railway transportation; sandy deserts; crust proof to a stream of a wind with sand; a withdrawal of cotton manufacture; impregnation; humidity; plastic durability; experiment planning; optimisation

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DIFFERENCES AND COMMONALITIES IMPREGNATION OF DRY AND WET SAND

Summary. The article is devoted to research new methods of physic-chemical methods of preventing deflation to protect railways and highways from such phenomena as exogenous sand drifts. In particular, first studied the possibility of using binders in sand wet state. Results can significantly extend the scope of the method, and identified with particular impregnation maintaining stability requirements protective cover reduces both the concentration previously recommended binders, and their costs, thereby securing implementation in practice of shifting sands resource-saving technology.

РАЗЛИЧИЯ И ОБЩНОСТЬ ПРОЦЕССОВ ПРОПИТКИ СУХОГО И ВЛАЖНОГО ПЕСКА

Аннотация. Статья посвящена новому в исследованиях способов физико-химического метода предупреждения дефляции для защиты железных и автомобильных дорог от такого экзогенного явления как заносы песком. В частности, впервые изучена возможность применения вяжущих веществ в песках влажного состояния. Результаты позволяют существенно расширить область применения метода, а выявленные при этом особенности пропитки сохраняя требования к устойчивости защитной вяжущей песчаной корки приводят к снижению как концентрации рекомендованных ранее вяжущих, так и их расходы, обеспечивая тем самым внедрение в практику закрепления подвижных песков ресурсосберегающей технологии.

1. INTRODUCTION

Sandy deserts have a number of peculiarities [1 - 3], first one is connected with the origin and propagation of sands in severe environmental conditions [4, 5] that effects on endangering the security of construction and using of transport lines: security of railroads and autoroads, of pipeline transport connected with their land retirement and sanding up [6]. Because of this, the urgent problem is protection of natural-technical facilities from sand dune deflation and sanding up.

2. ANALYSIS OF EXISTING METHODS

There are many methods of protection, for application of which a number of requirements [6-10], will be established. Among them, ecological cleanliness is in the first place. Most ecologically clean one is biological method. It consists in contributing ammophilous plants – psammophytes [9] to grow. However, in view of a number of external factors, effectiveness of dune sands fixation by plants are too low. The followings are related to these causes: wind erosion blowing away (deflation)- blow molding of seeds and of seedlings; moisture deficit due to its high evaporation potential.

In order to increase the effectiveness of biological method, it is combined with other technological solutions, known as mechanical protection that is made in the form of barrier, fixed in the path of wind-sand flow. Historically, mechanical protection made from dry materials of vegetable origin, which could be partly dug into the sand in the form of rods or cages is widely used. Low mechanization is the main defect of this kind of technological solution. It is overwhelmingly performed manually [7]. Further still, sand substance blowing and its transfer in this process are not completely ruled out (fig. 1).

Fig. 1. Ordinary mechanical protection device from materials of vegetable origin
Рис. 1. Устройство рядовых механических защит из материалов растительного происхождения

Consequently, it is advisable to apply physicochemical method [6], which provides a way of integrated mechanization of binding agent preparation and its application process. In addition, the method could be applied together with the biological method and/or coupled with mechanical protection devices, as an example, with mechanical ditching and barrier devices (Fig. 2).

By applying binding agent on the sand surface, desert varnish (protecting crust) is obtained. Desert varnish prevents the deflation and creates favorable condition for vegetation development of ammophilous plants. In such manner, the aim of protection of facilities from sanding ups will be achieved and the safe conditions for their operation will be created.

Application of binding agent on the sand surface by way of spraying is considered as the main materialization technique of the ways of physicochemical method. But, possibility of application of binding agents for the mentioned purposes of shifting (unfixed) sands fixation depends on impregnation peculiarities. Protecting crust is formed as a result of free-flow impregnation of binding agent [8].

