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Design and Technological Solutions for Construction on Collapsing Soils

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Abstract. *The solution to the problem of subsidence in the foundations of transport structures is becoming more and more urgent every year. This is due to the fact that when loess soils are soaked, irregular subsidence occurs, leading to complete or partial destruction of engineering structures and capital pavements on highways. Insufficient consideration of the deformability of structurally unstable soils, the lack of effective preparation of the foundations of structures leads to damage. The article presents an engineering and geological survey of the road section in Almaty (Kazakhstan). The analysis of changes in physical and mechanical properties of collapsing soils is given. According to the results, the type of ground conditions on the subsidence of the designed road section is determined. Taking into account specific properties of soils the efficiency of constructive and technological solutions for construction is justified, several measures are proposed. One of them is the reinforcement by geogrid as the material can bear a big weight of the soil layer and prevents it from displacement due to transport loading and other external factors. These solutions help to eliminate the destruction of the structure, excluding traffic accidents that can cause injury or loss of life.*

Keywords: *collapsing soil, physical and mechanical properties, road pavement, compression test, technological solutions, design, geogrid, bearing capacity, load, water content, waterproofing, measure.*

Introduction

Engineering-geological surveys provide information about the presence of dangerous geological processes, such as waterlogging, ground subsidence. Thus, it is possible to develop recommendations for taking measures to mitigate or prevent the development of geological risks that can lead to damage or destruction of the object [1-3].

A distinctive feature of collapsing soils is their ability to subsidence in the stressed state from their weight or external load from the foundation when the moisture content increases. Soil subsidence is caused by the peculiarities of formation and existence of these soils, as a result of which they are in an under consolidated state [4-6]. Under the consolidated condition of loess soils can be maintained throughout the whole period of thickness existence, if there is no increase in moisture and load. In this case, there can be additional compaction of the soil in the lower layers under the influence of its weight. But since subsidence depends on the magnitude of load, under compaction of loess soils concerning the external load exceeding the stresses from its weight of soil will remain [7-9]. The possibility of subsequent compaction of loess soil, which is under compacted by external load or its weight, with increasing humidity is determined by the ratio of reduction of its strength when wetting and the magnitude of the acting load. Soil subsidence is a complex physical and chemical process. Its main manifestation is compaction of soil due to movement and more compact stacking of individual particles [4].

Due to the increase in the degree of density of the soil after subsidence, its strength characteristics increase somewhat. With further increase in pressure, the process of loess soil compaction in water-saturated state continues, and with it, its strength also increases. To ensure the design reliability of structures on collapsing soils, researchers note the importance of conducting tests to determine and predict the magnitude of expected subsidence, one of which is compression testing.

Today compression testing is one of the most common types of tests used in laboratories to determine soil deformation parameters. Compression is defined as the compression of the ground that eliminates lateral expansion and compacts the specimen without destroying it. The choice of structural and technological solutions for construction on collapsing soils is open. Based on the above, this study proposes structural and technological solutions for the construction of roads on collapsing soils.

Materials

The object (automobile road) is located on the territory of Karasai district of Almaty region (Figure 1). Field work consisted of engineering-geological survey areas and production engineering and geological survey, which was carried out by the drilling of 9 wells with the selection of the required number of monoliths and soil samples undisturbed Alluvial-proluvial deposits of the Quaternary age (Q), represented by loams of different consistency overlain by a soil-vegetation layer, take part in the geological-lithological structure of the site.

Physic mechanical properties there were 7 engineering and geological elements (EGE) subtracted:

- EGE-1 – Top soil;
- EGE-2 – Asphalt concrete (pavement);
- EGE-3 – Bulk soil;
- EGE-3a – Bulk soil. Presented loam with solid content of gravel and pebbles;
- EGE-4 – Loam brown solid light subsiding;
- EGE-5 – Loam brown light semisolid not subsiding;
- EGE-6 – Loam brown light soft plastic not subsiding.

Standard values of the physical and mechanical indicators of strength and deformation properties of main EGEs are presented in Table 1.

Methods

Testing of collapsing soils has its own peculiarities [10-13]. The characteristics of subsidence are determined by relative strain, in compression devices (Figure 2). EGE 4 soil samples were subjected to tests. A specified load is applied using a moving die in the device and stresses are generated in the soil specimen under the influence of the external load. In the compression device, pressure is continuously applied to the specimen until conditional stabilization of the specimen is achieved.

