# RIO TINTO ALCAN GOVE G3 EXPERIENCE ON PRE-ASSEMBLED MODULES

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**Abstract**

Rio Tinto Alcan's Gove Alumina Refinery, located near the Township of Nhulunbuy on the north east tip of the Northern Territory, commenced the refinement of bauxite to alumina in 1972. To meet the growing demand, it was proposed to expand the refinery's alumina production capacity from 2.1 to 3.75 Mt per annum. Due to its isolation and the project size, it was obvious establishing a camp to service traditional stick built construction was prohibitive. Other strategies had to be investigated.

The Gove Refinery is strategically located on the Australian northern tip coastline in close proximity to South-East Asia. After a careful cost benefit analysis, the use of Pre-Assembled Modules was chosen as the most cost effective construction technique. This involved fabricating complete structural modules including associated equipment, piping systems and pre-commissioning at an Asian site and shipping and installing in position as a complete facility. This had the definite advantage of reducing construction time, minimising the impact of labour shortage & working on site, and thus alleviating risk of injury from site congestion.

This paper covers critical issues in accessing this construction technique and the experience gained by the structural design team. Emphasis will be placed on logistical issues as well as structural design considerations for not only in service conditions but also accelerations from the sea voyage and road transportation.

## 1. Introduction

Rio Tinto Alcan Engineering Pty Limited (Alceng) was established in 1997 as the engineering arm of Rio Tinto Alcan Incorporated providing full engineering design and construction management to Rio Tinto Alcan Gove Alumina Refinery located near the Township of Nhulunbuy in the Northern Territory (see Figure 1). In October 2007, Rio Tinto acquired Alcan Incorporated forming a new group within their structure called Rio Tinto Alcan Technology Pty Limited.

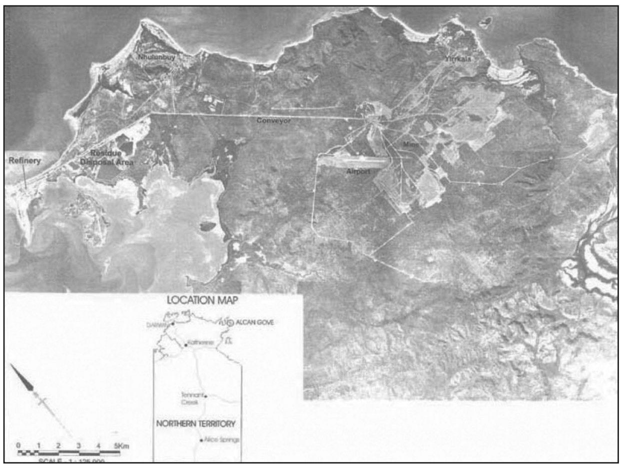


Figure 1. Site location plan

The recently completed project now being commissioned was the third stage (G3) expansion at Gove development. Due to the remoteness of the site resulting in shortage of labour and a tight schedule, off site construction was investigated for G3 and a Pre-Assembled Module (PAM) was adopted. From its strategic location of being close to Asia, two fabrication yards, one in Thailand and one in Vietnam were established. This took full advantage of this region's lower labour cost and higher productivity from a large available work force.

This strategy was further developed with a number of PAMs to include the concrete raft foundations forming Super Pre-Assembled Modules (SuperPAMs). These SuperPAMs, the largest weighing approximately 4000 tonnes, were at the time the heaviest structures transported by road in the southern hemisphere.

From a structural engineer and builder's perspective the introduction of PAM increased the complexity of the project. There were many issues to be considered and addressed. A number of these planning and project execution issues are discussed in this paper.

## 2. Definitions

This paper will focus on structures containing piping, plant and equipment. The same philosophy can be applied to tanks, washers, and other large pieces of equipment.

For the purpose of this paper, the various definitions used during this project are listed below.

(a) PAM (Pre-Assembled Module). This module comprised of structural steel framing, piping, cable trays and plant equipment. The module was designed and constructed with the purpose of transportation to site by road (using SPMT) and by sea.