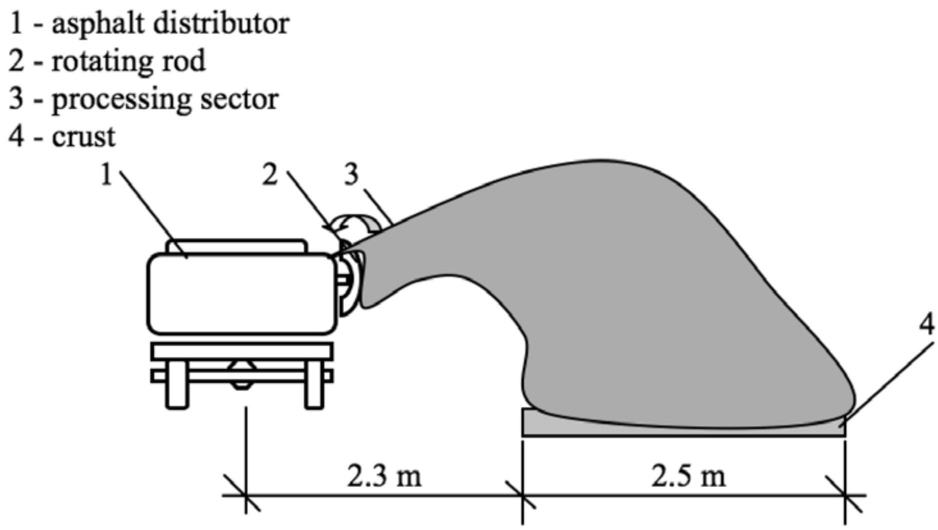

Fig. 2. The use of pavers for fixing sandy slopes and roadside road
Рис. 2. Применение автогудронатора для закрепления песчаных откосов и придорожной полосы дороги

Carried out investigation on application possibility in certain aims of binding agents in the form of macromolecular liquids, emulsions and solutions belongs to the air-dry sands, also application of advised binding agents is limited with dry periods of year. In connection with that, an idea of necessity of extending the application area of advised binding agents at the sacrifice of impregnation of the wet sand comes to mind.

Binding agents in the form of emulsion and solutions due to the general nature of their dispersion medium with moisture films on the sand particle surface could unobstructly become wet. However, availability of the moisture film could change the size of the equivalent diameter of soil spaces comparable with 10^{-2}мм. In this case, impregnation occurs under primary influence of capillary forces field as differentiated from impregnation of the air-dry sand. It could be presumed that this condition could bring to the reduction in speed of impregnation. Speed reduction of impregnation of binding agent will create the condition for most intensive degradation of binding agent and replacement of the water film on the substrate of dispersed phase of the binding agent to be impregnated. As a result of this, impregnation occurs more evenly, causing to obtain the material with the desired properties at a lower concentration of binding agent, as a result, it also causes to save the binding agent as a resource. In general, impregnation of wet sand, leads to expand the application area of physic-chemical methods and duration of work time. The fact is that the stability of the protective crust from the sand impregnated with binding agent is achieved when the aggregated characteristics of visco-plastic structure defined by the thickness of the crust and its plastic strength to the surface close to the horizontal must have values $h \geq 5$ mm and $P_m \geq (2{,}5 - 2\ 7) \times 10^3$ Pa. With an increase in the steepness of the slope for obtaining a solid layer, matter discharge is increased by 5-10%, and the lowest value of plastic strength reaches by $5x10^3$ Pa [6].

3. THE RESULTS OF EXPERIMENTAL STUDIES

Performed experimental studies revealed marginal maximum moisture content of sand, in which the possible impregnation. Emulsions are 17-24% and 24-32% for solutions [8]. An inverse dependence of the concentration and flow of various binding agents from sand moisture have been determined. In doing so, if in order to achieve the desired values of aggregate characteristics of viscoplastic crust at 24% of sand moisture, emulsion concentration equals to 20-25%, when the humidity at 32% -it is enough to use only 10-15% concentration. Binding agents in the form of solutions can be impregnated with sand from 24% moisture, i.e. humidity is sufficiently close to the threshold of maximum capacity. At the same time, binding agent discharge for impregnation of the wet sand is less than discharge for the dry one. These differences lie in the area of character features of impregnation.