The sequence of basic operations includes:

- weighing the sample in the working ring, followed by coating the ends with wet filters;
- placing the specimen into a compression device;
- adjustment of the specimen loading mechanism, installation of devices for measuring vertical deformations of the specimen, recording initial readings of the devices;
- stepwise loading of the specimen.

Physical properties of the soil for testing are presented in Table 2.

Results and Discussion

The results of tests of loam are shown in Figure 3 and Table 3.

According to compression tests, the loams

Figure 1 – The object

Table 1 – Physical and mechanical properties of the soil ground

Parameter name	Engineering and geological elements		
	EGE-4	EGE-5	EGE-6
Natural humidity, %	13.5	18.8	22.0
Humidity at the boarder:			
- flow, %	25.7	26.9	25.4
- rolling out, %	16.3	17.4	17.0
Plasticity index, %	9.6	9.5	8.4
Index of liquidity, %	-0.3	0.15	0.60
Soil stability	1.99	2.14	2.0
Soil particles density, g/sm^3	2.70	2.70	2.70
Dry soil density, g/sm^3	1.75	1.80	1.64
Void ratio	0.545	0.502	0.653
Specific cohesion, kPa	37.0/25.0*	42.0/25.0*	25.0
Angle of internal friction	25/19*	25/19*	19
Modulus of deformation, MPa	24.4/17.0*	30.5/17.0*	17.0/12.2*
Design strength, kPa	379	318	<98

**characteristics are given for soil at a water-saturated state*

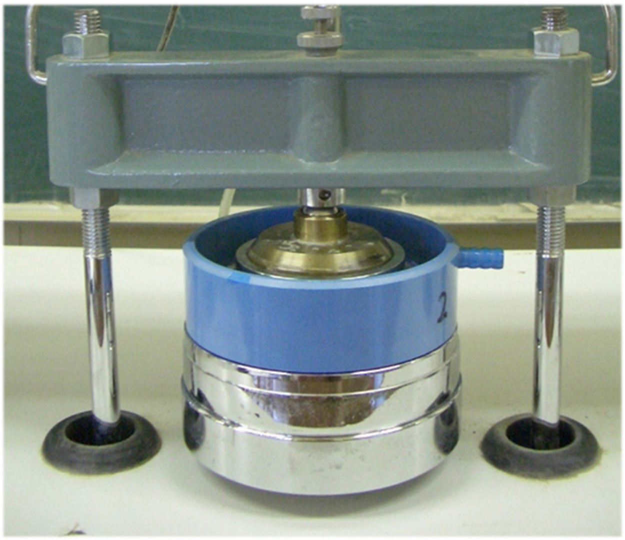


Figure 2 – Test

exhibit subsidence properties from additional loads. The initial subsidence pressure is 0.495 kg/cm². The coefficient of relative subsidence at a specific pressure of 0.5 kg/cm² is 0.009 to 0.011; at a specific pressure of 1.0 kg/cm² is 0.012 to 0.020; at a specific pressure of 2.0 kg/cm² is 0.018 to 0.028; at a specific pressure of 3.0 kg/cm² is 0.024 to 0.028.

According to the obtained test results, it is necessary to take into account that EGE-4 soils have subsidence properties when designing a highway [11, 14-16]. Engineering-geological conditions on the subsidence refer to the I (first) type. The remaining loamy soils are not subsidence.

Conclusions

The most important task for transport structures is to ensure the stability of foundations and soil embankments with high strength and low deformation characteristics of soils under constant dynamic impact. When designing automobile roads on subsidence soils, first of all, it is necessary to take into account the possibility of increasing humidity of such soils due to: their soaking from external sources from above; their soaking from below due to groundwater level rise; gradual accumulation of moisture in the ground due to surface water infiltration; simultaneous soaking from above and gradual accumulation of moisture in the ground. As the results of the study determined that the soil conditions of the site, formed by collapsing soils refer to type I, it is possible mainly subsidence of soils from the external load. It is necessary to provide for measures:

1. Provide waterproofing of foundations from aggressive soils.
2. Perform joint protection against corrosion.
3. Provide measures to prevent the penetration of surface water and man-made water into the foundations.
4. Provide for runoff and channel-regulating structures and measures to prevent flooding and under flooding adjacent to unregulated medium and small rivers, as well as to protect crossings under highways.

