Organosilane technology for sustainable road infrastructure

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Abstract. New Organo-Silane nanotechnology, apart from other green benefits, enables dropping of mixing and compaction temperatures of Hot Mixes. Although, the concept of Warm Mix Asphalt (WMA) has been around for a while, the available WMA technologies only talk of drop in mixing temperature and not the compaction temperature, which the new Organo-Silane technology does. It is therefore prudent to call this technology, a ‘Warm Compaction’ technology. In addition, this ‘Warm Compaction’ technology improves strength, fatigue resistance and water resistance, leading to potential extension of pavement life, contributing to sustainability. This paper presents the summary of laboratory studies made at the IMT (Instituto Mexicano del Transporte), Mexico, and Braunschweig University, Germany to assess stiffness modulus, fatigue resistance and water-resistance of this ‘Warm Compaction’ technology at different mixing and compaction temperatures for optimization.

1. Green road
We have taken this earth on lease from our future generations. It is our duty to return it to them in liveable condition if not better. Striving for sustainability through prudent use of limiting natural resources and restrain emissions is the call of the day.

As it is said, ‘Nations don’t build roads. Roads build a nation’. It is very important to develop road infrastructure at a brisk pace, if we want to attain / sustain high economic growth. At the same time, it is equally important to ensure that such infrastructure development is sustainable. Prudent use of limiting natural resources therefore, becomes our responsibility now, more than ever before.

There may be many ways of bringing in sustainability in building roads. Here are some of the ways in which Zydex Nanotechnology contributes to sustainability in road construction:

- Reducing the usage of limiting resources like bitumen, aggregates etc.
- Extending the life cycles of the roads, so as to defer the demand for such resources
- Reducing fuel consumption and low temperature operation leading to reduction in emission

This paper discusses the ‘Low Temperature Operation’ aspect of the Zydex Nanotechnology in particular.

2. Conventional warm mix asphalt and its limitations
The concept of Warm Mix Asphalt (WMA) has been around since the 90’s. It was developed in Europe in response to EEC countries signing the 1997 Kyoto Treaty to reduce greenhouse gases.

A warm asphalt mix process (WAM) has been developed in Europe and was reported at the First International Conference of Asphalt Pavements in Sydney, 2000. A more complete report was given by [2] at the Eurobitume congress in 2000. [1] describes an innovative warm mixture 3 process that was tested in the laboratory and evaluated in large-scale field trials (in Norway, the UK and the Netherlands) with particular reference to the production and laying of dense graded wearing courses [2]. Their work resulted in the development of WARM Foam, Warm Asphalt Mix with foamed bitumen [3]. At the Eurobitume congress in 2004, [4] introduced the use of a synthetic zeolite additive to produce warm mix asphalt. The zeolite creates a foaming effect that results in a higher...
workability of the mix [4]. Warm mixes have received some attention in Europe and Australia since around 2000. The pavement industry in North America started to give warm mixes some interest a few years later and in June 2005 the National Center for Asphalt Technology (NCAT) published two reports about the use of Sasobit, a synthetic wax, and Aspha-min, a synthetic zeolite, in warm mix asphalt [5,6].

Lower mixing temperature in case of WMA, is certainly a huge advantage, but the technology does have certain challenges as follows.

- Lower temperatures used for WMA can result in incomplete drying of the aggregates and the resulting trapped water in the coated aggregates may cause moisture damage.
- Finding the right balance between lowering the production temperatures, applying anti-stripping agents and achieving a sufficiently moisture resistant asphalt mixture might be a challenge when using WMA

This is probably the reason behind WMA technology not catching up all over the world at the pace initially anticipated.

3. Organosilane ‘warm compaction’ technology

The available WMA technologies only talk of drop in mixing temperature and not the compaction temperature. The new Organosilane technology now allows reduction in both, mixing as well as compaction temperature.

In addition the new Organosilane technology also improves coating efficiency, leading to faster and complete coating of even the fines. This is because the Organosilane chemistry reduces the surface tension of bitumen for faster and better wetting.

The workability of the Organosilane mixes is also observed to be better and the compaction easier. The low temperature mixing, low temperature compaction and the other benefits mentioned above are verified by laboratory studies.

4. Case study - transfer center for the road sector (tsw), Braunschweig university, Germany

Goal of the examinations carried out here was to document the influence of the binding agent ZycoTherm® on the mixing process and to document the compression properties of asphalt.

