Upper Heyford 1246 DOR

PFA Trial Mixes

Site Overview

The site is located on part of the former RAF and USAF Upper Heyford airbase known as Heyford Park. An extensive system of infrastructure consisting of pipework, pumps and valves known as a Petrol, Oil and Lubricant (POL) system is present on site as well as housing a number of Underground Storage Tanks (UST's) and Above Ground Storage Tanks (AGST's) which were previously the source of the system. The site will be subject to works to ensure these sources are not a source or pathway for contamination in future (minimum of 12 years). The Environment Agency classify the Great Oolite Limestone aquifer underlying the site as a principal aquifer that is abstracted for local water supply therefore contamination could pose a threat to potential receptors.

Report Overview

It is thought a grout can be developed from a mix of Pulverised Fuel Ash (PFA), Ordinary Portland Cement and Water. This mix is an inert material that will cure within the POL system to occupy all the available void space. This will ensure that no potentially harmful gases will collect in the system or leachates originate from these sources.

Trial Regime

Trials were conducted within Vertase's in house laboratory, Sheffield from 09/08/2011 and are still ongoing (09/09/2011).

Reagent Selection and Justification

Two sources of PFA were used in the trials. A source named as 'Fluffy' containing a moisture content of 17% and a source of named 'M25' with a moisture content of 21% which was initially being used for the M25 extension works however now not required for that works were trialled.

PFA is combined with a low percentage of OPC powder and water to create a cementitious grout. When combined the mix design must demonstrate a high level fluidity so that the grout can be transferred to the POL system either though pumping or flow shoot. This fluidity must be maintained over a three our period following batch mixing.

PFA is a desirable material as it demonstrates a slower rate of hydration rate than OPC. The slower rate of hydration also allows the mix to maintain a better pumpability for a longer time period. The lower heat generation will also reduce thermal cracking which is a characteristic of OPC setting. Another desirable characteristic of PFA is that with an effective volume additions of water it can demonstrate a minimisation of bleed water after setting whilst maintaining the sufficient level of fluidity.

OPC content will increase the cured strength of the grout which is why it has been trialled as an additive. The use of OPC as the primary constituent of the grout would not be economically viable which is why PFA is considered as the main constituent. OPC also has a quicker setting rate and is also therefore more vulnerable to thermal cracking. Any void spaces within the POL system could lead to gas collection and therefore PFA is seen as a more desirable material to minimise this. The use of high percentages of OPC will also decrease the setting time of the mix and therefore may not create a material that is pumpable or flowable for a sufficient period of time.

An accurate addition of water must be added to the mix so that a minimum amount of bleed water occurs from curing and so that an adequate volume is added to maintain the pumpability/flowability for a 3 hour period.

Trial Stage 1

Initial trials were carried out to establish whether a mix of PFA and low percentage of Ordinary Portland Cement (OPC) could set. The mixes comprised of a variation of ½ - 7% OPC to the weight of PFA. A weight of 750g PFA when mixed with water and OPC yielded sufficient sample for one trial.

Initially 40% added water to the weight of PFA was added to the sample volume saturated the material with too much excess water so the volume of water was reduced to 27%. This created an initial product that could be poured and was not overly hydrated. This added water content give an overall water content of 34.5% within the Fluffy PFA source and 37.5% within the M25 source. Setting was clearly quicker within higher OPC contents

between ½ - 2% and the difference in setting times in OPC contents above this were negligible.

The conclusion of initial trials was that an OPC content of least 2% could create a mix that could set. Fluffy PFA was also was also more efficient at setting than the M25 PFA. It is most likely that the Fluffy source is demonstrating better curing properties because the overall moisture content of the material with the addition of equal amounts of water is lower than the M25 trials.

Trial Stage 2

Secondary trials were conducted on the M25 PFA only as the Fluffy source was identified as a superior curing material from stage 1 trialling. Trials were conducted using mix designs at a low OPC content (≤1%) as initial trials concluded an OPC content of this low percentage was capable of setting. PFA without OPC content were also trialled in order to determine whether the addition of water to PFA could create set mix which would eliminate the need for OPC addition. Mix designs were conducted open to the atmosphere and also with a closed lid to represent conditions within an UST. A comparison of the curing properties of samples open to the atmosphere and samples in closed condition could be observed. A further trial was also conducted to estimate the volume a trail mix occupies after mixing from of its original components.

The minimum amount of additional water required to reach a sample that can be pumped is 25%. Trials were then conducted using additional water contents of 27-29%. All trials at 0hrs were capable of being pumped. The samples were inspected after 3hrs to see whether the sample would still be able to be pumped. Samples containing additional water of 25% were not capable of being pumped after 3 hours. Samples containing an additional water content of 27% would require a very strong grout pump. Samples containing additional water of 29% were a pumpable state. It is therefore concluded that the setting time of the mix is directly related to the additional water volume. The greater the additional water the increased period of time that the material remains pumpability/flowability.

After four days of curing none of the samples had set. The sample that demonstrated the best setting was the trial containing 1% OPC. It is also doubtful that the trials containing no OPC percentage will set.

The mixed batch volume will be 73% of the initial volume of PFA. This was observed by measuring the reduction in volume within a known volume when the mix constituents are mixed.

Trial Stage 3

As an OPC content of 1% demonstrated the most effective properties from the second stage this was trialled further. As an OPC content of 0.5% did not demonstrate sufficient curing strength to be taken further. Trials consisting of 1% and 1.5% OPC to the weight of PFA were trialled with an additional water content of 27% and 29% as 25% additional water did not yield a product that could remain pumpable/flowable for a sufficient period of time. Again these trials were conducted open to the atmosphere and also with a lid.

Results showed that all trials demonstrated cured properties over the first three hours of trialling. The trials containing 27% additional water had cured so when pressure was applied a depth of a quarter of the sample could be reached. When pressure was applied to the 29% water depth of a half the sample could be reached. Therefore an addition of 29% water produces a more pumpable material for a longer period of time.

After 3 days the sample which demonstrated the best curing properties was M16+ which had totally set within the open lid trial. This sample consisted of 1.5% OPC and additional water added of 27%. The other open lid trials containing lower OPC contents had set after 4 days.

The first closed lid sample to set is M16 which also demonstrated the shortest curing time in open trials. The closed M16 trial (1.5%) OPC had set after 16 days. After 21 days of curing no other closed samples had yet set however M15 containing 1% OPC demonstrates properties that the mix will set with further curing time.

Conclusion

Stage 3 trials that were open to the environment could all achieve a set product within 4 days of curing. However only M16 consisting of 1.5% OPC and an additional water content of 27% achieved a set product over 21 days of observation. This will achieve a set mix within 3 days in an open environment and 16 days in a closed, confined environment. Although 1% could also achieve a set product 1.5% will be used to mitigate the degree of risk involved with achieving a set product within a closed environment.

It was evident from trials that altering the additional water percentage will alter the curing time to achieve a set product. Larger additional water content will increase curing time and will produce excess water on the top of mixed samples while lower additional water content will reduce curing time and reduce excess water. Within closed samples setting time is significantly reduced with increased quantities of OPC.

When water is added to the PFA the PFA will reduce in volume. Form trialling adding 27% additional water will reduce the initial PFA volume by 27%.

The optimum mix that can achieve a set product in a closed environment consists of:

PFA
27% additional water
1.5% OPC