Investigation on the rate of impregnation of the air-dry and the wet binding agents confirmed the previously expressed suppositions. It was revealed that in moist sand, the emulsion with high concentrations will be impregnated with slower rate than the less concentrated, which can be explained by a change in the nature of a capillary gravitation resulting in a narrowing of the pore space in moist sand. Emulsions of lower concentration are saturated at a higher rate (Fig. 2). In both cases, the depth of impregnation of the wet sand by binding agent is increased maintaining the uneven movement of the liquid front, as indicated by the lower surface of the crust. Moreover, this unevenness is more pronounced in the case of emulsions of low concentration than high, but in both cases is less expressed than for the crust obtained in the air-dry sand.

Average speed impregnation of ET in dry sand in the first second is 6 mm/s; second 4 mm/s, and the third is - less than 1 mm/s (Fig. 3). In moist sand there is a different showing. In the first 10 s average speed of impregnation is 0.6 mm/s; over the next 200 s decreases sharply and it makes up – 0.03 mm/s. Further reduction of the rate of impregnation is insignificant; it can be argued that it is evenly. At the same consumption of binding agent, impregnation time in the dry sand was 3-4 s, in the wet sand - 10-11 s. However, an advantage of impregnation of the wet sand is its thickness: in the dry sand 10-12 mm, in the wet - 20-22 mm. A comparative analysis of dependence of depth of impregnation of emulsion on the time showed that the velocity of the emulsion in the wet sand is ten times less than as in the air-dry sand and it can be expressed by characteristics (Fig. 3).

Composition of lower surface of the crust obtained on the dry sand is less expressed than in the dry one (Fig. 4). Expressed convex indicates uneven movement of liquid front during its high speed. With even without noticeable convex, lower surface of the crust on the wet sand indicates more even movement of liquid front (Fig. 5). Deep depth of impregnation under observation in relatively low speed gives an indication of active involvement of humidity in the mass transfer.

In such a manner, the following changes of impregnation process nature were revealed:

- forces, which impact on impregnation, are changed from predominantly gravitational (the air-dry sand) to capillary (the wet sand);
- from our point of view, as a result of mixing with pore water binding agent (emulsion) concentration decrease occurs;
- impregnation speed attenuation with increase of depth and emulsion impregnation depth in the wet sand is explained by capillary forces ($\leq 10^{-2}$мм) due to the decrease of active pores and pore spaces up to the sizes comparable with the pore of predominant influence of capillary forces spaces as a result of prior humidification of grain sand.

The order of examination construction and operational characteristics of protective cover, shown in Table 1, is to identify the thickness and strength of the plastic protective cover that is obtained by spraying a binder known concentration on the surface of sand known humidity. Results of the measurements are compared with the aggregate construction and technological characteristics to ensure the stability of the protective cover against wind-sand flow ($h \geq 5$ mm, $P_m \geq 3x10^3$ Pa).

In previously performed investigation, we obtained the results of possibility of achieving 5 mm thickness of the crust and required plastic resistance by $3x10^3$ P_m in 2x times decrease of consumption decrease of binding agent against recommended ones [5]. Possibility of obtaining stable crust on the wet sand (humidity of the sand up to 17%) is high, therefore, binding agent consumption may be decreased by 4 times. For emulsified binding agents of 10 – 12% concentration, optimal plastic endurance on the air-dry sand is achieved while consuming equally to 1.0 – 2.5 l/m^2, then as it was on the wet sand, this conditions are performed while consuming 1.5 - 2 times less 1.5 - 2 ($q = 0.5$ – 1.5 l/m^2). Due to the acceleration of the adhesion process of binding agent on particles of the wet sand it is possible (table 2).

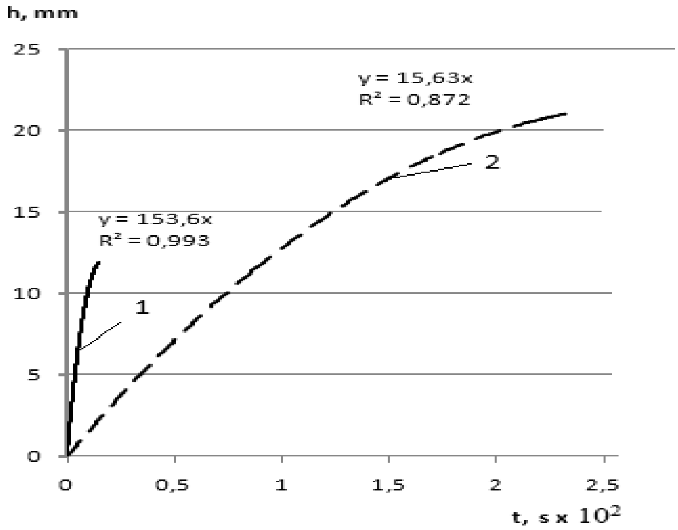

Fig. 3. A plot of depth and time of impregnation resin emulsion of cotton in the sand: 1 – in air-dry sand, 2 – in the wet sand

