17. Performance of Ngcingcinikhwe Village concrete geocell access road

J.J. Maastrecht[1] and N.G. Mcilroy[2]

[1] Kaytech Engineered Fabrics, Business Manager, Eastern Cape Region, East London, South Africa

[2] Ingwenya Engineers cc, East London, South Africa

ABSTRACT

In 2007 the Eastern Cape Department of Roads and Transport and the isolated community of Ngcingcinikhwe identified the need for a road linking the village to the provincial road network. Under the "inaccessible roads" community-based transport programme, cast-in-situ 100mm high geocells, in-filled with 20 MPa hand-mixed concrete, were used to construct a 3,0 m wide by 1 100 m long road at a 16 % design grade. The geocells were placed on a base of reworked in-situ material, compacted to a G7 quality. Geocells were selected because of their suitability for labour intensive construction (LIC) methods, low permeability, interlocking flexibility, durability and low maintenance characteristics. The labour tasks involved in this project, its benefits to the community and the current performance of the road are discussed in this paper.

1. INTRODUCTION

Ngcingcinikhwe is a small, isolated village within the Mnquma Local Municipality district, approximately 20km west of the R409, Ndabakazi to Nqamakwa (Figure 1). It is physically isolated, with the Kei and Tsomo Rivers to the south and west and steep escarpments to the north and east.

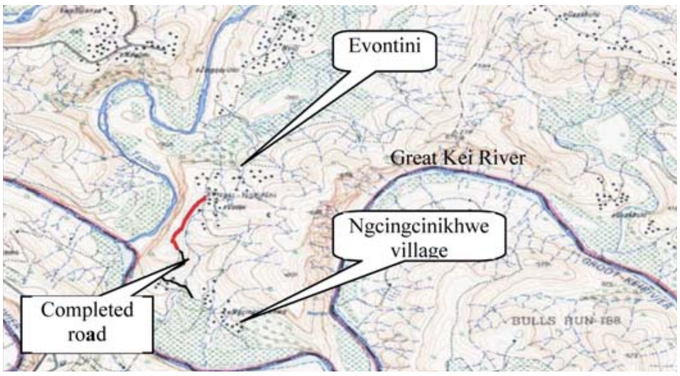

Figure 1 : Locality plan

The existing access was more than a kilometre up a 45 degree steep slope by way of a poorly maintained, eroded footpath. This made access to schools, employment and medical facilities an arduous and time consuming operation. All construction materials, supplies, water, agricultural produce and personal belongings had to be carted by hand or donkey. In 2007 the need for an all weather access road was identified as a priority by the residents of Ngcingcinikhwe Village and the Department of Roads and Transport, under the 'inaccessible roads programme'. Temporary employment during construction provided an important economic boost, injecting R660 000 in wages into the area and providing training and employment for 111 local residents (EPWP Update 2009).

2. SCOPE OF WORKS

The appointed consulting engineer provided the functions of design, project management and the procurement of equipment, materials and labour on behalf of the Eastern Cape Department of Roads and Transport. All work was completed in strict compliance with the Expanded Public Works Programme (EPWP) guidelines (SALGA 2005). A project steering committee recruited local labour, who were then employed by the Eastern Cape Department of Roads and Transport on a contract basis. The committee was pivotal in ensuring fairness in all employment opportunities. Employees were required to open bank or Post Office bank accounts and payments for "tasks completed" as measured by the engineer's representative on site were deposited electronically on a monthly basis. Wages of R 60 per task for labour and R 70 per task for supervision and security were paid out over the duration of the contract. The total cost of the project was R 3 017 856 of which R665 290 (22%) was paid out in wages. A monthly summary of the number of persons summarised by gender and age is given in Figure 2. Total employment opportunities and cost of work opportunities are summarised in Figure 3 and Figure 4 respectively. A total of 556 person-days of non-accredited training was given by the full time site technician. (Neil Mcilroy, unpublished data).

