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ROAD PAVEMENT USING GEOSYNTHETICS ON THE TERRITORY OF RURAL SETTLEMENTS

*Tymarkul Muzdybayeva[1], Onggarbek Alipbeki [1], Amanzhol Chikanayev[1], Sholpan Abdykarimova[1]
[1]Saken Seifullin Kazakh Agro Technical University, Nur-Sultan, Kazakhstan

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ABSTRACT: Quantitative and qualitative changes in recent years in the road industry require new technological approaches to road construction. Today some of the most used materials in road construction are geosynthetics. Geosynthetics have become interesting engineering materials in a wide range of applications and geotechnical, environmental, hydraulic, environmental, and private developments. The paper presents the research on the load and operational condition of the test model of a road reinforced with different geosynthetic materials. Geogrid and geotextile were used in testing. High-strength geotextiles or geogrids can provide adequate embankment reinforcement when properly designed and selected. Both materials can be used equally well, provided with the requisite design properties. Under the influence of the load from transport, the filler used for the cells is compacted. Currently, there is a redistribution of load throughout the entire volume of the monolithic structure with the grid. The tests carried out showed that using geotextiles leads to a decrease in the settlement coefficient by 25% and the use of a geogrid - by 38%. In rural areas of Kazakhstan, where the road network is in poor condition due to weak soils, strengthening the roadway with traditional materials will require large sums of money. Reinforcing the soil of unpaved roads with geosynthetic materials will allow more rationally and at a lower cost to improve the performance of unpaved roads in rural areas of Kazakhstan.

Keywords: Reinforced Soil of Unpaved Road, Cyclic Loading, Vehicles, Embankment construction, Empirical Equations

1. INTRODUCTION

The quality criterion of engineering solutions is one of the general prerequisites of geoengineering development as one of the inalienable parts of state development [1-3]. In its turn, the performance of engineering solutions must lead to the use of high-quality materials and technologies [4]. The reinforced soil model is one of the best illustrations of high-quality engineers' solution performance.

Nowadays, in the progressive construction development epoch, reinforced material diversity has a place on the world market.

Asian and European developed countries are suggesting new reinforced materials and technologies. It is approved of the superiority of the reinforced soil model and its application urgency. Today reinforced soil model has a practical value find out the principal application in road construction.

It is one of the solutions for construction in subsidence soil because when the settlement of the foundation is stabilized, and after operation of the structure with watering of soils in the basement, uneven can occur deformation occurs [5-8].

Road construction as an integral part of the infrastructure requires maximum convenience and comfort for the residents. This requires increased attention to the choice of a suitable reinforced material and technology.

Therefore, the choice of geosynthetics is not accidental. The material has long established itself in world practice as one of the most reliable and durable reinforcing materials [9-10].

Today experimental tests for a long-term analysis of reinforced foundation soil and unpaved road and analysis of the load-settlement state in soft soil grounds conditions are very actual [11-14].

For this investigation are necessary to pay attention to stability analysis of reinforced structure, which includes determination of bearing capacity of foundation soil; interpretation of laboratory testing results of the foundation soil, fill soil, and reinforced materials; according to the laboratory test results to fulfill forecast of the load-settlement condition by elapsed a long time. The purpose of the study is to conduct experimental tests on reinforcing soil samples of unpaved roads with geosynthetic materials to identify the degree of their influence on the bearing capacity of roads.

2. RESEARCH SIGNIFICANCE

Construction of roads in difficult engineering and geological conditions requires reliable foundation design. Today several innovative materials can improve the quality of road construction. The study presents experimental test performance to research load-settlement condition of reinforced foundation by geotextile, geogrid, and interpretation of obtained results. This study is relevant to the choice of constructive and technological solutions in the design of subsidence soils when selecting measures to improve the properties of the soil.

3. MATERIALS AND METHODS

A modern highway is a complex of engineering structures that ensures the movement of traffic at high speeds and the necessary safety and comfort of movement. Roads should be designed and built in such a way that vehicles can fully realize their dynamic qualities under the normal mode of engine operation.

