Good Practice For Risk Assessment for Coal Mine Gas Emissions Mitigation Measures

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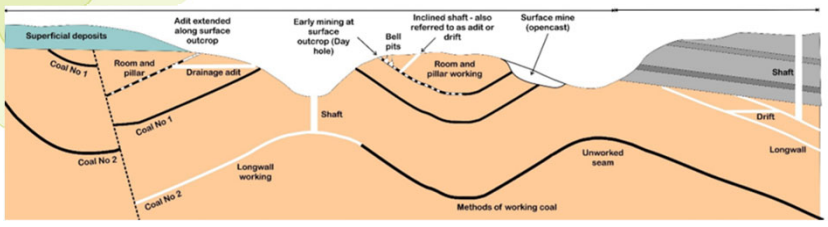
Content

- Deciding on the scope of protection measures



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Key points

- Do not use points approach from BS8485 – it is not appropriate on its own and in high risk scenarios not at all
- It is a screening approach and a more robust assessment will be required to assess site and choose appropriate measures
- Raft foundation and an appropriate membrane will be acceptable for most sites
- Membrane above raft - typical membranes on market acceptable
- Membrane below raft – needs to be robust and protected – aluminium foil membranes are not appropriate
- Sub-slab venting not required with raft foundations
- Ventilated void and membrane will also be suitable
- Seal the ducts!

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What should you avoid?

- If advising on risk assessment where there is a mine gas risk what should the development design avoid?

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Key points – what to avoid

- Avoid ground bearing slabs
- Avoid stone columns (they can be used but often increase risk so more protection measures will be required)
- Avoid drainage runs below buildings as far as possible
- Avoid deep stormwater attenuation tanks and soakaways – use shallow sustainable drainage systems (SuDS)

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Raft foundations

- Are they a good barrier to gas ingress from the ground?
- Reasons to support your answer

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Concrete and resistance to gas ingress

- Concrete construction can provide a good barrier to gas ingress
- Depends on quality of construction and design
- Greatest resistance by waterproof concrete to EN 1992 – 3
- Lowest from residential ground bearing slabs
- Engineer designed raft foundations to residential housing will provide good resistance
- Concrete is gas permeable and it can migrate through cracks - but often the slab alone gives sufficient resistance and should certainly be considered as the first line of defence, especially on high risk sites
- Don't believe what you are told by waterproof and gas membrane "specialists" (aka waterproofing system/gas membrane sales people) about cracking in concrete

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Evidence

- VOC attenuation factors from USA – at least 100 (mainly based on residential slabs)
- Swiss Radon guidance
- Evidence from monitoring gas ingress through slabs in UK
- Attenuation factors of at least 100 (between gas concentration in ground and internal ambient air concentration) in slabs with open cracks

Material	Thickness (mm)	Radon-tight?
sheeting		
PEHD foil	1.5	yes
PVC alloy	1	yes
Polymer bitumen	3.8	yes
Paints, coatings		
Plastic paint	0.2	no
Epoxy resin	3	yes
Building materials		
Reinforced concrete	100	retards radon
Calcareous sandstone	150	no
Plaster	100	no
Brick	150	no

Tab. 5.1: Radon diffusivity of building materials (in undamaged, crack-free condition).

Structural components that are designed to be watertight are also radon-tight. In construction areas with a high groundwater table or on hillsides, buildings are generally well protected against radon. In radon areas with a high availability of radon (permeable soil structure), we can rely on the tried-and-tested sealing technology of groundwater-tight building. The solutions include both the sealing of surfaces and the use of special structural components and constructions for water-tight pipe penetrations, contraction joints, etc.

Laying extensive, gastight sheeting on the outside of a building is appropriate
- if the planned building is in a radon area, or
- if it is not constructed in continuous reinforced concrete.

