GROUND GAS

Ground Gas Protection Best Practice Guide

This Ground Gas Protection Guidance Document, developed by leading experts in the field and driven by the Offsite Alliance Technical Group, was created in response to growing concerns in the industry about the integration of effective ground gas protection measures in modern construction methods.

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FOREWORD

Ground gases such as methane, carbon dioxide, radon, and volatile organic compounds (VOCs) pose significant challenges to construction projects. Traditionally, gas protection systems have been designed for conventional buildings, but as Modern Methods of Construction (MMC) gain traction. The industry must rethink how these protective measures are integrated into offsite-manufactured structures.

This Ground Gas Protection Guidance Document, developed by leading experts in the field and driven by the Offsite Alliance Technical Group, was created in response to growing concerns in the industry about the integration of effective ground gas protection measures in modern construction methods.

Recognising this as an increasingly urgent issue, the Technical Group initiated a collaborative effort to provide a comprehensive best practice guide tailored for the offsite construction sector.

It explores key risks, design considerations, material specifications, and verification processes to ensure that modular and panelised buildings meet the highest safety and performance standards. From understanding gas migration pathways to selecting the right membrane solutions, the document offers practical insights into effective mitigation strategies. It highlights case studies demonstrating innovative approaches, challenges, and lessons learned from real-world projects.

Ensuring safe, compliant, and efficient construction requires industry collaboration, and this guide serves as a critical resource for designers, specifiers, manufacturers, and installers.

By adopting the best practices outlined, we can enhance safety, sustainability, and efficiency in the built environment.

LET'S BUILD WITH CONFIDENCE - protecting people, projects, and the future of offsite construction.

This guidance has been written and compiled by Justine Gray with contributions from Barrie Ackroyd, Matthew Egan, Matthew Lennard, Neil Salvidge, Mathew Spiller, Gaynor Tennant, Karen Thornton, Steve Wilson and the Offsite Alliance Technical Panel.

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INTRODUCTION

Ground gas protection has become a critical consideration in offsite construction, requiring a fresh approach to specifying, detailing, and installing effective systems. To address these challenges, the Offsite Alliance Technical Sub-Group for Ground Gas Protection was established, bringing together leading experts from across the industry.

Authored by Justine Gray, Technical Services Manager at Galaxy Insulation & Dry Lining Ltd, this sub-group has worked collaboratively with designers, product manufacturers, offsite manufacturers, specifiers, installers, and warranty providers to develop this comprehensive guidance document.

This document serves as a best practice guide for the offsite industry, ensuring that appropriate ground gas protective measures are implemented where required. It covers a wide range of hazardous ground gases, including methane, carbon dioxide, radon, and volatile organic compounds (VOCs), as well as less common gases such as hydrogen sulphide, hydrogen, and carbon monoxide.

Recognising the unique challenges presented by Modern Methods of Construction (MMC), the document examines two key scenarios:

1. **Membrane installation as part of the volumetric system - where protection is integrated during factory production.**
2. **Membrane installation onsite - where traditional and hybrid approaches are required.**

While not an exhaustive guide to ground gas risk assessment, design, installation, or verification, this document provides practical insights and references to existing industry standards, ensuring it can be used in conjunction with wider guidance to support safer and more effective ground gas protection in offsite construction.

ACKNOWLEDGEMENTS

Barrie Ackroyd – Director, Membrane Testing Solutions Ltd
Over 40 years in construction, 37 years of which in geomembrane supply/installation. Former UK Gas Sector Manager at Landline Ltd, developed passive/active gas ventilation systems, contributed to CIRIA best practice guidance, and founded MTS Ltd in 2014 to deliver independent validation, verification, and design services. Level 3 Assessor (NVQ Level 4 Validation) and active in CL:Aire accreditation schemes.

Matthew Egan - Director, By Design Group
An engineer and innovator leading Modern Methods of Construction (MMC) in the UK and globally. Co-founder of By Design Group, Lundell Ltd, and Rethink Corporation, integrating design and technology for smarter building. As Chair of BSI CB/301 and Advisor to ISO TC59/SC19, he shapes national and global MMC standards. Advancing productivity, safety, and sustainability through leadership and innovation.

Justine Gray – Technical Services Manager, Galaxy Construction Solutions
20 years' experience in ground gas and structural waterproofing qualified Certified Surveyor in Structural Waterproofing (CSSW). Provides impartial, compliant, and cost-considered technical solutions.

Matt Lennard – Principal Geo-Environmental Engineer, NHBC
Chartered Geologist and SoBRA-accredited risk assessor with 20+ years in contaminated land. Steering group member for NHBC Foundation NF94, CIRIA C795, and guidance on basements and ground gases.

Neil Salvidge – Director, Neil Salvidge Training, Assessment & Development Ltd
Construction professional with a career spanning site operations, contaminated land, and NVQ training. Specialist assessor supporting frameworks for gas membrane installation, supervision, and verification.

Mathew Spiller – Group Commercial Manager, Geoshield Ltd
Over 20 years in membranes, with the last 8 focused on ground gas protection. 2 years as Chairman of British Geomembranme Association, Radon Council member, and contributor to CIRIA guidance.

Gaynor Tennant – Founder & CEO, Offsite Alliance
A leading voice in modern construction, recognised for driving collaboration, policy reform, and best practice across the sector. She has extensive experience in MMC project delivery and industry transformation.

Karen Thornton – Land Quality Service Manager, NHBC
30 years in Brownfield redevelopment and new home delivery. Chartered Building Engineer, CIWEM Fellow, and Steering Committee Member for technical publications on ground gases and VOCs.

Steve Wilson – Technical Director, The Environmental Group Ltd
Chartered Engineer, SoBRA-accredited risk assessor, CL:Aire SGPV specialist, and BS8485 drafting committee member. Co-author of key ground gas guidance including NF94, CIRIA C795, and CL:Aire best practice. Expert in gas protection design for modular/offsite construction.

MODERN METHODS OF CONSTRUCTION

The construction industry is undergoing a significant transformation with the increasing adoption of Modern Methods of Construction (MMC). MMC shifts construction away from traditional, labour-intensive, and weather-dependent on-site processes toward offsite manufacturing and streamlined assembly.

At its core, MMC involves the factory production of building components, panels, or entire modular units, which are then transported to the construction site for final assembly.
This approach offers several key advantages, including:

- ✓ Faster build times due to controlled manufacturing environments.
- ✓ Improved quality assurance with precision-engineered components.
- ✓ Reduced material waste, making construction more sustainable.
- ✓ Enhanced energy efficiency through better insulation and airtightness.

The Challenge of Ground Gas Protection in MMC

While MMC delivers greater efficiency and quality control, it also presents unique challenges when it comes to ground gas protection. Unlike traditional construction, where gas membranes are typically installed beneath foundations, MMC often relies on alternative foundation types and integrated floor systems. These differences mean that conventional gas protection strategies may not always be directly transferable to offsite-manufactured buildings.

As MMC continues to evolve, so too must the approach to ground gas protection. The following sections of this report explore different MMC categories and how they interact with ground gas risks, setting the foundation for best practice solutions in offsite construction.

Simply - Modern Methods of Construction (MMC) or 'offsite construction' refers to the building or part of the building is constructed in a factory, and assembled on-site

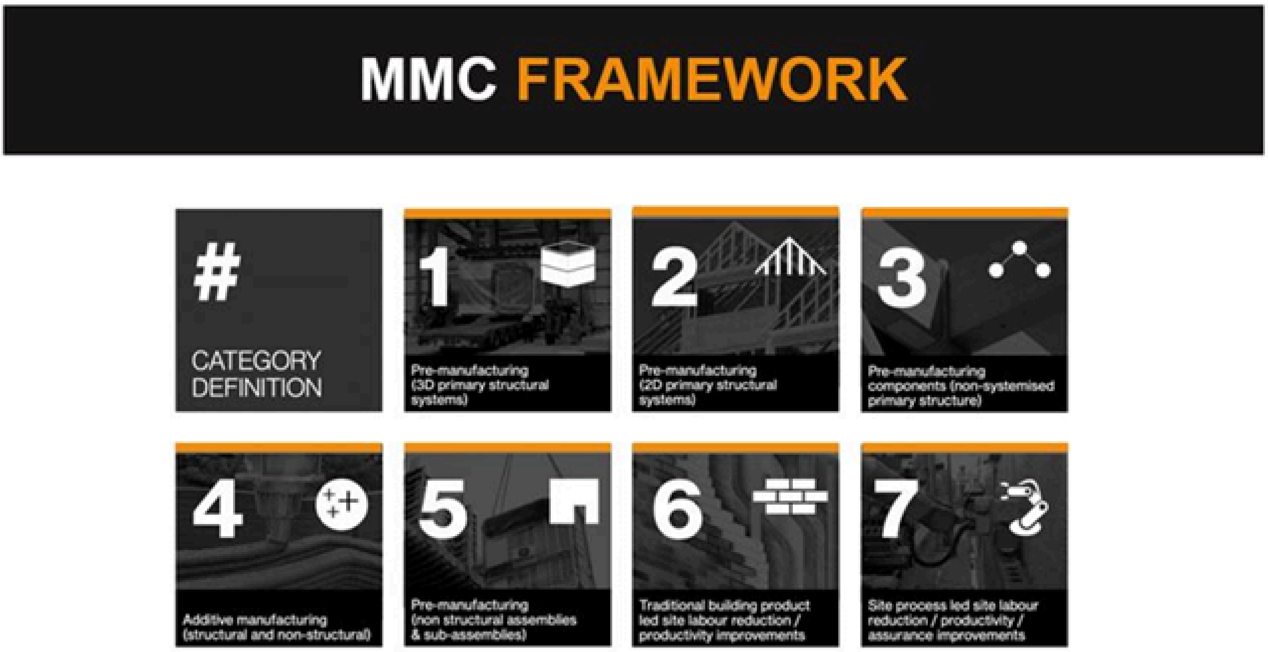
In April 2019, the UK government published the Modern Methods of Construction (MMC) Definition Framework, a key output from the Ministry of Housing, Communities and Local Government (MHCLG) MMC Working Group. This framework was designed to bring greater structure and consistency to the classification of offsite construction methods.

