Structural and geotechnical design of modular geocellular drainage systems

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Summary

Stormwater attenuation and infiltration tanks constructed using modular plastic geocellular units are commonly used as part of sustainable drainage and rainwater harvesting systems. These plastic products have proven to be an effective solution for many projects and as a result of this success the scale of applications has dramatically increased in recent years. Because of their size and below ground location many geocellular unit installations are now significant geotechnical and structural engineering designs with potentially severe consequences if failure occurs.

This guide discusses the different types of geocellular unit available and provides guidance on: the testing that should be carried out to determine their strength and deformation characteristics; the geotechnical and structural design and behaviour of the units and assemblages, practical issues affecting installation and construction works, maintenance of the installations. Recommendations for the design methodology to be followed are included, together with worked examples, which is consistent with the requirements of the Eurocodes.

The concept of a classification system for geocellular unit installations is introduced. The objectives for which allow all parties to understand the degree of complexity of the installation, and also the appropriate level of checking and structural and geotechnical competence needed to ensure safe and efficient design.
Executive summary

Stormwater attenuation and infiltration tanks constructed using modular plastic geocellular units are commonly used as part of rainwater harvesting and sustainable drainage systems (SuDS). These plastic products have proven to be an effective solution for many projects and as a result of this success, the scale of applications has dramatically increased in recent years. Due to their size and location many geocellular unit installations are now significant structural engineering designs with potentially severe consequences if failure occurs. The level of rigour in analysis, testing, design and construction needs to be commensurate with the specific application.

This guide discusses the different types of unit available and provides guidance on the geotechnical and structural behaviour of geocellular units. Recommendations for the design methodology to be followed are included, which is consistent with the requirements of the Eurocodes. The concept of a classification system for geocellular unit installations is introduced. This classification system allows all parties to understand the degree of complexity of the installation, and also the appropriate level of checking and structural and geotechnical competence needed to ensure safe and efficient design.

Detailed guidance is provided on the testing that should be carried out to determine the strength and deformation characteristics of the geocellular units. Previously there has been an over-reliance on short-term compression tests. The actual long-term strength of the units is dependent on how the test is carried out and on the duration of loading. There needs to be a change in testing practice towards more long-term testing and towards test methods that provide more relevant data for design. It is important that there is a commonly accepted and consistent testing regime that enables different products to be directly compared. A framework for this long-term testing is provided, including a methodology to derive an appropriate design strength for a particular application.

The buried units interact with the ground, and the pressures applied to the units are sensitive to the nature of the ground and groundwater regime at a site. Guidance is provided on simple design methods and on the situations where more sophisticated geotechnical analysis may be necessary.

A discussion on the practical issues that should be considered in construction and maintenance of geocellular unit installations is included. In particular, consideration should be given to how construction activities either for the geocellular installation itself or for adjacent works may affect the geocellular unit performance. The large majority of the documented failures of such systems have been as a result of poorly controlled construction processes. Improvements to procurement practice are given. Finally, the guide recommends further areas of research to better understand the behaviour of buried geocellular units by carrying out well-instrumented large-scale in situ tests and for these tests to be back-analysed by calibrated non-linear numerical modelling.
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### Glossary

**Action**
Forces (loads) applied to a structure.

**Amorphous**
A material with no regular crystalline structure. Such plastics exhibit a glass transition or softening point, but have no melting point. Polystyrene, polycarbonate and polyvinyl chloride (PVC) are examples of amorphous plastics.

**Attenuation system**
A system designed to control the peak flow from a given site by providing a facility for the temporary storage of stormwater.

**Battering back**
“The process of removing material around a trench or excavation such that the walls are sloped back at an angle rather than vertical.” (from BAC Australia, 2010).

**Benkelman beam deflection survey**
A static deflection method to determine the rebound deflection of a pavement under a standard wheel load and tyre pressure, with or without temperature measurements.

