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Reinforcement effect of geotextiles on pavement with weak subgrade

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ABSTRACT: With the aim of examining the reinforcement effect and the mechanism of geotextiles used in pavements on weak subgrade, as well as study on their application range and design method for such pavements, investigations were conducted through laboratory repeated loading tests. In the tests, specimens representing parts of a pavement from the subbase course down were used and the cumulative and elastic deformation under loading condition corresponding to L, A, and B traffic volume was measured. The geogrid and non-woven fabric were place beneath the subbase course. It was observed in these tests that the both geotextiles would reduce the cumulative deformation by reinforcing the subbase course through either restraint or separation effect and improve the CBR of the weak subgrade (= 1 to 2) to a level that could be regarded as being equivalent to 3. From the tests design curves for the reinforced pavements by geotextiles were obtained.

1. INTRODUCTION

While there have not as yet been many cases of application of geotextiles to road pavements in Japan, there has been rising expectation in recent years for the application of geotextiles to pavements in various ways. One of these is their application to reinforcement of weak subgrade soil, to prolong the life of the pavement and reduce the required thickness of the subgrade by installing geotextiles on top of, for example, weak the subgrade (Makiuchi et al., 1987). Since the report by Makiuchi et al. was based on studies published abroad (Kennepohl et al., 1985), there have as yet been few studies conducted on the matter in Japan and the reinforcement effect, design methods and application range of such geotextile reinforced pavements have not been yet established.

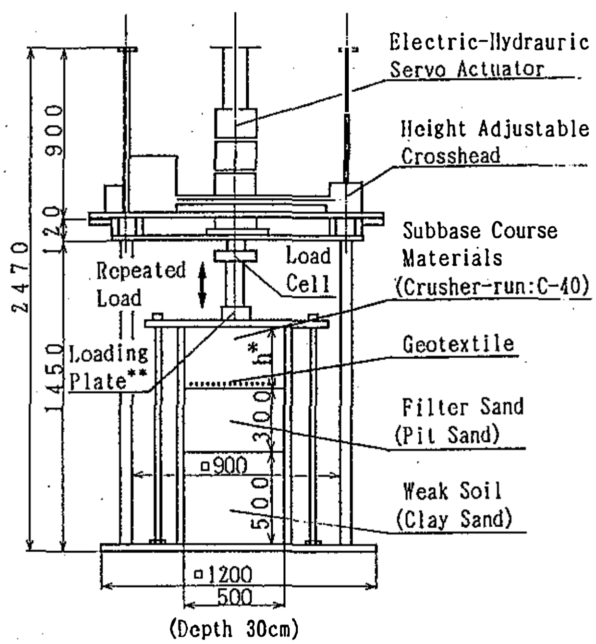
In the procedure used in Japan for the design of an asphalt pavement, thickness of each course is determined so that the equivalent thickness T_A (the pavement thickness required if the entire depth of the pavement were to be constructed of hot asphalt mixture used in the surface and binder course(Japan Road Association, 1989)) and the total thickness H of the pavement should meet a target value set according to the traffic-volume classification. On a weak subgrade where the design CBR would be below 2, the weak subgrade should be improved so as to increase the design CBR to 3 or above. On a subgrade with a CBR of 2, a filter layer 15 to 30 cm in thickness is needed.

In this study, taking into account the present design method in Japan, laboratory repeated loading tests were conducted on two and three-layered test specimens representing parts of the pavements from the subbase course down, assuming the two types of geotextiles (geogrid and non-woven fabric) were embedded above the filter layer in pavements with various CBR and with L, A and B traffic load (the number of 5 ton-equivalent wheel load applications: 30,000, 150,000 and 1 million, respectively). Investigations were made on (1) the reinforcement effect and reinforcement mechanism of the geotextiles, (2) the design method for reinforced pavements and (3) application range of geotextiles in terms of subgrade conditions and traffic-volume classifications.