For this purpose, two types of asphalt that are common in Germany, an asphalt binding agent AC 16 B S with 50/70 and an asphalt concrete for asphalt surface layers AC 11 D S with 25/55-55 A, were mixed with and without ZycoTherm® and compressed at different temperatures. An overview of the variants produced is specified in table 5-1.

During the mixing processes, the power consumption of the laboratory mixer was recorded and the time that the degrees of coating of 50 %, 75 %, 90 % and 100 % were reached was noted. The times for reaching the degree of coating of 50 % are specified in table 5-1. Therefore, the mixed material is coated quicker when ZycoTherm® is added. On average, 20 % less time is required. With regard to the mixing performance, for AC 16 B S a tendency was recognised that less performance was required when adding ZycoTherm®.

The compression resistance does not show any difference for both asphalt types when adding ZycoTherm®, as documented in table 5-1. The raw density of the asphalt mixture produced can be considered as equal for both types of asphalt. The densities by volume of the roller compressed asphalt test plates only indicate small differences. The void content is specified as outcoming result in table 5-1.
**Table 1. Compositions of the type of asphalt applied**

| Asphalt | Ac 16 B S | AC 11 D S |
|---------|-----------|-----------|
| Bitumen | 50/70     | 25/55-55 A|
| Bindemittelgehalt | M.-% 4,3 | 6,0 |
| Anteil ZycoTherm®, bezogen auf den Bindemittelgehalt | M.-% 0,10 | 0,15 |
| Gesteine | Gabbro | Gabbro |
| > 16,0 mm | M.-% 2,8 | - |
| 11,2 - 16,0 mm | M.-% 28,5 | 0,5 |
| 8,0 - 11,2 mm | M.-% 12,1 | 20,2 |
| 5,6 - 8,0 mm | M.-% 12,8 | 10,8 |
| 2,0 - 5,6 mm | M.-% 15,2 | 23,3 |
| 0,063 - 2,0 mm | M.-% 22,0 | 37,6 |
| < 0,063 mm | M.-% 6,6 | 7,6 |

**Figure 1. Coating efficiency of ZycoTherm at different mixing temperatures**
Figure 2. Effect of ZycoTherm on power / energy consumption while mixing

Table 2. Effect of ZycoTherm on Compaction Resistance and Voids

| Mix Type | Binder Type | C / ZT | Compaction Temp °C | 50% Coating Sec | Compaction Resistance 21Nm | Void Content Vol % |
|----------|-------------|--------|---------------------|-----------------|-----------------------------|-------------------|
| AC 16 BS | 50/70       | C      | 135                 | 25              | 41.6                        | 7.0               |
|          |             | ZT     | 135                 | 15              | 43.5                        | 7.1               |
|          |             |        | 115                 | 19              | 42.8                        | 7.2               |
|          |             |        | 95                  | 19              | 41.3                        | 6.9               |
| AC 11 DS | 25/55-55 A  | C      | 145                 | 37              | 37.3                        | 4.3               |
|          |             | ZT     | 145                 | 22              | 34.2                        | 4.6               |
|          |             |        | 125                 | 30              | 36.5                        | 5.0               |
|          |             |        | 105                 | 30              | 36.5                        | 5.3               |
### Table 3. Overview for producing the asphalt variants

| Variant | Mix type | Binder type | Addition of ZycoTherm | Compaction Temp. | 50% Coating achieved | Compaction resistance | Void content |
|---------|----------|-------------|----------------------|------------------|----------------------|-----------------------|--------------|
| -       | -        | -           | -                    | 0°C s            | 21 Nm Vol.-%         |                       |              |
| 1a      | AC16 B S | 50/70       | No                   | 135 25 s         | 41.6                 | 7.0                   |              |
| 1b      | AC16 B S | 50/70       | Yes                  | 135 15 s         | 43.5                 | 7.1                   |              |
| 1c      | AC16 B S | 50/70       | Yes                  | 115 19 s         | 42.8                 | 7.2                   |              |
| 1d      | AC16 B S | 50/70       | Yes                  | 95 19 s          | 41.3                 | 6.9                   |              |
| 2a      | AC11 D S | 25/55-55 A  | No                   | 145 37 s         | 37.3                 | 4.3                   |              |
| 2b      | AC11 D S | 25/55-55 A  | Yes                  | 145 22 s         | 34.2                 | 4.6                   |              |
| 2c      | AC11 D S | 25/55-55 A  | Yes                  | 125 30 s         | 36.5                 | 5.0                   |              |
| 2d      | AC11 D S | 25/55-55 A  | Yes                  | 105 30 s         | 36.5                 | 5.3                   |              |

For AC 16 B S, no tendency could be specified with regard to the void content. The void contents are within a narrow range so that this can be considered as equal.

