Sustainable Construction Products **for Renewable Energy Projects**

SCOTASH

A Lafarge ScottishPower Joint Venture



HOW GREEN IS YOUR PROJECT?

WIND ENERGY PROJECTS create significant environmental benefits, generating electricity with none of the CO_2, SO_2 and NO_x emissions associated with thermal power generation.

But the use of traditional materials, such as Portland Cement in construction can generate a CO_2 burden of around one tonne per tonne of cement used – excluding transport emissions.

ScotAsh, the UK's leading manufacturer of PFA based green construction products, can offer a sustainable alternative.

Our range of cements, grouts and stabilisation products, manufactured from re-engineered Pulverised Fuel Ash, can help windfarm developers to minimise the carbon burden of their projects.

As well as enabling low carbon construction, using PFA based materials displaces virgin aggregates, making them the natural choice for green energy projects.

ScotAsh supplied cement products to Black Law windfarm in Lanarkshire, the largest operational onshore windfarm in the UK.



ABOUT SCOTASH

ScotAsh, based at Longannet Power Station, Kincardine-on-Forth, manufactures a range of cements, grouts and waste stabilisation products from Pulverised Fuel Ash (PFA).

A significant proportion of the PFA we use is re-engineered through an electrostatic beneficiation plant to optimise the carbon content, enabling us to manufacture superior products, with quality built in to every batch.

ScotAsh is a founder member of the UK Quality Ash Association and the Scottish Forum for Sustainable Low Energy Construction, which has been awarded significant funding from the Department of Trade and Industry to develop low energy sustainable construction techniques.

All of our products are manufactured under a Quality Management System that is certified to BS EN ISO 9001:2000. Trojan cements contain between 27% and 55% PFA and can be blended to the customer's requirements. Our cements comply with the requirements of BS EN 197-1 for CEMII A/B-V and CEMIV A/B cements.

THE QUEEN'S AWARDS FOR ENTERPRISE: INNOVATION 2005

VISION IN BUSINESS FOR THE ENVIRONMENT
VIBES OF SCOTLAND
AWARDS WINNER 2004
www.vibes.org.uk

Business in the Community AWARDS 2006

Over the years we have won many awards including the Environment Award in the Utility Industry Achievement Awards, a Vision in Business for the Environment of Scotland (VIBES) Award, a Queen's Award, and an Environmental Big Tick from Business in the Community.

In 2006 we were short-listed in the biennial European Business Awards for the Environment.

USE OF PFA BLENDED CEMENT IN WINDFARM PROJECTS

PFA based cement from ScotAsh is used extensively in windfarms for the turbine bases as it provides a lower heat of hydration for large concrete bases and long-term durability for the exposed cement.

We have supplied products to the following windfarm projects:

- Beinn an Tuirc (ScottishPower)
- Deucheran Hill (Powergen Renewables)
- Bowbeat Hill (Powergen Renewables)
- Causey Mire (np Renewables)
- Crystal Rigg (Natural Power Consultants)
- Cruach Mhor (ScottishPower)
- Black Law (ScottishPower)

PFA based cement in concrete offers the performance benefits over conventional Portland Cement of increasing strength over time and increased resistance to chemical attack.

Over the next few pages we will examine the benefits of PFA based cement from ScotAsh, including its properties, cost and environmental considerations.

Beinn an Tuirc windfarm in Kintyre

Cruach Mhor windfarm on the Cowal Peninsula



ENHANCED DURABILITY

TURBINE FOUNDATIONS

Turbine foundations are generally piled with reinforced concrete pilecaps, or gravity solutions consisting of reinforced concrete pad footings.

Typically the volume of a gravity base is between 250-300 m^3, although this can vary depending on ground conditions, turbine tower height and the susceptibility of the supporting soil to degrade under cyclic loading.

On recent Arup onshore projects in Scotland the typical design strength of the bases has been C28/35, sometimes with a C40/50 for the plinth forming the connection to the turbine tower.

Projects at Cruach Mhor in Argyll and Wether Hill in Dumfriesshire have used blended mixes, with a 30% PFA replacement.

It is now widely recognised that as well as offering environmental benefits, PFA blended cements can provide significant durability advantages.

They are less permeable than Portland Cement, reducing shrinkage and creep whilst increasing resistance to chloride ingress and sulphate attack.

Blended cements have also a lower heat of hydration and, due to a reduced rate of bleeding, blended mixes tend to be easier to compact.