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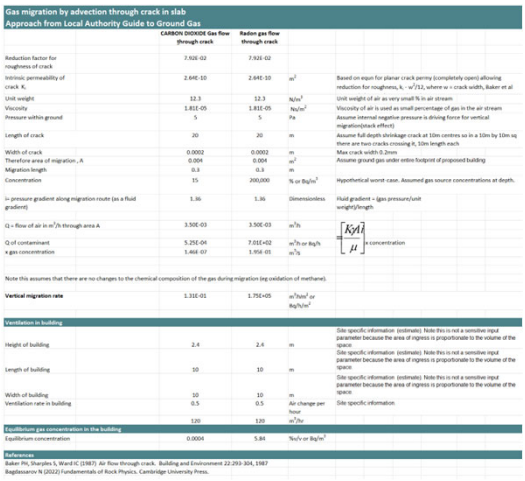
Evidence

1. Analysis of rafts in residential developments with conservative assessment of extent of cracking



Gas migration by advection through crack in slab Approach from Local Authority Guide to Ground Gas				
	CARBON DIOXIDE Gas flow through crack	Radon gas flow through crack		
Reduction factor for roughness of crack	7.92E-02	7.92E-02		
Intrinsic permeability of crack K_i	2.64E-10	2.64E-10	m^2	Based on equn for planar crack penny (completely open) allowing reduction for roughness, $k_i = w^2/12$, where w = crack width, Baker et al
Unit weight	12.3	12.3	N/m^3	Unit weight of air as very small % in air stream
Viscosity	1.81E-05	1.81E-05	Ns/m^2	Viscosity of air is used as small percentage of gas in the air stream
Pressure within ground	5	5	Pa	Assume internal negative pressure is driving force for vertical migration(stack effect)
Length of crack	20	20	m	Assume full depth shrinkage crack at 10m centres so in a 10m by 10m sq there are two cracks crossing it, 10m length each
Width of crack	0.0002	0.0002	m	Max crack width 0.2mm
Therefore area of migration , A	0.004	0.004	m^2	Assume ground gas under entire footprint of proposed building
Migration length	0.3	0.3	m	
Concentration	15	200,000	% or Bq/m^3	Hypothetical worst-case. Assumed gas source concentrations at depth.
i= pressure gradient along migration route (as a fluid gradient)	1.36	1.36	Dimensionless	Fluid gradient = (gas pressure/unit weight)/length
Q = flow of air in m^3/h through area A	3.50E-03	3.50E-03	m^3/h	$\left[\frac{K_i \gamma i}{\mu}\right]$ x concentration
Q of contaminant	5.25E-04	7.01E+02	m^3/h or Bq/h	
x gas concentration	1.46E-07	1.95E-01	m^3/h	
Note this assumes that there are no changes to the chemical composition of the gas during migration (eg oxidation of methane).				
Vertical migration rate	1.31E-01	1.75E+05	$m^3/h/m^2$ or $Bq/h/m^2$	
Ventilation in building				
Height of building	2.4	2.4	m	Site specific information (estimate). Note this is not a sensitive input parameter because the area of ingress is proportionate to the volume of the space
Length of building	10	10	m	Site specific information (estimate). Note this is not a sensitive input parameter because the area of ingress is proportionate to the volume of the space
Width of building	10	10	m	Site specific information (estimate). Note this is not a sensitive input parameter because the area of ingress is proportionate to the volume of the space
Ventilation rate in building	0.5	0.5	Air change per hour	Site specific information.
	120	120	m^3/hr	
Equilibrium gas concentration in the building				
Equilibrium concentration	0.0004	5.84	$\%v/v$ or Bq/m^3	
References				
Baker PH, Sharples S, Ward IC (1987) Air flow through crack. Building and Environment 22:293-304, 1987 Bagdassarov N (2022) Fundamentals of Rock Physics. Cambridge University Press.				

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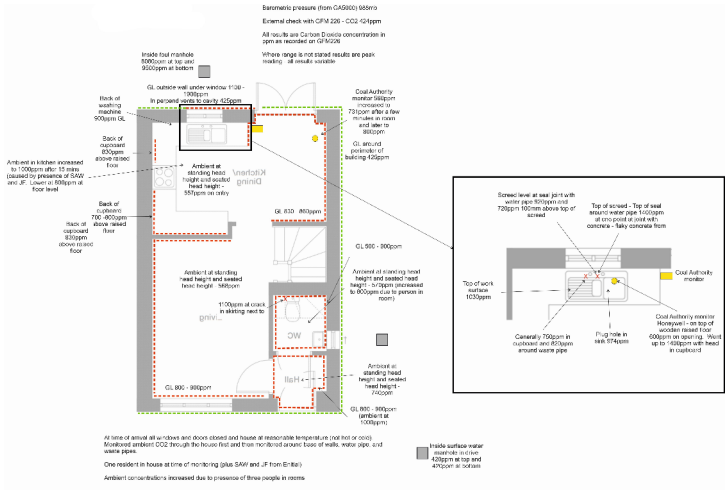
Evidence

