RAILWAY & HARBOUR ENGINEERING

- CONSTRUCTION OF BERTH 306 AT RICHARDS BAY
- REPAIRING THE STURROCK DOCK SLIDING CAISSON
- TRACK DEFORMATION MEASUREMENT
ON THE COVER
Liviero Civils has been involved in several high-profile projects ranging from the Gautrain and the Gauteng Freeway Improvement Project to two 2010 World Cup soccer stadiums, namely Soccer City and the Royal Bafokeng Sports Palace Stadium (the latter is depicted on the cover).

ON THE COVER
Liviero Civils – Major player at Soccer City and Royal Bafokeng Sports Palace Stadiums 4

OPINION
A ticket to ride  3

RAILWAY AND HARBOUR ENGINEERING
New berth 306 expands capacity of Richards Bay coal terminal  8
Sturrock Dock sliding caisson – repairing a 65-year-old marine structure  14
Track deflection measurement using particle image velocimetry  18
Benefits of routine ballast inspection using ZARR – Zetica’s Advanced Rail Radar  25
The design and construction management of Umlabu private siding  32
Retention of technical professionals – a reminder for engineering and technology organisations  37

HISTORY AND HERITAGE
Railway track material and maintenance in South Africa – a brief history up to 1988  43
Past Master 20 – George Craig Saunders Pauling  54
Past Master 21 – James Bisset  56

GENERAL
CRB retaining walls – aiming for zero defects  59

IN BRIEF  64
The tough all-in-one Terragrad for Mapei superplasticiser used in the manufacture of Gautrain sleepers  69
Bigen Africa appoints new chairman  71
Much Asphalt reduces carbon footprint with new technology  72
Demanding concrete specifications for new French rapid rail system  73
Sustainable engineering solutions in Mauritius  74

SAICE AND PROFESSIONAL NEWS
Developing a capacity building manual – Brasilia, 2008  72
Membership Committee – SAICE membership categories  74
SATC 2009  75
Nominations for election of Council for 2010  76
Obituary – Denis (DAB) Mills  78
SAICE Photo Competition 2009  79
Diarise this!  80
FOR MANY, OR PERHAPS even most South Africans, mass transit in its purest forms of “trams+trains+buses+metros+tubes+undergrounds” remains a dream and something that only happens overseas. Where trains or buses are operational in South Africa, it traditionally represents a mode of transport that is often dirty, unreliable, unsafe and therefore not first choice.

If our transport authorities really concentrate on running the new BRTs, Gautrain and new trains effectively, there is a chance for change, but we have only this one window of opportunity and have to use it NOW. We have to support all proactive initiatives by authorities, such as taking unroadworthy or unlicensed vehicles, as well as over-exploited and tired drivers, off the road.

There is a certain joy in using efficient public transport, and I never pass up the opportunity to go for a special ride when I get the chance. Recently in Holland, I found the new trams a pleasure to travel in, but the older trams are getting rather tatty. The so-called Randstad Rail coaches between Rotterdam and Den Haag are also not really of the standard that I would usually associate with Dutch public transport.

On the other side of the world, in the city of Brasilia in Brazil, their fairly new Metro is a shiny clean mode of transport. Kevin Wall and I, during our visit to a WFEO workshop in December 2008 (see page 72 – Ed.), went for a quick ride to experience the ‘look and feel’ and were suitably impressed. At one of the stations we even found a guy busy cleaning the handrail fence at 18:30 in the evening! The only criticism is possibly that there are too few seats and too much standing room, with too little to hang on to.

A lesson to be learnt from them is definitely that ticketing should be painless and easy to understand. Even with our almost non-existent Portuguese we were able to buy a ticket, from a FRIENDLY lady at the ticket booth. This stands in stark contrast to the rather unhelpful and hard-to-understand New York transit system and their staff, where everything was in English!

A ticket to ride should be a ticket to an experience, not merely getting from one place to another.
Liviero Civils, part of the Liviero Group, which last year celebrated 25 years of active construction in South Africa, has, according to Liviero CEO Richard Saxby, developed a very firm foundation. “Our strategy of ‘planned, controlled focus’ is producing solid results and we are expanding in a balanced and sustainable way,” he says.

The story of Liviero is one of single-minded determination. The roots of the company can be traced back to its founding in Mirano, Italy, in 1955 by Giosue Liviero – late father of current Liviero Group Chairman Luca Liviero – and its eventual opening in South Africa in 1983.

Luca joined his father in the company in 1989 and although Giosue laid the foundations of this dynamic company, after his death in 1996 Luca ensured the continued successful growth of the Liviero Group.

The company initially concentrated on building in KwaZulu-Natal and grew into a well-known name there. Many recent landmark buildings in Durban, including the Standard Bank Head Office KZN, Quays and Quayside at the Point and 7 On Palm in the Gateway, are the work of the Liviero Building Company.

Capitalising on the successes of the Building Company, the Liviero Gauteng and Limpopo branches were established in 2002 and have grown from strength to strength, complementing the excellent growth in KwaZulu-Natal.

Liviero has become a force in the building industries of KwaZulu-Natal, Limpopo, North West and Gauteng, and the company’s considerable private
holding of scaffolding and formwork has contributed significantly to its cost-effectiveness and given it an enviable competitive advantage.

THE EMERGENCE OF LIVIERO CIVILS

Liviero expanded into the civils market with a calculated plan to become a force in the industry. Luca Liviero started putting in place a uniquely experienced team of leaders in the civils industry, including CEO Richard Saxby, Liviero Civils MD, Stuart Knight, and the Operations Director, Charles Wright.

He also immediately began to strategically build up a substantial fleet of quality plant, largely Mercedes transport and Caterpillar equipment, when purchase conditions regarding foreign exchange and lower interest were at their most economic levels. This has largely protected the company from the effects of financial fluctuations and ensured self-sufficiency. This commitment has also contributed to the successful growth of Liviero Civils.

“This calculated strategy has paid off in so many ways,” says Stuart Knight, “but perhaps its most potent result is the effect it has had on the Liviero brand. Today the company is recognised for the quality it produces across the board and the immaculate condition of its plant and equipment.”

Knight says that from early on Liviero Civils concentrated on entering the larger market of technically challenging civils works. “This strategy has also paid off handsomely,” he says. “Within a short time we were active on the Gautrain project in Sandton and Rosebank, and in two 2010 World Cup soccer stadiums, including major earthworks and construction at Soccer City and the reconstruction of the Royal Bafokeng Sports Palace Stadium to ensure compliance with the high FIFA standards. This included a major increase in the seating capacity of the grand stand with its striking roof design. We are also involved as a joint venture partner on two major sections of the Gauteng Freeway Improvement Project.”
In addition, Liviero has become a respected name with most public and private sector clients. “Our goal is always to be a contractor of choice,” says Knight.

THE FUTURE
Liviero Civils is in a planned growth stage. They believe in quality and reliability and their vision is to consolidate and grow their strengths and to further develop their unique position in the southern African market.

The dynamic approach of Luca Liviero and his senior management has helped attract to the company men and women of the highest quality who have the common purpose of seeking opportunity and personal growth in a rapidly growing yet focused team.

Liviero’s head office in Kyalami has recently been extended with the addition of a new building for Liviero Civils. “I think the building symbolises in many ways what we are,” says Knight. “Its central positioning in Gauteng is excellent, it is an impressive and commanding structure and, above all, it is new and dynamically designed to accommodate future changes.”

Richard Saxby adds: “Our future will be developed by selectively researching new areas of enterprise and carefully weighing up our resources and overall ability to tackle them successfully. We will grow with a view to long-term sustainability.”

Stuart Knight concurs: “Planned profits are our aim, produced with committed and focused personnel whose wellbeing is regarded as a cornerstone of our business. The commitment and perseverance of our team are of the utmost importance to our ability to succeed in an ever-changing and exciting South African civil engineering market.”

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New berth 306 expands capacity of Richards Bay Coal Terminal

The construction of berth 306 at Richards Bay Coal Terminal, involving 11 caissons, has increased the capacity of the terminal from 72 to 82 million tons per annum. Extensive monitoring of the dredging operation was carried out, and it appears that the construction had very little negative effect on the environment.

BACKGROUND
The Port of Richards Bay, situated on the eastern coastline of South Africa, 170 km north of Durban, is one of the country's premier ports. It was opened in 1976 for the exporting of 10 million tons of coal over a three-year period. Since then the
The port has grown continuously and today handles more than 80 million tons of cargo per year, which is 50% of the total tonnage of cargo handled in all the ports in the country. Sixty-five million tons of coal is handled annually by the Richards Bay Coal Terminal (Pty) Ltd (RBCT), which is one of the largest coal terminals in the world. Coal is transported to the terminal by Transnet Freight Rail in 200-wagon trains from the mines in the Mpumalanga region.

In 2001 RBCT approached the Transnet National Ports Authority to provide an additional berth which would increase the capacity of the coal terminal from 72 to 82 million tons per annum. Approval was granted in 2003 for the provision of the additional berth. Tenders were called for in April 2004 and the construction was awarded to a consortium, BRSB Joint Venture, which consisted of Basil Read (Pty) Ltd, Sivukile Construction (Pty) Ltd, Bhoe Construction (Pty) Ltd and Van Oord ACZ Marine Contractors, in April 2005, with a value of R250 million.

**PROJECT DESCRIPTION**

The berth to be provided had to accommodate a bulk carrier of 150 000 tons with a draft of 18.5 m. It was to be 320 m in length, which would increase the total length of the coal terminal’s berths to 1 950 m.

The provision of the berth required the following: excavating a caisson pit; casting 11 caissons; flooding the pit and floating the caissons to the quay wall site; improving the soil in the area where the caissons were to be founded; sinking the caissons; backfilling behind the caissons; constructing the mass capping and proving the bollards and fenders; dredging the caisson foundation trench; dredging the basin and disposing of the spoil; obtaining approval to mine sand offshore; sand winning offshore; and conducting environmental monitoring throughout the process.

**CAISSON CONSTRUCTION**

It was decided to construct the caissons in a pit because land was available in the port, port operations would not be adversely affected and this method had been used successfully in the past. The internal dimensions of the pit were 185 m long, 85 m wide and 15.5 m deep. Groundwater seepage into the pit was contained by creating a trench along the sides of the pit from which seepage water would be removed since the only source of seepage water was along porous layers found in the sides of the excavation. As a portion of the pit had been used as a caisson pit in the past, the pit first had to be closed off by constructing a berm across the entrance – this was later removed to allow the caissons to be transported to their final resting place.

Eleven caissons were required to construct the quay wall. Each caisson had a base which measured 27.9 m by 19.8 m and was 1.5 m in depth. Onto these bases the caisson walls of 22.7 m in height were cast. Each caisson consisted of two circular cells which were joined by a dividing wall and required 2 130 m³ of concrete. Casting the eleven caissons took 8 months to complete. Once the caissons had been cast, the basin was flooded which allowed them to be floated. Flooding of the basin was carried out by inserting three pipes of 900 mm in diameter into the berm wall with an invert level of +0.5 m, which allowed the variations in tidal levels to fill the basin in a controlled manner within five days. Once the basin had been flooded, the berm wall was excavated, allowing the caissons to be towed from the basin.

Due to their uneven wall heights, the caissons did not float in a vertical plane but listed at an angle of 20 degrees. This tilt was reduced to 3 degrees through a process of ballasting the chambers, inserting...
12 concrete blocks and 92 tons of sand into each caisson. Once the required degree of tilt had been reached, the caissons were towed 5.5 km to the construction site.

**EXCAVATING THE CAISSON TRENCH AND SOIL IMPROVEMENT**
Before the caissons could be placed into position, a trench had to be excavated to a depth of 18 m and the soil improved to ensure the stability of the caisson wall. This excavation was carried out by dredger. Where there was insufficient water depth for the dredger to pass through, a water-injection dredging technique was used which fluidised the material and allowed it to flow to areas that the dredger could traverse. Due to the poor soil conditions under the proposed quay wall, soil improvement was required. This was carried out by a combination of constructing stone columns in the silty or clay layers and deep vibration of the sandy layers to reduce settlement and improve bearing capacity.

**PLACING THE CAISSONS**
The caissons were placed in their final position by flooding the cells and filling them with sand. The sand was, in turn, compacted by lowering a compaction probe into the saturated sand at 23 positions over the entire area of the cell. The joints between the caissons were sealed with a concrete-filled sock in the front and a sock filled with graded stone at the rear of the caisson. Once the caissons had been placed and fixed, the construction of the mass capping could commence and the bollards and fenders could be fitted.

**DREDGING AND RECLAMATION**
The project required 3.8 million m$^3$ to be dredged and spoiled, and 0.53 million m$^3$ to be dredged offshore and reclaimed. Two trailer suction dredgers were used during this process. The dredging of the basin and spoil disposal took 22 weeks and the offshore winning and reclamation took one month to complete. The dredged material was dumped in a designated area approximately 3.5 km from the harbour.
entrance, which had also been used for dumping dredged spoil from normal maintenance since 1987. The disposal of material resulted in two mounds forming offshore, 5 m in height. This was due to the fact that a large amount of material was being dumped in one position in a very short period and there was therefore no time for nature to disperse it quickly enough. Since then, these mounds have been eroded and the sea bed is exposed again. Sand winning was done at a site 7 km offshore and stockpiled in an area behind the quay wall, from where it was spread along the newly placed caissons to create the berth.

ENVIRONMENTAL EFFECTS
As large volumes of dredged material would have to be disposed of for future expansion projects, the Record of Decision (ROD) for this project required extensive monitoring of this dredging operation to be carried out, the results of which would assist in formulating the basis for future similar projects. In the past, all dredged material was disposed of onto the beaches surrounding the port. Due to a concern raised by Interested and Affected Parties (I&APs) as to the possible impact on the environment of continuing with this practice, the tender documents made provision for two areas where the dredged material could be disposed of. The areas of concern included the port confines, the Mhlumu estuary adjacent to the port and the offshore marine waters. It was, however, decided to dispose of all the material on the offshore dumpsite to minimise costs as the allocation of 0.5 million m³ allotted to beach disposal did not warrant the cost incurred per m³. This was the first time since the port had been opened that dredged spoil as a result of capital dredging was required to be dumped offshore.

Since the start of construction of the port in 1974, the beaches in the vicinity of the port had been used for disposal of dredged spoil. The spoil would be piped from the dredger to a point above the high-water mark on the beach and the spoil would be pumped into the surf zone. To date 98 million m³ of material have been pumped onto the beaches. Dumping the spoil onto the beaches in this way reduced the cost of the project and also allowed the beaches to be nourished with sand, which assisted in reducing the erosion that is a characteristic of KwaZulu-Natal beaches.

The required monitoring had to take place before, during and after dredging. Data was to be collected before dredging which would form the baseline against which the effects of dredging operations and recovery times could be assessed in the various stages of construction and after construction had ceased. Sampling sites were situated at various locations within the port and offshore.

The parameters that were to be monitored were: water quality (physico-chemical, nutrient and metals); sedimentation; sedimentation quality (metals); benthos (soft substrate); benthos reef; fisheries; mangrove swamps; and zostera.

The results of the sediment monitoring showed that the highest levels of turbidity and deposition occurred closest to the dredging operations and at the dumping site. The greatest impact was restricted to a distance of 500 m from the dredging operations, where 5 mm of deposition took
place. The turbid plumes that were visible in the port were due largely to wind. From the data available, this could have occurred 11% of the time that dredging took place. There was no evidence of sediment entering the estuary as a result of dredging activities at the coal berth. At the dumpsite there was significant evidence of sediment deposition, as could be expected, and mounds had formed where the material had been dumped.

The water quality was monitored to establish whether any changes had occurred to the physico-chemistry of the water as a result of any increase in turbidity and/or the potential release to the water column of nutrients, metals and organic contaminants. Pre-dredging data indicated a high level variation in these characteristics, which is considered normal for a port or estuarine environment. The results of the monitoring did not give a clear indication as to whether or not the physico-chemistry parameters had been affected by the dredging, other than in one instance. This was at a site next to the dredging operations which was in a sacrificial zone. Where non-compliances did occur, it was difficult to distinguish whether they had resulted from normal port operation activities or the dredging activities.

The change in sediment granulometry and the total organic content parameters were also monitored. There was no evidence that the sediment suspended during dredging operations had significantly altered the sediment granulometry. Similarly, no evidence was found of changes in the total organic content that could be ascribed to the dredging operations.

The degree to which sediment was contaminated by the following metals was also assessed: arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc.

Pre-dredging and post-dredging data showed no evidence that surface sediment from five sites within the port was contaminated. The same applied to samples taken offshore, where little evidence of any contamination was found after dredging had been completed.

The monitoring of offshore fisheries showed that the spoil disposal had not obviously benefited or compromised the fishes retained by offshore fisheries. In fact, there is evidence to suggest that the catch rate increased in the vicinity of the disposal site and commercial fishermen were not concerned about the possible impacts of disposal of dredged spoil.

The one area on which disposal did have a negative effect was the offshore benthic reefs. Monitoring showed that spoil disposal smothers the reefs in localised areas. As this practice had been taking place for many years and there were other factors that were influencing the condition of the reefs, it was difficult to determine exactly what the effect of the construction of berth 306 had had on the reefs in the area. It was, however, suggested that the dump site be moved further offshore to deeper water.

CONCLUSION

The construction of berth 306 at Richards Bay Coal Terminal, involving 11 caissons, has increased the capacity of the terminal from 72 to 82 million tons per annum.

