WATER RESISTANT BASES
For Paved / Gravel / Soil Roads
Clay has a very large volumetric expansion when water is added. Moisture causes swelling and drying causes shrinkage and cracking, leading to loss of strength.

Water addition to the level of OMC is necessary though, to achieve adequate compaction.

The paradox is, water is WELCOME for compaction but MOST UNWELCOME after compaction and drying, because subsequent water ingress is detrimental to the strength of soil bases.

The new water soluble nanotechnology additives make use of this paradox to the best advantage, as they can be dissolved in water to achieve OMC. Upon drying, the soil becomes hydrophobic and water entry is restricted.
When soil gets wet, it swells and leads to undulation & cracking.

*Organosilane Nanotechnology substantially reduces swelling (by 90% and more). This imparts dimensional stability to soil bases.*

This technology also makes soil surface water-impermeable. *Permeability drops to $10^{-8} \text{ cm/s}$ (>100 days resistance) from usual $10^{-5} \text{ cm/s}$ (1 day).*

Commercially viable for the first time in the world
**TERRASIL CHEMISTRY**

- OH groups make surface very hydrophilic (water loving)

Particle surface

Soil/clay particle surface silicate structure

Terrasil molecule creates molecular level hydrophobic zone (water repellent)

Particle surface

Soil / Clay surface silicate structure after Terrasil reaction

Newly formed Siloxane bonds

Internal Siloxane bonds
TERRASIL & WATER PERMEABILITY

Permeability reduced by 500 folds

CH (Black Cotton) Soil, India
NEW ORGANOSILANE NANOTECHNOLOGY

Improved Compaction and Hydrophobicity

Charge shielding & oil (alkyl) lubrication

Enables optimum compaction

Field proctor density of 100 to 105 have been observed
NEW TECHNOLOGY ENHANCES CEMENT STABILIZATION

Cement - Soil Stabilization

- Proctor 95
- Cementitious bonds degrade with time and lose strength due to wet and dry cycles

Silane + Nano Polymer + Cement

- Proctor 100 to 105
- Unaffected by wet and dry cycles due to hydrophobicity
- Log term strength retention of cementitious bonds

- Cement Particle
- ZycoBond Particle
TERRASIL & ZYCOBOND : APPLICATION

Note:
In case equipment are not available, agricultural implements like ploughs, rotavator etc. can be used.
ORGANO SILANE TREATED SOIL DISPLAYED THE FOLLOWING,
- Soil Swelling Reduced by 85 %
- Compaction Density Increased by 4%

<table>
<thead>
<tr>
<th>Sr</th>
<th>Parameters</th>
<th>Measure</th>
<th>Soil w/o additive</th>
<th>Soil + Cement 3%</th>
<th>Soil + Silane 0.75 kg/m³ + nano polymer 0.75 kg/m³ + Cement 3%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CBR</td>
<td>%</td>
<td>7</td>
<td>67</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>% Improvement</td>
<td>-</td>
<td></td>
<td>857%</td>
<td>1685%</td>
</tr>
<tr>
<td>2</td>
<td>UCS</td>
<td>MPa</td>
<td>0.27</td>
<td>1.02</td>
<td>2.43</td>
</tr>
<tr>
<td></td>
<td>% Improvement</td>
<td></td>
<td></td>
<td>278%</td>
<td>800%</td>
</tr>
<tr>
<td>3</td>
<td>Durability (Wet – Dry Cycles)</td>
<td>No. of cycles</td>
<td>0</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>IS : 4332 (Part 4)</td>
<td>Fails</td>
<td>Fails</td>
<td>Passes</td>
<td>(Simulates 20 years life)</td>
</tr>
</tbody>
</table>
CEMENT VS NANO-POLYMER

