global environmental solutions

Doncaster Gasification Scheme
Kirk Sandall Industrial Estate
Doncaster

Bunker Design

SLR Ref: 403.04318.00001

August 2013

CONTENTS

APPENDICES

1.0 INTRODUCTION

The production process for the proposed energy from waste project at Kirk Sandall Road requires the temporary storage of waste derived fuel in a reception bunker.

The bunker will be located below ground level to enable delivery vehicles to directly tip the fuel material into it. The fuel is subsequently fed into the energy from waste process by means of a grab operated from an overhead gantry structure.

The bunker will be sized to accommodate sufficient volume of fuel to maintain a continuous through-put that will allow the process operations to continue uninterrupted should there be temporary breaks in delivery.

The choice of material for the bunker construction has been carefully considered and this report will demonstrate that insitu reinforced concrete will meet the standards required.

2.0 BUNKER LAYOUT

The bunker size and layout is shown on Drawing ‘Site Plan ref 2012-177_B01/102 rev A’. The bunker dimensions are 30m x 24m on plan and 8.0m in depth measured below intended ground floor slab level (which at this stage of design is assumed to coincide with existing ground level). All dimensions are internal.

3.0 EXISTING GROUND CONDITIONS

A site investigation was completed by Solmek during 2007 in accordance with the requirements of BS5930 ‘Code of Practice for Site Investigations’.

The field work comprised the excavation of 15 trial pits and the drilling of 18 percussive boreholes to a maximum depth of 4.5m BGL.

Made ground was found in all locations, generally to a depth of 0.4-0.75m BGL but exceptionally to 1.3m BGL.

Natural soils were recorded as medium dense and dense locally slightly clayey sand to depths between 0.9m and 3.6m BGL.

Underlying the natural soils is dense red weathered sandstone, which was recorded between 2.5m – 4.5m BGL.

In terms of their Engineering properties, these ground conditions are considered to be ‘good’ and will present no unusual problems in the design and construction of the bunker. No boreholes were progressed deeper than 4.5m BGL, but based on the typical geology of the area it is assumed that the dense sandstone continues significantly below this level and that the bunker will be constructed within it.

It should be noted that occasionally this type of sandstone contains thin layers of clayey material, and can also exhibit faulting. Both of these issues would need to be addressed if present on site, although neither would preclude construction. In addition, the wider geographical area is known to have been used for coal mining, and it is unclear if coal mining records have been consulted to identify if any historic workings are present on site.

These issues would need to be addressed by means of further desktop studies and site works prior to detailed design and construction.

4.0 HYDROGEOLOGICAL CONDITIONS

The Solmek site investigation carried out limited investigation into groundwater levels by means of monitoring measurements taken from shallow boreholes. During three monitoring visits, groundwater was only identified in one borehole, at a depth of 1.65m below ground level.

Given the limited nature of the site investigation and groundwater monitoring works to date, along with the typical properties of the ‘Sherwood Sandstones’ underlying the site, we have assumed a worst case scenario that groundwater may rise up to existing ground level. This will produce maximum hydrostatic head on the concrete elements of the bunker for the purposes of this initial design.

5.0 DESIGN CONSIDERATIONS

The bunker has been designed to totally contain the stored fuel material and prevent any possible risk of ingress of aqueous liquids from the surrounding ground or egress of liquids or contaminants.

Although the structure will be designed to retain any liquid present within the bunker, the fuel will be essentially dry with any small amounts of liquid being absorbed within the material as it is mixed prior to introduction to the gasification process.

The following design criteria have been considered in the bunker design in arriving at the choice of construction material appropriate for the proposed use and environmental conditions: - impermeability, structural capability, durability and constructability.

A bunker of insitu reinforced concrete construction has been chosen as it is considered to fulfil all the above conditions.