The void contents for AC 11 D S increase with reducing compression temperature. This increase however, is not within the testing accuracy so that here, only one tendency can be specified, there is no statistical security. Deviations within these ranges can still be considered as close to practice.

As a summary, it can be stated that when adding ZycoTherm® you can reduce the time for coating the stones and with a significantly reduced compression temperature, you can achieve an almost consistent void content.

### 5. Case study – instituto mexicano del transporte (imt)

Parameters for testing are as following:

- Asphalt binder: AC 20 (PEMEX, Mexico) with ZycoTherm: 0.075%; reference OBC 5.5% and with ZycoTherm OBC 5.8%; Aggregates: La Canada Quarry
- Sample size: 50mm H X 63 mm W X 380 mm L
- Air voids: 6%
- Test temperature: 20°C
- Deformation Frequency: 10 Hz for four levels - 300, 400, 500 & 600 με (represents pavement deformation under normal transit condition)
- Asphalt mix fatigue life failure criteria: Number of cycles in which the beam stiffness modulus decreases 50% compared to its initial value

For all levels of deformation (300, 400, 500 and 600 με), samples with optimum content of Zycotherm (0.075%) presented extended life for fatigue, so the incorporation of Zycotherm significantly favors the asphalt mix. The amount of load repetitions recorded for the Zycotherm samples were increased by 37 to 180% depending on the level of deformation. It was also observed that Zycotherm addition to the asphalt mix modifies the slope of the fatigue law, which means that Zycotherm samples are less susceptible to deformation levels, compared with the reference samples.
**Figure 3.** Higher Number of Cycles means Higher Fatigue Life

**Figure 4.** Wohler curve (fatigue law)
It was observed that with the addition of Zycotherm in the highest dosage (0.125%) the TSR specification was achieved (≥80%), even when mixing and compaction temperatures were reduced to 135° and 110°. Asphalt mixes with 0.075% and 0.1% presented slightly inferior to 80% TSR values. The conditioned specimens with additive presented 2 to 3 saturation cycles to achieve saturation levels between (70-80%). For all missing dosages, it can be estimated that TSR results will be acceptable for temperature reduction. It was observed that for mixing 135°C and compaction 110°C temperatures, TSR increased when the Zycotherm dosage was increased as well.

![Figure 5. Effect of ZycoTherm on TSR](image1)

**Figure 5.** Effect of ZycoTherm on TSR

![Figure 6. Effect of ZycoTherm (@0.075%) on compaction density](image2)

**Figure 6.** Effect of ZycoTherm (@0.075%) on compaction density
Figure 7. Effect of ZycoTherm (@0.1%) on compaction density

Figure 8. Effect of ZycoTherm (@0.125%) on compaction density

When Zycotherm is used a greater compaction can be achieved for the same and lower temperatures than the reference mix. If mixing and compaction temperatures are reduced benefits in time can be obtained; more time for hauling and waiting before compaction is possible with the Zycotherm addition. Fuel savings during the mixing process and less carbon footprint benefits can be obtained as well.
When the 0.075% additive dosage is incorporated into the asphalt mix, it is observed that deformation is maintained with acceptable tolerance, for similar temperatures as the reference mix. When mixing and compaction temperatures are reduced, deformation is still within high transit levels, according to AMAAC specifications. There is not affectation in rutting behavior when lowering mixing and compaction temperatures.

The asphalt mix with Zycotherm present a superior behavior when produced and compacted at the same temperatures as the reference mix. When adding 0.1% of Zycotherm to the mix the mixing temperature can be lowered in 20°C and compaction temperature to 35°C, deformation is slightly affected, but it is still within the high transit levels and this results may be between the test dispersion. If mixing and compaction temperatures are reduced benefits in time can be obtained; more time for hauling and waiting before compaction is possible with the Zycotherm addition.
6. Conclusion
In summary, addition of ZycoTherm, the Organosilane additive to bitumen

1. Allows the mixing temperature to be lower
2. Gives equivalent or better compaction at lower compaction temperatures.
3. Improves coating efficiency, leading to faster and complete coating.
4. Reduces mixing effort and saves energy.
5. Results in acceptable levels of TSR at lower mixing temperatures.
6. Gives excellent rut resistance at lower mixing and compaction temperatures.

Overall, the Organosilane technology, in addition to lower mixing temperatures, allows lower compaction temperature and gives all the benefits stated above.

7. References
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