5. Internal monitoring of slabs to 2 houses where ground gas ingress was occurring (via open water pipe ducts)



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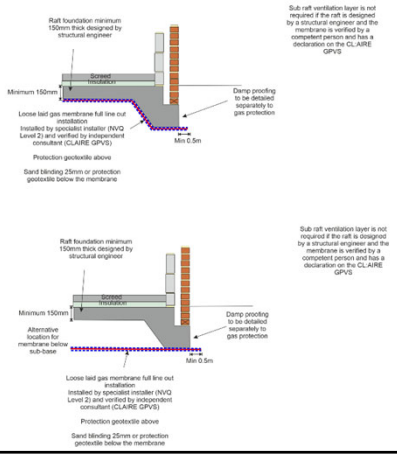
Raft foundation and membrane

- Placing membrane below the raft minimises risk of future damage
- It will require geotextile protection to reduce risk of damage during construction



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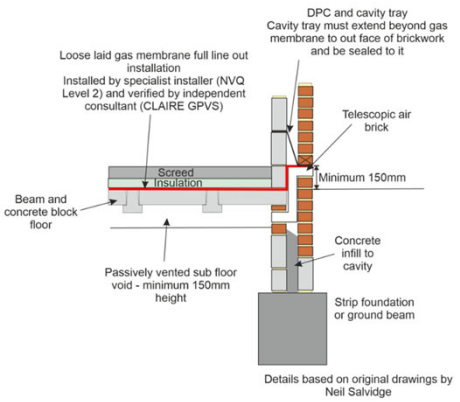
Sub floor void and membrane

- Note damp concerns from NHBC need to be addressed when detailing through the walls

Concrete beam and concrete block floor, block work inner and brickwork out walls



Details based on original drawings by Neil Salvidge

The ideal installation is to install in a "full line out" approach where the gas membrane is installed as one sheet across the floor and cavity wall. The advantages of this are:

Can be installed in one visit by a specialist installer (NVQ Level 2) using welded seams

Can be verified in one visit by an independent verification consultant (CL:AIRE GPVS)

Can be protected after installation to minimise risk of damage by follow on trades using insulation (for concrete B&B floors)

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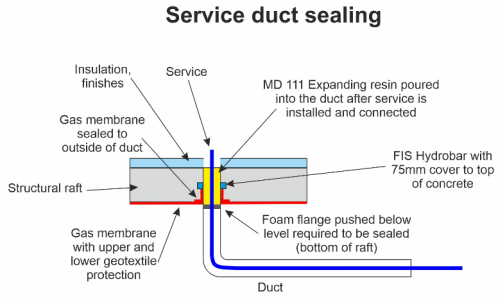
Seal the ducts

- Open ducts are the most common route of gas ingress to buildings
- Often forgotten
- For mine gas use sealant that is approved by water company
- For elect ducts expanding foam and a coat of liquid applied gas membrane over it would be suitable



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Example

- Housing development
- Raft Foundations
- Located over backfilled opencast and characterised as CS3
- Gas membrane and subslab venting specified
- But GSVs are not appropriate
- Requires a Design Report (as recommended by BS8485)


Rake Lane, Murton
Mine gas mitigation system, design report

epg

Rake Lane, Murton

Mine gas mitigation system, design report

1 Introduction

Story Homes Limited is developing a site known as Rake Lane in Murton, Northumberland for housing. The Environmental Protection Group Limited has been appointed by Story Homes to complete the detailed design of ground gas mitigation measures for the buildings in the development.

This report provides advice on the scope of protection that is required and the specifications for each individual element.