DURABILITY

Current onshore windfarm projects have foundation design lives of 25 years, mirroring those of the towers and turbines.

Compared with the 120-year design life of bridges, long-term durability is less of a concern in the selection of concrete mix than it would be for most other civil engineering projects.

> “It is recognised that as well as offering environmental benefits, PFA-blended cements provide significant durability advantages

However, enlightened designers and developers are now considering re-use of the bases with replacement turbines, possibly to accommodate the lifespan of several retro-fitted turbines.

In fact, the Sustainable Development Commission in its report ‘Wind Power in the UK’, states: “Repowering is a practical and economic option and has already been done in the UK.”

On this basis, the argument for adopting PFA blended mixes with their lower heat of hydration and increased durability is strengthened.

However, in considering future retrofitting, the new turbines must be compatible with the elements cast in to the base that provides the connection between base and tower.



LONG-TERM STRENGTH GAIN

HEAT OF HYDRATION

The temperature rise during the hydration of large concrete sections depends on the cement type and content, the temperature of the fresh concrete and the section size.

These factors affect the rate of strength gain and the ultimate strength values achieved, and can pose a risk of deterioration in later years due to delayed ettringite formation if temperatures are allowed to exceed 70 degrees Centigrade.

Ettringite crystals are formed as a product of the hydration process.

If their formation is delayed through higher temperatures during the initial hydration then crystallisation can cause an expansion pressure due to the adsorption of water, potentially damaging the structure.

Turbine bases form significant sized pours with section thicknesses of over one metre.

Careful selection of the cement, such as the use of blends containing PFA, can help to limit the temperature rise and reduce the risk of cracking.

EARLY AGE THERMAL CRACKING

Early age thermal cracking is associated with the release of the heat of hydration of the cement.

It occurs either due to a restraint to contraction on cooling of the concrete section or by differential expansion during the hydration process.

The risk of concrete cracking can be controlled through the careful selection of concrete mix constituents and attentive site practice.

The control of crack propagation, and more particularly crack widths, can be addressed through the placing of suitable reinforcement.

A buried concrete wind turbine base receives only a minimal amount of restraint from the ground that it is cast off and, assuming backfilling takes place shortly after casting, is not subject to significant temperature fluctuations in service.

Nonetheless, a reduction in the heat of hydration through using a PFA blended cement can reduce the requirement for reinforcement to resist early thermal cracking.

At the design stage, limited information may be available to the designer regarding the concrete constituents and mix proportions that will be used by the contractor. This leads to a conservative set of default assumptions being made.

> **“Careful selection of cement, such as using blends that contain PFA, can help limit temperature rise and reduce a risk of cracking**

More stringent specification of concrete requirements in specimen designs or client requirements would enable design improvements.

The calculation for reinforcement to control early thermal cracking includes determining several temperature factors, one of which, T1, is derived from the binder type and content. Figures published in the working draft of CIRIA's research project RP722 on early age thermal cracking show that PFA blended mixes with 35% replacement can provide a reduction in T1 of between 3-5°C compared with that of CEM1.

By way of example, taking a 1,200mm thick concrete slab and keeping all other parameters constant, such a reduction in T1 can translate into a reduction of reinforcement to control early thermal cracking of around 10%. In a wind turbine foundation this is estimated to translate into a saving of £100 per base.

As the wind can blow in any direction the principal reinforcement placed to resist the applied movement needs to run in both directions.

AGGRESSIVENESS OF GROUND CONDITIONS

Generally windfarms, currently at least, are constructed in remote greenfield locations.

Often in Scotland the founding sands, gravels and rocks are overlain by layers of peat. These conditions tend not to be particularly aggressive, with generally low levels of sulphate content.

Similarly, trigger levels of magnesium do not occur naturally in the UK, thus the increased durability potential of PFA blended cements takes on less significance. However, in coastal locations PFA blended cements offer resistance to chloride ingress and sulphate attack.

IMPORTANCE OF RATE OF STRENGTH GAIN

PFA blended mixes normally offer a lesser initial rate of strength gain compared with CEM1.

The construction sequence normally adopted in windfarm construction tends to mean this is not of prime concern.

If a casting rate of one base per day is followed then there is sufficient time in the programme for the required strength to have been attained before delivery of the turbines.

Preparing the base for a new turbine at Black Law

Upland windfarms are often in areas of peatland



ENVIRONMENTAL CONSIDERATIONS

The use of PFA based cements, such as the Trojan range from ScotAsh, provides strong environmental benefits.

