Vol. 5, No. 2, 2023

https://doi.org/10.23939/jtbp2023.02.12

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FEATURES OF THE MIX TIME OF BITUMEN EMULSIONS WITH CEMENT FOR SLURRY SURFACING TECHNOLOGY

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Pavement grade cationic bitumen emulsions formulations were developed for Slurry Surfacing based on orthophosphoric and hydrochloric acids with both all-purpose and specialized emulsifiers used. As a result, there were established relations of mix time upon cement - for Slurry Surfacing based on various acids and emulsifiers. Mix time of Slurry Surfacing mix (having different cement content) with bitumen emulsions on both orthophosphoric and hydrochloric acids is characterized by parabolic relation, branches of the parabola going down. Still, parabola slope steepness for Slurry Surfacing with cement and bitumen emulsions on orthophosphoric acid is higher than for emulsions on hydrochloric acid. The regularity investigated allows affirming that dosing cement for Slurry Surfacing with orthophosphoric-based bitumen emulsions shall be more diligently checked and controlled – so as to avoid the premature mix time.

Keywords: cationic bitumen emulsions, hydrochloric, orthophosphoric acids, Slurry Surfacing, cement, mix time.

Introduction

For Slurry Surfacing road pavements the optimum for usage still remain bitumen emulsions produced on distilled high-acidic bitumen obtained from heavy high-resinous low-paraffinic crude oil (Saghafi, 2019; Dong, 2018; Son, 2014; Apaza, 2021; Grilli, 2019; Terrones-Saeta, 2020; Johannes, 2014; Destree, 2022; Usman, 2019; Johannes, 2019; Izadi, 2020; Pyshyev, 2015). Still, such bitumens are high-cost and not always available for usage due to deficiency on the market. Therefore, both abroad and in Ukraine more and more often applied are special bitumen emulsion formulations on orthophosphoric acid intended for Slurry Surfacing (Hajj, 2011; Hwan, 2015; Wang, 2013). Slurry Surfacing pavements construction is highly sensitive to changes in both Slurry Surfacing mix components and their dosage, as for instance: origin and type of bitumen (distilled from heavy crude oil or oxidized from light one), type and quantity of acid, emulsifier in emulsion and control agent for mix time, water in the mix etc. (Sidun, 2019; Sidun, 2020). Besides, present in Slurry Surfacing mix is Portland cement, performing the function of both finely dispersed filler and control agent for the mix time of the mix. The previous studies (Sidun, 2021; Sidun, 2021; Sidun, 2023) have shown the efficiency of emulsions on orthophosphoric acid for Slurry Surfacing. Still, when designing the mix by mix time criterion it was noticed that regularities of mix time for Slurry Surfacing mixes with emulsions on hydrochloric and orthophosphoric acids are somewhat different. Thus, the purpose of this article is to precisely study the mix time peculiarities for Slurry Surfacing mixes on different bitumen emulsions and cement.

Materials and Methods

For the investigations the emulsions were produced on one and the same oxidized bitumen grade 70/100 (produced by UkrTatNafta, Ukraine) and amine-type emulsifiers (produced by Nouryon, Sweden – designed especially for Slurry Surfacing) and the appropriate acids. With Redicote E-11 emulsifier there was used the hydrochloric acid, while with Redicote C-320E – the orthophosphoric acid. Besides, there was used Redicote EM44 emulsifier. This one can be used with both acids. The emulsions obtained following the formulations presented in Table 1 were also modified by synthetic latex Toptex B (produced by Algol Chemicals, Finland). Bitumen emulsions for Slurry Surfacing were produced in lab conditions by means of bitumen emulsion plant SEP 0.3-R (produced by DenimoTECH, Denmark, Fig. 1).

