Ground Gas Information Sheets

Basement waterproofing and ground gas
Wilson, Card, Mortimer and Roberts

Ground Gas Information Sheet No 4
Paper 4.0 19/11/2018
Keywords: ground gas, dissolved methane, landfill gas, risk assessment, basement, waterproofing

Basement Waterproofing and Ground Gas

Steve Wilson MSc BEng CEng MICE CEnv CSci CWEM MCIWEM FGS ROGEP ASoBRA
Technical Director, The Environmental Protection Group Limited, Warrington, UK (stevewilson@epg-ltd.co.uk)

Geoff Card BSc PhD CEng FICE EurIng CGeol FGS CSci
GB Card and Partners

Sarah Mortimer BEng CGeol ASoBRA
Associate, The Environmental Protection Group Limited

John Roberts CSSW
Principal Engineer, The Environmental Protection Group Limited




Waterproof basement construction is, in many cases, inherently resistant to ground gas ingress. A simple process to design waterproof basements that also provide gas resistance is explained in this Ground Gas Information Sheet. The method does not require any special site investigation or characterisation of gas risk to be completed, over and above that which would normally be completed for any development. Detailed Quantitative Risk Assessment is only likely to be required where higher risk gas sources are present or if the gas protection system requires value engineering to rationalise it (or remove it altogether).

Introduction

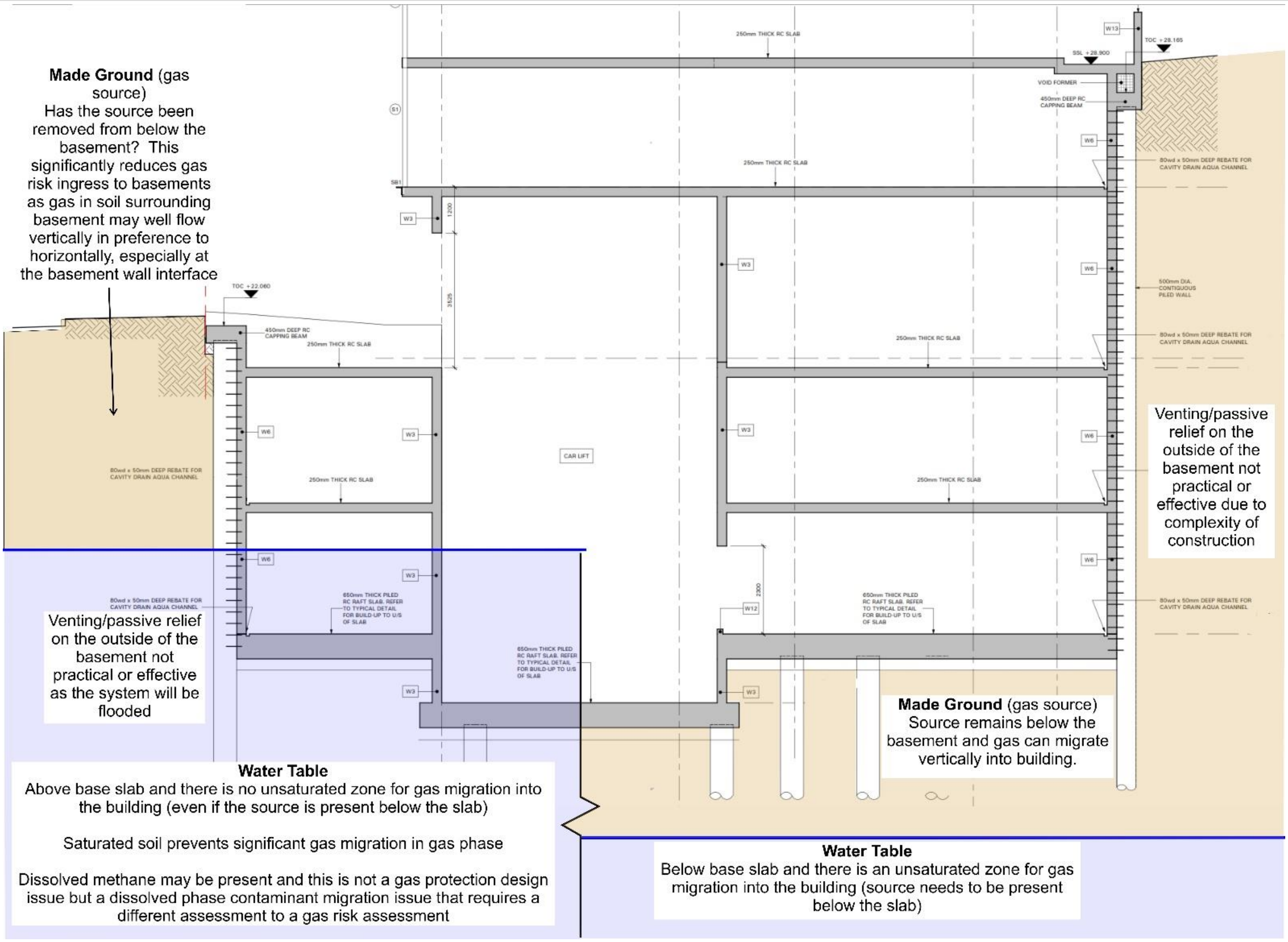
Designing basements to be both waterproof and gas resistant is a relatively straight forward process on most sites. In urban areas where the majority of basements are constructed the risk from ground gas migration is normally very low and many waterproofing designs will be sufficient to manage the gas risk as well.