2 Information

The following information has been provided to EPG:

- RWO Group Ltd, Rake Lane, Murton, Typical Standard Details. Reference Dwg No 5020 Rev 3, 21 September 2021.
- SIRIUS, Preliminary Geotechnical Appraisal Report for Land Proposed for Development of Murton Gap, North Tyneside. Report C7459, August 2017.
- SIRIUS, Coal Mining Risk Assessment attached to letter regarding Murton Gap, North Tyneside. Report C7459A, August 2017.
- SIRIUS, Gas Monitoring Results attached to letter regarding Murton Gap, North Tyneside. Report C7567, January 2018.
- SIRIUS, Geoenvironmental Appraisal of Land at Murton Gap, North Tyneside. Report C7567 Rev A, March 2018.

This report is based on the factual information in those reports. They are normative references to this report and should be referred to for the detailed site investigation data.

3 Author and competence

This report has been prepared by Steve Wilson. Steve is a Chartered Engineer, Member of the Institution of Civil Engineers and Registered Ground Engineering Advisor with over 30 years experience in geotechnical design and the investigation and assessment of ground gas (including mine gas). He is a SoBRA Accredited Risk Assessor (permanent gas) and thus meets the competence requirements described in the CL:AIRE document " Good practice for risk assessment for coal mine gas emissions", for assessing mine gas risk and designing the gas protection measures.

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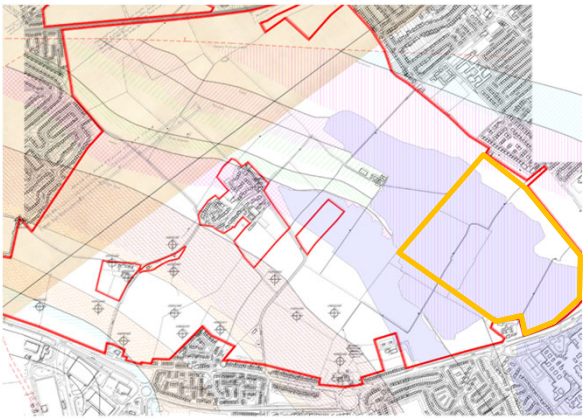
Example

- Old shafts but not below the opencast and >50m from development



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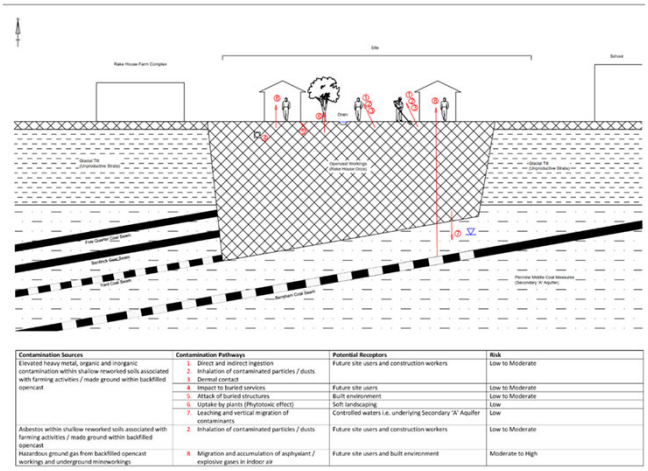
CSM



Contamination Sources	Contamination Pathways	Potential Receptors	Risk
Elevated heavy metal, organic and inorganic contamination within shallow reworked soils associated with farming activities / made ground within backfilled opencast	1. Direct and indirect ingestion 2. Inhalation of contaminated particles / dusts 3. Dermal contact	Future site users and construction workers	Low to Moderate
	4. Impact to buried services	Future site users	Low to Moderate
	5. Attack of buried structures	Built environment	Low to Moderate
	6. Uptake by plants (Phytotoxic effect)	Soft landscaping	Low
	7. Leaching and vertical migration of contaminants	Controlled waters i.e. underlying Secondary 'A' Aquifer	Low
Asbestos within shallow reworked soils associated with farming activities / made ground within backfilled opencast	2. Inhalation of contaminated particles / dusts	Future site users and construction workers	Low to Moderate
Hazardous ground gas from backfilled opencast workings and underground mineworkings	8. Migration and accumulation of asphyxiant / explosive gases in indoor air	Future site users and built environment	Moderate to High

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Example

- The Coal Authority viewer indicates that the site sits in the Algernon Hebburn groundwater block (Category C2). The fact sheet for this block indicates that groundwater levels were rising generally in 2017. but are controlled by Coal Authority pumping to stop excessive rise.
- Evidence from SI – possibly flooded but not conclusive
- Assume not flooded and that gas emissions can occur.
- Made Ground typically comprises an upper horizon of sandy gravelly clay.