The results of the monitoring programme suggest that the construction of berth 306 had very little negative effect on the environment and that natural events play a larger role in changing the environment. It is hoped that with the results obtained, there will be far fewer uncertainties to be investigated and taken into account when a similar project is undertaken in future.
The Port of Cape Town currently has three ship-repair facilities (Sturrock and Robinson Dry Docks and Duncan Dock), backed by a range of specialist service providers, all of whom are able to offer a comprehensive choice to serve the sea routes of the South Atlantic, and especially the local fishing industry and the fast-expanding West African oil industry offshore from Angola and Nigeria. This range of facilities, added to the advantage of location, enhances the already strong position created by the quality of local yards, the support services and the extensive skills on offer.

The unusual feature of the Cape Town ship-repair scene is that while the Port owns and provides the docking facilities, all work is carried out by independent companies, which book one of the yards for the period of the contract. Although this arrangement has its advantages and drawbacks, the reputation of the local industry is high. It has a record of fast turnarounds for a huge

### Table 1 Dimensions of Sturrock Graving Dock

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall docking length</td>
<td>360,0 m</td>
</tr>
<tr>
<td>Length at bottom</td>
<td>350,4 m</td>
</tr>
<tr>
<td>Width at entrance top</td>
<td>45,1 m</td>
</tr>
<tr>
<td>Width at bottom</td>
<td>38,4 m</td>
</tr>
<tr>
<td>Depth over entrance sill (HWOST)</td>
<td>13,7 m</td>
</tr>
</tbody>
</table>

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**Sturrock Dock sliding caisson – repairing a 65-year-old marine structure**

Sturrock Dry Dock in the Port of Cape Town, the largest of the two dry docks, is an important facility. Transnet required a detailed condition report on the dock and the compilation of a comprehensive repair programme for the sliding caisson and associated equipment. The gate has been drydocked for some four months now and the assessment is still in progress.
variety of craft, ranging from the local offshore fishing fleet, to larger vessels of all types, including drilling platforms and other huge structures deployed by the oil industry.

The largest of Cape Town’s two dry docks is the Sturrock Graving Dock (Figure 1). Located at the end of the Duncan Dock, it has the dimensions shown in Table 1.

UPGRADING REQUIREMENTS

Transnet Projects, by means of a letter of invitation in April 2007, approached Frans Kapp (coastal and port engineer) for a quotation for providing a detailed condition report, compiling a repair programme and estimating the cost of repairs to and/or possible replacement of the Sturrock Dry Dock sliding caisson and associated equipment.

Frans, being the marine consultant to Africon (Pty) Ltd, approached this firm for assistance and the tender for this work was subsequently awarded to Africon (Pty) Ltd, with Frans to manage the project.

A comprehensive condition report, cost estimates for repairing the existing Sturrock sliding caisson and equipment, and costing for four proposed options were required. The report covered the condition of the following items:

- the metal structure and all plating and tanks, including an ultrasonic survey
- all railings and pipework, including an ultrasonic survey
- all pumps, valves, pipes and equipment
- the lifting deck pivots and moving parts, including counterweights, bearings, bushes, etc
- the haulage winch and chains, and related mechanical parts involved in the operation of the gate, including those parts that are in the quay wall
- the quay slider groove
- the sealing surface on the caisson

In addition, the structure had to be evaluated and other associated work needed to be done to ensure proper completion of the contract.

ASSESSMENT OF THE CAISSON

The assessment consisted of: a site visit; arranging for cleaning where necessary; inspecting all equipment on the caisson and reporting on acceptability, repairs or replacement; inspecting the caisson structure and arranging for measurements to be taken; inspecting the caisson tunnel; deciding on the repairs to be carried out; and selecting a contractor to assist with pricing.

Prices had to be obtained for: repairs and upgrading; replacement with a new sliding caisson; replacement of the sliding caisson with a floating caisson; converting the existing sliding gate into a floating gate; and rating the various actions in terms of practicability and cost.

The condition of the infrastructure (mechanical and structural) was assessed visually, by non-destructive testing (plate thickness and crack detection tests) and by an underwater survey for the caisson groove.

The condition of the infrastructure was summarised according to the different components of the caisson.

Structural condition

Machinery pit

The structural inspection of the machinery pit indicated that the roof structure was severely corroded and unsafe. The equipment supports also appeared to be corroded. The concrete seems to be in reasonable condition.

The mechanical inspection indicated that most of the equipment is in bad condition due to lack of proper maintenance, but all equipment is salvageable through a proper strip-and-clean process.

Caisson tunnel

The concrete elements of the caisson tunnel were judged to be in fair condition, with severe concrete degradation only at the entrance to the caisson tunnel. The steel roof elements have suffered some corrosion. The steel supports of the haulage chain require replacement.

The assessment consisted of: a site visit; arranging for cleaning where necessary; inspecting all equipment on the caisson and reporting on acceptability, repairs or replacement; inspecting the caisson structure and arranging for measurements to be taken; inspecting the caisson tunnel; deciding on the repairs to be carried out; and selecting a contractor to assist with pricing.
The haulage chain is severely corroded, but as in the machinery pit, only the mechanical elements require replacement as the metal elements have not suffered noticeable metal loss (Figure 2). Structurally, the caisson seems to be in good condition considering its age. However, the outside metal elements in the tidal/surf zone have been severely corroded. Internally, the caisson structure is in good condition, but it does show signs of corrosion.

The falling deck mechanism has seized due to lack of proper lubrication and the front section has been removed to allow the caisson to seal properly. The internal drainage/ballast pump is not operational. The pipework in the caisson is also corroded.

The sealing face of the caisson is in good condition, although some minor leaks are visible. The survey of the sliding caisson groove indicated some minor chips and cracks in the sealing face.

**Mechanical**

**Machinery pit**

All the bearings are to be stripped, cleaned and replaced, and all gearboxes are to be reassembled. Where possible, the labyrinth seals are to be changed, with a positive seal arrangement. All plumber/pillar blocks are to be stripped, cleaned and re-bushed or have new bearings. All girth and pinion gears must be cleaned and the rust must be removed. All driving mechanisms for the limit switch and position indicators must be replaced, including all limit switches. All the fluid drives are to be serviced and all the couplings are to be stripped and cleaned.

An automatic grease lubrication system (air atomising) must be installed for all open gear and pinion arrangements. An automatic grease lubrication system is to be installed for all plumber/pillar block bearings (including motor bearings). The main haul chain sprocket guards must be remanufactured, installed and made watertight (complete bottom and top). A new pump for the drainage sump is to be installed, complete with level control and alarm, and finally, the wheels of the haul chain sprocket are to be cleaned and dressed.

**Caisson tunnel**

Both haulage chains need to be removed, stripped and cleaned. Where necessary, all bushes and pins are to be replaced with suitable synthetic bushes (Vesconite) and all guide wheels are to be replaced, followed by reassembly.

The chain tensioner assembly is to be stripped, cleaned and reassembled. The haulage chain support guide/brackets are to be repaired. The complete haulage frame must be cleaned and all bushes replaced with Vesconite bushes. The chain sprocket wheel assembly on the caisson must be removed, cleaned and reassembled. All bearings/bushes must be replaced. Two new 5 m lengths of haulage chain will be manufactured for use in maintaining the main chains.

**Falling deck**

The falling deck structure will be removed and repaired. The structural steelwork is to be replaced where necessary. The option of replacing the current wooden deck with a lighter grated deck can be considered, but the effect on the buoyancy of the caisson should be investigated before the final decision is made. In addition, the following tasks needs to be performed:

Strip-clean and apply new corrosion protection to the total operating mechanism. Re-bush total operating mechanism using Vesconite bushes. Install an automatic lubrication system, which should be time-based to deliver a metered amount of lubricant to each individual bush/bearing on an adjustable time period.

**Caisson**

The whole operating mechanism is to be stripped and cleaned, and all valves in the caisson are to be serviced. The drainage/ballast pump will be replaced and the sealing rubber or face is to be repaired where it is leaking.

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**Table 2 Options for upgrading the sliding caisson**

<table>
<thead>
<tr>
<th>Option</th>
<th>Action</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Replace existing caisson with new sliding caisson</td>
<td>R94 344 000</td>
</tr>
<tr>
<td>2</td>
<td>Replace existing caisson with new floating caisson</td>
<td>R130 262 000</td>
</tr>
<tr>
<td>3</td>
<td>Refurbish existing sliding caisson</td>
<td>R186 056 000</td>
</tr>
<tr>
<td>4</td>
<td>Refurbish and convert existing sliding caisson to a floating caisson</td>
<td>R210 471 000</td>
</tr>
</tbody>
</table>

Structurally, the caisson seems to be in good condition considering its age. However, the outside metal elements in the tidal/surf zone have been severely corroded.
UPGRADING OF SLIDING CAISSON

For the upgrading of the sliding caisson, the required Remaining Useful Life (RUL) for the structure was set at 20 years. Four different options were considered, and their Net Present Values (NPVs) were calculated (Table 2).

From the assessments, the refurbishment of the existing sliding caisson and its conversion to a floating caisson appears, in terms of both the NPV and the capital cost, to be the preferable option (Option 4). However, there are various concerns regarding stability and operational viability that count against this option. Also, the logistics for converting the caisson are more complex than for a straight refurbishment. In this case, a realistic assessment must be made of the potential loss of revenue if the caisson conversion takes longer than envisaged.

In view of the above, it was recommended that the existing sliding gate be refurbished (Option 3) at an estimated repair (capital) cost of R88 754 000.

From discussions with contractors capable of carrying out the proposed work, the time required to refurbish the sliding caisson was estimated to be 74 weeks.

For the refurbishment work, the caisson will be docked in the Sturrock Dry Dock for the required period. The refurbishment will be planned in consultation with the National Ports Authority staff to ensure minimum loss of income on the Sturrock Dry Dock operations.

CONCLUSION
Assessing the sliding caisson of the Sturrock Dry Dock at the Port of Cape Town was a unique experience and a number of lessons were learned in the process. For example, it was realised that some six decades ago, steel of very good quality was being produced. We also noted the fine quality of the workmanship at the time of construction and were able to evaluate the maintenance work performed on the gate and its components. The fact that the last proper maintenance work was done almost two decades ago is evidence of the high quality of materials and men at the time of construction.

The Sturrock Dry Dock is an important facility in the Cape Town shipping scenario and it should be properly maintained.

Subsequently, Africon has been employed on the same basis by the National Ports Authority to conduct investigations into the underwater sections, which could not be assessed while the caisson was in operation. The gate has already been drydocked for some four months and the assessment is still in progress.

Note
On the 16 March this year, Africon, Connell Wagner and Ninham Shand came together to form a new multi-disciplinary global group. The newly created group, called Aurecon, provides professional technical services on large-scale integrated infrastructure projects to clients across Europe, the Middle East and Africa (AME) and the Asia Pacific (APAC). Given the geographical reach of Aurecon’s operations, the global group is headquartered in Singapore and employs over 6 700 people across 87 offices in 28 countries.
A new optical track deflection measurement device was developed for Transnet Freight Rail (Track Technology) to be used for track research carried out in both field and laboratory investigations. The functioning and calibration of the system are demonstrated and examples are given of measurements taken on the South African rail network. The article discusses the advantages of the system, further developments and the implications for design and analysis.

**INTRODUCTION**

Repeated (cyclic) loading on a track structure causes resilient (recoverable) and permanent (non-recoverable) deformation (Brown 1996). In the case of elastic track formation design, the permanent deformation is relatively small compared with the resilient deformation component. Track engineers measure resilient and permanent deformation as these parameters enable them to derive track stiffness values, as well as to calculate the expected design life based on cumulative plastic strain (Li & Selig 1998). The measurement, or prediction, of track deflection therefore forms the basis of track performance and design. Over the years, various instruments have been developed and used for the measurement of track deflection. This article covers existing instrumentation, as well as the development of a novel technique for the measurement of resilient track deflection.

**BACKGROUND**

Deflection measurement devices are commonly used in field and laboratory testing. A mechanical device was developed to measure the deflection of a sleeper relative to the ballast bed. Although crude in its design, this instrument provided reliable and immediate measurement of relative sleeper movements.

The instrument that is probably most widely used for measuring track deflection is the LVDT (Linear Variable Differential Transducer). Figure 2 demonstrates the use of LVDTs for measuring absolute horizontal rail and sleeper deflections. The
LVDTs are attached to anchor rods embedded into the track formation below the ballast.

The challenge with accurate field deflection measurement is to find a non-movable reference in the area of the track structure, which usually extends a couple of metres in all directions from the track centreline. To overcome this difficulty, absolute measurements are often purposefully avoided by concentrating on relative measurements only, e.g. horizontal rail movement relative to the sleeper. Nevertheless, LVDTs are extremely useful and accurate in measuring dynamic track displacements.

Certainly the most advanced and sophisticated instrumentation in the field of substructure deflection measurement is the Multi-Depth Deflectometer (MDD) developed by the CSIR for use in the Heavy Vehicle Simulator (HVS). This technology uses specially manufactured LVDTs to measure the deflection of individual formation layers and enables the calculation of resilient and permanent strains at different depths. MDDs are anchored in rock at depths of 3 to 5 m and measurements can be referenced to the rock or relative to the MDD directly below the one under consideration. Figure 3 shows a cross-section model with MDDs installed at different depths in the track formation.

MDDs deliver extremely accurate formation deflection measurements, but their use is limited due to the complexity of the instrumentation and its installation. Total track occupation is also required for the installation of the equipment. This involves the drilling of a vertical hole, lining of the hole with a flexible tube and the placement of the MDD modules at the different layer interfaces. MDDs can be used to measure the permanent deformation of track (and pavement) formation layers over extended periods. A research site on the Coal Line (Bloubank – between Vryheid and Ulundi) has 54 MDDs in nine holes, of which 53 are still functioning after 5 years of permanent installation in the track formation.

The value of these measurements supersedes that of most other deflection measurement devices.
PARTICLE IMAGE VELOCIMETRY (PIV)

Particle Image Velocimetry (PIV) is a measuring technique that originated in the field of experimental fluid mechanics (Adrian 1991). It has recently been used to measure soil deformation in soil laboratory testing (White et al 2003 and White & Bolton 2004), as well as for measuring landfill settlement (White et al 2003). This research is based on work by Bowness et al (2006) who used PIV to monitor railway track displacements by employing a webcam attached to a telescope, which was used to monitor a target attached to the side of the rail. The telescope magnifies the video images that are captured by the webcam and these are analysed by a computer to calculate horizontal and vertical displacement.

A similar system was developed for Transnet Freight Rail (Track Technology) to be used for a variety of track research projects in the laboratory and in the field. This system uses a high-specification video recording camera to capture video images of the movement of a target fixed to the track component under consideration. Software is then used to calculate the horizontal and vertical displacements of the target in real time or afterwards in the office. The system is shown in Figure 4.

The target comprises a black square on a white background, 2 cm x 2 cm, but it could be any size depending on the accuracy and resolution required (see Figure 5). For track deflection applications, a white area with a width of 2 cm around the black target is adequate for the optical recognition software to calculate the horizontal and vertical displacements successfully.

The resolution of the system is approximately 0.001 mm and the accuracy is between 0.010 mm (in the laboratory) and 0.050 mm (in the field). The optical measurement is sensitive to changes in the light exposure and the target should preferably be in the shade during measurement to prevent shadows from falling onto it. Special covers have subsequently been developed to ensure that the target is in the shade at all times.

Trial measurements during the night using a spotlight to illuminate the target proved to be even more successful than the daytime measurements.

Figure 6 shows an example of a PIV measurement where multiple targets were placed on a Tubular Track module. The four targets were placed in the rail, in the concrete beam, in the grout filling layer and in the formation respectively. With only one camera, multiple passages of the same train at the same speed have to be measured to obtain results of the type presented in Figure 7.

The graph in Figure 7 enables the calculation of the deflection of an elastic pad placed between the rail and the concrete beam, as well as the size of the gap between the concrete beam and the grout layer. These measurements are of considerable importance as they can be used for numerical analysis and design improvements to the track structure.

A test was carried out to determine the common error of a false reference, as shown in Figure 8. The LVDT attached to an anchor in the ground, ± 1.0 m from the rail, measured approximately 60% of the absolute vertical deflection of the concrete beam due to the vertical movement of the reference point itself. The PIV method as shown in the figure also enabled the determination of the pad’s deflection (i.e. the compression of the continuous elastic pad between the rail and the concrete beam).

FURTHER DEVELOPMENT OF THE SYSTEM

The software was modified to allow two modes of data capturing:

Mode 1: Real-time deflection measurements allowing the user to observe the measured deflections in the horizontal and vertical directions as they are measured.

Mode 2: Post-processing of the recorded video file which allows more flexibility and does not require the use of a computer in the field.

More sophisticated video cameras can be used to enhance the quality of the measurements by doing the following:

- Increase the resolution and accuracy of the measurements by increasing the optical zoom capability of the camera.
- Increase the number of measurement points by increasing the number of frames per second (currently limited to 25) or the frequency at which the video images are captured. LVDT and MDD data are normally captured at a frequency of 1 000 Hz or higher.

A method was also developed whereby two targets (one attached to the rail and another attached to a steel rod anchored in the top formation layer) can be captured by the same video camera. Post-processing of the data then allows the user to obtain two sets of measurements, synchronised and related to exactly the same loading case. Figure 9 shows the rail and formation deflection set-up, as well as...
the strain gauges attached to the rail for measuring the accompanying wheel loads.

Improvements to the tripod on which the video camera is mounted also reduced the ground-borne vibrations originating from a passing train.

ADVANTAGES
The advantages of PIV track deflection measurement can be summarised as follows:

=i The measurement principle is optical – the most reliable type of instrumentation.
=i No calibration is required and the accuracy of the instrument depends solely on the accuracy of the dimensions of the printed target.
=i Deflections can be measured over a wide range, from 0,100 mm to 100 mm, to an accuracy of less than 1% of the full scale of the measurement.
=i The equipment is relatively simple, available and affordable.
=i Both horizontal and vertical displacements can be measured during a single test.

Post-processing of the data can also be done in the office, reducing the set-up time in the field and allowing enhancement of the video images to eliminate invalid readings.