Roads are subject to the active influence of numerous natural and climatic factors (snowdrifts, moistening by precipitation, surface, and groundwater). These peculiarities of highway operation must be considered when designing the design line of longitudinal profile (setting of guiding working marks, checkmarks of culverts) and the roadbed [15-17].

When designing a road, it is necessary to master perfectly the methods of optimal choice of route on the ground and the collection of data necessary to justify design decisions, calculate the technical standards of the road, and ensure the convenience and safety of freight and passenger road traffic.

Temporary roads are built simultaneously with those permanent roads that are intended for construction transport: they form a unified transport network, providing a thorough, circular, or dead-end traffic scheme.

Problems usually arise with the subgrade and traditional solutions do not solve the problem. Excavators and the replacement of unsuitable materials are expensive solutions. Geosynthetics is a profitable solution [17-18].

The reinforcing materials for the reinforced wall are mainly stiff geogrid (PP) and flexible geogrid (PET), geosynthetic strip type, galvanized steel strip, and soil nailing. The wire mesh type reinforced steel bar and steel bar with a cross-reinforcing angle are also used for the reinforced wall.

The most popular basal reinforcing materials for the embankment or land reclamation area are woven and non-woven geotextiles, which are also used as a separation purpose between original ground and backfilling soil.

However, stiff geogrids are mostly utilized to reinforce the foundation soil for the oil tank storage facilities, airfields, roads, railways, and retaining wall structures [19].

Geocell is usually used in slope protection and construction of staged earth walls. It is sometimes used in soft soil improvement to reduce the probable settlement and take care of the traffic load of construction equipment. Mainly in road construction in Kazakhstan, geotextile and geogrid are widely used.

Therefore, two types of geosynthetic materials were chosen for the study [20-21]. Smart-Grid PP (biaxial) geogrid and non-woven geotextile were used for tests which are shown in Fig. 1-2.

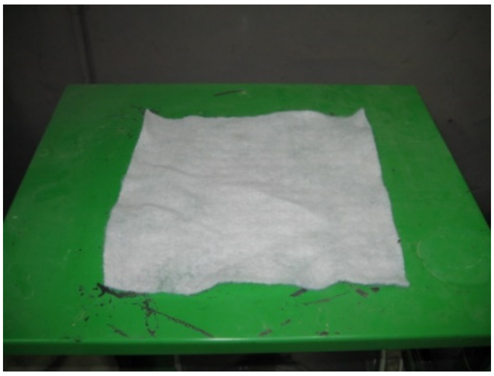

Fig.1 Non-woven geotextile

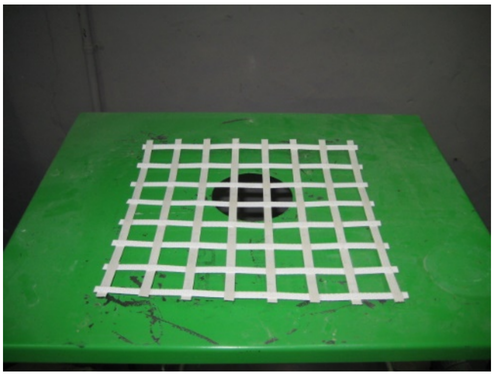

Fig. 2 Smart-Grid PP (biaxial) geogrid

The physical properties of the geogrid are given in Table 1 and the properties of the geotextile are given in Table 2. Sandy gravel and gravely sand soil were used for laboratory tests.

Laboratory studies on the soil samples consisted of determining the grain-size distribution, specific gravity, liquid and plastic limits, consolidation characteristics, and standard proctor compaction test.

