Pavement innovation down-under, CCPs rigid and flexible pavement applications

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ABSTRACT

Coal Combustion Products (CCPs) are composed of many non-combustible components and the continuous production of these materials for over more than 50 years, has highlighted the long-term management challenges for these growing resources. Increased utilisation of CCPs in road pavements has the potential to provide economic and environmental benefits to communities and power plants alike.

Historically, proponents of CCP use in pavements have engaged State Road Authorities (SRA) or Department of Transport (DoT) with anecdotal claims of CCP performance arising from ad hoc field trials. Majority of these trials occurred in New South Wales during the early 2000s and some uptake occurred within TfNSW (Transport for New South Wales). However, limited pavement trials were conducted in other states, e.g. Queensland resulting in no further investigation being undertaken by SRAs/DOTs and the proponent's product was not considered for use in major road applications.

In mid 2020, Stanwell approached Arcadis for technical advice about establishing a trial with the intent to prove the performance of traditionally non-conforming CCPs. Arcadis developed an SRA/DoT-level trial design which was designed, constructed and progressively monitored similar to a major highway. The goal was to proactively engage SRAs/DoTs in a demonstration trial around which scientific rigour was framed. Subsequent to the trial at Stanwell Power Station, a number of industry workshops were facilitated by the Ash Development Association of Australia (ADAA) where the process and benefits were discussed. This project aimed to increase and demonstrate the beneficial use of CCPs in rigid and flexible pavement applications.

INTRODUCTION

Coal Combustion Products (CCPs) generally fall into two broad categories, a finer component called fly ash and a coarse component called furnace bottom ash. Fly ash is typically used as a Supplementary Cementitious Material (SCM) in blended cement and concrete manufacture. On the other hand, furnace bottom ash is mainly used as fine and coarse aggregate in various construction applications. Fly ash and furnace bottom ash may be classified as either graded or ungraded (run of station).[1] Graded materials have been processed or classified to meet specific grading and property requirements while ungraded materials are the opposite and have not been processed or classified to meet specific grading and property requirements.

CCPs are the by-products generated from the combustion of pulverized coal-fired boilers used for power generation. Globally, coal fired power stations generate large quantities of these products. In Australia, 12.6 million tonnes of CCPs were produced by power stations in 2018 and 47% or 5.93 million tonnes of CCPs were utilised within various civil and construction applications.[2] The production of large quantities of coal ash has highlighted the long-term management challenges of these resources with growing ash dams – with estimated reserves in storage of +700 million tonnes. One of the solutions to this problem is increasing the utilisation of CCPs in road pavement products.

Arcadis were engaged by Stanwell Corporation as an independent pavement designer to conduct a Highway Department of Transport (DoT) style design for the Stanwell Power Station site to ensure that there was a certain level of rigour and detail in the development of the trial site.

STANWELL POWER STATION SITE TRIAL

The typical approach to field trial assessments related to resource stream materials often start with providers appealing for the inclusion of these materials as conforming materials, with anecdotal claims about the apparent performance of a traditionally non-conforming material. These claims are usually based on field trials that were established ad hoc with no control pavements, supporting data, surveillance or monitoring. With this knowledge, a best practice field trial was conducted and an over-engineered approach was followed to ensure a high level of detail in the development of the site and to provide factual results.

The first step to a best practice field trial is establishing the trial site and setting up control pavements. Stanwell Power Station, a major power station in Queensland, was the location of the trial site. Although the Stanwell Power Station site is not a highway, it is heavily trafficked by major trucks. Figure 1 shows the intersection at Stanwell where the trial pavements were built. The red/orange hatches represent the rigid pavements built at First Street while the blue hatches built at the South Stockpile Road and gray hatch at the intersection represents the flexible pavements.