**CAT SCAN**
A tool that is used to locate buried utilities.

**CAT II/CAT III**
Independent checking categories according to HA (2012).

**Catchpits**
A chamber located at regular intervals along a piped drainage system. The catchpit has a sump that allows collection of sediment and foreign objects, which have entered the drainage system and also allows access to the pipework for survey and maintenance works.

**Characteristic load**
The expected (representative) loads to be supported by a structure.

**Characteristic strength**
The strength at the given design life derived from creep rupture tests. This is a cautious estimate of strength derived from a suite of creep rupture tests minus two standard deviations. If specialist tests are carried out, then the cautious estimate of strength may be modified as outlined in Section 4.2.1.

**Creep**
Increase in deformation over time under a constant applied load.

**Creep rupture**
The failure to hold a load over time. In a creep-rupture test failure is defined as either rupture of the unit, an increase in the rate of displacement (when plotted on a graph of log displacement against log time) or when displacement has reached an equivalent of six per cent strain.

**Design load**
The characteristic load multiplied by the appropriate partial factors of safety relevant to the limit state being considered.

**Design strength**
The characteristic strength modified by the appropriate material partial factor.

**Differential scanning calorimeter (DSC)**
A thermal analysis instrument frequently used for the melting point determination of plastics. It also yields the energy of a melting process, which can be used to assess the level of crystallinity in a plastic (see Level of crystallinity).

**Forebay**
A small basin or pond upstream (or at the upstream end) of the main drainage component, with the function of trapping sediment.

**Geocellular tank**
This comprises a number of geocellular units joined together to form a tank that performs the required design function, eg soakaway.

**Geocellular unit**
Plastic structure used to form geocellular tanks, upon which load testing is undertaken to determine design strength.

**Geocellular unit installation**
See Geocellular tank.
Abbreviations and acronyms

CAT       Cable avoidance tool
CBR       California Bearing Ratio
CCTV      Closed-circuit television
CDM       Construction (Design and Management)
CEN       European Committee for Standardisation
CF        Clay fraction
CSWIP     Certificate Scheme for Welding and Inspection Personnel
DSC       Differential scanning calorimeter
EA        Environment Agency
EC0       Eurocode 0 (BS EN 1990)
EC7       Eurocode 7 (BS EN 1997-1 and BS EN 1997-2)
HE        Highways England
HGV       Heavy goods vehicle
HSE       Health and Safety Executive
GC        Geotechnical Categories (Eurocode 7)
GI        Ground investigation
IGS       International Geotextile Society
RoGEP     UK Register of Ground Engineering Professionals
SLS       Serviceability limit state
SSSI      Sites of Special Scientific Interest
SuDS      Sustainable drainage systems
TSS       Total suspended soils
UDL       Uniformed distributed loads
ULS       Ultimate limit state
1 Introduction

1.1 BACKGROUND

1.1.1 Scope for new guidance

In the mid-1980s plastic honeycomb structures (known as geocellular units) were first used for stormwater storage in mainland Europe, below permeable pavements. Their use became more widespread in the early 1990s and in the late 1990s honeycomb attenuation structures were introduced into the UK.

During the last 15 years, there has been a rapid increase in the number and different types of geocellular units available and they are now widely used for attenuation, storage and infiltration in stormwater drainage systems. They can also be used for other uses such as gas venting and drainage. Geocellular units can be considered to be a versatile void former, as the nature of the material (eg geotextile, geomembrane) used to wrap around the unit will dictate its functionality.

Despite this widespread use, consultants and contractors tend to rely on manufacturers to provide structural design and construction advice. Guidance by Wilson (2008) was a considerable step forward, and for the first time provided a single source of design guidance.

Following the work by Wilson (2008), there have been further developments including:

- understanding of geocellular unit behaviour
- guidance documents that have been published in other countries
- lessons learnt from project experience.

In recent years the scale and complexity of geocellular unit installations has significantly increased, eg depths in excess of three metres, and located adjacent to or beneath heavily trafficked highways. Many installations are now significant structural engineering designs with potentially severe consequences if failure occurs. So, the level of rigour in analysis, testing, design and construction needs to be commensurate with the specific application, and in some cases should be similar to or in excess of that given to, for example, an underground basement for a building.