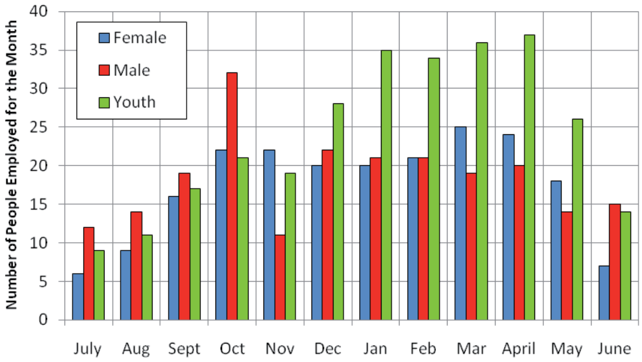

Figure 2 : Work opportunities summarised by gender and age

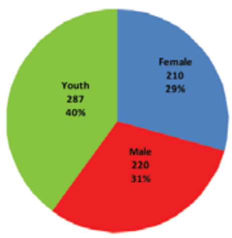

Figure 3: Total employment opportunities

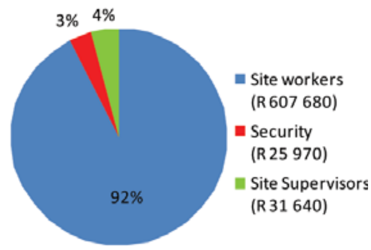

Figure 4: Cost of work opportunities

3. CONSTRUCTION

The design was based on the lowest design traffic class of E0 (<2 x 10^6 E80s). A 3.0 m wide road, with regular passing bays was selected to serve the very low traffic volumes. About 50% of the road (600m) was constructed at a 16% longitudinal gradient. The pavement design was based on Draft TRH 4 and Draft UTG 2. The insitu material was found to have a CBR between 7 and 15%, which required a minimum 100mm to 125mm G5 base material. G5 material was not locally available and prohibitively expensive to import. As an economical solution the designed G5 layer was substituted with a 150mm layer of G7 quality selected material, while the paving blocks were changed to cast insitu 20 MPa concrete blocks (geocells) and the thickness increased to 100mm. This provided a total layer thickness of 250mm on top of the G7-G9 quality subgrade. The subgrade was ripped and worked laterally, in a hand "cut to fill" operation across the width of the road (Figure 5). Cut to fill was minimised on the steeper sections by construction of a stone masonry gravity retaining wall on the low side, secured by dowelling into the bedrock. The reworked subgrade was shaped to the profile of the road (Figure 6) and compacted with a pedestrian roller to a G7 to G9 quality.

Figure 5 : Reworking insitu Material & Shaping road base

A further 150mm of selected insitu material was placed and compacted to 93 % Mod AASHTO density (G7) to provide the base layer (Figure 7). On completion of the base layer a 100 mm deep by 200 mm wide excavation for a concrete edge thickening was cut along the inside of the side forms to provide a restraint for the completed concrete block finish (Figure 8).

Figure 7 : Compaction of base layer

Figure 8 : Excavation of edge thickening

All work, including selected layer, cut to fill excavation, spreading, levelling, trimming to levels and collection of water from the Kei River for compaction was carried out by hand with the exception of compaction which was achieved using a pedestrian roller. A typical section is shown in Figure 9.

