IMPROVED JOINT SAND

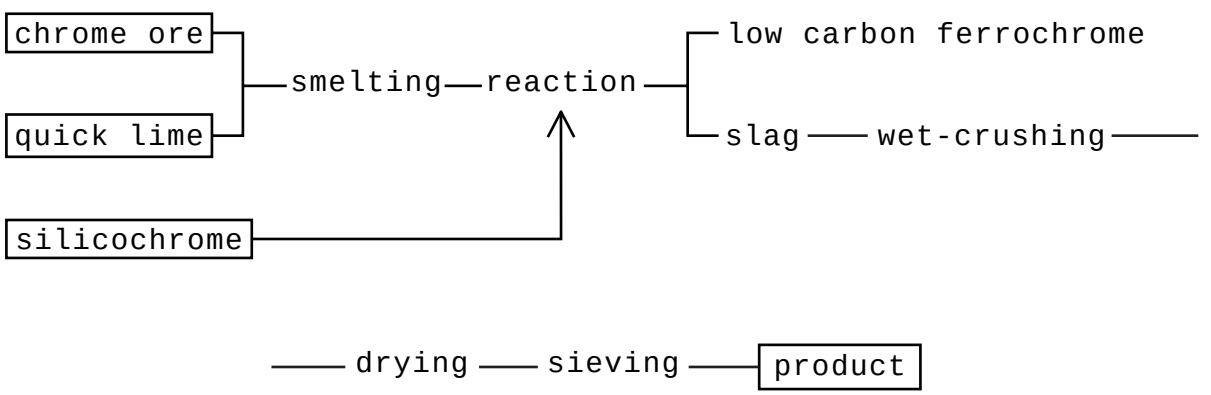
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Summary
Since joint sand used for interlocking block pavement is usually river sand and mountain sand,it has defects that weeds are apt to grow and that rains and winds wash it away.
This development of joint sand calls for hydraulic slag and water soluble high polymer to be used for joint sand in order to get rid of these defects. Hydraulic slag is a glassy byproduct which takes place in low carbon ferrochrome production. This hydraulic slag has a property that it sets in 3-6 months after water is added.Since the time until it sets is too long, powder of high polymer is mixed with it to make it set quicker so that sand cannot be washed away easily. The usage is to fill joints with it just like usual sand and then you spray water over it.
It has been five years since the test began and we have acquired good results without weeds growing and washing-away of sand by rains and winds except for special cases.

1.Hydraulic Slag

1.1 Production Method of Hydraulic Slag

The production method of hydraulic slag is shown below;



Chrome ore and quick lime are smelted at high temperature to produce slag which is wet-crushed, dried and sieved to adjust particles into the final product of hydraulic slag.

1.2 Chemical Composition of Hydraulic Slag

The chemical composition of hydraulic slag is shown in Table 1.

Table 1 Chemical Composition of Hydraulic Slag

Component	CaO	SiO_2	Al_2O_8	MgO	FeO	density
Weight %	47~52	28~30	7~12	8~11	0.1	1.6

As you can tell from the chemical composition(Table l),CaO and SiO_2 occupy approximately 80% and no such components as harm human health and environment are not included.

The phenomenon for this hydraulic slag to set with addition of water is based on hydration of 2-calcium silicate (2CaO.SiO2, hereafter abbreviated as C2S) which is the main component in hydraulic slag.

The reaction of this C2S is so slow that some bonding agent is necessary in order to raise preliminary strength.

Hydration speed of main components contained in cement is shown in Fig.1.

