Third A-NZ Young Geotechnical Professionals Conference, Cameron, Collingwood & Slatter (eds), Feb. 1998, Melbourne, Australia.

Development of a Pavement Management Strategy for Tomago Aluminium Smelter

Jason Lee, BE(Hon) ,Grad IE Aust, P Eng

Summary: This paper outlines the development of a site specific Pavement Management Strategy for Tomago Aluminium Company Pty. Ltd. (TAC). Existing pavement management strategies were found to be too general and more suited to public road systems, with TAC requiring an individually tailored, site specific study to be carried out. As a result the Pavement Evaluation Study incorporated new technologies adapted to the geotechnical field, such as Ground Penetrating Radar together with more common, standard geotechnical practices. Factual data obtained during the study was reported in a simplified format summarising existing road condition to aid TAC staff in prioritising areas requiring remedial work, based not only on existing pavement condition, but also dependant on the roads usage as part of the smelter operations. The majority of site roads within the smelter road network were found to be structurally sound, with poor road pavement conditions generally associated with ride comfort, roughness and road serviceability.

1 INTRODUCTION

This paper outlines the development of a site specific Pavement Management Strategy for Tomago Aluminium Company Pty. Ltd. (TAC) at the Tomago Aluminium Smelter Plant Site located just north of Newcastle, N.S.W. The study covered a road network of approximately 15 kilometres within the smelter. Site roads are trafficked by standard highway type vehicles, as well as primary production vehicles with solid rubber tyres and non standard axle and load configurations. These vehicles are used for transporting raw materials, molten metal and finished metal products. The study included a re-assessment of traffic patterns and volumes on the smelter road network, provided estimates of remaining road pavement life and presented recommendations on a Pavement Management Strategy over a five year period.

2 BACKGROUND INFORMATION

2.1 Design Vehicles

The majority of TAC bulk material handling is by means of wheeled vehicles. These vehicles transport raw materials, molten metal, potline consumables, waste and by-products and carry finished metal product off site. The main contributor to pavement distress appeared to be

- Molten metal tankers travelling between the potlines and the casthouse (See Figure 1).
- Anode transporters carrying fresh and spent anodes to and from the potlines.
- Potshell transporter (Scheuerle).
- Forklifts for loading and unloading semi trailers, servicing casthouse and product storage areas.
- Special permit vehicles and semi trailers for transportation of raw materials and finished metal products on and off site.

Details of axle loads and axle configurations were obtained for all design vehicles on site.

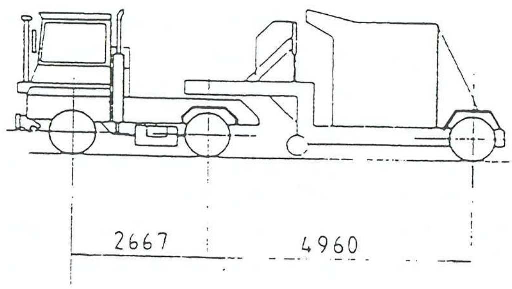

Figure 1 – Hot Metal Transport Vehicle

2.2 Traffic Data

Traffic patterns had recently been altered as a result of additions to the plant, but it was expected that existing patterns would remain stable in the medium term (3 to 5 years). Traffic patterns for all site vehicles involved in smelter operations were provided by the client.

Traffic density figures were collated from smelter production records, with figures generally indicating the number of trips per day for that activity. Trip numbers were projected for the full production rate of the smelter in the medium term.

2.3 Pavement Types

Generally roads within the smelter are comprised of flexible pavements constructed from crushed rock basecourse and sub-base with an asphaltic concrete, (AC) wearing course.

Pavement materials generally consisted of unbound material except for a number of areas across the site, where sections of road had been reconstructed using crushed and granulated slag.

Roads from the initial construction stages were approaching about 15 years of age for an initial design life of 20 years. Significant reconstruction and overlay works had taken place to extend the life and improve serviceability of some of the more heavily trafficked sections of these roads.

Roads associated with recent additions to the plant site also consisted of flexible pavements constructed from unbounded fine crushed rock basecourse and sub-base with an A.C wearing course. These roads were about 5 years old and were generally in good condition.

As built records of pavement types and records of subsequent reconstruction and overlay were available for a number of site roads, however additional geotechnical testing of questionable areas would be required to verify pavement profiles and subgrade conditions.