The framework currently outlines seven distinct categories of MMC, covering a broad spectrum of offsite construction approaches. These range from structural building systems and elements to non-structural assemblies and advanced material innovations**, with categories 6 and 7 focusing on process improvements aimed at reducing on-site labour and increasing efficiency.

However, significant work is currently underway to refine and evolve this framework further. Industry stakeholders, and technical experts are actively working to bring more clarity, guidance, and alignment to the MMC definitions.

This includes:
Improving classification criteria to better reflect emerging technologies.
Enhancing regulatory guidance to ensure MMC methods align with building safety and performance standards.
Developing clearer implementation pathways to support widespread industry adoption.

As MMC continues to advance, these refinements will play a crucial role in standardising best practices, ensuring the framework remains fit for purpose and adaptable to future innovations in offsite construction.



MMC encompasses a wide breadth of solutions and products. As the market continues to evolve and expand, flexibility is required to optimise the programme or project strategy to incorporate MMC and deliver against the intended outcomes. In this, there is no ‘one-size fits all’ approach and it is important to recognise that some sites will require more than one category or may not be suitable.

CATEGORY 1 - Modular volumetric

3D volumetric construction is a highly systematic approach where entire three-dimensional building modules are manufactured in controlled factory conditions before being transported to site for final installation. These volumetric units can arrive in varying levels of completion, from a basic structural shell to fully finished modules with internal and external finishes, services, and fittings pre-installed. This method ensures structural integrity, enhances quality control, and significantly reduces on-site construction time.

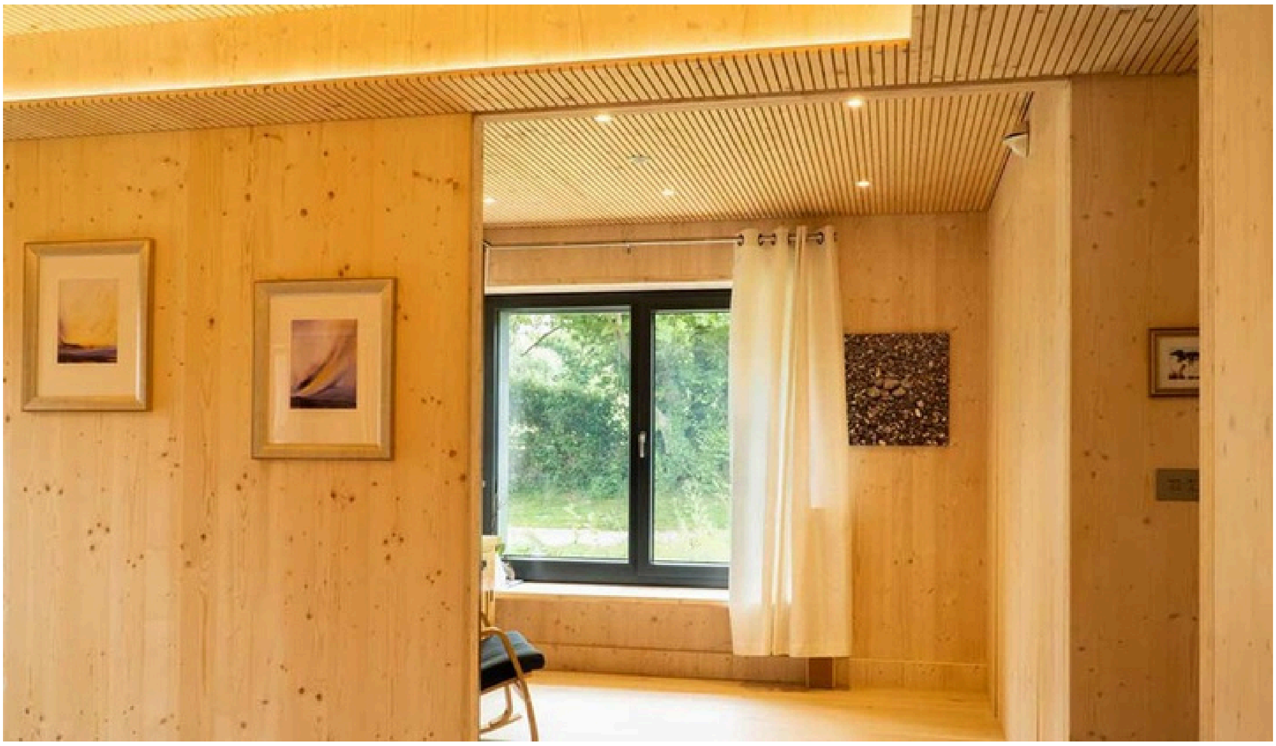
CATEGORY 2

Panelised Systems There are several categories of panelised systems, which are 2D shapes. The most common approach, and the one industry is most familiar with, is open panels, or frames, which consist of a skeletal structure only. The services, insulation, external cladding and internal finishing are installed on-site. A good example is timber frame construction.

The amount of work on open panel systems completed in the factory can be increased to reduce site work required. Often the panel component is finished on one side and in the case of a wall, they often encompass windows, doors and façade. More complex panels, typically referred to as closed panels, involve more factory-based fabrication and include lining materials and external claddings. The system includes structural performance for primary walls and all floors. Examples include light gauge steel frames, structural insulated panels (SIPs), prefabricated wall panels and balcony assemblies.

CATEGORY 3

Pre-Manufacturing – Non systemised structural components Use of pre-manufactured structural members made of framed or mass engineered timber, cold rolled or hot rolled or pre-cast concrete. Members to include load bearing beams, columns, walls, core structures and slabs that are not substantially in-situ workface constructed and are not part of a systemised design. This category, although focused on superstructure elements, would also include sub-structure elements such as prefabricated pile caps, driven piles and screw piles. Category 3 MMC methods offer advantages in terms of efficiency, quality control, and reduced construction waste compared to traditional onsite construction. However, they require a higher degree of on-site labour and coordination for finishing and integrating components. These methods can be suitable for projects where a balance between offsite prefabrication and on-site customisation is desired.



CATEGORY 4

Additive manufacturing, commonly known as 3D printing, involves the layer-by-layer fabrication of building components using digital models. This technology can be applied both onsite and offsite, offering the potential for customized, resource-efficient, and rapid construction.

While additive manufacturing holds significant promise in the MMC sector, its adoption in large-scale construction projects remains limited. Challenges such as material constraints, regulatory approvals, and scalability have slowed its widespread use. However, ongoing advancements in printing technologies and sustainable materials could see this method play a more prominent role in the future of MMC.

CATEGORY 5

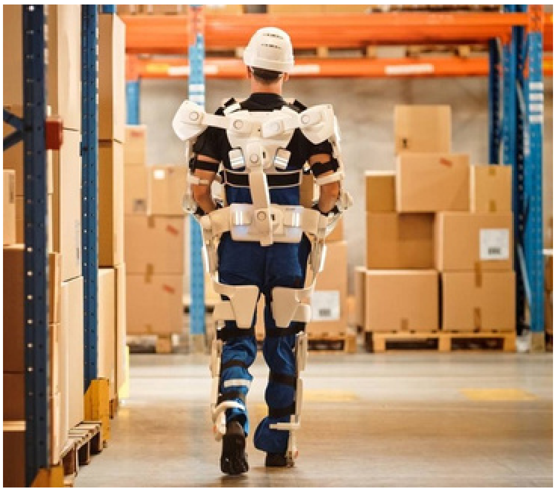
Pre-Manufacturing – Non-structural assemblies and sub-assemblies Category 5 refers to pre-assembled component systems. These are items manufactured and installed as part of building adding pre-manufactured value and are often seen on traditional construction sites Some of the most common are pre-assembled roof trusses, door sets, GRP chimneys and dormer windows. Other common items include bathroom pods and pre-assembled utility cupboards. On larger buildings preassembled M&E cassettes can be manufactured off site and connected on site.

CATEGORY 6

Traditional building product led site labour reduction This category comprises traditional building materials that have evolved so that they are quicker, easier and safer to install. They are either large format versions of traditional materials, or materials that have been developed to be easier to install with less reliance on onsite labour. Category 6 solution types include internal walls, external walls, roofing finishes, materials that have been specifically cut to size, e.g. pre-sized plasterboard and also materials that have been adjusted to be easier to install, e.g. brick slips.

CATEGORY 7

Site process led labour reduction This includes the use of systems and processes onsite to drive productivity by removing unnecessary work stages, enabling better and faster installation and improving health and safety. Examples include measures to encapsulate a site to secure weather-proof conditions, standardised temporary work (e.g. a modular scaffold), use of BIM connected to onsite workflows, visual aids such as AR or VR, physical aids such as exoskeletons and productivity tools such as GPS.



BACKGROUND TO GROUND GAS PROTECTION

Integrating traditional ground gas protection methods into modular construction has proven challenging. Conventional gas protection measures are typically incorporated within on-site foundation construction, following established principles designed for traditional building methods. However, with the rise of Modern Methods of Construction (MMC), the industry must reconsider how ground gas protection is achieved within modular and panelised systems.

This shift presents an opportunity to explore alternative materials and innovative approaches, many of which may already be integrated into the floor construction of modular units. By leveraging these advancements, the offsite sector can develop more efficient, adaptable, and cost-effective gas protection solutions while maintaining compliance with safety standards.

Understanding Ground Gases and Their Risks

A wide range of gases can be found in the ground beneath buildings. Some are naturally occurring, such as radon, while others result from human activity, including methane from landfills or industrial contamination. These gases do not always pose a direct risk—hazards arise when gas movement leads to accumulation in confined spaces, potentially reaching toxic, flammable, or explosive concentrations.

The Source-Pathway-Receptor Model

Gas protection design follows a risk-based approach, which assesses:

Source – Where the gas originates (e.g., landfill sites, natural geological formations).
Pathway – How the gas migrates through the ground and structures (e.g., through permeable soils, service trenches, or cracks in foundations).
Receptor – The building and its occupants who could be affected by gas ingress.

