

Carbon8: Combined Carbon Capture and Waste Treatment – A Commercial Reality

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Abstract

Waste valorisation is essential to ensure future sustainability. However, often technologies are either undeveloped, remain uneconomical, or hindered by legislative barriers. Using technology developed by Carbon8 Systems Ltd, industrial thermal residues can be solidified and stabilised in a hardened pellet form that can be a direct substitute for natural aggregate e.g. for the production of concrete construction blocks. The route to commercialising the technology, which has required demonstrating the transition from hazardous waste feedstock to safe usable product, has been difficult and complex. The aggregates produced were rigorously tested and finally given ‘end-of-waste’ designation by the Environment Agency. In early 2012, a bespoke commercial plant was commissioned at Brandon in Suffolk, UK. In 2014, a second production line was added to the Brandon facility, increasing its capacity to 60,000 tonnes per year. The ACT-produced aggregate is carbon negative as it contains more imbibed carbon than is generated by its production. Consequently, concrete construction blocks produced can also be carbon negative, and are marketed under the name ‘Carbon Buster’. Plans are at an advanced stage for the construction of a second production facility in the UK. This is scheduled to be operational by late 2015.

Keywords: aggregate; recycling; waste; CCS; incineration

1 Introduction

The valorisation of waste is essential to achieve a sustainable economy, by supplementing rapidly depleting natural resources, and negating the need for landfilling.

At present, the UK incinerates 10% of municipal waste (the current EU average is 17.3%) (CIWM, 2015). Flue gases generated by municipal incineration contain pollutants, which are removed via air pollution control (APC) systems. The residue, known as air pollution control residue (APCr), is typically in the range of 2-6% of the total throughput of an incinerator (DEFRA, 2013a & 2103b). The majority of UK APCr is sent to either specialized hazardous landfill facilities or placed in underground storage.

Accelerated carbonation is employed by Carbon8 to effectively solidify and stabilise APCr. The carbonation process comprises several reactions. Firstly, carbon dioxide gas hydrates in water, then reacts with calcium ions (dissolved from the reactive material), and forms solid calcium carbonate (limestone). The formation of calcium carbonate has the effect of reducing the alkaline pH of the material, reducing the solubility of many heavy metal contaminants. As calcium carbonate is more voluminous than the reactant minerals, it infills pore space and acts as a binding cement, physically encapsulating contaminants and solidifying the material. The process enables fine-grained waste powders to be formed into aggregates with properties which render them suitable for use as a construction aggregates. Many wastes are susceptible to carbonation, particularly those derived from industrial thermal processes.

Carbon8 Systems' sister company, Carbon8 Aggregates, has been operating commercially since 2012. The present work discusses the development of the process, the legislative and commercial challenges encountered, and the future potential of the technology.

2 A Decade of Development

The potential to rapidly harden pelleted materials was unwittingly discovered during pilot scale trials to assess the use of carbonation to promote the rate and extent of setting of stabilisation/solidification (s/s) treated soils (Antemir, 2010). The production of carbonation-hardened agglomerates from a number of industrial residues was progressed through laboratory research at the University of Greenwich (Gunning *et al.*, 2011; Padfield *et al.*, 2004).

In January 2010, a pilot scale trial was undertaken to demonstrate the larger-scale application of the technology. This led to the construction of a full-scale demonstration plant in November 2010. This temporary installation was used to manufacture approximately 200 tonnes of aggregate, for use in validation trials as a gravel-replacement in concrete construction blocks (Gunning *et al.*, 2011b).

European waste legislation and its implementation in the UK has presented numerous challenges to the development and commercialisation of the process. At each stage of the scaling-up process, the support of the UK Environment Agency was required. Accredited laboratory testing of the aggregate and block to European Standard validated these materials as products. By working closely with the Environment Agency, 'End of Waste' status for the aggregate was approved. As a result, a production facility capable of producing 18,000 tonnes of aggregate per year was built in 2012 (Gunning *et al.*, 2012).

3 Legislative and Commercial Challenges

European waste legislation and its implementation in the UK has presented a number of challenges to the development of the carbonation process. Once the technology moved beyond the laboratory, the activities were regulated by the Environmental Permitting regime under the control of the UK Environment Agency. During the ten years of development, the way in which the legislation was implemented has undergone huge changes. This has led to some considerable delays in gaining the necessary permissions to orchestrate the pilot scale trials. Maintaining a close working partnership between Carbon8 and the UK Environment Agency has been essential to ensure that there has been a good understanding of the aims and objectives by both parties.

The early trials were conducted with Environmental Position statements issued by the Modernising Waste Panel. Obtaining these statements required providing clear and detailed method statements and environmental risk assessments for each trial. These position statements permitted the trial to proceed without risk of prosecution as long as the method statement was followed and the environmental risks were mitigated. The trial site had to be registered to receive Hazardous Waste, and mandatory quarterly summaries of waste received were made to the Environment Agency. Manufactured products had to be quarantined until fully tested, and had to be stored and transported according to strict procedures set out in the method statement.

The commercial installation was granted a full Environment Permit as a Waste Recycling Installation in December 2011. Carbon8 actively sought for designation of the aggregate as a product rather than remaining a waste. This would then permit transport of the aggregates for use on other sites, without the need for further waste management controls. Accordingly, the company submitted an application to the Modernising Waste Panel for 'End of Waste' status for the aggregate. In accordance with the European Waste Legislation, it was necessary to demonstrate that; the aggregate did not pose an environmental risk, had a clear end use, and was a suitable replacement for virgin natural aggregate.

