ULTRA THIN REINFORCED CONCRETE PAVEMENTS: EXPERIENCES ENCOUNTERED DURING THE CONSTRUCTION OF TWO ROADS

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ABSTRACT

During the beginning of 2002, a section of mesh reinforced concrete pavement 50mm thick was constructed as part of a thin concrete road experiment to a quarry at Roodekrans in the vicinity of Krugersdorp. As a result of the performance of this 50mm section of ultra-thin reinforced concrete pavement (UTRCP) the CSIR was appointed by the Eastern Cape Roads and Transport to apply the concept to the construction of a 2,4 kilometre access road to a quarry in the vicinity of Mthatha. The road would also benefit communities along the road, not only by providing improved access and reducing the risk of accidents but also by improving the quality of life by reducing the dust created by the trucks hauling aggregate along the road.

Towards the latter half of 2007, as part of its 20T programme (*Twenty Identified Townships Roads Upgrading Programme*), which also targeted the implementation of innovative technologies and the creation of employment opportunities in the construction of the roads, it was decided by the Gauteng Department of Public Transport, Roads and Works to pilot the UTRCP concept in this programme. CSIR was appointed to provide specialist support to the Department relating to the construction of ultra-thin reinforced concrete pavements.

It is the intention of this paper to share the findings and experiences encountered and lessons learnt in the construction of these two roads. The paper also touches briefly on the preliminary findings of experimental work that the CSIR has been carrying out in collaboration with the University of Pretoria on comparison of the performance of concrete using reconstituted bottom dump ash as aggregate and conventional crushed stone aggregate in the construction of ultra-thin reinforced concrete pavements.

BACKGROUND

Towards the end of 2001 the CSIR was given the opportunity to take part in a joint experiment with the University of Pretoria and the Cement and Concrete Institute on the performance of thin concrete pavements at Roodekrans near Krugersdorp on the exit lane of the access road to the quarry.

The CSIR's involvement in the experiment was the inclusion of three sections of thin Continuously Reinforced Concrete Pavement (CRCP) with a total length of 40 metres with concrete thicknesses of 50mm, 75mm and 100mm (sections 4, 5 and 6 of the experiment) reinforced with 200 x 200 x 5.6, a reference 193 (SANS 1024 – 1991), welded wire mesh (Photo 1).

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Photo 1: View along CSIR section prior to casting concrete

Construction of the concrete surface was commenced and completed during February 2002 and the road opened to traffic in early March 2002. Heavy loaded vehicles from the quarry have been using this lane since March 2002. Some six years and 900 000 E80 loadings later the three sections are still performing well, with the performance of the 50mm thick section surprising all.

Photo 2: View along section of Road Dr 0 8645

DESCRIPTION OF THE PROJECTS

Road DR 08645 (Mthatha Quarry access Road) (Photo 2)

As a result of the performance of this 50mm section of ultra-thin reinforced concrete pavement (UTRCP), the CSIR was appointed by the Eastern Cape Department of Roads and Transport to apply the concept to the construction of a 2,4 kilometre access road to a quarry in the vicinity of Mthatha (Road DR 08645). The road would also benefit communities along the road, not only by providing improved access and reducing the risk of accidents but also by improving the quality of life by reducing the dust created by the trucks hauling aggregate along the road. It is estimated that the road provides access to the quarry for approximately 400 heavy vehicles daily.

Road DR 08645, which is 9,6 meters wide, was constructed in half widths of 4,8 meters. The foundation for the road is:

- 50mm UTRCP
- 100mm ETB
- 150mm *in-situ* stabilised with 3% lime, compacted to 95% mod AASHTO density (CBR ± 80)
- Roadbed preparation

Construction of the road commenced during January 2008 and was completed in December 2008. The 50mm UTRCP and 100mm ETB were constructed by local labour using light plant and equipment. The road is regarded as a pilot project and a 200 meter section of the road has been identified for ongoing monitoring. Accurate records have been kept of all layerworks on this section of road. It is intended to monitor the performance of this 200 meter section over a period of four to five years.

Road 36.11 Soshanguve (City of Tshwane) (Photo 3)

The Department of Public Transport, Roads and Works (DPTRW) initiated the *Twenty Township Upgrading of Roads Project*, which is but one of Gauteng Government's flagship interventions to address infrastructure backlogs in identified townships. Key elements of the project are:

- Upgrading of gravel streets in existing townships to surfaced roads.
- Construction work to be aligned with government's Expanded Public Works programme (EPWP) to optimise job creation and ensure capacity building in life and technical skills.
- In its endeavours to eliminate the huge backlog in infrastructure, DPTRW realised that new technologies should be considered to ensure value for money in terms of available financial constraints.