(b) SuperPAM (Super Pre-Assembled Module). This was a further development of the PAM concept. This structure combined a PAM with a precast concrete slab.

(c) SPMT (Self Propelled Modular Transporter). This is a purpose built hydraulic propelled trailer capable of being driven under, raising, transporting and lowering PAMs and SPAMs onto the deck of a sea vessel, staging area or final location.

## 3. Planning and Logistics

### 3.1 PAM Master Log

A part of the planning process when considering the use of PAMs was establishing a PAM Master Log (PML). This document broke the project's structures into individual transportable units. Each unit was assigned a unique identification number within the PML. The log also listed important information such as physical dimensions, weight, proposed method of sea and road transport, and method of installation.

The purpose of the PML was to aid planning. The information contained within the log was used to further develop the project and provide input into execution plans. Preliminary delivery strategy, lift studies, ship or barge selection, road works and wharf facility requirements and upgrades were all developed from the PML.

There were a number of issues to consider during the process of sub-dividing a structure into transportable units, thus creating PAMs. Issues such as transport weight, physical clearances during transport, natural breaks in piping and/or equipment, available sea vessels and fabrication limitations were recycled into the PML. The PML was a live document and was constantly being reviewed.

During the G3 project, the length of a number of PAMs was increased to improve site productivity. This resulted in additional road works to allow the PAM to be manoeuvred on site. This change was captured in the PML thus ensuring the PML remain a valuable tool during the life of the project.

### 3.2 SuperPAM Planning

The introduction of the SuperPAM created significant challenges for the project team. Their development came from the need to maintain the construction schedule without increasing the site workforce. The concept had been discussed early in the project but never taken further than a study. The decision was now made to take the concept to detail design. Figure 2 shows a SuperPAM being transported to a ship using SPMT trailers.

While the PAMs were arriving on site and on schedule, time was being lost constructing the ground slab and tying in all the piping and mechanical equipment located on grade. The amount of pre-commissioning that could be completed in the PAM yard was also limited since not all the piping and equipment was present. The SuperPAM circumvented this problem by including the precast concrete slab complete with falls, bunds, and plinths. A significant amount of pre-commissioning could now be completed prior to delivery to Gove.

Once again, the PML was revised to capture the change in direction. Important issues such as lifting weights and clearance were identified. While lifting of the PAMs were well within the SPMT capacity, the axle loads while lifting SuperPAMs were close to the SPMT's capacity and in some cases it was exceed. This was solved by introducing additional axles or reducing the SuperPAM weight by removing equipment.

**Figure 2. A SuperPAM being transported to a waiting ship for delivery to Gove. The SPMT trailers were used to load the structure. Note the sea fasteners mounted on the concrete side ready for welding to the ship deck.**

### 3.3 Infrastructure

The appeal of the preassembled option for the G3 project came from the proximity of low cost Asian fabrication yards and sea access to the Gove refinery.

An audit of existing infrastructure and its suitability for a PAM project was critical. If a module was too large or heavy for the wharf, then the only two options were to review the PAM or upgrade the wharf. The wharf at Gove was not capable of servicing the G3 project so a new wharf was constructed. Figure 3 shows the wharf at Gove under construction. This wharf was designed to sustain SPMT trailers loaded to their maximum axle load. It was also designed to accommodate roll on roll off (RORO) type sea vessels. This meant the PAMs, and subsequent SuperPAMs could be loaded and unloaded directly from the ship using SPMT trailers.

Other issues to be considered included dredging of the sea bed to allow access to the wharf and capacity of the existing road infrastructure. The SPMT require specific minimum grades and clearances during maneuvering on site. This was especially critical for long delivery loads. In addition road bridges and culverts needed to be strengthened and issues such as clearances under power transmission lines needed to be addressed.

**Figure 3. The new wharf being constructed at Gove. This wharf was purpose designed to accommodate RORO type vessels and sustain SPMT trailers loaded to capacity.**

### 3.4 Delivery

Critical for the success of the project was to engage specialist transport contractors to assist in preparing a delivery execution plan. For the G3 project, a heavy lift contractor and naval architect were brought onto the team in the early planning phase. The reports generated greatly assisted in providing input into the design of the PAMs and SuperPAMs.