Table 1 Physical properties of the geogrid

Contents	SMART-Grid (polypropylene-PP)	
contents	$L_{in} \times B_{in}$	$L_{out} \times B_{out}$
dimensions (mm)	30.5 × 30.5	40 × 40
Thickness (mm)	1.3	1.3
Density (g/m^2)	445	
tensile strength (t/m)	5.53	

Table 2 Physical properties of the geotextile

Contents	Geotextile
Thickness (mm)	2
Density (g/m^2)	125
tensile strength (t/m)	1

The load was carried out experimental work on the wheel tracking load test (Fig.3-4). Dynamic load from a moving vehicle was simulated by applying different loads to the wheel of the passing of a car wheel with a maximum load of 30 kg. To measure the fallout from the action of dynamic load applied measuring devices [16].

Fig.3 Wheel track load test

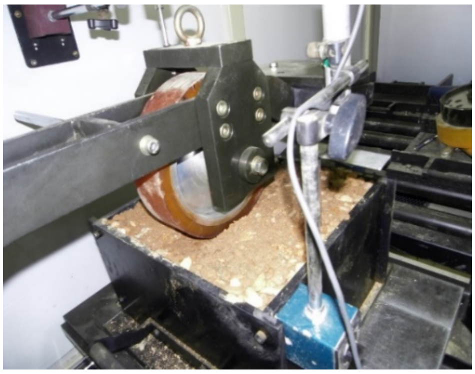

Fig.4 Measurer instruments of the settlement

A cyclic loading test was performed on unreinforced soil unpaved roads (UnRS-UR), geotextile reinforced unpaved soil roads (GtRS-UR) a, and geogrid reinforced unpaved soil roads (GrRS-UR).

Nine loading tests were performed on a UnRS-UR, GtRS-UR and GrRS-UR with different loads. An experimental program for the wheel tracking test is presented in Table 3.

4. RESULTS AND DISCUSSION

To determine the ultimate bearing capacity of soil were carried out three experiments with different variants of the reinforcement and the graphs were based on the results of the experiments. Fig.5 shows the limiting bearing capacity of the soil.

Table 3 Experimental program for wheel tracking test

№	Reinforcement condition	Load, kN	σ_d (MPa)	(σ_d/q_u) x 100%
UnRS-UR1	Unreinforcement	0.030	0.24	90.80
UnRS2	In reinforcement	0.020	0.16	60.5
UnRS3	In reinforcement	0.015	0.12	45.4
GrRS-UR1	With geotextile	0.030	0.24	73.0
GrRS-UR2	With geotextile	0.020	0.16	48.6
GrRS-UR3	With geotextile	0.015	0.12	36.5
GtRS-UR1	With geogrid	0.030	0.24	66.1
GtRS-UR2	With geogrid	0.020	0.16	44.0
GtRS-UR3	With geogrid	0.015	0.12	33.0

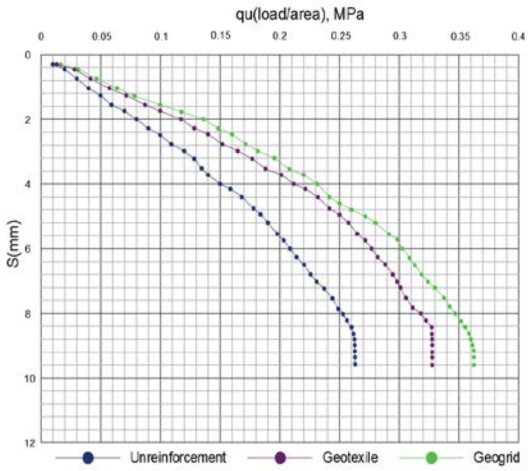

Fig.5 Determine the limiting bearing capacity of soil

The coefficient of bearing capacity of soil is equal to the bearing capacity ratio (BCR): BCR_1=1.244; BCR_2=1.374.

Results of experiments with static loading are presented in Table 4 and Fig. 6-7.

Table 4 Results of experiments with static loading

Number of experiment	q_u	$q_{u\ (experiment)}$, MPa
Exp. 1, $q_{u(ur)}$	2.644	12.762
Exp. 2, $q_{u(gt)}$	3.289	12.762*1.244=15.876
Exp. 3, $q_{u(gr)}$	3.633	127.62*1.374=17.534

Figure 6 shows the results of testing the subgrade of a dirt road not reinforced with geotextiles with a calculated level of the number of cycles (s2) with a static load of 30.20 and 15 kg.