At the other end of the risk scale gas ingress will be a significant concern when basements are constructed in or close to landfills that are producing large volumes of gas, into colliery spoil, where VOCs are present or where gas migration from open mine workings or abandoned gas/oil wells could occur.

This Ground Gas Information Sheet provides a simple framework for designing waterproof structures so that they also provide adequate gas resistance.

The framework covers the assessment of gas or vapour phase migration in the unsaturated zone. A contaminated groundwater migration assessment is necessary where basements are constructed into groundwater that contains dissolved gases or VOCs, or where non aqueous phase liquids may be present in contact with membranes. The guidance on ground gas risk assessment is not relevant in these cases. The two different scenarios are shown in Figure 1.

Citation: Wilson S, Card GB, Mortimer S and Roberts JH (2018). Basement Waterproofing and Ground Gas. Ground Gas Information Sheet No 4. EPG and GB Card and Partners Limited.



(a) Basement below groundwater **(b) Basement above groundwater**

Figure 1 Gas phase and contaminated groundwater migration into basements

Process

A flow chart showing the design process is provided in Figure 2. This identifies two routes, the first is a routine approach that should apply to most designs. The second involves more comprehensive DQRA that will be required in some cases. This will be the exception rather than the rule.

The flow chart refers to different waterproofing types which are those in British Standard BS8102: 2009 as follows:

Type A – Barrier protection which comprises a separate barrier to gas ingress in addition to the structure (ie waterproof membranes). For gas resistance GCLs are not acceptable unless they have an integral polymeric membrane to provide the gas resistance.

Type B – Protection that is integral to the structure. For gas resistance this could be reinforced concrete or sealed steel sheet piles. For gas resistance the concrete should be designed to BS EN 1992 to limit crack widths to 0.3mm.

Type C – Protection against water ingress that is provided by an internal water management system. Commonly referred to as a drained cavity.

Citation: Wilson S, Card GB, Mortimer S and Roberts JH (2018). Basement Waterproofing and Ground Gas. Ground Gas Information Sheet No 4. EPG and GB Card and Partners Limited.

If a drained cavity is used as part of a gas protection system (by providing ventilation) it must be assumed that at some point it could have methane >5% (unless proven otherwise) and it must be isolated from the occupied space by a gas membrane. The gas membrane itself may be part of a cavity drain sheet but it must be protected from damage (for example by drilling into walls for fixings) by at least 150mm of blockwork or concrete. It must also be sealed on all laps and penetrations and have a gas transmission rate less than 40ml/m^2/day/atm. The drainage should be a standalone system and should not be connected to any internal drainage system. All sumps, etc should be vented externally to prevent gas building up.