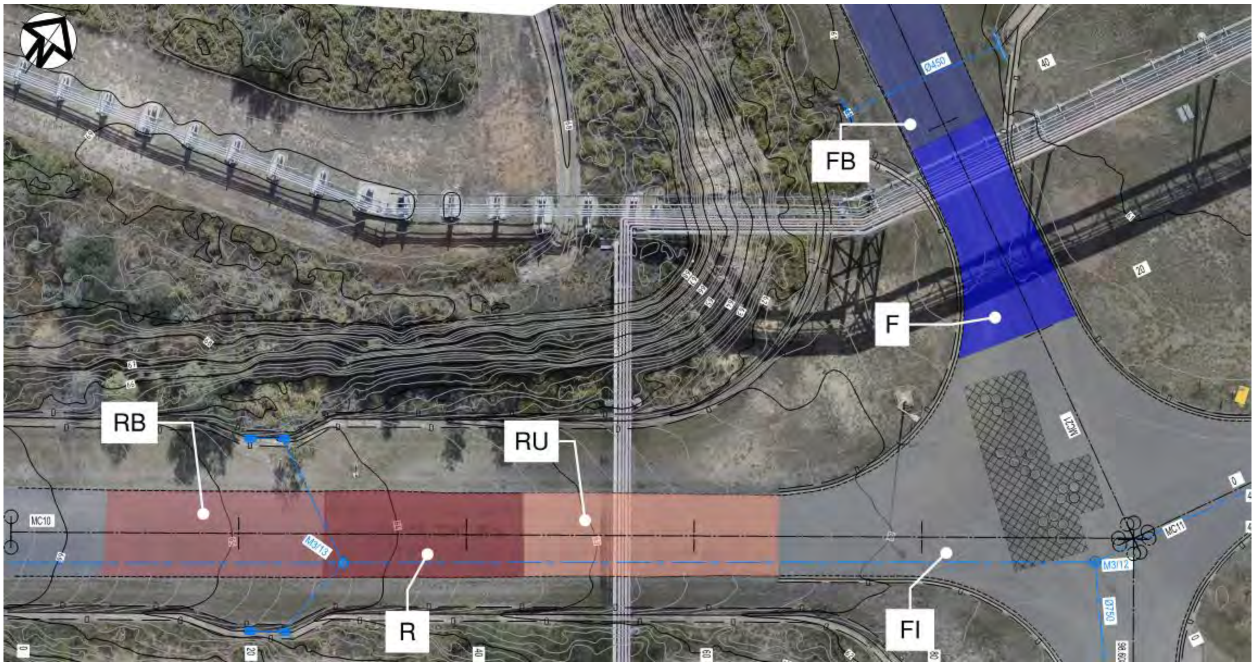

Figure 1 - Design trial site plan at Stanwell Power Station

Once the trial site was set, the usual process of determining pavement thicknesses for highway design projects was conducted. One major determinant of pavement thickness is the design traffic. In Table 1, a design traffic analysis on First Street is presented showing four different vehicle classes and their respective counts. The other key part of pavement design is to conduct a subgrade analysis. A highway class pre-treatment of the subgrade in accordance with MRTS04 Earthworks was undertaken and necessary measures were taken to guarantee that the investigation of the subgrade was accurate. Importantly, the design life of the pavement was reduced and the pavement thicknesses were developed to deliver 5 years of reliable service to provide a realistic turnaround in comparison of the pavement performance.

Table 1 - Design vehicle class and count over the design period of 5 years at First Street

Design Vehicle	Movements
CAT 725C2 Articulated Truck (unloaded)	250
CAT 725C2 Articulated Truck (loaded)	250
Hyundai HL740-9	520
Water Truck	11,000

Both flexible and rigid pavement profiles were developed as shown in Figure 2 and Figure 3. Each group had a control pavement and all pavement profiles were customised to provide the set design life for the traffic experienced in the power station using the methods for designing a major highway in Australia. The dark grey shaded area in the profiles denote the layers in which a non-conforming level of CCP products were substituted.