The cumulative deformation on the surface of the subbase course under repeated load was used as the criteria and evaluation for the reinforcement effect were made according to whether the geotextiles would improve the CBR of the weak subgrade soil (CBR ≤ 2) in real terms to 3 or not.

2. TEST METHOD

The test specimens used, 50 cm wide and 50 cm deep, consisted of either three layers of granular base course materials (C-40), filter sand (pit sand) and weak subgrade soil (dried powdery clay sand mixed with water to give the required CBR), or two layers without the filter sand layer (when the specimen, of which subgrade soil has a CBR of 3, was not reinforced with geotextiles) (Figure 1). The geotextiles used were of the two types, namely polypropylene geogrid (30 x 40 mm mesh, tensile strength: 1,500 kgf/m [longitudinal], 2,800 kgf/m [transverse]) and non-woven fabric (thermal adhesion type, tensile strength: 86 kgf/m), and were placed on top of the filter sand layer. In preparing the test specimens, the layers were compacted in the reverse order against the layer order in the actual tests to ensure that the subbase course materials would be compacted adequately. After being turned up side down, the specimens, including the compacted layers, were used in the tests. The test specimen types are listed in Tables 1 and 2.



*) Variable (10~35cm)
**) Width 8cm, Depth 30cm
Unit : mm

Figure 1. Overview of repeated loading test

Table 1. Type of specimens with geotextiles

CBR Value of Weak Soil	0.5			1					2					
Thickness of Subbase Course (cm)	25	30	35	15	20	25	30	35	10	15	20	25	30	35
Use of Geogrid	○	○	○	●	◎	◎	◎	◎	●	●	◎	◎	◎	◎
Use of Non-Woven Fabric					△	◎	◎	◎		●	◎	◎	◎	◎
Without Geotextile														

Note ; ◎Done for L, A and B traffic roads
○Done for only A traffic roads
●Done for only L traffic roads
△Done for L and B traffic roads

Table 2. Type of specimens without geotextiles

CBR Value of Weak Soil	3				
Thickness of Subbase Course (cm)	15	20	25	30	35
Without Geotextile	●	◎	◎	◎	◎

Note ; ◎Done for L, A and B traffic roads
●Done for only L traffic roads

The repeated loading tests (sinusoidal waves, frequency: 5 Hz) were carried out using the apparatus shown in Figure 1. The cumulative and elastic deformation on the surface of the base course materials were measured. The number of repeated load was made to correspond to the number of 5 ton equivalent wheel load applications under the present design method (i.e. 30,000, 150,000 and 1 million cycles, respectively for L, A and B-traffic roads). The loading stress was set at 2 kgf/cm^2 for L and A traffic and 1 kgf/cm^2 for B traffic, estimating the stress on the subbase course with the design CBR of 3 by the multi-layer elasticity theory according to the traffic volume classification.

3. DISCUSSION OF RESULTS

3.1 Reinforcement effect

Examples of the relation between the subbase course thickness and the ultimate cumulative deformation (for L and B traffic) on test specimens with geogrid and non-woven fabric are shown in Figures 2 and 3. The following observations may be made from these figures.

(1) Under the loading conditions corresponding to L traffic, with both types of geotextiles, values for the ultimate cumulative deformation on the subgrade soil with a CBR of 2 are lower, regardless of the base course thickness, than that in the case without geotextiles and with the same base course thickness (CBR of soil: 3). Although the deformation is actually larger on the subgrade soil with a CBR of 1, the deformation can be brought down to about the same level with slight increase of the subbase course thickness.

