# PREVENTION OF EARLY LIFE FAILURE ON COLD BITUMINOUS EMULSION MIXTURES

**I Nyoman Arya Thanaya**

Civil Engineering Department , Udayana University , Denpasar – Bali

*Abstract*

*Hot asphalt mixtures for road pavement reach their best performance as soon as the mixtures cool down. Strengthening pavement by means of polymer grid reinforcement had been investigated in the early 1980's, in order to prevent deformation and cracking. It was found that the best grid reinforcement position was at bottom of the asphaltic layer, which is in line with the elastic layer theory.*

*Meanwhile Cold Bituminous Emulsion Mixtures (CBEMs) are weak at their early life time. Therefore, reinforcement may be required to prevent deformation of the mixtures, because they still contain some amount of water. The objective of the investigation was to find out the suitable location of the reinforcement on CBEMs at earliest age practicable for preventing early life failure. The reinforcement materials used was 'plastic cells' which were made from standard extruded polyvinyl chloride (PVC) sheet. The plastic cells were positioned at the middle height and close to the surface of the CBEMs samples. The samples were subjected to a dynamic cylindrical loading, where the number of dynamic load applied and the deformation were electronically recorded. Stress and strain distributions were analyzed using BISAR 3.0 software from Shell company.*

*It was found that the suitable position of the reinforcement on CBEMs is on the upper side (close to the surface), which give significant prevention on deformation and cracks during early age.*

***Keywords:*** *cold asphalt mixtures, early failure, reinforcement.*

## 1. Introduction

Strengthening of *asphaltic HOT mixtures* by means of high tensile polymer grid reinforcement had been investigated in the early 1980's (Brown *et. al*, 2001). When properly applied, grid reinforcement can enhance the cracking and rutting resistance of asphalt concrete layer in pavements. It was found to be essential to locate the grid at the correct level within the asphalt layer.

Research carried out at Nottingham University investigated the performance of hot asphaltic concrete layer without and with grid reinforcement, constructed over a low stiffness of granular base and subgrade. The asphalt concrete layer was subjected to a simulated traffic loading. It was found that grid positioned at bottom of the asphaltic concrete mixture gave minor evident of cracking with no significant deformation. This confirms that placement of grid at bottom is the correct position to encounter the tensile strains which cause cracking (Brown *et. al*, 2001). The loading was carried out when the hot asphalt concrete mixture at optimum strength, i.e. soon after the hot mixture cooled down.

Meanwhile, early life failure prevention by application of 'plastic cells' reinforcement on CBEMs (a mixture of properly graded coarse and fine aggregates, pre-wetted water and bitumen emulsion) described within this paper, was an investigation of *a different nature*, where the weak early life strength of the CBEMs is the main concern (Thanaya, 2003). The objective of the investigation was to find out the suitable location of the reinforcement on CBEMs at earliest age practicable, i.e. when the CBEMs are generally still weak (Asphalt Institute, 1989) for preventing early life failure due to excessive deformations.

## 2. Methodology

The type of materials used for manufacturing the CBEMs were: limestone coarse aggregates with max aggregate size of 12.7 mm, asphalt sand and red porphyry sand fine aggregates, cationic bitumen emulsion binder produced by Nynas-UK, with 100 pen base bitumen. The aggregates gradation was determined by means of Modified Fuller's Curves or Cooper's Curve/Formula (Cooper et.al., 1985). The CBEMs designed method was based on modification of the Marshall Design method (Thanaya and Zoorob, 2002).

The 'plastic cells' or 'blocks of plastic strip' (supplied as a courtesy of 'Phi Design Ltd'., Northampton, UK) was made from *standard extruded polyvinyl chloride (PVC) sheet that had been cut into strips*. The plastic strip was of 20 mm width, 0.40 mm thick (measured using an electrical vernier caliper 'Micro 2000'). It was supplied with 600 mm long. The length can be supplied to meet demand. The Plastic Strip was 'slotted' or 'cut' with cut size of 1mm width and 10 mm length (half of its 20 mm total width) to enable the formation of plastic strip blocks or 'plastic cells' with block size of 35 x 35 mm. The wall side of the plastic cells was given two holes of 6mm diameter in order to provide better bonding of materials within the plastic cells blocks (this was based on trials results that were carried out beforehand) as shown in Figure 1.