Comparative analyses can be done in a quick and economical way.

The instrumentation developed is an attractive alternative to other methods for evaluating slacks, track condition and transition areas.

CONCLUSIONS
The PIV method has proved to be a successful alternative for measuring horizontal and vertical track deflection. A number of advantages make this method the preferred option over conventional instrumentation such as LVDTs and MDDs. Although it has some limitations, it constitutes a fast and cost-effective tool for measuring deflections over a wide range in the field and in the laboratory. The resolution and accuracy of the measurements depend on the optical characteristics of the video

![Measurement example with targets placed on the rail, beam, grout and formation of a Tubular Track module (Ermelo yard)](image1)

![Example of results showing the horizontal (X) and vertical (Y) deflection of the different track components](image2)
recording equipment, which are becoming more sophisticated and affordable as the technology advances. Although specific applications related to railways were demonstrated in this article, the equipment will undoubtedly be useful in other fields of engineering too.

ACKNOWLEDGEMENTS
This development has been made possible by the assistance of Transnet Freight Rail (Track Technology), Metrorail, Tubular Track (Pty) Ltd, Motswedi TLC and the University of Pretoria (Department of Civil Engineering). The contributions of F J Shaw and A P Powell (Transnet Freight Rail) are gratefully acknowledged. The experimental PIV measurements at Bloubank were done by final-year civil engineering students D J Vorster and T Ramasindi (University of Pretoria).

REFERENCES
Benefits of routine ballast inspection using ZARR – Zetica’s Advanced Rail Radar

This article describes how ZARR can be used for planning maintenance, site investigations and ballast cleaning or renewals.

BACKGROUND

The ballast layer is designed to distribute the loading force of a passing train evenly over the formation layer to preserve a smooth ride. The ballast also acts as a drainage layer to prevent significant accumulations of moisture. The optimum ballast thickness is the thickness at which the ballast exerts constant pressure on the subgrade. The design thickness is a function of the load and speed of rail traffic.

A homogenous ballast layer results in a stable and safe track. Any departure from the construction design, such as changes in the thickness of the ballast layer and the degree of contamination within the ballast matrix, will affect the dynamic behaviour of the trackbed. Contaminated ballast causes an unstable pressure distribution on the subgrade.

ZARR utilises ground penetrating radar (GPR) and is a uniquely powerful desk-study tool for continuously mapping changes in the thickness and quality of the ballast layer across a network.

MEASURES OF BALLAST LAYER GEOMETRY AND IDENTIFICATION OF DISCRETE FAULTS

The quantity of raw GPR data collected in a typical ZARR survey is around 50 Mb per km. ZARR summarises this information in a number of indices to provide a statistical representation of the data which serves to guide track engineers to problem trackbed areas.

The ballast depth exceedance (BDE) index, which is defined by the difference...
Example of combining track geometry showing (a) at top left and right, standard deviations with trackbed geometry indices derived from GPR; (b) BDE = ballast depth exceedance, PWB = probable wet bed; (c) LRI = layer roughness index for two wavelengths and (d) TQI = trackbed quality index (the area outlined in red is discussed in the text)

Example of the use of a standard ZARR report to provide detail to manage tamping site works; the location of the underbridge is highlighted in red rectangle

Traditionally, a site investigation based on a fixed 50 m interval would have resulted in 8 holes (circle symbols) in potentially unrepresentative locations. GPR can be used to target half the number of holes (triangle symbols) to sample the trackbed in more representative areas

Results of repeat surveys over a relayed section of track in the UK; the most significant changes are outlined by coloured rectangles and are discussed in the text

Results of GPR scan before relaying works in February 2007 (max speed 70 mph or 112 km/h)

Results of GPR scan after relaying works in July 2008 (max speed 125 mph or 200 km/h)
in modelled ballast thickness versus a desired depth, provides a visual indication of the spatial variation in ballast thickness, helping the engineer to identify layer thickness irregularities quickly. The BDE is typically displayed as a colour-coded, bar-code-style strip chart. Colour-coding thresholds can be customised on the basis of traffic characteristics.

In Figure 2 the red-coloured BDE represents a severe exceedance, corresponding to an area where the ballast layer thickness is less than 50% of the design depth. The red rectangle identifies a significant BDE recorded in two GPR runs, which is not associated with any anomaly of the track geometry. Elsewhere, the cause of anomalies in track geometry can be clearly related to irregularities in the ballast layer and to wet beds.

Small wavelength variations in the ballast-subgrade interface can be significant as indicators of subgrade erosion. A layer roughness variation index (LRI) for characterising subgrade erosion and indications of larger scale ballast pockets is provided. LRI thresholds can be used to prioritise maintenance and to measure changes in time. The trackbed quality index (TQI) is derived from a weighted ranking of a series of trackbed GPR measurements, including layer thickness and variations in layer roughness.

The following case studies demonstrate the value of ZARR for a range of engineering applications, including trackbed maintenance, site investigations and quality control of works carried out.

CASE STUDIES

Maintenance of ballast depth
An underbridge was relayed in 2004 and the track engineer assumed that the ballast depth was compliant. In 2008 re-canting works were halted when a tamper struck the bridge deck. ZARR data in a national database were accessed from a local office after an urgent phone call had been received from site. A review of the GPR data (red rectangle in Figure 3) showed less than 250 mm from the top of the sleeper. The advice given was to abort works in this area, resulting in minimal downtime.
for the tamper. A redesign with 130 mm track lift was proposed and delivered two weeks later once consent had been obtained to increase loading on the bridge deck.

Compared with ballast monitoring through systematic manual sampling methods, up to 50% of the budget required to investigate sites by hand can be saved by focusing on areas showing significant change only. ZARR allows robust planning of site investigation works and reduces the time needed for completion.

ZARR further provides an independent measure of the quality of the

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6 Geographic display of results of GPR survey using Google Earth

7 In this example Indexes 1–4 represent relatively highly fouled to clean ballast on GPR scans of both shoulders and the centre. One division, comprising 60 km of track (a) clearly has a greater proportion of relatively highly fouled ballast (Index 1) compared with the other (b)

8 ZARR was used to accurately define the extent of works required to clean or renew the ballast
works carried out and a register of located assets. The information provided by ZARR can also be used to plan follow-up site investigations (Figure 4).

Figure 5 (a) shows a section of track before relaying works took place and Figure 5 (b) shows the trackbed after extensive upgrade works. The works allowed line speeds to be increased from 70 mph (112 km/h) to 125 mph (200 km/h) on a main line in the UK.

The red rectangle confirms a change in formation treatment, with new ballast and sub-ballast layers. The green rectangle shows a new junction with five drive units and an automatic warning system (AWS) magnet. The blue rectangle confirms that the newly laid ballast layer conforms to the minimum design depth specified for the required load and line speed.

Prioritisation of ballast cleaning
GPR can be used to provide an indication of priority areas on the network that require ballast cleaning and trackbed maintenance or renewals. Figures 6 and 7 show how ZARR summarises this information in statistical charts and maps.

Significant changes can occur at different stages in the lifetime of a ballast layer under repeated loading. Regular monitoring with GPR allows decisions to be made on timely and cost-effective interventions to extend the ballast life.

This allows the development of a robust ballast management strategy and prioritisation between sites, which can result in significant cost savings.

Defining the extent of works
For many railroad companies the cost of rehabilitating ballast before the expected end of life of the asset is high. One company reported that the implementation of incorrect work scope and limits had caused an 11% revisit rate over an 8-year timescale. Their aim is to have a ballast life of at least 15 to 20 years, so any revisits within 8 years constitute a significant underperformance. By introducing GPR into the assessment of work sites, they aim to reduce this waste to less than 1% within the next 3 years.

Revisits are often caused by insufficient information on the nature and extent of trackbed problems, which are therefore not effectively addressed during routine maintenance. ZARR can be used to delineate the extent of the maintenance work required.

One major railroad company found that 7% of sites have been withdrawn from the renewals programme on the basis that the GPR data, supported by targeted trial-hole data, did not justify ballast renewal, thus providing significant financial savings. In addition, the original limits and scope of work were changed at one in eight sites to ensure the appropriate length of track and depth of renewal. An example of such a revision is shown in Figure 8.

The benefit of using ZARR is that it provides specification accuracy, leading to more certainty in cost forecasting and the correct allocation of resources. The number of revisits to correct problems can also be significantly reduced.
Detailed follow-up surveys
Regular monitoring with GPR also allows decisions to be made on timely and cost-effective interventions to repair structures. For example, early indications of ballast thickening derived from GPR systems based on inspection trains can be flagged for detailed follow-up with ground GPR surveys (Figure 9).

Train-based and ground GPR systems can also highlight the possible presence of buried hazards, such as cross-cutting services and buried rails, which could affect the safety and progress of intrusive works, such as ballast cleaning or renewals.

SUMMARY
This article has outlined various practical applications of ZARR for assisting track engineers and planners to manage ballasted trackbed more efficiently.

Impressive cost savings can be achieved through:
- Improved targeting of intrusive investigations to maximise the value of time on site
- More accurate prioritisation of problem lengths of trackbed
- More accurate delineation of the extent of remedial works required
- Improved quality control measures
- Reduction in the number of interventions needed during the planned life of the ballast

In addition, a number of safety benefits can also be achieved with ZARR, such as reduced exposure of staff to the hazards of working trackside, less risk of striking buried services or other hazards during intrusive site works, and reduced risk of rough ride or derailment, by focused repairs to discrete faults early in their development.

In the words of the Head of Development at Network Rail (UK), GPR has made "...a significant impact on maintenance and renewals decisions by providing accurate and regular information on trackbed condition."
BACKGROUND
South African Coal Mine Holdings Limited (SACMH) is a new player in the coal mining industry and recently acquired a coal mine near Ermelo. Being new in the industry, SACMH wanted to construct a rail siding from where they could load their coal into rail wagons to be exported through Richards Bay Harbour. SACMH approached Arcus GIBB (Pty) Ltd to conduct a feasibility study for their proposed new siding near Ermelo. The feasibility study was completed during the latter half of 2007, followed by detailed design and construction in 2008.

PROJECT DETAILS
Arcus GIBB (Pty) Ltd was appointed in March 2008 by SACMH to undertake the detailed design and construction monitoring of their new private siding 20 km north of Ermelo. This was a greenfields project and the most appropriate location for the siding was identified to be on SACMH’s property, approximately 7 km from the mining operations. This position of the siding allowed easy linkage with the Transnet Freight Rail (TFR) main line.

OPERATIONAL REQUIREMENTS OF THE SIDING
The capacity of the siding was based on 100 wagons, able to carry 5 800 tons of coal.

TFR has the following operational requirements for the construction of new private sidings:
It must be able to accommodate 100 wagons.
- It must be able to load jumbo wagons.
- All shunting operations must be performed in the private siding.
- Wagons are not allowed to occupy TFR lines when being loaded.
- It must be capable of 24-hour loading operations.
- An in-motion weighbridge must be provided.

SACMH requested the following to be incorporated into the design:
- A loading area with a stockpile capacity of 36 000 tons (enough for six train loads)
- Space allocated for a future rapid loading terminal (RLT)

**TECHNICAL PROJECT REQUIREMENTS**

Technical project requirements were established in collaboration with SACMH and TFR and included:
- 1:12 concrete turnouts from TFR main lines,
- Road access from the R36 provincial road, and
- Electrical supply to support future electrification of the railway siding.

**DESIGN COMPONENTS**

A multi-disciplinary design approach was required to ensure integration of the siding components. The following components form part of the private siding and each component was designed taking cognisance of the other components.

- Rail layout to incorporate future RLT loading with minimal alterations in future
- Siding to be operational by October 2008

**Civil works**

The scope of the civil work that formed part of the siding was as follows:
- Bulk earthworks (loading platform)
- Construction of two evaporation ponds with a combined capacity of 13 500 m³
- Drainage structures
- Haul roads – 1,6 km
- Road access to the R36

The bulk earthworks on the siding totalled 180 000 m³ of fill. The fill material, required for the loading area, which was designed to be situated in a location
with a steep cross-gradient, was imported from several borrow pits situated near the site.

Runoff on the siding is managed by separating storm water runoff from the loading area and that from other areas. Storm water from the loading platform drains to concrete-lined side drains and from there to a silt trap, which serves as a first screen to remove coal particles from the water. The water then flows to a settlement pond and overflows into an evaporation pond.

Electrical

TFR requires that loading must be able to take place 24 hours a day and lighting infrastructure is therefore required for safety reasons. The installation of 49 medium-high masts with 66 luminars mounted on them ensured that all work carried out at night can be done safely. Each mast was fitted with a day-night switch which will switch the lights on automatically at nightfall. The electrical installation included supply to the mainline turnouts, the weighbridge and the signalling equipment.

Wayside signalling

Signalled access to a siding increases the efficiency of the siding and no further authority from the local centralised train control (CTC) office is required before trains may enter the siding. Access to the private siding is obtained by remotely setting the mainline turnout for the siding. The train driver selects the route (i.e. triggers the system) by means of a radio signal which is sent to the signalling system. TFR’s mainline is protected from runaway trains by safety sets on either side of the siding. The signalling system consists of the following components: an electro-mechanical interlocking system, electrical two-way points indicators, track circuits, electrical points machines fitted to the turnouts and a backup power supply system.

In-motion weighbridge

An in-motion weighbridge was installed in the siding. It is able to weigh the coal wags in motion and, once calibrated, is accurate to 0,3% which allows the mine to use it for commercial purposes.

Siding operations

SACMH also requested Arcus GIBB to advise them on the siding operations. This included the development of a train-shunting plan in conjunction with TFR and a coal stockyard layout to minimise the coal loading time.
PROBLEMS ENCOUNTERED AND INNOVATIONS

Various problems were encountered and solved as described below.

The siding is situated on SACMH property which is encroached upon by the road and rail at the northern and southern boundaries. This called for the rail layout to be significantly changed from what was originally foreseen. It was decided to have two lines running parallel to the loading area, such that loading of coal with front-end loaders can be done from the outside. This shortened the original layout by 670 m and made it possible to fit the siding into the available land.

There was a tight construction deadline of five months. This called for the overall construction programme to be properly planned and for the discipline work to be phased in order to achieve the shortest possible construction period.

In all, 180 000 m³ of fill material had to be obtained, transported to site and used to construct the loading area in only three months. When construction was at its peak, 5 000 m³ of fill material was being imported, placed and constructed per day. This was done by only using 6 and 10 m³ tippers, and 17 m³ scrapers.

Safety during construction was a prime concern. Safety talks were held daily and contributed to the achievement of more than 80 000 incident-free man hours.

PROJECT STATUS

Five contractors worked together during the construction phase to ensure the proper integration of tasks and to reduce the construction time to the minimum possible. The civil contractor started in June 2008, followed by the other contractors. The construction of the siding was signed off on 22 October 2008 and final testing took place on 11 November 2008. The first train entered the siding on 28 November 2008. The retention period of 12 months will be completed on 22 October 2009.

CONCLUSION

The detailed design, tender and construction management of a private siding for the SACMH coal mine near Ermelo was completed in nine months, within budget and on time.

Acknowledgement

Arcus GIBB (Pty) Ltd would like to acknowledge South African Coal Mine Holdings Ltd, Fraser Alexander and all the contractors who helped to construct the siding.

PROJECT TEAM

Client South African Coal Mine Holdings Limited
Consulting Engineers Arcus GIBB (Pty) Ltd
Project Managers Fraser Alexander (Pty) Ltd
Contract value R53 million
Contract duration 9 months
Retention of technical professionals – a reminder for engineering and technology organisations

The loss of skills and knowledge of technical professionals experienced by many organisations in South Africa has serious implications for the local and international competitiveness of these organisations. Research has indicated that there are fundamental differences between technical professionals and other staff in organisations, so that they need to be managed in a different way. Retaining talent calls for innovative human-resource practices. This article discusses various management and retention strategies.

INTRODUCTION

Employee turnover in South Africa is highest for two categories of personnel: the low-level unskilled workers and the highly skilled technical professionals (Kransdorff & Klegon 1999).

Managers generally have more success in attracting and selecting talented employees than in retaining them. A possible reason for this is that the training and development of technical professional talent are rarely integrated into technical professionals’ career paths (Von Glinow 1995).

There are fundamental differences between professional culture and corporate culture due to the differences in the background of professionals and that of their organisational counterparts (Gouldner 1957; Bailyn 1994). The characteristics of technical professionals play a distinct role in how they should be managed (Manz & Sims 1990; Katz & Tushman 1993). There is some conflict between what professional employees want and need in a job situation, and what management requires (Van de Ven & Delbecq 1986) and this conflict can extensively influence the retention of technical professionals (Raelin & Leonard 1995).

A comprehensive review of the literature by Kerr et al (1987) concluded that the following characteristics are critical to professionals:

- Expertise – normally gained from prolonged specialised training in a body of abstract knowledge
- Autonomy – a perceived right to make choices that concern both means and ends
- Commitment to the work and the profession – in short, the “calling”
- Identification with the profession and other professionals
- Ethics – a felt obligation to render service without concern for self-interest and without becoming emotionally involved
- Collegial maintenance of standards – a perceived commitment to police the conduct of other professionals

The loss of skills and knowledge experienced by many organisations in South Africa has serious implications for the local and international competitiveness of these organisations. Research has indicated that there are fundamental differences between technical professionals and other staff in organisations, so that they need to be managed in a different way. Retaining talent calls for innovative human-resource practices. This article discusses various management and retention strategies.
MANAGING TECHNICAL PROFESSIONALS

These characteristics result in key dilemmas in managing technical professionals (Raelin & Leonard 1995). Much of the work done by professional employees is intangible. The production and development of ideas can be difficult to define, measure, evaluate or control. Furthermore, the success of those ideas may not be immediately visible (Raelin 1985).

