WATER RESISTANT BASES
For Paved / Gravel / Soil Roads

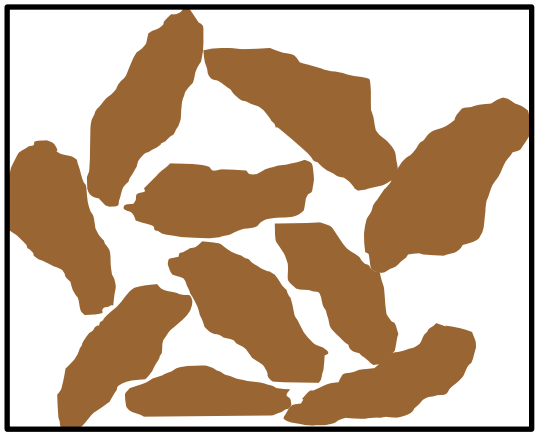
NANOTECHNOLOGY

For Improved Swell Control, Strength & Flexibility

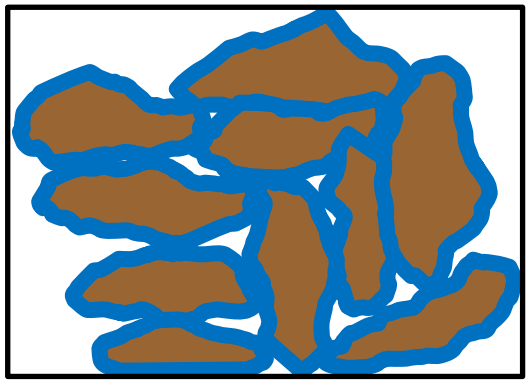
WATER IN SOIL BASES – A PARADOX

- 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

Compacted Dry Soil



Compacted Soil at OMC



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.

The Technical Challenges – Dimensional Stability

When soil gets wet, it swells and leads to undulation & cracking.

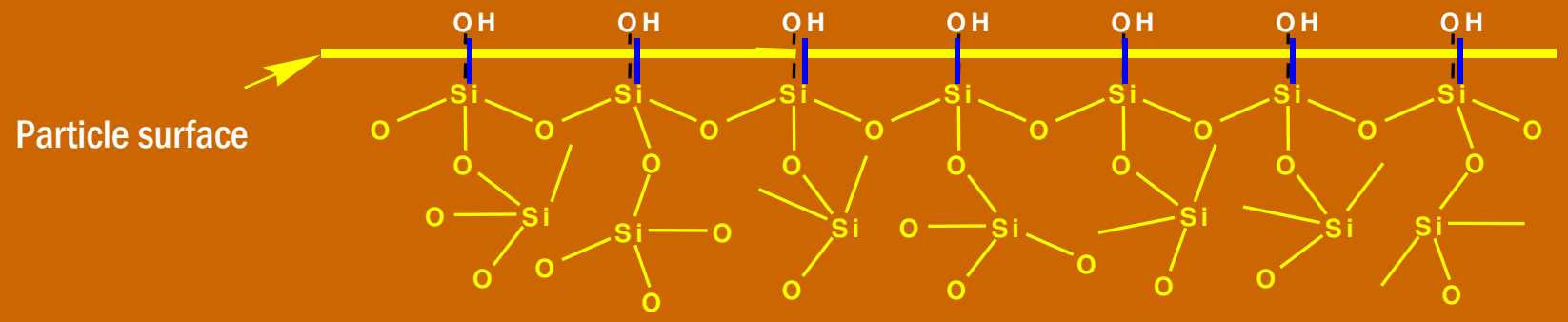
Organosilane Nanotechnology substantially reduces swelling (by 90% and more). This imparts dimensional stability to soil bases.

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

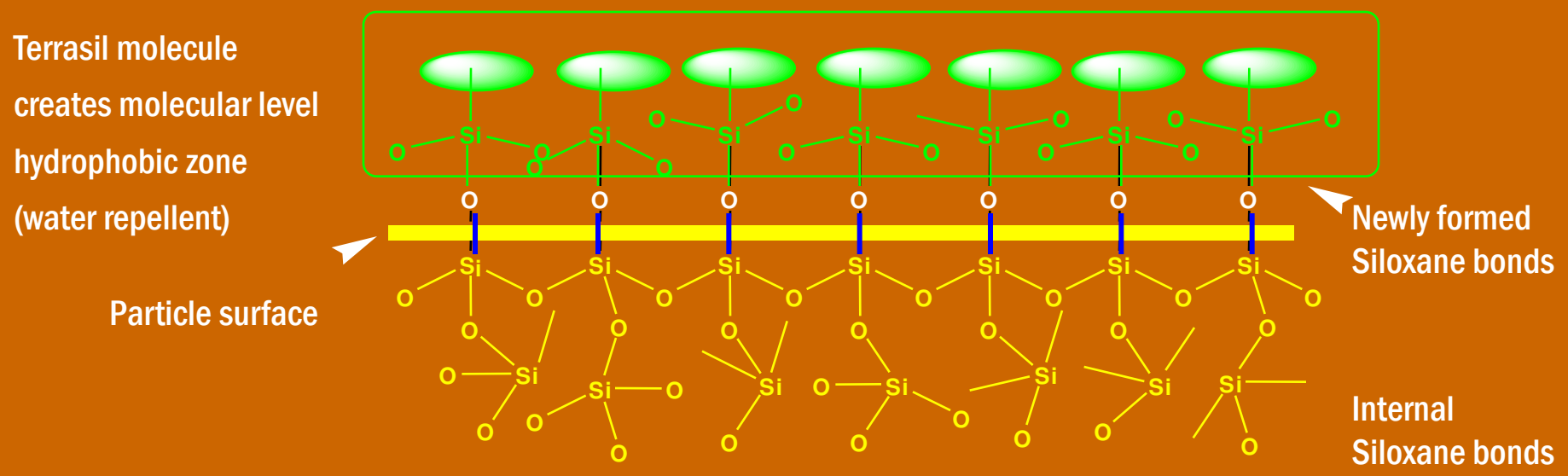
Commercially viable for the first time in the world

TERRASIL CHEMISTRY

-OH groups make surface very hydrophilic (water loving)