The CBEMs samples were of 150 mm diameter, and were tamped and then compacted using a Gyropac compactor with 240 revolutions, at 540 kPa vertical pressure (equals to 2 times Marshall heavy compaction level) for obtaining about 8 % porosity value to meet most specifications (MPW-RI, 1990 and Nikolaides, 1994). Two types of sample were manufactured, i.e. with and without plastic cells.

Regarding the positioning of the plastic cells, it was thought that it would not be the same as in hot mixture where the correct positioned was found at the base of the pavement. As cold mixtures are weak at their early life time, therefore it would be more suitable if the reinforcement is positioned closer the surface which is the area of highest stress (the load contact area). Based on this consideration, *the plastic cells were then positioned at mid height and close to the surface of the samples.*

**Initially**, a trial on sample of 4 weeks of age with *plastic cells positioned at mid height* was carried. Based on evaluation of this trial (see the section on Results), **further trials** were done on sample without and with *plastic cells positioned close to the surface of the sample.*

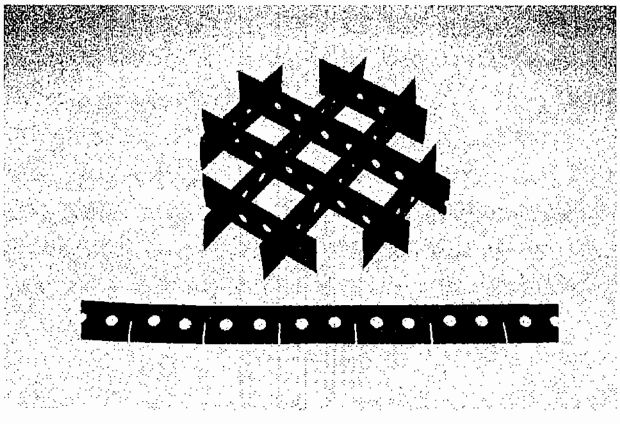

**Figure1.** Plastic Cell with two holes on it's wall side.

The samples were tested at *earliest age practicable (3 days)*, in order to evaluate the effectiveness of the utilization of the plastic cells. The samples were extruded from the mold soon after compaction. It was found the samples were practically can be handled (although they were weak). Then the samples were then left *(cured) for 24 hours* at room temperature 24 °C, and then tested for *indirect tensile stiffness modulus* (ITSM) at 20 °C. The sample was then capped with sand cement mortar (Figure 2) for obtaining even surface (parallel flat) and cured for a further 48 hours to allow the mortar to harden. The overall age of the samples by the time it was subjected to dynamic loading was 3 days of age. The dynamic loading was done using MATTA machine.

After carrying out several trials, for convenience, the dynamic loading was set at: terminal pulse count: 100,000 pulses, conditioning stress: 10 kPa, loading stress: 100kPa (standard loading for dynamic creep test), conditioning time: 2 minutes, pre-load rest time: 1 minute, recovery time: 60 minutes, testing temperature: 40°C.

Stress and strain distributions were analyzed using BISAR 3.0 software from Shell company.

## 3. Results and Discussion

### Results from the initial trial

The sample was with *plastic cells positioned at mid of its height*. The age of the sample was 4 weeks with ITSM at 20°C of 1427.5 MPa. It was observed that *significant cracks and deformation occurred*, as shown in Figure 3. However the sample did not totally collapse. This was because the total failure was prevented by the plastic cell as shown in Figure 4.

### Results from the further trials

Based on result from the initial trial, at this trial the samples were prepared without and with *plastic cells positioned close to the surface of the sample* (about 5 mm from the surface). *These samples were tested at earliest age possible (3 days of age)*. The ITSM at 20 °C of the sample without (No) plastic cells (NPC) was 469.62 MPa, and the one with plastic cells (WPC) was 355.61 MPa.

The NPC sample totally collapse as shown in Figure 5, whereas the WPC sample remained intact (Figure 6).

**Figure 2.** Capping of samples to obtain two parallel flat surfaces, where the capped surface was positioned as the base side during testing (Figure 3).