The nature of the work performed by technical professionals causes them to resist organisational control. Highly specialised employees are typically not always open to conventional bureaucratic control systems, which put emphasis on a management culture concerned with company loyalty, financial soundness, hierarchical authority and control, and growth in production output, volume, and size, and this often leads to conflict (Raelin 1985; Presthus 1988; Benveniste 1997).

The relationship between the organisational manager and the professional is not improved when the manager downgrades the values of professional workers. These values influence all aspects of their behaviour, including their loyalty, their commitment and their productivity – all of which are important to the employing organisation (Presthus 1988). How can these concerns and conflicts be addressed?

Management should recognise that a certain amount of conflict is natural and it should be used in mutually beneficial ways. Managers need to learn when and where professional values must take precedence over organisational rules and regulations (Benveniste 1997), and when it is essential that those values must take a back seat to the organisational controls.

The consequences must be considered because productivity, loyalty and commitment are at stake and will not be enhanced by rejecting the values of the professionals. The skilful management of professionals requires knowledge of their loyalties, not only to the organisation, but also to their professional associations and standards. Failure to do this will inevitably result in mismanagement of these valued human resources (Benveniste 1997).

Just as it is difficult to describe a typical technical professional, so is it difficult to describe the typical organisation. Each organisation has a different organisational culture, and how each organisation will respond to the suggestions made here will undoubtedly vary.

MOTIVATING TECHNICAL PROFESSIONALS

It is widely accepted that the retention and productivity of workers is a function of how well the individual is motivated. The research and findings of Maslow (1943) and Herzberg et al (1959) are the cornerstone of much of the work done in the field of human motivation and job satisfaction.

Once technical professionals have been appointed, it is important to continue to motivate them throughout their organisational careers. Yet how can the manager induce these employees to pursue the company’s goal and not just their own goals? What is particularly different about motivating professional employees is that they respond to different types of rewards (Kerr 1985).

The “work itself” is an important motivator. In addition, career development is important, particularly since technical obsolescence threatens almost all technical professional specialities (Dalton et al 1990). Miller (1996) rightly points out, however, that professionals respond to continuing education and development for personal development reasons as well. Some organisations have recently discovered this and are acting on it. Transnet Freight Rail, for example, attempted to introduce a “Professional Practitioner Scheme” whereby professionals are treated differently from non-professional employees in terms of compensation and training.

Other basic extrinsic benefits are likely to appeal to professionals, such as a private office and a personal assistant or the dedicated assistance of a technician.

REWARDING AND COMPENSATING TECHNICAL PROFESSIONALS

Financial or economic rewards do not form the most important retention strategy to the same extent for technical professionals. But although they have a particular attachment to their work, this does not mean they do not want to be paid well for their expertise, effort and performance. Like other employees, they also compare their salaries and benefits with those of employees having similar workloads and responsibilities, whether inside their own organisation or elsewhere. Any evidence of significant inequities, whether in absolute compensation or relative increases, will not be good for attitude or performance (Ewing 1987).

Other incentives for technical professionals include time off, the freedom to select tasks or projects, the freedom to implement their own ideas, flexible working hours, and funds for personal goals unrelated to organisational goals.

Promotion into management has been the usual route for technical professionals interested in advancement. While this move may be appropriate for some, many professionals are so committed to their fields that moving away from their technical specialty can be unsuccessful (Von Glinow 1993).

PERFORMANCE MANAGEMENT

Performance appraisal is possibly management’s best tool in controlling human resources and their productivity (Fombrun & Laud 1993) because performance appraisal not only measures performance but also indicates where and to whom rewards should be given. Performance appraisal can also serve as motivation for employees to perform if it is linked to a reward system.

When we consider the special characteristics of the technical professional, and some of the fundamental dilemmas in managing these valued people, the performance appraisal process becomes critical. In the process of evaluating these workers there are important new questions: What aspects of the technical professional’s performance should be evaluated? Who should evaluate that performance? How should it be evaluated? (Newman & Hinrichs 1990). These three categories represent the “measurable domain of individual job performance”.

In most organisational settings that include technical professionals, the immediate superior is responsible for the performance evaluation, but that choice may not be appropriate (Newman & Hinrichs 1990). The credibility of the evaluator has been documented as a major factor influencing the acceptance of that evaluation (Ilgen et al 1989). Two factors appear to be important in determining the credibility of the superior as an evaluator of the performance of the technical professional: the superior’s expertise and his or her
trustworthiness. Peer ratings are a popular form of evaluation and another rating system, prevalent in universities, is rating by subordinates. A third option is having technical professionals rate themselves, in addition to having their superiors rate their performance. Finally, performance may be evaluated by outsiders, such as psychologists or experienced managers trained in evaluation techniques (Newman & Hinrichs 1990). Note that feedback to the person being evaluated is a critical element of the process.

**Table 1 Comparable areas of managerial and liaison authority**

<table>
<thead>
<tr>
<th>Managerial hierarchy</th>
<th>Liaison hierarchy</th>
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</thead>
<tbody>
<tr>
<td>Purchasing of general clerical supplies and equipment</td>
<td>Purchasing of specialised technical supplies and equipment</td>
</tr>
<tr>
<td>Selection and training of office and low-level administrative personnel</td>
<td>Selection and training of professional and technical personnel</td>
</tr>
<tr>
<td>Supervision of non-professional managerial and office personnel</td>
<td>Supervision and coordination of professional activities</td>
</tr>
<tr>
<td>Responsibility for evaluation of office and low-level administrative personnel</td>
<td>Responsibility for conducting or coordinating professional employee performance appraisals</td>
</tr>
<tr>
<td>Distribution of resources required by non-professional employees</td>
<td>Distribution of resources required by professional employees</td>
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<tr>
<td>Budgeting for non-professional activities</td>
<td>Budgeting for professional activities</td>
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</table>

**ORGANISATIONAL STRUCTURE ACCOMMODATIONS**

Managing a professional work force involves recognition of the fact that conflict exists, and reducing this conflict. Three structural accommodations have been discussed regularly in the literature and are listed below. Miller (1996) and others noted that the best solution is to present the professional with a choice of career growth opportunities, so that he or she does not have to aspire to management. Dual ladders, triple hierarchies and broadbanding have been implemented with varying degrees of success as solutions to accommodating the career concerns of technical professionals.

**Dual ladder structure**

In an attempt to reduce the professional-organisational conflict and to provide technical professionals with alternative career paths, organisations may implement a dual-ladder structure. “The dual ladder is a set of positions for technical professionals that are designed to be parallel to the managerial ladder, but with evaluation, control, authority, and advancement criteria appropriate for the technical professional” (Kerr et al 1987).

The objectives of using such a dual ladder are: “to provide promotion opportunities for technical professionals who are unable or unwilling to climb the managerial ladder; to provide compensation, recognition, and prestige equivalent to that of successful managers; to provide technical professionals with greater autonomy; and to create a set of positions with administrative duties light enough to not interfere with professional contributions” (Kerr et al 1987).

**Triple hierarchy**

A variation on the dual ladder, the “triple hierarchy,” provides three different promotion opportunities: (1) the managerial hierarchy is available to those who want promotions into managerial positions; (2) the dual ladder or technical ladder is available to those who want only professional and technical positions; and (3) a “liaison hierarchy”, the third ladder, is occupied by technical professionals in important administrative positions. They have regular technical duties, but also have authority over technical professionals in those areas where differences between professional goals and organisational goals are most likely to cause conflict (Kerr et al 1987).

In those areas with high potential for conflict, managers have no authority. Such areas tend to vary by organisation. Table 1 briefly describes some areas where the liaison hierarchy would take precedence over the managerial hierarchy in most organisations.

1. Example of a conventional salary grade structure
2. Example of a broadbanded structure
Broadbanding is the compression of a hierarchy of salary grades or salary ranges into a small number of wide bands. Each of the bands then covers the salary opportunities of several original bands. The focus is on lateral career movement within the bands and on competency growth and continuous development (Miller 1996).

Broadband structures are very different from conventional salary structures. There are fewer organisational levels and the emphasis is on flexible roles, individual career development and competency growth rather than progression based on position in the hierarchy. Career moves are more likely to be horizontal along the band. There is much less emphasis on movement upwards through a hierarchy (Miller 1996).

Broadbanding in its fullest sense would mean, for example, converting a traditional graded structure with twelve 30% grades into a structure with five 200% bands. In other words, the salary ceiling for a person in one of the original grades would be 30% higher than the lowest or starting salary in that particular grade, whereas the same person in a broadbanded structure would be able to earn three times the lowest salary for that band. Some jobs previously in separate grades would now be in the same band.

A good computer programmer, for example, will be able to earn more than his manager. This will ensure that the best programmers keep programming as opposed to advancing to management for the sole purpose of earning more money. This will prevent the organisation from exchanging an excellent programmer for a mediocre manager. Figures 1 and 2 illustrate the difference between a conventional and a broadbanded structure.

**CONCLUSION**

Managing talent is difficult and time-consuming, but very rewarding (Kerr et al 1987). Too often, senior management has the best of intentions for developing people, but they fail to invest the time and resources needed to realise these benefits. Organisations with long-term, sustained success are those that focus on growth and achievement by retaining the best talent (Miller 1996). An organisation can create the best business strategy, make the right acquisitions and invest in the right programmes, but if it does not have the necessary talent, those strategies will fail to be implemented, the advantages from acquisitions will fail to materialise and investment will not earn the desired returns (Kerr et al 1987).

The central managerial challenge of the future is to design systems that have a reflexive capability built into them (Kerr 1985). These systems must monitor and match the needs of technical professionals with the goals of the organisation. This is no easy challenge, since the goal of maximising the productivity of technical professionals may cause conflict due to the values of these workers (Bailyn 1992).

Designing reward systems that encourage the professional’s talent is very important. Much attention has been focused on financial incentives as the major means of retaining these workers, but financial rewards alone have little importance for these workers, despite the repeated emphasis in the literature on

When managers pay attention to the unique characteristics and values of their professional workers, it is less difficult to understand that they are motivated and driven to perform by a whole different set of motivators. Critically important here is the challenge and meaningfulness of the work that the professional performs. Equally important is that the work should retain its meaningfulness over the course of the professional's career.
salary plans and complicated compensation options (Ewing 1987; Jones 1963). Instead, professional, career and content rewards tend to be more valued by these workers (Ewing 1987). When managers pay attention to the unique characteristics and values of their professional workers, it is less difficult to understand that they are motivated and driven to perform by a whole different set of motivators. Critically important here is the challenge and meaningfulness of the work that the professional performs. Equally important is that the work should retain its meaningfulness over the course of the professional’s career (Jones 1963). Hence, paying attention to career development is a very important challenge for managers of these workers.

Equally important to technical professionals is the design of appropriate performance appraisal systems that are attentive to their standards of evaluation (Resnick & Mohrman 1992). Since technical professionals are largely responsible for new product and process innovations, these employees become the gatekeepers of information. An important challenge for managers of these gatekeepers is to assess performance accurately within the context of the organisation’s culture (Fombrun & Laud 1993).

Some alternatives to conventional performance appraisal systems should be considered for evaluating the performance of technical professionals. These include self-evaluation, peer evaluation and evaluation by subordinates, all of which match the characteristics and values of the typical professional.

Due to the “cultural” differences between professionals and non-professionals, various accommodations with regard to the organisational structure could be made to help technical professionals feel comfortable in the organisation. Some options are: dual ladders, triple hierarchies and broadbANDING. These structural accommodations can ensure that technical professionals do not have to make the transition to management in order to obtain more responsibility, recognition and status in an organisation (Kerr et al 1987; Miller 1996).

**RECOMMENDATIONS**

Managers and the organisations they work for would be well advised to increase their capacity to meet new challenges in the following ways:

- Managers should recognise that managing professional employees is significantly different from managing non-professionals. This is partly because professionals have a different set of values and characteristics, which have been gained through their socialisation in the technical specialty. Managers need to be cognisant of those values and characteristics if they are to anticipate tension points and enhance the fit between the individual and the job.

- They should recognise that a certain amount of conflict will almost always exist between professionals and hierarchical authority and control systems. The key is to transform this conflict into motivation by separating these workers from organisational pressures, while simultaneously making them aware of the importance that their work holds for the organisation’s wellbeing and its continued competitive advantage.

- They should attempt to develop human resource practices and policies that have had some success in retaining the professional workforce.

- They should articulate the organisation’s vision, clearly establish the organisation’s goals and ensure that all relevant parties are exposed to that thinking.

- They should design jobs and work relationships to take advantage of technical specialties. For example, rotating professionals through multiple roles and job responsibilities can sensitise them to new ideas and opportunities.

- They should establish career-sensitive tracking systems so that career development becomes an integrated part of their organisations’ practices.

- They should utilise rewards that are relevant for technical professionals. Ideally, these rewards should be linked to performance, but in some cultures they might be linked to effort, risk-taking or other relevant behaviours.

- They should study the change process and learn from their experiences. Organisations change owing to internal and external factors, including departures from tradition, new leaders with new visions, crises or other startling events, key decisions on the part of senior management, or simply to test their infrastructural ability to accommodate change. Organisations also change because of change itself, but professionals must clearly see the need for such change; otherwise, they may not support the change or they may even sabotage it. Therefore, communication is vital.

**NOTE**

The list of references is available from the editor.
INTRODUCTION
Railway track maintenance is a highly specialised and scientific field covering materials, the most economical methods, and determining when maintenance and renewal are required. Maintenance problems normally require thorough investigation and experimentation before a solution is reached and the rectification usually has to be done under operating traffic conditions.

RAILS
The first rail used by the Cape Town Railway and Dock Company was of wrought iron (first used in Europe in 1820). It had an inverted V profile thickened at the apex as the running surface. The legs of the V were flared and tapered to the ends. The ends had holes punched through to take the dogspike securing the rail to the transverse timber sleeper. With the development of steel by the Bessemer and Siemens processes, because of their longer life, all rails were subsequently rolled from steel.
When I entered the service of the SAR in 1950 there were to be found in the track a total mix of rails and various rail profiles (cross-sections) manufactured and supplied by various manufacturers. Subsequently, amended sections and heavier masses were introduced and certain rails of lesser mass have disappeared. In 1960 2% manganese rails were manufactured for use where excessive wear was experienced and in 1976 a chromium manganese (CrMn) S60 kg/m or UIC60 rail was introduced on the Sishen-Saldanah iron ore export line, and later on the Witbank–Richards Bay coal export line, known as the "heavy haul lines".

The Sishen-Saldanah line was built for Iscor but once operational was taken over by the SAR. Wisely, although the consultants to Iscor originally planned for a gauge of 1 435 mm, on the advice of the SAR authorities it was built to the SAR 1 065 mm gauge (known internationally as the "Cape gauge").

**Rail masses**

The phenomenal economic development in South Africa resulted in increased rail traffic over the years. Heavier and more powerful locomotives were needed to haul heavier loads and longer trains on the main lines emanating from the coastal harbours inland to the mines and industrial areas, necessitating rails of a greater mass.

It was the policy in South Africa to recondition rails that had been replaced with heavier ones and use them on lightly trafficked branch lines. This resulted in a complete mixture of rail profiles in the branch lines, requiring close inspection before replacement or renewal to ensure compatibility with the existing track.

The rail masses in the track went from 40.25 lb/yd (22 kg/m) through 60 lb/yd (30 kg/m), 80 lb/yd (40 kg/m) to 96 lb/yd (48 kg/m). The 120 lb/yd (60 kg/m) CrMn or UIC60 rail was first

1. **Running surface of rail at a thermit weld,** showing the weld metal in the centre and the heat-affected zones directly alongside
2. **Damage on the rail running surface due to a locomotive skid mark,** also called wheel burn, mostly since the advent of diesel and electric traction
3. **Broken rail with emergency "joggle" joint fishplates installed** (also used at broken thermit welds)
put to use in 1976 on the iron ore and later on the coal heavy haul export lines (Orex and Coallink).

**Rail markings**

On the lightly trafficked branch lines and in Namibia, 30 kg/m rails could be found in the track with the roll markings Krupp, NGR, CGR, Bochum and SAR, manufactured in various countries and foundries with various profiles.

In South Africa the SAR 30 kg/m rails were in general use on branch lines but, to eliminate the axle load restrictions, were systematically replaced with reconditioned used rails of greater mass released from the main lines during strengthening and re-railing programmes. These rails were to the SAR-designed profile for the 40 and 48 kg rail, both with a 127 mm (5 in) bottom flange so as to be suitable for the cast iron chairs and soleplates in use at the time.

Due to the various rail masses used on specific sections of railway line, the respective sections had to be classified and restricted to the use of only specific classes of locomotives and axle loading of the trucks, making it difficult to make up full train loads for a specific destination on a branch line, thus necessitating large marshalling yards at junctions.

**Rail lengths**

The predominant rail length supplied in 1950 was 40 ft (12 m), although in 1937 Iscor commenced rolling 18 m lengths. The 120 ft (36 m) rail was first introduced in 1938, being three 40 ft rails as supplied and arc flash butt-welded together at the welding depot at Diamana (Danskraal - Ladysmith, Natal). From November 1971 Iscor supplied rails in 36 m lengths. With the greater mass of the track structure (rails, concrete sleepers and ballast), continuously welded rail (CWR) had been introduced by thermit welding the 36 m rails in situ. Subsequently, on-track in situ arc flash butt-welding was introduced with splice joints only in specific and exceptional places. For the transport of the 36 m rails and later even longer lengths, special wagons had to be manufactured with transverse sliding cradles so that the rail train could negotiate curves. Shortly afterwards, 519 ft (158 m) CWR were introduced, with splice joints.

The first experimental relaying of track with 519 ft (158 m) CWR prebuilt, at an interloop, on concrete pot sleepers (Swedish 101 type) with a tiebar – and transported to site by gantries on rollers running on rails placed outside the running track – was introduced between Brandfort and Houtenbeck in 1959. At present, CWR is the norm on the main lines.