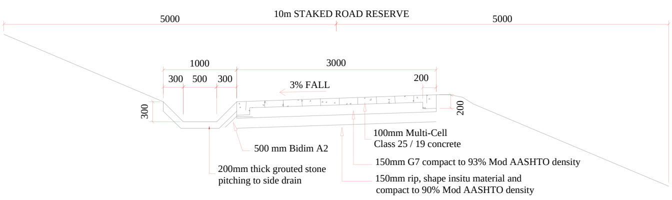

Figure 9 : Typical cross section

4. CONCRETE-FILLED GEOCELLS

Concrete-filled geocells were chosen as the surfacing layer to increase the combined base and surfacing layer thickness, while providing a durable, low permeability, low maintenance interlocking system that is simple to construct using labour intensive methods. The geocells are manufactured from laminated, polypropylene, slit-film woven tape strips that are stitched together, forming 200 mm by 200 mm square cells that provide a three-dimensional honeycomb structure. Geocells were supplied in custom made 10 m long by 3.0m wide by 100 mm high panels. Kaytech Multi-Cells™ were favoured because they are manufactured to the required custom width and are supplied with a half-height surrounding patented (Patent No. 2003/3945) tension frame, which simplified setting out by pegging or attaching the frame with binding wire to the steel side forms (Figure 10). Prior to fixing the geocells in place it is essential that the surface of base is accurately trimmed to ensure that the top of the geocells line up with the top of the side forms (T2Training Centre, 2005). Once expanded and installed the geocells provide a stiff, three-dimensional insitu shuttering which does not collapse while being filled with concrete. The 200 mm x 200 mm cell size provides a jointed concrete block system, similar to interlocking paving. In this instance the interlocking relies on small deformations of the cell walls whereas with interlocking paving reliance is placed on the jointing sand CIDB 1030, April 2000), (Figure 11). The tight geocell joints prevent the ingress of surface water thus protecting the G7 base layer. Compaction is achieved by tamping and general walking on the fresh concrete (Maastrecht et al 2007). All concrete work for the project was completed by hand, including transporting of all materials by wheelbarrow up to a distance of 500m, collection of water from the Kei River, mixing, delivery, placement and surface finishing. The final surface was wood-float finished.

Figure 10 : Setting out geocells

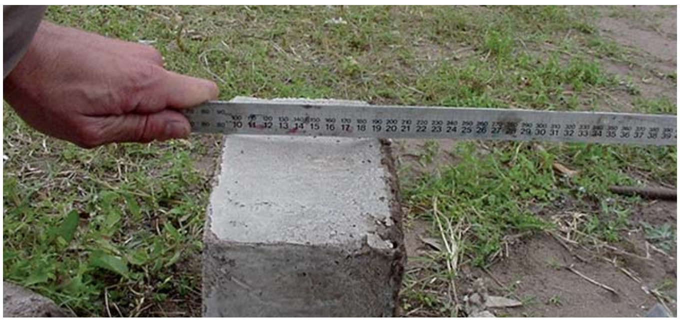

Figure 11: Interlock deformation of sidewalls

5. PRODUCTIVITY AND COSTS

The production for the road layerworks and surfacing was underachieved by approximately 50% of the estimated value (Table 1). This can be attributed to the logistics of working in the remote, hostile environment where materials were transported distances up to 500m by wheelbarrow and water had to be carried for over 1.0 km from the Kei River, uphill in 25 litre containers. Labour was paid per completed task, which was calculated per square metre for the selected layers and per cubic metre for concrete. A summary of the tasks completed and costs incurred is provided in Table 1.

Table 1 : Cost of tasks to construct the road

Operation	Unit	Quantity	Tasks	Planned quantity per task	Actual quantity per task	Cost per Task	Total Cost
Selected layers	m2	3667	2997	3.54	1.22	R 60.00	R 179,820.00
Concrete surfacing	m3	353	2453	0.2	0.14	R 60.00	R 147,180.00
							R 327,000.00

Material costs were relatively high for the concrete surfacing due to the remote location of the village and comprised approximately 66% of the total cost, with the balance of 34% being labour.

6. PERFORMANCE EVALUATION AFTER ONE YEAR

The system appears to be functioning well with a noticeable improvement in the standard of living of the local community (Figures 12 and 13). Many dwellings now have rainwater tanks for potable water, where previously it was not possible to deliver such large objects to the area. The 200mm by 200mm block "paving effect" is less pronounced in certain areas, where the concrete is marginally thicker than 100mm and the cracking has not fully reflected through yet. In a few places the geocell wall has extruded a few millimetres above finished concrete. Although visible, it does not have any effect on the performance of the road system. In one area near the top where the concrete road terminates, there is evidence of vehicles using the road before the concrete had sufficient time to cure. This has resulted in deformation of the concrete surface and spalling of individual block edges. Backfill was neglected along the side of a short steep section near the top, exposing what appears to be a very marginal thickened edge restraint (Figure 14).

