NANOTECHNOLOGY SETS NEW STANDARDS FOR SUSTAINABLE WATER RESISTANT PAVEMENTS

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Aggregates are water loving in nature. The bound moisture in aggregates due to precipitation, sudden rain or temperature drops cause issues during mixing, laying and pavement service life. The moist aggregates are highly susceptible moisture and cause de-bonding / premature failures.

Residual moisture in aggregates is a catalyst for reaction of new generation Organo Silane additive and creates substantially stronger bonding between bitumen binders and aggregates to give excellent resistance to prolonged moisture.

Time & Temperature extension on existing standards like ASTM D3625 Boil test, AASHTO T283, EN 12697-11 Rolling Bottle Test, ITSR EN 12697-23 point to an increase in the point of failure. It is concluded that there will be an extension of life of the bituminous layers / mixes due to chemical bonding of Organo Silane.

KEYWORDS

Nanotechnology, Organosilane compounds, Asphalt pavement, Moisture sensitivity, Antistrip, adhesion promoter, chemical bonding

INTRODUCTION

Asphalt concrete is the most common of the materials used to build and maintain roadways in the world, mainly because of their properties like elasticity, stability, durability, and moisture resistance when combined effectively to make HMA pavements. Common cause of failure for asphalt pavements is moisture-related distress. Moisture damage causes early loss of strength and durability caused by residual moisture in mixes as moisture penetrates asphalt-aggregate mixture.

Another mechanism of moisture damage is water entering the asphalt through absorption, reducing the cohesive strength of the HMA, and causing the mixture to lose stability. This is , termed as cohesive failure.

Residual moisture in HMA adversely affects pavement performance during the service life. While preparing hot asphalt mixes the presence of residual moisture escaping in form of vapour disrupts the coating. It also weakens asphalt-aggregate adhesion, thereby reducing mix strength and pavement strength. The weakened bonds in mixes cause stripping.

Typical residual moisture content ranges from 0.1 to 0.2% by weight of aggregates, in case of porous aggregates it can be even higher. Complete water removal from porous aggregates is very difficult in the limited mixing time available in a drum / batch plant.

In order to assess effect of residual moisture, two mixes were prepared in the laboratory, one with no residual moisture and the other with 0.1% residual moisture, using Pen. 70/100 bitumen binder and Otterbo (Granite) aggregates. The adhesion promoter organosilane was added to the bitumen binder to study the benefits in improvement in % retained coating after extended conditioning in water.

The new generation Organo-Silane additives to asphalt, aid faster wetting and substantially improve the coating efficiency.

New generation organosilane additives to the asphalt ensure chemical bonding between aggregates and asphalt. They not only bring down water susceptibility but also allow reduction in HMA mixing temperature (by 15 to 20 ^{o}C) and laying & compaction temprerature (by about 30 ^{o}C), reducing the fuel consumption by 7 to 10 %.

Zycotherm Organosilane contains three alkoxy groups. Alkoxy groups (OR') can form siloxane (≡Si-O-Si≡) bonds with Hydroxy (Silanols) groups of aggregate by chemical reaction. The R group contains long chain alkyl group that interacts with asphalt to provide lubricity and wetting with asphalt binder.

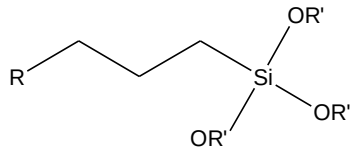

FIGURE 1 Zycotherm Molecule

R=Long Alkyl chain (C_{16}-C_{21})

OR'=Mineral reactive alkoxy group

ZycoTherm being polar in nature (water soluble) migrates to the polar water-loving surface and reacts with the silanol groups and condense to form a siloxane bond. Alkoxy group breaks and allows (RSi-) to react with SiOH to form Si-O-Si Siloxane bond. Now the silanol surface has been converted at nano level to chemically bonded siloxane with pendent alkyl group. This Alkyl Group is now compatible with maltenes in the asphalt and improves wetting, by reducing interfacial surface tension to give pinhole free surface and allow air to be released completely, forming a tightly bonded layer on the interface.

The reaction between substrates and Zycotherm can take place as follow:

≡Si-OR'	+	OH-Si---	⟶	≡Si-O-Si---	+	HOR'
Zycotherm		Aggregate		Siloxane bond		Alcohol

Aggregate-Asphalt Binder Bonding

- Aggregates are highly polar material because of surface silanol groups
- Asphalt binder contains 5-10 % Polar components
- Typically only 5-10 % of polar asphalt binder components are available for bonding with polar aggregate (Polar-Polar Interaction)
- Zycotherm additive reacts with polar silanol groups of the aggregates to convert the surface to a non-polar siloxane surface
- Zycotherm makes 90-95 % non-polar components of asphalt binder available for bonding with modified aggregate non polar surface (Non-polar-Non-polar Interaction)
- Zycotherm interaction with aggregates and asphalt binder provides better workability for mixing and compaction of HMA.