**Rail maintenance**

Rail maintenance was limited earlier to cutting out the battered rail ends, pulling up the rails, drilling new holes for the fishplates and bolts, respacing the sleeper at the joint, and inserting a closure rail to make up the loss in length at the end of each day’s work. Worn rails on the high leg of curves were cropped to the length required for the low leg and new rails inserted in the high leg.
Before the advent of diesel and electric traction, wheel spin burns were rare. There was no remedy for corrugated rails as rail-grinding machines had not yet been introduced.

Since the introduction of the ultrasonic rail-flaw detector, transverse fissures caused by hydrogen inclusions are detected before the rail breaks.

**Rail joints and maintenance**

When the rail length was predominantly 40 ft (12 m), most of the maintenance effort went into maintaining the joint. This problem was further exacerbated with the introduction of diesel and electric traction. Various schemes were evolved to reduce the effort, but most of them were not very successful.

With the 48 kg rail a 100% fishplate was introduced. This fishplate had wings that passed under the rail at the joint and prevented the sleeper from being placed directly under the joint. An angle iron and ribbed fishplate could also be found in the track.

After the welding of battered rail ends was introduced with the development of suitable welding rods and welding techniques, the cropping of battered rail ends was suspended.

A vertical "jimcrow" (a crowbar fitted with a claw for pulling nails) was introduced to bend out the dip in the rail end at the joint. To prevent creep, the Fair rail anchor was introduced. This was clipped to the bottom flange of the rail adjacent to the sleeper, on the opposite side to the direction of creep.

With the introduction of colour-light signalling, together with centralised traffic control, insulated rail joints (block-joints) were required as the rail was used for the electrical circuit that detected the position of the train. On the electrified lines and on other lines with colour-light signalling, there was a variety of insulated fishplates and joints. Ultimately, a factory-manufactured, glued, insulated rail joint was developed and used either with fishplates or welded into continuously welded track.

With the introduction of the continuously welded rail sections, a sliding spliced rail joint was designed and introduced, but this is now used only in exceptional circumstances, such as on long steel and concrete bridges.

**Rail-to-sleeper fastenings**

There is a great variety of fastenings specific to either timber, steel or concrete sleepers.

**Timber sleepers**

Early practice was to dogspike the rails directly to the timber sleeper, adzed to a cant for the bottom flange of the rail. Later, on timber sleepers for the 30 and 40 kg rails (and on occasions on the 48 kg rail), the ordinary canted soleplate under the rail was used, held down with coach screws specially made for soleplate use; these overlapped the bottom flange of the rail, so securing the rail to the soleplate and, simultaneously, the soleplate to the sleeper.

For the 48 kg rail, due to the same bottom flange width of 5 in (127 mm), there were two types of cast iron chair
fastened to the timber sleeper with special coach screws. With the E295 chair, the rail was held in position on the chair by means of a steel taper key, with the bottom flange of the rail wedged under the lugs on the chair casting. With creep and the expansion and contraction of the rail, the taper keys came loose and fell out, and the patrolman had to hammer the loose keys in firmly during his daily patrol. Various types of spring clip (e.g. the Fair rail anchor) attached to the bottom flange of the rail abutting the sleeper were used to prevent the creep that contributed to the taper key falling out. With the introduction of the E3131 cast iron chair, which had T-bolts and nuts and clips similar to those used on steel sleepers, the sleepers could be predrilled with a jig. The gauge was adjusted with the correct combination of clips where required on curves as well as to accommodate rails of various masses with different bottom flange widths. Care had to be taken with packing (tamping) the ballast under the rail, normally done by beater pick, so that the sleeper did not become centre bound and bend under load, losing gauge or, with corroded and worn sleepers, crack and break. Before delivery, steel sleepers were dipped in tar. The later steel sleepers had holes punched in them to accommodate the clips and buttress for the checkrail on curves.

With the introduction of concrete sleepers, all further experimentation with rail-to-wooden sleeper fastenings was suspended.

Steel sleepers
The first sleepers used in the Cape were two solid cast iron pots with lugs and a connecting bar. The rail was held secure on the pot with a wooden taper key, it being feared that a solid steel key would break off the lug. This sleeper was then modified to a pressed steel, inverted, hollow pot with pressed-out lugs, and the rail was secured with a steel tapered key. The gauge was held by a bar rivet connected to the two pots.

The first single-unit steel sleepers were flat-topped, called “peapods”, and the rail was secured vertically under lugs pressed out through the metal and fastened with a taper key. In 1927 the new-design canted steel sleepers were manufactured. They had two ribs on the underside to position the T-bolt securely. Various clip combinations were available for gauge adjustment on curves, as well as to accommodate rails of various masses with different bottom flange widths. Care had to be taken with packing (tamping) the ballast under the rail, normally done by beater pick, so that the sleeper did not become centre bound and bend under load, losing gauge or, with corroded and worn sleepers, crack and break. Before delivery, steel sleepers were dipped in tar. The later steel sleepers had holes punched in them to accommodate the clips and buttress for the checkrail on curves.

Concrete sleepers
Various types of experimental concrete sleeper were introduced from 1955. Owing to the sanctions against South Africa, the shortage of suitable local timber and inferior timber imports, concrete sleepers were fully introduced at this time and orders for various types (e.g. the Sommerville two-block type and the Stupp flexible solid type with prestressed ties) were placed in 1957, 1958 and 1959. Initially, the sleepers were of the two-pot type, except Stupp. Various types of rail-to-sleeper fastening were tried experimentally. A monolithic concrete sleeper with the Pandrol fastening is now standard.

For continuously welded sections of railway line, a heavy track structure with concrete sleepers and adequate shoulder ballast is essential to prevent horizontal kickouts of the track. Special concrete sleepers with wings at each end are used on steel and concrete bridges where there is a differential in expansion and contraction between the bridge structure and the track structure daily and seasonally. With concrete sleepers it is essential to maintain an elastic track structure by having a suitable elastic pad (made of high-density polyethylene – HDPE) between the rail and the sleeper, and a suitable depth of clean, angular ballast. Numerous experiments were performed with various designs of pad and material before a satisfactory solution to the rapid deterioration of this pad was found.

The maintenance effort on concrete sleepers is mainly in repositioning the sleeper to square where creep is evident and in replacing the HDPE pads and other fittings where damaged.
Initially, the railway builders did not realise that a durable, all-weather foundation – similar to that devised by Macadam for roads but without the fine material – was a requirement for railways, and any apparently suitable material was used as ballast, known as "muck" or "gravel ballast". It was normally the in situ material on which the track was laid or gravel from gravel pits if these were in close proximity. The muck ballast was filled in to just under the crown of the rail. Later, crushed stone ballast was used and on the Reef stone ballast was obtained from the waste rock mine dumps. Today, only crushed stone ballast to a standard specified size and grading, physical properties of abrasion and weathering is used.
In the 1940s, before the introduction of mechanised track maintenance, it was decided to introduce a major track ballasting programme. As there were not enough private quarries close to the railway line to supply crushed stone, the railways bought nine 8 inch gyratory McCully crushers and a few Kew Ken primary jaw crushers, with the necessary sieving apparatus and conveyors, from the firm Edward L Bateman. A rail siding was built to the quarry sites, together with a loading tunnel under the rock ballast stockpile. I recall some of these departmental quarries being established at Hartshill, Coega Kop, Brand, Upington, Aris, Machadodorp and Bellville.

Ballast maintenance

The maintenance of the ballast is most important to maintain good drainage and to distribute the load to the formation. The first ballast plough introduced for maintenance was a heavy steel plate with scrap rails welded in a V formation under the plate, and wide enough to extend beyond the ballast profile. Heavy shackles were welded on the outside of the steel plate to which were attached heavy chains. The track was boxed out to accommodate the plough, which was slid in underneath the sleepers. The chain was coupled to a steam locomotive which would pull the plough the required distance, so ploughing the ballast to the outside of the track. The ballast was then sifted with a ballast fork and returned to the track, the wastage made up with crushed stone to specification, and then packed by beater pick. Nowadays, this operation is done on track all by one machine, operating together with a ballast profiling machine, a heavy, on-track ballast tamper and a ballast consolidating machine.

When the track was ballasted with muck that was predominantly sand, the “gangers” (today known as platelayers) had 44 gallon (200 litre) drums of water on the push trolley so as to be able to pack out slacks in the track. It was impossible to beater pack sand under the sleeper when dry. At a slack the sand or muck would be boxed out, the track lifted to the required level, water poured in, the sleeper hastily packed and the muck ballast profile restored before the water evaporated.

FORMATION

The formation comprises that portion of the railway line below the ballast, including the sub-ballast and the consolidated in situ material with or without a bitumen seal coat.

Maintenance of formation and right of way

The most important aspect to be attended to in the maintenance of the formation, when correctly constructed, is the drainage of the formation and clean and well-drained ballast. This was acknowledged very early in the construction of the railway lines and to this day deep stone- or slate-lined side drains can be seen along the track. Invasive vegetation in the ballast and on the formation must be eliminated. The side drains must be deep, be kept clean and drain well by flowing freely and unhindered. This function was often overlooked, with resultant serious formation failures, creating slacks in the track that required the speed of trains to be restricted so as to avoid derailments. Catchwater drains must be as close as possible to the top of the cutting, be kept free of vegetation.
and must drain well as ponding of the water can cause landslides and slip circle failures to occur and obstruct the track.

To keep the formation clear of weeds and grasses, a weed-spray train was developed and various chemicals and herbicides were used. This, together with the firepaths or fire breaks (sparks being a particular problem with steam locomotives), prevented veld fires and eliminated claims from farmers for the loss of grazing or other crops.

**TURNOUTS**

There are turnouts with various angles of deviation from tangent. Earlier the 1-in-8, 1-in-9 and 1-in-12 turnouts were standard. At the Johannesburg Station, single and double 1-in-6 slips were introduced. Scissors made up of four turnouts and a diamond crossing are also common. When I retired in 1988, 1-in-20 turnouts were used.

**Turnout maintenance**

To achieve maximum turnout life, it is essential that the track is kept in alignment and level across the running rails at all times. All sleepers must be firmly packed and there must be no discernible whip or jar at the switchblades. The specified gauge must be maintained at all points within the turnouts. The nose of the frog must be welded when worn. Cast manganese frogs were introduced with a raised rim on the check to take up the conicity of the wheel so as to reduce the impact on the nose.

**MAINTENANCE OF ALIGNMENT, LEVEL, GRADE, CURVATURE AND GAUGE**

These are very important elements in track maintenance to maintain smooth running of the locomotives and rolling stock, passenger comfort and, most importantly, to prevent derailments. The latter occur when horizontal mal-alignment causes irregular running of the vehicles and too sharp a sag in the vertical curves causes bunching and jarring of the vehicles along the length of the train, consequently lifting it out of the track. Accurate maintenance of the geometry of the track, ensuring the smooth running of the trains, is beneficial to all track elements for increased service life.

**Manual maintenance methods**

The horizontal alignment was achieved visually using slewing bars. When curves were seriously out of alignment, the engineer would stringline the curve and provide pegs on the corrected alignment. Care had to be taken to ensure that with slewing the track, the structures remained outside the moving structure gauge and that the overhead power catenary and contact wires were within stagger specification.

The vertical alignment was corrected by sighting along the bottom edge of the rail crown on the one leg on tangent track and on the lower leg on curved track. The track was lifted by means of a jack to the correct height and packed with beater picks, using the track gauge with a spirit level on tangent track to obtain the correct cross-level and cant board on curved track.

Except for gauge adjustments, all these maintenance functions are today performed by machine.

**WELDING OF RAILS**

The first recorded thermit welding was at the workshops at East London in
1916, although such welding had been used in the mechanical workshops since 1914 for the repair of locomotive and tender frames. It was difficult initially to introduce arc welding as it was firmly believed that welders eventually went blind. However, in 1918 welding was recognised as a trade.

When oxy-acetylene welding was first introduced, vacuum hosepipe wire and baling wire were used – both unsuitable for the welding of rails. (Today, only approved brands of welding rods, to the specifications of the railways, are used for the welding of battered rail ends and wheel spin burns.) Arc butt-welding followed and the railways introduced the first resistance butt-welding machine in 1927. In 1933 the first experiments were undertaken in South Africa on the arc welding of 24 ft CGR rails in the branch lines into longer lengths. Arrangements were then made to import an arc butt-welding outfit for the welding of rails into longer lengths. Track welding gangs were established and battered rail ends were repaired by the electric arc method and the frog of the crossings by oxy-acetylene welding. In 1937 the flash butt-welding of three 40 ft rails into 120 ft lengths was introduced; these were then transported to site.

LABOUR

Over the period of 40 years that I was employed by the SAR (1949 to 1988) there were many changes in reducing the labour element in the maintenance of the permanent way. Maintenance has moved away from being a labour-intensive procedure to a highly mechanised one.

Initially, lightly trafficked branch lines were maintained by a ganger with labourers, and flagmen and patrolmen. These “flying gangs” consisted of 10 to 15 men covering a 30-mile section. They were equipped with a lightweight motor trolley with trailer and the normal hand tools were beater picks, ballast forks, shovels, a 4 lb hammer, a 10 lb sledge hammer, cold chisels, a double-handed saw, fishbolt spanners, an Abtus sleeper drill and bits, a rail drill and bits and a Windhond rail saw, slewing bars, boning rods, a track gauge, a cant board, a wire puller for fencing, fencing pliers, track jacks and a measuring tape – all manual tools. The gangs were accommodated in permanent quarters in section, not necessarily at a station, where a small stock of emergency permanent way material was kept.

On more heavily trafficked lines, push-trolley gangs operated. They covered 10 to 15 miles (16 to 25 km). These gangs were similarly equipped. In 1965 there were still a few labour push-trolley gangs and flying gangs on the Potchefstroom-Fochville line before the connection to Houthuwel necessitated by the sinkholes in the Bank-Westonaria region, and on the West Rand-Mafikeng and Upington-Kakamas lines.

Initially, the gangers were self-taught and instructed by the Permanent Way Inspector or Track Superintendent. The normal progression for labourers was from labourer to patrolman to flagman to ganger. The first training college for plate-layers was established after the Second World War at Kroonstad. A permanent Railway Training College was subsequently built at Kaalfontein (Esselen Park).

Only in the very late 1950s and early 1960s were experiments done with mechanised equipment of various kinds, the idea being to reduce the labour element in track maintenance. The mechanised equipment includes double-headed tamping machines with a lifting and aligning facility, ballast-cleaning and -sifting machines with a plough, rail-laying machines, self-propelled ultrasonic rail-flaw detectors, etc.

However, there are still many very important functions that must be done visually, on foot and manually which cannot be replaced by machines and require an experienced eye. These include bridge, culvert and catchwater drain inspections, and detecting the movement and deterioration of elements of the track structure, which cannot be done by machine.

CONCLUSION

Although the methods of maintaining the permanent way have changed over the years, the theory and principles involved in the maintenance of the right-of-way, formation, track and structures remain the same. There has, however, been a radical improvement in the quality of the materials used and the specifications for all materials, including the formation, are more stringent; this became necessary with the introduction of heavier axle loading and longer trains, particularly on the ore export lines.

Note

Photographs: Johan de Koker
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CIVIL ENGINEERS • TOWN PLANNERS • SURVEYORS • CONTRACTORS • ENVIRONMENTAL CONSULTANTS
IF A PIONEERING contractor, in the popular image, was big, bold, blustering and boozy, then George Pauling fitted the bill. He was an enormous man who stood back for nobody, but his reputation as the leading railway contractor in the development of southern Africa during the late 19th century was only partly due to his physical presence. His success was mainly based on shrewdness, common sense and a huge capacity for hard work – and, it may be said, a talent for making friends in the right places.

Pauling was born in 1854 in India, where his father Richard was resident engineer on the Delhi Railways. He came from a family whose construction connections stretched back to Elizabethan times – an ancestor reputedly worked for Wren on the dome of St Paul’s Cathedral, while another built the British Museum. The elder Pauling appears to have been somewhat erratic, and at the age of 15 George was forced to contribute to the family finances by taking a job with Firbanks, a well-known firm of railway contractors. It was a tough introduction to the working world, but young George gradually worked his way up to the position of timekeeper, where his dealings with the navvies taught him a lot about handling labour in the construction industry. He caught the eye of a member of the Firbank family, and by the age of 18 was promoted to office manager and measurer on a tunnel contract. His pay was still less than £2 per week.

In 1875 he and his brother emigrated to South Africa, where a great-uncle, Henry Pauling, was the resident engineer on railway construction at Wolseley. The brother, Harry, was employed there, but possibly because three Paulings would have been too much at one spot, George was sent to the Eastern Cape to work on one of the tricky tunnels on the Alice Dale – Grahamstown route. He quickly realised that it would be preferable to work for himself than for the Cape Government Railways, and he resigned and completed the project as a contractor. He formed an alliance with his old firm, Firbanks, to tender for the Kowie railway, and having completed that contract successfully, never looked back.

He had other strings to his bow besides contracting, and while in Grahamstown acquired a newspaper, an ostrich farm, and for a time was landlord of the Masonic Hotel. Here he was known to entertain guests by carrying his Basuto pony around on his back; he gave up the trick when he injured himself trying to carry it upstairs.

His first big contract was to complete the rail line from the Orange River to Kimberley. During the job he came across the well-known problem of the client who tried to increase the scope of the contract without compensating the contractor. The contract ended suddenly when the junior official who was causing the problem was sent sprawling by a punch from Pauling’s fit, extra-heavyweight frame. Pauling lost money but learned a lot.

The line reached its planned end in Kimberley in November 1885 amidst great celebrations.