Most often waterproofing will include two or more types of protection (for example a combination of Type A (waterproof membrane) and Type B (reinforced concrete structure). In terms of membranes some key criteria are provided in Figure 2. The list is not exhaustive and arguably the puncture and tear resistance are the most important factors in membrane selection.

The membranes should be assessed for suitability, considering the guidance in BS8485: 2015. The overriding requirements in the standard for a gas membrane (as stated in Clause 7.2.4) are that it should be:

a) Sufficiently impervious to methane and carbon dioxide (this is reflected by the GTR). The limiting values for GTR in Figure 2 are provided for guidance only when using the routine approach;

b) Capable after installation of providing a complete barrier to the entry of the relevant gas;

c) Sufficiently durable to remain serviceable for the anticipated life of the building and duration of gas emissions;

d) Sufficiently strong to withstand in service stresses (eg due to ground settlement if placed below a floor slab);

e) Sufficiently strong to withstand the installation process and following construction activities until covered (eg penetration from steel fibres in fibre reinforced concrete, penetration of reinforcement ties, tearing due to working above it and dropping tools). It is difficult to state global limiting values for thickness, puncture resistance and tear resistance because for example some thin membranes have superior puncture resistance. However, experience has shown that membranes with a minimum static puncture resistance of 2000N (tested to BS EN ISO 12236) and an impact resistance of 650mm or greater (tested to BS EN 12691 Method B) are sufficiently robust for basement water/gas proofing, although care is still required to ensure the membrane is not damaged. These values should be used as a guide. At the end of the day the choice of membrane cannot be based on tests results alone – a very good indicator of robustness is to take a sample of the material and try and push a screwdriver through it. CIRIA Report C748 (Wilson et al 2014) Section 6.4 provides a good overview of the key performance properties for membranes;

f) Chemically resistant to degradation by other contaminants that may be present.

Many waterproofing membranes meet the requirements for resistance to damage and durability better than some gas membranes. Thin scrim reinforced aluminium foil core membranes are not normally suitable for basement gas protection and will not have sufficient puncture resistance to perform adequately in this environment. If these are proposed a comprehensive assessment should be completed of likely movement in the membrane (which can tear the aluminium) and damage during construction (which can lead to corrosion of the foil core).

The maximum gas transmission rate (GTR) is different depending on the reliance that is placed on the membrane to prevent gas ingress. BS8485: 2015 suggests a maximum value of 40ml/m^2/day/atm. This applies where the membrane can be used in any situation, the most common being loose laid over block and beam floors in housing developments. In this case it is feasible

Citation: Wilson S, Card GB, Mortimer S and Roberts JH (2018). Basement Waterproofing and Ground Gas. Ground Gas Information Sheet No 4. EPG and GB Card and Partners Limited.

that the membrane will be the only protection against gas ingress and a low value of GTR is necessary. This would apply to waterproofing membranes that also act against ground gas ingress if they are the only method of protection.

Where waterproofing membranes are used with a Type B reinforced concrete barrier and are bonded to it, there is less reliance on the membrane. Concrete is inherently resistant to the passage of gas and flow only occurs in significant quantities at defects or cracks in the concrete that pass through the whole depth of the concrete. The risk of defects in either system coinciding with each other is very low. Therefore, the allowable GTR can be increased.

The percentage area of cracks that pass through the complete thickness of concrete in the Type B structure will be 1% or even lower so the gas ingress will be at least 100 times lower than if gas could permeate across the whole floor or wall area. Increasing the allowable GTR in this situation to 500ml/m^2/day/atm is acceptable (a factor of 12.5). Again it is stressed that these values are provided for guidance when using the routine approach in Figure 2 of this information sheet.