The design will be carried out in accordance with the requirements of BS EN 1992-3:2006, Eurocode 2 – Design of Concrete Structures, Liquid Retaining and Containment Structures. This Eurocode supersedes the UK code 'BS 8007:1987 Code of practice for design of concrete structures for retaining aqueous liquids'

5.1 Impermeability

Section 7 of the Eurocode classifies liquid retaining structures in relation to the degree of protection against leakage required. Table 7.105 gives the classification;-

Table 7.105 — Classification of tightness

Tightness Class	Requirements for leakage
0	Some degree of leakage acceptable, or leakage of liquids irrelevant.
1	Leakage to be limited to a small amount. Some surface staining or damp patches acceptable.
2	Leakage to be minimal. Appearance not to be impaired by staining.
3	No leakage permitted

We would adopt Class 3 Tightness, which represents the highest level of performance in which no leakage is permitted.

Achieving Class 3 tightness requires special measures to be taken in the design and construction process.

The use of a liner for the bunker is one possible measure to ensure Class 3 is achieved, but mechanical abrasion may be a detrimental factor during normal operations.

The use of pre-stressed concrete construction to maintain compressive forces within the bunker is another alternative, but such methods involve increased construction costs, higher maintenance requirements and potentially reduced durability.

The use of an additive such 'Caltite' in the concrete mix will produce an impervious and more durable concrete without requiring special construction techniques or maintenance. Technical details of the concrete produced using Caltite admixture may be found in Appendix A. Test details indicate water permeability of $0.15x10^{-12}$ m/s can be achieved.

The resulting concrete is non absorptive and moisture impervious providing permanent protection from water ingress/egress and proofed against soluble salt and acid attack. There would be no further need for coatings or additional liners to achieve the required tightness class.

Cracking is always a consideration in the design and construction of liquid retaining structures. Cracking can occur as a result of a number of factors - early thermal shrinkage and settlements, inappropriate curing regimes, internal restraint forces due to design and layout, excessive temperature changes during service and flexural movements.

All these issues are well documented and understood, and by following guidance in the Eurocodes for design and detailing and following normal good practice during construction works Class 3 tightness can be achieved. Measures include appropriate concrete mix design, correct sizing and spacing of reinforcing bar, correct layout and detailing of construction joints which will incorporate ‘water bar’ details to prevent leakage across the joints, and design of main members such that a percentage of the section always remains in compression.

During construction, appropriate quality control and inspection will be required, along with placing and curing procedures appropriate to the construction sequence and ambient weather conditions.

By adopting these procedures, cracks will be prevented from forming through the concrete section and there will be no pathway for liquids to penetrate. Micro cracks may form on the concrete surface but with the hydrophobic properties of Caltite and the autogenous healing properties inherent in concrete all such micro cracks will be self-sealing.

5.2 Structural Capability

The proposed layout and size of the bunker, along with the insitu ground conditions, can all be considered as ‘normal’ and fall well within the scope of all relevant design codes and methods of construction. No specialist or unusual techniques will be required to design and construct the bunker to resist all foreseeable forces during construction and operation.

Concrete strength can be expected to be C32/40 and reinforcement will be high yield deformed bars.

5.3 Durability

Concrete is an inherently durable material, and its long term behaviour is well documented and understood. By adopting a suitable mix design and by using appropriate structural detailing, it is anticipated that a durable, robust structure will be produced which will require minimal maintenance during its design life.

It is anticipated that the bunker will have a minimum design life of 50years. We would use the guidance in BS8500 to determine appropriate values for strength of concrete, cement type and quantity, aggregate type and cover to reinforcement in order ensure this is achieved.

If necessary, the design life of the bunker can be extended beyond 50 years by the adoption of suitable design measures in line with the requirements of the design code.

The pH and sulphate testing carried out as part of the Solmek soils report classifies the groundwater conditions as DS-1. This is the lowest classification, and will be addressed by specifying a C32/40 concrete. We would note that this will need to be reviewed following further site investigation works which are likely to include Boreholes to a depth exceeding 10m.

The proposed use of the Calite additive will tend to increase the durability of the concrete by reducing its permeability.

