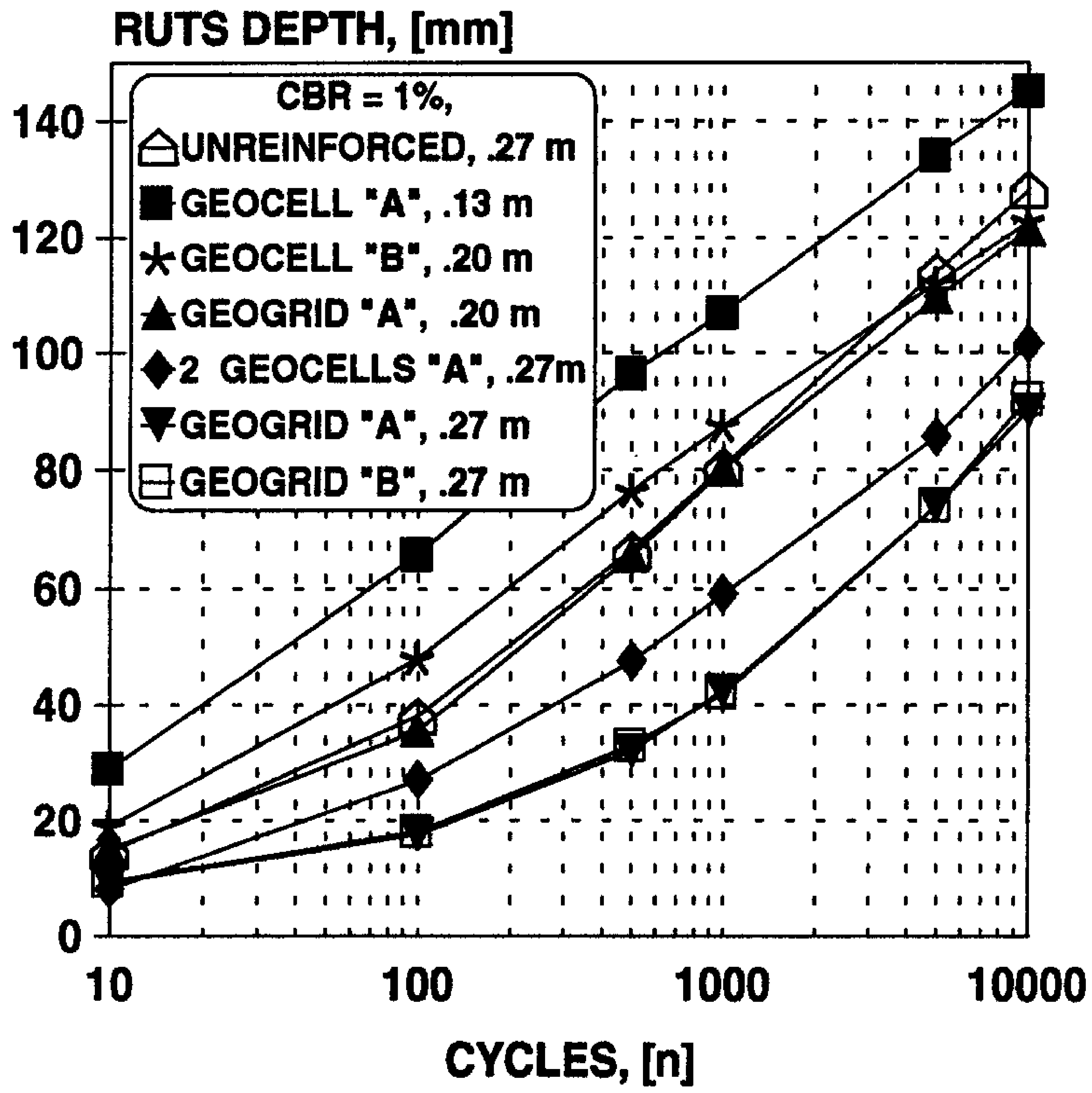

Figure 5 - Comparison between geosynthetic types.

It shall be noted that, even if the tests provide excellent qualitative results, the test frame is still too small to obtain precise quantitative information on geocells.

Ruts geometry for reinforced and unreinforced sections are analysed to determine differences in depth and shape of the reinforced deformed section, thus allowing the interpretation of the functions played by the geosynthetic, such as reinforcement, separation and membrane effect. The typical ruts geometry is shown in Fig. 6.