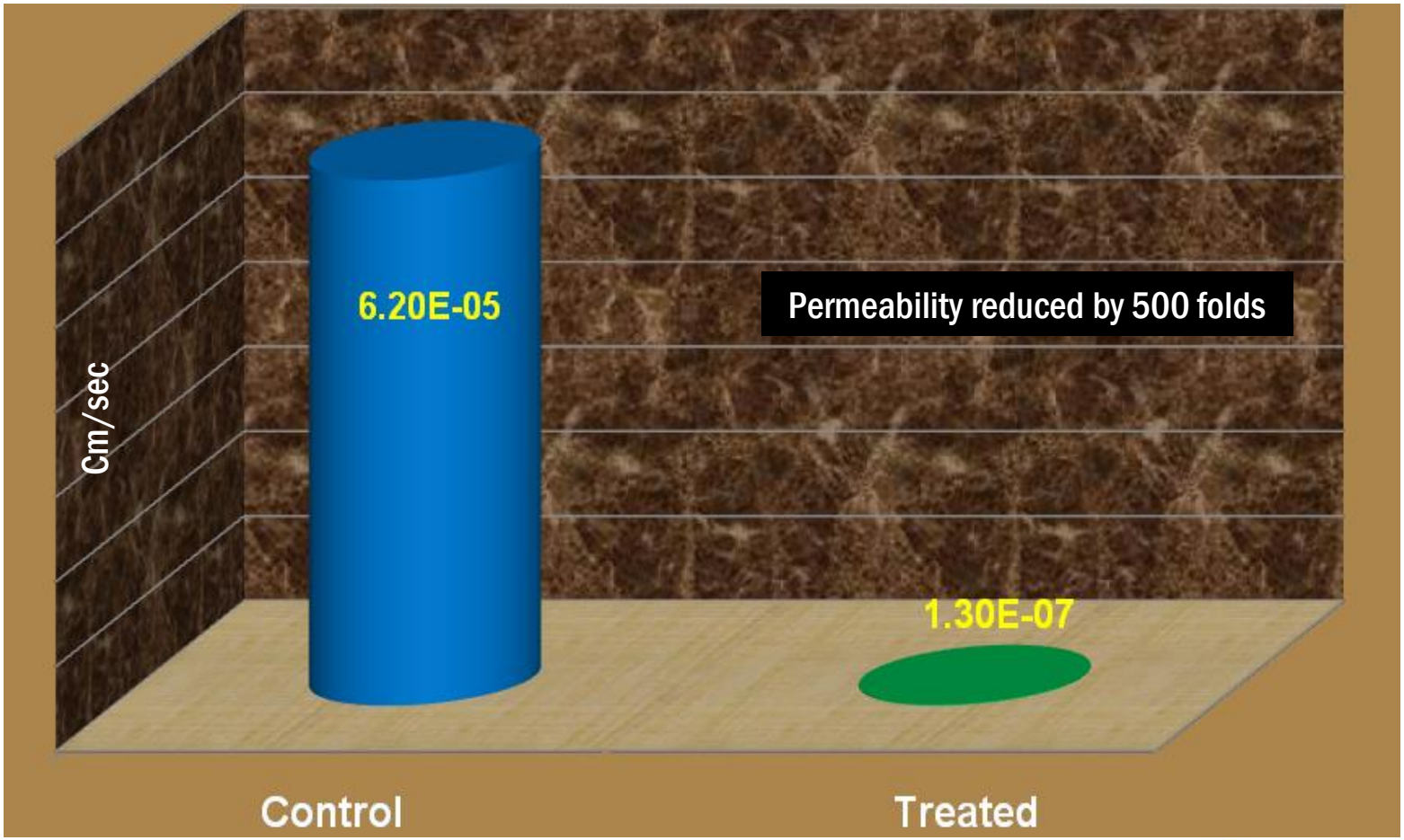


Soil/clay particle surface silicate structure



Soil / Clay surface silicate structure after Terrasil reaction

TERRASIL & WATER PERMEABILITY

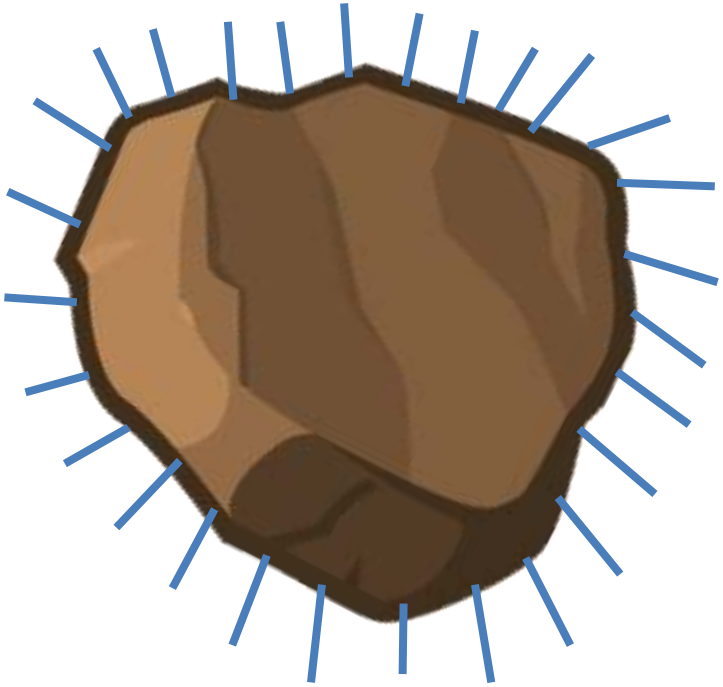


CH (Black Cotton) Soil, India

Central Road Research Institute

NEW ORGANOSILANE NANOTECHNOLOGY

Improved Compaction and Hydrophobicity



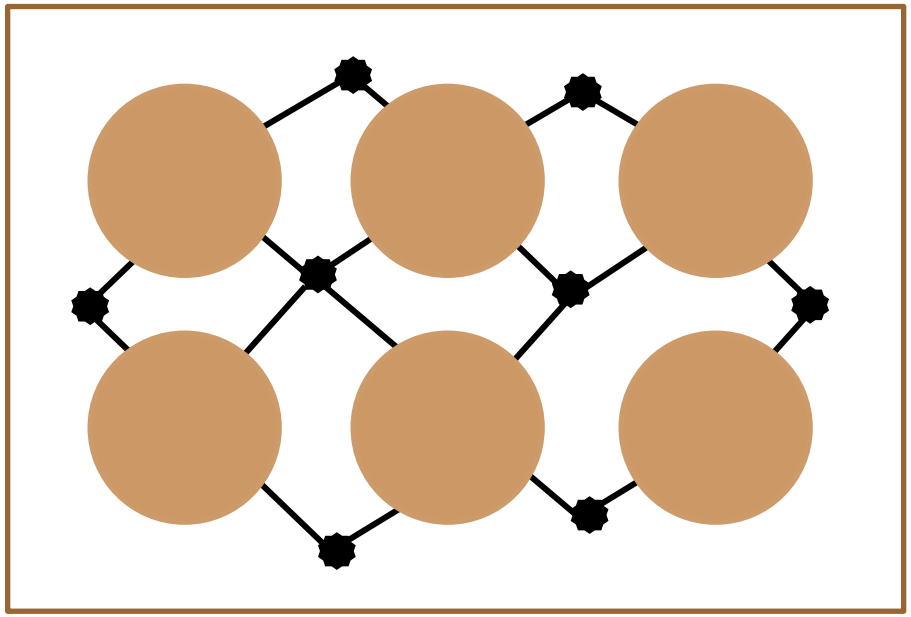
→ Charge shielding & oil (alkyl) lubrication

