Townsville Cement Terminal
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SUMMARY  The Townsville Cement Terminal constructed by Queensland Cement Limited commenced operation in late 1993. The terminal features a 35,000 tonne capacity storage silo, the largest of its type in the world, together with ship unloading facilities, pneumatic transport to storage and flyash blending facilities. This paper describes features of the design of this highly automated facility, which with its sophisticated control system, is operated from one central control position.

1 INTRODUCTION

In late 1991, Queensland Cement Limited (QCL) announced its intention to close the company’s aging cement production plant at Stuart near Townsville as part of a rationalisation of its Queensland operations. To replace the plant and supply the company’s North Queensland market of approximately 350,000 tonnes per annum, a decision was made to construct a modern cement grinding mill at QCL’s existing seaboard clinker production plant at Gladstone together with a bulk cement terminal at the Port of Townsville.

Connell Wagner Pty Ltd was appointed as Consulting Engineers for the project responsible for all design, project management and construction supervision.

The scope of work at Gladstone involved construction of:

- a 100 tonne per hour cement mill
- a 20,000 tonne cement storage silo with bulk dispatch facilities by sea and road
- fully automated bagging and palletising facilities.

The Gladstone plant had existing ship export facilities for clinker and flyash which could be readily adapted for cement export. A suitable seaboard site was required at Townsville.

After consideration of several available sites in the vicinity of the port area, none of which were ideally suited for the proposed terminal, an agreement between QCL and the Townsville Port Authority resulted in the Authority

Figure 1 Townsville Cement Terminal Site Layout
nominating Berth 4 for ship unloading and allocating a 2.3 hectare site on the eastern side of Benwell Road, some 200 metres away for use by QCL.

The Townsville Port Authority reclaimed the site to enable construction of the A$22.0 million cement terminal which comprised:

- cement receival and pumping facilities located at Berth 4, capable of accommodating self-discharging vessels up to 30,000 DWT unloading at a rate of 500 tph
- a 35,000 tonne capacity storage silo with bulk rail and road loadout facilities
- flyash receival, storage and blending facilities
- cement bagging, palletising and storage facilities
- road and rail access to the terminal.

This paper describes features of the Townsville Cement Terminal, in particular:

- ship unloading facilities
- pneumatic transport to storage
- design aspects of the 35,000 tonne storage silo
- flyash blending facilities
- road and rail dispatch
- control systems and automation

The terminal is illustrated in Figure 1.

2 SHIP UNLOADING

Although QCL planned to transport cement in their own 6000 DWT self discharging vessel Warden Point, the design brief specified that the unloading facilities also be capable of receiving cement from two other self discharging carriers operated by Australian National Lines (ANL), the River Torrens and River Yarra, each of approximately 30,000 DWT.

All three vessels are multipurpose carriers, i.e. able to carry both powders such as cement, flyash and alumina and coarser materials such as clinker, slag and gypsum. Their reclaim systems are therefore mechanical, involving scraper reclaimers, bucket elevator and a discharge boom.

Whilst the discharge boom on the larger vessels supports a conveyor, and is therefore able to operate through a range of angles, for cement discharge this is limited to around +/-5 degrees and for best performance, +0, -5 degrees. The Warden Point differs insofar that cement is discharged via an airslide and the boom therefore must be declined at an angle of -4 degrees.

Given the extreme tidal range of 3.93 metres and a change in draft on the vessel from full to empty of around 4 metres, a telescopic chute with a travel range of close to 8 metres was necessary to permit unloading through a full tidal range, without restrictions which would result in increased demurrage times. Developing a suitable ship unloading facility proved one of the most challenging problems on the entire project.

The problem was further complicated by the fact that on each ship, the discharge boom had not been designed to sustain the additional weight of a telescopic chute. Furthermore, QCL required the system to be designed to permit unloading to be fully controlled from the ship, without assistance from shore based personnel.

