



BONC WEN HOUSING DEVELOPMENT, RHOSLLANERCHRUGOG

Geotechnical Design Report
November 2015

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1. INTRODUCTION

The proposed development entails the construction of a new housing estate on a plot of land that currently serves as a car park. It is envisaged that the development will comprise of 9 dwellings arranged into 2 terraces and a detached property. The buildings will be of 2 storeys and traditional load bearing masonry and timber construction. A new estate road will be constructed to provide access to parking spaces for each property and connecting the development to the public highway.

This report discusses the findings of the second stage in the site investigation process which was the intrusive investigation with laboratory testing for contaminants. The investigation and this report have been prepared in accordance with the recommendations of the Desk Study and Site Walkover report which suggested the presence of shallow mine workings.

The report details and discusses the results of these investigations and recommends the most appropriate foundations to use for the structures. The report also utilises the findings of the investigation within a 'CLEA' conceptual model in order to quantify the risk posed by the ground conditions.

Reference should also be made to the Desk Study and the factual Geotechnical Investigation Report.

2. SITE INVESTIGATION

The intrusive site investigation was carried out between the 10th of February and the 3rd of March and comprised of the following:

- 4 x cable percussion boreholes taken to a maximum depth of 13.4m
- 3 x rotary cored boreholes to a maximum depth of 24.1m
- 15 x dynamic probe tests
- 9 x trial pits
- 4 x CBR tests utilising Clegg Impact Hammer
- 2 x soakaway tests to BRE 365
- Laboratory testing of Soils for geotechnical properties and chemical composition

The intrusive site investigation was designed based on the findings of the Desk Study and was in particular aimed at gathering information regarding the following:

- Soils strength for foundation design
- Near soil surface strength to support the road construction and slabs
- The permeability of the ground and its suitability for the use of soakaways to dispose of surface water
- Presence of shallow mine workings
- Potential contaminants from the former use of the site for railway sidings
- Ground gases

3. GROUND CONDITIONS

The site investigation revealed the following ground conditions:

Made Ground	Ranges in thickness from 1.5m to 3.7m. Generally consisted of road construction to 0.5m over 1m thickness of black sand /gravel ash over black/grey gravelly clay. The SPT values ranged from 7 to 16, increasing with depth.
Glacial Till	All four boreholes encountered stiff becoming very stiff gravelly CLAY and were proven to termination at a maximum depth of 13.0m. The thickness of the glacial clay ranged from 6.2m to 10.7m and terminated at 9.8 – 12.5m below ground level. Standard Penetration Test N values ranged from 10 to 26. Undrained cohesion values from the triaxial tests ranged from 56kPa to 274kPa.
Coal Measures	Three boreholes were continued to a depth of 19.7 – 24.1m. The material encountered was extremely weak to weak mudstone within which were interbedded weak to medium strong sandstone and siltstone bands. Coal seams were encountered in 2 boreholes at depths of 17.1 – 20m below ground level. The seam thicknesses varied 0.2 - 0.5m. In BH04 a void was encountered at a depth of 22.6m with a depth of 1.5m. The rock cover above the void was 12.8m

The desk study revealed that the site had historically only been used as railway sidings and the initial conceptual model demonstrated that there was a risk of contamination being present. As such, it was decided that samples would be taken for testing in order to quantify the findings of the conceptual model. The samples locations were chosen at random due to no features of interest showing up within the historical maps. Contamination testing was undertaken in the laboratory using samples of ground taken

from varying depths and locations over the site. The results are contained in the Ground Investigation Report by SRL (ref SRL 164).

5. DISCUSSION

Foundation assessment

The ground investigation revealed that the ground is composed of granular fill of thickness varying from 1.5 - 3.7m. It is considered that the material has been in place since the site was in use as railway sidings and its self-consolidating settlement potential would be low. The SPT N values indicate a loose to medium-dense material which would indicate a safe bearing capacity of 125kN/m² for a 0.75m wide strip founded at a depth of 0.75m below ground level. The anticipated settlement associated with this pressure would be less than 10mm.

