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The Study of Mixture Design for Foam Bitumen and the Polymeric and Oil Materials Function in Loose Soils Consolidation

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Abstract Due to the enormous growth of new chemicals, especially polymer materials in construction projects, and the importance and effectiveness of these new materials in poor soil stabilization, recently has closed chemistry and polymer sciences to civil science. The use of materials such as bitumen in stabilization of flowing and loose soil and using of polymer resins reflects the effect of these substances is very high on construction projects. Considering the importance of oil and polymer materials in soil stabilization, in this study performance of polymer materials and their comparison have been investigated. Oil materials such as bitumen can be used to stabilize the soil, and polymer resins such as polyvinyl alcohol and polyvinyl acetate, and also pointed polypropylene synthetic fiber can be considered as polymer materials. Bitumen foam is one of the fixative materials that obtain by adding water to hot bitumen, and is applicable to a wide range of stone materials. In addition to, polymer resins increase the burden go loose soils. Polymer fibers due to high durability and easy application and no problem at saturation conditions are highly regarded by civil engineers.

Keywords Soil stabilization, Bitumen, New chemical materials, Polymer resins

1. Introduction

Use of materials such as bitumen in stabilization of flowing and loose soil and using polymer resins reflects the importance of these substances on construction projects. Each pavement rehabilitation require a certain time period that best rehabilitation method chooses according to the road conditions. One method for rehabilitation is implementation of coating. The main problem is limitation of high quality materials and asphalt factories, which lead to increase costs of transportation of materials to the project site. Nowadays, advancement of technology in cold recycling machines minimizes these problems.

Foam bitumen produces by adding a small amount of water (2-3% by weight of bitumen) to hot bitumen (160-180 ^{o}C). After injection of water to hot bitumen, the water evaporates suddenly and leads to explosive bitumen foaming in the saturate stream.

2. Material and Methods

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2.1. Foam Bitumen

Figure 1 shows internal system of cold recycling machine. In this figure the asphalt pavement has been destroyed and need cover that is fixed by foam bitumen. A protective asphalt layer with thickness of 3 cm places on the stabilized basis of foam bitumen. Thickness of asphalt layer depends on the volume of traffic passing. This reduces costs of material transportation [1].

The foam bitumen produces when small amount of water add to hot bitumen. After water injection into the hot bitumen (figure 2), bitumen is formed into steam that consists of thousands of tiny foam vapor, and bitumen easily coat around the cold aggregates and increases the adhesion between materials [2]. This method can simply be implemented in most Iran streets. Streets that need rehabilitation the overall improvement of streets that needs to be coated. Destroyed asphalt pavement turned into the foam bitumen with this method and a layer of protective asphalt adds to it.

2.2. Advantages of using Foam Bitumen

Easy to use: similar to the bitumen emulsion, Foam bitumen can be used to stabilization of recycled materials by attachment of bitumen reservoir and foam chamber to recycler machine [1].