The system developed is described below and illustrated in Figures 2 and 3:

- A tower structure supports a telescopic chute on a travelling frame with the frame raised or lowered using a reeled rope and winch system. The chute travel is limited to 6.9 metres due to space constraints. This was accepted by QCL as unloading is restricted only during extreme tides and generally for no more than 12 hours.
- The chute inlet is provided with a weather cover to prevent water ingress when not in use. This cover is removed automatically, using a linear actuator, immediately prior to commencement of unloading.
- The bottom of the telescopic chute is fixed to a large airslide which transfers the product via a bucket elevator to the surge bin. The purpose of the surge bin is two fold:
  - to cater for product discharge surges from the ship.
  - to permit the cement to be divided into two separate streams.
- The surge bin feeds two pumps mounted at wharf deck level, via flow control gates, and a short airslide incorporating a nips trap. Each pump has a capacity of 250 tph.

Bearing in mind that all of the vessels were multi-product carriers with onboard mechanical discharge equipment, the function of the nips trap was to intercept before the pump intake, any lumps of clinker or hardened cement, as well as broken scraper blades or bolts.
As the discharge boom on each ship varies in length, and swings in an arc of a fixed radius, the location of the discharge point on the wharf was critical. The discharge position was selected to best suit Warden Point which has the shortest boom, but checked to ensure it could be accessed by the ANL vessels. Each ship requires a unique position longitudinally at Berth 4 and this has been identified by markings on the wharf.

The unloading procedure is as follows:

- The ship berths in the required position adjacent to Berth 4 and is manoeuvred longitudinally to its precise location if necessary, using on board winches.
- A specially designed weather shield is connected to the discharge chute at the end of the ships boom which is then swung into position.
- The shore based telescopic chute inlet cover is removed using an electric actuator and the telescopic chute support frame complete with chute, raised to the required height, depending on the state of the tide.
- Ship to shore communication is established and unloading commences.

Other than the communication cable, there is no direct connection between the ship and the wharf mounted receiptal equipment. The telescopic chute tracks the ship boom, rising as the ship discharges and/or the tide rises, and lowering as the tide falls. Ultrasonic sensors on the chute allow the control system to automatically adjust the vertical separation distance between the boom and chute.

The relative horizontal positions between the ships boom and the centreline of the inlet hopper are also monitored by ultra-sonic sensors. The control system transposes the relative positions of the chutes onto the ships control room display monitor to allow horizontal adjustments by the shipboard operator.

3 PNEUMATIC TRANSFER TO STORAGE

3.1 Determination of Transfer System

Prior to commencing final design, a study was undertaken to determine the most economical means of transferring cement from the ship unloading facilities at Berth 4 to the silo approximately 270 metres to the east. The conveying route crossed the main road access to the Port, several railway sidings and property leased by the Townsville Port Authority to Boral and Incitec. The most direct route involved crossing the lease area of Incitec.

Options considered included:

- conveying via belt or pipe conveyor.
- pneumatic transfer using either lean or dense phase systems.

It was not practical to convey directly from Berth 4 to the top of the 60 metre high silo, an average inclination of 13 degrees. Cement should be fed onto a level of slightly declining belt to avoid spillage, and this would have resulted in an even steeper inclined section. In addition, the conveyer gallery support trusses have been up to 50 metres high.

The most practical and economical conveying solution involved a combination of bucket elevators and belt conveyors; an elevator to initially raise the product to a conveyor, approximately 10 metres above ground level, a horizontal conveyor approximately 270 metres to the silo, followed by another 50 metre elevator to the root of the silo, and distribution via airslides. The capital cost however, was considerable and compared unfavourably with pneumatic transfer options.

The study could not identify a clear cost benefit between lean and dense phase conveying options, and accordingly, tenders were called on the basis of both.
systems. The pipeline route was nominated by Connell Wagner and two separate pipelines specified, each with a capacity of 250 tph. The pipeline size was left to the tenderers to nominate as part of a guaranteed performance.

It proved impossible to route the pipeline underground over its full horizontal length as there were some insurmountable obstacles in the way including a 1.8 metre diameter molasses pipeline running at right angles to the proposed cement pipeline route. Consequently, the route selected involved supporting the pipelines on an elevated bridge across the wharf access road and railway sidings, before returning to ground level and travelling underground through the incitex lease area, across Benwell Road and to the base of the silo.