DPTRW decided to explore the research done by the CSIR into 'Ultra Thin Reinforced Concrete Pavements' (UTRCP), with light reinforcing mesh, as a possible cost-effective solution with long-term low maintenance as an innovative road building technology.

The City of Tshwane agreed to participate and identified a road in Soshanguve for a demonstration project. The demonstration project was approved in November 2007 and, after the training of the construction team, construction commenced in mid-2008 and was completed in December 2008. Road 36.11, a bus route, is 7,2 meters wide and approximately 1,2 kilometres long, constructed in half widths of 3,6 meters. The *in situ* material consists mostly of a dark reddish-orange ferricrete that is slightly plastic and has a CBR: 30-50 at 93% mod AASHTO. The design of the road is as follows:

- Cut to line and level.
- 150mm subbase of *in situ* material scarified to 150mm and compacted to 95% mod AASHTO. In view of the demonstration approach, the top 40mm of the first 150 meters was scarified after the initial construction and treated with SS60 emulsion at the rate of 40 litres/m^3 and compacted with a pneumatic tyred roller (in practice the water cart was used). The remainder of the road was untreated.
- 50mm UTRCP (Ref 193) mesh.

The excavation to line and level and construction of the subbase was undertaken by 'conventional' plant.

Photo 3: Road 36.11

FINDINGS, EXPERIENCES AND LESSONS LEARNT

Tolerances of support layer

As the name implies, the concrete is only 50mm thick and, therefore, tolerances are critical and the success of the UTRCP process is dependant on attention to detail. This applies not only to the concrete layer (concrete strength, thickness, placing, curing) but also to the placing, supporting and joining of the steel mesh panels as well as the tolerances of the layer supporting the UTRCP. In view of the relatively thin layer of concrete being placed, the support layer should be constructed to levels to accommodate the concrete within 5mm of designed level. In order to achieve this, it was found advisable to establish levels at every 10 meters.

Side shutters

Construction of shutters

The side shutters must be robust enough to withstand the manhandling on site as well as to accommodate the vibrating beam used to level the concrete. It was found that 50mm high box sections with a minimum base of 50mm, cut to 2 to 3 meters lengths with 3 lugs per section were most suitable (Photo 4).

Length of shutters

It soon became obvious that side shutters longer than 3 meters (e.g., 6 meters) emphasised any high and low spots along the longitudinal section of the road resulting in pavement thicknesses in excess of the specified 50mm (up to 80mm) in places – an expensive exercise for the contractor.

Fixing of shutters

The lugs are necessary to fix the shutters in position with the steel pegs without affecting the smooth movement of the vibrating beam. Driving the pegs through the shutter led to uneven finishes and meant that the beam had to be lifted over each peg position and the resulting ridge in the concrete pavement evened out. Once the shutters had been fixed, it was found advisable to place a straight edge across the two sets of shutters to take dips to the top of the subbase to ensure that the 50mm concrete thickness will be obtained across the section prior to placing the mesh. High spots must be corrected.

Mesh reinforcement

Sheets vs rolls

As previously stated, the mesh being used is a ref 193 mesh, i.e., 200 x 200 x 5,6mm (SANS 1024 – 1991). Initially, a 150 x 150 x 4mm mesh was used but this proved to be too floppy and difficult to keep in position – hence the decision to go for a more 'stable' mesh. It also proved difficult to get the rolled mesh to lie flat and, therefore, the standard flat sheet of 6 meters by 2,4 meters was adopted for the construction of the 50mm UTRCP.

Photo 4: Box side shutter

Checking of mesh

On the Soshanguve site it was found that the mesh delivered to site was of such poor quality, such that, although the longitudinal reinforcing bars were parallel to each other, the cross bars were not, with spacing between the bars varying between 200mm at the one end of the panel to approximately 180mm at the other end. This caused innumerable problems for the contractor when trying to accommodate the overlapping of panels.

Batches of mesh should be checked on delivery to the site, prior to being placed on the road so that the contractor can take remedial measures without causing delays to the contract.