A plausible linkage between these three elements determines whether protective measures are required. Key factors include the rate of gas emission, the volume of gas present, and the potential for hazardous accumulation.

Purpose of This Guide

This guidance document aims to provide a practical framework for incorporating ground gas protection within modular construction. It outlines:

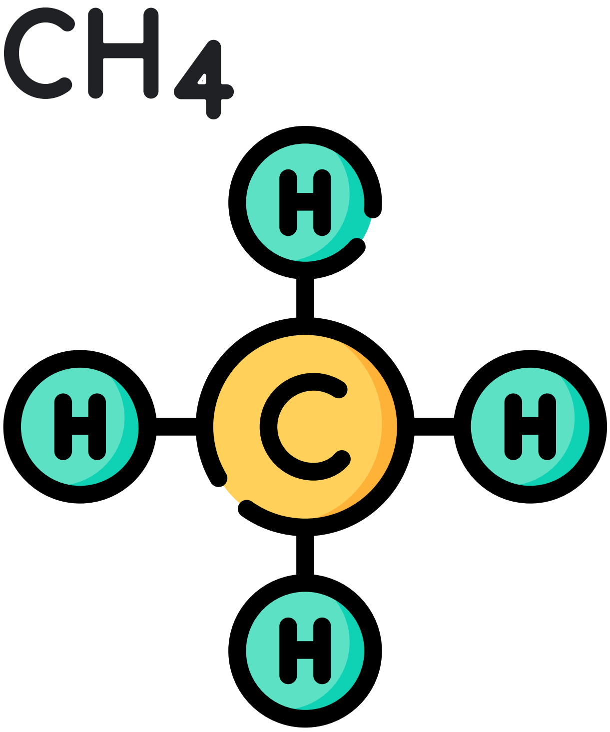
- ✓ Key risk factors and industry challenges related to ground gases.
- ✓ Design principles for gas protection in offsite-manufactured buildings.
- ✓ Material selection and integration with modular floor systems.
- ✓ Verification and compliance measures to ensure safety and effectiveness.

By adopting the best practices outlined in this document, the offsite sector can improve safety, performance, and regulatory compliance, ensuring that modular buildings remain resilient against ground gas risks.

Gases

There are numerous gases and vapours in the ground that can potentially pose a hazard to buildings constructed over or in the ground and consequently the health, safety and welfare of the occupants or users of the buildings.

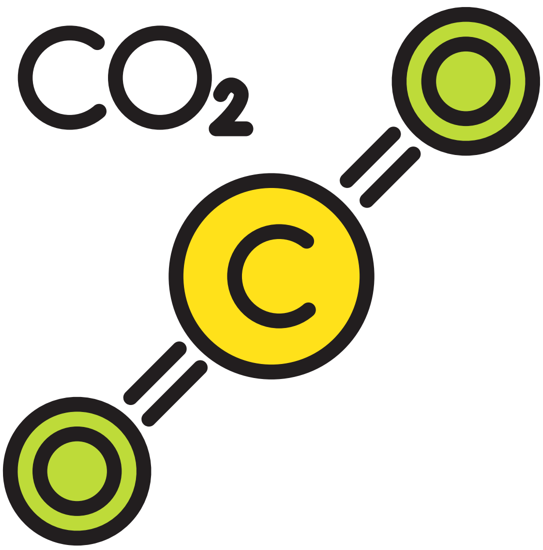
The principal gases and vapours of concern on most sites are one of the following:



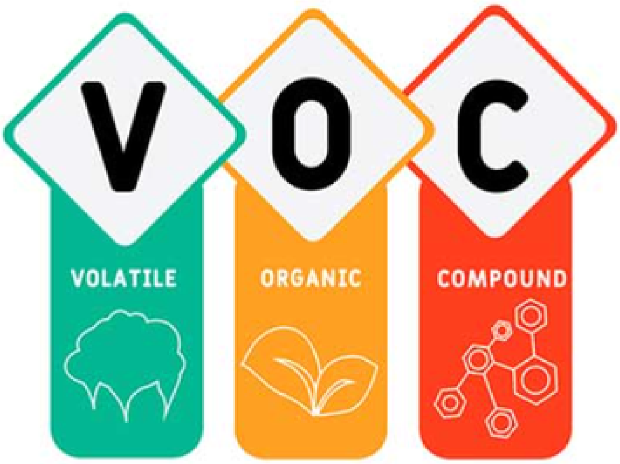
Methane – is odourless, colourless, nontoxic and is flammable at concentrations between about 5% to 15% in air. There is no intrinsically unsafe concentration of methane in the ground. If it enters a building and increases to a concentration of between 5% or 15% v/v in air, there is a risk of explosion. Commonly, where ambient concentrations in a building exceed 0.5% the risk is considered unacceptable. Buildings are normally designed to ensure that methane concentrations in the occupied space do not exceed 100ppm (0.01%) which is considered a minimal risk level (CIRIA C795).

The design of gas protection measures commonly requires the methane concentration in an underfloor void to be less than 1% although in some cases a concentration of 0.25% or 2.5% is allowed. The allowable concentration is determined by the gas protection designer based on the risk of gas ingress through the floor above and sensitivity of the building use.

Carbon dioxide – is odourless and colourless and is toxic with symptoms rising in severity with increasing concentration inside a building. Carbon dioxide is naturally everywhere in the ground at concentrations up to 21% without posing a hazard to overlying buildings. If it enters a building and increases to greater than 0.5% there is a risk of toxic symptoms which become increasingly severe with increasing concentration. Buildings are normally designed to ensure that carbon dioxide concentrations in the occupied space do not exceed 1000ppm (0.1%), which is considered a minimal risk level (CIRIA C795). The design of underfloor venting normally requires carbon dioxide concentration to be reduced to less than 1%.



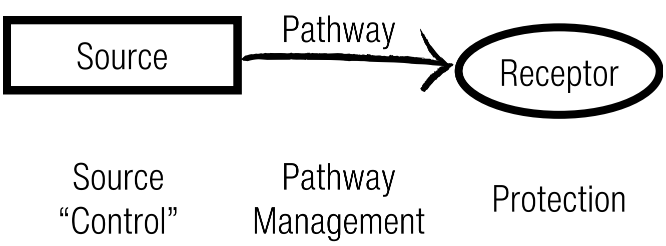
Radon - is odourless and colourless and is radioactive. High concentrations of radon inside a building can cause lung cancer, particularly for smokers and ex-smokers. The higher the concentration and the longer the period of exposure, the greater the risk will be. The UK Health Security Agency recommends that radon levels should be reduced in homes where the average is more than 200 Bq m3(known as the action level). New homes should be designed to ensure radon concentrations are less than 100 Bq m3 (known as the target level)



Volatile organic compounds (VOC)s – are a broad range of chemicals that have a high vapour pressure and low water solubility. Many VOCs (Volatile Organic Compounds) are human-made chemicals but there are natural ones as well. VOCs are common soil and ground-water contaminants and are emitted as gases from certain solids or liquids. They can have distinctive odours and depending on the compound may have short and long term adverse health effects including causing cancer in some cases. The allowable concentrations can be very low at a few parts per billion in some cases.

Other gases - There are, however, numerous other gases and vapours that could present a hazard, including (but not limited to) mercury vapour, cyanide, hydrogen sulphide, carbon monoxide, and hydrogen.

Source – pathway – receptor linkage The risk posed by the presence of gas in the ground is assessed based on the concept of the Source - Pathway - Receptor linkage. Gas in ground does not always pose a risk to buildings constructed over it. For there to be a risk a gas needs to move from the ground into the building quickly enough for a hazardous concentration to occur. Therefore, there needs to be a source of gas, a pathway along which it migrates and a receptor that can be affected (in this case the buildings and people within them).



Sources of Gases

The risk assessor and gas protection designer should know the potential source of gas in the ground. The reason for this is that the source of the gas often provides an indication of the likely generation pattern and gas potential, in terms of type of gas present, its form, rate and duration of generation and knowing the source often can provide a good indication of the likelihood of emissions out of the ground and possible level of risk.

Methane – Methane is most commonly present where organic material degrades in the ground. Sources where there is a low (if any) risk of emissions into buildings include Alluvium and Made Ground that is predominantly soil (NHBC NF94). Sources with a higher risk of emissions include domestic landfill sites, old coal mines and old oil and gas wells. The greater the organic content of Made Ground and the younger it is the greater the risk of emissions into buildings. Methane that accumulates in unflooded mine workings can also pose a risk if there is pathway to the surface via an entry or fractured rock. In the UK carbon dioxide is a greater risk from old shallow mine workings than methane.

Carbon dioxide – Carbon dioxide is everywhere in the ground even in natural soils. It is caused by oxidation of small amounts of organic material that are present in most soils. For example, it is commonly present at up to 21% in the glacial till in Northwest of England and in the River Terrace Deposits around London where it poses no risk to development. The sources that do potentially pose a high risk are old shallow mine workings and recent domestic landfill sites.

Radon – is naturally present in all soils and rocks. However, in some areas the concentrations are high enough in the ground to pose a risk of emissions into buildings that can cause unacceptable concentrations inside. The risk of emissions depends on the nature of the source rock and the permeability of the overlying soils and rocks.