Based on these developments, this new publication aims to provide guidance on:

- design management, appropriate competency and communication framework for the parties involved
- installation classification to allow the appropriate design and construction management effort for each project to be determined
- appropriate test methods to assess the reference strength and structural performance of the units over their design life
- different analytical methods, and the relevant material factors and load factors to ensure design is consistent with Eurocode requirements
- procurement of geocellular units
- construction methods and supervision
- long-term maintenance.

This guide provides information on geotechnical and structural behaviour. It does not cover other design issues such as hydraulic performance, for which the reader should refer to Woods Ballard et al (2007) and British Water (2005).
1.1.2 SUDS development and attenuation/infiltration tanks

With continuing urbanisation, climate change and intensified rainfall, Britain's surface water drainage infrastructure is becoming increasingly strained. This is causing more frequent and more severe flooding across the country.

To help combat this, sustainable drainage systems (SuDS) have been developed as a sustainable design philosophy for surface water drainage. The aim of SuDS is to mimic, as closely as possible, the natural drainage of a site before development and to minimise the impacts of the development on surface water flows and infiltration.

As an important part of the SuDS philosophy, infiltration or attenuation systems form a very attractive option to store rainwater until the receiving system can accommodate it. Infiltration techniques, such as soakaways as shown in Figure 1.1, discharge runoff directly into the ground using geocellular units. However, drainage by infiltration requires sufficiently permeable soil conditions and low peak groundwater table. Often it is not a practicable solution, particularly in urban areas. In terms of the attenuation technique in geocellular units (see Figure 1.2) rainwater is allowed to back-up behind a flow control device, which limits the peak discharge rate.

Woods Ballard et al (2007) gives more details about how to design infiltration or attenuation systems.

![Figure 1.1 Example of infiltration system](image1.png)

![Figure 1.2 Example of attenuation systems](image2.png)
1.2 GEOCELLULAR UNITS AND DESIGN PRACTICE

Modular plastic geocellular units are commonly used for providing stormwater infiltration and attenuation tanks for new developments (Figure 1.3). Geocellular tanks are usually constructed using modular units that are cuboid plastic structures with a high void ratio and porosity (both typically in excess of 90 per cent). The individual units or boxes are placed together to form a large tank surrounded by either an impermeable geomembrane or a permeable geotextile, or a combination of both.

Frequently engineers, architects and clients have been of the view that as the geocellular units are part of the drainage system, only drainage and overall hydraulic performance considerations are important. There has been an over-reliance on manufacturers’ information regarding the load carrying capacity of geocellular units and perhaps little understanding among design engineers of the types, validity and implications of the load testing undertaken. The implications of incorrect application and/or installation are not always fully understood.

It is important to realise that geocellular modular units should be considered as geotechnical structures from a design point of view because they act as pseudo-retaining structures and support earthworks materials. These installations are structures and should be designed by competent engineers using sound structural and geotechnical principles. They can be subject to significant loads when adjacent to existing structures and/or roads that can increase earth pressures on the units. They are vulnerable to becoming damaged during construction activities if site control is poor.

An understanding of the long-term deformation and load-carrying capabilities of the units over their required design life is needed. Reliable site-specific data needs to be obtained and appropriate analyses are required to ensure that installations do not collapse or move excessively under the imposed loads.

Geocellular units are not all the same. There are various types of box units that have different structural characteristics and load carrying capability. Load testing and design calculations should take account of these differences. As illustrated in Figure 1.3 a geocellular tank is composed of many geocellular units. For the purposes of this guide, a geocellular unit is defined as the plastic box that is load tested, ie it is the basic building block used to construct geocellular tanks. It is also important that
whoever is designing these systems has an understanding of the overall site development and envisaged construction activities. This will inform the design process and facilitate project risk management.