Securing sea transport for the project was identified as critical to its success. Items like design sea forces and overall PAM size were dependent on the type of vessel used. The hire of these vessels were long lead items and needed careful consideration and planning.

Heavy lift contractors were also required to be secured early. The geometry, clearance and capacity of the SPMT trailers were important to establish as they impacted on the design process. Sufficient axles were required to support activity at the various fabrication yards as well as at Gove. The availability of these special transporters had to be confirmed to ensure the success of the G3 project.

## 4. Design Criteria

The Design Criteria document used by structural engineers was prepared to ensure some uniformity in design output and conformity to the current design standards. It addressed the usual items such as live loads, environmental loads (wind, seismic, thermal), deflection limits, and minimum plate thickness. However, the PAM would be subjected to significant inertial loading from the rocking motion during road and sea transportation. The design criteria needed to include these loads as they can prove to be the dominant load case for design of elements such as lateral bracing.

### 4.1 Loads during Sea Transportation

Sea forces could be equivalent to over 1.3 times the structure's self weight but are applied in any horizontal direction. The

applied force also increased with height from the ship deck and the position of the centre of gravity of the relevant equipment was critical.

Sea forces were affected by the type of sea travel, season-dependent weather conditions as well as the travelling routes. Dumb barges tended to subject their cargo to higher accelerations than self propelled ships. A number of different sea transportation vessels were used which impacted the design loads. Assumptions were made in the initial design and final structural integrity checks were carried out once the ship and the locations of the structures on the ship deck were confirmed (Ho *et al.*, 2008).

### 4.2 Loads during Road Transport

Road transport of the PAMs from the sea vessel to construction site was carried out by SPMT trailers. These are hydraulically driven trailers that can be raised or lowered with the use of hydraulic pistons. The height for the trailers on this project varied from 1200mm to 1800mm. The wheels were also very manoeuvrable allowing the trailer to crab or turn on a spot. When loaded the trailers moved at walking pace.

The treatment of road transport forces was similar to sea forces, the main difference was the former tended to be lower. The main issue with road transport was how the PAM was supported on the SPMT. The use of transport beams permitted the trailers to be driven under the PAM, and then using the lifting capacity, to pick up the PAM and transport it to site.

**Figure 4. SuperPAM structures under trailers. The PAM was lifted by the SPMT using lifting beams. A temporary ramp was used to allow the SPMT to drive the PAM onto the precast concrete base forming a SuperPAM.**

## 5. Documentation – Deliverables

Various methods of project delivery were utilised on the G3 Project. This stemmed from the need to fabricate steelwork in different locations under different conditions. Two methods used in the majority of the project are described herein.

### 5.1 Three Dimensional Modelling

The structural designer (modeller) in conjunction with the structural engineer developed a three dimensional (3D) model of the structural steelwork. This was done using commercially available software packages. The model was electronically delivered to the shop detailers who then incorporated it into their detailing software and shop drawings were generated. Figure 5 shows a rendered model of the calciner along with the structure, under fabrication, broken into two parts for delivery.

The models were issued in three (3) phases to assist the shop detailer and fabricator meet tight schedules.

The first issue was after the major structural elements (primary steel) were designed. These included columns and beams on grids.