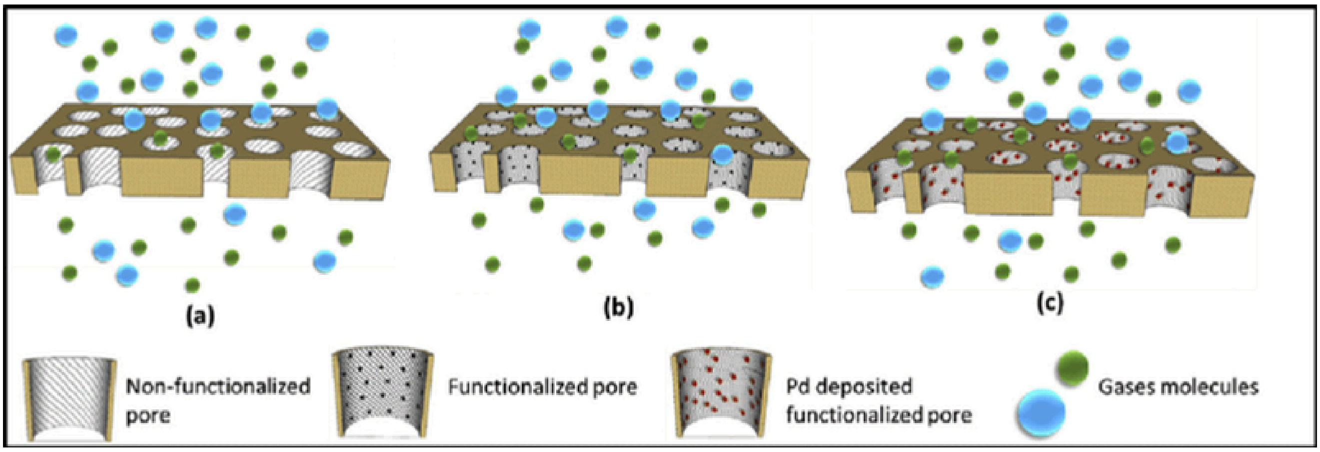
VOCs – can be present on many contaminated sites, including former landfill sites. The most common places are old petrol stations and gas works sites. However, they are likely to be present at many industrial or commercial sites where fuel storage was present, or degreasers used. There are numerous sources including paints, pharmaceuticals, refrigerants, industrial solvents, such as trichloroethylene; fuel oxygenates, such as methyl tert-butyl ether (MTBE); or by-products produced by chlorination in water treatment, such as chloroform. VOCs are components of petroleum fuels, hydraulic fluids, paint thinners, and dry-cleaning agents. VOCs are common ground-water contaminants.

Migration Pathways

Migration pathways are a route for gas to reach the receptor. For example if a gas source is deep and it is impeded by substantial thickness of impermeable clay it is unlikely to cause significant surface emissions and ingress into a building, unless a new pathway is created for example by stone column foundations.

Conversely a shallow source with a permeable pathway above it can allow large gas emissions to occur. The gas permeability and porosity of the pathway are critical considerations in the risk assessment and design of gas protection systems as they governs how fast gas can migrate out of the ground. The degree of saturation is also important as gas cannot migrate in significant quantities through saturated ground. Therefore clay often minimizes gas emissions whereas fractured rock or clean sand and gravel can allow large volumes of gas to migrate. In some cases preferential pathways may be present.

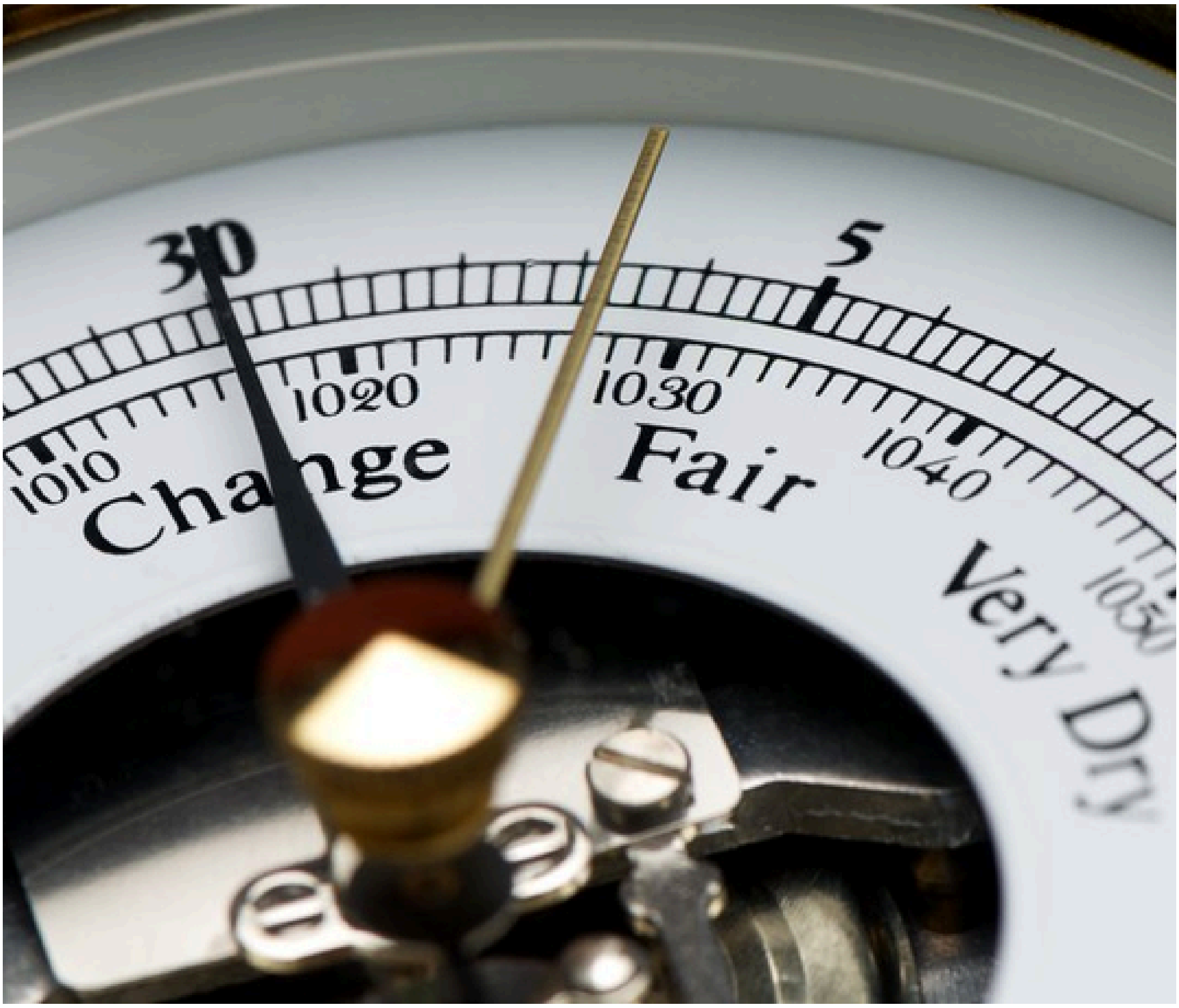
For a preferential pathway to exist it has to create a short cut from the source to the receptor, and allow gas to migrate faster than it would through the wider ground (an example would be a service trench that links a building to a landfill site). Preferential pathways require careful consideration in the risk assessment and design.



Note that piles are not likely to create preferential pathways except where there is gas under significant pressure in the ground and it is covered by a thin impermeable layer. Further guidance on migration pathways is provided in NHBC NF94.

Influences on Gas Emissions from the Ground

The are many temporal factors that influence gas emissions from the ground. These include rapidly falling barometric pressure, changes in groundwater levels, rainfall and temperature differentials. The risk assessor and gas protection designer should carefully determine which, if any of the factors, will be significant on a particular site. It is important to distinguish between effects on gas concentrations and flows in gas monitoring wells and those that can occur in the surrounding ground. For However, in the UK the ground conditions and shallow groundwater mean that barometric pressure effects often do not have a significant effect on emissions of gases such as methane and carbon dioxide into buildings where the migration pathway is through soil. However, for gases such as radon or VOCs barometric pressure is often a key driver, as well as where carbon dioxide is being emitted from mine shafts or fractured rock above shallow workings or there is pathway such as stone columns. Similarly tidal effects that can be seen in borehole may not be representative of emissions from the ground (the key factor with tidal effects is whether the gas in the soil voids can be replenished within the tidal cycle once it has been displaced). The influence of the various factors is complex and should be well understood by risk assessors and gas protection designers.



DESIGN

We would recommend the early engagement of a specialist in ground gas risk assessment and protection design is essential not to create delays and errors on site.

Industry Publications such as CIRIA C801 – Hazardous Ground Gas – A Site Management Guide provides specific guidance in relation to this topic and advises that competent designers should be Chartered Engineers or Geologists or have a similar level of knowledge, understanding and experience. Many regulators and warranty providers expect this, and CIRIA further advises the designer should have Professional Indemnity Insurance that specifically covers them for providing risk assessment advice and design services on contaminated land sites and landfills.

Gas Identification

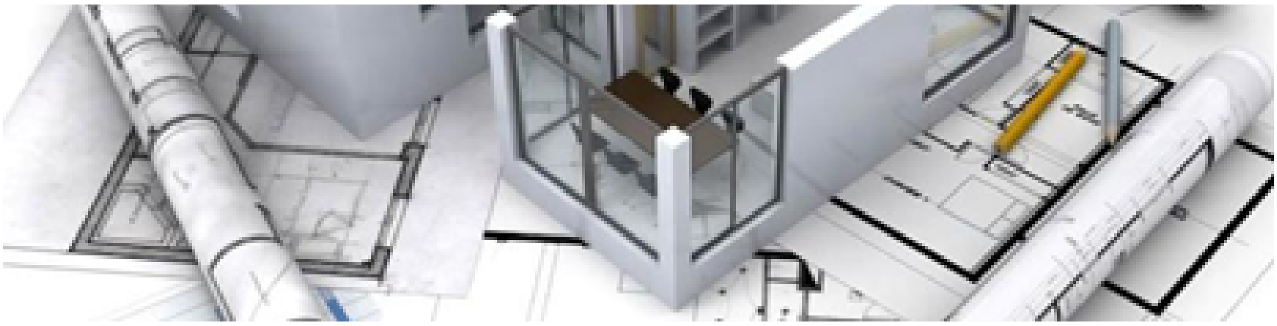
Identify the ground gases which affect the project from the site investigation report.

- **Radon**
- **VOCs**
- **Methane**
- **Carbon Dioxide**
- **Other gas**

BS8485:2015+A1:2019 Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings. BS8485 has two methods of design. The first is a very simple (and highly conservative) screening approach using Characteristic Situations and Points Scores for different types of protection. It was developed to give a quick and easy design approach based on traditional building construction that is applicable to simple and low risk methane and carbon dioxide sites. The points score is not applicable to radon or VOCs and did not consider modular construction.