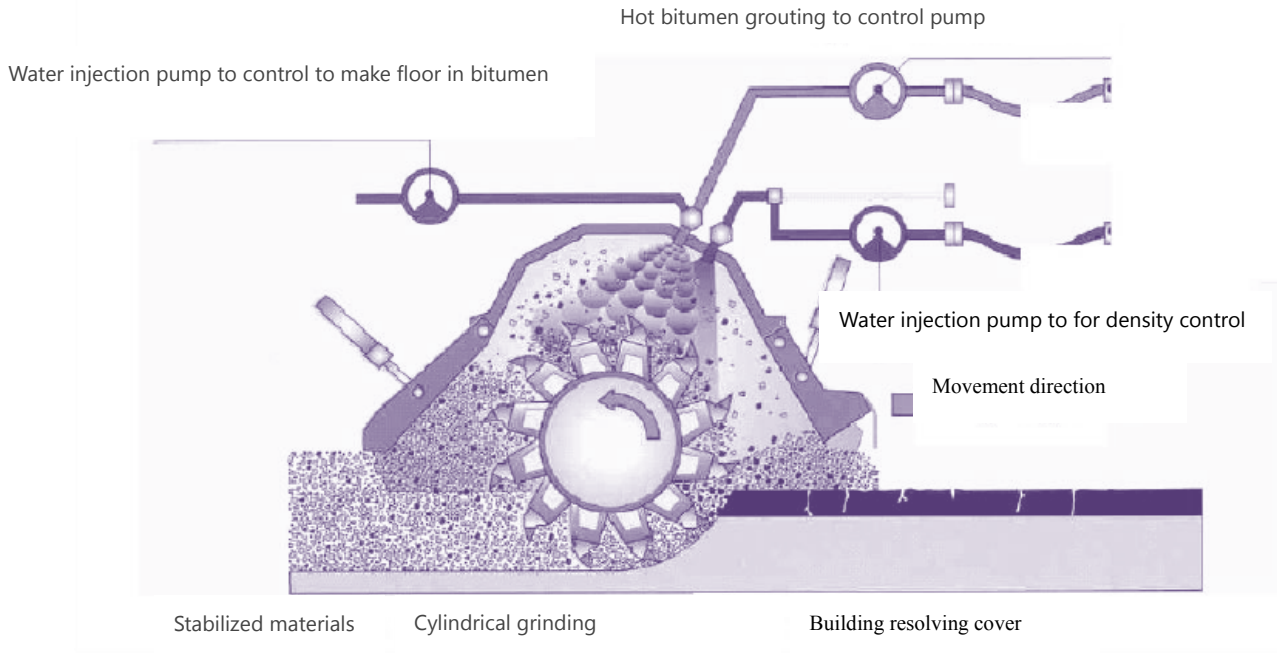

Figure 1. Ground system and distribution of the conversion of bitumen floor covering based on established dissolve

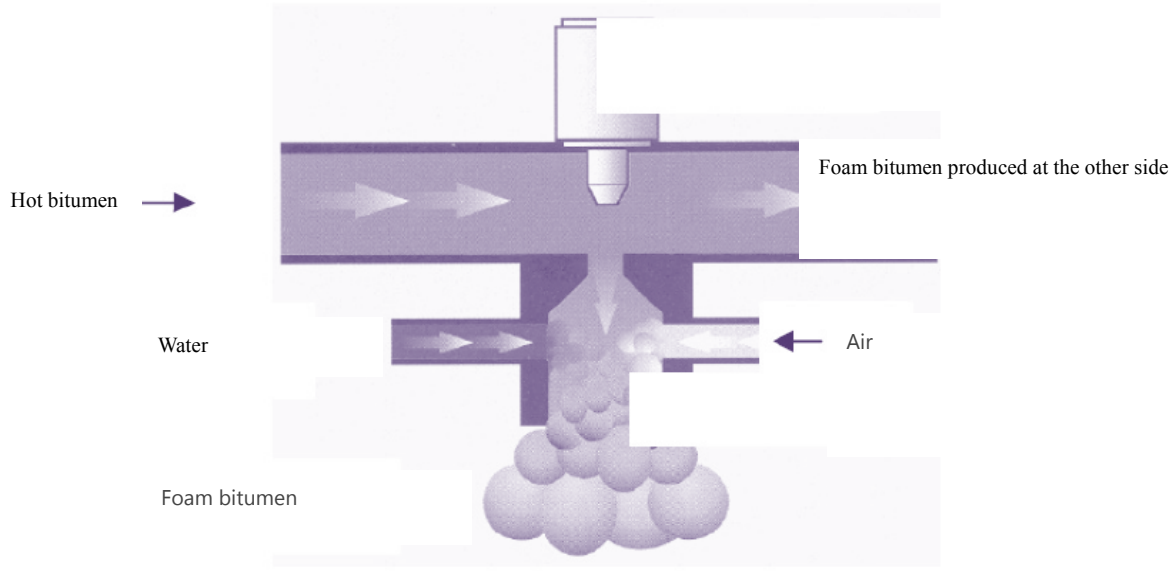

Figure 2. The process of foam bitumen production

Robust and flexible pavements: stabilized materials with foam bitumen contain flexible mortar that adhere large pieces to together. Therefore, have the resistance to deformation and fatigue properties for example fixed materials with cement have low fatigue properties [1].