Fig. 1. Laboratory bitumen emulsion plant

Table 1

Emulsion formulations for Slurry Surfacing

<table>
<tr><th rowspan="2">Formulation No</th><th rowspan="2">Bitumen content, % by mass</th><th colspan="2">Redicote emulsifier</th><th rowspan="2">Type of acid</th><th rowspan="2">pH in water phase</th><th rowspan="2">Latex content, % by mass</th></tr>
<tr><th>Brands</th><th>Content, % by mass</th></tr>
<tr><td>1</td><td rowspan="4">61</td><td>E-11</td><td rowspan="4">1,1</td><td>HCI</td><td rowspan="4">2,5</td><td rowspan="4">3,0</td></tr>
<tr><td>2</td><td>EM44</td><td>HCI</td></tr>
<tr><td>3</td><td>EM44</td><td>H_3PO_4</td></tr>
<tr><td>4</td><td>C-320E</td><td>H_3PO_4</td></tr>
</table>

For Slurry Surfacing mixes samples preparation and production (Table 2 and Table 3), besides of the emulsions (produced following the above mentioned formulations), there were used: the optimum and identical by methylene blue value granite screenings of Vyrivsky and Klesivsky quarries (Ukraine), which correspond (as per their grading) to the requirements of Type 1 by ISSA A 115, cement (with prilled blast-furnace slag) grade 400, drinking water and mix time control agent (10% water solution of Redicote E-11 emulsifier). The Slurry Surfacing mix was tested by mix time criterion according to ISSA TB-113.

Results and discussion

Determination of cement influence upon the Slurry Surfacing mix design was carried out by mix time criterion (Table 2, Fig.2). Mix time, which presents a time characteristic, for Type 1 by ISSA A 115 shall be not less than and maximum close to 180 seconds. Thus, there were determined the optimum mix design versions – with fixed values for all the Slurry Surfacing components, besides of cement.

When analyzing Fig. 2, the dependence of Slurry Surfacing mix time (on orthophosphoric acid) upon the cement content is different in contradistinction to the mixes on hydrochloric-acid-based mixes. The change of cement content by 0,5 part as per 100 parts of screenings in Slurry Surfacing on hydrochloric-acid towards the higher or lower part from optimum – leads to mix time change within 30 s, while that will have no significant influence on the mix during the production and laying. Still, the definite parabolic dependence of orthophosphoric-acid-based emulsion upon the cement content witnesses about the high emulsion sensitivity to even insignificant change of cement content in the mix, while that will lead to premature mix time.

Table 2

Portland cement influence upon the mix time for Slurry Surfacing mixes based on Vyrivsky Quarry screenings

Mix design version No	Content of components, parts					Mix Time, s
	Aggregate	Cement	Water	Mix time regulator (control agent)	Emulsion	
1.1V	100,0	0,5	10,0	2,25	14,0	106
1.2 V		1,0				159
1.3 V		1,5				193
1.4 V		2,0				166
2.1 V	100,0	0,5	10,0	2,0	14,0	112
2.2 V		1,0				161
2.3 V		1,5				199
2.4 V		2,0				173
3.1 V	100,0	0,25	12,0	2,0	14,0	90
3.2 V		0,5				150
3.3 V		0,75				180
3.4 V		0,85				160
3.5 V		0,95				85
3.6 V		1,0				80
3.7 V		1,25				80
4.1 V	100,0	0,5	10,0	1,0	14,0	95
4.2 V		0,75				161
4.3 V		1,0				181
4.4 V		1,1				156
4.5 V		1,2				101
4.6 V		1,3				84