→ Enables optimum compaction

Field proctor density of 100 to 105 have been observed

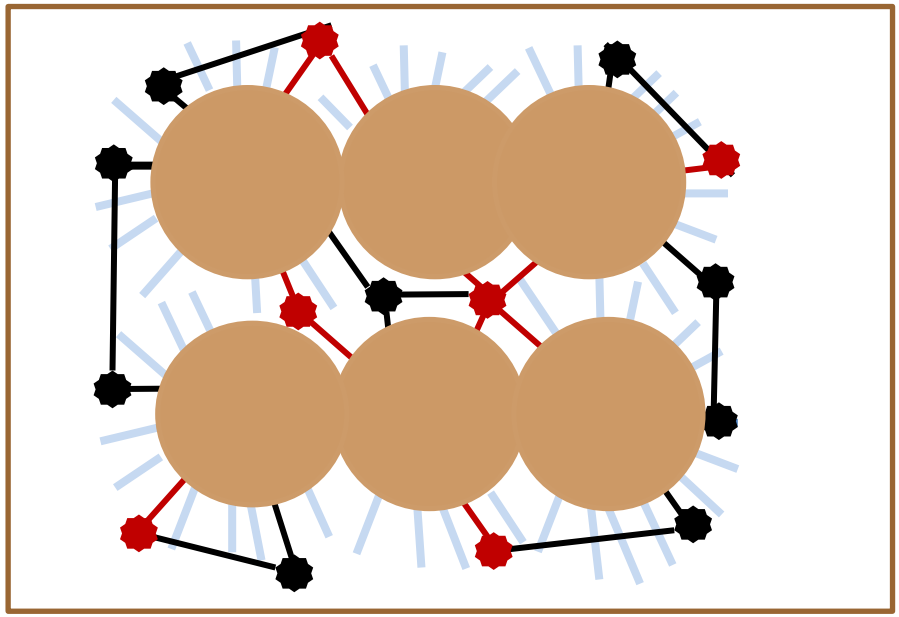
NEW TECHNOLOGY ENHANCES CEMENT STABILIZATION

Cement - Soil Stabilization



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

Silane + Nano Polymer + Cement

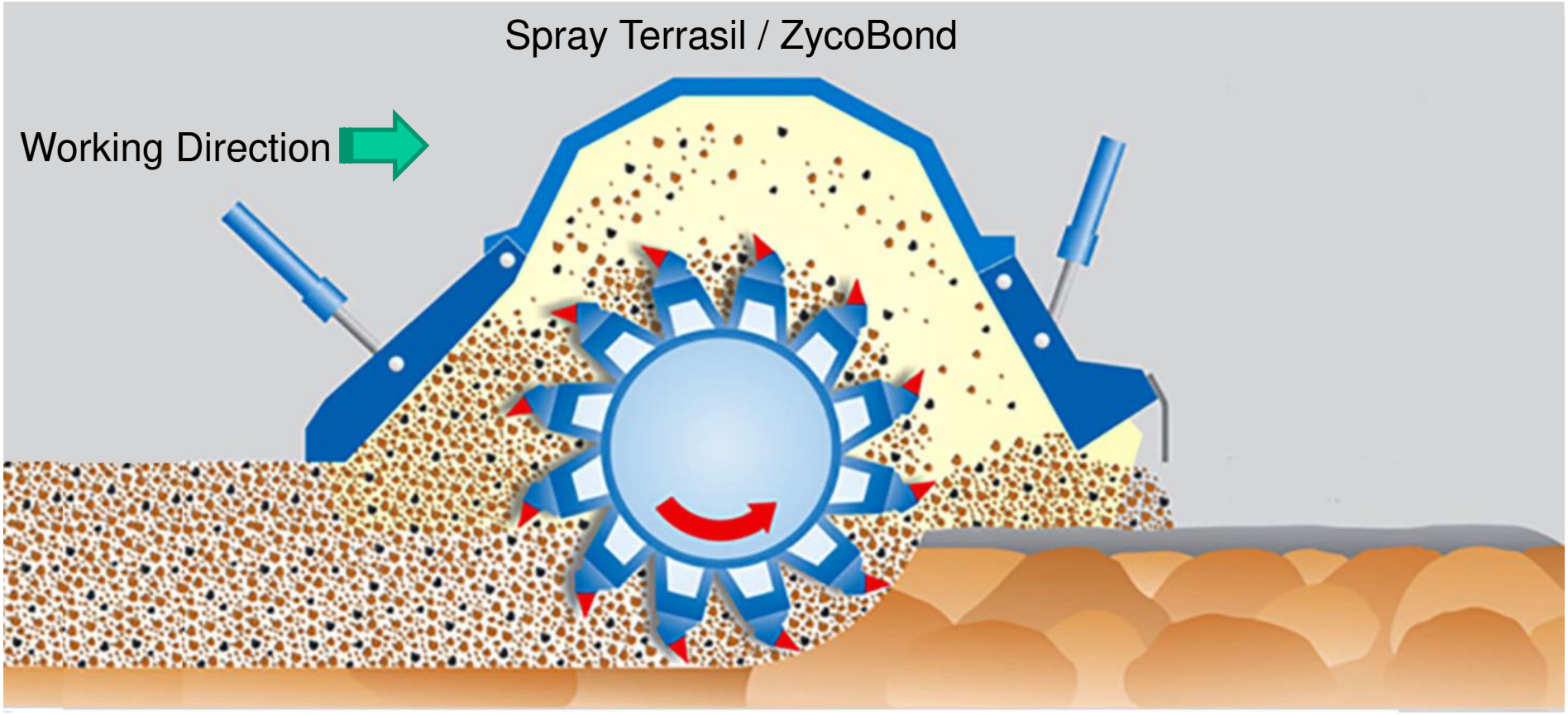


- Proctor 100 to 105
- Unaffected by wet and dry cycles due to hydrophobicity
- Log term strength retention of cementitious bonds

Cement Particle

ZycoBond Particle

TERRASIL & ZYCOBOND : APPLICATION



Note :

In case equipment are not available, agricultural implements like ploughs, rotavator etc. can be used.

CRRI Research : Executive Summary

ORGANO SILANE TREATED SOIL DISPLAYED THE FOLLOWING,

- ✓ Soil Swelling Reduced by 85 %
- ✓ Compaction Density Increased by 4%

Sr	Parameters	Measure	Soil w/o additive	Soil + Cement 3%	Soil + Silane 0.75 kg/m^3 + nano polymer 0.75 kg / m^3 + Cement 3%
1	CBR	%	7	67	125
		% Improvement	-	857%	1685%
2	UCS	MPa	0.27	1.02	2.43
		% Improvement		278%	800%
3	Durability (Wet – Dry Cycles)	No. of cycles	0	4	12
		IS : 4332 (Part 4)	Fails	Fails	Passes (Simulates 20 years life)

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 cementetious bonds
- Being It also imparts flexibility to stabilized soil layers, which cement alone cannot do.

Next Generation Specifications For Strength and Durability

Sr	Parameters	Unit	Value for stabilized soil	Test Code
1	Field Proctor Density	%	> 97	IS 2720 Part 18
2	CBR for Soil	%	50+	IS 2720 Part 16
3	CBR for GSB	%	100+	IS 2720 Part 16
4	Durability (Wet – Dry Cycles)	No.	12	IS 4332 Part 4
5	UCS	MPa	> 1.5	IS 4332 Part 5

Next Generation Specifications For Water Resistance

Soil Bases

Sr	Parameters	Testing method	Value	Remarks
1	Swell control	FSI	< 5%	Swell control imparts dimensional stability and reduces undulations/cracks on the surface. The non leachable new water based technology now enables control
2	Water permeability	Pour water and observe	Water should sand for more than 20 minutes. Permeability should 10^{-7} to 10^{-8}	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
3	Depth of water resistant layer	Scratch surface till 5mm depth pour water and observe again	Water should sand for more than 20 minutes.	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

CLIMATE-RESILIENT BITUMINOUS PAVEMENTS

NEW NANOTECHNOLOGY

For Improved Resistance to :