- With 63000 times higher number of particles, nano-polymer has very high dispersion efficiency.
- With 63000 m times more surface area, nano-polymer has far greater number of bonds.
- This allows reduction in cement % required for stabilization.
- When added with cement, nano-polymer reduces water damage and protects cementitious bonds.
- Being it also imparts flexibility to stabilized soil layers, which cement alone cannot do.
<table>
<thead>
<tr>
<th>Sr</th>
<th>Parameters</th>
<th>Unit</th>
<th>Value for stabilized soil</th>
<th>Test Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Field Proctor Density</td>
<td>%</td>
<td>&gt; 97</td>
<td>IS 2720 Part 18</td>
</tr>
<tr>
<td>2</td>
<td>CBR for Soil</td>
<td>%</td>
<td>50+</td>
<td>IS 2720 Part 16</td>
</tr>
<tr>
<td>3</td>
<td>CBR for GSB</td>
<td>%</td>
<td>100+</td>
<td>IS 2720 Part 16</td>
</tr>
<tr>
<td>4</td>
<td>Durability (Wet – Dry Cycles)</td>
<td>No.</td>
<td>12</td>
<td>IS 4332 Part 4</td>
</tr>
<tr>
<td>5</td>
<td>UCS</td>
<td>MPa</td>
<td>&gt; 1.5</td>
<td>IS 4332 Part 5</td>
</tr>
</tbody>
</table>
# Next Generation Specifications For Water Resistance

## Soil Bases

<table>
<thead>
<tr>
<th>Sr</th>
<th>Parameters</th>
<th>Testing method</th>
<th>Value</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Swell control</td>
<td>FSI</td>
<td>&lt; 5%</td>
<td>Swell control imparts dimensional stability and reduces undulations/cracks on the surface. The non leachable new water based technology now enables control</td>
</tr>
<tr>
<td>2</td>
<td>Water permeability</td>
<td>Pour water and observe</td>
<td>Water should sand for more than 20 minutes. Permeability should $10^{-7}$ to $10^{-8}$</td>
<td>Building impervious soil layers prevents water ingress into the soil bases and prevents water borne damages. The new technology now enables building water impermeable layer</td>
</tr>
<tr>
<td>3</td>
<td>Depth of water resistant layer</td>
<td>Scratch surface till 5mm depth pour water and observe again</td>
<td>Water should sand for more than 20 minutes.</td>
<td>Building impervious soil layers prevents water ingress into the soil bases and prevents water borne damages. The new technology now enables building water impermeable layer</td>
</tr>
</tbody>
</table>
CLIMATE-RESILIENT BITUMINOUS PAVEMENTS

NEW NANO TECHNOLOGY

For Improved Resistance to:
Oxidation, Moisture, Cracking & Bleed
OXIDATION RESISTANCE THROUGH COATING EFFICIENCY
Limited mixing time (20-45 sec) in the plant leads to inefficient coating, especially of fines. This is particularly relevant with higher viscosity grades and PMB / CRMB / RAP mixes (10 to 35%).

*ZycoTherm (ZT or ZT-EZ)* additive to bitumen decreases the surface tension of the binder by 8 to 10 dynes/cm. This leads to 30-40% faster coating with 15-20% less torque, leading to efficient coating in the available mixing time.
ZT EFFECT ON SURFACE TENSION

Study done at University of Texas at Austin, paper published in TRB Journal No. 2505
With addition of ZT, due to lower surface tension the bitumen wets the aggregate surface better. This results in improved wetting and saturation of micro pores on aggregate surfaces.

**COMPLETE COATING**

SLOWS AGEING PROCESS
FASTER COATING AT LOWER TEMPERATURE

20 % less time is required, even at 40 °C lower mixing temperature
In HMA plants, the mixes produced with ZT technology look glossier and jet black in color.

The ZT pavements have consistently remained blacker (visual Observation of the surface and the mastic compared to control sections).

*This confirms that the coating has substantially improved, especially of fines and saturation of micro pores.*

*This will have a very positive impact on oxidation resistance.*
JET BLACK LOOK

Colorado, USA

Complete Coating
**FIELD OBSERVATIONS**

**ZT** field sections have shown a remarkable reduction in cracking in the surface layers.

*Saturation of micro pores and complete coating of fines leads to higher bitumen-aggregate interface area leading to better load transfer.*

*Reduced stress for the same mix will improve the fatigue resistance.*
It is observed that ZT mixes during production, showed lower current drawn by 10 Amp, at 20 °C lower mixing temperature (Ref – Peab plant in Sweden).

This confirms easier mixing due to improved lubrication and workability.

All ZT mixes are observed to be less sticky to the production, trucks and paver equipment.