3.2 Pumping System

A lean phase pumping system offered by Fuller - F.L. Smith (Pacific) Pty Ltd was ultimately accepted, based on capital cost and a comparison of energy demand. An attempt was made to also account for maintenance costs although these costs were harder to quantify.

The lean phase system required approximately 2.4 kW hr/km of energy, more than double that for the dense phase system, but this was more than offset by the capital saving of approximately 45%.

The system essentially comprises 2 x 250 tph pumps each feeding a single pipeline, with air to each pipeline provided by two compressors (4 totally). A series of valves permits interchangeability of compressors and pipelines which ensures the system can still operate (at a reduced capacity) even if one pump and two compressors are out of service.

The four compressors are housed in a sound attenuated compressor building located on the wharf adjacent to the cement pumps. A switchroom for power supply was constructed above the compressor house together with a transformer enclosure. As the compressors require water cooling, an air cooled closed circuit cooling water system was also installed, with the cooling tower located on the roof of the switchroom.

The control philosophy for the cement delivery system involved a complex combination of feed forward and PID algorithms, so as to optimise the pump delivery rates. Analogue signals from the motor currents, bin level, delivery line pressures and gate positions were used for feedback data into the control loops.

3.3 Cement Delivery Pipelines

Each pipeline is 400 mm diameter for the initial 180 metres, stepping up to 450 mm diameter for the remainder of the total conveying distance of 330 metres (including 62 metres vertically up the silo wall). Heavy wall pipe was specified with a wall thickness of 12.7mm. The route includes 6/90 degree bends. Long radius bends were specified and formed using the induction Bending process. Bends were all concrete encased for additional wear resistance.

The pipelines are generally fully welded with all welds tested. Above ground bends are flanged jointed for ready replacement, however below ground, all joints are fully welded.

For maximum corrosion protection, the underground sections of pipeline were protected with a 2.2mm thick "Sintakote" polyethylene coating in accordance with AS2518. All site welded joints were coated using a heat shrinkable polyethylene cover. Above ground, the pipelines received a more conventional protective treatment system comprising 75 microns of inorganic zinc, 125 microns of high solids MIO epoxy and 75 microns of recoatable acrylic.

The pipelines were anchored at the base of the 35,000 tonne silo and adjacent to the pumps, and left free to expand elsewhere, utilising flexibility at bends.

4 SILO DESIGN

4.1 Type of Silo

A silo with a capacity of 30,000 - 35,000 tonnes was required to suit available ships and to act as sufficient buffer to cover unforeseen shipping delays or maintenance shutdowns in Gladstone. It was clear that an “inverted cone” type silo would be the most economical solution. Seven such silos existed in Australia at that time including two operated by QCL.

The concept of the inverted cone silo was first developed by Ibau Hamburg in 1977 and the system now dominates the cement industry with more than 1400 inverted cone silos existing worldwide. The Ibau system involves the construction of a 60° cone structure within the silo which forms the bottom of the storage zone and transfers the product load to the circumference of the silo. In large diameter silos, the inverted cone is structurally very efficient and a combination of the cone geometry and silo aeration, enables the stored cement to be almost totally recovered.

4.2 Silo Dimensions

A study to determine the optimum height/diameter ratio revealed a trend suggesting the larger the H/D ratio, the more economical the silo. Ultimately, the 30 metre diameter adopted at Townsville was the smallest possible in order to physically fit the 260 pipes required to support the silo in concentric rings under the silo wall, whilst also providing space for the three under silo weighbridges required together with a plant room and switch room.

After allowing for the lill profile of the pumped cement and suitable freeboard, the overall height of the silo was set at 60 metres resulting in a live capacity of 25,800 cubic metres and an H/D ratio of 2. (Refer Figure 4). The silo is currently the largest single cell inverted cone cement silo in the world.
tonnes, driven in four concentric rings under the silo walls, plus 4 internal piles to support secondary ground beams. Piles in the inner ring were vertical. Piles in the remaining rings were raked at 1:30, 1:15 and 1:10 in the outer ring to improve separation of the pile bases and resist lateral loads. The piles were staggered in adjacent rings to maximise clear spacing and minimise interaction effects.