Economic: foam bitumen obtains from bitumen with the standard penetration thus has not the factory cost. Stabilized materials with foam bitumen have the lower cost than stabilized materials with bitumen emulsion [1].

Strength gaining speed: stabilized materials with foam bitumen are reopened on traffic faster than stabilized materials with cement [1].

Very low environmental impact: During the curing process, volatile and evaporated materials will not emit from mixture [1].

Implementation in bad weather conditions: pavement layers can be stabilization using foam bitumen in bad weather conditions, such as cold weather or light rainfall without negative impact on functionality or quality of the final layer [1]. However, these materials cannot be used for soil stabilization due to environmental problems and fuel costs. Other materials such as PVA and PVA care polymer

materials that were investigated. Characteristics of these two polymers are shown in table 1 and 2 and their chemical formulas are shown in figure 3 and 4.

Table 1. Polyvinyl acetate characteristics

Appearance	White and soppy
Viscosity in 25 ºC	1.19
pH	4-6
Viscosity (Pas)	Molecular weight changed under different temperature
Particple size (μ)	0.1-3
Specific bulk in 28 ºC (l/kg)	0.84
Denaturation temperature (ºC)	150
Elasticity (Gpa)	1.275-2.256
TENSIONAL tolerance (Mpa)	29.4-49

Table 2. Polyvinyl alcohol characteristics

Appearance	White crystal
Non-crystal viscosity (gr/cm^3)	1.26
Crystal viscosity (gr/cm^3)	1.35
pH in 5% solution	5-6.5
pH in water solution	Neutral or a bit acidic
Viscosity (m.Pa)	28±4
Melting point (ºC)	180-190
Molecular weight (gr/mol)	30-36.3

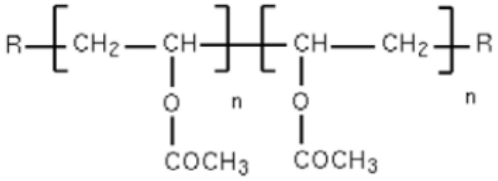

Figure 3. Polyvinyl acetate

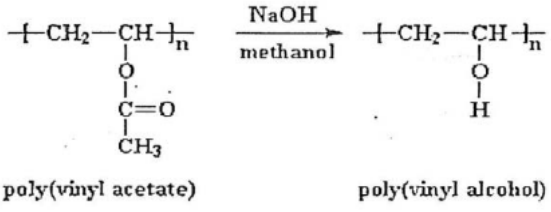

Figure 4. Polyvinyl alcohol Fibers

Stabilization of foam bitumen usage is increasing in worldwide because of safety benefit and high performance characteristics; quality of foam bitumen is investigated by two experimental parameters including half life time and expansion ration. Expansion ratio assesses the viscosity of the foam and determines its diffusion in the mix. Half-life assesses the stability of foam.

Triaxial test use to determine the fundamental strength characteristic in foam bitumen. After determination of the surface strength properties we can use other materials to bitumen layers.

Triaxial test equation is as below:

SR= $\frac{\sigma_d}{\sigma_{d,f}}$ SR= stress ratio, σ_d = deviator stress, $\sigma_{d,f}$=deviator stress at failure

Triaxiad test is defined as a test that measure stress in 3 perpendicular directions. This test is applied to measure the material strength.

2.3. Polyvinyl Acetate Resin (PVA)

Polyvinyl acetate is a polymeric material that obtains from free radical vinyl polymerization with vinyl acetate monomer origination. This material firstly was discovered and prepared by Fritz Klatte in Germany in 1912. This material is known as abbreviated name of PVAc in commerce and industry [3]. PVAc formulations are shown in Figure 3.

Further researches showed that application of this adhesive material improves soil structure, increase water infiltration and increase soil strength grain. In summary, the application of this material prevents erosion caused by wind and water [4].