Figure 12: Completed road one year later

Figure 13: Completed road displaying interlocking block effect

This has resulted in the concrete blocks diverging, decreasing the interlock characteristics and increasing permeability. Maintenance is to be done during the next phase. The general appearance is uneven, but this is intentional to ensure traction on the steep grade.
Maintenance will be required, in areas where the stone-pitched side drain has eroded and exposed the base, to prevent undermining of the road (Figure 15). Recent developments have lead to the development of a specialised specialised steel side form (Figures 16 and 17), where the geocell can be extended through the side form and beyond the edge of road.
The side form is supplied with slots cut at 280mm centres. The geocell panel is extended through the slots and tensioned. The concrete for the road is cast and finished to the top of the side forms.
The slotted side form is stripped once the concrete has set, the geocell extended and side drain completed in the concrete / geocell system. This will also eliminate the requirement for a thickened concrete edge to the road on the side where the drain is situated.

Figure 15: Erosion of stone-pitched drain

Figure 14: Exposed edge to geocells

Figure 17: Geocells through side form slot

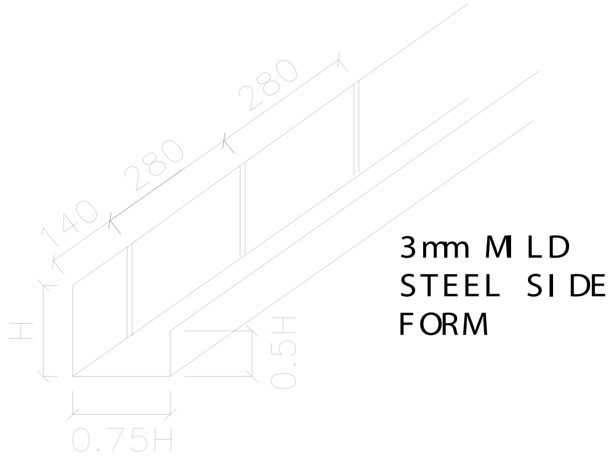

Figure 16: Specialised side form detail

7. CONCLUSIONS

Geocells provide an economical solution for labour intensive construction on steep grades. Low permeability joints coupled with a flexible interlocking system can be used over substandard materials. Custom made widths and heights and the introduction of an external patented tension frame around the geocells has made labour intensive construction considerably easier. Constructed correctly, the system has a low maintenance requirement and is easily repaired by the local community using skills learned during construction. Maintenance of stormwater drains has lead to the development of a specialised side form which in future will allow the road and side drain to be cast in a continuous width of geocells. Use of this system has provided the community of Ngcingcinikhwe with employment during construction and a vehicular access road of which they are particularly proud as they built it with their own hands.

In November 2009 the Eastern Cape Department of Roads and Transport was awarded the Extended Public Works Programme (EPWP) Kamoso National Award for "Best Innovative Project – Infrastructure Sector" for this project. The Kamoso awards were launched in 2007 by the National Department of Public Works to reward National, Provincial, Local government and Public bodies that have excelled in implementing the EPWP.

8. ACKNOWLEDGEMENTS

Permission to publish this paper has been granted by the Eastern Cape Dept of Roads and Transport, whose contribution is gratefully acknowledged.

9. REFERENCES

CIDB (March 2005). A Construction Industry Development Board guide to best practice Best Practice Guideline – Part 4-5 Labour-based methods and technologies for employment-intensive construction works Cast in-situ block pavement.

Draft TRH 4 (1996). Structural design for Flexible Pavements for Interurban and Rural roads

Draft UTG 2. Structural Design of Segmental Block Pavements for South Africa.

EPWP- Update (2009). Road links village to the world. Ngcincinikwe Access Road. Province of the Eastern Cape Roads and Public Works - Expanded Public Works Program. Issue 5, pg 8.

Ingwenya Engineers cc (2009), A cast in-situ block pavement suitable for low volume access streets. Unpublished technical report

J.J. Maastrecht, S. Narasimulu, K. Singh (2007). Using concrete filled geocells for the upgrading of a steep section of District Road d1125, Vulindlela, Pietermaritzburg, Kwazulu-Natal, South Africa. 3rd Africa T2 Technology Transfer Conference, Mangochi, Malawi

SALGA (July 2005). National Treasury, Department of Public Works: Guidelines for the Implementation of Labour-Intensive Infrastructure Projects under the Expanded Public Works Programme (EPWP): second edition.

T2 Training Centre (February 2005) Introduction to Labour Based Construction Course – Concrete Drifts. KwaZulu-Natal Department of Transport.