Below this, a mixture of cohesive and granular soils in discontinuous horizons.

- Gravelly clay with varying sand content.
- Gravel with varying clay content, and grey slightly silty (or clayey) gravelly fine to coarse sand
- Source of carbon dioxide but will also be a buffer to emissions from the workings

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Gas monitoring

- Gas monitoring was completed in four monitoring wells across the site in 2017 (six visits between 12th October and 19th December 2017).
- The well response zones were 1m to 5m and the wells were dry on all monitoring visits.
- The atmospheric pressure during montoring ranged from 977mb to 1027mb.
- Thus the data is considered adequate for a site such as this, where gas protection is to be provided to the buildings.
- Additional monitoring is not likely to change the recommendation to provide gas protection, nor the scope of it.
- The gas monitoring results show that methane in excess of 1% v/v was not detected in any of the wells. This is an indication that there is no significant gas generation occurring in the open cast backfill below the site.

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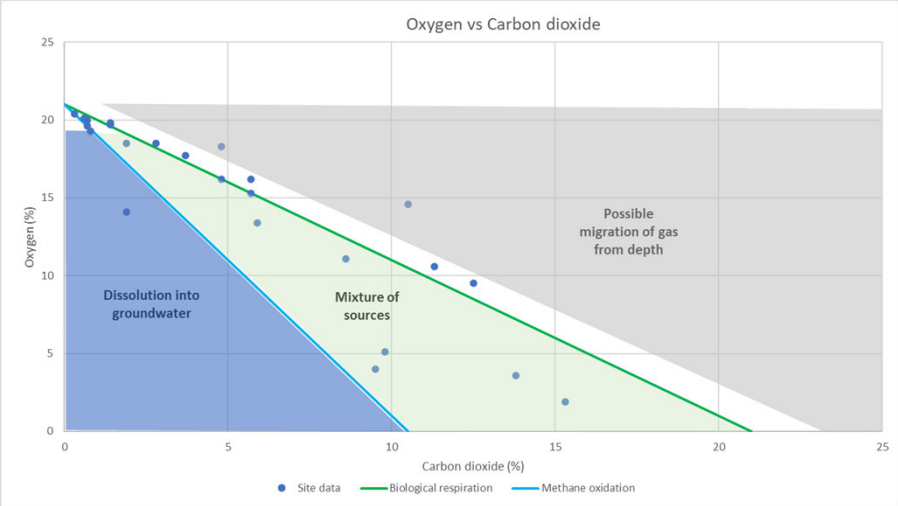
Gas monitoring



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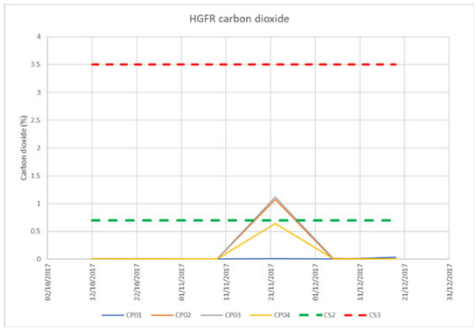
Gas monitoring

- Increase in HGFR when barometric pressure drops
- Limited data (spot monitoring)
- An indicator of possible emissions from workings
- Increase is sufficient to indicate gas protection required but it is not likely to require sub slab venting because the flow rates are still low
- Note – Limits for CS only used because at the moment it is needed to explain risk level to others – GSVs should not be used to assess gas risk and mitigation design on mine gas sites



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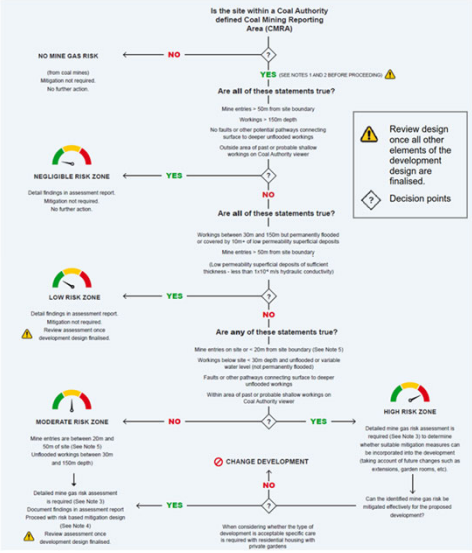
Example

- Likely flooded but cannot guarantee
- Where does this site fit in the CLAIRE Decision Tree?