Transporting

The contractor should not be allowed to transport mesh from his 'yard' to the site on any mode of transport that can damage the mesh. In one instance, the contractor chose to transport the mesh using his front-end loader, resulting in considerable distortion to the mesh causing great difficulty in getting the mesh to lie flat as well as getting the panels aligned (Photo 5).

Fixing of reinforcing stools (chairs)

On both projects it was found beneficial to fix the stools to the mesh in the yard and then transport the panels to the road. The primary stools were placed 800mm apart in both the horizontal and vertical direction and the secondary stools offset 400mm in both the horizontal and vertical from the primary stool. This would mean that the stools would be 400mm apart in the diagonal (45^o) direction. Both contractors opted for the use of plastic stools.

Photo 5: Mesh reinforcement damaged during transport

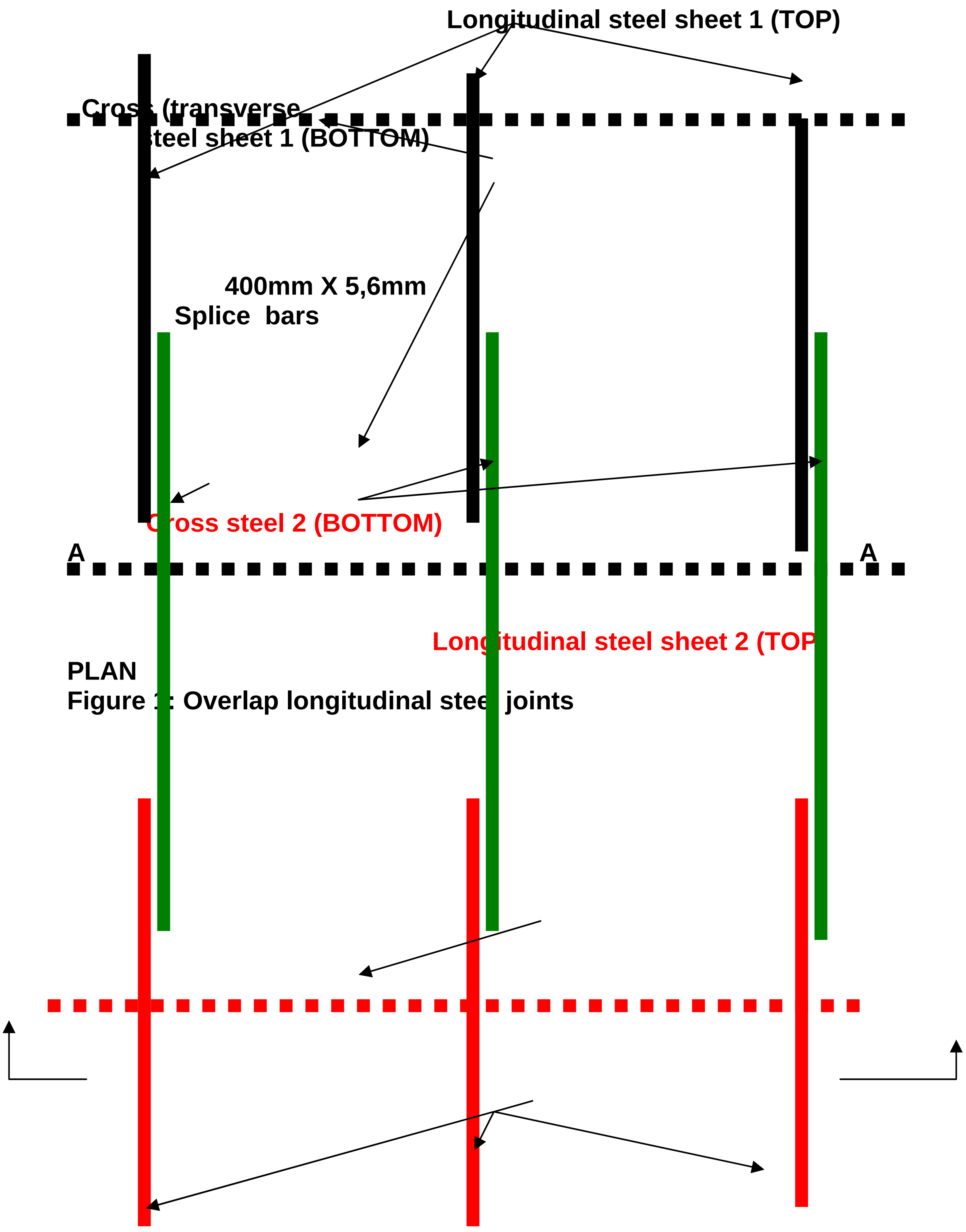
Positioning and securing

As the Reference 193 welded wire mesh, used for reinforcing, is fairly flexible care must be taken in placing the mesh and ensuring that its proper location within the layer is maintained so that, once the mesh has been placed in its correct position on the stools, it must not be walked on. As a result of input on the Soshanguve road this problem was solved fixing the stools to the steel so that the mesh rests on the support layer while splicing etc. is done. Once this is complete the stools can be flipped over in a sequence away from the completed concrete work. Care must also be taken not to disturb or distort the mesh during the concreting operations. The use of a bridge similar to that shown in Photo 6 has proved successful in assisting in achieving this.