1.3 PROJECT EXPERIENCE

There have been failures of modular geocellular units (Figure 1.4) both in the UK and elsewhere (Wendebourg, 2006, and Paul and Wieland, 2006). However, from the available evidence, none have been because of intrinsic problems with geocellular units or tanks, and the number of failures in relation to the number of completed installations is small.

The main contributing factors to most failures are:

- Inadequate information for designers and little appreciation of the importance of an appropriate structural and geotechnical design.
- Inadequate design, often not taking account of particular ground conditions on a site, or not allowing for long-term deformation of the units.
- Lack of understanding of the structural performance of the units. This can lead to overloading by, for example, running heavy plant across units that were not designed to carry such loads or using plant such as cranes adjacent to units (Figure 1.5), or by using unsuitable backfill containing, for example, boulders or soft clay.
- Lack of appreciation of the influence of groundwater levels or the effect of surface water flows into excavations during construction.
- Inappropriate laboratory testing that overestimates the strength of the units.
- Use of units not in accordance with the manufacturers' limitations, eg placing them too deep.
- Detailing errors and late on-site changes by contractors, eg changing pavement layers, spanning the units over channels or changing the type of unit.

*Figure 1.4 Example of the consequences of failure of a modular geocellular tank after three years*
1.4 THE IMPORTANCE OF APPROPRIATE STRUCTURAL DESIGN

 Apart from the obvious health and safety implications of a collapse and the cost of replacing a tank, there are other implications that should be considered:

- The cost of replacing overlying construction such as car parks and the resulting costs due to loss of use can be far more than the cost of replacing the tank.
- The reputation of the designers and/or suppliers and relationships with clients will be damaged.
- The acceptance by the industry of modular plastic geocellular units for such use will be undermined.

The consequences of tank collapse can be far reaching and appropriate structural design should be a high priority for clients, consultants and suppliers, in the same way that it is for other underground structures (see Figure 1.6).
1.5 CONCEPT OF GEOCELLULAR TANK CLASSIFICATION

There are many geocellular units available in the UK (see Chapter 2). Different tank installation configurations and layouts can lead to different structural behaviours, depending on the unit type, site location, construction factors and predominant loading direction. So it is necessary to understand the fundamental properties of each type of unit and the tank assembly in the context of the applied loads, and site-specific ground conditions.

In order to achieve this, a system of classification is proposed in this guide for geocellular tank installations (see Chapter 3). Eurocode 7 (EC7) defines three Geotechnical Categories (GC) that may be used to establish geotechnical design requirements. The basic EC7 approach has been developed, to provide specific classification criteria for geocellular systems.

The classification system will allow the parties involved, ie the client, designer and manufacturer, to understand the degree of complexity of the project. It will also define the appropriate level of checking and structural and geotechnical competence needed to ensure safe and efficient design.

It is important that a competent engineer is appointed to oversee the design and construction of the geocellular tanks. In particular to categorise the design and develop solutions with respect to the specific application, site and ground conditions, design requirements and criteria, risk allocation and assessing the consequences of non-performance of the installation. The tanks interact with the ground, so the responsible engineer needs to be experienced in ground engineering.

1.6 DESIGN MANAGEMENT

Design responsibility must be clear. However, at present there is often unclear design responsibility between the client, overall scheme designer and geocellular manufacturer. Geocellular units may not be specified properly and the main contractor can often source supplies independently without having clear criteria.

Design of installations constructed using modular geocellular units should:

- Define the design and communication responsibilities between the appointed parties, ie client, designer, contractor and unit manufacturer. This can be done in accordance with the Construction (Design and Management) Regulations 2015 (CDM2015).
- Take account of overall site topography and potentially adverse effects of nearby structures/earthworks, vegetation (eg retaining walls, slopes, temporary, permanent or future planned works).
- Take account of site history and geology (eg ground/groundwater contamination, historic landslips, or mining).
- Consider the soil-structure interaction and all applied (both vertical and lateral) loads, including accidental and construction loading.
- Take account of construction sequencing, both for the actual geocellular tank installation and the surrounding works.
- Be based on appropriate laboratory tests, testing duration in-line with design life taking account of creep and creep rupture (see Glossary) of the plastic units.
- Use appropriate partial factors for material and ground strength, and load factors.
- Analyse all appropriate limit states (deformation/failure modes), in particular consider serviceability deflections due to long-term deformation (ie creep) of the plastic units and the tanks.

