NANOTECHNOLOGY FOR PAVEMENT LIFE EXTENSION CASE STUDIES IN INDIA OVER 7 YEARS

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Organo-Silane compounds have been in use in pavement construction in India and world over and its use is fast picking up following positive results in terms of moisture resistance and other benefits.

The paper presents case studies sharing experience of use of new organo-silane nanotechnology in pavement construction in India, over last 7 years. The case studies cover field applications of organosilanes with different construction materials across different weather conditions in India.

Long term study of pavements built with this new technology reveals substantially lower pavement distress, which is indicative of efficacy of the new technology in dealing with variety of construction materials and overcoming different adverse climatic conditions.

KEYWORDS: Nanotechnology, Organosilane compounds, Moisture sensitivity, adhesion promoter, chemical bonding

INTRODUCTION

Effective road transport is essential for developing countries like India, for long term sustainable growth, contributing to the economy.

It is also important to ensure that the road infrastructure being built is long lasting and does not call for frequent maintenance.

New generation of organosilanes address issues related to different layers of the road, from sub-grade soil to top asphaltic layers, to make the roads long lasting and maintenance-free. The key benefits are as follows.

- Nanotechnology based treatment of soil substantially reduces water permeability and drastically improves CBR values when used with polymers / cement. This allows either full replacement or thickness reduction of Granular Sub Base, leading to **reduced stone consumption**. The organosilane resolves critical issues like
- Loss in strength and expansion in wet conditions for soil sub grade
- Reduce water permeability of soil bases while maintaining 100% vapour permeability
- Utilization of in-situ soils
- Maintains frictional values between silt, sand, clay particles leading to retention of strength and resistance to deformation
- Nanotechnology based additives to bitumen emulsions make the bond coats penetrative and chemically bound to surfaces. This gives much better surface coverage and waterproofing at much lower residual bitumen content, leading to **substantial saving in bitumen consumption**.
- Nanotechnology based additives to bitumen binder ensure chemical bonding between aggregates and bitumen. It 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 %.**

1. Case Study – Bharthana Bharthali Village, Dist. Vadodara, Gujarat (YR 2010)

Road section of Bharthana-Bharthali, Karjan Taluka of length **700** meters with 8 meter average width was selected. This road was water logged for 60 days every monsoon with poor drainage resulting into repairs every year.

The soil was of high clay content BC soil of CBR 1.29 - 2. Laboratory test observations of the black cotton soil are as under.