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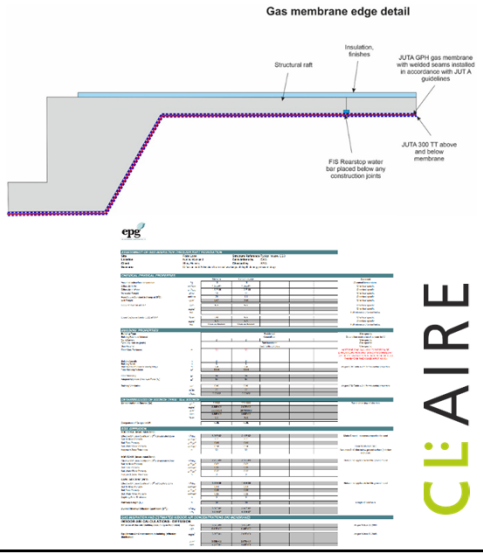
Mitigation

- Raft and membrane demonstrated to be adequate by design modelling
- The Modular Approach to Analysing Vapour Migration Into Buildings in the UK, Published in Land Contamination and Reclamation in 2008
- Properties for methane and carbon dioxide used (eg diffusion coefficients, etc)
- Large barometric pressure drop causing emissions from the worked coal seam at depth
- Water pipes to be sealed (and verified)



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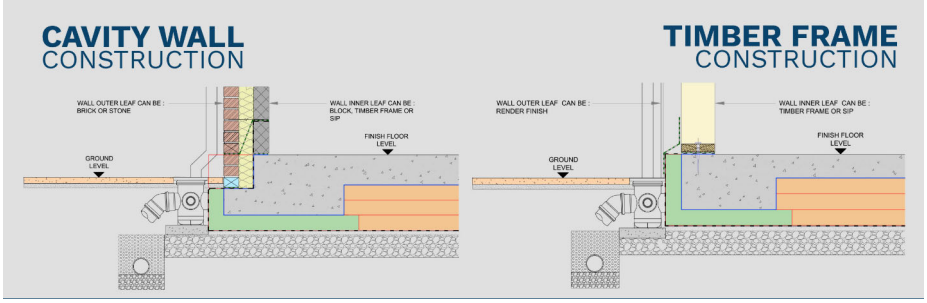
Raft foundations



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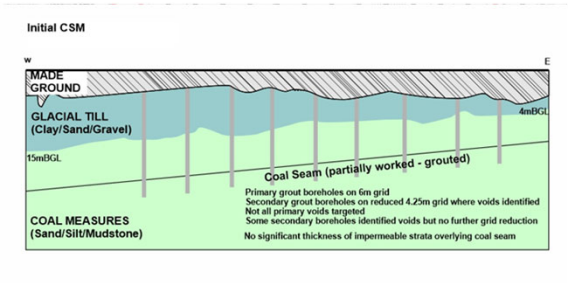
Example 2

- Initial CSM
- Coal seam (worked) at shallow depth <30m
- Glacial Till present over it – is this thick enough to act as a barrier?



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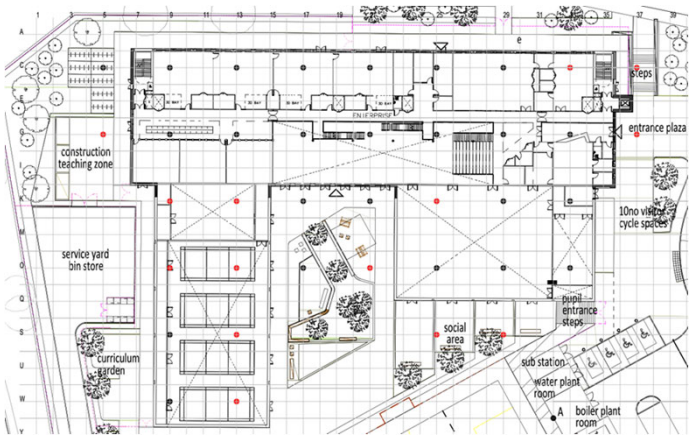
Shallow coal workings