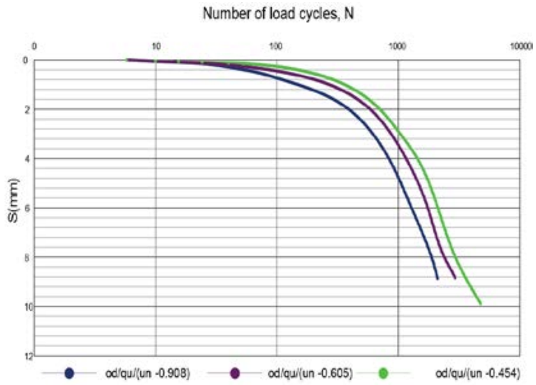

Fig. 6 The settlement level (s_2) number cycles of loaded for unreinforced unpaved road, 10000 cycle

The graph below shows the results of testing the subgrade of a dirt road not reinforced with geotextiles with a calculated level (s1) of the number of cycles and a load of 30, 20, and 15 kg.

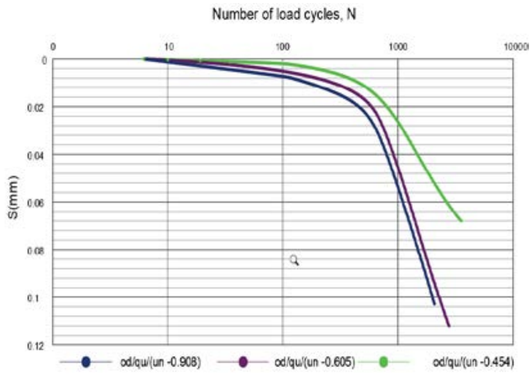

Fig.7 The settlement level (s_1) number cycles of loaded for unreinforced unpaved road, 10000 cycle

Wheel tracking test for geotextile:

1) reinforced pavement with an additional layer of geotextile material on the surface of subgrade under an additional layer of foundation and with a load of 30 kg;
2) reinforced pavement with an additional layer of geotextile material on the surface of subgrade under an additional layer of foundation and with a load of 20 kg;
3) reinforced pavement with an additional layer of geotextile material on the surface of subgrade under an additional layer of foundation and with a load of 15 kg.

The results of load for the reinforced road with geotextile are presented in Fig.8-11.

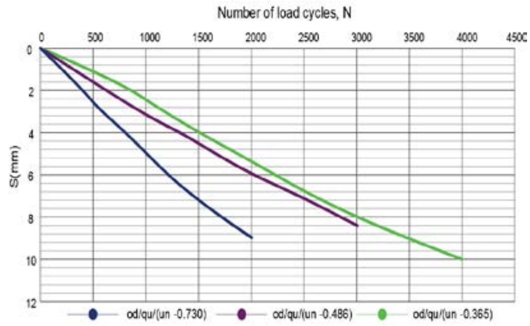

Fig.8 The settlement level (s_1) number cycles of loaded for reinforced with geotextile unpaved road, 5000 cycle

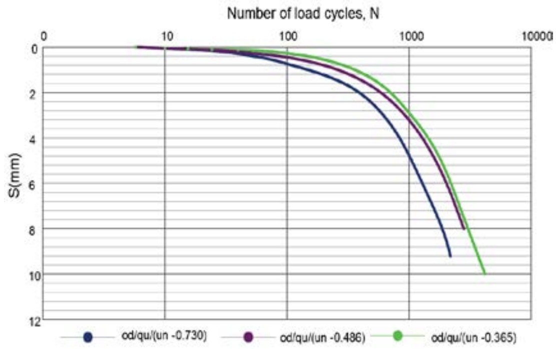

Fig.9 The settlement level (s_1) number cycles of loaded for reinforced with geotextile unpaved road, 10000 cycle