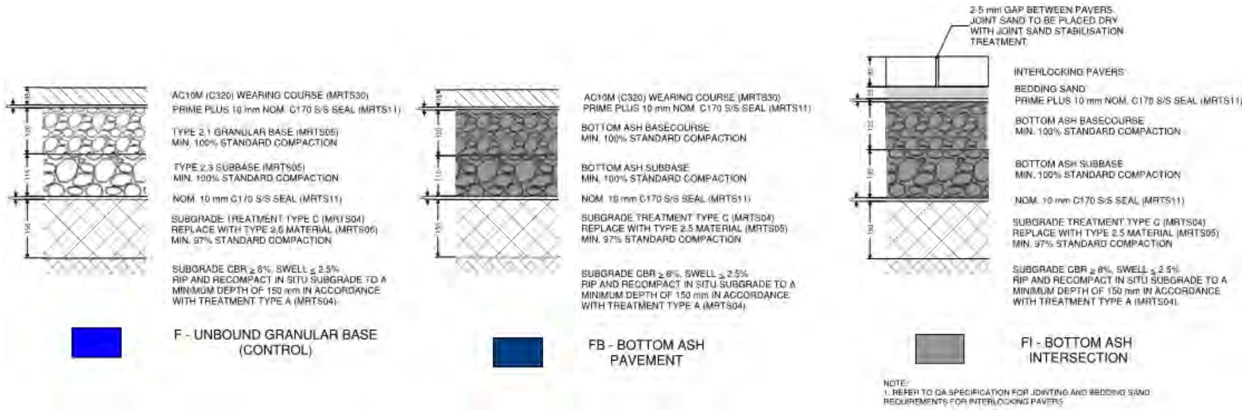

Figure 2 - Flexible pavement profiles

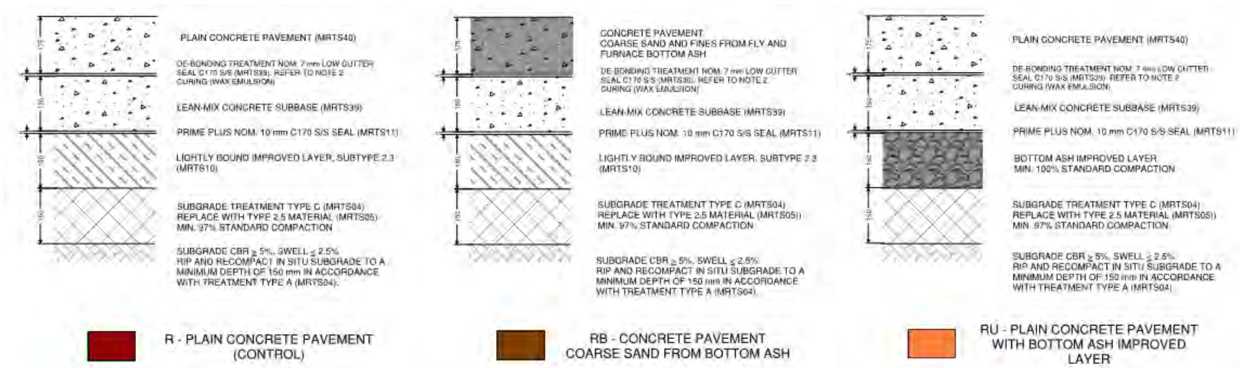

Figure 3 - Rigid pavement profiles

The control flexible pavement (Figure 2) is a standard unbound granular pavement with a thin asphalt wearing course and the experimental pavements follow the same structure, but with alternative CPP products. In the base and subbase layers, the granular material was substituted with bottom ash. Pavement FI (Figure 2) is solely used for the sustainability assessment and is excluded from any performance assessment. From a pavement design perspective, intersections are typically difficult to model as there are factors such as turning forces, braking/accelerating and high degrees of wander that cannot be accurately accounted for or predicted.

The control rigid pavement (Figure 3) is a concrete pavement base over subbase with lean mix concrete over a lightly bound granular improved layer. Significant proportions of the natural coarse sand and fines were substituted with fly ash and furnace bottom ash for experimental pavement RB. For experimental pavement RU, the improved layer was replaced with a 100% bottom ash mix instead of the granular material, which is normally used in highway design projects.

On the trial site, subsurface drainage was installed as per typical pavement design along with traffic delineation to ensure that the traffic movements along the site were uniform and constrained. For consistency and similar to any major highway design, Arcadis developed a full drawing set including plans and details for construction.

The comparison of the potential environmental benefits of the candidate pavements are presented in Table 2 and Table 3. For the flexible pavements, the control pavement F utilised a minimal amount of CCPs as compared to the experimental pavements FB and FI, which utilised 452 and 487 kgs of CCPs per m^2 respectively. The rigid pavements show a similar trend but with a different magnitude. Pavement R, the control pavement, utilised a standard inclusion of fly ash at approximately 45 kgs while experimental pavements RB and RU utilised a total amount of 151 and 383 kgs of CCPs per m^2 respectively. In both cases, the increased utilisation of CCPs substantially improved the CO_2 offset in the process.

Table 2 - CCPs component of flexible pavement types

Pavement Type	F	FB	FI
Fly Ash (kg/m^2)	3	3	0
Bottom Ash (kg/m^2)	0	449	487
Total (kg/m^2)	**3**	**452**	**487**

Table 3 - CCPs component of rigid pavement types

Pavement Type	R	RB	RU
Fly Ash (kg/m^2)	45	112	45
Bottom Ash (kg/m^2)	0	39	293
Total (kg/m^2)	**45**	**151**	**383**

One significant component of major highway construction project is surveillance and monitoring including conducting quality control measures and ensuring that on-site testing is properly done. For consistency, on-site testing conducted on major highway construction projects were also done for the Stanwell trial site. Figure 4 below shows different photos taken for surveillance of the site during construction.

Figure 4 - Stanwell Power Station trial site construction

A best practice field trial does not end with the construction of the trial site and must be followed with a series of performance monitoring measures. For the flexible pavements, observation of both control and experimental pavements must be conducted for performance parameters such as rutting, skid resistance, cracking and deflection. The control and experimental rigid pavements must also be monitored and observed for parameters such as skid resistance, cracking and compressive strength. The compressive strength comparison between the control and experimental rigid pavements could determine a measurable difference since the strength development of concrete with the inclusion of fly ash is slow at early ages.[3]

CONCLUSION

Rigorous trial site establishment maximises engagement and efficacy, which means that a Department of Transport (DoT) or State Road Authority (SRA) quality design must be conducted. A best practice framework must be followed in order to attain a DoT/SRA quality design. This framework consists of key scientific approach principles catered to an engineering trial site assessment which involves selecting the candidate site, setting up control pavements, undertaking the design and construction to DoT standards, constructing the pavement, surveilling the pavements to ensure that the construction is carried out in accordance with the design and lastly, monitoring the site after construction. Following this framework may increase cost however, the quality of results obtained may be improved.

Incorporation of higher levels of CCPs in road pavements is practical and substantially improves the CO_2 offset in the process which provides economic and environmental benefits. An important part of this whole process as well, is the engagement with upstream stakeholders. Several workshops were facilitated by the Ash Development Association of Australia (ADAA) with a diverse cross section of industry members. The purpose of the workshops were to challenge prescriptive specifications and wider applications of CCPs through demonstration of equivalent performance in trials similar to the one at Stanwell Power Station.

Following the framework outlined in this paper, ADAA has initiated opportunities and approaches to capitalise on previous work on the trial site project with the sustained goal of increasing and maximising the use of Coal Combustion Products (CCPs).

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