Рис. 3. График зависимости глубины пропитки эмульсии из госсиполовой смолы от времени: 1 – для воздушно-сухого песка, 2 – для влажного песка

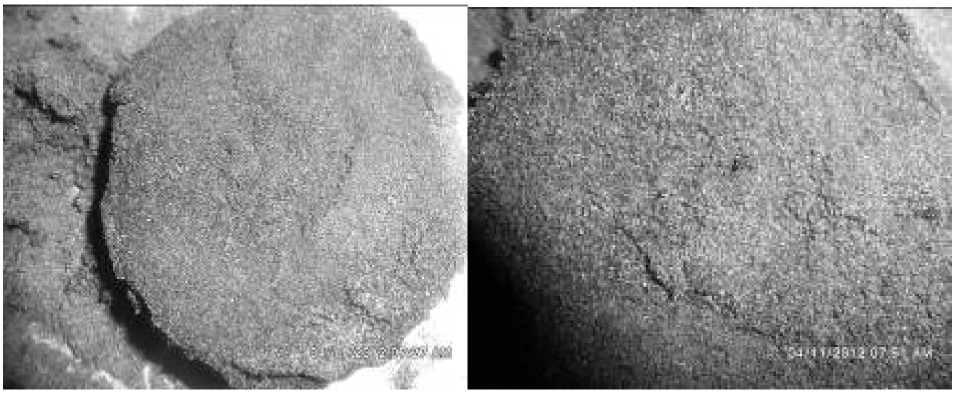

Fig. 4. View of the protective layer on the border line of impregnation in air-dry sand: a) top view; b) side view

Рис. 4. Вид защитного слоя на границе линии пропитки в воздушно-сухом песке: а) вид сверху; в) вид сбоку

Fig. 5. View of the protective layer on the border line of impregnation in the wet sand: a) top view; b) side view

Рис. 5. Вид защитного слоя на границе линии пропитки в мокром песке: а) вид сверху; б) вид сбоку

Table 1

Examining the protecting crust tolerance on the wet sand

Examination	Conditions	Analysis
1. Definition h –impregnation thickness, mm	1. C–binding agent concentration, %; 2. W – sand humidity, %	Comparing the results with tolerance requirement h ≥ 5 mm
Definition P_m – crust plastic tolerance, 10^3 P_m		Comparing the results with tolerance requirement $P_m \geq 2.5 \times 10^3 P_m$

Table 2

Binding agents consumption for obtaining tolerant protecting crust

Binding agent name	Concentration, %	Sand crust tolerance parameters					
		air-dry, W = 3-5%			wet, W = 21 %		
		h, mm	P_m,3x10^3, Pa	Q, l/m^2	h, mm	P_m,3x10^3, Pa	Q, l/m^2
Floor emulsion	25		5.8	3	7		1.0-2.0
	10		3.3	2.7	5		1.5
Bitumen emulsion	25		1.1	3.1	7.5		1.0
	10	5	7.1	2.5	5.2	2,5	1.5
Oil	-		6.5	1.2	7		0.7-1.2
SDB	14		1.5 – 2.5	2.8	7.2		1.7
	10		2.6 -5	2.5	6		1.5

According to the above mentioned method, specific binding agents' consumption on the air-dry and with humidity 21% sand to produce a stable protective crust (Table 2).