Oxidation, Moisture, Cracking & Bleed

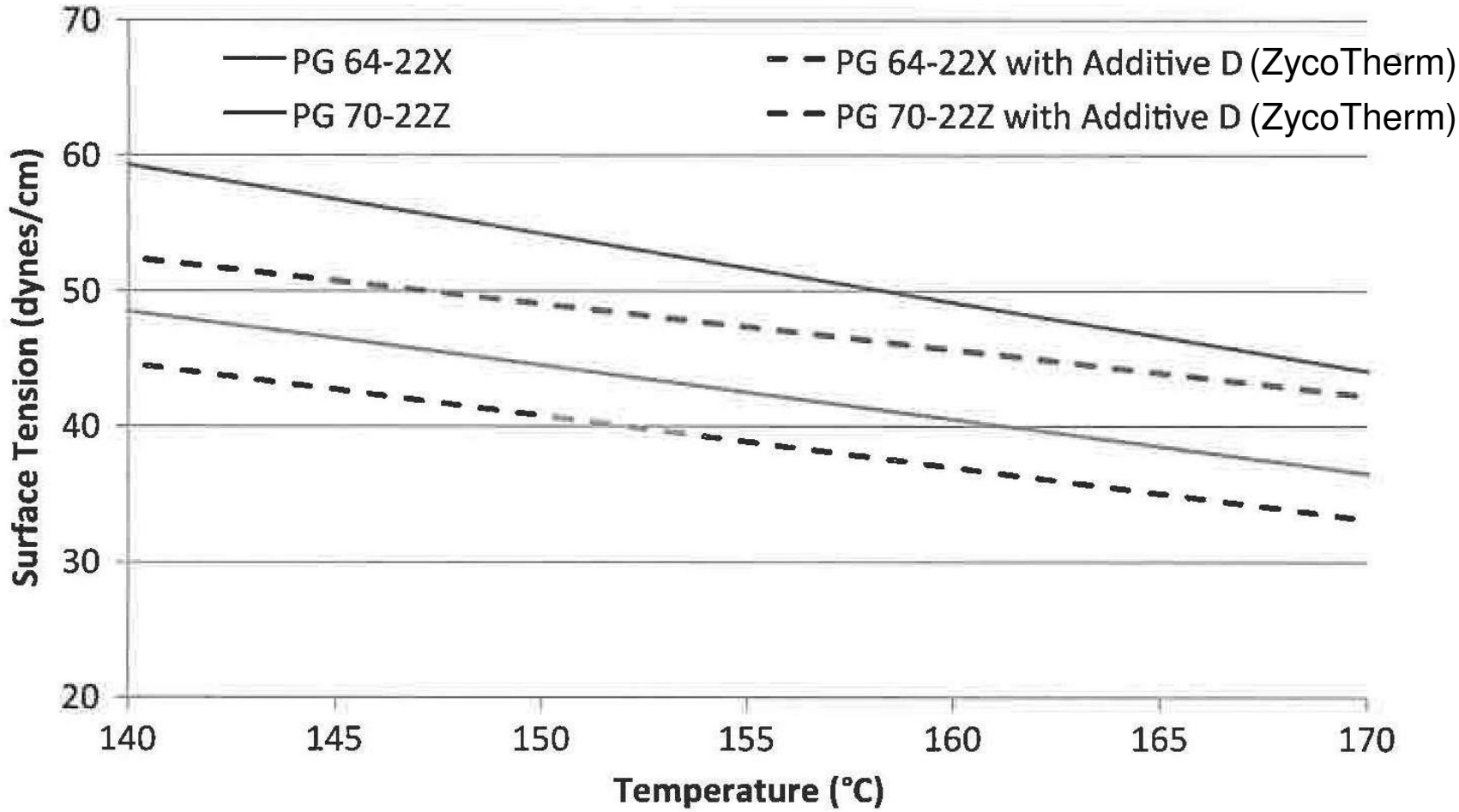
OXIDATION RESISTANCE THROUGH COATING EFFICIENCY

PRACTICAL DIFFICULTIES IN THE FIELD AND MITIGATION

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

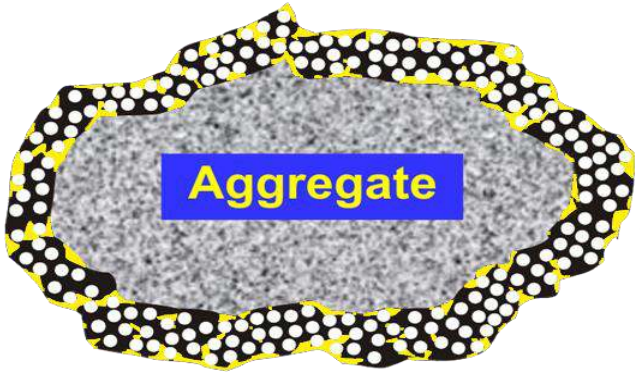


Study done at University of Texas at Austin, paper published in TRB Journal No. 2505

COMPLETE COATING

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.

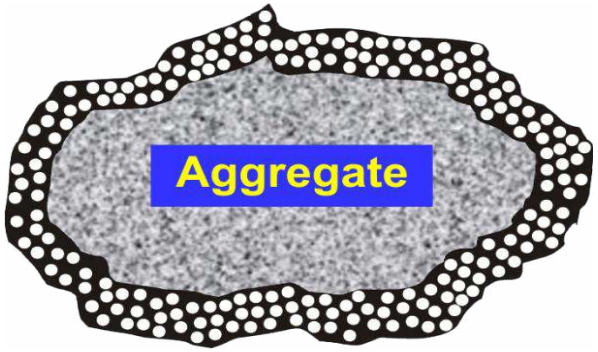
Control



Entrapped Air

Bitumen
Binder

With ZycoTherm

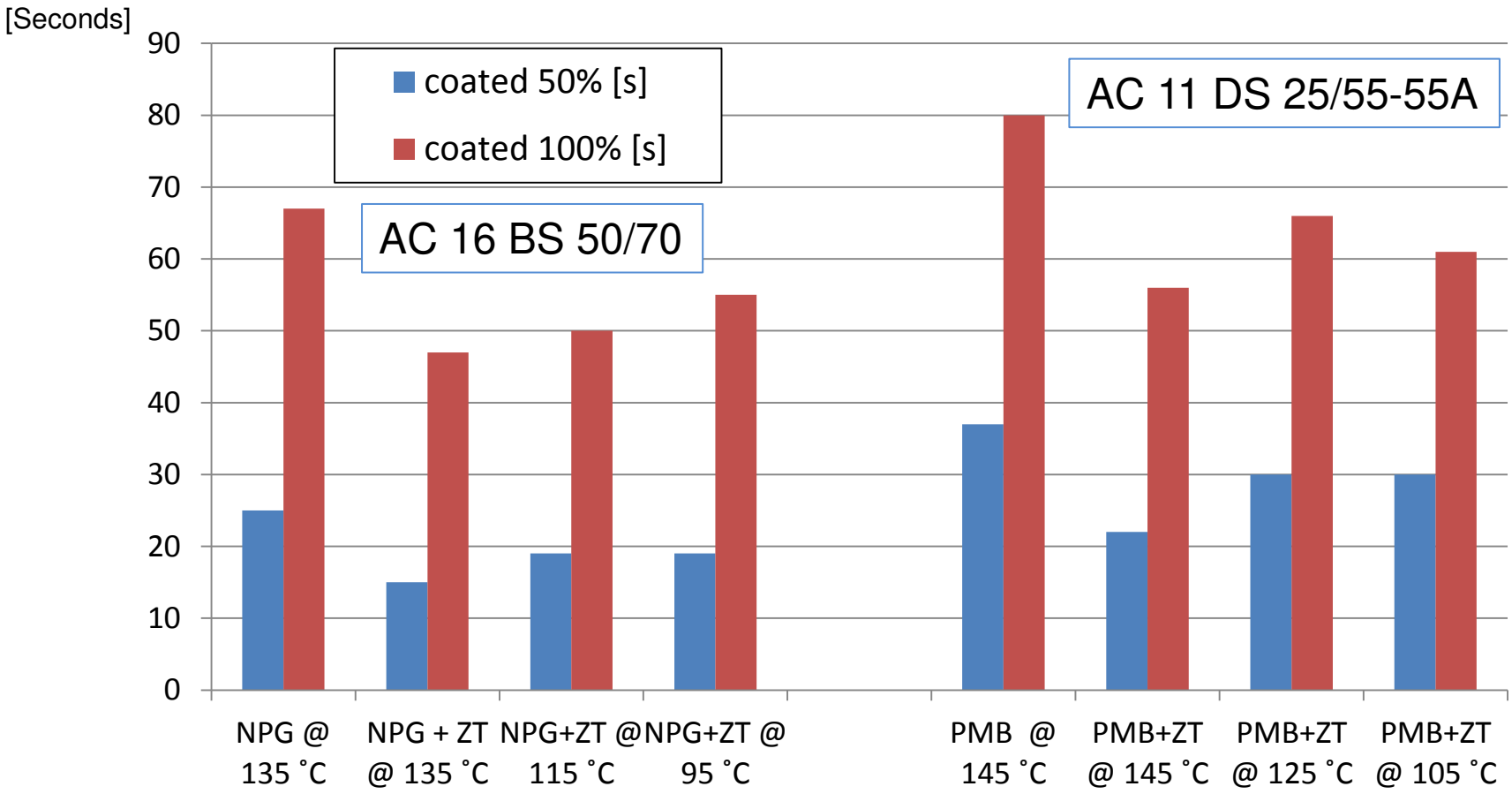


Pinhole Free Surface,
Complete Saturation

SLOWS AGEING PROCESS

FASTER COATING AT LOWER TEMPERATURE

20 % less time is required, even at 40 ^{0}C lower mixing temperature



FIELD OBSERVATIONS

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

FIELD OBSERVATIONS

<u>ZT field sections have shown a remarkable reduction in cracking in the surface layers.</u>

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.

EASIER MIXING & WORKABILITY – FIELD OBSERVATIONS

It is observed that ZT mixes during production, showed lower current drawn by 10 Amp, at 20 ^{0}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.

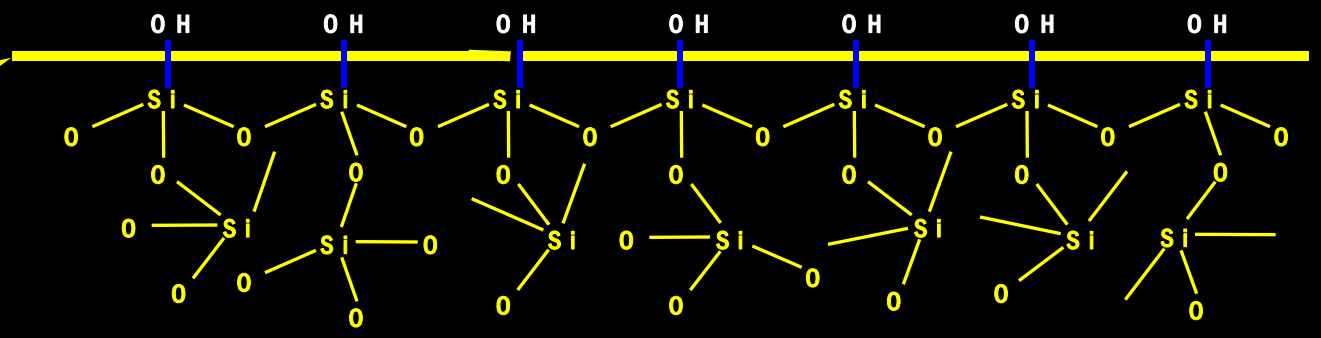
ZT mixes flow easily and consistently, with improved control on segregation. Workability with hand is also seen to be excellent. This is particularly relevant for achieving better lane joint densities.