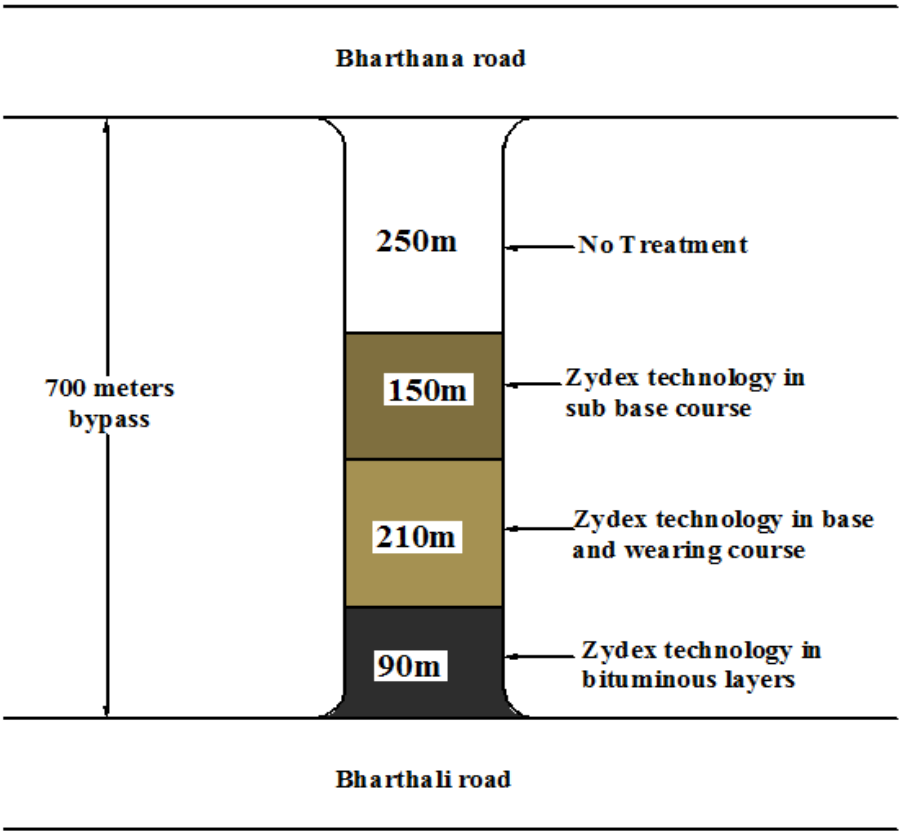
Existing Soil properties

Sieve analysis	Atterberg limits	IS classification	Density: MDD	OMC	CBR
Gravel: 2%	LL:53 PL:30 PI:23	CH	1.44gm/cc	20%	1.29
Sand: 9%					
Silt &clay: 89%					

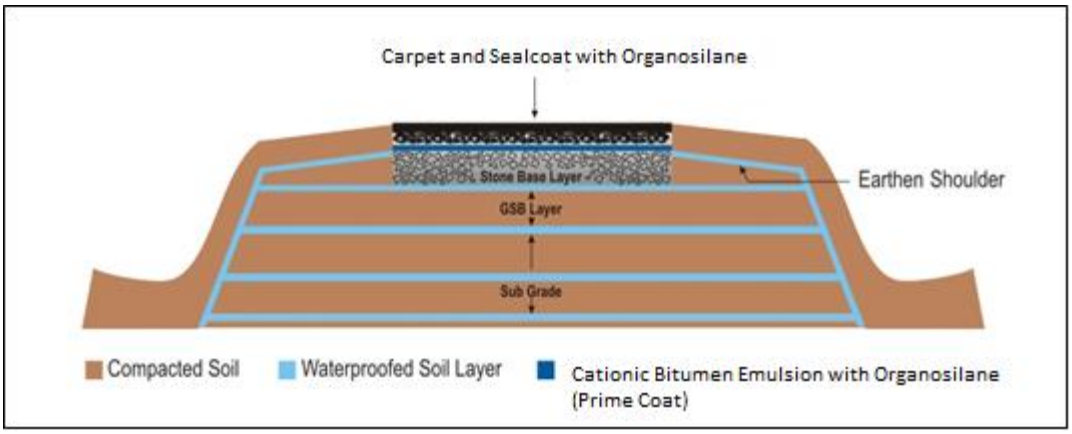
Road Initial Condition

Selected Soil properties LHS & RHS

Sieve analysis:			Atterberg limits			IS classification		Density:MDD		OMC		CBR	
	LHS	**RHS**		**LHS**	**RHS**	**LHS**	**RHS**	**LHS**	**RHS**	**LHS**	**RHS**	**LHS**	**RHS**
Gravel:	**4%**	**5%**	LL	36	35	CI	CI	1.58 g/cc	1.57 g/cc	18.9 %	18.4 %	2.1	2.0
Sand:	**14%**	**16%**	PL	22	20								
Silt&clay:	**82%**	**79%**	PI	14	15								



Length in meters	Width in meters	Stretch Treatment Details
250	3.75	• Control section with no treatment.
150	3.75	• Soil waterproofing with organosilane nanotechnology in three layers of full formation width. • No treatment in Base course and Wearing course. • After Bituminous layer, waterproofing treatment on earthen side shoulders with Organosilane.
210	3.75	• Soil waterproofing with organosilane nanotechnology (in three layers) of full formation width. • Organosilane induced cationic bitumen emulsion prime coat over WBM base course prior to BUSG work. • Untreated BUSG work. • Organosilane induced Bitumen for carpet and seal, wearing coats. • After Bituminous surface layer, waterproofing treatment on earthen side shoulders with Organosilane.
90	3.75	• Organosilane induced Bitumen for carpet and seal, wearing coat layers.
700 meters of total stretch		



Surface Waterproofing

Water Drop Test

Prime coat with Organosilane

Waterproofing Confirmation

Organosilane mixing in bitumen

Carepet & Sealcoat Layer

Conclusion: Multilayer Waterproofing Envelope on highly expansive clayey soil layers followed by water resistant bond coats and chemically bonded bituminous layers eliminates water ingress and is effective for long time so as to maintain the design life of road. It also prevents distresses and pre-mature failures as happens in road constructed conventionally.