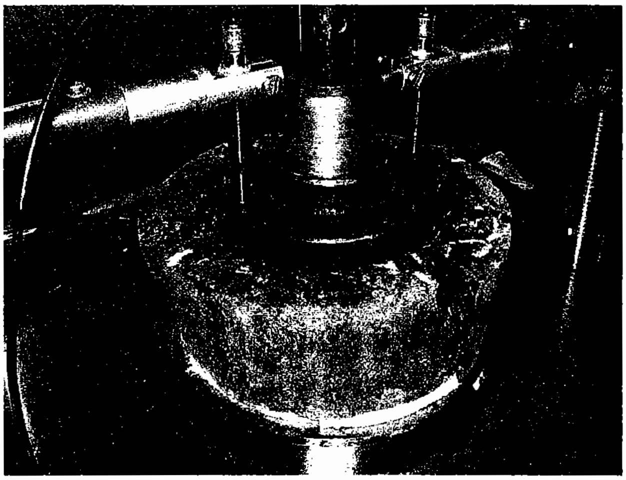

**Figure 3.** Significant cracks occurred on sample plastic cells at mid depth.

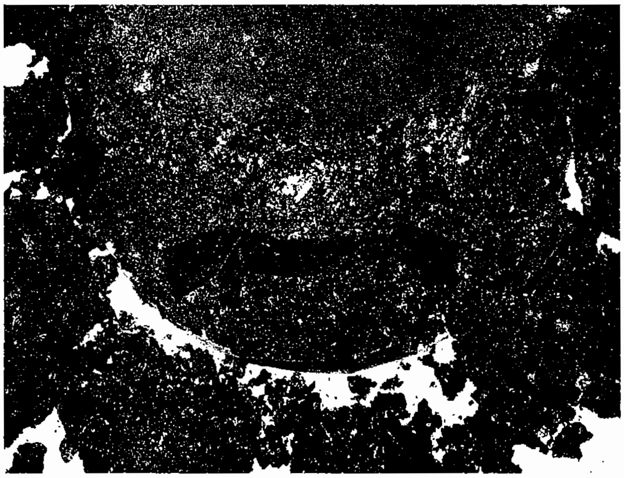

**Figure 4.** The plastic cells prevent the total failure of the sample.

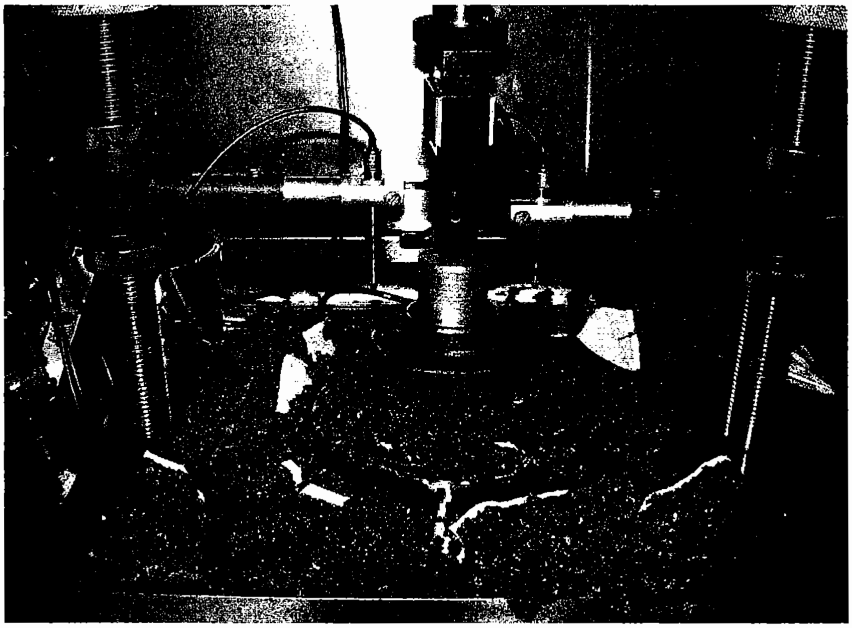

**Figure 5.** Failure of the sample without plastic cells (NPC).

**Figure 6.** WPC sample at the end of dynamic creep test, remained intact.

**Discussion**

The result from the initial trial showed that the sample was heavily cracked. This is because the upper side of the sample was still weak, and cannot withstand the stress applied.

On the further trials, the ITSM of samples with plastic strip (WPC) were *slightly lower* than the samples without plastic cell (NPC), although effort had been made to provide two holes on the wall side of the plastic blocks for giving additional interlocking. This is because the WPC samples do not behave as a composite mass. There is no continuous bonding of the mix due to the presence of the plastic strip blocks. Additionally, bonding between the mix and the plastic strip is weak as the surface of the plastic is very smooth and absorbs no liquid. Therefore, the WPC test resulted in greater deformation during ITSM test, hence gave lower stiffness values. *This trend met with laboratory evidences which indicated that there is a potential bond reduction between the asphalt mixture above and below any geosynthetic reinforcement* (Brown *et. al*, 2001). Although the plastic strip does causes less stiffness of the sample, the reduction of stiffness was minor and within a repeatable stiffness values under ITSM testing mode.