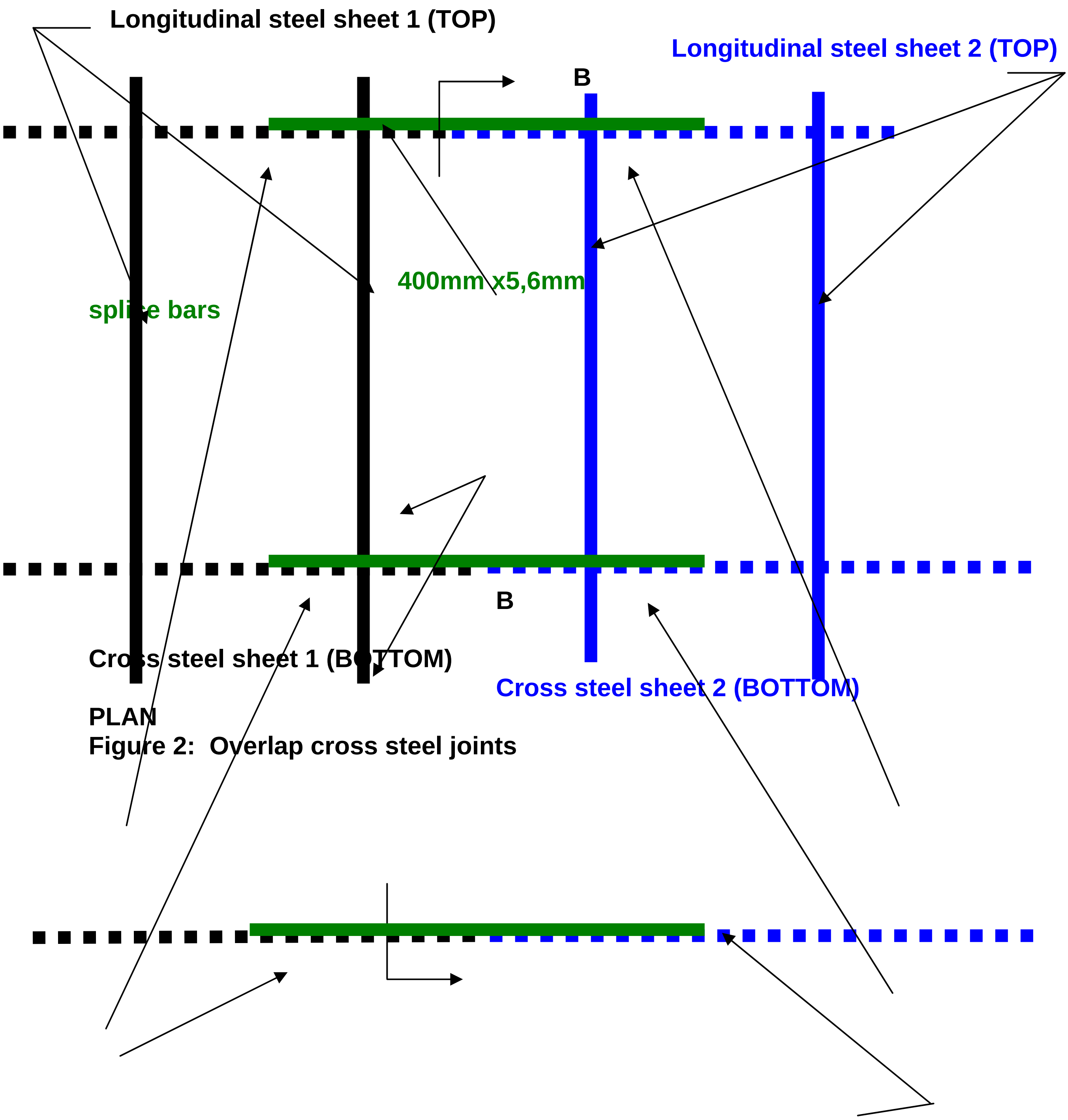
Overlapping

In order to ensure that the cover to the mesh of 25 mm is obtained the respective longitudinal steel wires and cross steel wires of the mesh respectively are always placed in the same plane. The problem occurs at overlaps where the layers tend to build up and the cover is affected. This problem was solved by laying the mesh butt jointed in both the longitudinal and transverse direction and the overlap achieved by splicing the individual 5,6mm bars of the mesh with a 5,6mm splice bar 400mm long as shown in Figures 1 and 2.

Photo 6: Use of bridge during concreting operation



PLAN
Figure 1: Overlap longitudinal steel joints



PLAN
Figure 2: Overlap cross steel joints

Concrete mixing operation

It was observed that there was often efficient and effective control of the batching and mixing process. It is imperative that the type of cement must be carefully controlled at the mixer site and must not deviate from the cement used in the design mix. This also applies to the quality of the aggregate. Mixing must be done in suitably sized concrete mixers in good condition. Experience has shown that a reverse drum type mixer with a hopper for feeding the ingredients works well (Photo 7).

Photo 7: Example of reverse drum mixer

The mix must be closely controlled during construction by way of frequent slump cone measurements and the meticulous taking and handling of cubes for testing at three, seven and 28 days. The concrete mix design should preferably by undertaken by a laboratory using all the materials that are going to be used during construction. Both contractors used a local laboratory to do the mix design. The specified strength is 30 MPa after 28 days.

Concrete construction

Concrete transporting and placing

At Mthatha it was found beneficial to batch and mix the concrete at a few selected locations along the road and transport to the work area using mechanised wheelbarrows. The following observations, to promote the efficient and effective placing of the concrete, were made:

- The concrete should be placed expeditiously after mixing.
- The concrete should be placed as close to its final position as possible and not moved by shovels. Use of the bridge described earlier in the paper will promote this.