Using PFA displaces primary aggregates, helping to conserve valuable natural resources.

Due to its low density, re-using ash in this way saves a greater weight of natural aggregates and reduces transportation impacts and costs.

The re-use of ash also saves energy (and CO_2 emissions) that is required to crush, grind and heat raw materials. The manufacture of traditional Portland cement, widely used in construction, is one of the most energy intensive production processes – only materials such as aluminium and steel require more.

Making one tonne of Portland cement requires about 4Gj of energy. This makes the process a significant contributor to the greenhouse gas CO_2.

The embodied CO_2 content of a 30% PFA cement is almost 30% lower than that of CEMI.

In addition less CO_2 is released to the atmosphere from cement clinkering (mainly from decomposition of calcium carbonates) and less energy is used in production. Typical estimates give figures of 917.3 kg CO_2/tonne for CEMI and 13.6 kg CO_2/tonne for PFA.

Calculations performed by Arup for a typical C40 on a sample project give a total of 272 kg CO_2/m^3 for 30% PFA concrete against 329 kg CO_2/m3 for the equivalent CEMI concrete.

These numbers are "factory gate" figures and exclude vehicle emissions resulting from delivery.

In addition, using processed PFA as an addition to concrete lowers the water demand which, in turn, saves energy. Processing a by-product into construction products avoids the need to landfill substantial quantities of ash, either to ash lagoons or landfill sites.

During the last three years ScotAsh has

- Saved more than two million tonnes of primary aggregates
- Saved 120,000 tonnes of CO_2
- Avoided the need to landfill more than 1.6 million tonnes of ash

COST

Cements containing PFA typically cost about five per cent less than conventional blends.

However cement contents are typically about 10% higher for 30% PFA mixes than CEMI mixes.

For a typical mix of say 300 kg/m^3 CEMI (330 kg 30% PFA) this brings the price difference down to around £1/m^3, with the market price of ready-mixed concrete being around £65/m.*

Currently the foundation costs for a relatively small turbine will account for around six per cent of the total installation cost.

However, the trend towards larger turbines and taller towers means that this will increase. For a gravity foundation, the base size increases approximately in a cubic relationship to tower height making foundations a more significant cost component of the development.

For larger foundations and bases, therefore, the use of PFA blended cements offers sizable cost savings in addition to strength, long-term durability and environmental benefits.

** As at January 2007*

Re-using ash saves natural resources and energy



WHAT OTHERS HAVE SAID ABOUT SCOTASH

"I have often quoted the use of ScotAsh products in the development of a windfarm as being the epitome of a closed circle of resource utilisation, with ScottishPower producing the ash as a waste at its power stations but using it via ScotAsh as a substitute material for construction of the infrastructure of its windfarms."
David Middleton, CEO, Business Council Sustainable Development

"The Scottish Executive welcomes the contribution you are making to sustainable development."
Kevin Philpott, Waste Regulation Team, Scottish Executive

"ScotAsh ticks all the boxes. Not only does the company recycle a by-product into quality construction products, it is environmentally-friendly – and it makes money and supports jobs too."
Margaret Dean, Lord-Lieutenant of Fife

"We need more forward-thinking businesses like ScotAsh who, through better use of resources and good operational practice, have reduced their impact on the environment and made significant financial savings or gains into the bargain."
Barry Greig, Scottish Executive Sustainable Development Directorate

"I am impressed with the innovation shown by ScotAsh in processing a by-product into high-quality construction materials. These products save natural aggregates, avoid sending ash to landfill and save significant quantities of carbon dioxide."
Willie Rennie, MP for Dunfermline and West Fife

Dunfermline MP Willie Rennie (left) with Peter Quinn and Production & Lab Support Operative Peter Shearer

OTHER SCOTASH PRODUCTS IN WINDFARM DEVELOPMENT

- FBA and PFA can be used in road sub-bases
- PFA based stabilisation products can be used to stabilise waste aggregates for road construction
- PFA based environmental binders can be used in the remediation of contaminated land, or the stabilisation of poor ground
- PFA grouts can be used to fill voids from mining
- PFA and FBA based products can be used in the construction of substation buildings, control rooms, offices and visitor centres.

> "Using PFA-based products across a project can help make your windfarm carbon neutral from day one of commissioning.

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To contact ScotAsh, please telephone or visit our website, where you can access data sheets on our wide range of sustainable construction products and learn more about our recent activities.

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