- Red dots are boreholes with evidence of workings



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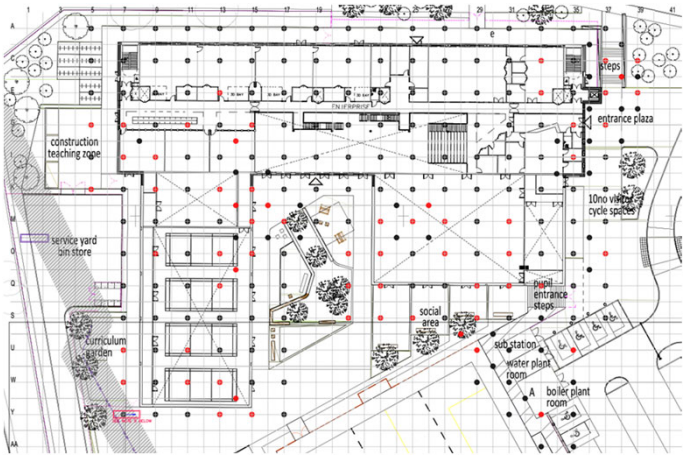
Grouting

- Grouting only for stability – infill grouting not completed in all locations where excess take occurred (should have reduced spacing again to deal with gas risk)



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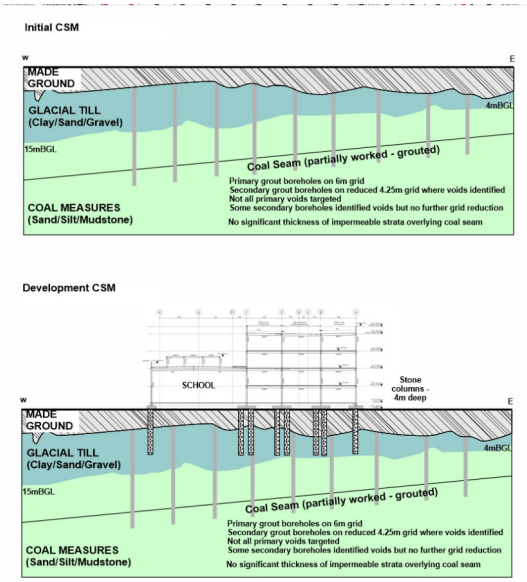
Example 2

- CSM after development
- Stone column foundations
- Not fully grouted
- What is the risk now?



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Risk Assessment

- No entry points have been identified within 50m of the site, however the shallow workings are unregistered and as such this is not definitive.
- The site is underlain by a previously worked seam below the building footprint at depths of significantly less than 30m, with the shallowest identified depth to the top of the seam being 4m.
- The workings are likely to be unflooded.
- Stone columns have been installed across the footprint to a maximum depth of 3.8m.
- Grouting has been undertaken for geotechnical purposes, however data presented in the completion report indicates that there is the potential for residual voids to be present.
- On this basis the site is deemed high risk. Therefore the design of the mitigation system should not use the BS8485 points system (as advised in the CL:AIRE guidance).

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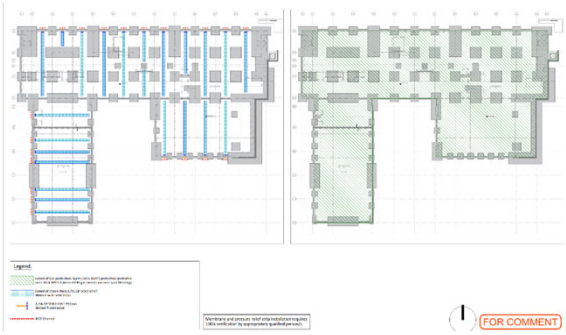
Gas Mitigation

- Gas membrane, floor construction and pressure relief layer
- 100% verification of membrane and pressure relief
- Consequences of underestimating the mine gas risk
- Additional cost of pressure relief layer at construction stage
- By the time this was raised it was too late to install an effective sub slab venting system



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Thank you for listening

Time for Q&A

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