- Steel squeegees, and not rakes, should be used to spread the concrete.
- Leaching of the concrete should not take place at the joints.
- There should be no walking on the wet concrete.
- Clean-up of the work is automatically done as work progresses – e.g., concrete spillage next to shutters, from wheelbarrows, etc. Cleanliness of operation is essential – attention to 'job hygiene' must be developed.
- No concrete should be allowed to dry or set on or next to the concrete pavement.

Concrete screeding and finishing

Screeding

Experience from both sites has indicated:

- That the width over which the vibrating screed operates should not exceed 3,6 meters. When the screeding width exceeds 3,6 meters difficulty was experienced in moving the screed forward and the screed was more susceptible to sagging in the centre.
- The proper spreading of the concrete prior to screeding promoted the effective and efficient operation of the vibrating screed.
- The vibrating screed beam as well as the other tools and equipment used in the placing of the concrete must be clean and in good working order.
- The vibrating screed beam must ride smoothly on the side shutters and be moved at an even pace allowing sufficient time for bubbles to escape but not over-vibrating and bringing the fines to the surface.
- To facilitate the smooth running of the vibrating screed on adjacent completed concrete surfaces a 1-2mm thick galvanized sheet, approximately 300mm wide, should be placed on the top of the previously cast section for the vibrating beam to ride on.

Vibrating screed

As previously stated some problems were encountered with sagging of the screed where the width being screeded exceeded 3,6 meters. Another problem experienced with certain screeds was that the frequency and/or amplitude of the screed appeared to be too high resulting in the screed 'vibrating itself to pieces' as the work progressed. As a result of this tendency and the possibility of 'over-vibration' the use of a roller to compact the concrete is being investigated. The roller basically consists of a 100mm diameter pipe, usually aluminium that spins in the opposite direction to which it is being advanced, thereby compacting the concrete. An example of such a roller is shown in Photo 8.