The routine method in the flow chart can be applied to all grades of waterproofing. There are however two routes depending on the internal use of the basement. These uses are based on those described for different grades of waterproofing in BS8102: 2009:

Grade 1 – Car parking, plant rooms and workshops that have high ventilation rates. Similar low risk situations include tanks in water treatment works that are only accessed occasionally under confined space working rules.

Grade 2 and 3 – Areas that are occupied and require a drier environment. This includes residential, commercial, leisure and office use.

Site investigation

Consideration of a basement does not impose any additional requirements for site investigation where ground gas may be present. As for any site the investigation should be managed and approved by a suitably qualified and experienced professional. It should follow the guidance provided in the following British Standards as appropriate:

BS5930 – Ground investigations.

BS10175 - Investigation of potentially contaminated sites.

BS8576 - Investigations for ground gas.

As with any investigation monitoring well response zones should be isolated into a single source or pathway. This is especially important if a source may be removed (eg Made Ground) as part of the basement construction. It is important that all potential (and credible) sources of gas and pathways for gas migration are investigated.

Gas monitoring wells should ideally be installed in the unsaturated zone. Gas monitoring data from flooded wells is not reliable and can give an unreliable indicator of elevated gas risk where none is actually present.

If basements extend below groundwater level then the dissolved gas concentration should be measured along with groundwater concentrations of VOCs. However, the assessment of such data is a contaminated water issue and is beyond the scope of this information sheet.

Citation: Wilson S, Card GB, Mortimer S and Roberts JH (2018). Basement Waterproofing and Ground Gas. Ground Gas Information Sheet No 4. EPG and GB Card and Partners Limited.