Groundwater was not encountered in most of the excavations. Of the 9 pits excavated 5 were dry. Of those showing the presence of water 2 appeared to be associated with saturation of the granular sub-base beneath the slab and only 2 showed water at any depth. The depths in these instances were at 1.3m and 2.2m. The former may affect deeper excavations for drainage but otherwise groundwater is not an issue for consideration within the design of the foundation if they are kept at a shallow depth.

The nature of the underlying ground being of fill with a varying thickness does give rise to concerns as to its uniformity. Whilst the calculated settlements associated with the above foundation loads are small and may be anticipated largely to occur during the construction phase there is a residual risk of some differential settlement due to the non-uniformity of the fill material. To address this concern use could be made of a pseudo-raft foundation with reinforced concrete edge beams tied with an integral slab and designed in accordance with the NHBC recommendations. A lower safe bearing pressure of 100kN/m² would also be appropriate to reduce the magnitude of differential settlement.

The investigation encountered coal seams and a void which may indicate the presence workings. In general the small thicknesses of the seams (less than 0.6m) are such that the risk of their having been worked is low. The void encountered in BH04 was of 1.5m thickness and would be consisted with a thickness of seam that could be worked.

The thickness of rock cover above the void was 12.8m giving a ratio of rock cover to seam thickness of 8.5. This value is less than the generally adopted limit of 10 when considering conical void migration. The quoted ratio is recognised as being conservative with regard to the bulking factor associated with coal measures. The required value of the bulking factor to achieve the cover to seam thickness ratio would be in the lower 30% of the quoted range for bulking. Additionally the use of a conical shape factor leads to a significantly higher migration height than that associated with either a prismatic or rectangular shape. The adoption of a value that is 15% lower than the quoted limit of 10 is therefore not considered to be unreasonable. The use of the pseudo-raft is also considered to an appropriate form of foundation in these circumstances.

Permeability

Permeability tests were carried out in 2nr trial pits in accordance with BRE Digest 365. No movement of the water was measured and the ground is considered to be unsuitable for the use of soakaways. As such storm water flows should be directed either to any nearby watercourses or into the public sewer subject agreement with DCWW. Attenuation of the runoff will be required in either instance.

CBR's and pavement design

CBR testes were carried out using the Clegg hammer method at varying depths in trial pits TC 01 – 04. The results varied from 6% to 23% at depths of 0.6m and 0.7m respectively. The average value was 15% for all results and also for the upper layers. These values indicate the predominately granular nature for the fill material and its suitability as a formation for the access road and as a support for the ground slabs of the dwellings.

Notwithstanding the consistent value of the average for all depths the adoption of the lowest values of 6% is deemed appropriate for the design of the road foundation. At this value capping will not be required unless it is adopted to reduce the depth of the sub-base material for reasons of cost.

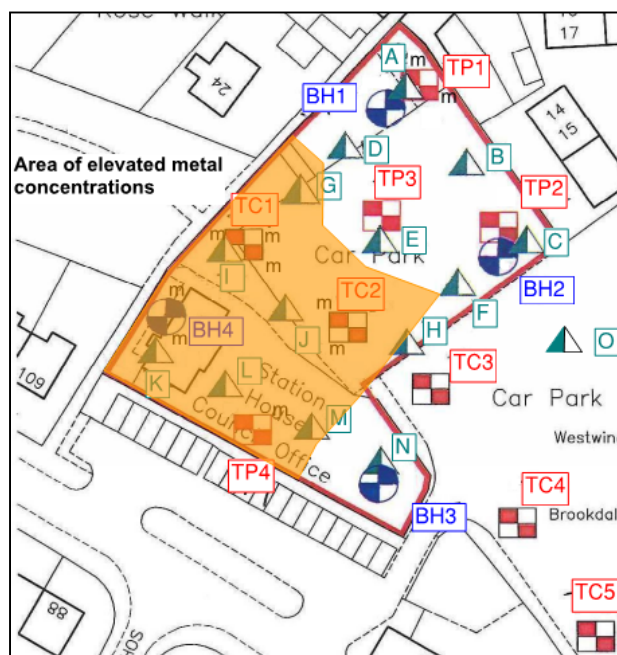
Contaminants

The results of the sample chemical testing have provided detailed information on the concentration levels of chemicals present in the soils of the site. Comparison with the SIRIUS GAC has revealed that the trigger levels for residential use have been exceeded in the following:

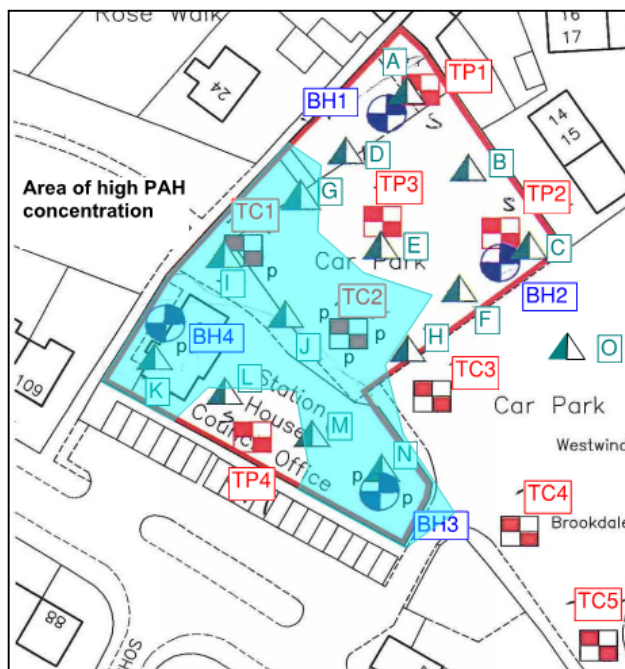
Chemical	SGV	Location	Depth (m)	Measured	Measured / SGV
Metals					
Arsenic	30 mg/kg	TP 04	1.75	79	2.46
Cadmium	10 mg/kg	TC 02	0.9	18	1.80
		TC 01	1.3	19	1.90
Lead	450 mg/kg	TP 01	0.5	550	1.22
Zinc	450 mg/kg	TC 02	0.9	1200	2.7
		TC 01	1.3	1100	2.4
		TP 01	0.5	980	2.1
		BH4	1.0	1400	3.1
		BH4	3.0	1000	2.2
		TC 01	0.6	860	1.9
Inorganics					
pH	4 - 8	TC 02	0.9	8.6	1.1
		BH2	1.0	8.1	1.0
		BH3	0.5	11.5	1.4
		BH3	2.0	11.8	1.5
		BH3	3.0	11.2	1.4
		BH4	0.2	10.8	1.4
		BH4	0.5	9.0	1.1
		BH4	1.0	10.0	1.3
		BH4	2.0	9.6	1.2
		BH1	1.0	8.3	1.0
		BH1	2.0	10.3	1.3
		TC 02	0.6	9.5	1.2

PAH's					
Benzo(a)anthracene	3.3 mg/kg	BH3	0.5	4.3	1.3
		TC 02	0.6	7.7	2.3
Benzo(a)pyrene	0.83 mg/kg	BH3	0.5	4.6	5.5
		BH4	0.2	1.7	2.0
		TC 01	0.6	2.1	2.5
		TC 02	0.6	6.7	8.1
Chrysene	6.1 mg/kg	TC 02	0.6	7.7	1.3
VOC's					
Benzene	0.054 mg/kg	TP 04	1.75	0.11	2.0
1,3,5-trimethylbenzene	0.16 mg/kg	TP 04	1.75	6.4	38.1
1,2,4-trimethylbenzene	0.16 mg/kg	TP 04	0.3	0.48	3.0
		TP 04	1.0	0.17	1.1
		TP 04	1.75	12	75

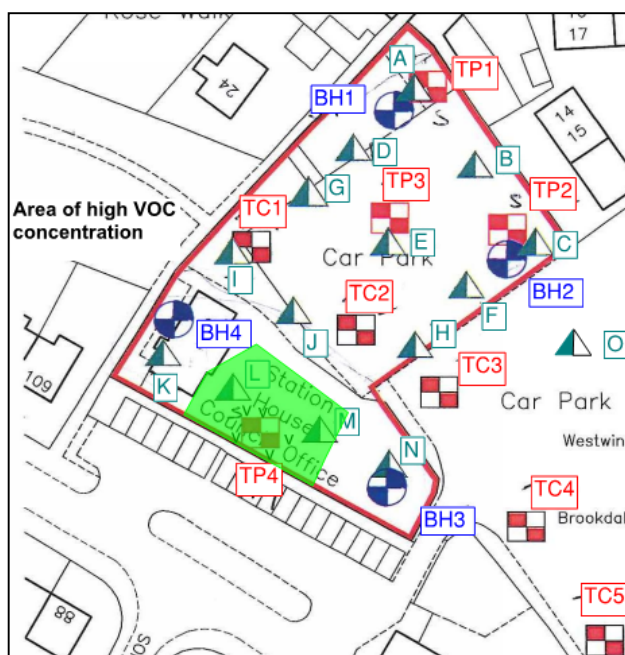
The potential areas associated with the above elevated concentrations are plotted below. The boundaries have been derived by extending the area of contamination midway to a sample point that is below the SGV level.