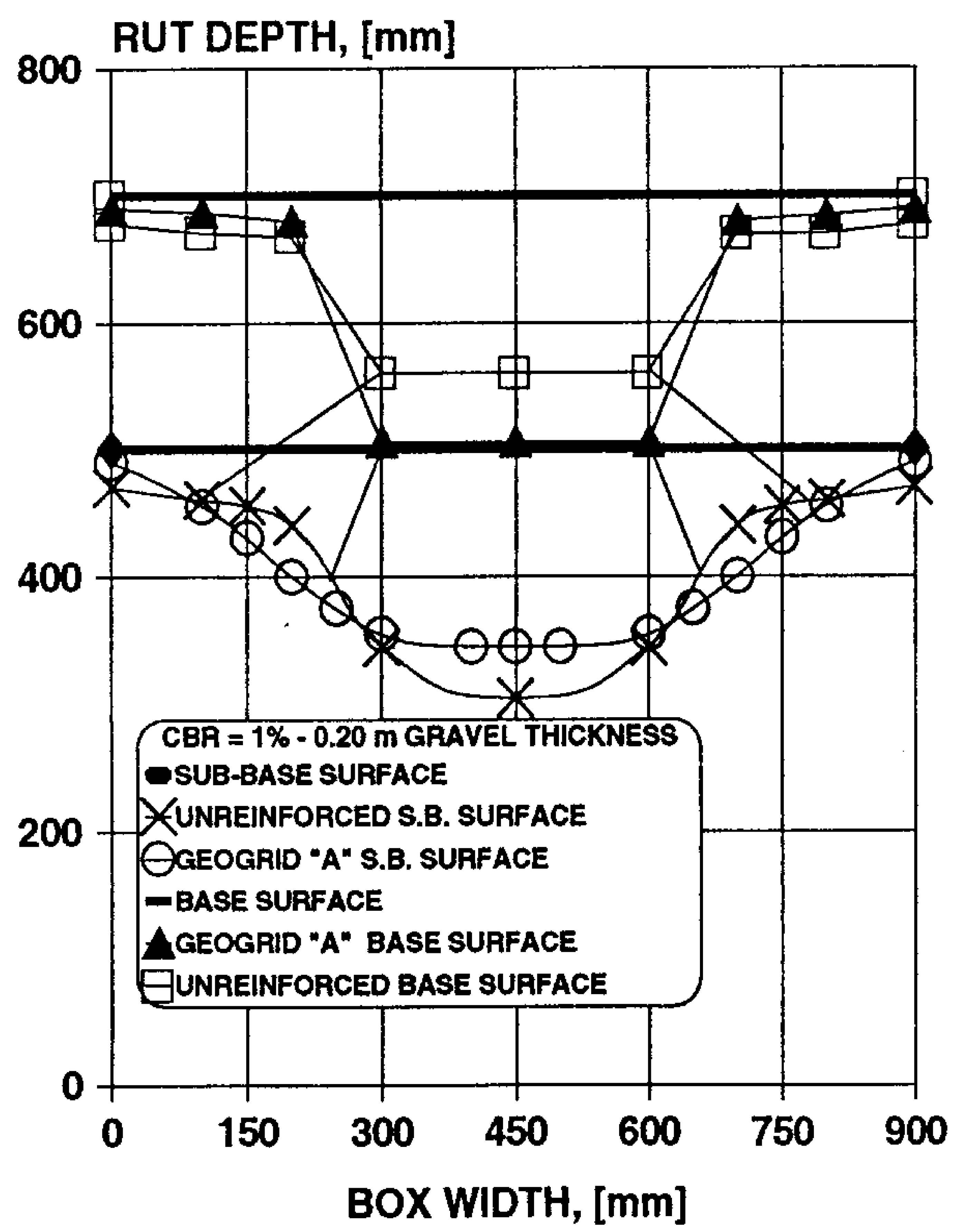

Figure 6 - Typical ruts geometry.

Suggested design charts, function of the geosynthetic type, subbase soil shear strength, number of cycles, aggregate thickness and allowed settlements are presented in Fig. 7 and 8 to allow engineers a proper design of unpaved roads.