His sojourn on the diamond fields had introduced Pauling to the mining fraternity and he tried some speculation in gold in Barberton and Johannesburg. Along the way he met Cecil Rhodes, and the two must have seen complementary energies in each other. The mining ventures put him in touch with the French bankers d’Erlangers, who became the chief financiers of his construction ventures.

While in the region he became involved in the construction of a railway from Boksburg to Johannesburg, which to placate some ultra-conservative old Transvalers had to be called...
a “tramway”, and thus the “Rand Tram” was born – a railway in all but name. He was introduced to President Kruger, who thereupon arranged for him to complete the railway through Crocodile Poort when the original Dutch contractors failed.

After completing contracts to connect Kimberley with Mafeking, Pauling was earmarked by Rhodes as the man who could bring his great plan of a Cape to Cairo railway to fruition. He engaged him to build the line from Mafeking to Bulawayo, on condition that the last 400 miles of track were laid in 400 days. By a great feat of project management, this was duly accomplished and Pauling was thereafter in Rhodes’s first team.

An even more daunting project was to build the line to link Rhodesia to the port of Beira through the fearsome fever belt of the Mozambique coast. The alignment was difficult, and on Pauling’s suggestion the entire village of Umtali was demolished and re-erected nine miles away to suit the preferred route. But the fever took its toll, and a great many European workers, including his brother Harry perished from malaria, and other unfortunates were taken by lions. Pauling maintained that teetotalers were bound to perish from the dreaded malaria and attributes his survival to the liberal intake of whisky. He had a phenomenal capacity for liquor and on one forty-eight hour trip up the Beira railway, he and two companions put paid to three hundred bottles of German beer.

For a while Pauling acted as Minister of Mines and Commissioner of Public Works in the fledgling Rhodesia, and he also took on the job of Postmaster-General. He led a Pooh-Bah existence – any complainants were referred from one office to the other, and while the parties were waiting for an appointment with the next official, Pauling took them for drinks – after which the complaints were lost in an alcoholic mist.

Meanwhile the railway work in Central Africa forged ahead. On Rhodes’s instructions Pauling located the bridge across the Zambezi at the Victoria Falls “close enough for the spray to wet it” – and was then furious when he failed to land the construction contract. In the end he was probably mollified because the Cleveland Bridge Company lost a considerable sum on the job.

While the bridge was under construction he carried on with the line on the northern side of the river, conveying all the material across the gorge by cableway. Thousands of tons were transported in this way, including locomotives which were knocked down and carried across piece by piece, and then used to ferry material to the head of construction. The rail network moved forward through the then Northern Rhodesia and made it possible for the Copper Belt to be developed and become an economic asset. Overall Pauling and Company were responsible for constructing over 1 500 miles of the Cape to Cairo Railway during the period 1893 to 1910.

By this stage the Pauling Company had gained a world-wide reputation, and apart from further work in South Africa, including the Selati railway in the Lowveld and the line up Sir Lowry’s Pass to Caledon, there were ventures in Palestine, Borneo, India, China, Argentina, Greece, and a substantial amount of work in England. He continued to pick up relatively minor contracts in South Africa, and his final major work was the fearsome Benguella Railway between the Copperbelt and the Atlantic.

George Pauling retired to his mansion in Surrey in 1915, and became a genial host and public benefactor – a far cry from his rum-bustious days in Africa. Surprisingly, he wrote an autobiography. He died in 1919. By any standards he was a giant among contractors.
IN PRESENT TIMES THE prospect of Bus Rapid Transit may be exciting the imagination, but the concept, and the public interest it has created is scarcely something new. In the 1850s there was a flurry of activity in the Cape Colony as tram transport became a definite possibility. The taxis of the time were the “omnibuses” – horse-drawn carriages, usually overcrowded, plying indefinite routes to irregular timetables in cutthroat competition with one another. To be fair, many performed a very useful function, providing a link with the outlying districts over unmade tracks in all kinds of weather. But the local services were less admirable. The Southern Suburbs of Cape Town were ripe for expansion, but the advantages of living in the countryside were offset by wage-earners having to travel daily to town in the uncomfortable, dusty and unreliable “buses”. The citizens, it was felt, deserved something better. There were talks of railways, but these required considerable capital investment and thus an extensive customer base.

Strangely for the times, the first campaigner for tramways in the Cape was a woman, Mrs Jane Silberbauer who edited a local newspaper, The Cape Chronicle. In 1860 she wrote glowingly about the benefits of the new form of transport recently introduced in England. Carriages on rails, she pointed out, could carry many more passengers, required fewer horses and provided a much more comfortable ride than the omnibuses. Her article was read by well-known businessman and public benefactor Henry Solomon. He was one of the most prominent residents of Sea Point, then a rather isolated and sparsely populated suburb which had little chance of affording a railway link. Within a short while he had formed a company of interested citizens, and he engaged James Bisset, a young engineer who had been assisting on the Cape to Wellington railway contract, to design a scheme for official approval.

James Bisset was born in Aberdeen, Scotland, in 1836, the son of William Bisset. He trained under Professor Shelly of London University, and this was followed by an appointment with Fox Henderson and Co of Birmingham. After experience in England and on the continent he came to South Africa in 1858.

His scheme for a tramway through the centre of the city to the far end of Sea Point had to overcome many hurdles, and many modifications were necessary before the city fathers finally gave it the green light. The Legislative Assembly was similarly obstructive – it was a time when delegates from the Eastern Cape opposed any improvements for Cape Town on principle – but eventually the bill was passed into law in August 1861.

Henry Solomon was appointed Secretary to the Green Point Tramway Company while Bisset was designated as General Superintendent. Besides drawing up plans for the permanent way and supervising construction, he designed the two coach cars which were built locally and were meant to carry 54 passengers in relative comfort – but would take up to 90 during rush hours when the demand was high. (Overloading is not a modern phenomenon!)

The grand opening took place on 1 May 1863, and the public soon took to the new facility. The company prospered despite several snags that arose when the public resisted the intrusion into their roadways. Routes had to be changed when it was found that the horses could not draw the loaded trams up the gradients in Strand and Shortmarket Streets, and several modifications were necessary to keep the fault-finding public at bay. But the passenger numbers grew, and to cope with the demand a third, larger tramcar was built, incorporating an improved braking system – designed by Bisset – better ventilation, and a more convenient stairway, which allowed ladies to ascend to the roof and be introduced to the pleasures of open-top driving.

But while Solomon and Bisset had set the project in motion with great flair, they seemed less suited to keeping it going efficiently. There were complaints about lack of maintenance of the roadways, and a petition was circulated asking the
municipality to pull up the offending tramlines. When shareholders objected to some accounting practices, Solomon summarily resigned and tossed the books to Bisset, who protested that he was an engineer and not an accountant. As the financial affairs of the company became more chaotic, Bisset resigned in March 1865. This did not improve the finances, as a new accountant absconded with some of the cash. Eventually the fortunes of the Tramway Company recovered and it provided a service for many years before eventually becoming part of the giant City Tramways organisation.

Bisset meanwhile engaged in various local engineering projects, and his designs for the Dutch Reformed Church at Graaff-Reinet and Trinity Church at Port Elizabeth are tributes to his architectural skill. In 1871 he was appointed as Resident Engineer of Harbour and Public Works at Port Elizabeth. He built the railway from Port Elizabeth to Uitenhage and designed Port Elizabeth station, and in 1873 built the line from East London to King Williams Town. He was an ardent proponent of the 3 ft 6 in gauge eventually adopted for the South African system and he also promoted the use of wood from the Knysna forests for railway sleepers.

In 1892 he retired from engineering and returned to Cape Town where he entered local politics and became Mayor of Wynberg. In this capacity he instigated construction of the Wynberg Power Station (which preceded the Cape Town installation by a few years) and the Wynberg water scheme, which led to the construction of three dams on Table Mountain and the first wastewater treatment works in South Africa. During the Anglo Boer War he saw service with the rank of major.

He married Miss E M C Jarvis in 1862 and his descendants became well known in Cape legal circles. A son, Murray, practised with distinction at the Cape Bar and was invited to become a judge in Southern Rhodesia, where he subsequently became Chief Justice and was knighted for his services. Murray Bisset was also South Africa's second international cricket captain and led the country on several occasions between 1898 and 1912.

James Bisset died at his home in Kenilworth, Cape Town, in 1918.

REFERENCE
When interviewed by David Beer, Silvio Ferraris, president of the Concrete Manufacturers Association (CMA) and vice-president of its Concrete Retaining Blocks (CRB) Division, outlined his reasons why CRB wall failures occur and what can be done to avoid them.

Since they made their first appearance in South Africa some 26 years ago, concrete retaining block (CRB) walls have become a readily recognisable feature of the South African landscape. Used widely for residential, commercial and industrial applications, CRB’s favoured status among property owners and developers is due in large measure to the competitive advantages of low cost and fast construction. The ability to follow any contour and the suitability for greening are other factors that make them popular. This success rests on sound design principles and adherence to correct construction procedures. Given the relative simplicity of the entire process, nothing should go wrong. So why does it?

It should be stated at the outset that CRB walling is one of the construction industry’s many success stories, with its proven capacity to provide innovative and eco-friendly solutions to retaining wall challenges. Of the hundreds of CRB walls built every year only a very small percentage fail, usually within a year of completion. However, no matter how few the failures, or how small the percentage, the figure is still too high.

CRB WALL FAILURES

Some of the more common causes of CRB wall failure are as follows:

- No engineering designs or drawing sections
- Inadequate foundation detail or no foundations at all
- Wall slopes that are steeper than those allowed for in the design
- Height of wall exceeds design and/or is too slender for wall height
- Backfill material unsuitable
- Backfill insufficiently compacted – the major cause of most failures
- Using in structural applications CRB blocks meant only for low walls and landscaping purposes
- No drainage detail
- Geotextiles (where required) not installed correctly or incorrect products used

These are, of course, just the symptoms. The underlying is human error, either at the design stage or, mainly, during construction or both. In many instances CRB walling forms the minor leg of a much larger project such as a shopping centre or office park, and as such it does not receive the focused attention it deserves. But it is primarily a structural element and should be treated as such. However, unlike other areas of the construction industry where a philosophy of zero defects is or should be rigorously applied, such as in the construction of bridges or dam walls, CRB walling’s status often rates not much higher than nuisance value – small wonder then that errors and corner cutting occur.

WHO IS RESPONSIBLE?

Several professions, such as the project engineer, architect and quantity surveyor, have some responsibility for the design and construction of CRB walls, especially on large multi-faceted projects. They are the professionals at the top of the project chain responsible for assembling tenders and bills of quantity documents. The main contractor, the CRB design engineer and the CRB subcontractor who actually builds the walls should work closely with the professionals, but this is often not the case.

The subcontractor is usually responsible for the wall design and he will use the services of a design engineer for this purpose. However, the initial structural design specification and drawings, which are not meant to show much detail, are the domain of the project engineer with additional input being made by the architect and quantity surveyor. The project engineer is responsible for ensuring that the project adheres to the local by-law requirements, such as reticulation, drainage and road levels.

Problems can arise right at the outset when the project engineer’s CRB design specification and bills of quantity briefs lack essential information, which is often the case. Missing information typically includes irrigation systems, the layout of services and even basic essential information such as soil parameters, surcharge loadings, wall height and angles. And
more often than not no drawings are supplied with the specifications.

It is virtually impossible for the subcontractor and his design engineer to second-guess, with a reasonable degree of accuracy, what the actual requirements are if the bill of quantities lacks relevant details and drawings.

CRB contractors generally react in one of two ways to this type of specification. They can either make certain assumptions in their own favour (one being the height of the wall and another the quantity of fill required) or, if the site is ready for viewing, they can visit it, make more realistic assumptions and quote more appropriately. Although a higher quote would reflect the actual requirements far more accurately, the client generally opts for the lowest quote, which is when the problems start.

Then, when the winning CRB contractor arrives on site he usually finds that the project involves a higher wall, as well as additional elements not dealt with in his quote, such as poor access, more backfill, fabric reinforcement, drains and stronger foundations. So he either cuts corners, building a wall for which the risk of failure is high, or he revises his quotation and the project goes hopelessly over budget. Either way, the project eventually ends up costing someone considerably more.

There is no excuse for the submission of inadequate CRB wall specifications and all CRB wall specifications should be accompanied by a set of drawings. These should include a typical cross-section showing wall angles, the quantity of concrete needed for the foundations, the drainage detail, the height of the wall and the area it will cover. Furthermore, an architect should ensure that the wall doesn’t interfere with the architectural theme of the overall project.

**CRB WALL INSTALLATION MANUAL AND STANDARDS**

For those not sure what a comprehensive specification entails, the CMA has published a CRB wall installation manual which includes a typical bill of quantities and covers most of the requirements for constructing a CRB wall. The CMA has also produced a film (available on CD) which provides step-by-step construction guidelines and is available at no charge.

CRB wall specifiers can also refer to two SABS standards: SANS 207: 2006 for the design and construction of reinforced soils and fills, and SANS
508: 2007, the specification for retaining blocks, which was published in August 2008.

**INFORMATION REQUIRED**

Despite having to work with inadequate bills of quantity and no drawings, it is still the responsibility of the design engineer to see that walls are built according to sound design and building principles. If the original specification does not carry sufficient detail, then either the CRB contractor or the design engineer must establish the parameters within which the wall must be designed and constructed.

This means sourcing the necessary information from the project engineer who, because he is focused on the whole project, is usually unable to provide it immediately. For example, he may not have the soil parameters required to design walls as per SANS 207, and he may be uncertain of the loading, heights and angles, all of which makes the design and pricing of the wall very difficult. The CRB design engineer also needs to know about groundwater conditions and services, such as water, sewerage and storm water pipes, not to mention irrigation systems and electrical reticulation details.

All these aspects ought to be taken into account before or during design to avoid the type of situation in which once a wall has been constructed, a services trench is excavated, cutting into the geofabric and rendering it useless. Or an irrigation system is installed with similar consequential damage.

**SOURCES OF FLAWS**

Design flaws can also occur when the main contractor, who really acts as the interface between the project engineer and the subcontractor, issues an instruction to the subcontractor that changes the original design, without having informed

1. A failed CRB wall where a blocked storm water pipe and subsequent joint leakage meant that water permeated the soil under the roadbed, completely saturating the fill behind the CRB wall
2. Photos such as this should be taken at regular intervals during the construction of CRB walls as proof that design specifications are being followed
3. Construction of a CRB wall in progress. This 6.8-m-high wall was built at 60° to within accuracy tolerances of +1°, -2° as specified in the CMA’s Code of Practice for the construction of CRB walls
or consulted with the CRB design engineer. This could involve raising the wall or changing a kerb position, which can alter and ultimately compromise the safety and structural integrity of the wall.

Furthermore, it is always the main contractor’s responsibility to set out the wall before the foundations are excavated, and this is not always done correctly. The reason for this is that CRB specialists do not allow for surveyors in their quotation, whereas all the site plans and surveyors are at the disposal of the main contractor to ensure precise setting out. This practice of the main contractor setting out the foundations is clearly most appropriate and forms part of the CRB specialist’s terms and conditions.

**SOLUTIONS AND TESTS**

To avoid the scenarios sketched above, adherence to the SANS standards, as well as to the CMA manuals, available at no charge, consisting of the *Installation manual, Code of Practice for gravity walls, Design of reinforced walls, Design checklist* and various project reviews such as *Hydraulic applications*, should be mandatory. Adherence would remove the ambiguity as to where responsibility for the design and construction procedure lies. One of the important rules covers design deviations and how best to handle them. In this instance, good liaison between the project engineer and CRB design engineer is a prerequisite.

Most walls fail because their design or structural weaknesses make the fill prone to water saturation. Besides storm water, which is often a cause of the failure of construction works in progress, irrigation and storm water systems, which often leak and become blocked with debris, can also undermine the integrity of a wall. It makes sense therefore for design engineers to be involved in the design and specification of irrigation systems as this would help lessen the threat of leaking.

In an ideal world the backfill of CRB walls would contain a substantial percentage of coarse material and a low percentage of fines (<15% passing a 75 micron sieve). This would reduce the incidence of wall failure dramatically, but importing selected fill is an expensive option, which is why soil found on site is generally selected. Before the engineer can design a wall, he needs to know what the internal friction angle (φ) of the soil is and its cohesion (c). To establish this information accurately, a shear box test is required. SANS 207 prescribes this test, yet on most retaining wall sites it is not undertaken.

Instead, as a fallback measure, design engineers use the geotechnical report, which includes results on the fines content of the soil. Geotechnical reports are intended mainly for piling and building foundation designs and almost never include shear box tests. This means that if a design engineer relies solely on a geotechnical report, his assumptions could be off the mark by a considerable margin. The initial geotechnical investigation must also include undisturbed shear box test results as per SANS 207 if the project is to include a retaining wall element.

Some design engineers insist on a Troxler test, a nuclear device which tests compacted soil density. As this is expensive and involves testing at every 300 mm, it is generally called for when the walls are very high or when there is a substantial amount of fill.

As the compaction of backfill is a critical aspect which, if overlooked, can lead to wall failure, all CRB contractors should own a DCP (dynamic cone penetrometer) compaction test kit. They are inexpensive and pay for themselves many times over. Besides doing regular compaction tests before placing foundations and during the construction of a wall, the CRB contractor should also take photos regularly. This means that in the case of any comeback, the contractor and the design engineer will have proof that the wall was built according to design.

DCP indicator tests should be mandatory and should be conducted to check compaction to the full height of the fill at height intervals of 1 000 mm. Troxler tests can be done less frequently and the results can be correlated with the DCP results to ensure compaction uniformity.

A final aspect of responsibility for storm water management during construction work deserves mention. This is the joint overall responsibility of the professional team, project managers and the main contractor as it is unreasonable to expect a subcontractor to manage the other subtrades such as bulk earthworks, plumbers and bricklayers whose site works often have a direct impact on the CRB contractor’s progress and performance.