Area of elevated metal concentrations



Area of elevated PAH concentrations



Area of elevated VOC concentrations

It is clear from the above that contamination is present in the south western portion of the site and that area to the north west and the car park approach to the east is clear

of contaminants. These considerations do not apply to the values of pH quoted above which have elevated levels indicating high alkalinity throughout the site.

Gas Monitoring

The results of the gas monitoring have been assessed in accordance with the NHBC requirements under *Guidance on Evaluation of Development Proposals on Sites where Methane and Carbon Dioxide are Present*. Using the traffic light system within the report no single reading is above the threshold concentrations and the calculation of the corresponding GSV's indicate Green category and that no protection is required.

Using a similar approach to the concentrations of carbon monoxide indicated GSV values that were again Green. However there were instances of concentrations of carbon monoxide which were above the safe value of 350ppm and as such the category should be elevated to Amber 1. The measures would entail a gas membrane and vented slab.

The site is within an area where basic radon protection is required (3-5% of properties above action level). Basic radon protection will also act as a protective measure to natural ground gas such as carbon dioxide, methane and carbon monoxide. As basic radon protective measures have been specified for the residential premises CIRIA guidance advises that further gas monitoring is not required.

6. TREATMENT STRATEGY

In accordance with current guidance the information collated during the preliminary site assessment has been reviewed to establish the conceptual model for the site. The conceptual model is based upon the identification and assessment of potential 'hazards', identified or suspected from the results of the preliminary assessment; the potential 'receptors' that may be affected; and the anticipated 'pathways' to those receptors.

The 'Conceptual Model' takes into consideration the proposed redevelopment of the site with a residential development and the sites environmental setting.

Potential On-Site Contamination Sources and Hazards

The main data source for the hazard identification are the Laboratory Test results quoted above and information on the historical activities both on the site and neighbouring land uses. From the assessment of this data, information on the potential source, type and location of contamination hazard has been identified.

Potential Pathways

There are a number of potential pathways by which contamination may migrate and impact a particular receptor. The following pathways have been identified for the study area:

- *Migration through semi-permeable soils / Made Ground* – The Made Ground / shallow soil at the site is likely to be of medium to high permeability. This material may have the potential to allow migration of contaminants in gaseous or aqueous form.
- *Groundwater within Aquifer* – The solid and drift deposits indicated to underlie the site are shown to constitute aquifers of low susceptibility to groundwater flooding (BGS source). Should contaminants reach the groundwater within these strata, they may affect the quality of the aquifer and / or migrate to potential receptors.

- *Direct contact with contaminants* – Ingestion or dermal contact of contaminants that may be at or near the surface or which become exposed through excavation.
- *Direct and indirect inhalation of contaminants* – From airborne particles, ground gases and vapours, which might be present on site or migrate through services.
- *Direct and indirect Ingestion of contaminants* – From consuming affected ground material, soil, dust or water.
- *Migration through underground service trenches & drains* – Contaminants may migrate off site to local receptors through permeable service trenches or through the site drainage system. This is particularly the case for more mobile contaminants such as oils and solvents.