4.4 Pilecap and Ground Beams

The silo wall is supported on a ring pilecap with an outside diameter of 33.6 metres, an inside diameter of 25.0 metres, and a thickness of 1.5 metres. In addition, a grid of ground beams inside the pilecap support ground level pits and slabs and undercone steelwork. The pilecap comprised over 600 cubic metres of concrete and 80 tonnes of reinforcing steel and was the largest single pour on the project.

4.5 Silo Wall

4.5.1 Silo Pressures

Silo pressures were calculated according to AS 3774-1990 Loads on Bulk Solids Containers. This code accounts for all relevant effects, including increased wall and hopper pressures during discharge and non-uniform pressures due to eccentric discharge. For design purposes, a range of physical properties for cement was used, as shown in Table 1.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Density</td>
<td>13.0 - 16.0 kN/m³</td>
</tr>
<tr>
<td>Mean Angle of Repose</td>
<td>28°</td>
</tr>
<tr>
<td>Effective Angle of Internal Friction</td>
<td>40° - 50°</td>
</tr>
<tr>
<td>Angle of Wall Friction</td>
<td>28° - 33°</td>
</tr>
</tbody>
</table>

![Figure 4 Silo Section and Plan](image)

4.3 Piling

Geotechnical conditions comprised 6 metres of sand fill overlying bands of organic silts and clays overlying very dense sands.

The pile layout adopted comprised a total of 260 precast concrete piles each with a working capacity of 180
The calculated design wall and cone pressures are shown in Figure 5. The maximum wall pressure at the base of the silo wall was 139 kPa while filling and 185 kPa while emptying (before allowing for eccentric discharge effects).

The principle of the inverted cone silo discharge is to ensure 'first in - first out' flow of cement through the silo. By controlling aeration and continually alternating the outlets in use, the level of cement within the silo can be drawn down reasonably uniformly.

However, at any instant, the discharge may be eccentric, as the outlets are located next to the silo wall. The effects of eccentric discharge were considered and found to increase local pressures by up to 32% (diametrically opposite the active outlet), and resulted in local pressure reductions of 48% (adjacent to the outlet). These non-uniform pressures produced significant bending moments in the wall and cone, in addition to the hoop stresses generated by a uniform pressure load.

4.5.2 Thermal and Wind Loads

Thermal loading (due to the elevated temperature of incoming cement) and wind loading on the empty silo wall were also significant. A differential temperature of 75°C was adopted through the wall when not subjected to internal pressure. A lower figure of 50°C was used in combination with wall pressure loading, as thermal losses cool the cement adjacent to the wall creating an insulating layer.

Cyclonic wind loads were calculated in accordance with AS1170.2-1999 SAA Loading Code - Part 2: Wind Loads. The ultimate wind speed applicable was 70 m/s (at 10 metres above ground level). A non-uniform wind pressure distribution around the silo was considered. Maximum wind pressure on the windward face at the top of the silo was 43 kPa, with a maximum suction on the leeward face of 2.4 kPa.

4.5.3 Wall Design

For silos of greater than approximately 20 metres diameter, it becomes impractical to resist hoop tensions using passive reinforcement alone and post-tensioned walls become more economic. The Townsville silo design therefore adopted a post-tensioned wall design.

A detailed finite element model of the silo wall was used to calculate the resulting distribution of bending moments and axial loads in the silo wall for all load cases. This modelling demonstrated that the interaction between the low-rise wall, high-rise wall and the cone resulted in a different stress distribution from that which would be obtained from a simplistic hoop tension model, enabling a significant reduction in the total prestress required, particularly at the bottom of the silo wall.

The silo wall and other concrete elements were designed according to AS 3600-1988 Concrete Structures. This code permits tension loads to be shared between passive and tensioned reinforcement i.e. "partially prestressed" concrete design. The design philosophy adopted was to carry the ultimate hoop tensions (at 1.5 times the maximum wall pressure, while emptying) by the combination of both passive and post-tensioned reinforcement. Under serviceability conditions (i.e., 1.0 times the maximum emptying wall pressures) the aim was to provide sufficient prestress to control crack width and depth. Temperature differentials were considered in both cases.