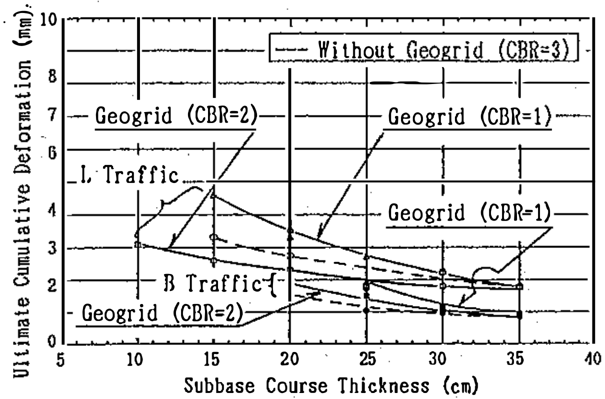


Figure 2. Relation between thickness of subbase and ultimate cumulative defoniation (geogrid)

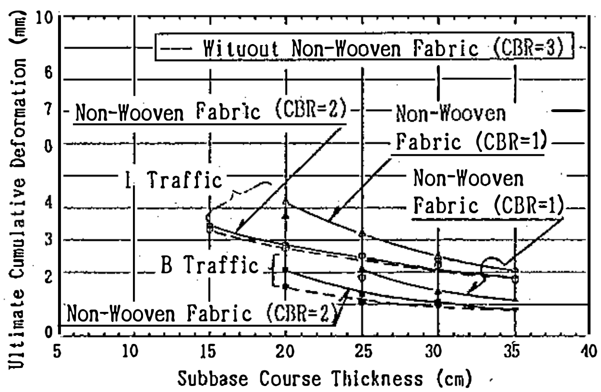


Figure 3. relation between thickness of subbase and ultimate cumulative deformation (non-woven)

(2) By the comparison in the same way, under the loading conditions corresponding to B traffic, the values for the ultimate cumulative deformation on the reinforced test specimens are greater, regardless of the CBR, than that on unreinforced test specimens (CBR=3) in all cases. But here also, the deformation can be brought down to about the same level by slight increase of the subbase course thickness.

Under the loading conditions corresponding to A traffic, results similar to those in (1) above were observed when the CBR was 1 and 2, while with a CBR of 0.5, it was not possible to expect improvement of strength equivalent to unreinforced soil with the CBR of 3, regardless of the traffic volume.

It was concluded from the above that when the CBR was between 1 and 2, both types of geotextiles had the effect of reinforcing the base course under all loading conditions (corresponding to L, A and B traffic) and could be used to reduce the ultimate cumulative deformation to a level similar to that obtained on the unreinforced subgrade soil with a CBR of 3 with a certain amount of reliance on an effect of increased base course thickness (load dispersion effect). It was confirmed, therefore, that both types of geotextiles, when embedded above the filter layer in L, A and B-traffic roads, would improve the CBR of the weak subgrade soil (1 ≤ CBR ≤ 2) up to 3 in practical terms (i.e. improve the CBR to so that the strength of the pavement can be regarded as being equivalent to that of a standard pavement section with a design CBR of 3).

3.2 Reinforcement mechanism

Figures 4 and 5 show examples of the relation between the number of repeated load and the elastic deformation (A traf-

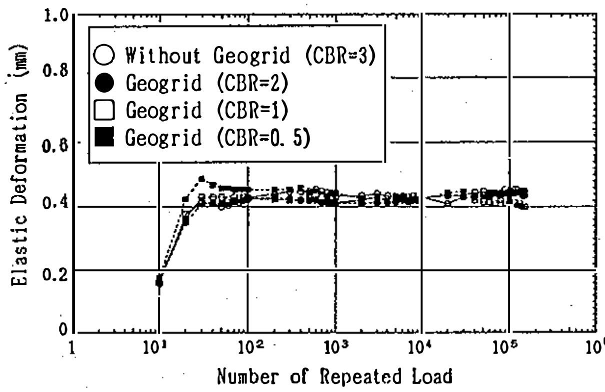


Figure 4. Typical results of the repeated loading test(geogrid, subbase course thickness:35cm)