**CONCLUSION**

In summary, the causes of CRB wall failures are many, but prevention can start from the beginning of a project when the initial geotechnical investigation and specifications are drafted. Even at the end of the project the integrity of a completed wall can be disturbed through unplanned and inappropriate intervention, or failure can occur at any time between. If we are to build CRB walls that are 100% reliable, i.e. built with zero defects, a substantial change of attitude on the part of the professional project team right down to the CRB subcontractor will be required, an attitude that recognises that CRB walls play an important structural role and that any wall failure will have serious consequences for both the client and the project team. It is certainly an attainable goal and one worth pursuing.
in impoverished and war-ravaged communities.

Hand the deteriorating infrastructural conditions remote parts of Africa, they encountered first-systems. During their visits supplying landmine equipment, including landmine detonation manufacturers of military and civil engineering Quaroni and Johan Wessels, who are effectively SMART Award.

The Terragrader is the brainchild of Luigi Quaroni and Johan Wessels, who are effectively manufacturers of military and civil engineering equipment, including landmine detonation systems. During their visits supplying landmine detonation systems to some of the most remote parts of Africa, they encountered first-hand the deteriorating infrastructural conditions in impoverished and war-ravaged communities.

says co-inventor Luigi: “We realised that unless something drastic and practical was done to maintain or upgrade rural roads that gave communities access to markets, thereby ensuring a sustainable life, local populations would remain in a downward spiral without any hope of ever escaping poverty. Using standard road construction and maintenance equipment to maintain and develop infrastructure was never going to be effective, because there simply is no existing infrastructure to cater for even the most basic requirements, such as fuel suppliers for instance.”

Sufficient aid money was available, but according to Luigi this money was not spent correctly. Deliveries of impractical, conventional machinery that was never designed to serve a rural African environment would eventually end up as a monument to the donor country whose conscience was clear since the money had been donated and spent in good faith. “This is Africa’s reality, and the problem needed an African solution,” Luigi concludes.

It was therefore of paramount importance to design a low-maintenance machine that would be tough enough for African conditions and would be able to fulfil its role in the construction and maintenance of gravel roads without relying on sophisticated support infrastructure or posing the problems normally encountered when using conventional plant and machinery in outlying areas. All consumable parts had to be standard, available off-the-shelf, and easy to replace items.

In liaison with the University of Johannesburg’s Department of Mechanical Engineering Technology, the manufacturers assigned postgraduate engineering lecturer Francisco Lardin Martinez to do his Master’s in Technology dissertation on the design and development of the proposed towed grader. The successful end product subsequently became known as the Terragrader.

The Terragrader, when filled with water, weighs 14 tons which is on a par with that of a conventional motorised grader. Other prominent features are as follows:

- The blade cutting edge is a standard 3 650 mm off-the-shelf item, which can be extended on both sides with supplied blade extensions to 4 360 mm.
- The blade operates on an articulation system allowing up and down movement to a depth of 150 mm; it angles at 24° and tilts 12° up and down on both sides, while displaying a 600 mm side shift to both sides. All operations are hydraulic and operate off the tractor hydraulic system.
- To wet the road surface the hydraulically-powered spray-bar operates through a hydraulic fire pump, discharging from a 6 000 ℓ baffled and lined rust-proof water tank, 80 ℓ of water per minute at 12 bar pressure through various spray nozzles.
- The scarifier (ripper tips) is standard and off-the-shelf. It is hydraulically operated, allowing the soil to be ripped up to 95 mm deep.
- The static compaction roller is a steel drum extending the full width of the Terragrader. During operation it remains under constant weight, varying from 8 to 14 tons depending on the fullness of the water tank. A spring-loaded scraper along the length of the roller ensures that the roller remains clean. Whether empty or full, the roller compacts most surfaces sufficiently and effectively.
- The hydraulically operated wheels at the back of the unit are fitted with pneumatic brakes and can be lowered quickly to raise the road building equipment, converting the Terragrader into a tow-trailer that allows the unit to move speedily during fire emergencies. The foam-filled tyres eliminate potential punctures and cost a fraction of conventional grader tyres.
- With its 6 000 ℓ water tank and hydraulic fire pump delivering 80 ℓ per minute at 12 bar pressure through a high pressure discharge hose and adjustable fire nozzle, the Terragrader is ideal for first aid fire fighting purposes and handy when doing planned and controlled fire breaks. The pump is fitted with an instantaneous fire hydrant coupling valve to allow the use of lay-flat fire hose. The delivery rate is 550 ℓ per minute. A suction hose fitted to the pump allows the tank to be re-filled from open source water at 600 ℓ per minute.
- The Terragrader is towed behind a 100 Kw 4-wheel drive powershift tractor with a maximum fuel consumption of 100 ℓ during a 10-hour working day (8–10 ℓ / hour), which

### IN BRIEF

THE TOUGH ALL-IN-ONE TERRAGRADER

A MULTI-PURPOSE ROAD construction and maintenance grader, known as the Terragrader, has been developed with the specific aim to help provide infrastructure in areas of Africa where roads and transport links barely exist.

Designed to mechanically refurbish or create earth roads in rural environments, the first manufactured prototype unit was awarded the 2006 South African Bureau of Standards Design Excellence Award as well as the SAICE SMART Award.

The Terragrader is towed behind a 100 Kw 4-wheel drive powershift tractor that hydraulically operates all the various functions of the grader. Its fuel consumption in comparison is a mere 10% of that of conventional equipment.
bears no comparison with the approximately 900 ℓ (80–100 ℓ / hour) consumed by the full complement of road grader / water tanker / compactor conventionally used – a logistical nightmare in rural areas.

The tractor, in isolation, empowers local populations to carry out agricultural and other tasks when the grader systems are not being used for road building or maintenance. It can also provide rural communities with clean drinkable water for storage in bulk tanks and water for irrigation during dry seasons.

“The Terragrader is not trying to compete with conventional plant and equipment,” says Neels Matthyser, Marketing Coordinator of Terratech, the South African company that obtained the sole distribution rights for the grader. “It has been designed as an all-in-one unit specifically to rebuild infrastructure in Africa. When it comes to rural environmental maintenance, construction and empowerment through agriculture, and the creation of employment opportunities at grassroots level, we regard its design as having no equal.”

INFO
Neels Matthyser
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www.terragrader.com

MAPEI SUPERPLASTICISER USED IN THE MANUFACTURE OF GAUTRAIN SLEEPERS

MAPEI’S DYNAMON SX 14, a superplasticiser for concrete, is being used by INFRASET Railway Products in the production of concrete sleepers for the Gautrain project, which is a project of the Gauteng Provincial Government. The plasticiser, which is being supplied by Engineered Concrete Systems (ECS), is also being used in the production of the LVT (low vibration track) sleepers that will be used in the tunnel sections of the project.

The sleepers, which are being manufactured to European specifications and standards for rapid rail passenger lines,
are being supplied by INFRASET to the Bombela Concession Company, the company responsible for the design, building and operation of the Gautrain.

As the Gautrain sleepers are larger than standard sleepers and the requirements regarding deflection and stresses are more stringent, a higher-than-normal grade of concrete strength was needed. Moreover, the high profile of the project, as well as durability considerations, required a high quality of finish, which also had to be considered in the design and production of the concrete. ECS began supplying Dynamon SX 14 to INFRASET’s Brakpan plant in October 2007. ECS product manager for admixtures, Antony Offenberg, says that the success of the project required close collaboration between concrete technologists from ECS and INFRASET working as a team in order to achieve optimal mix proportions.

“We were faced with many challenges at the onset of the project. For instance, we needed to overcome imperfections in the aggregates, plant limitations and mould turnaround demands. After an extended period of experimentation we achieved a mix that was user friendly in application and consistent in performance.”

Another challenge to be overcome by the ECS team is that limited vibration was allowed for compaction, due to operational factors, so the concrete needed to be placeable and responsive to vibration, while achieving high early-age strengths.

The correct selection of the appropriate Dynamon admixture, as well as various dosage considerations, played a vital role in the final concrete mix design. Mapei supplies admixtures in the Dynamon range for use in readymix, precast and multi-purpose appli-
Board of Directors. Dr Abedian is the Chief Executive Officer of Pan-African Capital Holdings (Pty) Ltd, a shareholder of Bigen Africa. Prof Nkuhlu has resigned from the board to pursue other interests.

Dr Abedian is a former chief economist of Standard Bank and has been a consultant on economic policy issues to public and private sector organisations in South Africa, as well as internationally. He is an honorary Professor of Economics at the University of Pretoria.

Dr Abedian says of his recent appointment: “I am delighted to have the opportunity to join the board of Bigen Africa. It is an opportunity to work with some of South Africa’s most competent and committed professionals. Bigen Africa runs one of the most successful operations in its field in South Africa and on the African continent, and for me it is a privilege to have the occasion to learn from and contribute to the company’s remarkable history.”

Francois Swart, CEO of Bigen Africa, adds: “It is indeed a privilege to have as our chairman one of South Africa’s most respected and foremost economists. I have personally got to know Dr Abedian during our frequent ventures with Pan-African Capital Holdings (PACH), our empowerment partners. I am confident that with Dr Abedian’s guidance, we are well placed as an organisation to navigate successfully through these awkward times and face our future with optimism.”

Dr Abedian and CEO Francois Swart

MUCH ASPHALT REDUCES CARBON FOOTPRINT WITH NEW TECHNOLOGY

MURRAY & ROBERTS company Much Asphalt is gearing up to meet asphalt production demand for SANRAL’s Gauteng Freeway Improvement Project with new plants at its Benoni and Pomona facilities to supply an additional 300 and 250 tons per hour respectively.

Both are twin-drum configurations capable of handling a wide range of different mixes, including efficient use of recycled asphalt (RA), an important requirement in the drive for sustainability of natural resources.

Of particular interest, however, is the plant built by Astec in Tennessee, USA, which is now being commissioned at Much Asphalt Benoni. This installation will allow Much Asphalt to employ foam technology for the manufacture of warm-mix asphalt (WMA) for the first time in South Africa. Not only will this enable the company to decrease its carbon footprint substantially, but WMA also provides several additional benefits in both asphalt production and paving. WMA allows the asphalt manufacturer to reduce the temperature at which the material is mixed and placed on the road through the use of either chemical additives or foam technology.

“We will be the first South African company to produce WMA using foam technology on a big scale,” says Much Asphalt technical director Herman Marais. “Foam technology as a cold process has been around for some time, but has been used to manufacture bitumen-stabilised basecourse material rather than asphalt.”

All previous technologies for warm mix production rely on chemical additives, special bitumen, special procedures and/or special bitumen-delivery systems to reduce the viscosity of the binder at lower mixing and placing temperatures. The additives add significantly to the cost per ton of mix.

The Double Barrel Green System built for Much Asphalt by Astec eliminates the need for additives through the use of small quantities of water that come into contact with the hot bitumen, generating steam and in turn causing foaming of the bitumen. The volume of the bitumen is drastically increased and the viscosity of the binder is reduced, improving coating on the rock and enhancing its distribution in the mix. The lower viscosity of the binder allows lower-than-normal compaction temperatures.

“Temperature reductions of 20 to 30°C are possible, with the obvious benefits of cutting fuel consumption and decreasing the production of greenhouse gases. This will reduce energy costs and the carbon footprint at Much Asphalt’s biggest and busiest plant,” Marais points out.

In theory, an energy saving of 11% can be achieved with a 10°C reduction in heat. However, energy savings of 30 to 35% have been reported due to the reduced heat losses during the mixing operation. Processes in which the aggregate is not heated above the boiling point of water have savings as high as 34 to 47%.

Research has shown that lowering the production temperature can also drastically reduce emissions, fumes and odours at the

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plant, improving conditions for workers and paving the way for better relationships with neighbouring industries. Smoke and smells are eliminated because the light oils in bitumen never reach boiling point. Working conditions at the plant and on the paving site also improve due to lower production and paving temperatures.

Maintaining a low viscosity at lower temperatures allows the mix to flow freely through storage, transfer and placement equipment and makes it easier to work by hand.

A higher content of recycled asphalt can be added to a conventional asphalt mix without incurring excessive emissions or poor workability, contributing to the environmental benefits of WMA. Less aging of the virgin binder in warm-mix production may also allow higher percentages of recycled asphalt to be used.

Operational benefits include an increase in plant production with no increase in the cost of the mix. This can be attributed largely to reduced temperature differentials. The greater the differential between the asphalt and ambient temperatures, the faster it cools off. With WMA this differential is low and therefore it cools more slowly. This allows a longer period for compaction to take place, improves density, and the asphalt can be stored for longer, hauled over longer distances and used in colder temperatures.

Much Asphalt offers best practice workshops on hand-laid hot mix asphalt as a value-adding service for emerging contractors and local and provincial authorities. “The aim is to establish a uniform, industry-wide standard for high-quality hand-laid asphalt,” says Herman Marais. “The WMA should benefit small hand-laid asphalt projects as the constructability time-window for successful compaction will be extended due to the workability of the mix at lower temperatures. We are also busy with research in conjunction with the CSIR on the use of high-RA-content...
mixes with the WMA technology; this will be aimed at labour-based township road upgrades."

WMA has received much attention worldwide as a technology that saves energy and improves conditions for workers and it is now being widely adopted in Europe and the USA.

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DEMANDING CONCRETE SPECIFICATIONS FOR NEW FRENCH RAPID RAIL SYSTEM

FRANCE IS RAPIDLY developing a world-class high-speed railway network, and the grand plan is being enhanced by the R25 billion Rhine-Rhône high-speed rail link which will require 270 000 cubic metres of concrete to construct.

The Rhine-Rhône LGV (ligne a grande vitesse) – the biggest railway engineering project in France at present – is the country's first provincial high-speed rail link and an important stage in the development of the European rail network.

Shaped like a three-pointed star (east, west, and south), the new line runs through Burgundy and Franche-Comté linking the Mediterranean LGV (Paris, Lyon, Marseille) with the rail network to the east of Europe. The goal is to link the north-south European network with the Rhône-Alps region, as well as the south of France and Spain, providing considerably reduced journey times on the 320 km per hour train. The eastern point of the star is the most advanced and will link Dijon to Belfort.

Construction work started in July 2006 and the service is expected to be operational by 2011. The line will comprise 160 bridges and 13 viaducts, two new stations and a tunnel. In total, 24 million cubic metres of earth will be removed. Two-thirds of this will be needed for the embankment construction, and 400 km of fencing will be needed to protect the route.

Concrete supplier SATM’s specifications stipulated concrete with mechanical strengths of 35 to 50 MPa – using different cements for different applications – and with a constant rheology time of 90 minutes minimum. SATM is providing the concrete for the batches that cover the building of most of the architectural concrete units which are made in two plants at Arcey and Thieffrans, and will use 270 000 cubic metres of concrete. The same admixture will be used for the 13 viaducts, the tunnel and 43 auxiliary structures.

For the first section of the eastern line of the LGV, Chryso’s long workability plasticiser, Chrysoplast Omega 132, will be used by SATM. The admixture was selected on account of its price-quality ratio and multi-dosage plasticising properties. At small dosage, the admixture works as a plasticiser while, at high dosage, it acts as a super-plasticiser. These multi-dosage possibilities helped meet all the concrete specifications while being fully compatible with the different cements used.

As environmental consideration for local residents, noise reduction barriers have been installed.

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The use of the admixture make it possible to meet all contractual strengths up to 50 MPa while guaranteeing homogeneous fresh concrete without bleeding or segregation before pouring – with a workable time of an hour-and-a-half.

It is doubly important to produce a homogeneous concrete to ensure a good surface quality for all parts straight from the mould, and to retain the option to pump or pour the concrete from the trucks depending on the accessibility of the site or application.

Admixtures from Chryso are also being used for various aspects of the construction of South Africa’s multi-million rand Gautrain project.

SUSTAINABLE ENGINEERING SOLUTIONS IN MAURITIUS

ONE OF THE HIGH-PROFILE projects in which Peter Brett Associates International (PBAI) South Africa is currently involved is a multi-million rand resort on the hillside of La Tourelle du Tamarin mountain in Mauritius. The resort accommodates 26 villas, extending across 26 acres. The villas blend into the slopes of the mountain and the setting offers stunning views of the west coast of the island.

PBAI South Africa has international experience in hydrology, storm water design, flood hydraulics, flood-line determination, reservoir analysis and storm water design and systems. The company was therefore commissioned as the storm water expert on this venture, in support of its Mauritius branch which is undertaking the design engineering for the project. “One of the challenges on the venture was the creation of the attenuation features without affecting the down slope on the site. This was particularly difficult, because the down slope environment is fairly heavily developed with expensive residential properties,” explains John Paterson from PBAI. They had to ensure that the storm water design minimised down-slope impact so that any existing gully that had become eroded over time could, as a result of the attenuation features, become rehabilitated.”

PBAI South Africa is a long-standing customer of the infrastructure design software Civil Designer and uses the software extensively in all its projects. They find the runoff event network analysis in the storm water module excellent. The package helped them to identify problem areas quickly so that they could analyse various scenarios until they found the perfect solution.

“I think the software definitely gives you the edge when you work on intricate scenarios,” says John. “Achieving our attenuation goals within the limited space available was the biggest challenge of all.”

The team conducted a hydrological assessment of what the greenfield runoff would look like before construction. The pre-development model took into account the rainfall intensity in Mauritius. From here, the team were able to use the post-development assessment to determine what impact the runoff would have.

Storm water design has recently placed increasing emphasis on responsible engineering. This includes looking at water recycling and also liaising with developers to ensure that sufficient attention is given to environmental issues. “Everything we do is according to best practice guidelines. We have long subscribed to the principles of sustainable urban drainage and continuously seek sustainable solutions. In addition, urban and storm water management is constantly reviewed in terms of climate change.”