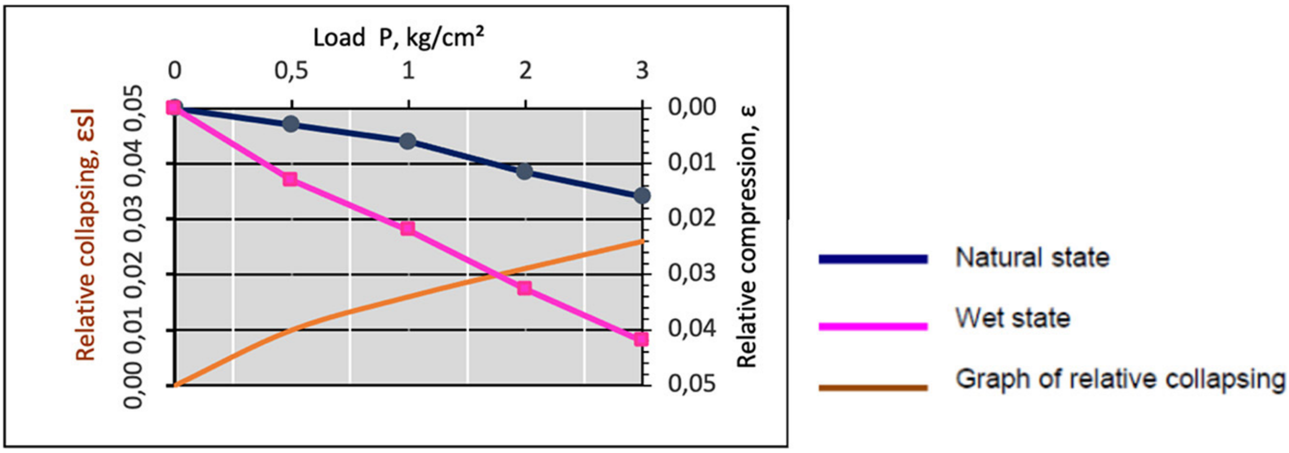
Design and engineering solutions for embankments are also important (Figure 4). The design of the pavement consists of fine-grained asphalt, coarse-graded asphalt, stone sand, sand and gravel mixture.

Table 2 – Data for testing

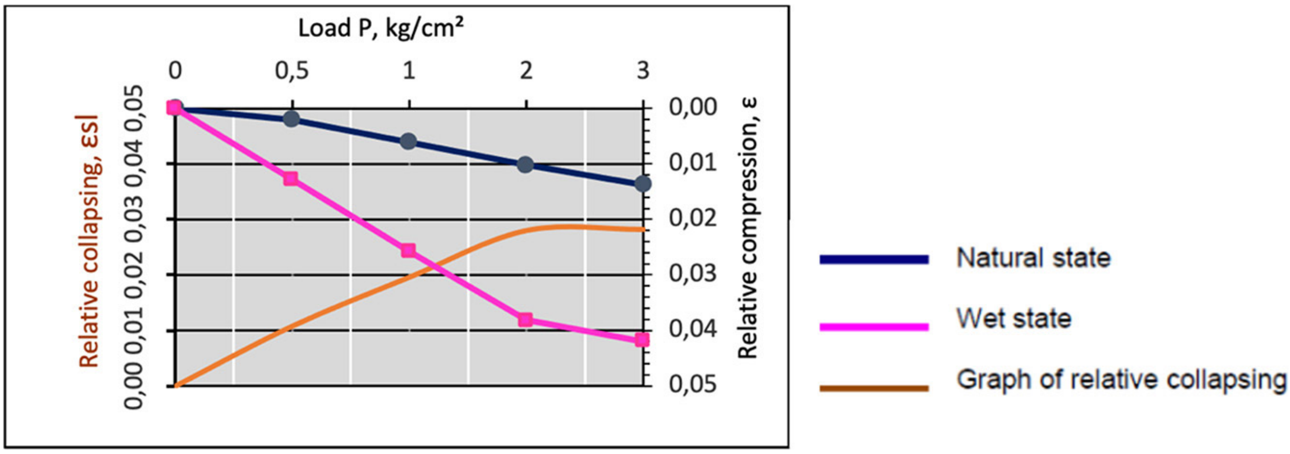
Physical properties of the soil before the experiment		Depth of well		
		1.5 m	2.5 m	3.0 m
Moisture on the boundary strength, %		24.1	28.5	27.3
Humidity on the border of rolling, %		16.5	17.5	19.1
Plasticity, %		7.6	11.0	8.2
Natural humidity, %		16.2	14.4	18.3
Soil density, g/cm³		2.04	2.03	2.13
Soil particles density, g/cm³		2.70	2.70	2.70
The density of the dry soil, g/cm³		1.76	1.77	1.80
Porosity, %		35	34	33
Voids Ratio		0.538	0.522	0.500
The coefficient of water saturation		0.813	0.745	0.989
Flow index		-0.04	-0.28	-0.10
Sample height, mm		25	25	25
	Natural state			
	0.5	0.009	0.006	0.011
	1.0	0.009	0.013	0.019
	2.0	0.008	0.006	0.004
	3.0	0.007	0.005	0.004
	Soaked state			
	0.5	0.040	0.039	0.039
	1.0	0.028	0.040	0.028
	2.0	0.016	0.019	0.013
	3.0	0.014	0.006	0.013
Relative subsidence	0	0.000	0.000	0.000
	0.5	0.010	0.011	0.009
	1.0	0.016	0.020	0.012
	2.0	0.021	0.028	0.018
	3.0	0.026	0.028	0.024