MOISTURE RESISTANCE

CHEMICAL BONDING OF ZYCOTHERM WITH AGGREGATES

-OH groups make surface very hydrophilic (water loving)

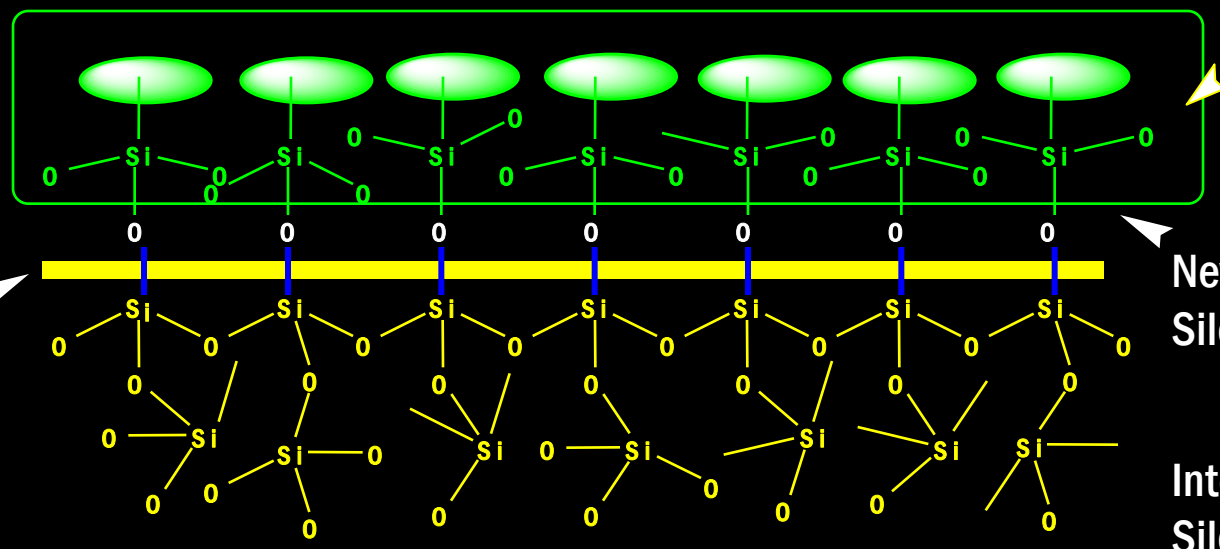
Particle surface



Soil/clay particle surface silicate structure

ZT molecule creates molecular level hydrophobic zone (water repellent)