2.4. Polyvinyl Alcohol Resin (PVA)

Polyvinyl alcohol was first prepared by hydrolysis of polyvinyl acetate in methanol in the presence of potassium hydroxide by Hermann and Haehnel in 1924. The acetate groups are hydrolyzed by ester interchange with methanol in the presence of aqueous sodium hydroxide and polyvinyl alcohol is produced (5).

The formulation of polyvinyl alcohol is shown in Figure 4. Polyvinyl alcohol is an odorless substance, translucent or opaque; with white or cream colored crystals that has crystal structure. Degree of its solubility is higher than 85 °C. It has high strength and stiffness. Its strength properties depend on moisture content. Increase in moisture content lead to reduce the tensile strength [6, 7]. Some of its characteristics are shown in Table 3. Other properties of this material are non-toxic, non-corrosive and non-contaminated water [8, 9]. In 1974 Stefans on stabilized the sandy loam soil using polyvinyl alcohol without any harmful effect on the environment and plant growth [10].

Yarn use for reinforcement, polypropylene fibers with a size of 12 mm and the weight percentages of 0.1 0.05, 0.25 and 0.15 were studied. These fiber properties are presented in Table 3. The soil that was examined in this study was selected from sandy-silt soils in Isfahan, Iran city that its characteristics are presented in Table 4. Soil combined with the Yarn and resin matrix was studied by laboratory CBR test that results showed in figures 8 and 5, 6, 7. These results indicate high performance of materials for soil stabilization.

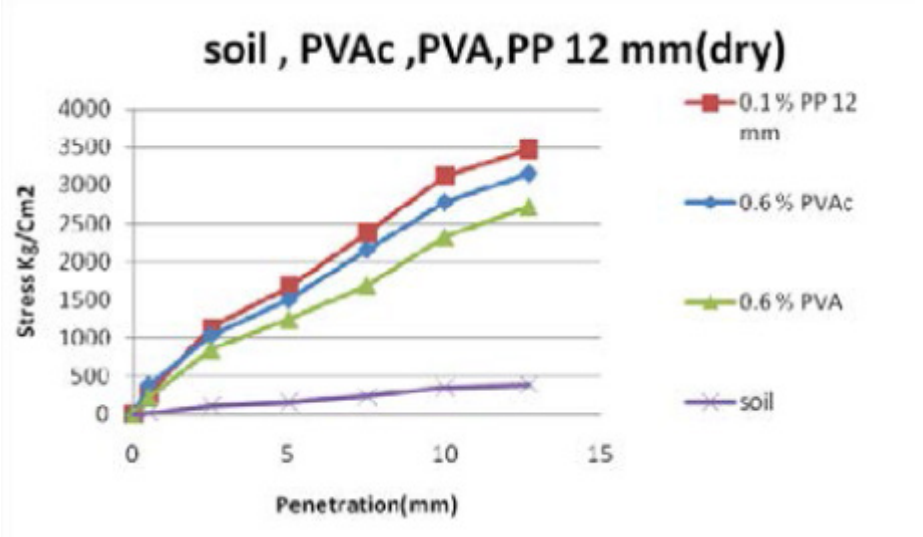

Figure 5. Power curve CBR experimental pressure of yarn and resin samples in dry condition