Potential Receptors

The following potential receptors have been identified and considered as relevant for the whole site. The receptors that may be significantly harmed or polluted by potential contaminative materials (if present) are considered to be:

- *Human health (site workers)* – are considered to be sensitive receptor due to the close proximity in which they are required to work, during the construction process, with contaminated ground/soils and / or contaminated surfaces (if present)
- *Humans (future site users)* – are considered to be a high sensitive receptor as it is proposed to develop the site to accommodate residential units. Future users are potentially at risk via direct contact (dermal), ingestion or inhalation of contaminants (if present) in shallow surface/soil, water or vapours.
- *Groundwater within Aquifer* – is considered to be a low sensitive (unlikely) receptor. The groundwater within 250m of the site is not used for abstraction and the site does not lie within a Groundwater Protection Zone.
- *Surface water* – is considered to be of very low sensitivity as there are no watercourses near the site.
- *Neighbouring properties & land use* – the site is located within a residential area. The nearest residential properties are 10 m to the west. As such neighbouring land users are considered to be of medium sensitivity.
- *Ecological receptors (i.e. fauna and flora)* – considered to be low sensitive receptor during and post construction as the site is within an existing urban area.

- *Building and structures* – considered to be of high sensitivity should chemically aggressive ground conditions or soil gas pose a risk to the future development.

Conceptual model conclusion for Ground and Gas Contamination

The following section combined the consideration of the level of risk given the findings of the investigation.

Ground contamination

The results of the sampling and testing of the sub-soil have been discussed and plotted under Section 5 above. The results indicated that contamination from metals and PAH's is present in the western portion of the site. This area corresponds with the line of the historical railway sidings. The east and south of the site are considered to be free of these contaminants.

There is a localised occurrence of high concentrations of VOC's detected in TP 4. This may be associated with a former fuel store or fuelling point. Its location adjacent to the boundary of the site suggests that it may also be present in the car park immediately to the south-west and the risk of its presence should be shared with the adjacent owner.

High pH levels were found across the site.

Potential receptors for the above hazards are construction workers and residents. In view of the above findings and in order to mitigate the risks potential receptors the following actions are recommended:

- Leave the site as undisturbed as possible and remove only the top layers of inert material comprising the concrete slabs and road construction. These materials arising from the west portion of the site to be disposed of to a suitably licenced tip and assumed to be contaminated unless tested to show otherwise.
- Provide inert capping material to a depth of 0.5m over the area of the site to provide a safe base for the construction of the dwellings and an adequate depth to mitigate potential plant uptake from gardens.

- Where any construction activity is below the level of the stripped site adequate protection and washing facilities would be provided to construction workers to protect them from the potential impact of the contaminants.
- In particular the presence of arsenic in TP 04 should be noted and the design of the development arranged so as to avoid any excavation to depth in this area.
- All material arising from the site should be disposed of to a suitably licenced tip.
- Any ground water from dewatering should be collected in tankers and similarly disposed of to a suitable treatment facility.
- Prior to capping all surface water run-off should be contained within the site and allowed to permeate into the sub-soil.
- The design of the development should seek to minimise excavation of the present sub-soil to minimise its disturbance and risk to construction workers.

Ground gases

The results of the Gas Monitoring indicate that the risk posed to the site by ground gas emanating has been classified as Low to Moderate (Amber 1). Radon protection measure should be adopted with a membrane and vented sub-soil. The Radon protection details would also mitigate any possible risk from ground gases such as carbon dioxide and methane as it is an impermeable barrier.

7. RECOMMENDATIONS

1. The foundations to the dwellings should comprise a pseudo-raft designed to NHBC standards. A safe bearing pressure of 100kN/m² may be adopted for the edge beams design where founded on the granular fill. The formation should be rolled before blinding.
2. Basic radon protection measures should be adopted including a gas membrane and under slab ventilation.
3. The site is not suitable for the use of soakaways.
4. All material arising from the site should be disposed of to a suitably licenced tip.
5. Any ground water from dewatering should be collected in tankers and similarly disposed of to a suitable treatment facility.
6. An inert capping should be laid over the site to a depth of 0.5m to provide a safe base for the construction of the dwellings and an adequate depth to mitigate potential plant uptake in gardens.
7. Prior to capping all surface water run-off should be contained within the site and allowed to permeate into the sub-soil.
8. The design of the development should seek to minimise excavation of the present sub-soil to minimise its disturbance and risk to construction workers.
9. The presence of arsenic in TP 04 should be noted and the design of the development arranged so as to avoid any excavation to depth in this area.

10. Where any construction activity is below the level of the stripped site adequate protection and washing facilities should be provided for construction workers to protect them from the potential impact of the contaminants.