Particle surface



4 - 6 nm Alkyl Siloxane surface

Newly formed Siloxane bonds

Internal Siloxane bonds

Soil / Clay surface silicate structure after Zycotherm reaction

ZYCOTHERM – AGGREGATE - BINDER INTERACTION

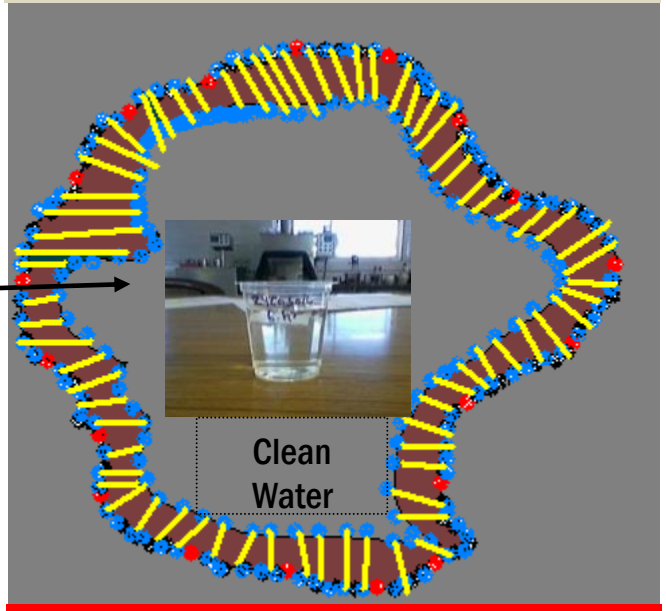
ORANGE PEEL EFFECT

Polar - Polar Interaction

5-15 % Asphalt participates in Bonding

Aggregate

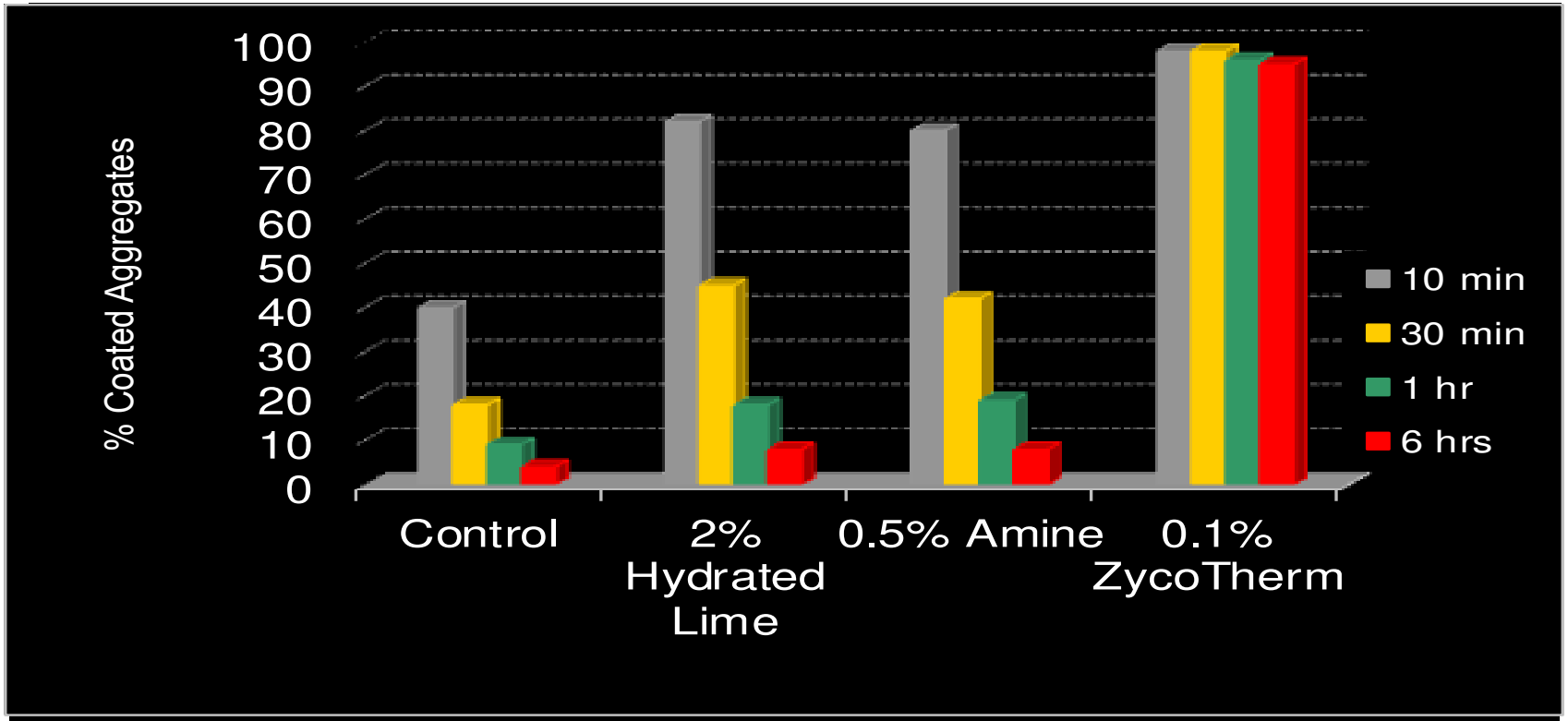
APPLE SKIN EFFECT



Non Polar – Non Polar Interaction

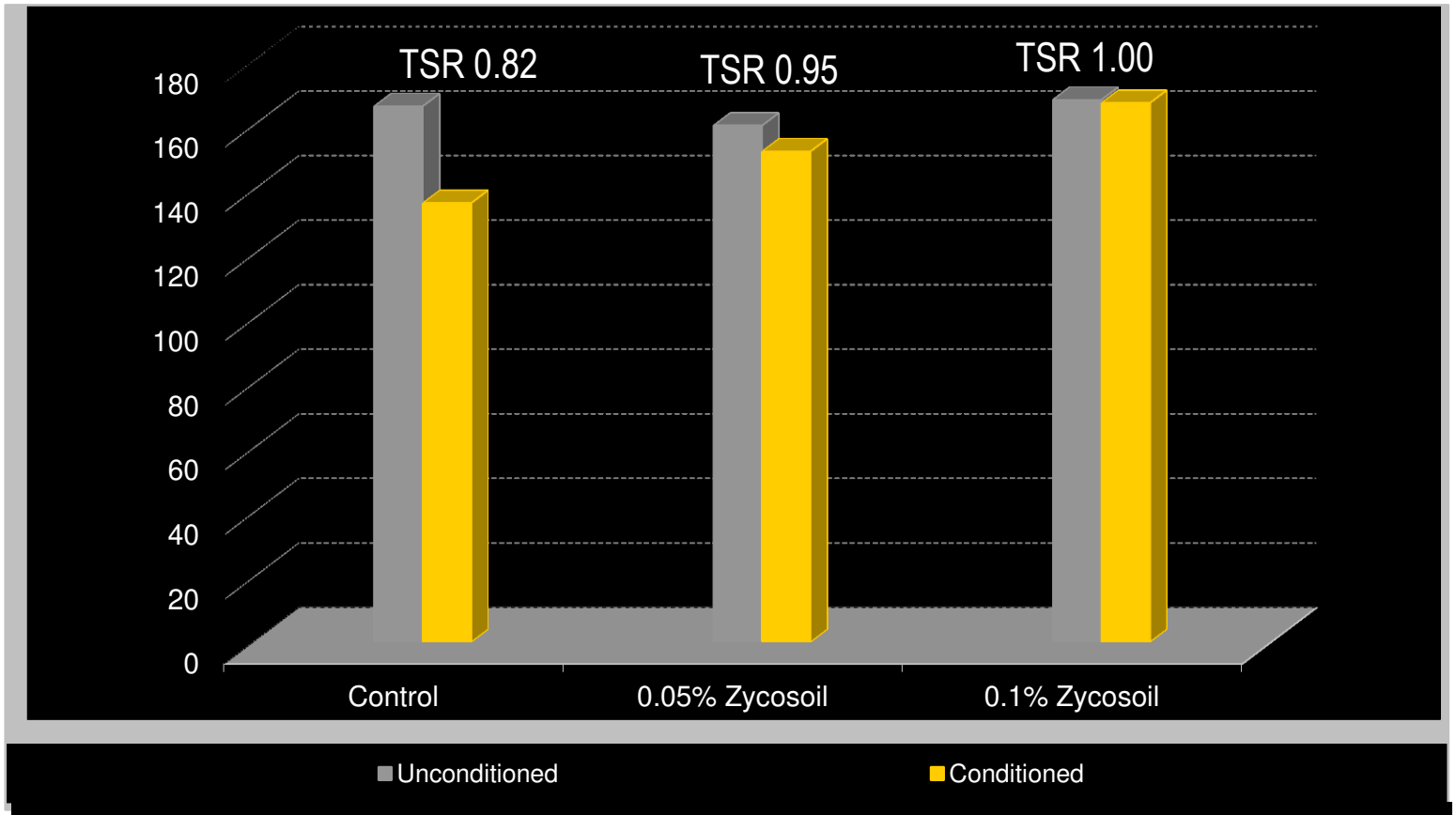
85-95 % Asphalt participates in Bonding

BOIL TEST ASTM D3625 : EXTEND TO 6 HOURS



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)