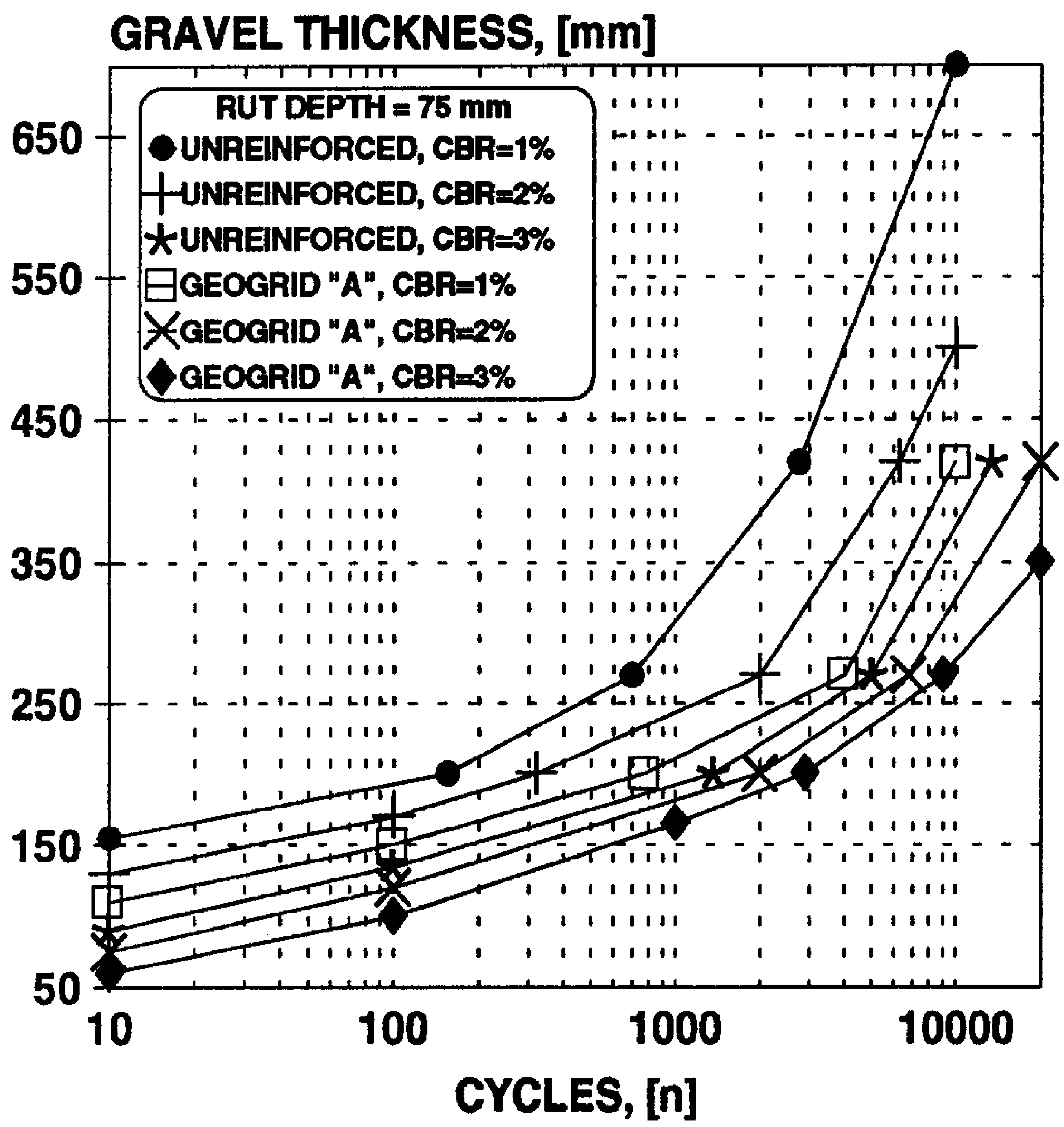

Figure 7 - Constant rut depth curves for geogrid "A".