The as built records indicated pavement thicknesses of existing roads to vary from about 300mm to 500mm, with an AC wearing course typically in the order of about 50mm. Subgrade soils across the site generally comprised of sand.

3 SCOPE OF WORK – FIELD TESTING

3.1 Initial Condition Survey

A road pavement condition survey was carried out in order to identify:-

- Areas of rutting.
- Areas of potholing and cracking.
- Areas of poor surface texture and skid resistance.
- Poor vertical and horizontal cross-geometry or
site intersections.

The visual survey was generally undertaken in ac
with NAASRA (Ref 1). The observations made
walkover assessment of the road system were rec
pro-forma sheets, coded in accordance with ter
suggested by NAASRA and related to road reference
chainage and lane.

In addition to the visual assessment, selected smelt
were tested for roughness using a multi-laser prof
measuring roughness in NAASRA counts/km to ai
assessment of pavement serviceability conditions.

Roughness results varied from values ranging from
counts/km for road sections in good condition, to
ranging from 200 to 400 counts/km for poor road
Based on these results, road sections were graded or
of low to high road roughness, with low roughness b
values of less than 75 counts/km, grading to high ro
for values of greater than 125 counts/km.

3.2 Road Serviceability Study

Ride comfort of the operator was one of the most in
factors with regard to pavement serviceability at the
Aluminium Smelter. This was particularly the case f
pavements which were utilised by non sprung vehic
solid rubber tyres (anode transporters, hot metal tanker

Road serviceability and ride comfort was assesse
interviews with road transport staff, and test riding in
vehicles operating around the site. The results were co
with road roughness testing carried out in the initial co
survey. The results of the study were used to set gu
for acceptable roughness condition for the roads desig
be trafficked by these specialised vehicles.

Good correlations were obtained between areas identi
transport staff as having poor ride comfort and obser
from the visual condition assessment and roughness tes

3.3 Load Deflection Testing

Load deflection testing was carried out on the smelte
network using a "Dynatest 8000" Falling

Deflectometer (FWD). The FWD uses a falling mass to generate a load pulse of similar magnitude and duration as that of an Equivalent Standard Axle (ESA) travelling at normal road speeds. Geophones placed on the pavement at set intervals from the single stationary load point measures the resultant velocity, enabling deflection to be calculated at each geophone location. The basic output consists of a deflection bowl providing maximum deflection and curvature functions which can be further processed to provide stiffnesses of the various pavement layers including the subgrade.

The characteristics of the deflection bowl can be used to provide a prediction of the pavements future performance. The assessment procedures outlined in AUSTROADS (Ref 2) consist of two values used in the structural evaluation of pavement condition as shown in figure 2.

- maximum deflection (d_o)
- curvature ($d_0 - d_{200}$),

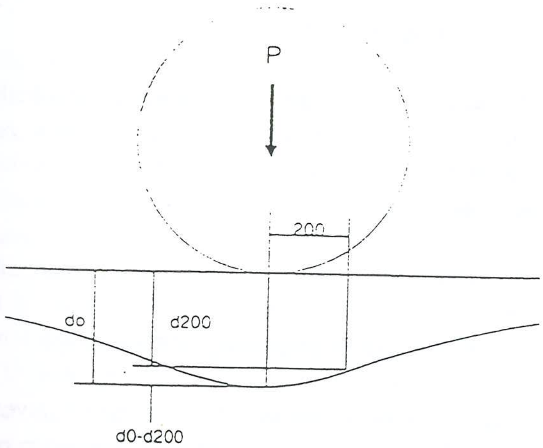

Figure 2 – Deflection bowl of a pavement under a wheel load

The data collected during testing was used to divide the smelter road network into relatively homogenous sections with similar characteristic values for deflection and curvature. An assessment of remaining pavement life was then made for each section.

Maximum deflections are mainly influenced by pavement thickness and are closely related to subgrade vertical compressive strain. Maximum deflections are used to predict the number of cycles (ESA's) to cause a certain increase in surface rutting. Very high deflections (greater than 1.5mm) usually indicate weak subgrade conditions. The test results indicated all site roads to have characteristic maximum deflections of less than 1.0mm, with the majority of road sections typically in the range of 0.2mm to 0.6mm.