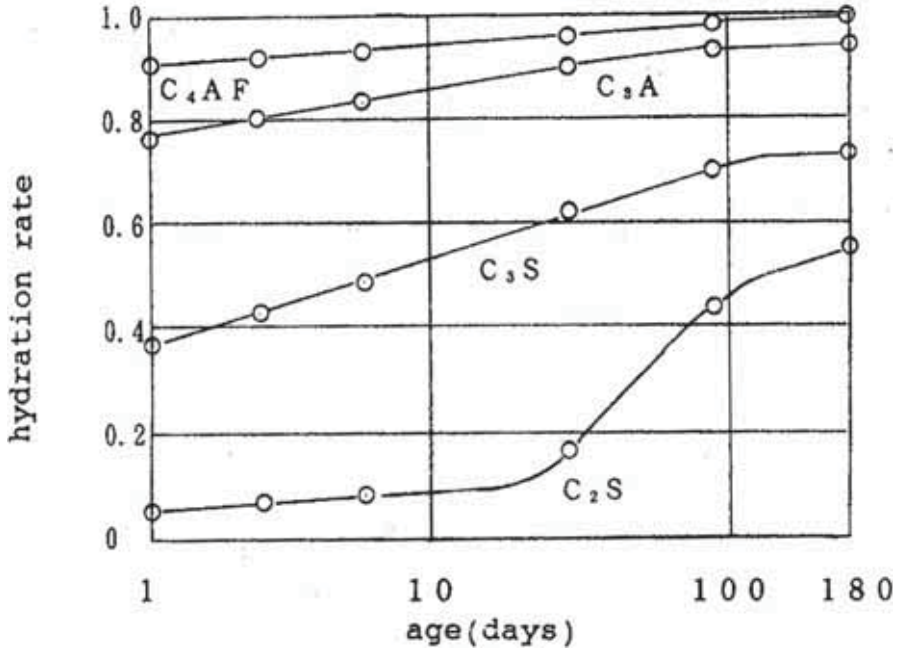


Fig.1 Hydration Speed of Pure Compounds

1.3 Particle Size of Hydraulic Slag

The particle size distribution is shown in Table 2.

Table 2 Grade Distribution of Hydraulic Slag

Sieve Mesh (mm)	2.5	1.2	0.6	0.3	0.15
Sieve Passages (%)	100	91	68	32	12
Fineness Modulus	1.97				
Average Grade (mm)	0.3~0.6				

As the particle size is adjusted to less than 2.5mm, it can easily fill joints.

2.Selection of Bonding Agent

2.1 Experiment 1 The setting situation when water soluble high polymer resins are mixed

1) Bonding Agent
starch(1.5%) and carboxymethylcellulose(1.5%)
cornstarch(3%)
cornstarch(2%) and carboxymethylcellulose(1%)
polyvinylalcohol(3%)
polyacrylamide(3%)
polyacrylic soda

2) Experiment Method
(1) A mixture of hydraulic slag (lOOgr), water (50gr) and the bonding agent was put into a round container, (test sample with dimensions 8x8cm, four 0.5mm holes)
(2) Luring at 20 C, the situation after 3 hours,6 hours and 24 hours was observed.

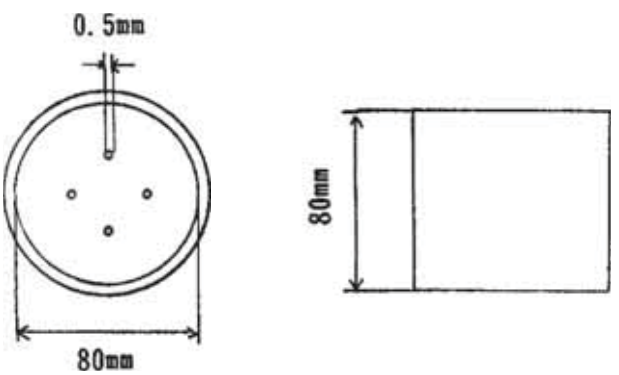


Fig.2 Container for Test Sample

◎ Excellent ○ Good x No Setting

No	Bonding Agent	Mixing Rate (%)	Setting Situation		
			3 hours	6 hours	12 hours
1	Starch Carboxymethylcellulose	1. 5 1. 5	○	○	○
2	Cornstarch	3	○	○	○
3	Cornstarch Carboxymethylcellulose	2 1	○	○	○
4	polyvinylalcohol	3	◎	◎	◎
5	Polyacrylamide	3	x	x	x
6	Polyaerylie soda	3	x	x	x

As polyvinylalcohol showed the best result, further study was made with inorganic bonding agents.

2.2 Experiment 2 In order to inspect the setting situation of polyvinylalcohol which showed the best result in the experiment and inorganic bonding agents, the resistance when a needle used in the cement setting test was penetrated at a certain speed was measured.

1) Bonding Agent
portland cement(10%,5%,2%)
calcium chloride(3%,1%)
calcium nitrite(3%,1%)
quick lime(5%,2%)
water soluble high polymer resin(3%)

2) Experiment Method
(1) A mixture of hydraulic slag(1,OOOgr), water(300gr) and the bonding agent was put into an aluminum can. (test sample with dimensions 10x10cm)
(2) Lured at 20 C for 3 days
(3) The resistance when a needle used in the cement setting test was penetrated at a certain speed was measured.