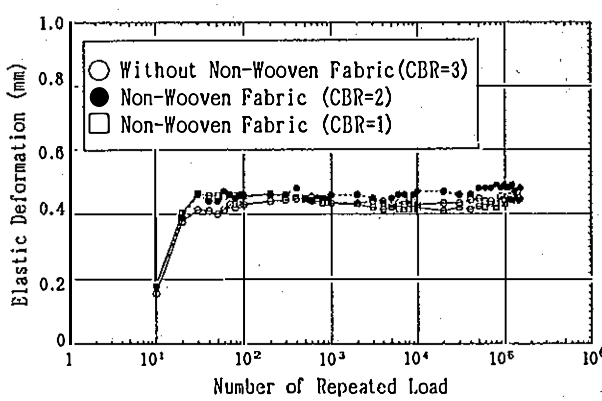


Figure 5. Typical results of the repeated loading test(non-woven fabric, subbase course thickness: 35cm)

fic) on the test specimens reinforced with geogrid and non woven fabric. The figures indicate that the elastic deformation remains more or less the same regardless of the types of specimens. Similar results were obtained in cases with loading conditions corresponding to L and B-traffic.

It is, therefore, estimated from the above that the geogrid reinforces the subbase course by restraint effect (i.e. increasing the rigidity of the subbase course by restraining the movement of the aggregate particles) and preservation of the original structural thickness of the subbase course (i.e. preventing the penetration of the base course materials into the layers below, which is known as separation effect). Similarly, in the case of non-woven fabric, it is estimated that the fabric reduces the elastic deformation by preserving the original structural thickness of subbase course, which comes from the separation effect, and reduces the load on weak subgrade soil, compared to that without geotextiles.

3.3 Design method

The subbase course thicknesses, obtained from Figures 2 and 3, on which the values for the ultimate cumulative deformation with geotextiles are the same as those on the specimen with a CBR of 3 and without geotextiles are shown in Figures 6, 7 and 8 (for L, A and B traffic, respectively).

Taking into account the reinforcement effect of the geotextiles discussed in 3.1, the concept of equivalent conversion strength evaluation illustrated in Figure 9 may be used in determining the thickness of the pavement in which the geotextiles

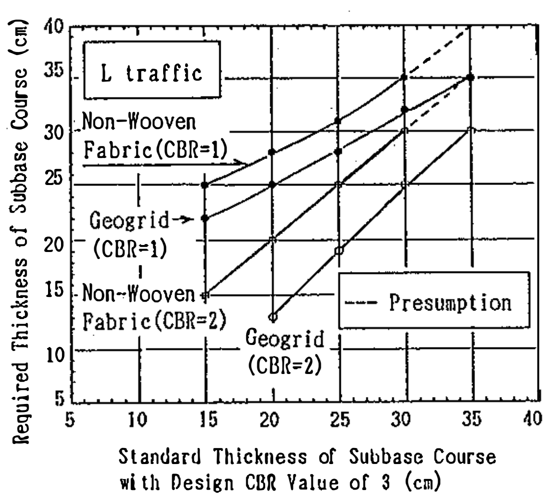


Figure 6. Design curves for required subbase course thickness (L traffic)

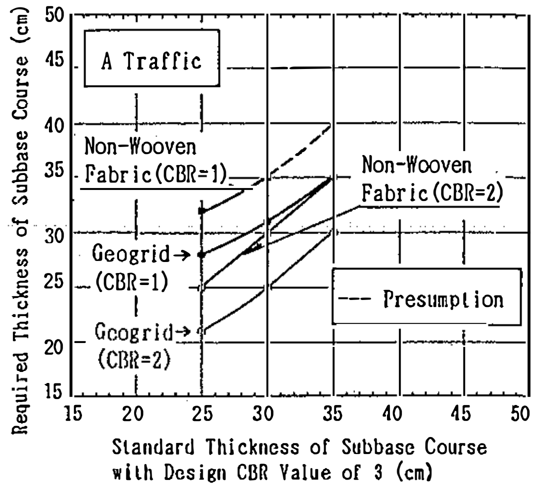


Figure 7. Design curves for required subbase course thickness (A traffic)