The design requirements for a safe and serviceable unit installation are summarised in Figure 1.7. The design methodology is considered in detail in Chapter 5.
1.7 INTERIM GUIDANCE

At the time of writing (2014) there are various standards that are under development relating to the testing procedures (short- and long-term testing) for geocellular units. As with all CIRIA publications, this provides guidance on good practice. The information given here, such as testing requirements, are consistent with those in the standards under development and are not necessarily the testing procedures currently employed.

So, it should be recognised that there may not be the testing data available, which is consistent with the requirements of this guide for all geocellular units commercially available. In the absence of this data the manufacturers will need to give guidance to the designers on the long-term strength and deformation properties of the units, and designers will need to make an appropriate judgement on the design strength to use.

However, by September 2015, manufacturers should have complied with the testing requirements outlined within and be able to provide relevant load testing data for their geocellular units.
1.8 LAYOUT OF THE GUIDE

Throughout the guide there may be some terms that are unfamiliar to the reader. Where this is the case reference should be made to the glossary, which can be found within the prelims. The guide is structured as follows:

Chapter 1 provides some background information on the use of geocellular tanks and outlines the purpose of the guide and the need for new design guidance.

Chapter 2 provides an introduction to the types of geocellular unit available, as well as an introduction to the raw material (plastic) used in their construction, key lessons learnt from previous use and developments in international design codes. The structural behaviours of geocellular units and of geocellular tanks are described. The concept of ground-structure interaction is also introduced. It is recommended that this chapter is read and understood before the following chapters on load testing, design, construction and maintenance.

Chapter 3 outlines the new site classification methodology – its principal aim is to identify projects with high intrinsic complexity and/or where the consequences of failure are severe. The scoring system and details of the proforma to be used to classify the sites are also outlined.

Chapter 4 describes load testing of geocellular units. Testing requirements that are consistent with the requirements of the Eurocodes are outlined. Note this requires a change from current practice towards more long-term testing.

Chapter 5 details the methodology to be followed for the geotechnical and structural design of the geocellular units in accordance with the Eurocodes. Guidance is also given on issues such as pavement engineering when the geocellular units are to be incorporated within a pavement.

Chapter 6 provides guidance on the procurement of geocellular units.

Chapter 7 details some of the issues likely to arise during construction of geocellular tanks that may affect their performance. This chapter is of importance to the designer as well as the contractor, as the construction methodology can affect the design of the geocellular units, eg pressures due to compaction of backfill, loading due to temporary stockpiles of material adjacent to the tanks.

Chapter 8 provides an introduction to maintenance of geocellular tanks including recommendations for maintenance strategies.

Chapter 9 presents the conclusions of the guide and details areas where it is recommended further work and research are undertaken.

Appendix A1 contains the site classification proforma to be used for a geocellular tank, more details of which are found in Chapter 3.

Appendix A2 contains some worked examples to illustrate the design methodology outlined in Chapter 5.

This publication provides guidance on the following issues:

- **Design management**: to ensure there is proper co-ordination and allocation of responsibilities.
- **Classification system for geocellular unit installations**: this allows the complexity of a particular project to be determined, which in turn determines the appropriate level of checking and structural and geotechnical competence needed to ensure safe and efficient design.
- **Test methods to determine the strength of the geocellular units**: short-term compression tests should be used to determine the variability in strength of a unit only, and not for design strength. Design strengths are obtained from creep rupture tests, which allow an appropriate strength to be determined for the design life of the installation.
- **Specialist testing**: for more complex installations specialist testing, eg fatigue testing when cyclic loads are being applied, may be required and guidance for this is provided.
- **Code compliance**: the introduction of the Eurocodes is a significant change in UK practice and this guide outlines how to develop Eurocode compliant designs.
• **Analysis**: an overview of ground-structure interaction is provided. Methods of analysis and the design checks required are discussed and the relevant partial factors are outlined.