The second approach is more involved, and applies where ground gas risk, or situations are more onerous and, or complex or the development is of a nonstandard design. This requires to undertake detailed risk assessment and a better and this requires competent professionals with risk assessment skills such as those that a SoBRA (Society of Brownfield Risk Assessment) accredited risk assessor will have. This second approach is likely to be beneficial in many cases for modular construction. By using a more refined approach it will result in a better, more robustly defined assessment of gas risk, often allowing a simplification of the gas protection system and remove some of the common problems.

See Case Studies – Page 30-33



Location of the Gas Protection

The provision of gas protection for modular units can take two forms:

1.

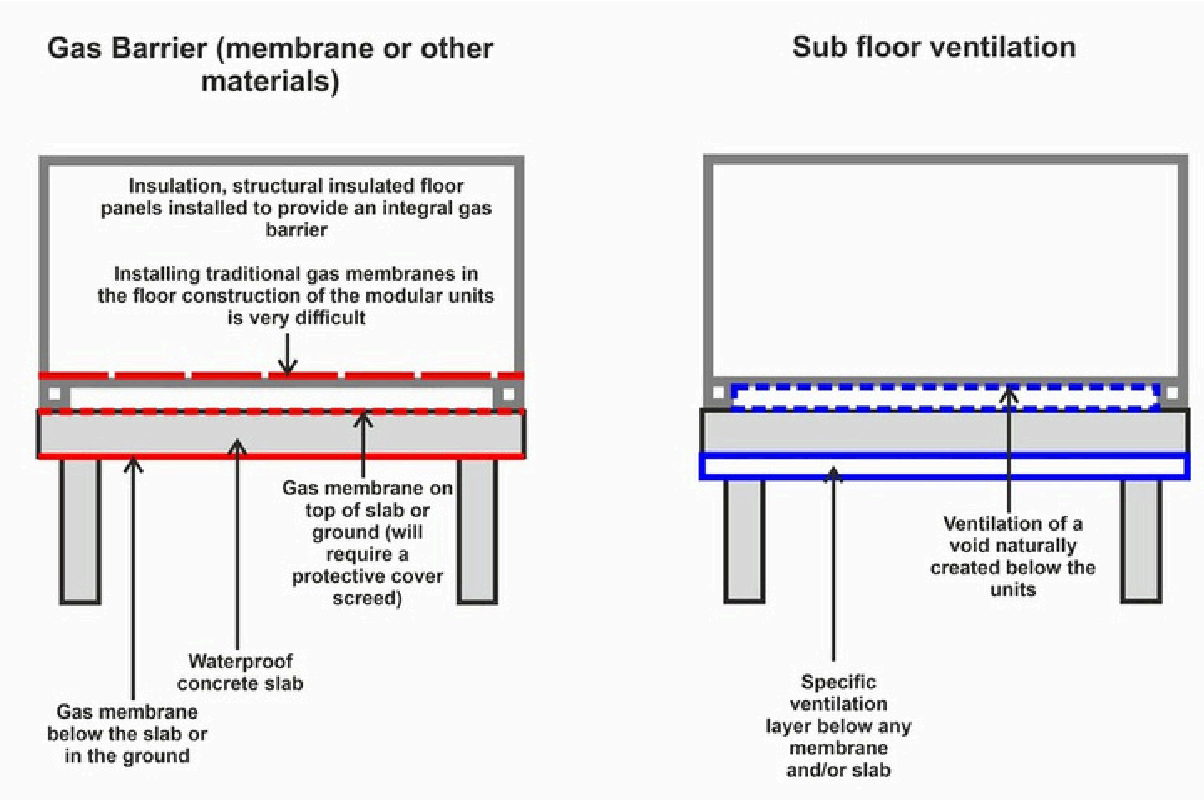
Incorporated into the module units -
Consideration of the gas resistance of the floor, insulation materials, structural insulated panels, etc. should be considered before assuming a gas membrane is necessary. For example, a designer may be able to demonstrate that insulation materials are gas tight or can be made gas tight (both sprays applied insulation foam and rigid boards can be used as a methane, carbon dioxide or radon gas barrier). There is often a “built in void” between the underside of the modular units and a ground slab. On low-risk methane, carbon dioxide and radon sites it is often possible for a designer to show that a sub building ventilated void provides more than sufficient protection. In some EU Countries such as Spain for example a ventilated void alone is acceptable as basic radon protection in low-risk areas but in the UK a radon proof membrane is required and depending on the radon potential provision for depressurisation or ventilation (either a radon sump or a ventilated sub void) may additionally be required. Note that ground level vents are not suitable for low rise housing and do not provide effect sub slab ventilation.

2.

Incorporated into the foundation/ground slab below the units -
In this case the protection is comparable to traditional construction methods. The designer should give consideration to the gas resistance of any concrete raft foundation below a modular building as this may provide sufficient gas resistance when combined with a ventilated void below the unit. However, any penetration through the slab such as these required to enable entry to services will need careful thought and detailing. Waterproof concrete is another consideration as this alone may provide a sufficient gas barrier. This will simplify the manufacture and installation of the units.

Potential Location for Membrane

3D VOLUMETRIC



The design should include the following key items (as advised in BS8485):

✓ Design Report clearly defined and justified.

✓ Calculations to demonstrate the performance of any ventilation layer or pressure relief system.

✓ Site specific pre-construction design drawings (not just a set of manufacturer's generic standard details) This should identify the requirements such as compatibility and integration with other components (ie Cavity Trays, thresholds, waterproofing, ventilation, sealing or welding requirements) and where applicable, need for protective elements such as protection fleeces.

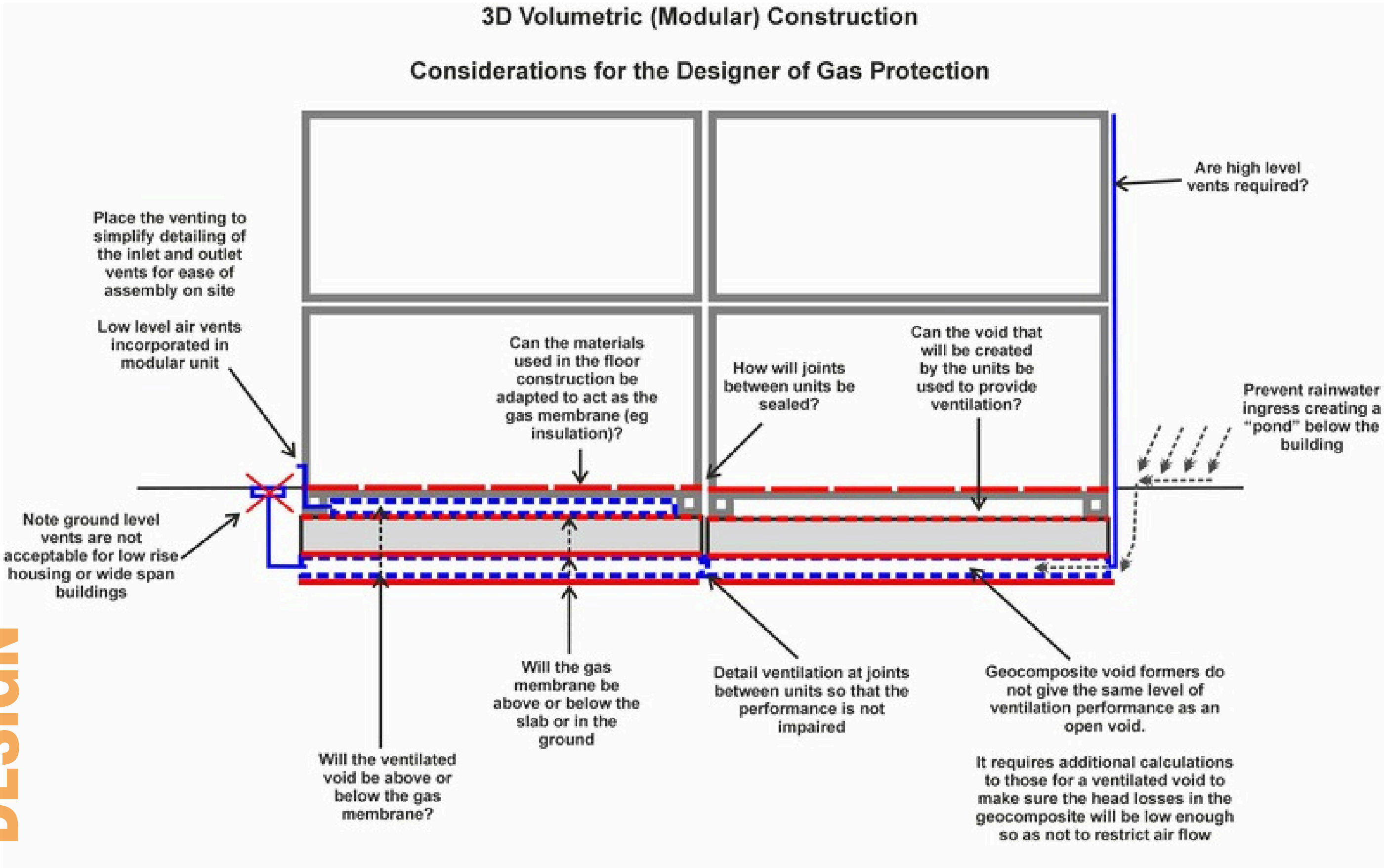
✓ Justification for the choice of gas membrane taking due consideration of all the factors listed in table 7 of BS8485

✓ Verification Plan.