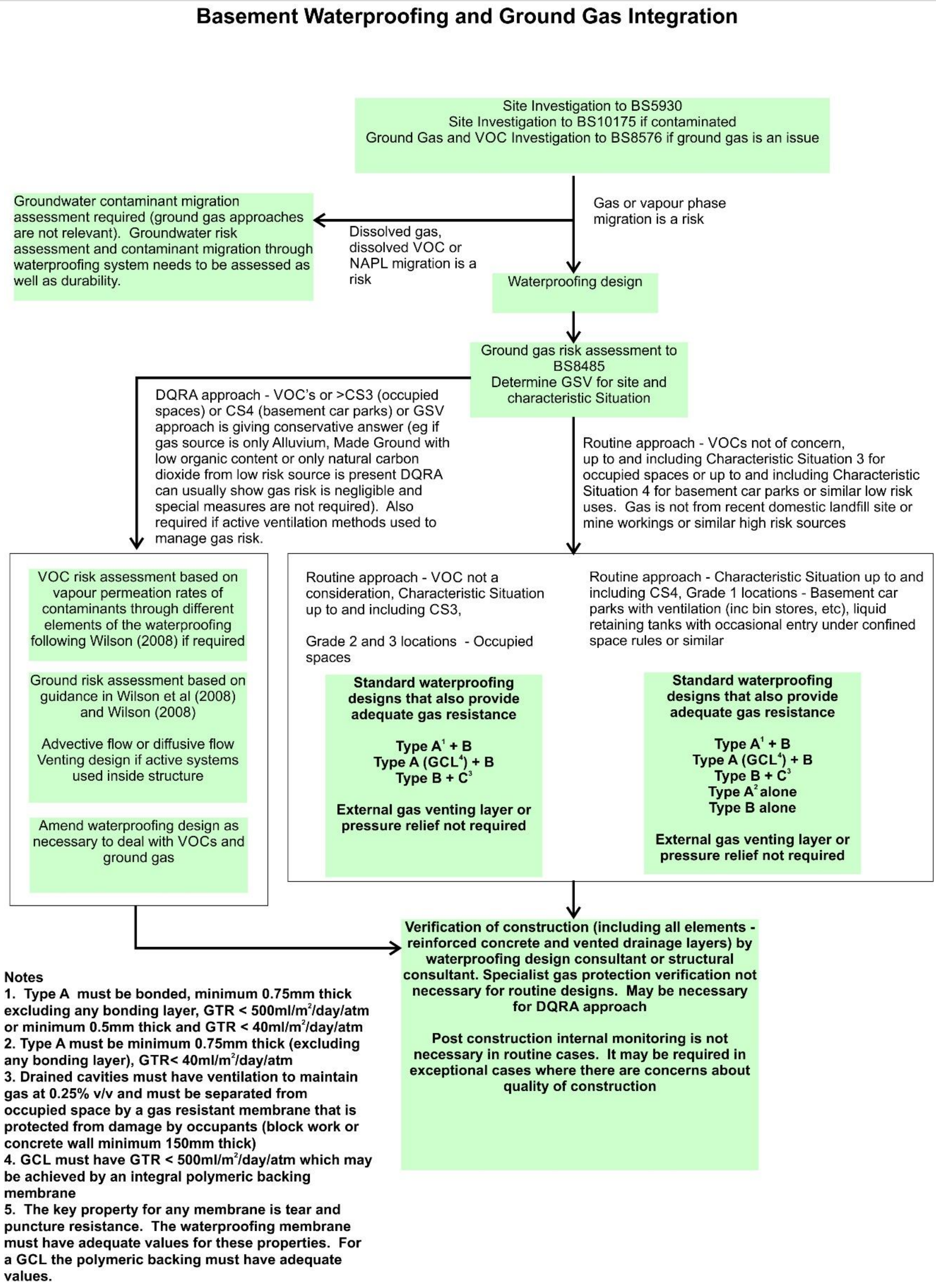


Figure 2 Flow chart for combined waterproofing and ground gas mitigation design for basements

Citation: Wilson S, Card GB, Mortimer S and Roberts JH (2018). Basement Waterproofing and Ground Gas. Ground Gas Information Sheet No 4. EPG and GB Card and Partners Limited.

Ground Gas Risk Assessment

The first consideration in a ground gas risk assessment for a basement is whether the gas source will be removed by the basement excavation. In many cases if Made Ground is removed from below the basement slab the gas risk is removed. If the Made Ground has low degradable content it would not generate sufficient gas to cause migration through walls into a building. An example is the general Made Ground that is present below most urban areas that has accumulated over time. Basements have been constructed through this with no gas protection for at least one hundred years with no known elevated risk from gas migration.

The site classification for ground gas risk is independent of the proposed development. The Characteristic Situation is an indicator of the gas risk associated with the source and migration pathways. Therefore, the GSV approach in British Standard BS8485: 2015 can and should be used in the first instance to classify the hazard posed by gas in a particular site. On most sites this will be sufficient along with the routine solutions given in Figure 1.

The assessment should be approved by a suitably experienced professional. That could be a Chartered Engineer, Chartered Geologist, SiLC, SoBRA accredited risk assessor or similar with suitable experience. Chartered professionals will have to comply with a code of professional conduct and have been scrutinised by their peers to assess their competence. Simply having a degree in a related discipline is not sufficient.

The assessment of ground gas risk and determination of the Characteristic Situation should follow the guidance in BS8485: 2015. It is beyond the scope of this GGIS but many assessments incorrectly estimate the gas risk based on gas concentrations (in particular where carbon dioxide alone is present above 5%) resulting in gas mitigation being specified when it is not needed.

Routine solutions can be used in the following instances

- Grade 2 and 3 waterproofing environments with gas Characteristic Situations up to and including CS3;
- Grade 1 waterproofing environment (basement car parks or similar) with gas Characteristic Situations up to and including CS4.

Detailed Quantitative Risk Assessment should only be required in the following instances and will be the exception rather than the rule:

- Basement is constructed in or close to recent (<40 years old) domestic landfill and gas migration to the basement is possible (the risk of gas migration should consider geology and topography and not just distance);
- Basement constructed in colliery spoil;
- Basement constructed over shallow mine workings or abandoned gas/oil wells;
- If the GSV approach is over conservative and the cost of a DQRA is less than the savings to be made in mitigation requirements; or
- VOCs are present.