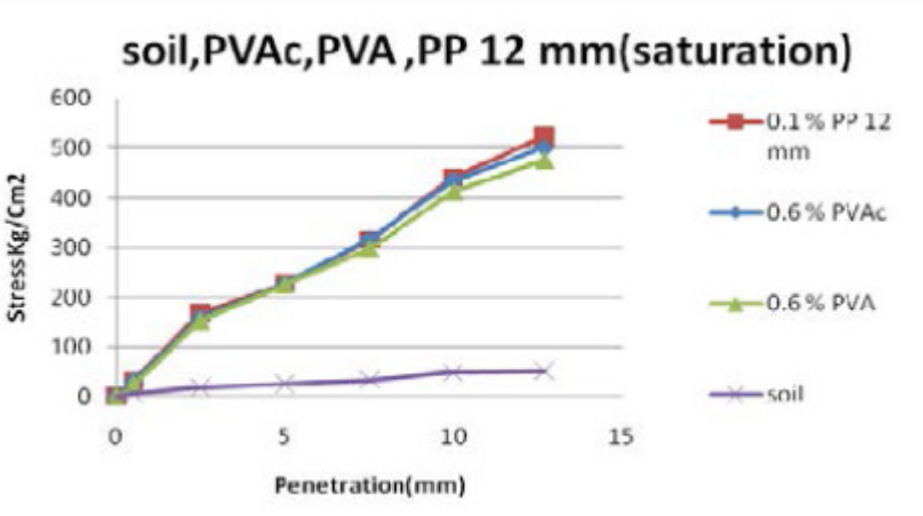

Figure 6. Power curve CBR experimental pressure of yarn and resin samples in saturated condition

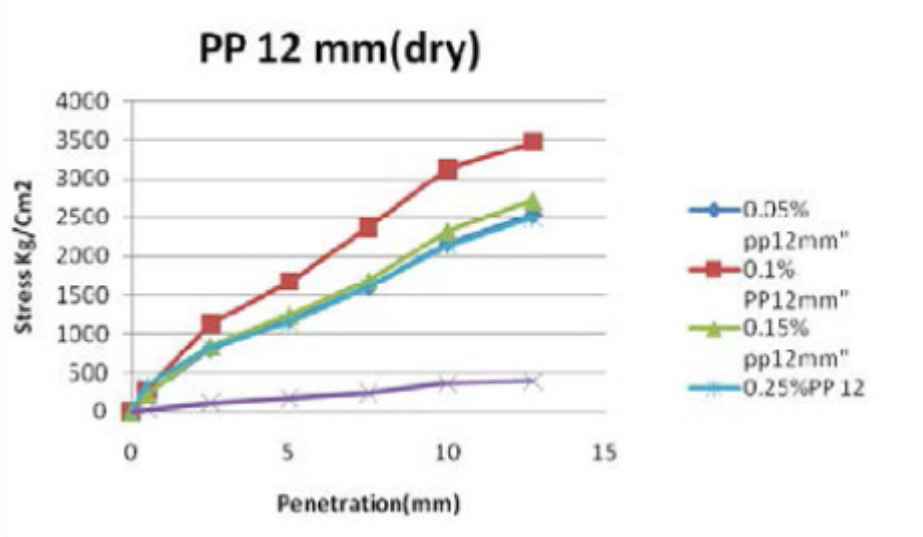

Figure 7. Power curve CBR experimental pressure of yarn sample in dry condition

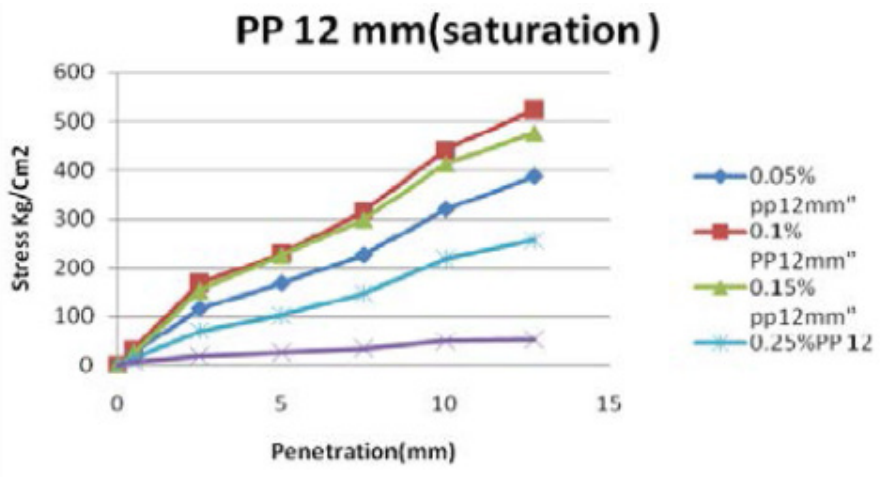

Figure 8. Power curve CBR experimental pressure of yarn sample in saturated condition