Test results of the dynamic loading was primarily evaluated on the *permanent axial strains* vs. *loading cycles* as presented in Figure 7. The NPC sample gives higher permanent axial strains and totally collapse at 68,000 loading cycles (see Figure 5).

On the other hand the WPC was not failed even at the end of 100,000 preset number cycles of loading, and showing very small deformation but with some minor cracks of about 0.5 mm width and 6 mm length at some parts of the upper side of the sample (Figure 6).

Figure 7 indicates that the plastic cells (*positioned close to the surface*) give significant prevention to deformation under dynamic loading. This is because the plastic cell is able to hold the mixture and *prevent the propagation of cracks*, hence significantly reduces vertical deformation.

Application of plastic cell on CBEMs during their early life appears to be encouraging for preventing deformation of CBEMs during early life time.

Analysis of stress distribution was carried out using BISAR 3.0 software of the Shell company. The test was analysed as a single asphaltic layer which rest on a semi infinite base.

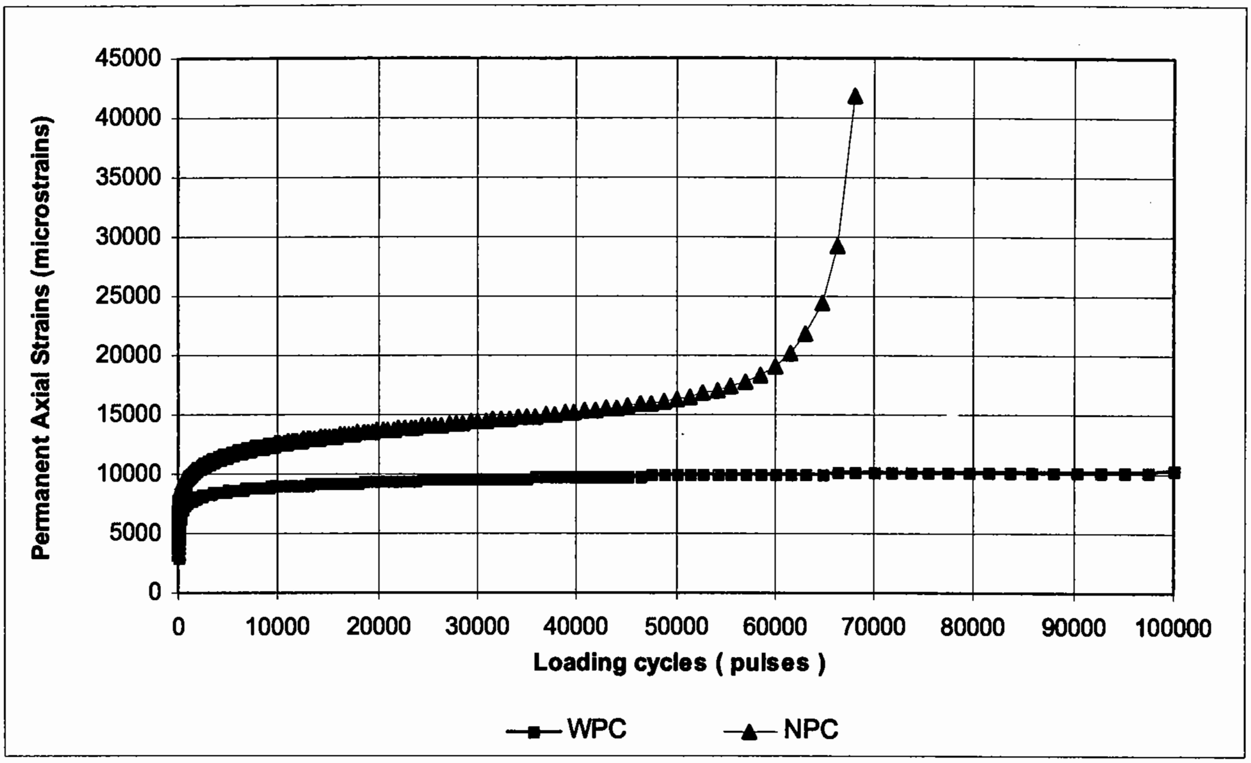


**Figure 7** Permanent axial strains vs. Loading Cycles, at 3 days of age
Note : WPSC= with Plastic Cell ; NPC = No (without) Plastic Cell

The objective of this analysis was to estimate the stresses act on the NPC sample which totally failed/collapse during testing (Figure 5), and to interpret that these stresses were resisted by the plastic cell as in the case of the WPC sample, hence prevented the sample from failure. The strength of the plastic cell was in fact was stronger than the stresses occurred due to the loading.