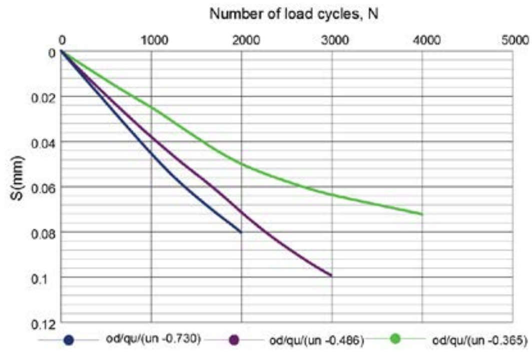

Fig.10 The settlement level (s2) number cycles of loaded for reinforced with geotextile unpaved road, 5000 cycle

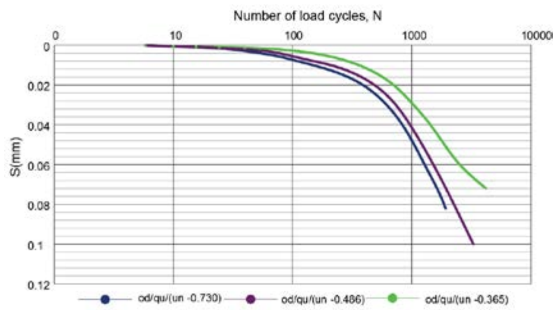

Fig.11 The settlement level (s2) number cycles of loaded for reinforced with geotextile unpaved road, 10000 cycle

Wheel tracking test for geogrid:
1) Reinforced pavement with an additional layer of geogrid at the subgrade surface by an additional layer of foundation and with a load of 30 kg.
2) Wired pavement with an additional layer of geogrid at the subgrade surface by an additional layer of foundation and with a load of 20 kg.
3) Wired pavement with an additional layer of geogrid at the subgrade surface by an additional layer of foundation and with a load of 15 kg.

The results of load for the reinforced road with geogrid are presented in Fig.12-15. Figure 12 shows the results of a wheel settling test for a dirt road pavement reinforced with a geogrid with a calculated level (s1) of the load number.

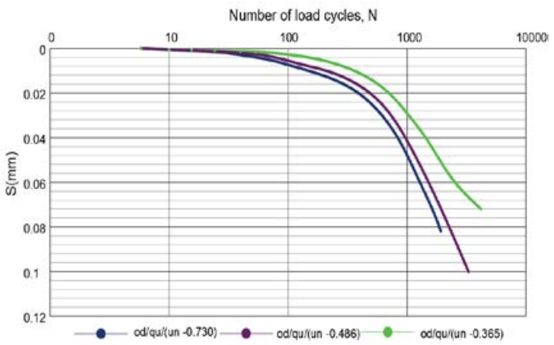

Fig.12 The settlement level (s1) number cycles of loaded for reinforced with geogrid unpaved road, 5000 cycle

. The graph below shows the results of a test for tracking the level of settlement (s1) from the wheels of a dirt road pavement reinforced with a geogrid during the production of 10.000 cycles of repetitions.

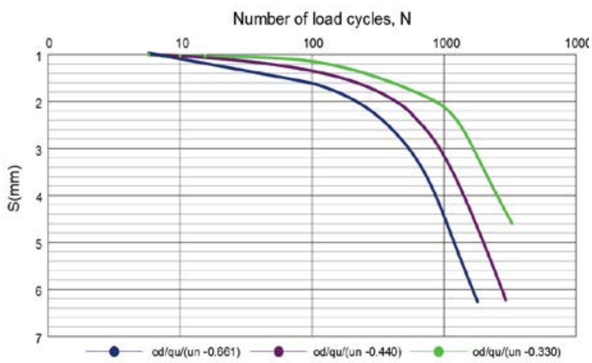

Fig.13 The settlement level (s1) number cycles of loaded for reinforced with the geogrid unpaved road, 10000 cycle

Figure 14 shows the results of a wheel settling (s2) tracking test on a geogrid-reinforced dirt road pavement during 5,000 load repetition cycles of 30, 20, and 15 kg.