Finishing

Both roads were finished with a broom finish as shown in Photo 9. In the case of the Mthatha road, it was necessary to finish with a bull float and in places with a wooden float before brooming (Photo 10). This is probably due to the width of screeding (4,8 meters). In the case of Soshanguve only minor touching up with a wooden float was required. From experience on the two sites, it is strongly recommended that a canopy consisting of a frame covered with a PVC tarpaulin prior to brooming and after brooming prior to covering with the plastic sheeting be used during curing of the concrete. Placing of the plastic sheeting too soon after brooming results in damage to the surface while covering too late results in drying out of the concrete (Photo 11).

Photo 8: Example of compaction roller

Photo 9: Broomed finish

Photo 10: Hand floating prior to brooming (note the use of a bridge)

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Photo 11: Damage to texture due to plastic cover sheeting

Concrete curing

The biggest problem experienced with curing the concrete by covering with plastic sheeting was that the contractors tended to skimp on the number and suitability of the weights for holding the plastic in position (Photos 12 and 13).

Photo 12: Plastic held securely in position

Photo 13: Inadequate provision

End of day joints

It soon became obvious that special attention needed to be given at the 'end of day' (construction) joints to:

- Make provision for the longitudinal steel to pass through to ensure the continuity of the steel;
- Provide a neat joint, and
- Minimise leaching of the concrete paste at the joints.

After various considerations, it was found that the best method of achieving these aims was to make use of a split shutter sealed with a shutter sealing foam strip (Photo 14).

Photo 14: End of day joint

UNIVERSITY OF PRETORIA EXPERIMENT

During 1995 to 1997, the CSIR in conjunction with SASOL conducted a number of experiments into, *inter-alia*, the suitability of SASOL bottom dump ash, a waste product from the production of liquid fuel from coal, as an aggregate in the manufacture of light-weight concrete for the construction of concrete road pavements. As a result of the exceptional performance of the 50mm UTRCP at the Roodekrans site, it was decided to proceed with further testing, in the laboratory, of sections constructed with 'ash' concrete and 'conventional' concrete in conjunction with the University of Pretoria to compare the flexibility of concrete manufactured with SASOL ash as aggregate (Photo 15).

Based on these findings of the ash concrete and the thin concrete experiments there would appear a number of advantages to using ash as an aggregate for construction of a 50mm CRCP pavement layer. Apart from cost advantage (waste product and reduced cement quantity) and the suitability of ash concrete for labour-based construction, as handling and working with the material will be easier, a result of the lower density that the increased flexibility observed when using ash as an aggregate should significantly extend the life of the pavement under loading due to the fact that it is less rigid than a pavement layer constructed with conventional concrete.

This would suggest that the life of an ash concrete pavement should exceed that of a conventional concrete pavement under similar conditions. As a result, it was decided to extend the laboratory testing to a field test where both concretes could be subjected to a 40 kN wheel load simultaneously. Field testing is presently being carried out at UP experimental farm on test facility of 8m long by 4m wide (Photo 16).

Photo 15: Laboratory testing

Photo 16: Field testing

The pavement consists of a 50mm UTRCP (reference 193 mesh) (half width ash concrete and half width conventional concrete) constructed on an ETB with an *in-situ* CBR of 30 founded on an *in-situ* material with an *in-situ* CBR of 17. The continuous effect is simulated by casting edge beams at extremities of slab. Loading is applied by means of the hydraulic press which applies an on-off load of 80kN to the axle, moving the axle vertically.

The pavement has been subjected to 2 million loads with neither slab showing any sign of stress. Deflections are constant at approximately 0,5mm. It has been decided to discontinue the on-off loading and provide a constant load of 80kN to the axle and to measure the deflection bowl around each wheel to get a better understanding of what effect the 50mm UTRCP has on how the load is distributed to the lower pavement layers.

COMMENTS AND CONCLUSIONS

The technology associated with the construction of the 50mm UTRCP to date has largely been based on observation and lessons learnt on the projects as is indicated by this paper. It is hoped that the constant load testing to be carried out at the University test site, as described in the previous section, as well as the HVS testing described in the paper dealing with that aspect will shed more light on the mechanisms occurring within the UTRCP regime.

With the present knowledge and observations on the various projects and preliminary test results from the Heavy Vehicle Simulator (HVS) and the University of Pretoria (UP) to date the authors are confident that the UTRCP technology is suitable for urban streets and bus routes and all indications are that it is suitable for application on 'provincial' roads carrying up to 3 000 vehicles per day with 5 to 7.5% heavy vehicles.

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