• **Procurement**: guidance on the procurement of geocellular units is provided.

• **Construction**: the need for good site control is emphasised. Good communication between all parties (geocellular unit supplier, designer, contractor, client) is very important.

• **Maintenance**: many units can be difficult to maintain, so greater effort is needed in hydraulically designing systems in order to reduce the risk of long-term siltation. Reducing uncontrolled runoff into tanks during construction is particularly important.

Of these, the two key areas are the introduction of the classification system and the change in testing practice of the units, and these are summarised in Chapter 9.
SITE CLASSIFICATION PROFORMA

Design and construction classification and check proforma

Proforma objectives and general notes
1. The PRINCIPLE AIM of the scoring system is to identify projects with high intrinsic complexity and/or where the consequences of failure are severe.
2. CIRIA C737 Chapter 3 Site classification methodology; should be studied before using the proforma.
3. Proforma provides the methodology to classify installations and recommend the appropriate level of expertise to oversee design and construction.
4. Proforma is user friendly to non-technical clients, highlighting basic checks/tasks and guides building professionals to basic design and construction considerations.
5. The methodology utilises the existing Construction Design Management Regulations 2015 (CDM2015), which provides the legal framework and duties for construction projects.
6. Can be used as auditable evidence that the design process, checks and duty of care obligations discharged.
7. The principal designer (CDM2015) will be tasked with the responsibility of ensuring the project proforma are utilised and signed off by the building professional(s) and countersigned by the principal designer. The client or principal designer may delegate this task to the installation designer to manage and ensure completion of the forms.
8. Methodology considers structural and geotechnical design and construction and NOT hydraulic design or performance or Environment Agency (EA) consents.
9. This Proforma pack is to be retained together so that all appointees are able to review the whole. The enclosed forms will be completed by the various parties.

CDM background: note that under CDM2015 the following legal duties apply.

Client (commercial)
- To appoint the principal designer and principal contractor, ensuring they have the skills, knowledge, experience and organisational capability.
- Provide pre-construction information.

Principal designer
- Identify, collect and pass on pre-construction information between the parties.
- Co-ordinate all aspects of the design work.
- Liaise with the principal contractor regarding ongoing design work.
- Facilitate good communication between the appointees.
- Prepare and update the Health and Safety File.

Definition of zones of influence:

Slopes or stockpiles beyond h +10 m are not considered to be of influence.
Foundations or loaded/trafficked pavements beyond h +2m are not considered to be of influence and considered to be remote*

NB: Pile supported structures: zone of influence should be taken as \( x + h \), where \( x = 5D \) for piles supporting vertical load only, \( x = 8D \) for piles supporting horizontal loads (\( D \) = pile diameter)

Excavation in front of retaining walls will need to take account of the passive zone supporting the wall. Angle \( P \) typically will vary from 55 to 65°.
\( \phi \) = the angle of shearing resistance of the soil.
The distance \( d \) is dependent on the depth of the wall and the soil strength. Excavations beyond \( d + h \) are considered remote*.

Notes on use of proforma
1. Each box in the following sections is awarded a score. All applicable boxes should be ticked, ie potentially more than one per section. The sum of the scores will determine the appropriate classification determined for the project assessed.
2. In general the greater the perceived risk the higher the score for the assessed element.
3. NB: Building Control Regulation specifies that a soakaway, domestic or otherwise, must be at least 5 m from any adjacent structure.