With the same thickness, plastic strength of protective crust on the wet sand is less than plastic strength of protective crust on the dry sand. To produce a stable crust on the dry sand, it is sufficient to fulfill one indicator from construction aggregates and technological characteristics of stability of protective crust - crust thickness is h ≥ 5 mm, while the plastic strength in all cases is provided. On the wet sand, required thickness of protective crust is provided in all the cases studied, and for the sustainability of the protective crust it is enough to perform the second condition, i.e plastic strength shall be Pm ≥ 2,5 x103, Pa. Obviously, this fact is explained by a decrease in the amount of binding agent per unit of volume of the wet sand, and as a result, formation of a protective crust with advantage of elastic-plastic bonds between the sand particles. Moreover, at concentrations less than 10% emulsions first condition for stability is achieved with much lower consumption. However, the second condition for stability does not reach the correct amount, the elastic- viscous-plastic connection between the sand particles are changed to predominantly elastic- plastic, that according to [6] should reduce the resistance to wind sand flow. In practice, the protective crust remains stable. Possibly, with thicker protective cover with other than viscoplastic type of communication, the crust gets quality, which gives resistance to wind sand flow in expressed elastic- plastic type of communication.

4. CONCLUSIONS

Preparation of the protective cover is resistant to the wind flow of saturated sand in a pre-wetting or impregnation naturally moist sand is achieved by a qualitatively different nature of the impregnation binder. Mostly gravitational character changes on the capillary. In this peel resistance is achieved at a concentration and flow rate of the binder lower than in the case of impregnation sand air-dry state, which leads to significant savings (up to 30%) binder. Thus, fixing moving sand with a preliminary (artificial or natural) moisture will significantly expand the production of works, to use technology and human resources, to save resources.

References

1. Vilchinska, N.A. Formation of ripples on a sand surface as the result of nonlinear interaction of sound waves and wind drift particles. *Proceedings of Meetings on Acoustic.* 2008.Vol. 4. No. 8. P. 1-8.
2. Ashkenazy, Y. & Yizhaq, H. & Tsoar, H. Sand dune mobility under climate change in the Kalahari and Australian deserts. *Climatic Change. 2012.* Vol. 112. Nos. 3-4. P. 901-923.
3. Khalaf, F.I. & Al-Ajmi, D. Aeolian processes and sand encroachment problems in Kuwait. *Geomorphology*. 1993. Vol. 6. No. 2. P. 111-134.
4. Kasper-Zubillaga, J.J. & Zolezzi-Ruiz, H. Grain Size, Mineralogical and Geochemical Studies of Coastal and Inland Dune Sands from El Vizcaíno Desert. Baja California Peninsula. Mexico. *Revista Mexicana de Ciencias Geologicas.* 2007. Vol. 24. No. 3. P. 423-438.
5. Fryberger, S. & Ahlbrandt, T. & Andrews, S. Origin, sedimentary features, and significance of low-angle aeolian sand sheet deposits. Great Sand Dunes National Monument and vicinity, Colorado. *Journal of Sedimentary Petrology*.1979. Vol. 49. No. 3. P. 733-746.
6. Мирахмедов, М. *Основы методологии комплексной системы организации пескозакрепления.* Дисс. … д.т.н. Ташкент: ТашИИТ. 2003. P. 363. [In Uzbek: *Foundation of complex organizations fixing moving sands.* Dissertation for the degree of Doctor of Technical Sciences. Tashkent: TIRE. 2003. P. 363].
7. Berte, Ch.J. & Mohamed, M.O. & Saleck, M.O. *Fighting sand encroachment: Lessons from Mauritania.* Food and agriculture organization of the United Nations. Rome. 2010. 77 p.
8. Mirakhmedov, M.M. & Muzaffarova, M.K. Expansion of a scope of methods of protection of the railways from entering by sand. *I International symposium of young researcher «Transport problems»*. Katowice: SUT. 2012. P. 83-89.
9. Mason, J.A. & Swinehart, J.B. & Lu, H. & Miao, X. & Cha, P. & Zhou, Y. Limited change in dune mobility in response to a large decrease in wind power in semi-arid northern China since the 1970. *Geomorphology*. Vol. 102. Nos. 3-4. 2008. P. 351-363.
10. Al-Enezi, A. & Pye, K. & Misak, R. &. Al-Hajraf, S. Morphologic characteristics and development of falling dunes, northeast Kuwait. *Journal of Arid Environments.* Vol. 72. No. 4. 2008. P. 423-439.

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