Four stressing butresses were provided, equally spaced around the circumference of the silo. Tendons comprised 19, 12 and 7 strands with the largest tendons having a jacking force of 300 tonnes. Calculations for losses in the tendons showed that approximately 40% of the initial jacking force would be lost for a typical tendon.

The high rise wall was 350 mm thick, with 19 strand tendons at an average spacing of 500 mm at the bottom of the storage zone, reducing to 7 strand tendons at an average spacing of 750 mm at the top of the wall. Two layers of passive reinforcement were also provided for crack control and bending moment resistance. Below the inverted cone, the low rise wall was 800 mm thick, providing a 450 mm ledge to support the cone.

4.6 Inverted Cone

Prior experience with the design of inverted cone type silos had shown that the most economical method of constructing the cone was with precast concrete panels, forming a faceted cone. Previous precast cone designs had used a single tier of triangular panels temporarily supported until the joints between the panels could be concreted, to produce a monolithic concrete shell structure. However, for the 30 metre diameter silo, this was not practical, as the individual panels would have been too long and too heavy to be readily positioned using available cranes. The final design was therefore based on two tiers of panels, with the lower tier consisting of 30 flat panels each 600 mm thick and 14 metres long, and the upper tier consisting of 15 "folded" triangular panels each 400 mm thick and 13 metres long, producing a cone with 30 flat faces. The maximum mass of a single panel was 32 tonnes.

The entire cone structure was analysed using a three dimensional finite element model, including the effects of non-uniform pressure distributions and thermal effects. In addition, individual panels were analysed and designed for loading conditions arising during lifting and erection prior to continuous shell action being achieved.

The joints between panels were required to resist substantial bending moments and tensions, primarily due to non-uniform pressures. The panels were designed with exposed ligatures, into which additional closed ligatures could be inserted after the erection of the panels, thereby creating continuous reinforcement around the circumference of the cone. The joint between the panels was then to be concreted in situ.

A cast in situ concrete ring beam was incorporated at the top of the lower tier of panels to ensure the lower truncated cone had sufficient stiffness and strength to support the upper tier of panels during erection.

The base of the cone required substantial ring tension capacity to resist the tendency to spread outwards under the load. A 2 metre deep triangular shaped ring beam was cast between the base of the cone and the silo wall to resist this load, and heavy post-tensioning was incorporated in the silo wall adjacent to this beam. Mass
concrete fill above this beam produced the slopes required for the ring aislades.

4.7 Silo Roof

The silo roof was designed as a 150mm thick concrete slab supported on a grid of steel beams. The roof structure was designed to act as a composite structure for live loads, although all dead loads were carried by the roof beams alone. “Bondek” steel deck permanent formwork was used to span between beams without intermediate support, and to provide the main slab reinforcement. A heavy mat of top reinforcement was also provided to give a very high degree of crack control. All reinforcement and steel fittings in the roof slab were hot-dip galvanised as a precaution against corrosion.

5 SILO DISCHARGE

5.1 General

The cement stored in the 35,000 tonne silo is aerated and discharged by means of a series of ring aislades running circumferentially around the base of the cone inside the silo and 10 discharge aislades which transfer the product radially to a central bin under the cone. Silo aeration and discharge is carefully controlled and applied in predetermined cycles around the silo to ensure the level of cement within the silo remains reasonably uniform to avoid gross asymmetric loadings on the silo wall. From the centre bin, product may be directed to either one of two truck loading weighbridges, rail wagon loading on a third weighbridge, the bagging plant or flyash blending facilities. All cement paths can be operated simultaneously and independently, at a combined discharge rate of around 900 tph.

Three floors below the silo cone contain more than 50 tonnes of structural steelwork supporting the central collection bin, three dust collectors, the numerous aislades and other items of mechanical handling equipment.

Rail bulk loading is assisted by an innovative wagon indexer which automatically places each wagon on the weighbridge, permitting rail loading to be completed by a single operator. The rail loading chute is capable of travelling up to 14 metres to cater for the wide variety of wagons used to transport cement.