Abrasion resistance will be a significant factor during the life of the bunker, due to the likelihood of mechanical damage from grab cranes whilst handling the fuel along with the abrasive action of fuel being tipped into and extracted from the bunker. Over the long term this could reduce the cover to the reinforcing steel. We would address this by using an appropriate concrete mix with a minimum cement content of 350kg/m3 and a maximum water / cement ratio of 0.45. In addition, we would recommend over-specifying the reinforcement cover to the inner walls of the bunker by 25-50mm to provide a ‘sacrificial’ layer to the concrete that can be damaged / abraded without affecting the durability of the underlying structure.

As with all structures, we would recommend that regular maintenance is carried out to identify and repair any minor defects. This would be done by periodically emptying all fuel from the bunker using the grab cranes and skid steer loaders working from within the bunker. This would allow the bunker walls and base to be inspected, and any defects such as mechanical impact damage to be repaired. A shallow sump will be incorporated into the base of the bunker to assist in the removal of any accumulated wash down water used during maintenance works. This sump will not serve any function during the normal operation of the bunker.

Experience from other similar sites would suggest that a full ‘man entry’ inspection of the bunker will be required at intervals of around 10 years. In-between these visits the condition of the bunker will be assessed by regular (every 2 weeks) visual inspections of the bunkers from ground floor level.

6.0 MAIN MEMBER SIZING

It is assumed that bunker will be of internal dimensions 30m x 24m x 8m depth with no internal walls.

6.1 Design Assumptions

The following assumptions were made for the analysis;

- The depth of the bunker is measured from existing ground level which will be the level of the new ground floor of the building
- Maximum groundwater level is equal to existing site ground level therefore maximum head acting on bunker wall is 8.0m
- The upper 3m of ground comprises various soils, the lower sections comprise insitu Sandstone.
- The bunker base will be bearing directly onto the Sandstone at formation level.

6.2 Main Member sizes

Based on these assumptions, the main members in the bunker have been sized as follows;-

External Wall thickness	750mm
Base thickness at junction with Wall	750mm
Base thickness in centre of bunker	500mm

Note: The design incorporates a triangular fillet detail at the junction of the wall and base slab in order to provide enhanced structural capacity in this area.

Total volume of structural concrete = **1203m3**

Reinforcement will be a mixture of H20 and H25mm diameter bars at 125mm c/c in the walls and thicker sections of the base, with H12mm bars in the thinner section of base. This gives a weight of rebar of approximately 190kg/m3 and 130kg/m3 respectively.

Overall weight of reinforcement = **220tonnes**.

Design calculations are included in Appendix B

7.0 CONSTRUCTION ISSUES

The bunker construction requires no specialised construction techniques, and many similar structures have been successfully constructed in similar situations. Subject to the selection of suitably experienced Contractors, and appropriate site supervision, no exceptional construction related issues are anticipated.

The excavation for the bunker construction will be around 9m depth below existing ground level, and so consideration will need to be given to the stability of the excavation during the construction period.

The upper layers of soils from ground level to a maximum of 3.6m BGL comprise made ground overlying dense clayey sand. This material would have to be cut back to a slope angle of around 30 degrees or less to remain stable over the duration of the construction work, which would make the excavation significantly larger than the plan area of the bunker and impact on adjacent elements of the building. We would recommend that the upper layers of material are supported using interlocking steel piles, which will enable the excavation to be dug with vertical sides and reduce the overall volume of excavation. The piles would be toed into the underlying stone where possible, and anchored back into the underlying sandstone using rock anchors and walers at suitable intervals. This will avoid the need to install props across the full width of the excavation, simplifying access during construction and construction sequencing.

Below approx. 3.6m, the excavation will be undertaken in the Sherwood Sandstone. Based on the SPT values given in the Solmek report, which generally exceed 50 blows, and based on our knowledge of similar materials, we would anticipate that this section of the excavation will be stable without additional support and can be cut to a notionally vertical face. This material typically requires hydraulic breakers to assist with excavation, although it is also sometimes possible to remove the material using 'oversized' excavators fitted with suitable digging buckets.