AASHTO T283 TSR TEST

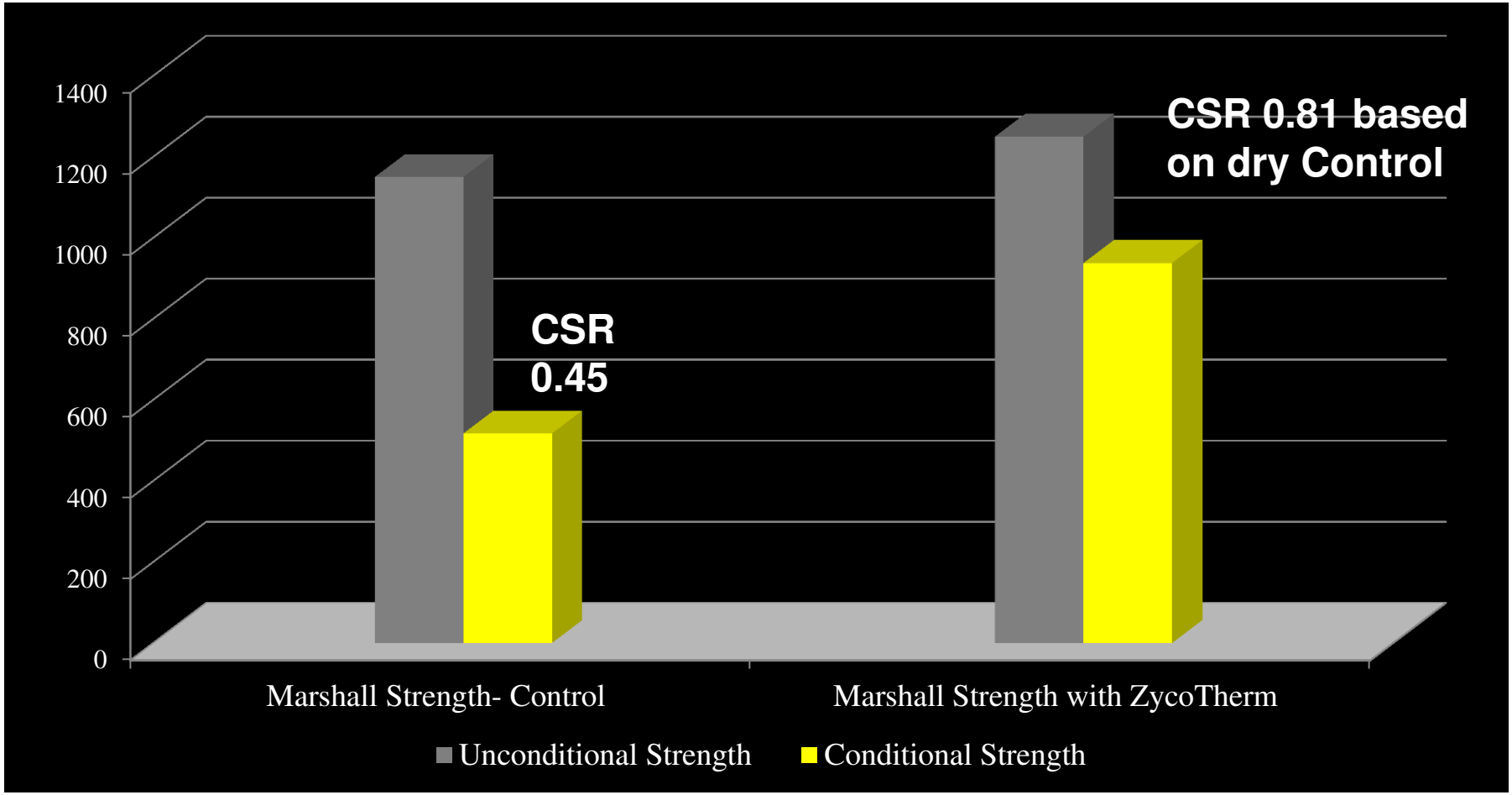


Georgia, USA Granites with PG 64-22 Asphalt binder

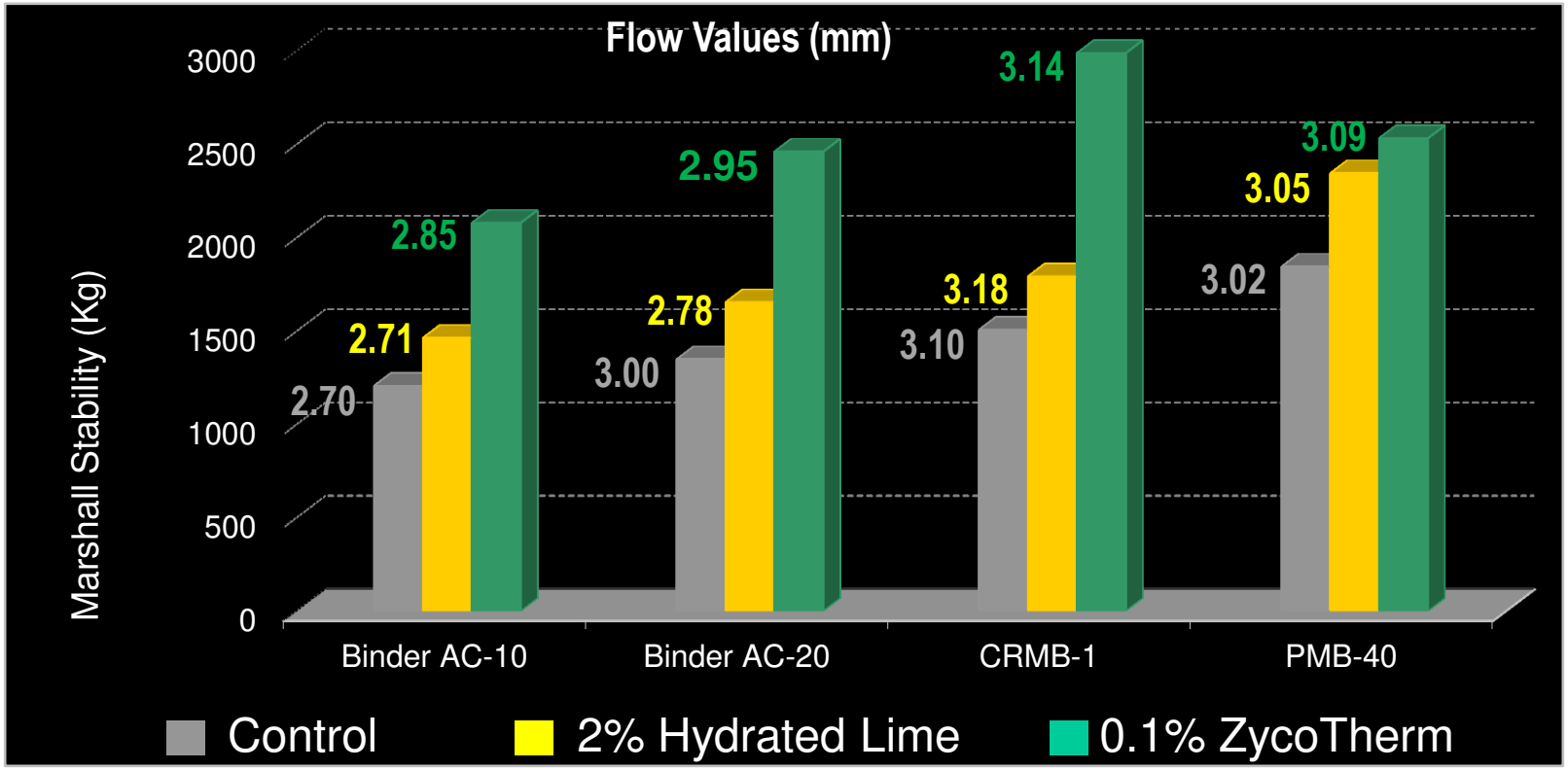
National Center for Asphalt Technology
NCAT
at Auburn University

MARSHALL COMPRESSIVE TEST AASHTO T165 / ASTM

EXTEND TO 15 DAYS



MARSHALL WET COMPRESSIVE STRENGTH
AASHTO T165 / ASTM D1075



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

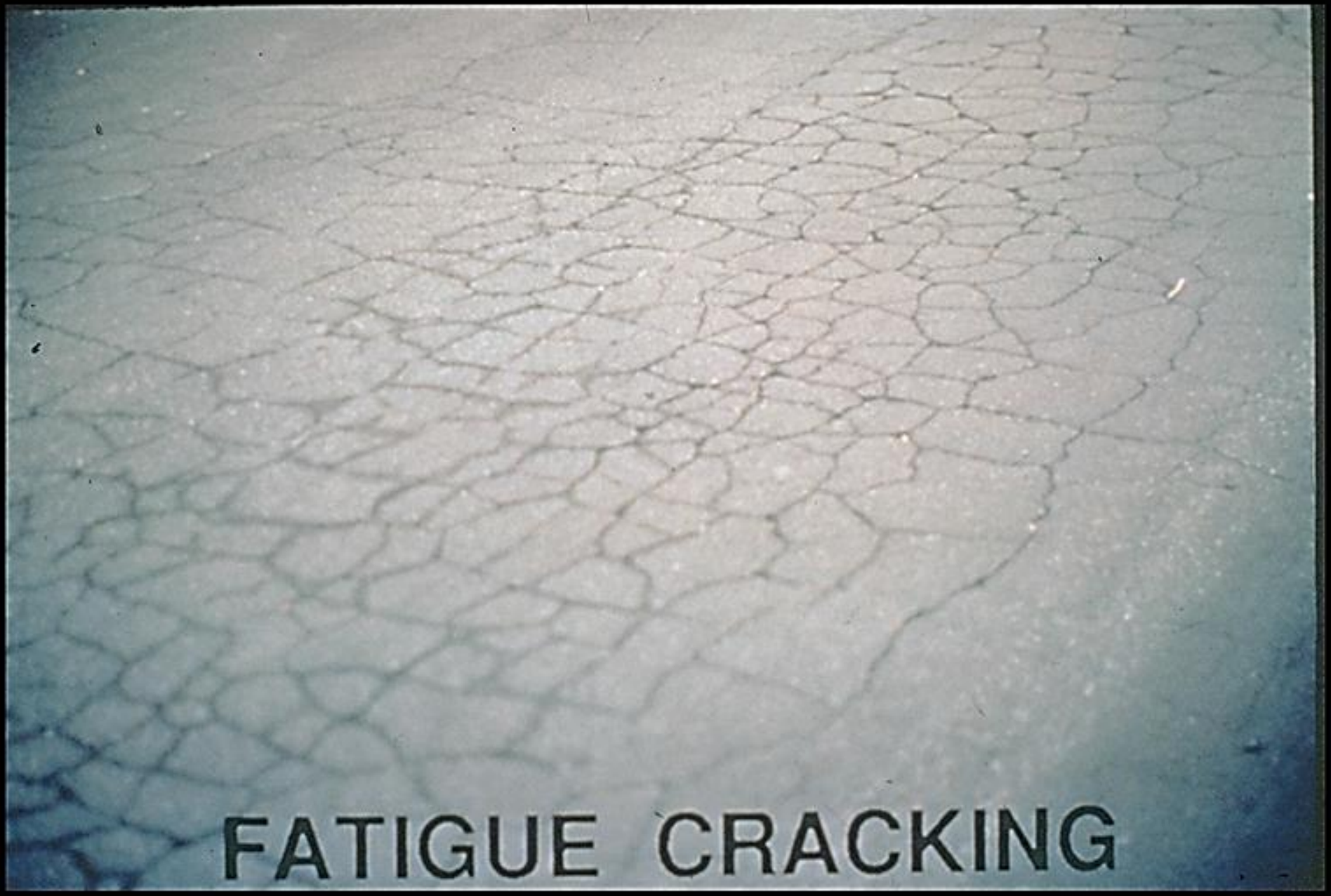
	Control		ZycoTherm					
Sample Number	9	10	11	12	13	14	15	16
ZT %	0%	0%	0.025%	0.025%	0.05%	0.05%	0.10%	0.10%
Max. Penetration in mm	5	3	0	2	2	3	0	0

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.