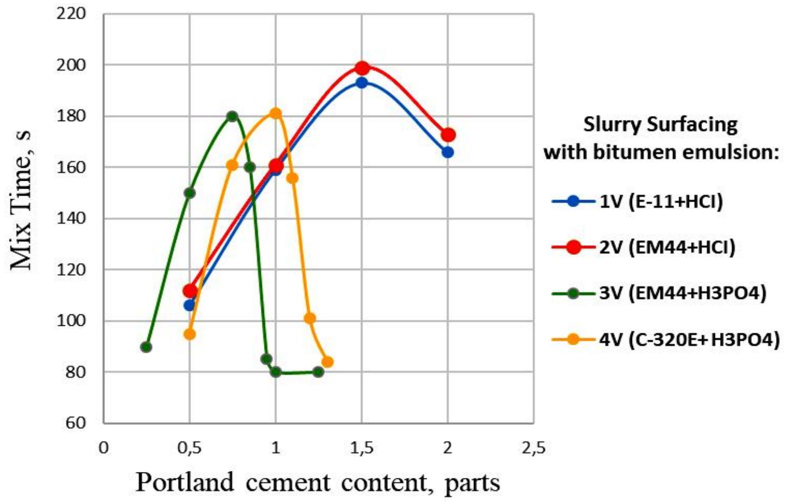

Fig. 2. Cement influence upon the Slurry Surfacing mix time with Vyrivsky Quarry screenings.

Similarly as for the Vyrivsky Quarry screenings, the investigation was carried out for the cement influence on Slurry Surfacing mix time for the Klesivsky Quarry screenings (Table 3). For this purpose there were chosen the emulsions exclusively on orthophosphoric acid, as far as those were that very emulsions which have shown higher sensitivity to cement content.

Table 3

Portland cement influence upon the mix time for Slurry Surfacing mixes based on Klesivsky Quarry screenings

Mix design version No	Content of components, parts					Mix time, s
	Aggregate	Cement	Water	Mix time regulator (control agent)	Emulsion	
3.1 K	100,0	0,25	12,0	1,8	14,0	85
3.2 K		0,5				112
3.3 K		0,65				168
3.4 K		0,75				182
3.5 K		0,85				148
3.6 K		1,0				115
4.1 K	100,0	0,5	10,0	0,9	14,0	82
4.2 K		0,75				106
4.3 K		0,9				167
4.4 K		1,0				183
4.5 K		1,1				137
4.6 K		1,2				115

The results obtained for the bitumen emulsion interaction with orthophosphoric acid (both on Klesivsky and Vyrivsky Quarry screenings – so as to provide for their comparison) are presented on Fig. 3.

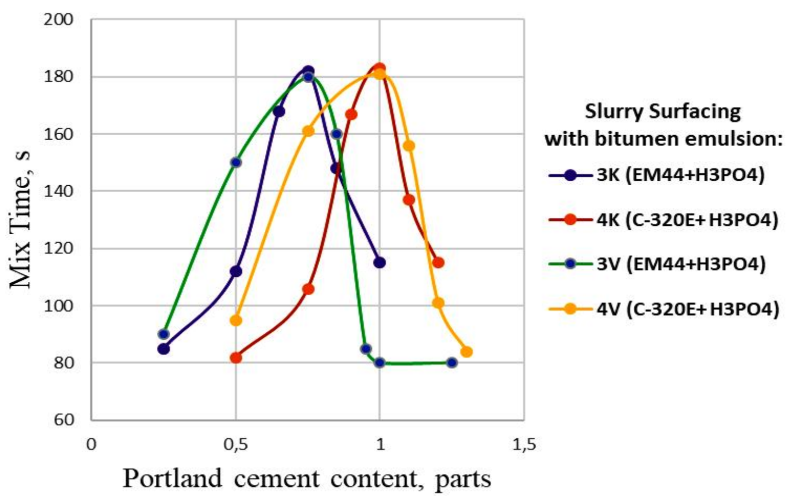

Fig. 3 Portland cement influences upon the mix time for Slurry Surfacing mixes with orthophosphoric acid and based on Vyrivsky and Klesivsky Quarry screenings

The comparison of interaction for two screenings from different quarries (with the same methylene blue value) with emulsions on orthophosphoric acid and different emulsifiers (for Slurry Surfacing mixes) provides for tracking the similarity of results and dependencies. While analyzing the results (Fig. 3) one can conclude that cement dosing is much more important for the mixes on orthophosphoric acid than for the systems on hydrochloric acids, and that is because the change of its content by 20% in the mix on H_3PO_4 leads to decrease of the mix time by two times (for 50%), in contradistinction to the system on HCI, where cement content change by 30% decreases the mix time just by 20%. Besides of that, from Fig. 3 one can see that for the systems with emulsions on orthophosphoric acid with different emulsifiers used there are different values of optimum cement content by mix time criterion – regardless of the screenings. It shows that change of aggregate (with fixed methylene blue value) will have less influence upon the mix time than change of emulsifier in emulsion.