Based on the dynamic load setting as previously described with loading stress set at 100 kPa stress, it was found to give *2.5 kN actual vertical force*. This actual load was calibrated using a calibrated proving ring. The 2.5 kN force was dynamically loaded on to the *NPC sample* through a cylindrical plate of 16 mm thick and 100 mm diameter or *50 mm radius (Figure 3)*. This loading condition was use as the input load into the BISAR 3.0 software.

With reference to Figure 3, the pavement structure for the analysis was considered consisted of one CBEM (asphaltic) layer with *74 mm thick*, to rest on a very rigid base, which was a steel base. The modulus elasticity for the CBEMs and the steel base was *355.61 MPa* and *190 GPa* respectively. The *Poisson's ratio* of the CBEM and the steel base was *0.35* (commonly use value), and *0.28* respectively. The property of the steel base was taken as a typical of stainless steel property (UMIST, 2003). The stresses occurred due to loading was compressive stress of 145 kPa, which failed the NPC sample, but can be resisted by the plastic cells on the WPC sample.

## 4. Conclusions

There are two points can be concluded from this investigation, namely:

1. The plastic cells (or any type of geosynthetic) reinforcement of CBEMs does reduce stiffness, however the reduction of stiffness was not significant.
2. The suitable reinforcement position of CBEMs is on the upper side (close to the surface), which can give very significant prevention to deformation and cracks at early age due to dynamic loading which simulate loading from passing traffics.

3. The plastic cell used can resist the stress applied hence prevent the sample from failure.
4. Further works however, are still need to be done in order to ensure efficiency, i.e. the type, the strength capacity, and the dimensions of the geosynthetic cells and aspect of practicality on reinforcement of CBEMs.

**Acknowledgement**

I would like to express my appreciation and thanks to my supervisor Dr. S.E. Zoorob for his technical supports and guidance, and to colleague Dr. Latif B. Suparma for his valuable discussions.

**References**

Asphalt Institute, 1989, *Asphalt Cold Mix Manual*, Manual Series No. 14 (MS – 14), Third Edition, Lexington, KY 40512 – 4052, USA.

Brown, S.F., Thom, N.H., and Sanders, P.J., 2001, A study of grid reinforced asphalt to combat reflection cracking, *Proceeding of the Association of Asphalt Paving Technologists (AAPT)*, Vol. 70, 2001, pp 543-571, Florida, USA.

Cooper, K.E. , Brown, S.F. and Pooley, G.R., 1985, The Design of Aggregate Gradings for Asphalt Basecourses, *Journal of The Association of Asphalt Paving Technologists* , Vol. 54 , pp. 324 to 346.

Ministry of Public Works Republic of Indonesia (MPW-RI), 1990, *Paving Specifications Utilizing Bitumen Emulsions*, Jakarta, Indonesia.

Nikolaides A.F., 1994, A New Design Method for Dense Cold Mixtures, *Proceedings of the 1st European Symposium on Performance and Durability of Bituminous Materials*, University of Leeds, March 1994, Editors: J.G. Cabrera and J.R. Dixon, pp. 262 to 269, E & FN Spon, London

Thanaya I.N.A., 2003, Improving The Performance of Cold Bituminous Emulsion Mixtures (CBEMs) Incorporating Waste Materials, *Thesis submitted to the University of Leeds for the degree of Doctor of Philosophy*.

UMIST, 2003, *Wrought martensitic stainless steel.* http://www2.umist.ac.uk/material/teaching/year2/ml2211/icepin/results/materia/martensit.htm , *ML2211 : Design I.* Visited 11-02-03.

Thanaya I.N.A., and Zoorob S.E., 2002, Improved Mix Design Procedure for Cold Asphalt Mixes, *Proceedings of 5th Malaysia Road Conference (MRC)*, 7-9 October 2002, Kuala Lumpur.