On most sites piled foundations will not provide a preferential pathway for gas migration. This is explained in Wilson and Mortimer (2017) which identifies the specific situations where piles may form pathways and the extent to which this could change the gas risk.

Compatibility with BS8485 generic scoring system

The scoring system in BS8485: 2015 is a generic screening approach to the design of gas protection. It is empirical and can be over ridden by detailed quantitative risk assessment (DQRA). It also requires DQRA for higher risk sites. This approach for waterproof structures adopts the same philosophy with the routine approach used for most designs.

The solutions arrived at in the routine approach are consistent with the scoring system in BS8485. A comparison is provided in Table 1.

Citation: Wilson S, Card GB, Mortimer S and Roberts JH (2018). Basement Waterproofing and Ground Gas. Ground Gas Information Sheet No 4. EPG and GB Card and Partners Limited.

Table 1 Comparison of routine design approach to BS8485

Waterproofing Grade	BS8485 Building type	Maximum CS in routine design	Routine Solutions	BS points summary
Grade 1	Type D	CS4 (3.5 points required)	Type A + Type B	Type A membrane or membrane backed GCL = 2pts, Type B structure = 2pts
			Type B + Type C	Type B structure = 2 points, Type C cavity = 1.5 points if designed to give "good" ventilation
			Type A	Type A membrane = 2 points, Basement car park ventilation = 4 points
			Type B	Type B structure = 2 points, Basement car park ventilation = 4 points
Grade 2/3	Type A to C	CS3 (4.5 points required)	Type A + Type B	Type A membrane or membrane backed GCL = 2pts, Type B structure = 2.5pts
			Type B + Type C	Type B structure = 2.5 points, Type C cavity = 2.5 points if designed to give "very good" ventilation

Grade 2 and 3 waterproofing design situations are analogous to Type A to Type C building use in BS8485 (Grade 3 is likely to be required for residential use, Type A building in BS8485). Grade 1 waterproofing is comparable to Type D buildings.

Verification

Historically there have been problems with gas membrane installations in housing developments where the use of extremely thin aluminium foil laminate membranes that are very prone to damage is common. This is less of an issue in basement waterproofing because waterproof membranes are generally thicker and more puncture resistant than many gas membranes. In many cases the gas resistance also relies on the structural reinforced concrete element of the basement. Therefore, the requirement for verification of installation is different for basements. Specialist gas membrane verifiers are not necessary to verify waterproof construction in routine situations. Verification can be undertaken by the waterproofing designer or the structural engineer. Both should be appointed under a suitable form of contract to supervise or inspect the construction. In any event, concrete construction should be verified by someone with suitable experience. Using the designer to verify the construction may be better for the client as it gives one point of responsibility.

It is not necessary to verify basement gas protection using internal monitoring apart from exceptional circumstances (eg where the construction is in doubt). There are practical and commercial difficulties in doing this. To be of any use the monitoring must be completed when the basement is fully heated and vented to replicate in service conditions. This may cause delays in handover to allow the monitoring to take place. Furthermore, the monitoring requires instruments with low limits of detection (1ppm) and in a new building there are numerous sources of VOCs and other flammable gases that can give a false indication of gas ingress from the ground. Continuous monitoring at fixed points is of little use in verifying the performance of gas protection.

Conclusions

In urban areas where the majority of basements are constructed the risk from ground gas migration is normally very low. At the other end of the risk scale gas ingress will be a significant concern when basements are constructed in, or close to, landfills that are producing large volumes of gas, where VOCs are present, into colliery spoil or where gas migration from open mine workings or abandoned gas/oil wells could occur.

A simple framework is provided for designing waterproof basements or other structures so that they also provide adequate gas resistance. This gives routine solutions for low risk situations and identifies the exceptions when DQRA may be necessary.

The framework covers the assessment of gas or vapour migration in the unsaturated zone. A contaminated groundwater migration assessment is necessary where

Citation: Wilson S, Card GB, Mortimer S and Roberts JH (2018). Basement Waterproofing and Ground Gas. Ground Gas Information Sheet No 4. EPG and GB Card and Partners Limited.

basements are constructed into groundwater that contains dissolved gases or VOCs, or where non aqueous phase liquids may be present in contact with membranes.