The road bulk dispatch is fully automatic and operated by the bulk tanker driver. A “Mill” key system controlling the plant entry gates and silo discharge facilities, permits customers to collect bulk cement 24 hours per day.

The pressurised and air-conditioned switchroom, at ground level under the silo, houses the 415V motor control centre (MCC) and programmable logic control (PLC) system. The MCC is a fully withdrawable Form 3 construction with full arc fault containment.

All compressors and blowers are also housed at ground level in a sound insulated plant room.

A fully automatic bagging and palletising plant was constructed adjacent to the silo, capable of producing 2400/40 kilogram bags per hour. Automatic shrink wrapping facilities were also provided together with warehouse storage for over 1200 tonnes of palletised bags.

5.2 Control System

Connell Wagner was responsible for preparation of the control system software and all site commissioning of the plant.

The silo controls are part of the overall plant control system which is made up of Allen Bradley 5/40 processors distributed throughout the plant and connected together as a data highway network. Each PLC processor controls local inputs and outputs (both digital and analogue) to achieve the desired control philosophy in each area. Conventional ladder logic programming methodology was adopted in conjunction with standard function block facilities available in the Allen Bradley system. The silo discharge facilities are essentially sequential in nature and as such, are capably handled by ladder logic software.

The dispatch facility has one rail and two road weighbridges. At each of these weighbridges there is a driver control station (DCS) for operator input of load details and subsequent dispatch docket collection. The DCS's have their own local PLC processors to handle the complex serial data associated with weighbridge weight data and the relevant load transaction information. Each DCS is connected through to the clients central VAX system which provides a single source for invoicing, cost control, quality control and credit management. The complex logic requirements of the DCS system are managed with a "state engine" software technique in order to reliably process the command functions.

A supervisory control and data acquisition (SCADA) system was utilised to provide the plant operator with all controls and functions necessary to operate the plant from one central location. The CITEC system was used for this purpose. From the central position, the operator can control all plant functions as well as log any fault and status messages. A second CITEC station is located onboard the ship for controlling the unloading operations.

Over 2000 inputs and outputs are controlled by the PLC in a system which was designed to provide reliable status and fault finding information. As a result of this, minimal resources are required for plant operations and maintenance.

6 FLYASH BLENDING

Flyash blends represent a significant and increasing market in North Queensland due to their low heat of hydration properties. Flyash is railled to the terminal from Gladstone and discharged into a 750 tonne storage bin (Bin 1), adjacent to the 35,000 tonne cement silo.

Two alternative methods are available for blending flyash, batch blending and continuous blending.

The primary advantage of batch blending is that a product of any flyash/cement proportion can be produced (essentially mixed to order whilst the customer waits) and...
no storage is required, the mixed product being loaded directly into the bulk tanker. The disadvantage of batch mixing is that the mixing rate is limited to around 150 tph and the cost of a mixer of such capacity is high.

OCL required possible simultaneous loading of blended product to both road and rail, and not necessarily of the same flyash/cement proportions. It was therefore essential that the product be preblended and stored. Such a system generally favours continuous blending.

The problem with continuous blending and storage is that storage can only be provided for a limited number of mixes. Furthermore, a customer may pre-order 200 tonnes of a special mix but eventually take only 150 tonnes. The problem arises as to what to do with the small quantity left over which is occupying vital storage required for another blend.

After extensive discussions with OCL marketing staff which focused on the market demand for the main blended products, Connell Wagner developed a solution involving continuous blending and storage, whilst still permitting total flexibility to meet any market demand.

The storage consists of:

- 1 x 750 tonne flyash bin (Bin 1)
- 1 x 750 tonne blend bin (Bin 2) for storage of the most common flyash blend, currently 25/75 flyash/cement
- 2 x 250 tonne bins (Bins 3 and 4) for storage of other flyash blends, preordered by customers.

The blending system is shown in Figure 6 and comprises:

- 1 x 5 tonne capacity cement weigh bin (Bin 5) mounted on load cells and supplied directly from the 36,000 tonne silo.
- 1 x 5 tonne capacity flyash weigh bin (Bin 6) mounted on load cells and supplied from the 750 tonne flyash silo (Bin 1).