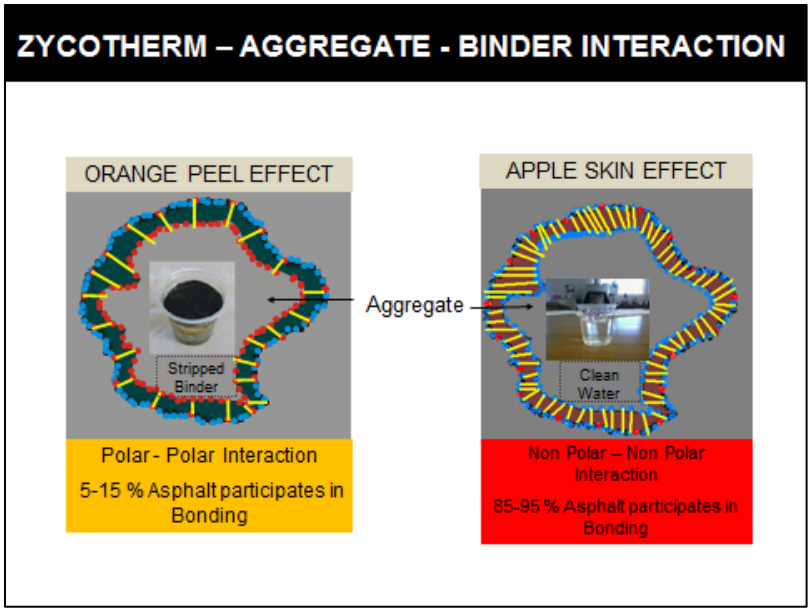

Table 1 and 3 indicates difference in stripping value evaluated of the mix as per ASTM D 3625, Table 2 indicates difference in stripping value evaluated as per EN 12697-11 and Table 4 indicates the improvement in strength and eliminate moisture susceptibility.

LABORATORY STUDY

The laboratory studies of HMA containing residual moisture with and without Organosilane additive (ZycoTherm) in bitumen binder were conducted in independent laboratory.

1. Veidekke Testing Laboratory, Trondheim, Norway

- Granite aggregates with Pen. 70/100 binder for HMA mix was used,
- Asphalt binder Pen 70/100 with and without 0.1 % organosilane were used to study improvement in % retained coating due to chemical bonding.
- 0.1% residual moisture on aggregates created by water spray on the dried aggregates before pouring of bitumen.
- ASTM D 3625 and EN 12697-11 moisture susceptibility test methods were used for evaluation of effect of moisture in HMA mixes. The results are illustrated in Table-1 & 2.

TABLE 1 Boil Test Results (ASTM D 3625)

Sample	Additive	Aggregate with residual moisture (0.1% by weight of aggregate)	% Retained Coating		
			10 min	30 min	60 min
1	Organosilane (ZycoTherm)	No	100	100	100
2	Organosilane (ZycoTherm)	Yes	100	100	95
3	No	No	70	55	35
4	No	Yes	20	15	10

TABLE 2 Rolling Bottle Test Results (EN 12697-11)

Sample	Additive	% Retained Coating		
		10 min	30 min	60 min
1	Organosilane (ZycoTherm)	90	50	35
2	No	85	25	5

2. Zydex Industries, Vadodara, India
   - Basalt aggregates with VG 30 binder for HMA mix was used,
   - Aggregates with 0%, 0.1%, 0.3%, 0.5% and 1.0% residual moisture were used for studying the effect of moisture susceptibility
   - Asphalt binder VG 30 mixed with and without 0.1 % organosilane were used to study improvement in % retained coating due to chemical bonding.
   - 0.1%, 0.3%, 0.5% and 1% residual moisture created by water spray on the dried aggregates before bitumen binder addition for mix preparation.
   - 1% water spray on loose hot mix before compaction and preparation of Marshall mould to simulate the rainy field condition.
   - ASTM D 3625 and AASHTO T165 Marshall Stability test methods were used for evaluation of effect of moisture in HMA mixes. The results are illustrated in Table-3 & 4.

TABLE 3 Boil Test Results (ASTM D 3625)

Sr. No.	Sample	Water spray	100% Coating time	% Retained coating on aggregates			
		%	Sec.	30 min	60 min	3 hr	6 hr
1	VG 30	0	35	85-90	85	65-70	55-60
2		0.1	35	85	85	65	55
3		0.3	37	85	80-85	65	55
4		0.5	40	85	80	65	55-60
5		1	40	85	80	55-60	45
6	VG-30+ 0.1% ZT	0	25	100	95-100	85	75
7		0.1	27	100	95-100	85	75
8		0.3	30	100	95-100	85	75
9		0.5	32	100	95-100	80	65-70
10		1	32	95-100	90-95	75	60

TABLE 4 Effect of Water on Compressive Strength of Compacted B ituminous Mixtures (AASHTO T165)

S. No	Sample	Water Spray on hot aggregates before binder addition	Water spray on hot mix before compaction	Bulk Density	Stability	Flow Value
		%	%	gm/cc	kg	mm
1	VG-30	0.1	1	2.439	1056	5.88
2	VG-30	0.3	1	2.428	995	6.12
3	VG-30	0.5	1	2.412	875.5	5.86
4	VG-30 + 0.1% ZycoTherm	0.1	1	2.442	1156	5.96
5	VG-30 + 0.1% ZycoTherm	0.3	1	2.406	1037	6.21

Results and Discussions

These results suggest that ZycoTherm improves moisture resistivity of HMA mix resulting in higher Marshall strength with maintained flexibility (flow value).

Conclusions

Based on the lab tests it can be concluded that organosilane based ZycoTherm additive can offer ease of mixing, improved coating, moisture resistance and strength. It can substantially improve the stripping resistance of bitumen mixes.

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