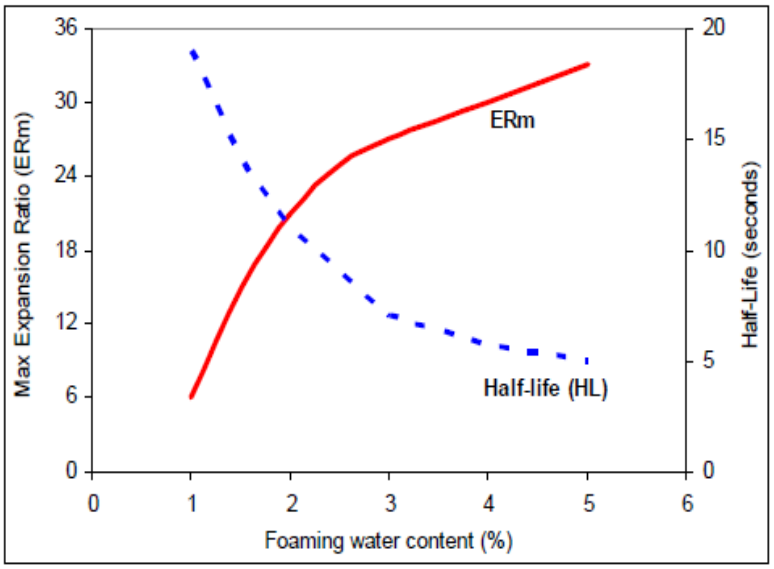

Figure 9. Characteristics of foamed bitumen in terms of maximum expansion ratio and half-life

Table 3. Consumed yarn characteristics

Appearance	White
Bulk density (gr/cm^3)	1
Diameter (μ)	23
Elasticity (Gpa)	400
pH in water solution	160-165
Buffer ability	High
Salt tolerance	High

Table 4. Soil characteristics

characteristics	Amount	Standards
Soil type	(A-2-4)	AASHTO
Classification	SM based on unified classification	ASTM-D2478
Participle kind	Sandy silty	
Specific bulk density	2.94 (gr/cm^3)	ASTM 854
Flow limitation	34.67 %	
Mash limitation	27.04 %	ASTM-D4318

3. Results and Discussion

Figure 9 show characteristics of foamed bitumen including expansion ratio and half-life. It can be seen that expansion ratio increases with increasing foaming water content, whereas the half-life values tend to decrease.

Addition the small amount of stabilizer to recycled materials in cold recycling process compensates resistance required with less cost. Foam bitumen is a kind of stabilizer that obtains by adding small amounts of water to hot bitumen. By injection water into hot bitumen, bitumen volumes increase temporarily (about 15 times) and its viscosity decrease significantly. In this status, bitumen is appropriate material for mixing with cold and wet aggregates (like recycled materials). The amount of water that is added to the bitumen obtains according to foam characteristics (half-life and expansion ratio). When the bitumen stabilized materials, in case of shortage of bitumen content, 0.5-2% cement add to it. Sampling of some of the pieces is needed to ensure the

amount of fine aggregate before consolidation of destroyed layer with foam bitumen. Stabilization with foam bitumen compare with other stabilizers has less thickness and cost for asphalt pavement reconstruction.

Researcher assessed the effect of bitumen grade. They found low bitumen grade (90pen) to give a material to repeated loading is better than using high bitumen grade (200pen), but the effect under repeated load was less than under monotonic load. Others have reported the effect of foamed bitumen characteristics on mixture properties. They have assessed the effect of expansion ratio and half-life on the characteristic of foam mixture flow. Fine sand aggregate (nominal size 1.18 mm) was mixed with 4% foamed bitumen Pen 200/300. The foams covered an expansion ratio range of 5 to 20 and a half-life range of 11 to 136 [6].This method is suitable for roads with structural failure and peaks and valleys in comparison with coating. Most cities in Iran, especially Tehran, faced with this problem and the method that explains in the present study can be used for problem solving.

If aggregation of water in foam bitumen occurs incorrectly, the quality of fine materials is insufficient and finally bitumen becomes unworkable. In addition to, is water and materials have been made correctly but these components are not accompanied by proper method, the mixture will be inconsistent and its efficiency will be undesirable [10].

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