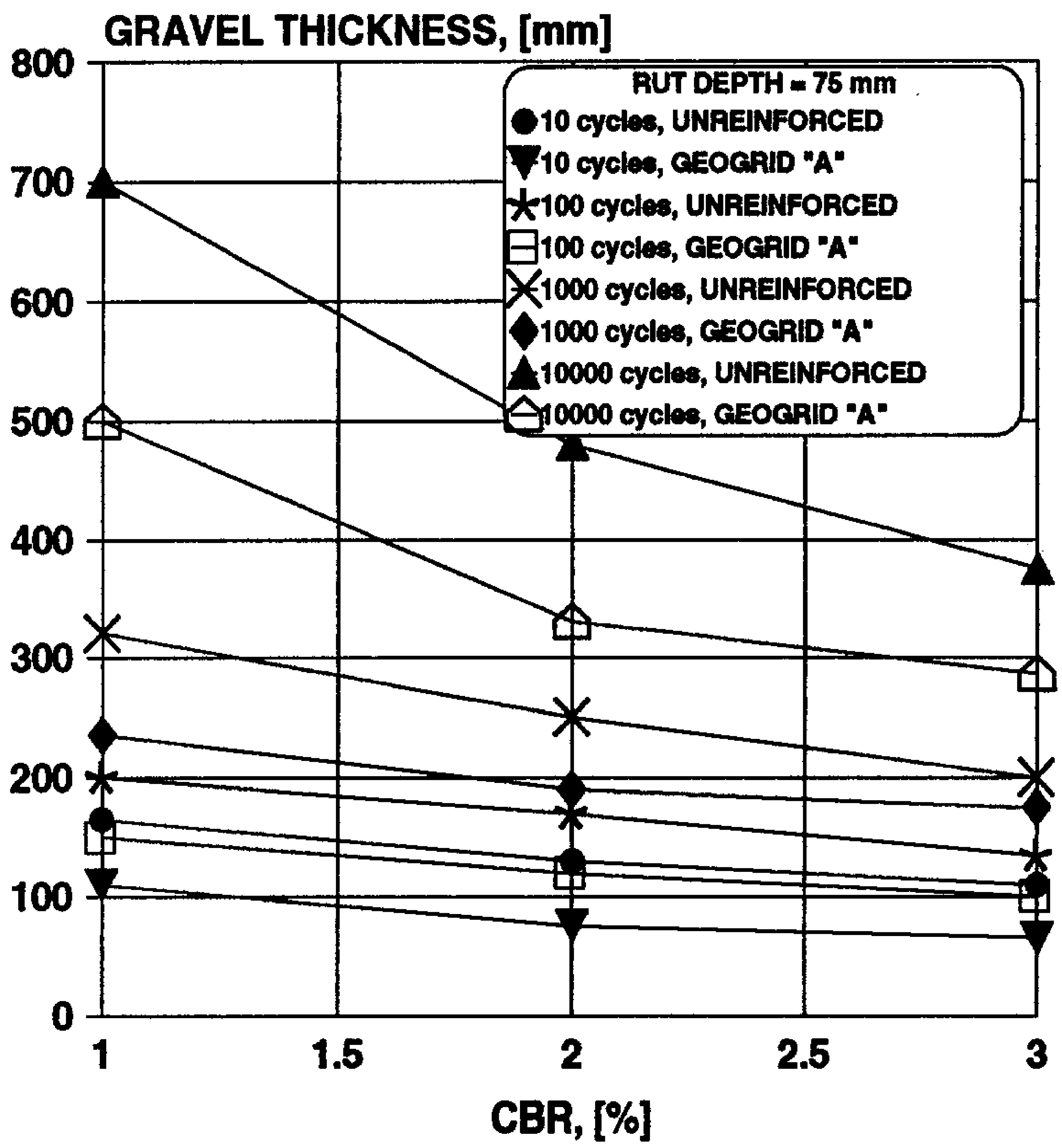

Figure 8 - Isocycle curves for geogrid "A".

Figure 9 shows the relationship, based upon actual performances, between aggregate thickness of unreinforced and geogrid reinforced road sections.