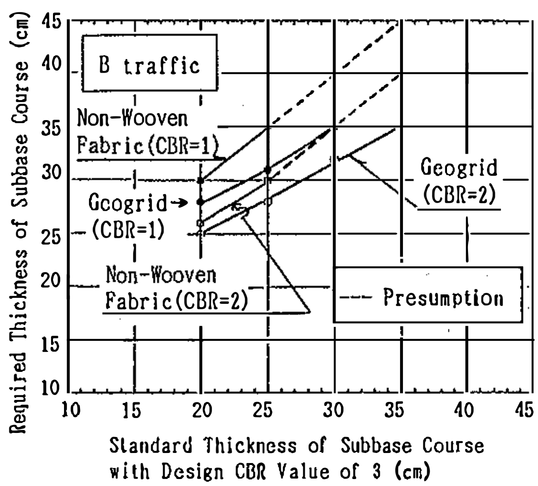


Figure 8. Design curves for required subbase course thickness (B traffic)

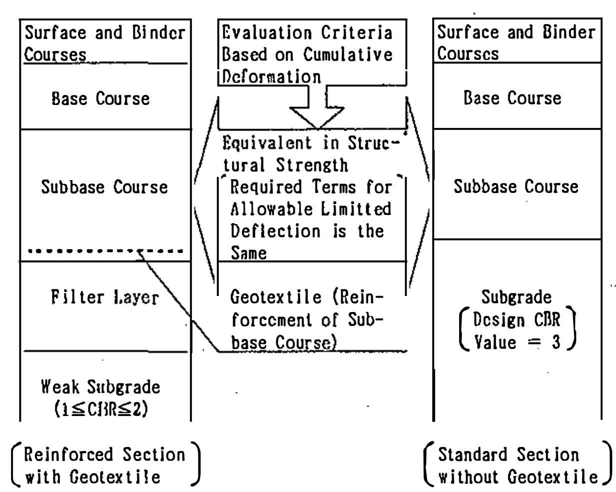
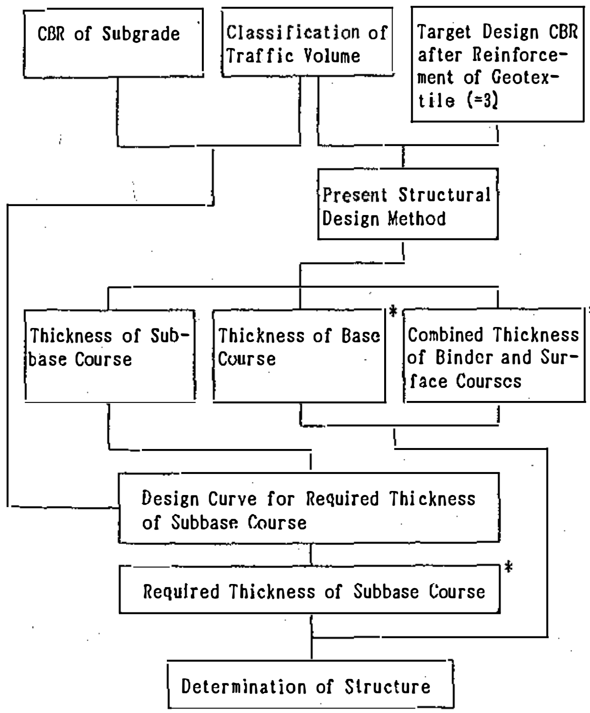


Figure 9. Illustrated concept of equivalent conversion strength evaluation

are placed above the filter layer, determining the subbase course thickness from these figures(6 to 8) so that the strength of the reinforced pavement section is equivalent (i.e. gives approximately the same ultimate cumulative deformation) to that of a standard pavement-section (design CBR = 3). In this case, only the subbase course contiguous with the geotextile is considered as being reinforced. In conducting the design practically (Figure 10), therefore, the thicknesses of each course in a standard pavement section (design CBR = 3) may first be determined by the conventional design method. Using the obtained thickness of the surface, binder and upper base course, the thickness of the subbase course may then be determined using the subbase course thickness obtained from the conventional design method and the design curves for the required subbase course thicknesses shown in Figures 6 to 8.