Specialist verification of routine designs is not necessary and normal site supervision or inspection to confirm adequate construction will be all that is required.

References

BSI (2006) British Standard BS EN ISO 12236: 2006. Geosynthetics. Static puncture test (CBR test).

BSI (2018) British Standard BS EN 12691: 2018. Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of resistance to impact.

BSI (2009) British Standard BS8102: 2009. Code of Practice for Protection of Below Ground Structures Against Water From the Ground.

BSI (2011) British Standard BS10175: 2011. Investigation of Potentially Contaminated Sites. Code of Practice (+A2:2017).

BSI (2013) British Standard BS8576: 2013. Guidance on Investigations for Ground Gas – Permanent Gases and Volatile Organic Compounds (VOCs).

BSI (2015) British Standard BS5930: 2015. Code of Practice for Ground Investigations.

BSI (2015) British Standard BS8485: 2015. Code of Practice for the Design of Protective Measures for Methane and Carbon Dioxide Ground Gases for New Buildings.

Wilson S, Abbot S and Mallett H (2014) Guidance on the use of plastic membranes as VOC vapour barriers. CIRIA Report C748.

Wilson S and Mortimer S (2017) Piled Foundations and Pathways for Ground Gas Migration in the UK. Environmental Geotechnics Paper 17.00009, 14/11/2017.

Examples

The following are examples of design combinations and approaches that have been used for successful waterproof structure design in sites affected by ground gas.

Example 1

Basement grade	Grade 3 – residential use
Characteristic Situation	Characteristic Situation CS2.
Floor slab and wall construction (Type B barrier)	650mm thick reinforced raft and 200mm thick reinforced concrete walls
Waterproofing membrane (Type A barrier)	External bonded waterproofing membrane
Approach used	Routine approach – Type A + Type B

Example 2

Basement grade	Grade 1 - Car park
Characteristic Situation	N/A – VOCs are risk driver
Floor slab and wall construction (Type B barrier)	1000mm thick raft with designed to watertight construction
Waterproofing membrane (Type A barrier)	VOC resistant primary membrane with permeation rates assessed by risk assessment, 1mm thick GCL sacrificial layer to protect primary membrane – GCL with contaminant resistant bentonite and integral polyethylene liner
Approach used	Groundwater contamination migration assessment required to assess risk from dissolved VOC migration

Citation: Wilson S, Card GB, Mortimer S and Roberts JH (2018). Basement Waterproofing and Ground Gas. Ground Gas Information Sheet No 4. EPG and GB Card and Partners Limited.

Example 3

Basement grade	Grade 1 – water treatment tank with occasional access under confined space working procedures (ie gas monitoring before entry)
Characteristic Situation	Characteristic Situation CS3.
Floor slab and wall construction (Type B barrier)	500mm thick reinforced concrete slab with 300mm thick reinforced concrete walls. Watertight construction to retain liquids (Class 1 to BS EN 1992-3)
Waterproofing membrane (Type A barrier)	Not required
Approach used	Routine approach – Type B only

Example 4

Basement grade	Grade 3 – residential use
Characteristic Situation	Characteristic Situation CS2 (but hazardous gas flow rates indicate CS1, elevated carbon dioxide at 7.4% resulted in the consultant incorrectly classifying the site as CS2).
Floor slab and wall construction (Type B barrier)	500mm thick reinforced concrete slab with 300mm thick reinforced concrete walls. Watertight construction to retain liquids (Class 1 to BS EN 1992-3)
Waterproofing membrane (Type A barrier)	Not required
Approach used	DQRA approach used to remove need for gas protection to basement

Citation: Wilson S, Card GB, Mortimer S and Roberts JH (2018). Basement Waterproofing and Ground Gas. Ground Gas Information Sheet No 4. EPG and GB Card and Partners Limited.