1. Type of site
   - Domestic single dwelling. (units less than 3 m³ capacity, project below notification requirements for CDM) Score = 0
   - Commercial application (CDM applies Part 3) Score = 10

2. Use
   - Soakaway Score = 5
   - Grey/rainwater storage Score = 10
   - Attenuation Score = 10
   - Other Score = 15

Specify ...........................................................................................................
### 3. Pre design/construction information held

Information held by principal designer and distributed to the designer, supplier/manufacturer and principal contractor. Score = 0 for single domestic dwellings. Tick all boxes where info held. If any information missing Total score for this section = 35

<table>
<thead>
<tr>
<th>Information Held</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local knowledge/geological mapping</td>
<td></td>
</tr>
<tr>
<td>Basic ground investigation, confirmation of soil type</td>
<td></td>
</tr>
<tr>
<td>(window samples + TP)</td>
<td></td>
</tr>
<tr>
<td>Desk study</td>
<td></td>
</tr>
<tr>
<td>Services information/search</td>
<td></td>
</tr>
<tr>
<td>Ground water data/assessment</td>
<td></td>
</tr>
<tr>
<td>Overall site development plan</td>
<td></td>
</tr>
</tbody>
</table>

### 4. Topography/retaining walls/stockpiles/foundations (within zone of influence)

Adjacent to sloping existing ground, embankments or temporary stockpiles: Score = 30

Adjacent to existing or planned, structures retaining walls, piles or shallow foundations: Score = 60

Adjacent to level ground (defined as h + 10 m, see definition diagram): Score = 0

### 5. Installation development location and use

<table>
<thead>
<tr>
<th>Location and Use</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential garden (remote)</td>
<td>0</td>
</tr>
<tr>
<td>Pasture/woodland/parkland (remote) landscaping</td>
<td>0</td>
</tr>
<tr>
<td>Arable farmland (tractor/harvester access)</td>
<td>5</td>
</tr>
<tr>
<td>Residential driveway/play areas/sports field</td>
<td>5</td>
</tr>
<tr>
<td>Car park (light use with height access restrictions)</td>
<td>15</td>
</tr>
<tr>
<td>Car park general (no height access restrictions)</td>
<td>20</td>
</tr>
<tr>
<td>HGV parks/low speed roads, installation within zone of influence</td>
<td>30</td>
</tr>
<tr>
<td>Full highway loading installation within zone of influence</td>
<td>80</td>
</tr>
<tr>
<td>Railway loading installation within zone of influence</td>
<td>110</td>
</tr>
</tbody>
</table>

### 6. Depth of installation

<table>
<thead>
<tr>
<th>Depth of Installation</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 1.0 m to base</td>
<td>0</td>
</tr>
<tr>
<td>Cover less than 1.0 m and trafficked</td>
<td>25</td>
</tr>
<tr>
<td>Between 1.0 and 3.0 m to base</td>
<td>5</td>
</tr>
<tr>
<td>Cover greater than 1.0 m and trafficked</td>
<td>15</td>
</tr>
<tr>
<td>Greater than 3.0 m to base</td>
<td>20</td>
</tr>
<tr>
<td>Cover to units 0.3 m to 2.0 m landscaped</td>
<td>10</td>
</tr>
<tr>
<td>Cover greater than 2.0 m</td>
<td></td>
</tr>
</tbody>
</table>

### 7. Construction phase (temporary works, TW)

<table>
<thead>
<tr>
<th>Construction Phase</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>TW stockpile/plant stored within zone of influences</td>
<td>25</td>
</tr>
<tr>
<td>High ground water likely within excavation</td>
<td>20</td>
</tr>
<tr>
<td>TW access/construction plant tracking over installation (excluding plant used in construction of the actual tank)</td>
<td>20</td>
</tr>
<tr>
<td>Plant/materials exclusion zone implemented within zone of influence</td>
<td>0</td>
</tr>
<tr>
<td>Use of mobile or tower cranes within zone of influence</td>
<td>30</td>
</tr>
<tr>
<td>No provision for ground/rainwater removal, ie pumped sump</td>
<td>15</td>
</tr>
</tbody>
</table>

**Assessment total score**