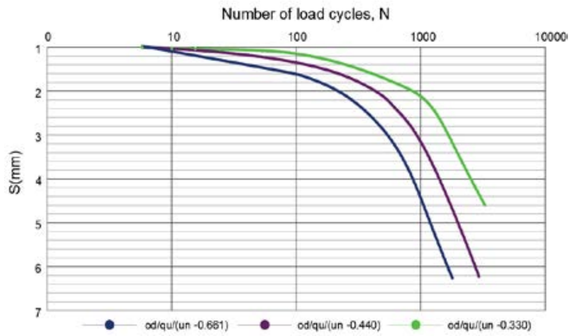

Fig.14 The settlement level (s2) number cycles of loaded for reinforced with the geogrid unpaved road, 5000 cycles.

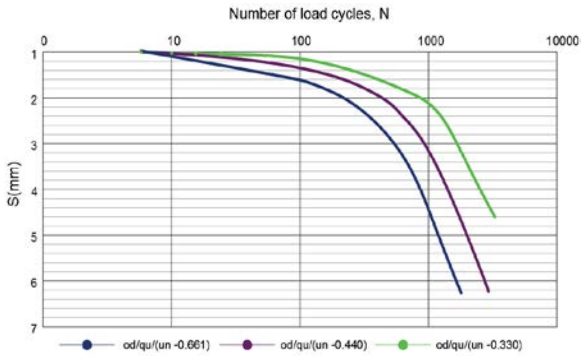

Fig.15 The settlement level (s2) number cycles of loaded for reinforced with the geogrid unpaved road, 10000 cycle

The graph shows the results of a wheel tracking test on a geogrid-reinforced dirt road pavement with settling level (s2) from 10,000 load repetition cycles of 30, 20, and 15 kg.

Comparing strain subbase of unreinforced and reinforced geosynthetics is presented in Table 5 which shows the numerical values of the indicators for comparing the deformation of the underlying layer of a dirt road unreinforced and reinforced with geosynthetics

The empirical equation for (Sd/B) versus (σd/qu(max)) on the unreinforced soil was determined from the wheel tracking test result shown in Figure 16. The wheel tracking test results can be categorized into two straight-line parts by bbythedynamic load increment ratio (σd/qu=50%) :

$Sd/B=0.17\ (\sigma d/qu(max))$,

$$0 \le \sigma d/qu(max) < 50 \qquad (1)$$

$Sd/B=30+0.24\ (\sigma d/qu(max))$,

$$50 \le \sigma d/qu(max) \le 100 \qquad (2)$$

Similarly, the empirical equation for (Sd/B) versus (σd/qu(max)) on the geotextile reinforced

the soil was determined from the wheel tracking test result shown in Figure 16, which shows the results of the wheel tracking test on the distribution of precipitation in the soil layer depending on the dynamic load increment coefficient.

The wheel tracking test results can be categorised into two straight line parts by the dynamic load increment ratio (σd/qu=50%):

Sd/B=0.61 (σd/qu(max)),
0≤σd/qu(max)≤50 (3)

Sd/B=30.50+0.114(σd/qu(max)),
50≤σd/qu(max)≤100 (4)

Similarly, the empirical equation for (Sd/B) versus (σd/qu(max)) on the geogeogrid reinforced soil was also determined from the wheel tracking test result shown in Figure 16.

The wheel tracking test results can be categorised into two straiget line parts by the dynamic load increment ratio (σd/qu=44%):

Sd/B=0.52 (σd/qu(max)),
0≤σd/qu(max)≤44 (5)

Sd/B=23+0.063(σd/qu(max)),
44≤σd/qu(max)≤100 (6)