Curvature is influenced mainly by basecoarse stiffness and is related to the strain in the AC wearing course. It can be used to estimate the number of cycles (ESA's) to induce fatigue failure. As a general guide, high curvatures of >0.3mm may indicate a weak or thin pavement lacking stiffness, or a pavement with cracked wearing coarse. Characteristic curvature values for the site roads tested were all less than 0.3mm, with the majority of road sections typically in the order of about 0.1mm.

3.4 Pavement Profiles

Pavement profiles were assessed using Ground Penetrating Radar (GPR) calibrated with pavement profiles obtained from a number of boreholes drilled through the road pavements at selected locations.

GPR has been trailed by several road authorities with mixed success. It was judged that GPR would be particularly useful on this site due to the expected relatively consistent pavement and subgrade conditions. GPR offered the opportunity of quick conformation of pavement depths and a reduction in required subsurface investigations across the site.

GPR works on the same principle as navigational radar used by ships and planes. A pulse of high frequency electromagnetic energy is transmitted into the ground and reflections of the pulse from buried objects are received and recorded. The GPR reflections are caused by changes in the electromagnetic character of the material. The GPR response for a particular pavement type has a general character which is related to the pavement structure and the type of construction material used. GPR profiles were recorded using the SIR-2 GPR system. The testing comprised of dragging the recording unit equipped with a 500MHz and 900MHz antenna on a sleigh behind a station wagon containing the recording software and computer.

At this site, GPR was used to give an indication of variations within the wearing course, basecourse and subgrade and to identify possible weak zones or anomalies within the pavement or underlying subgrade. Estimates of layer depths were made from the unprocessed recorded time sections, an example of which is shown in figure 3.

The time to a particular anomaly on the time sections is the time for the radar pulse to travel to the anomaly and return to the antenna and is usually called the two way travel time. The depth estimate is calculated from the two way travel time and the velocity of the pulse in the material(s) through which it passes. The GPR anomalies which are considered to represent the pavement layer interfaces are selected from time sections which have been digitally processed to subdue the appearance of spurious events such as multiple reflections in the time sections and to enhance the appearance of the reflections from the interfaces of these layers.

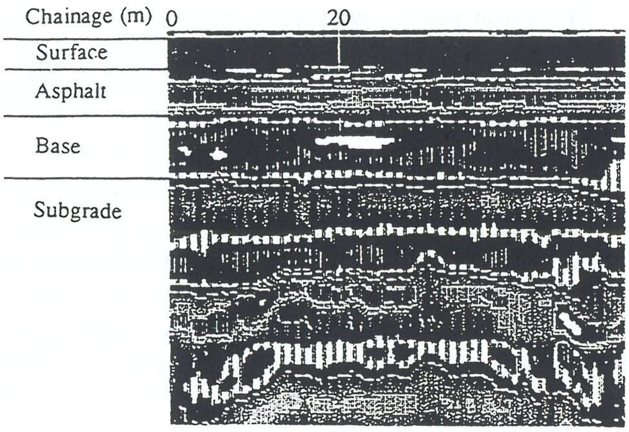

Figure 3 – Unprocessed time section

The GPR testing showed relatively few major anomalies which were usually of limited extent. The regions which exhibited major GPR anomalies generally correlated with high FWD deflection results.

The use of GPR testing allowed a large volume of data relating to pavement and subgrade profiles to be collected over the entire smelter road network in a relatively short period of time. At the same time the testing methods provided minimum disturbance to on going smelter operations. The information collected was used to identify areas of different pavement construction and helped to target areas where subsurface investigations to assess pavement and subgrade profiles would be most suitable.

3.5 Subsurface Investigations

Based on FWD and GPR test results, twelve locati selected where subsurface investigations would b out. These were selected to confirm general paveme and also target anomalies identified by th Investigations comprised the drilling and sam boreholes using a trailer mounted drilling rig to a quality, thickness, moisture and material types pavement construction and the underlying subgrade s

The results of the subsurface investigations were provide correlations with the GPR testing and to su known data previously collected. The extent of s investigations was minimized to limit any disturbances to ongoing smelter operations.

The results of the investigations generally confi pavement types as outlined in Section 2 3.