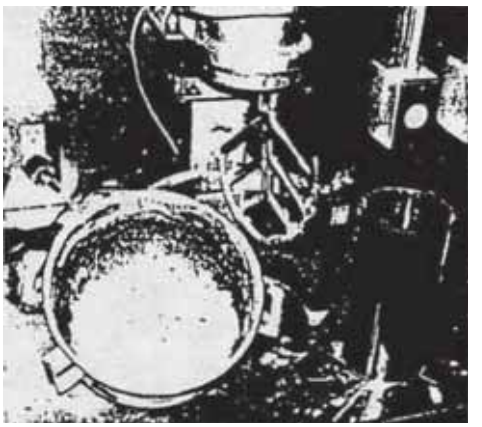


Fig.3 Mixer and Aluminum can

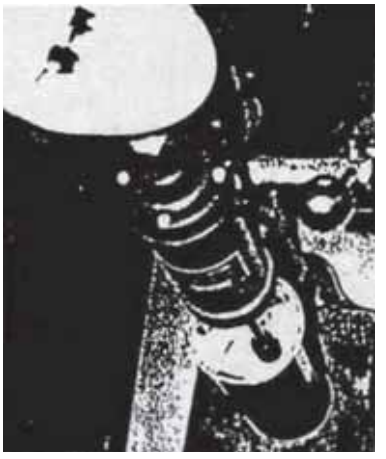


Fig.4 Measuring of the Resistance

3) Experiment Result

No	Bonding Agent	Mixing Rate (%)	Resistance (psi)
1		2	420
2	portland cement	5	1,295
3		1 0	3,760
4	calcium	1	63
5	chloride	3	114
6	calcium	1	67
7	nitrite	3	60
8	quick lime	2	2,560*
9		5	3,680*
1 0	polyvinylalcohol	3	98

*Cracks took place in the test sample.
If 2% of portland cement is added, the resistance is bigger than polyvinylalcohol(water soluble high polymer resin), but in the actual test on interlocking blocks, cement powder contaminates the surface of the block.
Though the resistance of calcium chloride(3%) is as high as 114(PSi) showing a good setting situation, it also contaminates the surface of the block like cement.
After research on inorganic as well as organic bonding agents, we have found out that polyvinylalcohol(water soluble high polymer resin) is best.

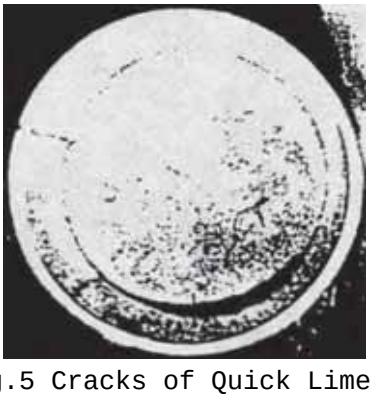


Fig.5 Cracks of Quick Lime

3.Site Situation

The implementation method is almost the same as filling river sand in the joint, that is, this joint material is taken out of a bag to be spread over laid interlocking blocks and swept over by broom or the similar to fill in the joint, after that it is compressed by compactor. Extra material is cleaned and the joint is watered sufficiently.
The Photo 1 shows a site in Chiba-ken implemented in 1992. Around the place is an athletic park where it is very likely for weeds to grow but no weeds are growing and no joint sand is washed away after 4 years.
The Photo 2 is a photo of the same place but of after repairing work around the electric pole. River sand was used then and weeds grew exclusively in the place where river sand is used.



Photo 1 Appearance of the Site



Photo 2 After Repairing Work

4.Conclusion

The properties of this joint material with water soluble high polymer resin mixed with hydraulic slag are;

1)It is very effective to prevent weeds growth

2)It prevents washing-away of sand by rain falls.

The main reasons for 1) are;

(1) weeds' seeds are difficult to get in as it is calcined and dried in the production process,

(2)It inhibits germination and growth of weeds' seeds due to its weak basic property,

(3) The main component is calcium silicate and contains nothing to help plants to grow.

The main reasons for 2) are;

(1) Hydraulic slag sets,

(2) Water soluble high polymer resin sets.

As it takes 3-6 months until hydraulic slag sets, water soluble high polymer resin is mixed and this resin begins working when it gets dry after spraying water.

Washing-away by normal rain falls is prevented by virtue of the combined effects of hydraulic slag and water soluble high polymer resin.

The strength at the setting state of this joint material is not as high as that of mortar and the water soluble high polymer resin has water-resolubility which enables blocks to be replaced easily.

Therefore, such properties of interlocking blocks which use sand for the joints as the load-distribution property and the principle as flexural pavement are not lost.

Its recent application is extending to the joints of colored flag stone and brick pavements and in some special cases, such a joint material mixed with high polymer resin with no water-resolubility is coming to be used.

Last but not least, I wish to express my greatest gratitude to Cement Concrete Laboratory of Chichibu-Onoda Corporation for their kindest cooperation in regard to developing this joint material.

References

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