Once excavated, this material typically breaks up easily into a fairly loose, sandy material, and so can be easily handled out of the excavation for on-site reuse or disposal.

We would anticipate that the Contractor will size the excavation to provide adequate working room for plant and personnel, along with suitable access and egress routes. We would also expect that the Contractor will carry out regular inspections of the excavation and temporary works to ensure they are in a safe and stable condition and are performing as intended.

The Solmek report did not encounter groundwater during drilling / trial piting, and with the exception of one reading in one borehole did not locate any groundwater during subsequent monitoring visits. However, the maximum depth of boreholes was 4.5m BGL, and given the location of and geology of the site it is highly probable that groundwater will be encountered during construction of the Bunker.

Depending on the level and inflow rates of the groundwater, this can be handled in a number of ways.

Should the groundwater be at or around formation level for the bunker, then localised pumping from sumps within the excavation may be sufficient to keep the working area dry.

If the water is higher, but within the sandstone, then it may be necessary to set up a dewatering system via a series of well points to locally depress the groundwater level around the excavation. This may also be necessary to minimise or avoid base heave effects acting on the concrete base slab during the early stages of concrete curing which may act to destabilise it until it has achieved sufficient strength.

If the groundwater level is above 3.6m BGL, and falls within the superficial deposits, then care will need to be taken to design a dewatering and temporary works system that considers the interface between the superficial deposits and underlying solid geology. In such circumstances it may prove necessary to install a complete cofferdam using interlocking steel piles to the full depth of the excavation, as well as dewatering system to control water flows into the base of the cofferdam.

During dewatering it is anticipated that extracted water would be returned to ground by means of a soakaway arrangement within the site boundary, subject to the approval of regulatory bodies. If the volume of extracted water exceeds the disposal capacity, then arrangements will be need to be made to dispose of this water off site.

None of these solutions require specialised techniques or procedures, and it is anticipated that they could be implemented by any suitably qualified Contractor. Further information will be required on the ground conditions below 4.5m BGL before any definitive designs can be prepared for the temporary works for the bunker construction.

8.0 OPERATION AND MAINTENANCE

In operation the incoming fuel will be directly tipped from road going vehicles into the bunker. The fuel will be mixed in the bunker using remotely operated overhead cranes with grabs. These cranes will be used to feed the fuel into the gasification process at an appropriate rate.

The incoming fuel is essentially ‘dry’, with low moisture content, and will be transported to site in covered / sealed vehicles and tipped within a covered tipping hall. As such, there is no opportunity for the fuel to become wet through exposure to rainfall.

It is not anticipated that any leachate or effluent will be produced during storage of the fuel within the bunker, therefore there is no requirement to install drainage within the bunker.

A maintenance schedule will be implemented, which will involve regular visual inspections of the bunker from ground floor level (without entry to the bunker) with less frequent man entry inspections at either pre-set intervals or when the visual inspections indicate they are required.

This type of inspection methodology is in common use in many safety critical situations, such as Railway and Highway bridges, tunnels and culverts and has been used successfully for many years.

The most likely maintenance works that will be required to the bunker will be repairs to surface abrasions maintenance of joints. Repair technology for concrete is well developed, and there are numerous cementious and epoxy based materials that can be used to repair areas of minor mechanical damage. Such materials will equal or outperform the original construction.

Repair works will be tied into the ‘man entry’ inspections of the bunker, and are normally carried out to coincide with plant shut downs.

During maintenance inspections and works, fuel will be removed from the bunker and there may be requirement to ‘wash down’ the bunker during inspection or maintenance works. An open sump will be incorporated into the base of the bunker to permit easier extraction of any such liquid by means a temporary pump. The method of disposal of this liquid will be dependent upon the works underway ie inspection or maintenance works, and will therefore be subject to discussion and agreement with the appropriate regulatory bodies prior to the works commencing.

Given the robust nature of the construction, it would be extremely unlikely that damage or cracking of the bunker walls would occur or develop to the extent where leakage of liquids could occur