Conclusions

Special bitumen emulsions formulations were developed for Slurry Surfacing with orthophosphoric and hydrochloric acids, same as with both specialized and all-purpose emulsifiers of amine type. Mix time was determined for Slurry Surfacing based on bitumen emulsions with different acids, emulsifiers and screenings having identical methylene blue value – depending upon the cement content in the mix. Mix time of Slurry Surfacing with bitumen emulsions on both orthophosphoric and hydrochloric acids with different cement content is characterized by parabolic dependence, branches of the parabola going down. Still, parabola slope steepness for Slurry Surfacing with cement and bitumen emulsions on orthophosphoric acid is higher than for emulsions on hydrochloric acid. Besides of that, for the emulsions on orthophosphoric acid with different emulsifiers used there are different values of optimum cement content by mix time criterion – regardless of the screenings. It shows that change of screenings (with fixed methylene blue value) will have less influence upon the mix time than change of emulsifier in emulsion.

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ОСОБЛИВОСТІ ВЗАЄМОДІЇ БІТУМНИХ ЕМУЛЬСІЙ ІЗ ЦЕМЕНТОМ ДЛЯ ТЕХНОЛОГІЇ ЛИТИХ ЕМУЛЬСІЙНО-МІНЕРАЛЬНИХ СУМІШЕЙ

Підібрано склади дорожніх катіонних бітумних емульсій для литих емульсійно-мінеральних сумішей із ортофосфорною та соляною кислотами та спеціалізованими та універсальними емульгаторами амінного типу. За допомогою лабораторної бітумно-емульсійної установки по типу колоїдного млина виготовлені бітумні емульсії емульсій із різними кислотами та емульгаторами та полімерним модифікатором латексом. Запроектовано склади литих емульсійно-мінеральних сумішей для типу 1 за нормами ISSA. Литі емульсійно-мінеральні суміші були виготовлені на основі приготовлених емульсій, цементу із гранульованим доменним шлаком, води, регулятора розпаду та гранітних відсівах із двох українських кар'єрів, що мають однакові значення показника метилену синього. Литі емульсійно-мінеральні суміші випробували за критерієм розпаду суміші, за яким час змішування компонентів для обраного типу 1 за ISSA має бути не менше 180 с. Визначення оптимальних складів за критерієм розпаду суміші проводили змінюючи вміст цементу у суміші за фіксованого значення усіх інших складників суміші. Внаслідок чого було встановлено залежності розпаду суміші від цементу. Розпад суміші із бітумними емульсіями на ортофосфорній та соляній кислотах та варіацією вмісту цементу характеризується параболічною залежності із направленими гілками параболи до низу. Проте ступінь крутизни параболи для суміші із цементом та бітумними емульсіями на ортофосфорній кислоті є вищим ніж у емульсій на соляній. Досліджена закономірність дає змогу стверджувати, що дозування цементу для суміші із бітумними емульсіями на ортофосфорній кислоті має бути ретельніше вивірене та контрольоване, щоб уникнути передчасного розпаду. Також емульсії на ортофосфорній кислоті за використання різних емульгаторів мають різні значення оптимального вмісту цементу за критерієм розпаду суміші не залежно від відсіву.

Ключові слова: бітумні катіонні емульсії, соляна, ортофосфорна кислоти, литі емульсійно-мінеральні суміші, цемент, розпад суміші.