KEY ISSUES FOR THE DESIGN OF GAS PROTECTION FOR MODULAR CONSTRUCTION:

- Can the ventilated void be above the gas membrane? Yes – however it is the designer's responsibility to demonstrate that this is acceptable on a particular site. Placing the ventilation above any gas membrane or concrete slab/raft can simplify detailing of the inlet and outlet vents.
- Does a Geo composite void former give the same level of ventilation performance as an open void? Not normally and it requires additional calculations to those for a ventilated void to make sure the head losses in the geo composite will be low enough so as not to restrict air flow.
- Strips of geo composite or perforated pipe reduce the ventilation performance of a gravel layer on a large footprints or long terraced connected units. Ventilation calculation should always be required to demonstrate effectiveness.
- Sub slab ventilation – ground level vents are not acceptable for low rise housing because of the risk of blockage or complete removal/sealing over. Ventilation should be detailed appropriately at joints between units so that the performance is not impaired.
- Water ingress and the design of gas membranes below the modular units needs to be managed so that ponding is not created below the building.
- Gas membranes should not be left exposed, even in a void below a building. They require covering with at least a layer of blinding concrete.
- If the module floor construction is used to provide adequate gas resistance or a gas membrane is placed on the underside of the units, How will joints between units be sealed? This is a difficult area that requires careful consideration by the designer. The actual detail will depend on the module construction and new methods of sealing and jointing may become available in future. If a membrane is placed on the underside of a unit it is likely that it cannot be sealed effectively at the present time using normal methods (taping or welding) because of inaccessibility once the units are in place.

The questions that should be asked and the areas that require careful consideration by designers when deciding on the arrangement of any gas protection system are shown below.



DESIGN

Design of protection against VOCs and the other gases described above is a specialist area that requires risk assessment skills. It requires a competent professional such as a Society of Brownfield Risk Assessment (SoBRA) accredited risk assessor in vapour intrusion and permanent gases.

Ground Gas Design Drawings

The designer ascertains the position of the membrane and considers the incorporation of ventilation if required and details the drawings on a project specific basis to ensure the gas protection covers the whole footprint and is ventilated to the atmosphere.

The detailing of specific designed elements as stated in CIRIA C801, will require professional experience and understanding of construction detailing. A clear difference between design and detail would be, the designer assesses the ground gas hazard and considers the characteristic situation of the site to fulfill the design requirements as BS8485 The detailer will apply principles of construction to accommodate the designer recommendations, sequencing, combining various elements (structure, ventilation and membrane) to fulfil suitable solutions considering build ability, cost efficiency and material compatibility.

The competency of most detailers in the sector tends to be purely based on experience as no formal qualification exists. Charactered engineers/ architects will cover this element, but too often simply cut and paste from manufacturers details with little or no comprehension of its dynamic situation or buildability, especially if reliance is on non-skilled installers to fulfil the details of the design.

Common failures incorrect membrane selection, ventilation media installation not to a design, or installed the wrong way up, location of services not differentiated as either SVP's or service ducts. Sometimes individual elements forming the complete design might not be even buildable or compatible. Therefore, it is essential that not only the design is in place but the site-specific detailing prior to commencement of installation on site

Material Specification

The specification of materials should be the responsibility of the project designer who:

- **Prepares and coordinates with the design team**
- **Prepares and integrates specialist subcontractor Building Systems information**
- **Prepared at RIBA Stage 4 Design & Detailing**

The material specification should be clearly defined in the design pack. In traditional building gas membranes are the most common form of barrier to gas. BS 8485 provides six requirements for the design of a gas membrane in traditional building construction.

BS8485 is not a specification, and membrane specifications alone cannot comply with it. It provides guidance on a limiting value for one parameter (the gas transmission rate of gas membrane for methane). This can be exceeded if a designer considers it is acceptable to do so and can justify an increased rate.

Guidance on gas membrane specification and the use of membranes with a gas transmission rate greater than 40ml/m2/day/atm is provided by the BS8485:2015+A1:2019 and the NHBC NF94 Guidance Document. The NHBC NF94 Guidance Document also provides advice on the minimum thickness of membranes in different locations within the construction as relevant for modular construction with protection either side by thick geotextile fleeces. Aluminium foil membranes are not suitable when they come into contact with wet concrete or aggressive environments and may not be suitable where movement or settlement between a structural element and, or the ground might be a possibility.

The other properties are of more importance and the designer should ensure that a membrane is sufficiently strong and durable to avoid damage after installation (which is when most holes in membranes occur). Protection should also be considered if necessary.

For VOCs and other gases, the membrane supplier should provide permeation test data for the contaminant of concern (See CIRIA C748). An important consideration is that tests should be run until a breakthrough of the contaminant occurs. Short duration tests of only a few days may not be representative.

For all gases the insulation materials used in the floor construction may be suitable to act as a barrier to migration. The same considerations apply as with gas membranes, ie the gas transmission rate should be low enough and the whole installation including joints should have a sufficiently low transmission rate.

Some insulation materials and waterproof concretes have been tested to determine radon diffusion coefficients and methane gas transmission rates. However, the tests used for thin gas membranes are not suitable for thicker materials and usually alternative bespoke test methods are used. One approach is to do full scale tests on a prototype unit to assess the gas transmission rate of the whole floor construction. Concrete slabs can also act as a barrier and should be specified and designed to minimise shrinkage and cracking. Open movement joints should be avoided.

Specification of Gas Membranes

The gas membrane specification is established on a site-specific basis and engagement with the project designer is essential. The British Standard BS8485 requirements for the gas membrane design are provided below together with the critical properties to be considered. Note that BS8485 is not a specification and it covers the design of the membrane. BS8485 Requirement Properties to be considered.

BS8485 Requirement	Properties to be considered
Sufficiently impervious, both in the sheet material and in the sealing of sheets and sealing around sheet penetrations, to prevent any significant passage of and/or carbon dioxide through the membrane	Methane gas transmission rate
Sufficiently durable to remain serviceable for the anticipated life of the building and duration of gas emissions	Depends on design and potential exposure to chemicals and oxidation conditions, exposure to wet cement (alkaline conditions) as well as the required service life of the building. The following tests may need to be considered Resistance to chemicals in the ground, used in building or building materials Oxidation resistance Resistance to soil burial Service temperature Accelerated aging Note most membranes have limited resistance to UV exposure and should not be left exposed to light in the long term.
Sufficiently strong to withstand the installation process and following trades until covered (e.g. penetration from steel fibres in fibre reinforced concrete, penetration of reinforcement ties, tearing due to working above it, dropping tools, etc);	Tensile strength and elongation at break Tear strength Impact resistance Resistance to static penetration Thickness
Able to withstand in-service stresses (e.g. settlement if placed below a floor slab)	Tensile strength and elongation at break
Capable, after installation, of providing a complete barrier to the entry of the relevant gas	Gas transmission rate and resistance to damage as above
Verified in accordance with CIRIA C735	N/A

BS8485 advises that reinforced LDPE (virgin polymer) membranes having a minimum mass per unit area of 370 g/m2 and not significantly less than 0.4 mm thickness between the reinforcement scrim (tested in accordance with Procedure D (2 mm diameter tip) of BS EN ISO 9863-1:2016) installed above floor slabs are considered sufficiently strong to meet the performance criteria. It also advises that thicker and more robust membranes or an additional membrane protection layer should be installed directly beneath cast-in-situ floor slabs. Most BBA certificates state that membranes are only resistant to damage from normal foot traffic so thicker membranes or substantial protection above and below are required where they are likely to be driven on. Use of fiber reinforced concrete or screeds can result in puncture of 0.4mm thick membranes (NHBC NF94).

Specification of VOC/ Hydrocarbon Membrane

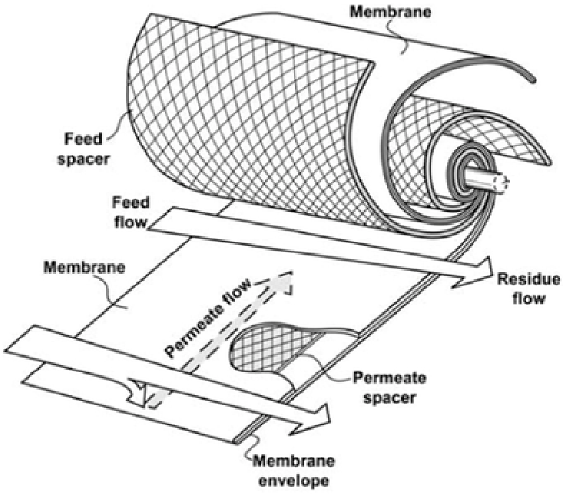
VOC membranes do not completely prevent the ingress of VOCS. It is important to ensure that the permeation of VOCS through the membrane (and associated floor construction) does not result in unacceptable concentrations inside the building. The VOC/Hydrocarbon membrane specification is established on a site specific basis and engagement with the project designer with competency in assessing the site-specific hydrocarbon risk typically a SOBRA accredited (or equivalent) risk assessor with experience in contaminated land risk assessment. The design and specification should follow the guidance in CIRIA C748. The membrane should consider the same factors as for a gas membrane above. The membrane manufacturer should be able to provide the designer with independent test results showing the results of permeation rate tests for the given VOC/hydrocarbon at risk and the membrane together with properties such as thickness, methane permeability rates and puncture resistance. The VOC/hydrocarbon must be heat welded and installed by a NVQ L2 Specialist Installer.

Specification of Protection Fleece

The protection fleece specification is to be provided by the project designer. When used, a geotextile protection layers should be sufficiently robust to prevent puncture of any adjacent impermeable membrane. The puncturing of membranes tends to be derived from sharp points of contact from the substrate or reinforcement as well as impact from dropping objects on the membrane. The use of a geotextile below a membrane provides some cushioning that increases the membrane puncture resistance. The selection of a suitable protection geotextile is therefore largely based on the membrane used and individual site conditions. Material properties to be taken into consideration are thickness, puncture resistance and tensile strength.

Specification of Geo composite Vent Layer

The specification of the Geo composite Vent Layer to be determined by the project designer and accompanied with venting dilution calculations as per BS8485. The ventilation effectiveness depends on a number of different factors including the intrinsic permeability of the medium, the width and height of the building, the side ventilation spacing and type and the thickness of the layer. The geocomposite layer properties to be considered are compressive strength (short and long term), in plane intrinsic permeability, thickness, width (if used as strips).