The scaling-up process and successive trials provided clear evidence of the quality of the aggregate that could be produced. Third party accredited testing of the physical and chemical testing of the product allowed Carbon8 to provide a specification for the aggregate. The production of concrete

blocks using the aggregate product manufactured in the trials and the testing of these blocks to BS EN 771 demonstrated that there was a clear end use for the material. Following repeated requests for additional testing, the ‘End of Waste’ status for the aggregate was finally approved in August 2011. Continued collaboration with the UK Environment Agency has asserted the status of the aggregate as a product. It should not be underestimated the considerable costs involved in compiling a testing portfolio for this purpose, which may prove prohibitive to SMEs lacking university or external support.

The legislative framework continues to impose restrictions which hinder the full potential of the operation. Sporadic availability of finite quantities of other useful waste materials which can be incorporated into the process e.g. construction and demolition waste or other thermal residues, presents further recycling opportunities. However, despite demonstrating the compatibility of such materials, and that the resulting product still complies with the End of Waste specification, barriers still exist.

4 Commissioning the Plant

The commissioning of the carbonation facility in 2012 made it the first commercial plant of its type in the world. Demand for the aggregate was such that a second line was installed in early 2014, increasing production to 36,000 tonne per year (see figure 1).



Figure 1. APCr processing plant (second phase)

The full-scale process for the production of the aggregate is shown in figure 2. APCr arrives by powder tanker truck and is transferred to storage silos. A refrigerated tank stores liquid CO₂ for use in the process. This CO₂ is derived from industrial gaseous waste emissions and thus has been diverted from atmospheric release. The APCr passes through a carbonation pre-treatment chamber, into a batch mixer where reagents are introduced as necessary. The resulting mixture is aggregated in pelletising units. Further addition of CO₂ in the pelletising stage induces chemical stabilisation and solidification of the aggregate.

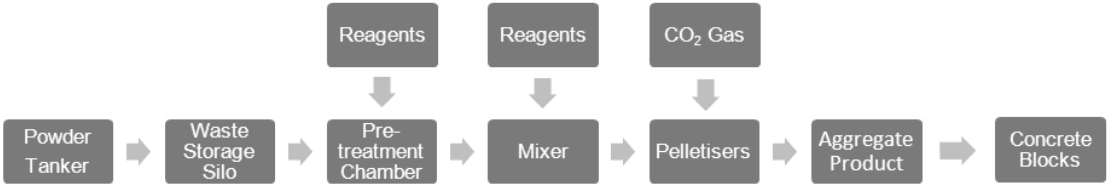


Figure 2. Flowchart of the full-scale process

5 Full-Scale Production

Carbon8 operates under a strict quality system in compliance with ISO14001, OHSAS18001 and ISO9001. Daily checks on the physical and chemical properties of the incoming APCr and outgoing aggregate product are carried out to ensure that the latter meets the specification set out in the End of Waste documentation.

The aggregate product (known as C8A), is a rounded pelleted material, which can be supplied in particle gradings between 50mm and sub-1mm. The product is independently verified as carbon negative, imbibing more carbon dioxide than is generated in its manufacture. C8A typically has a carbon footprint of -46kg CO₂/tonne aggregate.

The aggregate has been trialled and is suitable for use in a range of products, including concrete construction blocks, concrete, and floor screeds (see figure 3).

Blocks made with C8A can fully comply with European Standard BS EN 771-3. Lignacite Ltd is amongst several manufacturers utilising C8A in concrete block production, and is one of the UK's largest independent producers. Their 'Carbon Buster' block contains up to 50% recycled content, and is certified as carbon negative up to -14kg/tonne. Quality control testing carried out by an independent third party UKAS ISO 17025:2005 accredited laboratory has shown comparable properties between the traditional blocks and the Carbon Buster product in terms of strength (compressive and transverse failure), density, and stability.

6 Plant No. 2,3,4....

A second carbonation plant is currently under construction at Avonmouth in South-West England. Production at this site is scheduled to begin in late 2015. A third plant in the North-West is in the advanced design stage, and is due to begin construction in 2016. Plans for a fourth plant in the South-East and a fifth in the North-East are already being formulated.





Figure 3. Clockwise from top left – The Brandon plant; aggregate in storage bays; newly formed blocks; and stacked blocks ready for shipping (courtesy of Lignacite Ltd)

7 Summary

Carbon8 Ltd has developed a process for valorisation industrial thermal residues, and operates a commercial process for the recycling of municipal incinerator air pollution control residue as construction aggregate:

- Development of the process spanned more than a decade from laboratory developed through proof of concept trials, to commercial production
- Legislative barriers have significantly slowed the passage of commercialising the technology
- The aggregate product has been rigorously tested and received ‘end-of-waste’ classification by the UK Environment Agency
- The world’s first commercial carbonated aggregate facility was installed in Brandon, UK in early 2012
- Product manufacture is according to a quality system in compliance with ISO14001, OHSAS18001 and ISO9001
- A second plant is under construction, with a third plant in the advanced stages of planning, with a further two plants due for construction over the next two years.

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