Table 3 – Results of EGE-4

P, kg/cm²	Parameter											
	1.5 m	2.5 m	3.0 m	1.5 m	2.5 m	3.0 m	1.5 m	2.5 m	3.0 m	1.5 m	2.5 m	3.0 m
	e			h			ε			E, kg/cm²		
The natural state												
0.0							0.000	0.000	0.000			
0.5	0.533	0.519	0.494	0.075	0.050	0.095	0.003	0.002	0.004			
1.0	0.529	0.512	0.485	0.150	0.155	0.250	0.006	0.006	0.010			
2.0	0.520	0.506	0.481	0.288	0.255	0.315	0.012	0.010	0.013	102.6	141.6	217.0
3.0	0.513	0.501	0.476	0.400	0.345	0.385	0.016	0.014	0.015			
The soaked state												
0.0							0.000	0.000	0.000			
0.5	0.518	0.502	0.480	0.325	0.320	0.325	0.013	0.013	0.013			
1.0	0.504	0.482	0.466	0.550	0.645	0.555	0.022	0.026	0.022			
2.0	0.488	0.463	0.454	0.816	0.955	0.765	0.033	0.038	0.031	55.15	47.14	69.8
3.0	0.473	0.458	0.440	1.050	1.050	0.985	0.042	0.042	0.039			



a



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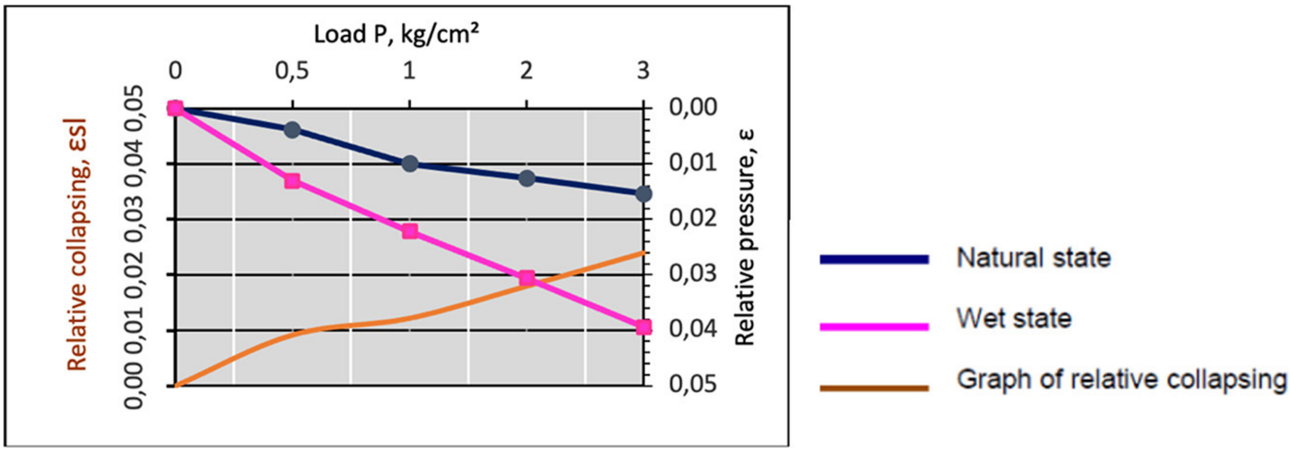