The project is currently in its final phase of design and construction is likely to commence at the end of 2009.

ENQUIRIES

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Panoramic views from the upper parts of the La Tourelle development in Mauritius
Developing a capacity building manual – Brasilia 2008

ANOTHER MILESTONE achievement on the list of SAICE international outreach projects took place during the first week of December 2008 in Brasilia, capital of Brazil. This occasion was the workshop of the Committee for Capacity Building (CCB) of the World Federation of Engineering Organisations (WFEO), in conjunction with the World Engineering Conference, to develop a Guidebook for Capacity Development.

This effort was spearheaded by myself, as Executive Director of SAICE in South Africa, together with Andrew Cleland, Executive Director of IPENZ in New Zealand, and actively supported by Mike Satio, Director of International Alliances at ASCE, Tony Marijoram from UNESCO and Dan Clinton, Chair of the WFEO-CCB. The South African Department of Science and Technology generously sponsored the visit.

South Africa took the lead in discussions and presented a meaningful number of capacity building ‘tools’ and valuable insights as to what needs to be done to get this project off the ground.

INSIGHT INTO SUSTAINABILITY

Sustainable engineering infrastructure and services are the basic cornerstones of life, civilization and economic wellbeing of communities.

Engineering professionals are the custodians of infrastructure and have taken upon themselves the task of assisting decision-makers from all levels of society to ensure a sustainable world for all.

Across the world there exists a huge deficiency in capacity, firstly to understand the need for infrastructure and sustainability, and secondly to develop, deliver and maintain infrastructure and services.

The following six pillars of capacity and sustainable engineering were recognised by SAICE some time ago, and all of them need to be in place for success:

- Individual – the needs of the technical practitioner are met
- Institutional – stable institutions are in place
- Technical – standards and codes are operationalised
- Decision-making – is informed at all levels from government down to ordinary citizens
- Business – business structures support technical development (financial, legal and commercial)
- Resources – the materials required can be sourced

WHAT IS CAPACITY BUILDING?

This complex term can be defined in many ways, but essentially it is the building of human, institutional and infrastructural capacity to help societies develop safe, secure, stable and sustainable economies, governments and other institutions.

Capacity building can also be assisting people to develop the technical skills to address their own needs for improving the living standards and prosperity of their own people and building an environmentally sustainable society.

Capacity building is relevant and important for all nations, and although unique circumstances exist everywhere, some universal principles apply:

- Capacity building in developing nations – establishment and development phase
- Capacity building in developed nations – renewal phase

Capacity can be developed and maintained through mentoring, training, education, physical projects, the infusion of financial and other resources and, even more importantly, the motivation and inspiration of people to improve.

TOP-DOWN VERSUS BOTTOM-UP

Success is most likely if appropriate and well-managed public policies or ‘top-down’ approaches are in place. Implementations of these public policies are more likely to succeed if the public policy identifies and makes use of established non-governmental institutions such as professional societies and their programmes. Although success from the ‘bottom-up’ approach is possible without public policies in place, the impact and success rate would be lower.

WHY A GUIDEBOOK OR MANUAL?

- Lessons learnt in one nation can be shared with others.
- Many who are undertaking capacity building activities are isolated from support systems and a guidebook can provide advice and prevent reinvention of the wheel.
- A guidebook will record success and
commentary to act as a guide to others. Under the WFEO and UNESCO brands a guidebook will provide credibility with governments, funding and aid agencies. The time has arrived to develop an integrated, generic, appropriate, effective and comprehensive set of engineering-related guidelines related to capacity building programmes that can be promoted and implemented without delay.

The manual will also be useful for aligning our efforts, which could in turn facilitate common understanding amongst decision-makers as to ‘where, how and what’ is needed to satisfy the capacity building requirements throughout the entire pipeline.

However, capacity building is more difficult than it seems and even well-intended programmes can fail despite the efforts of those involved. The intention of this best practice manual will be to assemble and distill the experiences of many people and institutions in order to assist those who are developing new programmes to minimise the risk of future failure.

The manual will also:

- enable the team of contributors to assemble packaged solutions and programmes
- serve as a template to custom-fit the needs of a specific country
- reduce risks for, and enhance trust and credibility with, funding organisations and other decision-makers

THE ENVISIONED 10 CHAPTERS OF THE GUIDEBOOK

1. Principles of capacity building
2. Defining needs and desires in nations
3. Influencing and defining public policy
4. Establishing education and skills development programmes
5. Achieving participation in education and skills development
6. Support networks and systems for technical professionals
7. Adoption of technical and business standards
8. Project execution throughout its lifecycle
9. Using externally provided funding
10. Special issues

Significant progress has been made on this project, as lead authors were defined for all ten chapters and key success factors and examples for content were identified and discussed. A start was made with listing programmes which will form an annexure or compendium of good and best practice examples.

First drafts are currently being completed and peer-reviewing of the contents will be done during the next phase. The launch is planned to take place at the WFEO event in Kuwait in November 2009.

CONCLUSION

We have to bridge the gap before the chasm becomes too wide. It is primarily an engineering race, and it is a race against time - it is now or never. We can now build on foundations laid to develop the pillars that underpin a sustainable society, for the sake of the communities we serve and for the sake of our world in crisis. Engineering professionals will have to go above and beyond the call of duty.
Communication from the SAICE Membership Committee

SAICE membership categories

For too long we at the SAICE Membership Committee have been plodding along faithfully, without sharing our trials and tribulations with you, our members. So the Membership Committee has decided to publish a regular column in the magazine to share membership statistics, look at address issues, and answer any of your questions. In this first article we will look at SAICE’s membership categories, and at the roles and responsibilities associated with these categories.

MEMBERSHIP CATEGORIES - AN OVERVIEW

The two main categories of SAICE membership are the following:

- Corporate Membership – these members have full voting rights at all levels of the Institution
- Non-Corporate Membership – these members have voting rights only at Branch and Division level

SAICE MEMBERSHIP COMMITTEE

MEMBERSHIP TRENDS FROM 2002
CORPORATE MEMBERSHIP is divided into the following three grades:

- An Honorary Fellow is a person of distinction who is honoured by the SAICE Council for:
  - service to the Institution
  - service to the civil engineering profession
  - his/her eminence

Honorary Fellows are nominated by Corporate Members, recommended by the College of Fellows and approved by Council.

- A Fellow is a person who, at the time of election:
  - has, in the opinion of the Executive Board, achieved sufficient status in the civil engineering profession
  - is older than thirty-six years of age
  - has been a corporate member for more than five years

Fellows are nominated by Corporate Members, recommended by the College of Fellows and approved by the Executive Board. In 2008 a Council decision was taken to reduce Fellows’ fees to the same as those for members by 2010.

- A Member is a person who at the time of admission:
  - is actively engaged in civil engineering
  - holds an academic qualification from a tertiary educational institution recognised by SAICE
  - is professionally registered with a statutory council, or with an international body recognised by SAICE for this purpose

NON-CORPORATE MEMBERSHIP is divided into the following two grades:

- An Associate Member is a person who:
  - is actively engaged in the civil engineering profession in one form or another, but does not hold an academic qualification from a tertiary educational institution recognised by SAICE
  - holds an academic qualification from a tertiary educational institution recognised by SAICE, but is not professionally registered with a statutory council or with an international body recognised by SAICE for this purpose
  - holds an academic qualification from a tertiary educational institution not recognised by SAICE

- A Student Member is a person who is registered as a student at a tertiary educational institution recognised by SAICE.

It was initially envisaged that only final year students would apply for membership, with the first year of membership being free. However, first and second year students are also applying for membership, placing a financial burden on themselves during their entire study period. A suspension of fees for their study period has therefore been approved, provided that they apply for said suspension, and provided that they are registered students.

Individuals satisfying the requirements in the various grades mentioned above may apply to the Executive Director for membership.

MEMBERSHIP EVOLUTION

A person may apply for any grade of membership if the prerequisites (as set out above) for the particular membership grade are satisfied. Based on the application received, the Membership Committee will ensure that the applicant is placed in the correct grade of membership.

Transferring from one grade to another grade of membership is not automatic, and will only be activated on receipt of an application.

When a student member has obtained an academic qualification in civil engineering from a tertiary educational institution recognised by SAICE, the student would need to apply to be upgraded to an Associate Member. Failure to do so will result in the student being removed from the membership role. Student Members who upgrade to the grade of Associate Member have five years in which to upgrade to the grade of Member. Failure to do so will result in the member remaining an Associate Member, but paying the membership fees of a Corporate Member.

A member may resign from the Institution by submitting a written resignation to the Executive Director. However, all outstanding fees have to be settled before the resignation can take effect.

MEMBERSHIP STATUS

The accompanying graph shows the membership trends since February 2002. The negative trends represent the annual “struck-offs” (members who have been removed from the role). As can be seen there were no significant “struck-offs” in 2007. The positive trends over 2007-2008 are predominantly due to an extensive recruitment drive among students. On the other hand, the negative trend in 2008 was predominately due to the loss of contact with student members.

INVITATION

Should you have any questions, or issues that you would like the Membership Committee to address, please e-mail these to me (aschwarz@hatch.co.za) at any time.
TO: ALL CORPORATE MEMBERS

NOMINATIONS FOR ELECTION OF COUNCIL FOR 2010

THE SOUTH AFRICAN INSTITUTION OF CIVIL ENGINEERING – Nomination for election of Members of Council for the year 2010 in terms of Clause 3.1 of the By-Laws

Clause 3.1.1 of the By-Laws reads as follows:

“Every candidate for election to the Council shall be a Corporate Member and shall be proposed by a Corporate Member and seconded by another Corporate Member.”

Nominees accepting nomination are required to sign opposite their names in the last column of the nomination form. Nomination for election to Council must be accompanied by a Curriculum Vitae of the nominee not exceeding 75 words. The CV will accompany the ballot form, and the format of the CV is shown below in Sections A and B. According to a 2004 Council resolution, candidates are requested to also submit a focus statement. Please see Section C in this regard.

Section A: Information concerning the nominee’s contribution to the Institution.

Section B: Information concerning nominee’s career, with special reference to civil engineering positions held, etc.

Section C: A brief statement of what the nominee intends to promote / achieve / stand for / introduce / contribute, or preferred area of interest.

Please Note: Nominations received without an attached CV will not be considered.

Closing date: 31 July 2009. Acceptable transmission formats - email, fax and ordinary mail. All nominations are treated with due respect of confidentiality.

If more than 10 nominees from Corporate Members are received, a ballot will have to be held. If a ballot is to be held, the closing date for the ballot will be 31 August 2009. Notice of the ballot will be sent out using two formats, i.e.

1 By e-mail to those Corporate Members whose electronic address appears on the SAICE database, and
2 By normal surface mail to those members who have not informed SAICE of an e-mail address.

In accordance with Clause 3.3 of the Constitution, the Council has elected Office Bearers for the Institution for 2010 as follows:

President
Mr AM Naidu

President Elect
Mr CJ Campbell

Vice President
Mr TW McKune

Vice President
Mr W Jerling

Vice President
Mr SN Makhetha

Vice President
Prof H Gräbe

In terms of Clause 3.2.4 of the Constitution, the following are ipso facto members of the Council for the year 2010:

The immediate Past President
Prof EP Kearsley

The two most recent Past Presidents
Mr JJ de Koker
Mr NA Macleod

DB Botha Pr Eng
Executive Director
21 April 2009
# NOMINATION FORM 2010

## 10 Corporate Members

<table>
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<tr>
<th>SURNAME</th>
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Please fax this form, *plus the CV of the nominee*, to SAICE National Office, for attention Memory Scheepers, by **31 July 2009** – Fax number (011) 805-5971
Denis (DAB) Mills

DENIS (DAB) MILLS passed away in Cape Town on 13 November 2008 aged 77, after a short illness.

The only son of pre-war SA Grand Prix driver and record-breaker WAF 'Billy' Mills, he was a devoted husband and father, career civil engineer, and lifelong motor sport enthusiast. Having matriculated at the age of 16 from Maritzburg College, he paid his way through his BSc civil engineering degree at the University of the Witwatersrand by working on fellow students’ cars. In a 50-year contracting engineering career, half of which was spent as a director of the Cape firm WJM Construction, he was involved in a number of noteworthy projects including the Colenso and Hex River railway tunnels, the Touws River railway marshalling yard, Montague Gardens, Settlers’ Way, and the development of services for Mitchells Plain and Khayelitsha in Cape Town. Denis, usually accompanied by one of his prized Jack Russell terriers, was a notable and feared attendee at site inspections, where his searching but usually fair questions could reduce an under-prepared design engineer to stuttering! His competence and fairness in carrying out contracts gained the admiration of the industry.

He served as the regional chair of the South African Federation of Civil Engineering Contractors for a number of years. More recently he had taken on a volunteer training and examining role for the professional registration of younger engineers.

A member of the Western Province Motor Club since its founding in the early 1960s, he participated in a number of rallies (including the legendary LM), gymkhanas, sprints and races, sometimes in his (unusually) supercharged side-valve Morris Minor producing, as he would joke, “28 unreliable horsepower”, or his Austin-Healey which he retained for nearly fifty years. With Edgar Hoal, who was the best man at his wedding to Nanette Elliott, he laid out the modern incarnation of Cape Town’s Killarney motor-racing circuit. He served as chairman of the WPMC kart section in the 1970s, and was immensely supportive of the motor sport activities of his sons Roddy and Greg. He steered them both to national representation and championships, while his record-keeping diligence and encyclopaedic memory of cars and the early history of SA motor sport was crucial in the recent recreation of his father’s 1936 SAGP ‘Pyroil Special’ and in the numerous publications detailing the record and characters of southern African motor-racing.

In later life he became an enthusiastic supporter of the SA Botanical Society, serving on the committee at Kirstenbosch. His legendary stubbornness was always tinged with humour, his gruffness with generosity. More than that, his remarkable loyalty to employers and employees alike, and his many friends, and the unqualified love of his family will be much missed by his wife of 51 years, Nanette, children Roddy, Shelley and Greg, eight grandchildren, and sister Hazel.

Tony Murray
asmurray@africa.com
The competition is open to the general public to submit photographs. 

1. It is essential that entries portray people and/or projects in civil engineering.
2. Photographs will be judged in ONE general category only.
3. Entries must be colour prints and in A4 size. Only quality prints will be accepted. Please supply electronic copies of the print/s in jpeg format, 300dpi.
4. Please supply details of the client, consultant and contractor involved in the project.
5. The entrant is responsible for obtaining permission for the use of the photographic material as well as subject material from the authority or project manager concerned.
6. Entries submitted by organisations must be accompanied by written consent of the photographer.
7. Permission for the reproduction of photos for any exhibition or publicity is assumed unless the entrant specifies otherwise. Due recognition will be given to the photographer.
8. No responsibility will be accepted for any loss or damage to entries.

Closing date: 22 July 2009

Please complete the entry form and send to: Private Bag X200, Halfway House, 1685. Fax: (011) 805 5971. This form is available on the SAICE website: http://www.civils.org.za/portals/0/pdf/pc/pc-entry-form.pdf
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<th>Date</th>
<th>Event and CPD validation number</th>
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| 8 – 9 June Nelspruit  
27 – 28 July Bloemfontein | Handling Projects in a Consulting Engineer’s Practice  
SAICEproj08/00404/11 | Wolf Weidemann | Dawn Hermanus  
dhermanus@saice.org.za |
| 01 June Midrand  
27 July Port Elizabeth  
21 Sept East London | Structural Steel Design Code to SANS 10162: 1-2005  
SAICEstr06/00050/09 | Greg Parrott | Sharon Mugeri  
cpd.sharon@saice.org.za |
| 2 – 3 June Cape Town  
22 – 23 July Gauteng  
11 – 12 Aug Durban  
30 Sept – 1 Oct Durban | The Basics of Track Engineering  
SAICErail09/00496/12 | Ed Elton | Dawn Hermanus  
dhermanus@saice.org.za |
| 2 – 5 June Durban | Project Management  
SAICEbus07/00252/10 | Tony Lydall | Sharon Mugeri  
cpd.sharon@saice.org.za |
| 02 June Midrand  
28 July Port Elizabeth  
22 Sept East London | Reinforced Concrete Design to SANS 10100-1  
SAICEstr09/00432/11 | Greg Parrott | Sharon Mugeri  
cpd.sharon@saice.org.za |
| 6 – 12 June Gauteng  
4 – 10 July Cape Town  
15 – 21 Aug Durban | The Application of Finite Element Method in Practice  
SAICEstr06/00018/08 | Roland Prukl | Dawn Hermanus  
dhermanus@saice.org.za |
| Johannesburg  
Nelspruit  
Polokwane  
Mmabatho  
Kimberley  
Bloemfontein  
Pietermaritzburg  
Richards Bay  
Durban  
East London  
Port Elizabeth  
Cape Town  
George | GCC 2009  
CPD number to be announced | Willie Claassen | Dawn Hermanus  
dhermanus@saice.org.za |
| 2 – 3 July Gauteng | Technical Report Writing  
SAICEbus09/00427/12 | Les Wiggill | Sharon Mugeri  
cpd.sharon@saice.org.za |
| 22 June Port Elizabeth  
24 June East London  
26 June Durban  
24 August Cape Town | Ridding Stormwater of Litter  
SAICEwat08/00361/11 | Prof Neil Armitage | Sharon Mugeri  
cpd.sharon@saice.org.za |
| 16 July Midrand | Essential I.T. Knowledge for Business Executives  
SAICEit08/00345/11 | Dr James Robertson | Sharon Mugeri  
cpd.sharon@saice.org.za |

For more information on courses, venues and course outlines please visit [http://www.civils.org.za/courses.html](http://www.civils.org.za/courses.html) or contact cpd.sharon@saice.org.za