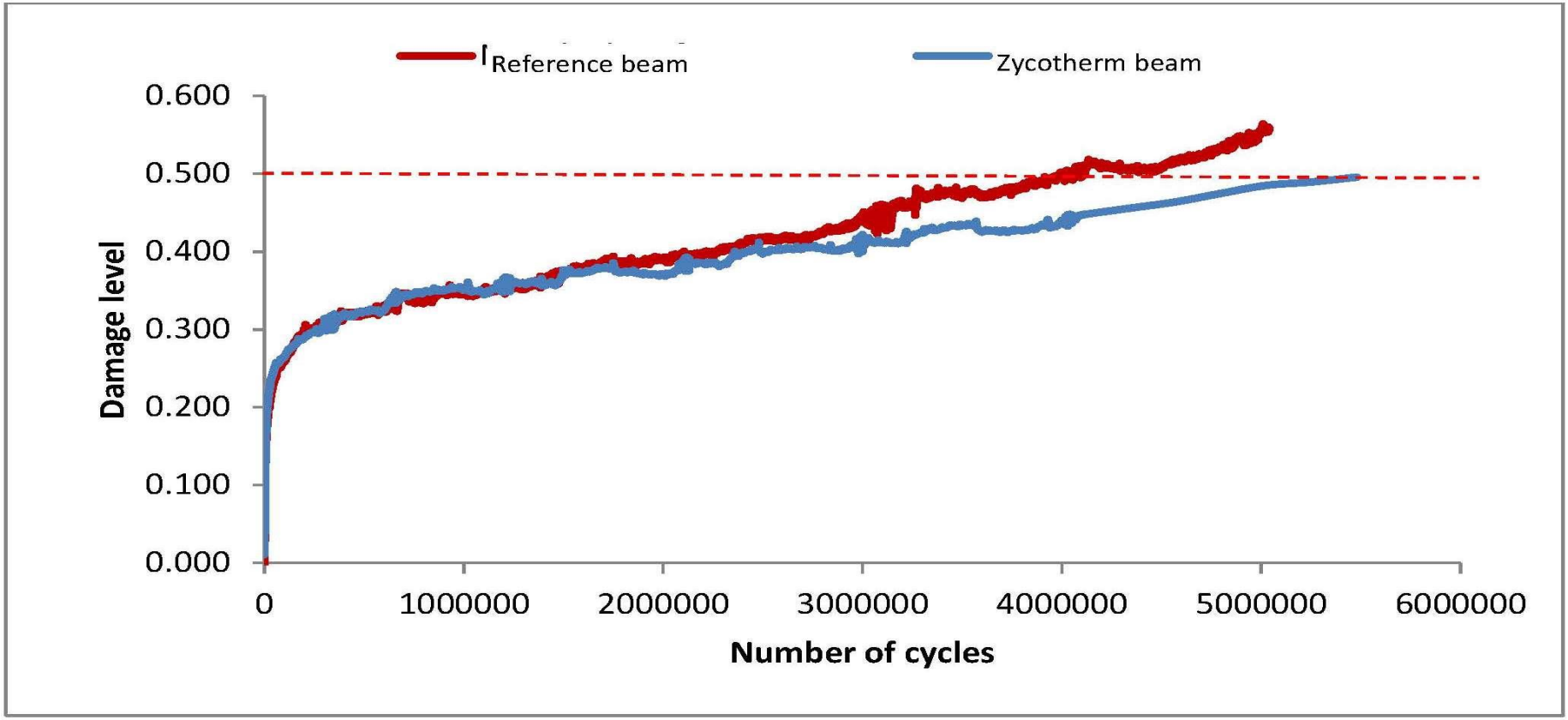
TARMAC
SOIL & MATERIAL TESTING LABORATORY LLC

DUBAI

FATIGUE RESISTANCE

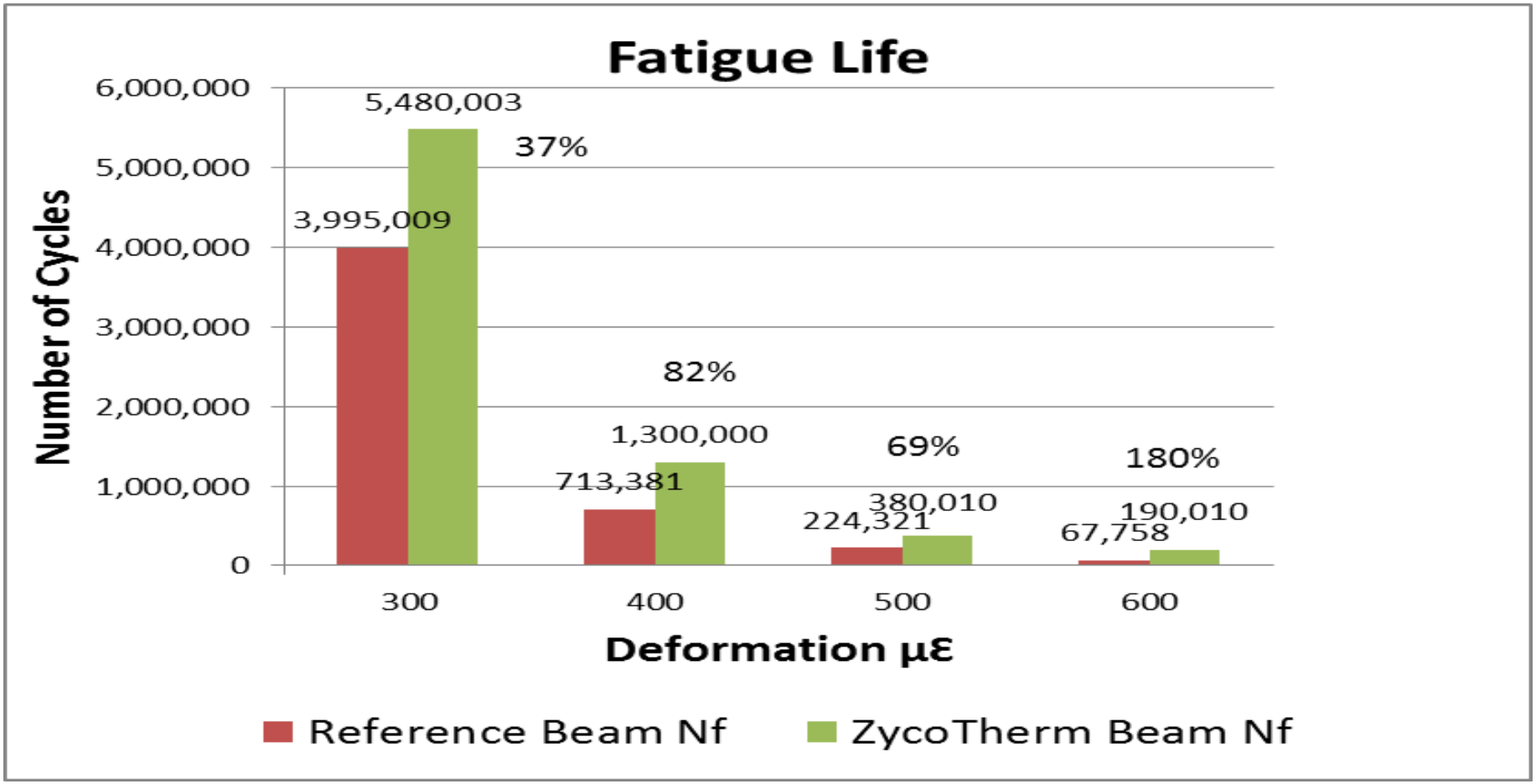

FATIGUE CRACKING

FLEXURAL FATIGUE TEST AASHTO T321-07



Damage level evolution for beams tested with 300 με

FLEXURAL FATIGUE TEST



Higher Number of Cycles means Higher Fatigue Life

FLEXURAL FATIGUE TEST AASHTO T321-07

Beam	με	Reference Beam N_f	ZycoTherm Beam N_f	Fatigue life Increment
1	300	3,995,009	5,480,003	37%
2	400	713,381	1,300,000	82%
3	500	224,321	380,010	69%
4	600	67,758	190,010	180%

Higher Number of Cycles means Higher Fatigue Life

Thank You