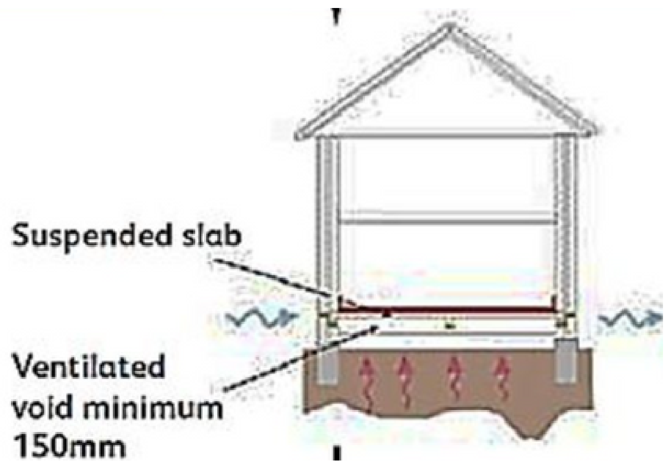
DESIGN

Specification of gravel vent layer

A gravel vent layer should comprise of clean stone and the minimum particle size should be 20mm and should not contain any significant amounts of finer material (clay, silt or sand). Aggregates such as MOT Type 1 and Type 2 are unsuitable. The layer should be a minimum of 300 mm in thickness and not to be compacted to maintain the high porosity of the stone. The aggregate layer properties to be considered are intrinsic permeability and particle size distribution (grading) of the compacted material.

Specification open void vent layer

The open void vent layer needs a suspended floor such as a block and beam floor slab with a minimum depth determined by the project designer, considering internal obstructions to air flow caused by beams. There should be three times the area of the side vents provided in the internal obstructions following the guidance of BS8925:1991. The designer of the gas protection should provide a layout plan of the underfloor void showing the locations of all air bricks/ventilators (so it is not left down to the bricklayers or others on site). This is to ensure that all compartments are adequately ventilated (See NHBC NF94). The designer should also ensure that all air bricks are above external ground levels. The air brick ventilation area should be specified.



Specification of Sub-base

Any sub-base or capping materials below modular units should not contain any incinerator bottom ash or other materials that contain aluminium and have an alkaline reserve.. This is to prevent hydrogen generation below the building.

Buildability in the Design Process

Buildability must be incorporated into the design with correct consideration of material choice.

VERIFICATION

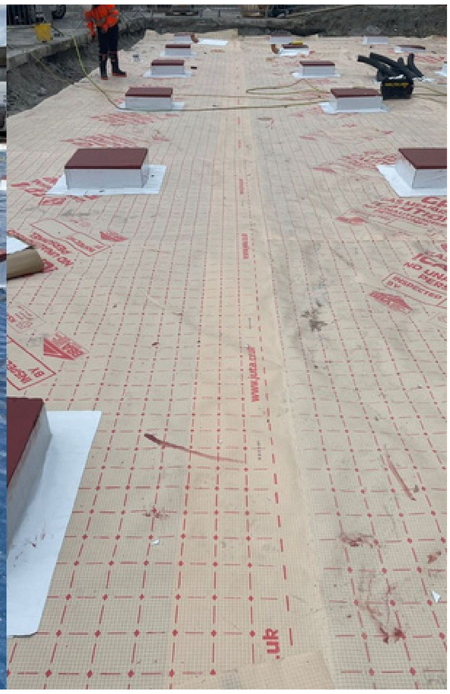
BS 8485 requires verification of ground gas protection measures installed on construction sites. The requirement is that verification follows the guidance in CIRIA C735. The reason CIRIA C735 was published was due to a serious problem of poor installation and verification of gas protection systems on traditional construction sites where each installation is unique. Modular buildings are manufactured in a controlled repetitive process in a factory. Manufacturing quality systems should be sufficient to ensure that any part of the gas protection system that is installed in the factory is of an acceptable standard. In factory verification by a specialist verification consultant is not necessary. There are still critical items that will be finished on site and in many cases the gas protection will be built into the site foundation for the modular system. These will need verification in the normal way by specialist verification consultants with CL: AIRE accreditation. Where the protection is built into the modular unit the joints between modules will require on site verification and verification will be required to ensure any exposed membrane is not damaged during installation.

The gas protection designer should provide a verification plan in the design report.

Relevant issues for modular construction are:

- **Ensuring site joints between modules are gas tight.**
- **Ensuring any ventilation that is installed on site below the building is connected properly to outlets of the modular unit**
- **Ensuring no site damage during installation to exposed gas protection that is integral to the modular unit.**
- **Sealing service penetrations (both to the gas barrier and internally for water pipe or electrical ducts).**





TRAINING

Since the early involvement of ground gas protection and membrane installation in the 1990's, training in the sector has grown and the needs of industry are struggling to follow. From 2010 when the National Vocational Qualification (NVQ) level 2 was introduced, uptake was initially slow in signing up to the scheme with those who had previous industry experience, until British Standard and CIRIA guidance documents emphasised the expectations of installation and good quality workmanship. Especially in 2014 with the C735 guidance for the Testing and inspection of ground gas protection systems.

Important consideration should be made here in relation to the training, knowledge and understanding of the designers of such systems. This has been overlooked with no formal recognition of qualification as found in other sectors, Certified Surveyor of Structural Waterproofing (CSSW) for example, often required in gaining appropriate insurances against the products, methods and competencies being specified in their design. CDM 2015 regulations state that designers of any part of the "gas protection" in this instance, must be competent, experienced, and suitable trained, hold appropriate Professional Indemnity insurance, maintain Continued Professional Development (CPD) and/or hold status via chartered bodies and industry affiliation etc.

For the technician sector and on-site operations, a definition of NVQ "training" is often misused and misunderstood. A clear difference in that training is being shown how to, and development of practice to gain experience, as opposed to "Assessment" which allows that training and experience to be witnessed by an accredited Assessor and prove that training has been successful, and the Technician is competent. Like having driving lessons, your instructor guides you and corrects you. When you take your test, will the Examiner assist you? This basic competency chart will hopefully explain: -

Level/ Experience	Definition	Endorsements	Scope of Projects
NVQ Level 2	Fully Completed the NVQ Level 2	Ofqual Certificate, Blue CSCS Card with Gas Membrane Accreditation	All (CS1 – 6)
1.5*	Registered and working towards their NVQ Level 2	Proof of NVQ registration Possible Red CSCS trainee card or existing Green CSCS Card	All, with NVQ another level 2 or 3 OWS**
1*	Initial Training	CPD certificate issued as proof of training. Must be able to provide CQA (Sign off/hand over)	CS2 with 100% verification.
0*	No proof of training	None	CS2 with 100% verification No VOC/HC projects

These levels/experiences are not NVQ structured. Solely a scale to locate individuals owns ability
***Occupational Works Supervision – NVQ Level 3*

Site Installation Examples

WARRANTY PROVIDER REQUIREMENTS

Warranty providers will typically require sites to be properly investigated and correctly assessed with any hazards identified to be suitably managed via appropriately designed and verified (where appropriate) measures. Risks associated with ground gas would usually be deemed as a potentially high risk item by warranty providers, therefore requiring further information and the input of appropriate competent persons to undertake the design, installation and verification of the ground gas protection measures.

Early engagement with warranty providers is therefore recommended to ensure their requirements, which could vary or be enhanced from the guidance in this document, are met through the design and construction process such that, on completion, a warranty will be available for a new building.

PREMIER GUARANTEE

NHBC

CASE STUDIES

CASE STUDY: Steel Container Buildings on a Former Landfill Site

This case study demonstrates the following:

- Some modular buildings have inherent and very robust gas resistance and do not require additional protection.
- The points score system in BS8485 is not applicable to some types of modular building.
- The joints between modules must be sealed if there is a pathway for gas into the building.
- There may be areas of exposed ground between units that are enclosed (eg walkways) that may require gas protection on higher risk sites. The development is located on an old landfill site and gas protection needed to be considered.

The development is constructed from shipping containers stacked on top of one another. The space between the containers has a performance area covered by a tented roof structure spanning between the shipping containers on three sides, up to three storeys. Vents were provided where the roof meets the top of the shipping containers to allow passive ventilation of the space. This is due to the buildings being modular and not of normal construction a DQRA (Detailed Quantitative Risk Assessment) approach to the design was adopted rather than the simple points system in BS8485.

The proposed development provides some significant inherent mitigation for the ingress of ground gases because:

- All of the shipping container structures are raised above ground level on columns with a clear 150mm void below. The void is left open, not enclosed, so that it is freely passively ventilated (if this had been enclosed it could have been provided with suitable ventilation points). The 150mm clear void provides sufficient mitigation for the potential gas fluxes at the site.
- The steel floors of the containers would prevent gas ingress. However, it was specified that they must be in good repair and not have any rust holes or penetrations through the base. If service penetrations were required through the base of the containers, then these were sealed to prevent open pathways for gas migration. Utilities were entered through the sides, rather than the base wherever possible.

There was no need for specific gas membranes or venting layers.

It was also specified that any roof structures spanning between shipping containers should not be sealed at the sides. Openings were provided at roof level to ensure that the structure was well ventilated and not fully enclosed. Any gaps between cladding panels to the containers would also require venting.