Simultaneously and in the required proportions, cement and flyash are each fed from Bins 5 and 6 respectively, through flow control gates, an airslide and impact flowmeter, before coming together in the hopper of a 70 tph pumping system. Mixing is achieved in the pump screw and during pneumatic transportation to the storage.

The mixing rate was set at 70 tph and the system can in theory, produce products in the range of 10/90 to 90/10 (flyash/cement) to the required accuracy. In practice, the product range is generally 25/75 to 60/40. The dead storage in Bins 3, 4, 5 and 6 was specified as effectively zero to avoid contamination problems resulting from product changes.

Flyash stored in Bin 1 can be simultaneously discharged to road, bagging and Blend Bin 6 at a combined rate of 550 tph. There is no provision to discharge to rail as flyash is received by rail. The main blend stored in Bin 2 can be simultaneously discharged to road, rail and the bagging plant at a combined rate of 650 tph. Bins 3 and 4 can be discharged to road, rail and bagging, but in addition, product from these bins can be directed to Bin 6 for reblanding and addition of cement from Bin 5, converted to the main blended product stored in Bin 2. In this manner, Bins 3 and 4 can be fully emptied and made available for storage of another customer's special order. In reality, the need for reblanding is relatively infrequent, but the design is flexible to meet future market trends.

Prior to commencing a session of continuous blending, the impact flowmeters are calibrated by filling the weigh bins (Bins 5 and 6), running out a set quantity using the load cells to record this, and comparing the load cell records with that registered by the impact flowmeters, then adjusting as necessary. Once blending commences, the system is fully automatic and continually monitors blending rate and proportions of cement and flyash.

If product starvation occurs from one weigh bin, the system automatically reduces flow from the other bin to maintain the required proportions, and the overall blending rate reduces. A warning signal registers on the control system and the operator can investigate the problem. Similarly, should the product ratio vary by more than a preset limit, an alarm is activated and if not responded to, the system will shut down.

As an additional safeguard, product quality can be checked by sampling blended product in storage, prior to dispatch.

7 CONCLUSIONS

Construction of the Townsville Cement Terminal commenced on 23 July 1992 with commencement of piping for the 35,000 tonne silo. The terminal was commissioned in late November, 1993 with the receipt of the first shipment of cement from Gladstone. Some initial problems were experienced, primarily relating to ship
unloading, the cement pumping system and the bagging plant, but these have now been overcome and the terminal is operating satisfactorily.

This modern and highly automated facility which is controlled by just seven operators, permits Queensland Cement Limited to better service its customers whilst improving the company's overall cost efficiency. Connell Wagner is proud to have been responsible for its design.

8 ACKNOWLEDGMENTS

The authors express their appreciation to the management and staff of Queensland Cement Limited for their support and assistance throughout the project and for permission to present this paper. The efforts of all of the contractors involved in the project construction are also acknowledged.

H A MCKAY

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Jim Amos is an Associate in the Industrial Section of the Brisbane Office of Connell Wagner. He commenced his engineering career as an Electrical Fitter/Mechanic, and went on to complete his Bachelor of Engineering (Electrical) at Queensland Institute of Technology in 1987. Jim joined Connell Wagner in 1990, and has been responsible for the design and commissioning of power distribution, control and instrumentation systems associated with materials handling, process systems and water pumping schemes. Other areas of involvement have included design, documentation and programming of numerous programmable logic control and SCADA systems.

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Julian Hardy is a Senior Associate in the Brisbane Office of Connell Wagner. He completed his Bachelor of Engineering at Queensland University in 1979, and in 1995 he completed a Graduate Diploma in Management (Technology Management) through Deakin University. Julian joined Connell Wagner in 1980, and has been responsible for the design of structures and foundations on many industrial and materials handling projects. He has gained particular experience in the design of silos, ship loaders and chimneys. In his fifteen years' experience, Julian has also developed a thorough understanding of application of the finite element method, and is frequently engaged on projects to undertake the detailed stress analysis and dynamic analysis required on projects of a diverse nature.