ZT mixes flow easily and consistently, with improved control on segregation. Workability with hand is also seen to be excellent. This is particularly relevant for achieving better lane joint densities.
MOISTURE RESISTANCE
CHEMICAL BONDING OF ZYCOTHERM WITH AGGREGATES

-OH groups make surface very hydrophilic (water loving)

Particle surface

Soil/clay particle surface silicate structure

ZT molecule creates molecular level hydrophobic zone (water repellent)

Particle surface

Soil / Clay surface silicate structure after Zycotherm reaction

4 - 6 nm Alkyl Siloxane surface

Newly formed Siloxane bonds

Internal Siloxane bonds
Polar - Polar Interaction
5-15% Asphalt participates in Bonding

Non Polar – Non Polar Interaction
85-95% Asphalt participates in Bonding
Basalt Aggregate (DBM): 45% 20 mm, 10% 10 mm, 45% less than 6 mm with stone dust
Asphalt Grade: AC-20 (VG-30, 60-70 penetration grade)

BOIL TEST ASTM D3625: EXTEND TO 6 HOURS

% Coated Aggregates

- Control
- 2% Hydrated Lime
- 0.5% Amine
- 0.1% ZycoTherm

10 min, 30 min, 1 hr, 6 hrs
AASHTO T283 TSR TEST

Georgia, USA Granites with PG 64-22 Asphalt binder
MARSHALL COMpressive TEST AASHTO T165 / ASTM

EXTEND TO 15 DAYS

CSR 0.81 based on dry Control

CSR 0.45
MARSHALL WET COMPRESSIVE STRENGTH
AASHTO T165 / ASTM D1075

Flow Values (mm)

<table>
<thead>
<tr>
<th>Material</th>
<th>Control</th>
<th>2% Hydrated Lime</th>
<th>0.1% ZycoTherm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binder AC-10</td>
<td>2.70</td>
<td>2.71</td>
<td>2.85</td>
</tr>
<tr>
<td>Binder AC-20</td>
<td>3.00</td>
<td>2.78</td>
<td>2.95</td>
</tr>
<tr>
<td>CRMB-1</td>
<td>3.10</td>
<td>3.18</td>
<td>3.14</td>
</tr>
<tr>
<td>PMB-40</td>
<td>3.02</td>
<td>3.05</td>
<td>3.09</td>
</tr>
</tbody>
</table>

Basalt Aggregate (DBM): 45% 20 mm, 10% 10 mm, 45% less than 6 mm with stone dust
Asphalt Grade: AC-20 (VG-30, 60-70 pen. Grade)
DEPTH OF PENETRATION OF WATER UNDER PRESSURE

**ASTM D 6927 : 2005**

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Control</th>
<th>ZycoTherm</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>10</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>11</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>12</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>13</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>14</td>
<td>16</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ZT %</th>
<th>0%</th>
<th>0%</th>
<th>0.025%</th>
<th>0.025%</th>
<th>0.05%</th>
<th>0.05%</th>
<th>0.10%</th>
<th>0.10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Penetration in mm</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Lower penetration indicates better packing and reduced pore size. This will restrict water entry during rain / snowfall and improve moisture susceptibility. This will also result into better fatigue resistance and reduced cracking.
FATIGUE RESISTANCE
FATIGUE CRACKING
Damage level evolution for beams tested with 300 µε
Higher Number of Cycles means Higher Fatigue Life
<table>
<thead>
<tr>
<th>Beam</th>
<th>$\mu \varepsilon$</th>
<th>Reference Beam $N_f$</th>
<th>ZycoTherm Beam $N_f$</th>
<th>Fatigue life Increment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>300</td>
<td>3,995,009</td>
<td>5,480,003</td>
<td>37%</td>
</tr>
<tr>
<td>2</td>
<td>400</td>
<td>713,381</td>
<td>1,300,000</td>
<td>82%</td>
</tr>
<tr>
<td>3</td>
<td>500</td>
<td>224,321</td>
<td>380,010</td>
<td>69%</td>
</tr>
<tr>
<td>4</td>
<td>600</td>
<td>67,758</td>
<td>190,010</td>
<td>180%</td>
</tr>
</tbody>
</table>

Higher Number of Cycles means Higher Fatigue Life
Thank you