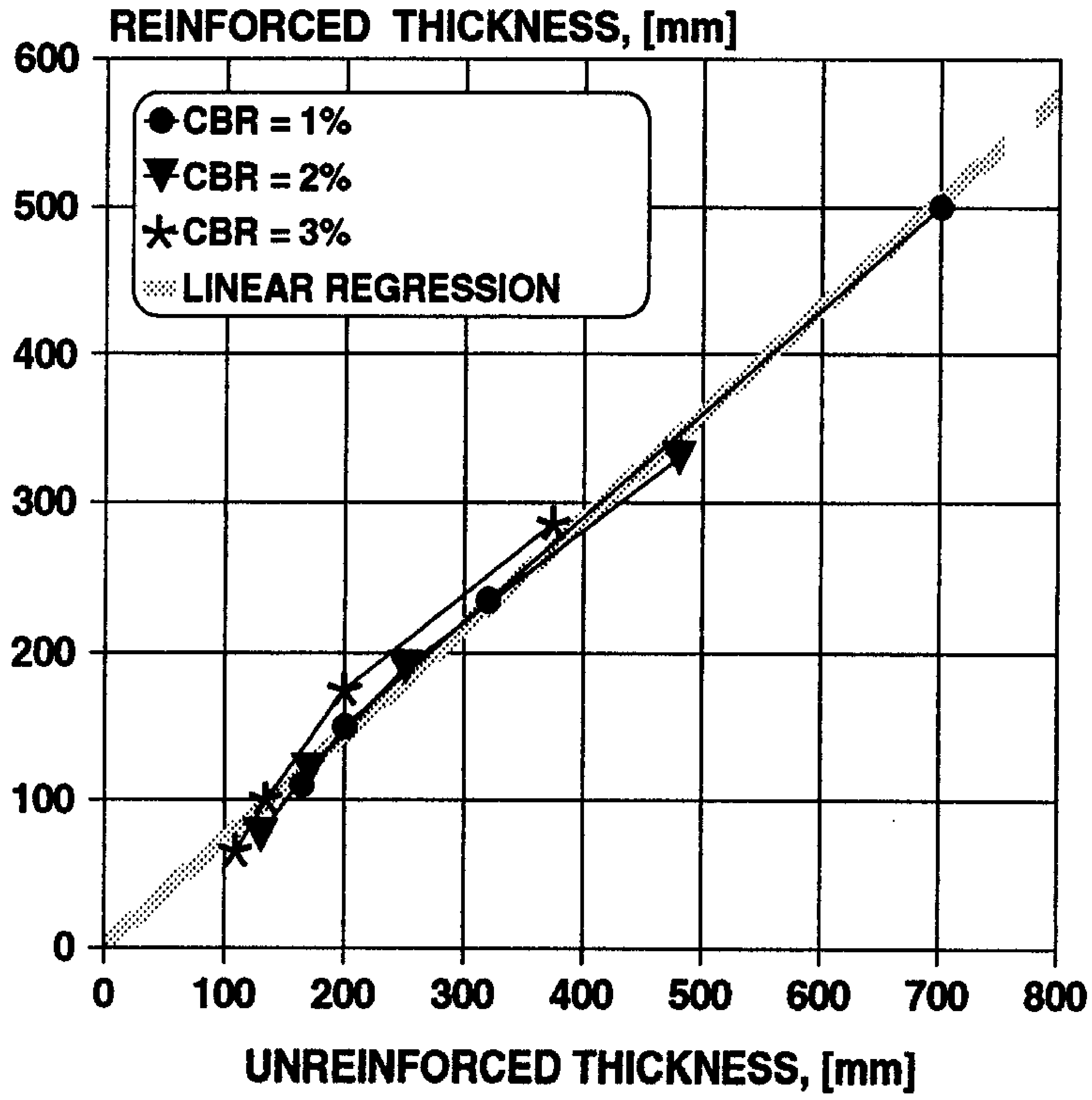

Figure 9 - Reinforced Vs. unreinforced thicknesses for geogrid "A".

6 CONCLUSIONS

A geogrid layer provides a typical base aggregate saving of 30% for the examined aggregate. Further savings are expected using higher quality aggregates. A double layer of geogrids, one at the base and one at the mid gravel thickness, strongly reduces the settlements compared to a single layer. The reduction of rutting percentually increases with reducing the subgrade CBR. The effect of 200 mm deep geocells is almost equivalent to that of a geogrid with the same thickness of gravel; for higher thicknesses the geogrids result more effective. The stress distribution angle in the reinforced structure is almost double the one for the equivalent unreinforced structure. Therefore a geogrid layer prevents the puncturing of the subgrade and distributes loads over a larger area, thus lowering the applied stresses. Based on the test results, design charts have been presented. These charts are in good agreement with similar ones from previous authors (Giroud et al., 1985).

7 REFERENCES

Giroud, J.P., Ah-line, C. and Bonaparte R. (1985) *Design of unpaved roads and trafficked areas with geogrids,* Thomas Telford Limited, London.