*) Design Thickness

Figure 10. Flow chart of design process for reinforced pavement by the geotextile

3.4 Application range

Examples of subbase course thicknesses required to render the ground strength equivalent to that in a normal cross-section (design CBR = 3) according to Figures 6 to 8 are given in Table 3.

It may be observed from Table 2 that,

Table 3. Examples of the required thickness of subbase course

Type of Geotextile	Classification of Traffic Volume	Required Thickness of Subbase Course (cm)	
		CBR=1	CBR=2
Geogrid	L Trafic	25 (+5)	13 (−7)
	A Trafic	35 (±0)	30 (−5)
	B Trafic	35 (+5)	32 (+2)
Non-Wooven Fabric	L Trafic	28 (+8)	20 (±0)
	A Trafic	40 (+5)	35 (±0)
	B Trafic	40 (+10)	35 (+5)

Note ; Figures in parentheses mean thickness added to the required thickness of the subbase course in a standard pavement section with the design CBR value of 3

with the exception of the L and A-traffic cases for CBR = 2, the required thicknesses above the subbase course in the standard pavement sections (design CBR = 3) (shown in parentheses in the table) are greater in the cases for A traffic than for L and B traffic. This is thought to be due to the fact that in the case of L traffic, under a severe subgrade condition with CBR of 1, the difference in the strength between the reinforced and standard pavement sections is greater than for A traffic because of the smaller pavement thickness, while with B traffic the reinforcement effect on the layer is reduced by the greater pavement thickness.

From this fact, it is expected that the reinforcement effect due to the geotextiles will be even smaller in the case of C and heavier traffic. Therefore, the application range within which the geotextiles may be applied with effect, in terms of the traffic classification, is restricted to that from L to B traffic.

As mentioned in the section 3.1, furthermore, it was observed the effect of the both geotextiles in the specimens with the subgrade soil which has the CBR of 1 and 2, but in the case of the subgrade which has the CBR of 0.5, it was not observed the effect that can reduce the ultimate deformation to the same level as that on the specimen with the CBR of 3 even with greater subbase course thickness. It is, therefore, estimated the application range of the geotextiles in terms of the subgrade condition is restricted from a CBR of 1 to 2.

4. CONCLUSIONS

The repeated loading tests, corresponding to L, A, and B traffic, in the laboratory were conducted with or without two types of geotextiles placed on the filter layer, so that the following conclusions were made.

(1) Under the loading conditions, both

geogrid and non-woven fabric show reinforcement effect, so that they reduce the cumulative deformation under repeated load and improve the CBR of the weak subgrade (= 1 to 2) to 3 in practical terms without much of increase of the subbase course thickness.

(2) This reinforcement is due, in the case of geogrid, to the strengthening of the subbase course by the restraint effect and preservation of the original structural thickness of the subbase course, and in the case of the non-woven fabric, similar to the geogrid, to preservation of the original structural thickness of the subbase course by the separation effect.

(3) Design curves for the subbase course thickness required to make the strength of the pavement reinforced with geotextiles equivalent to that of a standard pavement section with a CBR of 3 were obtained.

(4) A possible procedure for the design of the reinforced pavement is to first determine the surface, binder and upper base course thicknesses by the present design method in Japan (CBR-TA method) and then to obtain the design subbase course thickness using the design curve for the required subbase course thickness.

(5) The application range of the geotextiles is $1 \le CBR \le 2$ in terms of the subgrade conditions, and L, A and B traffic in terms of the traffic volume conditions.

The authors hope in the future to conduct tests on the reinforcement effect of geotextiles in actual pavements and to verify the validity of the design method discussed above.

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