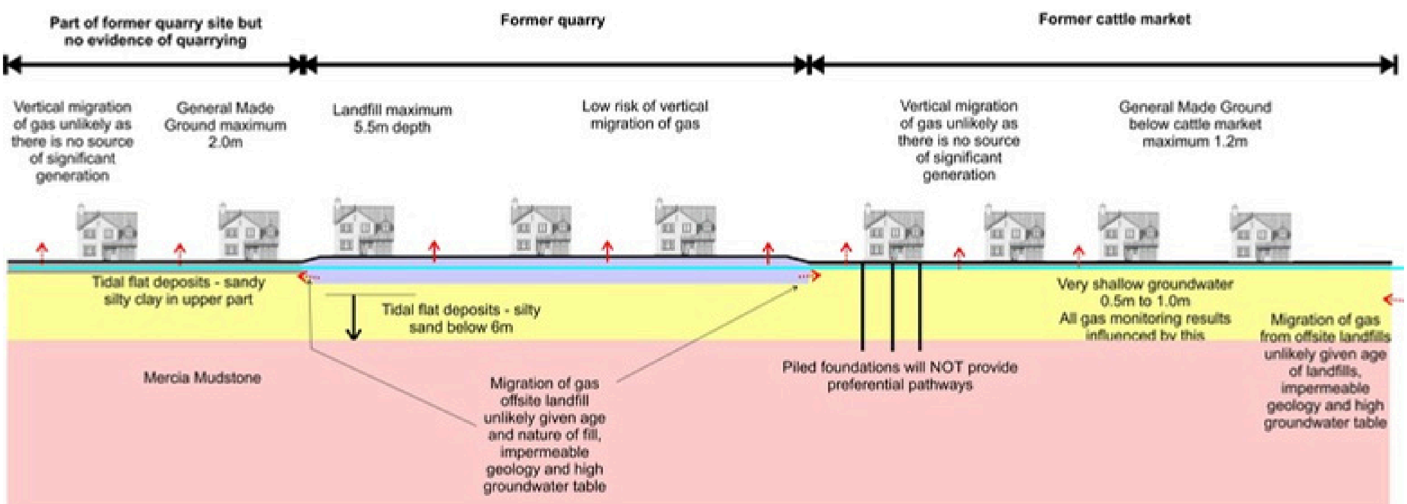
It was also specified that no ground-level vents were to be used on the development site unless constructed over a concrete pad or gas membrane covered by aggregate.

CASE STUDY: Modular Housing Units

This case study demonstrates the following:

- The need for a robust risk assessment to avoid over design of gas protection. With modular buildings specifying gas membranes and/or vent layers that are not required causes significant problems for the design and construction that could be avoided.
- The points system in BS8485 is a simple screening method of design. It is highly over conservative. For modular buildings more robust detailed quantitative risk assessment design methods as allowed by Clause 6.2.2 of BS8485: 2015 + A1: 2019 are likely to be beneficial and allow the gas protection to be reduced. This approach requires qualified risk assessors.
- Effective sub floor gas venting layers are very difficult to incorporate into modular buildings and should be avoided unless a void that is already part of the construction can be used.
- If specific gas membranes are required, the best location is below a concrete slab. When placed on top and exposed they are more prone to damage during installation of the modular units.

Verification is required during placement of the units and possible repair which can cause delays and increase cost. Housing was proposed on a site that was partly over a very old landfill. Although there was methane in the ground the risk posed to the development was low. The conceptual site model is shown below.



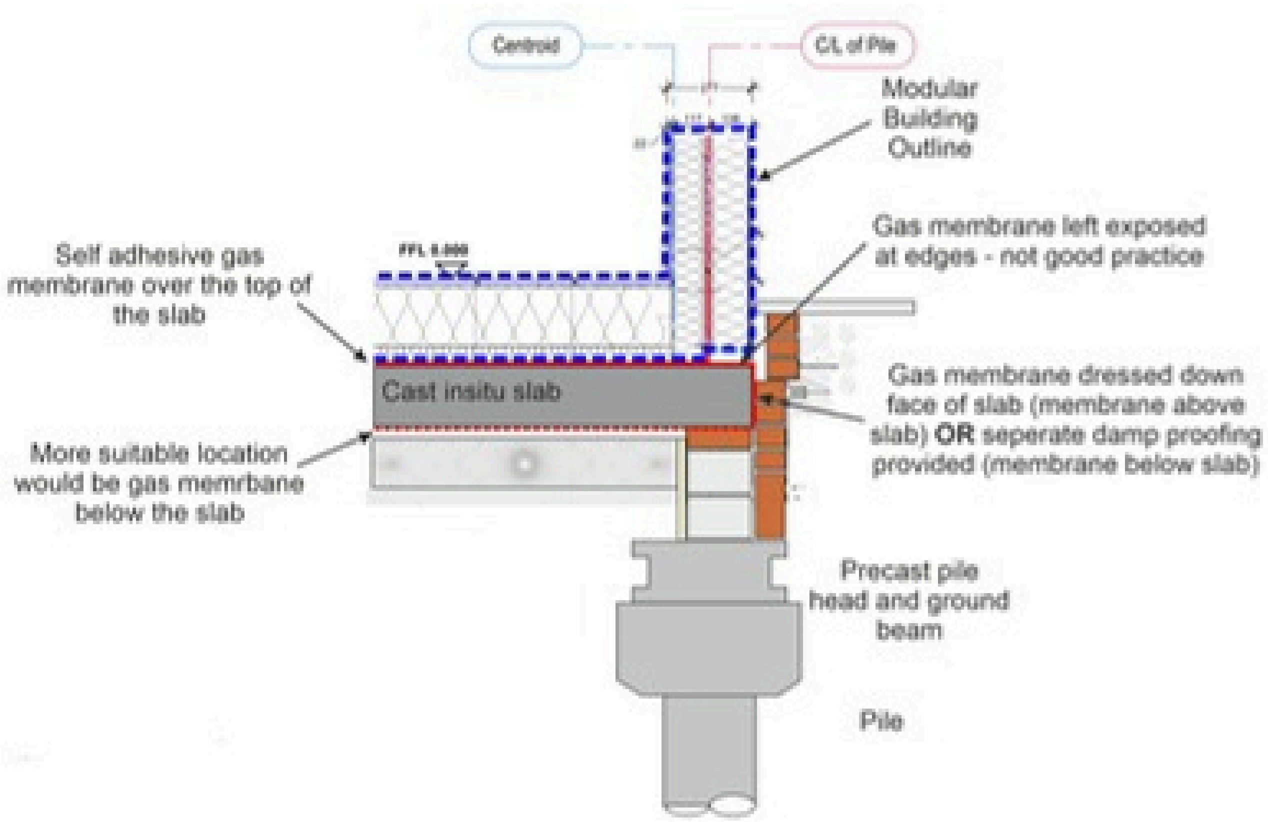
The very high groundwater table meant that there was a low risk of gas emissions into a building. It also meant that any venting layer below the concrete slab onto which the modular units were to be placed would potentially be flooded and ineffective.

The original gas risk assessment had incorrectly used monitoring data from flooded wells and classified the site using the simple screening method in BS8485 to determine that subfloor ventilation and a gas membrane was required. A reassessment using DQRA methods indicated that a gas membrane and the proposed concrete sub slab would provide sufficient protection against ground gas ingress to the buildings.

The problem with the subfloor venting was that it was very difficult to incorporate above ground vents into the construction. Ground level vent points are not suitable for private low-rise housing because of the risk of blockage.

The final solution was to place a gas membrane over the top of the cast in situ slab below the modular units. The membrane design could have been simplified to a single sheet membrane as a full line out and there was no need for the perimeter detail specified by the supplier. It did require the verifier to be present during installation of the units to reduce the risk of damage.

Even so the membrane was damaged in places during placement of the modular units which caused some delay while it was repaired. It was also exposed under the unit at the edges. A better solution would be to place the membrane below the slab.



CASE STUDIES

PUBLICATIONS

CIRIA C735 (2014) Good Practice on the Testing and Verification of Protection Systems for Building against Hazardous Ground Gases.
Item Detail (ciria.org)

BS8485:2015+A1:2019 Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings.
BS 8485:2015+A1:2019 | 31 Jan 2019 | BSI Knowledge (bsigroup.com)

PCA (2021) Discussion Document Ground Gas Protection Below Modular Buildings.
Our Ref: 00 (property-care.org)

NHBC Good practice guidance on ground gas issues and housebuilding
Hazardous Ground Gas - An essential guide for housebuilders | NHBC

BRE 211 (2023) Radon Guidance on protective measures for new buildings.
BR211 RADON: Guidance on protective measures for new buildings (including supplementary advice for ...

CIRIA C748 Guidance on the use of plastic membranes as VOC vapour barriers
Item Detail (ciria.org)

CIRIA C801 Hazardous Ground Gas – A Site Management Guide
New guidance: Hazardous ground gas - site management guide (C801) (ciria.org)

CIRIA C795 Retrofitting hazardous ground gas protection measures in existing or refurbished buildings
New guidance: Retrofitting ground gas protection measures (C795)

ABOUT THE OA

The Offsite Alliance is an exciting organisation at the forefront of promoting and advancing the construction industry. With a mission to drive sustainable and efficient building practices, the Offsite Alliance brings together a diverse group of industry professionals, stakeholders, and thought leaders to accelerate the adoption and growth of offsite construction methods.

As a not-for-profit organisation we serve as a collaborative platform that facilitates knowledge sharing, fosters industry partnerships, and advocates for policy reforms to overcome barriers and increase the potential to drive a more sustainable, transparent and resilient construction sector.

By leveraging the collective expertise of our members, we aim to revolutionise the way we think, procure design, deliver and maintain our buildings.

OUR AIMS

Increase awareness

Raise awareness about offsite construction by actively promoting its benefits and dispelling misconceptions through targeted marketing campaigns, industry collaborations, and educational initiatives.

Expand membership

Grow the Offsite Alliance's membership base by attracting professionals from diverse backgrounds, including architects, engineers, contractors, suppliers, developers, and researchers.

Foster collaboration

Create opportunities for networking, collaboration, and knowledge sharing through events, workshops, online forums, and signposting.

Enhance education and training

Develop and deliver educational programs, certification courses, and webinars to equip professionals with the necessary knowledge and skills in offsite construction.

Drive research and development

Undertake research projects, collaborate with academic institutions, and partner with industry stakeholders to advance offsite construction techniques, materials, and processes.

Influence policy

Engage with policymakers, industry associations, and regulatory bodies to advocate for supportive policies, codes, and standards that promote the growth of offsite construction.

Promote sustainability, digital and modern construction

Promote sustainable practices and solutions within the construction industry to reduce waste, minimise environmental impact, and improve energy efficiency.

Ground Gas Best Practice Guide