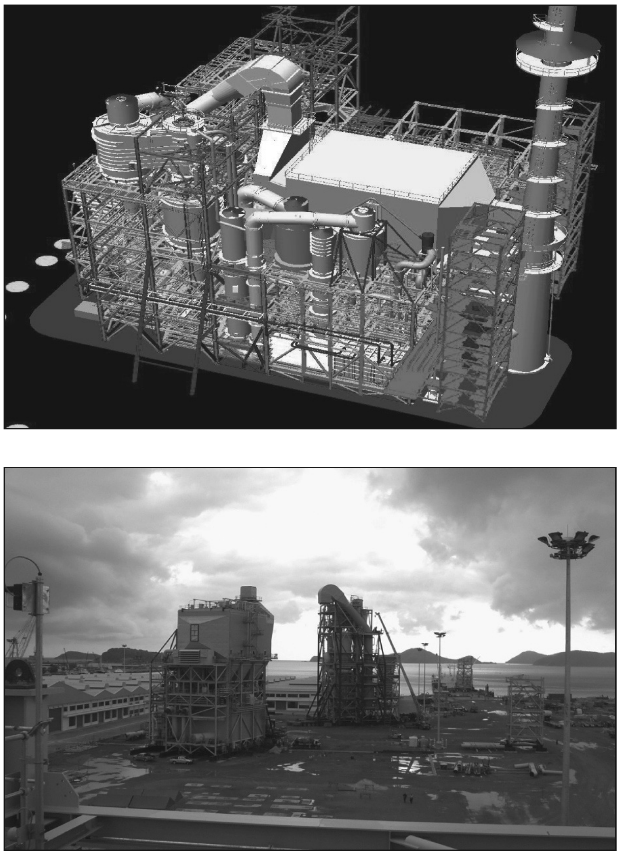

**Figure 5. Rendered three dimensional model of the calciner. This model was used by the shop detailer to produce fabrication drawings. The completed calciner was constructed in two parts for delivery.**

The second issue was after the secondary steel was modelled. This secondary steel included items such as floor joints, floor bracing, and grating.

The final issue was for minor steelwork including pipe and cable tray supports and other miscellaneous items.

Any amendments to the model were identified using an agreed colour system.

### 5.2 Two Dimensional Engineering Sketches

Using the 3D models, the designers prepared two dimensional (2D) cuts on grids and at each floor level. These cuts were then placed onto drawing sheets and then assigned sketch numbers.

The issue of 2D engineering sketches was the method of communicating connection details to the shop detailer. Standard details were prepared and referenced by the design engineer on the sketches. Any special detail was sketched by the design engineer and issued with the 2D sketches. Note that preference was given to using the standard details where possible.

## 6. Fabrication

One of the important factors that affect the success of this type of project is the selection of off-shore fabrication yards with reasonable facilities, skilled labour and resources. To this end, a number of processes were needed requiring structural engineering input.

### 6.1 Selecting a Yard

This was a high level activity and required senior management involvement in selecting steel fabrication and concrete pouring yards. A technical evaluation of each proposed facility and a capability report giving weighted scores for critical attributes was compiled. This report considered items such as the yard's proximity to a wharf and wharf capacity, available skills and

workforce size, access to mobile equipment and cranes, and local contractor's experience with similar projects.

Other criteria that were considered included political risk, security issues, foreign exchange fluctuations, and likely weather conditions. As the PAMs were to be transported by sea, issues such as likely sea conditions (wind speed, tides, and wave heights) and safe ports while on route were included as important criteria.

### 6.2 Detailing for Local Skills

Expectations and reality do not always coincide. Some details had to be amended to match local work practices and experience. For example, complete penetration butt welds were changed to fillet welds in non critical locations.

## 7. Foundation Preparation

The geological profile of Gove site varies from shallow to well over 35 meters deep of granite bedrock. Some areas are covered with Aeolian below which is decomposed granite to granite bolder with clay infill. To suit the site conditions, a suite of foundation designs were detailed ranging from piled foundations for large tank base to concrete rafts and piers for pipe racks and equipment framed structures.

To support the PAMs and SuperPAMs, foundations were required to be completed well ahead of the deliveries. Where this was not possible, precast concrete pad footings were fabricated off site, delivered and installed at Gove to ensure site was prepared for the PAM delivery.

## 8. PAM and SuperPAM Installation

Three methods of installation for the preassembled modules were used on this project. These are discussed below.

### 8.1 Lowering onto Pedestals using SPMT Trailers

This was the preferred option. The PAMs were transported and located over their foundations. Using the SPMT trailers, the modules were then lowered onto steel plates and then welded into position. Figure 6 shows the PAM being driven over the plinth.

