CASE STUDY

Selby Bypass - PFA takes CBM1A sub-base to new levels

Introduction

Selby bypass was constructed during 2000-2004 by Skanska for the Highways Agency. The pavement construction employed is a significant example of the optimisation of the use of site and local materials. An integral part of the pavement was the CBM1A sub-base made from a mixture of site material and imported conditioned PFA from Drax Power Station. This resulted in;

- impressive strength results for the CBM1A,
- significant savings in black-top,
- programme advantages because of the use of site and local material for a significant part of the pavement,
- an economical solution.

Overview of CBM1A operation with continuous pugmill mixer in background

Pavement Design

The pavement construction for Selby consisted of capping overlain by CBM1A sub-base in turn overlain by bituminous base, binder course and surface course. Following considerable design input from Andy Brown of Highways Agency, a thicker-than-standard CBM sub-base, with a compensating reduction in bituminous base thickness, was ultimately accepted by the client. The adopted pavement construction is shown in the table together with a conventional design for comparison.

Table 1. Pavement construction (design traffic>80msa)

Pavement course	Illustrative conventional flexible construction	Actual construction
Surface course	30mm thin surface course system	30mm thin surface course system
Binder course	60mm HMB35	60mm HMB35
Base course	220mm HMB35	150mm HMB35
Sub-base	150mm Type 1	240mm CBM1A made from Sherwood sand and PFA
Capping	Sherwood sand	Sherwood sand

As can be seen from the table, by optimising the use of site material and thus the thickness of the CBM1A sub-base, significant thickness reductions and cost savings were possible with the overlying HMB base and thus black-top import to the site.

Materials and mixture design for CBM1A

One of the indigenous materials on site was Sherwood sand. This is a fine silty sand with 93% passing 300 microns and 27% passing 75 micron. The sand was used for capping, producing insitu CBRs of 25/30%.

The sand was also tested for use as the sole aggregate for the CBM1A. It became apparent however that the grading characteristics, fines content and subsequent large surface area of the sand meant that a significant proportion of cement was required to achieve the specified 7 day cube strength of 10 MPa. In addition, after its use for capping, supply of the sand was limited and it therefore became necessary to find another material to blend with the sand to make it go further as well as trying to reduce cement demand.

Extensive laboratory trials were undertaken with blends of the sand with an imported coarse limestone, limestone fines and also with conditioned PFA from nearby Drax Power Station. In the event, the PFA from Drax was selected. It proved to be a sound technical and economic solution because the use of the PFA realised impressive improvements in strength which allowed a significant reduction in cement demand.

PFA is a pozzolan, that is, it is a material that sets in the presence of calcium hydroxide [$Ca(OH)_2$] when in contact with water. $Ca(OH)_2$ is liberated by cement during hydration. Thus if PFA is used with cement, the strength development of the mixture is enhanced by the secondary $Ca(OH)_2$ / PFA reaction. This so called secondary reaction can be significant, particularly in the case of CBM where cement contents tend to be low, and indeed may contribute more than cement to the ultimate long term strength of the CBM. This has undoubtedly been the case at Selby.

In order to determine the optimum proportions of cement and PFA, Skanska, through their testing laboratory LJ Church Ltd, undertook strength testing of various mixtures containing PFA. The chosen mixture by dry mass was;

- 5.5% cement, 33% PFA and 61.5% Sherwood sand

Typical results for the selected mixture are shown in Table 2. Alongside these results, the typical strength development is shown for a theoretical CBM1A without PFA that just satisfies the specification.

Table 2. Cube strength development of chosen mixture (proportions by dry mass)

Mixture	Cement kg/m³	PFA kg/m³	Sand kg/m³	Cube strength at 3 days in MPa	At 7 days	At 28 days	At 56 days	At 84 days	At 360 days
Selected mixture	95	475	1425	3	4	6	12	15	~20
Theoretical mixture proportions and strength development of CBM1A without PFA	200	-	1800	6	10	12	13	14	15

In order to optimise the mixture proportions, it is apparent from the table that the performance of CBM with PFA compared to CBM without PFA needs to be judged at ages later than 7 days, preferably 56 days or later. Obviously this has a contractual disadvantage since the SHW dictates that strength should be judged at 7 days. In addition there is the risk of leaving compliance until 56 days or more when significant areas of pavement could be at risk of non-compliance.

With the agreement of the Highways Agency, this was overcome at Selby by using a reduced 7 day strength requirement to judge that satisfactory CBM1A strengths were going to be achieved in the medium term of 2 to 3 months.

More significantly, it is possible to see from the Table that compared to a straight cement CBM, the chosen mixture had in theory marked long term strength advantage and reserve beyond 3 months, with ultimate strengths more in line with a CBM4.

Production, construction and control

CBM1A construction was carried out conventionally with the exception that the total course thickness of 240mm was undertaken in 2 lifts. Bay lengths of full carriageway width were typically 80m long with the second lift laid immediately after compaction had been finished on the first lift.

Site production of the CBM was carried out by McArdle Ltd using a continuous pugmill mixer with the sand and conditioned PFA (note that conditioned means with added water, typically 15%) hopper-fed into the pugmill. Cement was added conventionally via the silo.

The mixture was transported by dump trucks to the point of placement where it was laid by paver by Roadstone Recycling Ltd. Following groove installation for crack inducement, compaction was by tandem roller consisting of vibrating drum at the front and pneumatic tyres at the rear.

Laying and compaction of CBM1A showing 2-lift operation

The CBM operation was completed by the application of a bitumen emulsion cure coat with the layer left for 7 days before trafficking and overlaying. It should be noted that even though the early age strengths were less than normal for CBM1A, they were similar to CBM1 strengths of 4.5 MPa and thus no changes needed to be made to the normal 7 day curing and non-trafficking period.

Conclusions

The Selby bypass clearly shows the advantages of using PFA in CBM. These advantages accrued across the board from the contractor Skanska to the client the Highways Agency.

- Firstly, the PFA solved Skanska's aggregate shortfall problem at reasonable cost,
- secondly, it reduced the cement requirement of the CBM1A,
- thirdly, it gave the Highways Agency a CBM with a superior long term performance to cement-only CBM.

These benefits are not unique to Selby. PFA is widely and economically available. Its versatility as an aggregate or filler, coupled with its pozzolanic strength-contributing properties, can thus be enjoyed with CBM all over the country.

Acknowledgement

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In general usage the term 'fly ash' is used for pulverized coal ash but it can also cover ash from burning other materials. Such 'fly ash' may have significantly differing properties and may not offer the same advantages as ash from burning pulverized coal. UKQAA datasheets only refer to PFA / fly ash produced from the burning of predominantly coal in power stations.