c

Figure 3 – Results of tests: a – 1.5 m of well, b – 2.5 m, c – 3.0 m

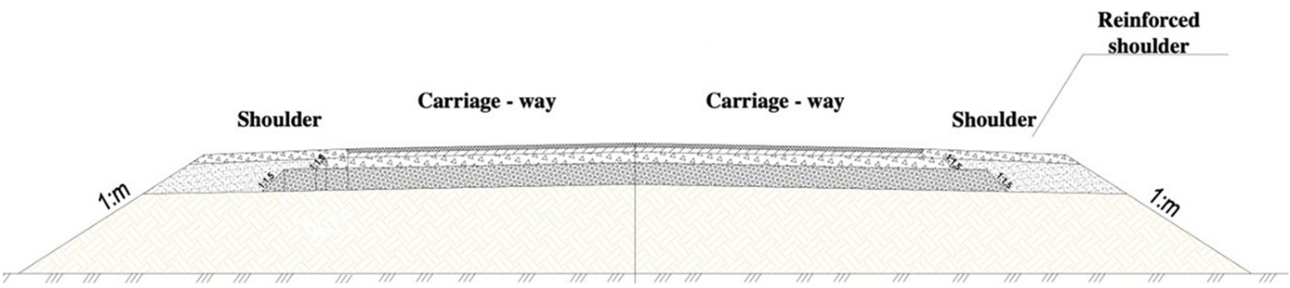

Figure 4 – Design of pavement

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Шөгінді топырақтарда құрылыс салуға арналған жобалық және технологиялық шешімдер

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Аңдатпа. *Көлік құрылыстарының негіздерінде шөгудің пайда болу проблемасын шешу жыл сайын өзекті болып келеді. Бұл лёсс топырақтарын суландыру кезінде біркелкі емес шөгулер орын алып, инженерлік құрылымдар мен автомобиль жолдарындағы күрделі жабындардың толық немесе ішінара бұзылуына әкеледі. Құрылымды тұрақсыз топырақтың деформациялық қабілетін жеткілікті есепке алмау, құрылыс негізінің тиімді дайындалуы болмауы зақымға әкеледі. Мақалада Алматы қаласындағы (Қазақстан) автомобиль жолының учаскесін инженерлік-геологиялық зерттелуі ұсынылған. Шөгінді топырақтардың физика-механикалық қасиеттерінің өзгеруі жайлы талдау жасалған. Алынған нәтижелер бойынша жобаланған жол учаскесінің шөгуі бойынша топырақ жағдайларының түрі анықталды. Топырақтың өзіндік қасиеттерін ескере отырып, құрылыс кезіндегі құрылымдық және технологиялық шешімдердің тиімділігі негізделген, бірқатар шаралар ұсынылған. Олардың бірі георидті нығайту болып табылады, себебі бұл материал топырақ қабатының үлкен салмағына шыдап, көлік салмағы мен басқа да сыртқы факторларға байланысты оның ығысуына жол бермейді. Бұл шешімдер құрылымның бұзылу, жол-көлік оқиғаларының кесірінен адамдардың жарақат алу немесе өліміне әкелу мүмкіндігінің болдырмауына көмектеседі.*

Кілт сөздер: *шөгінді топырақ, физика-механикалық қасиеттер, жол жабыны, сығымдау сынағы, технологиялық шешімдер, жобалау, геогрид, көтергіш қабілеттілік, жүктеме, ылғалдылық, гидрооқшаулау, өлшеу.*

Конструктивно-технологические решения при строительстве на просадочных грунтах

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Аннотация. *Решение проблемы возникновения просадки в основаниях транспортных сооружений становится с каждым годом всё актуальней. Это связано с тем, что при замачивании лёссовых грунтов происходят неравномерные просадки, приводящие к полному или частичному разрушению инженерных сооружений и капитальных покрытий на автомобильных дорогах. Недостаточный учет деформативной способности структурно-неустойчивых грунтов, отсутствие эффективной подготовки основания сооружений приводит к повреждениям. В статье представлено инженерно-геологическое обследование участка автомобильной дороги в г.Алматы (Казахстан). Приведен анализ изменения физико-механических свойств просадочных грунтов. По результатам определен тип грунтовых условий по просадочности проектируемого участка дороги. С учетом специфических свойств грунта обоснована эффективность конструктивно-технологических решений при строительстве, предложен ряд мероприятий, одними из которых является укрепление георешеткой, так как материал выдерживает большой вес грунтового слоя и предотвращает его смещение из-за транспортной нагрузки и иных внешних факторов. Данные решения позволяют исключить разрушение конструкции, дорожно-транспортные происшествия, которые могут повлечь за собой травмы или гибель людей.*

Ключевые слова: *просадочный грунт, физико-механические свойства, дорожное покрытие, испытание на сжатие, технологические решения, проектирование, георешетка, несущая способность, нагрузка, влажность, гидроизоляция, измерение.*

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