Table 5 Wheel tracking test results for unreinforced and reinforced road

Settlement σ/q_u	Unreinforced S(mm)	(S/B)x100%	Reinforced geotextile S(mm)	(S/B)x100%	Reinforced geogrid S(mm)	(S/B)x 100%
0.908	11.897	47.59	8.850	35.4	6.627	26.512
0.730	10.912	43.648	8.297	33.19	6.383	25.538
0.661	10.530	42.12	8.083	32.333	6.289	25.16
0.605	10.22	40.88	7.909	31.638	6.212	24.853
0.486	9.37	37.476	7.539	30.16	6.528	24.202
0.454	9.14	36.56	7.025	28.102	6.006	24.027
0.440	9.04	36.159	6.80	27.202	5.987	23.95
0.365	8.503	34.138	5.596	22.38	5.017	20.07
0.330	8.253	33.012	5.034	22.187	4.564	18.26

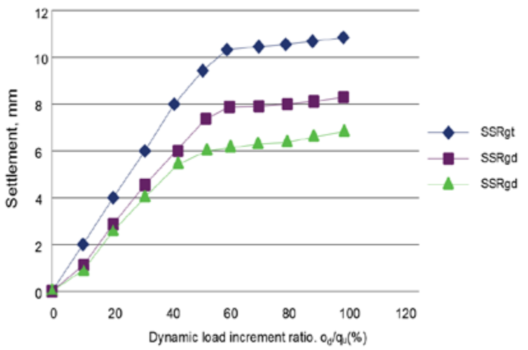

Fig.16 Settlement distribution according to dynamic load increment ratio

Figure 17 shows the benefit of settlement reduction with the induction of geosynthetics as a reinforcement element in the unpaved road.

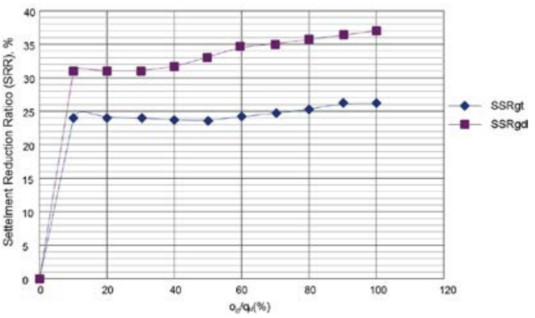

Fig. 17 Normalized maximum settlement reduction ratio with the given dynamic load increment ratio for reinforced soils

4. CONCLUSIONS

The relationship between the processes of socio-economic development of society and the processes of settlement at the present stage is one of the main architectural problems of the Republic of Kazakhstan.

Significant improvement in the comfort of living is associated not only with finding significant additional sources of accelerating the development of social infrastructure but also with a significant increase in the efficiency of capital investment.

The main purpose of investing in the development of the material and technical base of the non-productive sphere is to achieve the social or socio-economic effect, expressed in the growth of meeting the needs of the population in services and increasing the comfort of living of the population in the Republic of Kazakhstan. The road industry is also an important sector of development.

When the choice of structural and technological solutions when designing in difficult ground conditions is required, the design and construction of embankments on soft foundation soils is a very challenging geotechnical problem. Most steep slope reinforcement projects are for the construction of new embankments, alternatives to retaining walls, widening of existing embankments, and repair of failed slopes. Another use of geosynthetics in slopes is for compaction aids. In this application, narrow geosynthetic strips, 1 to 2 m wide, are placed at the edge of the fill slope to provide increased lateral confinement at the slope face and therefore increased compacted density over that normally achieved.

Based on the laboratory wheel tracking test results, the following conclusions can be made:

1. The magnitude of cyclic load, stiffness of reinforcement material, and the number of load cycles are greatly influenced by the settlement of the unpaved road.
2. The empirical equations for (sd/B) versus the unreinforced, geotextile reinforced, and geogrid reinforced unpaved roadbed were proposed based on the laboratory wheel tracking test results.
3. The settlement reduction ratios for the geotextile and geogrid reinforced unpaved road against the unreinforced unpaved road are approximately 25% and 38%, respectively.
4. The geosynthetics application in the unpaved road is greatly influenced by the settlement reduction and hence the lifetime of the road would be greatly extended.

5. ACKNOWLEDGMENTS

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