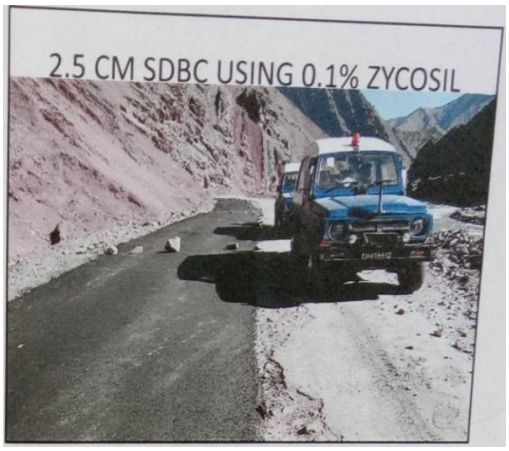
2. CASE STUDY – UPSHI SARCHU ROAD, PROJECT HIMANK, LEH

The existing wearing course was damaged due to moisture susceptible aggregate. Organosilane was incorporated in the estimate by Border Roads Organization engineer. Total resurfacing work to be done on Leh-Upshi roads was approximately 8.0 km in length with Organosilane additive.

Organosilane provides anti-stripping properties widely used to mix with bitumen to improve the adhesion on aggregate surface. It forms silanols (Si-OH) groups. These silanols are reactive and can form siloxane (Si-O-Si) bonds with surface silanol groups of inorganic surface like gravel soil, sand etc.

Organosilane mixing with hot liquid bitumen react with the gravels and improves wetting and spreading power of chemically modified bitumen on inorganic surfaces of gravels, sand and soil. It also improves bitumen to aggregate adhesion.

Organosilane compound was mixed in VG 10 grade bitumen at optimum dosage of 0.1% by the weight of bitumen at 150 °C - 160 °C temperature.



Laying in Year 2011

Observations:

- ✓ Laying and compaction of Hot Mix was found to be better and no sticking was observed on the compactor's roller.
- ✓ Asphalt coating on aggregate found to be a very uniforming coating and mixture was found shiny.
- ✓ Stripping value at 0.1 % to 0.15 % dose was found 90 to 100 %.
- ✓ Better bonding and improved stability laboratory test samples of organosilane.
- ✓ Organosilane mixed easily in hot melted asphalt mix.

Control After 1year-2012

With Organosilane After 4 year - 2016

Conclusion: Performance evaluation was carried out in April 2013 after completion of 2 year. The resurfacing stretch where, Zycosoil-Nanotechnology was used no sign of distress was found. The surface is found intact without any reveling or other distresses.

3. CASE STUDY – VADODARA – AHMEDABAD NH 8, IRB INFRASTRUCTURE DEV. LTD.

Six laning of Ahmedabd – Vadodara Section of NH – 8 from starting point of Narol Village km 6.400 to end point Vadodara km 108.700 (length 102.300 km) in the state of Gujarat under NHDP Phase V, DBFOT. The organosilane mixed bituminous layer laid in section chainage 68+520 to 68+620 RHS main carriage in DBM Grade 2 and 57.0 to 62.0 km LHS in BC Grade 1. The objective was Improvement in coating of VG 30 / PMB binder on aggregates, consistent and higher compaction and reactive bonding for making durable pavements over the service life. Organosilane is added in VG 30 / PMB directly in the Bitumen storage tank. The parameters are like:

Parameters	
Mix design	DBM grade 2
Bitumen	VG 30
Bitumen content`	3.7% (for 120 MT for Trial)
Reduction of binder	0.2% (for 100 MT for Trial Base)

Bitumen Temp. ^{0}C	150
Aggregate temp. ^{0}C	170 -175
Mix temp. ^{0}C	155 -160
Laying temp. ^{0}C	140-145
Compaction temp. ^{0}C	110