Even though this appeared to be a very simple process, it did have problems associated with it. The process was reliant on maintaining a clear access for the SPMT between column plinths. Careful planning was needed to ensure no obstructions such as pump or tank plinths were in the trailer's path at time of delivery. These items were cast with some difficulty after the module was installed.

Other issues also needed consideration. If the ground slab was cast prior to PAM delivery, the concrete slab was covered with soil to protect it and level out surface for trailer. This soil had to then be excavated after installation which was time consuming.

When SuperPAMs were introduced to the project, the only method available for installation was SPMT trailers. Figure 7 shows two SuperPAMs during construction. The SuperPAM on the right is being driven toward the module on the left using the SPMT trailers. The precast concrete base supporting the steelwork can be clearly seen.

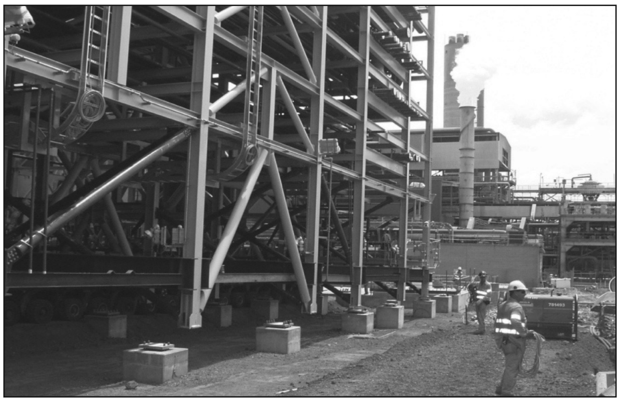

Figure 6. PAM being driven over steel plates bolted to the concrete pedestals prior to delivery. Once in place the PAM was lowered onto the plates and welded into position.

Figure 7. Two SuperPAMs being installed at Gove using SPMT trailers. Note the near perfect alignment of pipelines as the two SuperPAMs were brought together.

### 8.2 Lowering onto Plinth with External Hydraulic Jacks

This option was used for tanks to be placed onto concrete plinths such as flat bottom precipitation tanks. A variation to using only the SPMT trailer, it has the advantages using SPMT except it requires a few more steps.

Temporary steel brackets were welded to the tank walls. Figure 8 shows the brackets welded to a precipitation tank. The tanks were driven over the plinths where they were lowered onto hydraulic jacks placed under the brackets. This allowed the SPMT to be driven out from under the tank. The tank was then lowered onto the plinth using a process of jacking down and temporary packing under the brackets. When the tank was finally placed down, the brackets were removed.

Figure 8. Precipitation tanks being delivered on the SPMT. Note the brackets welded to the tank walls.

### 8.3 Place Into Position Using Crane

This method of placement is the more traditional approach. It was used for installing piperacks and smaller units. The limitation of lifting with cranes is the PAM weight and available crane reach. Generally, a module's weight exceeded 300 tonnes making the use of cranes prohibitive.

## 9. Conclusions

The success of a project like G3 involved many aspects of engineering and management planning. For any project to be successful, quality planning is essential. This was especially the case with a project using the pre-assembled modular strategy. The ability to crystallise the potential schedule reduction and subsequent cost savings was reliant on this good planning.

The development of the PAM Master Log was a central tool in the planning phase. A number of execution plans such as sea transport, road transport, and installation methods were developed from this log. It is also critical the log was reviewed to incorporate any strategic changes that would arise during the project's development.

There was a need to have a clear understanding of the design requirements and impact of management decisions on the project. If fabrication yards were selected in geographic locations resulting in higher sea transport forces, the steel quantity would increase. This increase in material cost needed to be appreciated when selecting the lower overall cost option.

A balance between the desire to maximise the module's size and the reality of transport constraints must be considered. Allowance had to be made for upgrade or establishment of new infrastructure. For the G3 project, new wharf facilities and extensive road upgrades were required.


**References**

Ho, P, Zhang, J, Holmyard, D 2008, 'Sea transportation analysis of pre-assembled modules', *Australian Structural Engineering Conference 26-27 June 2008, Melbourne*