4.0 RESULTS AND INTERPRETATION

4.1 Vehicle Loadings

The majority of Tomago Aluminium Smelter's bulk handling is by means of wheeled vehicles with var load and axle configurations for the range of vehic site roads.

Details of vehicle load configurations for "normal" vehicles were used to determine the number of E Standard Axle (ESA) repetitions to produce the same as one pass of the axle group. The number of E produce equivalent damage to a pavement layer given vehicle were assessed using the axle group equ relationships outlined in AUSTROADS (Ref 2).

As previously discussed, a number of design vehicle differed considerably from common axle confi associated with "normal" highway type vehicles and of standard load equivalency techniques were not ap For these vehicles, an assessment of the number of E each vehicle to produce equivalent damage to a p layer were calculated using finite layer elastic analy CIRCLY (Ref 3) software.

The following table presents a brief summary of the of ESAs produced per vehicle for a selection of vehic on site

Vehicle Type	Equivalent Damage To Layer (ESAs)	
	Asphalt	Subgrade
Tri-axle type trailer	3	4
Forklift (16 tonne)	8	20
Alumina Tanker	4	244
Potshell Transporter	3	423

4.2 Remaining Theoretical Life

An evaluation of remaining pavement life in terms of ESA's was made using the results of the FWD load deflection testing and adopting the criteria outlined in AUSTROADS (Ref 2). Traffic patterns and traffic count data for each site vehicle were used to assess equivalent number of ESA's per day for each road section, allowing an assessment of remaining road pavement life in terms of years.

Remaining road pavement life assessment was made for both structural integrity of the base and subgrade layers and the fatigue performance of the asphalt wearing course.

Traffic patterns indicated site roads to be subject to total traffic loadings per year in the range of $1x10^3$ to $9x10^6$ ESA's.

Results of the deflection testing indicated the road pavements to have theoretical remaining structural life varying from $5x10^5$ to greater than $1x10^8$ ESAs.

4.3 Pavement Management Strategy

Based on the data accumulated during the study, recommendations for a Pavement Management Strategy over a five year period were presented, with the format of the final report a result of consultation with TAC engineering staff to allow presentation of the data in the most effective way.

The information for each road section was presented in a spreadsheet, summarising the following:-

- Road section reference number
- ESAs per year
- Remaining structural life
- Remaining asphalt life
- Roughness and road serviceability
- Visual condition assessment
- Comments on remedial works recommended

The majority of site roads were found to be structurally sound, with poor road pavement conditions on site generally found to be associated with ride comfort, roughness and road serviceability. As a result, recommendations for remedial work typically comprised of milling and resurfacing of the asphalt wearing surface to provide improved road serviceability. Full reconstruction was only recommended for a few selected road sections.

The simplified table summarising all of the factual data collected, allowed quick and easy assessment of each road sections condition and highlighted any areas of potential concern.

The format of the data collected allowed TAC staff to be able to prioritise road sections requiring remedial work not only based on existing pavement condition, but also dependant on the roads usage as part of the smelters operations.

An ongoing program of maintenance, inspection and testing to assess changing traffic patterns and monitor road condition and serviceability was provided for future works.

5.0 CONCLUSIONS

The Pavement Evaluation Study demonstrated how new technologies could be incorporated and adopted to the geotechnical field, together with more common, standard geotechnical practices.

Due to the unique work environment and site conditions at the TAC Smelter, innovative and alternative methods for assessing road pavement condition were utilised. These methods included relatively standard techniques such as borehole investigations and deflection testing, as well as new technologies such as the GPR testing, with the factual data obtained used to formulate a Pavement Management Strategy tailored to meet the clients specific requirements.

GPR was found to be useful at this site as it allowed a large volume of data on road pavement profiles to be collected in a relatively short period of time, while causing minimal disruption to ongoing plant site operations.

The suitability of GPR on similar type projects is likely to be site specific, limited to sites where consistent pavement and subgrade conditions are expected, with different material properties allowing accurate delineation of pavement layers.

REFERENCES

Ref 1. NAASRA, A Guide To The Visual Assessment of Pavements, National Association of State Road Authorities, 1987.

Ref 2. AUSTROADS, Pavement Design. A Guide To The Structural Design of Road Pavements, 1992.

Ref 3. CIRCLY, Version 3.0h, MINCAD Systems Pty. Ltd. 1997.