Lab Study Marshall Compressive strength at 60 ^{0}C and 30 min in water

Mix design	Asphalt binder with additive	Weight of specimen in gm			Volume of Specimen	Density	Stability in kg	Flow value in mm
		In Air	In water	SSD				
		A	B	C	C-B			
DBM	VG 30 @ 4.52% OBC	1249.0	782.0	1253.0	471.0	2.652	17.13	3.50
		1248.0	789.0	1256.0	467.0	2.672	19.37	3.20
		1247.0	779.0	1252.0	473.0	2.636	17.13	3.50
		Avg.				2.654	17.88	3.40
	VG 30 + 0.1% Organo silane @ 4.52% OBC	1156.0	725.0	1157.0	432.0	2.676	20.70	3.10
		1247.0	781.0	1250.0	469.0	2.659	21.38	3.00
		1152.0	720.0	1154.0	434.0	2.654	13.37	4.00
		Avg.				2.663	18.48	3.37
	VG 30 + 0.1% Organo silane @ 4.22% OBC	1246.0	781.0	1248.0	467.0	2.668	16.33	4.30
		1253.0	786.0	1254.0	468.0	2.677	18.66	2.50
		1251.0	784.0	1251.0	467.0	2.679	16.72	4.50
						2.675	17.23	3.77
BC	PMB @ 5.06% OBC	1247.0	762.0	1248.0	486.0	2.566	12.31	6.80
		1243.0	774.0	1244.0	470.0	2.645	19.02	6.40
		1239.0	770.0	1240.0	470.0	2.636	13.08	4.50
		Avg.				2.616	14.94	5.90
	VG 30 + 0.15% Organosilane @5.06% OBC	1238.0	771.0	1239.0	468.0	2.645	15.85	4.40
		1241.0	766.0	1242.0	476.0	2.607	12.15	4.30
		1239.0	764.0	1240.0	476.0	2.603	11.77	4.90
		Avg.				2.618	13.26	4.53
	VG 30 + 0.15% Organosilane @4.86% OBC	1251.0	779.0	1252.0	473.0	2.645	18.60	6.40
		1243.0	769.0	1244.0	475.0	2.617	15.95	6.00
		1244.0	774.0	1245.0	471.0	2.641	12.91	5.80
		Avg.				2.634	15.82	6.07

Sr. No	Test Description	Results of DBM Grade 2			
		Normal Mix with VG30 at 3.7% Binder Content	0.1 % Organo Silane Mixed with VG30 at 3.7% Binder Content	0.1 % Organosilane Mixed with VG30 at 3.5% Binder Content	Specific Limit
1.	Bulk Density (gm/cc)	2.542	2.535	2.547	-
2.	GMM	2.670	2.654	2.675	-
3.	Air Voids (%)	4.79	4.48	4.79	3-5%
4.	VMA (%)	14.97	15.21	14.63	Min. 12
5.	VFB (%)	68.00	70.55	67.26	65-75%
6.	Stability (KN)	22.66	24.94	23.96	20.25 kN
7.	Flow (mm)	3.5	3.8	3.1	3-6 mm
8.	Compaction (%) with respect to GMM	93.3	94.7	93.4	Minimum 92% of GMM

Plant and Site Observations:

At Plant

- Easy Doping in the tank.
- 100% coating of aggregates.
- Mix black and glossy.
- After reducing 0.2% (Binder content 3.5%) by wt of mix is as good as at normal binder content (3.7%).

At Site

- Good Flow of mix observed.
- Odor of bituminous mix is reduced compare to normal mix.
- Uniform compaction of mix.


ZycoTherm
05.07.2014


ZycoTherm
05.07.2014


05.07.2014


05.07.2014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Site observations on May 2017 at chainage 57 to 62 km, left side (from Ahmedabad to Vadodara)

Organosilane mixed bituminous concrete layer laid in chainage between km 57 to 62. The site visit done in May 2017.

- ✓ No loose aggregates
- ✓ No pothole
- ✓ No reveling

Conclusion: Performance evaluation was carried out in May 2017 after completion of 2 year. The resurfacing stretch where, Organosilane-Nanotechnology was used the surface is found intact without any revelling or other distresses.

6 CONCLUSION

1. Multilayer Waterproofing Envelope on highly expansive clayey soil layers followed by water resistant bond coats and chemically bonded bituminous layers eliminates water ingress and is effective for long time so as to maintain the design life of road. It also prevents distresses and pre-mature failures as happens in road constructed conventionally.
2. Improves coating efficiency, leading to faster and complete coating.

3. Organo silane based additive can offer moisture resistance, improved swell control and strength. Excellent bond strength improvement in bitumen emulsion can be achieved with organosilane modifications. It can substantially improve the stripping resistance of bitumen mixes.
4. Gives better compaction at lower compaction temperatures.
5. This clearly indicates that organosilane additive has potential to extend significantly pavement life.