Unit 1. Principles of remedial design and gas protection
Principles of remedial design & gas protection

• Guiding principles - breaking the ‘pollutant linkage’
• Different types of development
• Different types of foundation construction
• Protecting the building envelope
• Modified gas regimes
• Legal issues
• Lessons to learn
Guiding Principles

Breaking the Pollutant Linkage

- Remove the source
- Break the pathway
- Protect the building envelope
Principal Ground-Gas Protection Measures

Wilson, Card and Haines, 2008
(adapted from Witherington and Boyle, 2007)
Removing the Source

2001

- Area of ‘improved’ farmland
- 2m of waste/made ground tipped in the 1970s
- Receives planning permission for 200 housing units
Removing the Source

2005

• Waste re-excavated and replaced in a new containment cell
• Still actively gassing
• Barrier and venting trench installed
Removing the Source

CIRIA 716
Removing the Source

What’s the best way to check the source has been removed?

“To test is best”
Breaking the Pathway

• In-Ground Barriers

• Venting (preferential pathways)

• Combination of both
Breaking the pathway

• Ground-gas plume migration prevented by
• Installing a barrier
Cement/bentonite Slurry Wall with HDPE Membrane

- < 20m
- High integrity
- Longevity
- Very messy
- Requires large plant
- Disposal of slurry & contaminated soils

Wilson, Card and Haines, 2008
Clay Filled Trench

- < 5m
- Requires stable ground
- Disposal of excavated (contaminated soils)

Wilson, Card and Haines, 2008
Membrane in Trench

- < 5m
- Requires stable ground
- Disposal of excavated (contaminated soils)
- Risk of damage to membrane

Wilson, Card and Haines, 2008
Sheet Pile Wall

- < 15m
- Requires stable ground
- No disposal of soils
- Vibration
- Clutch seal?

Wilson, Card and Haines, 2008
Breaking the pathway

• Ground-gas plume migration prevented by
• Installing a preferential pathway to atmosphere
• Ground-gas plume migration prevented by
• Installing a preferential pathway to atmosphere backed up by a barrier
Vented Trench (Gravel or Geocomposite)

- <5m
- Single sized gravel
- Performance improved by:
  - Pipework
  - Vent-stacks
  - Membrane
- Issue of disposal of excavated soils
- Long-term maintenance?

Wilson, Card and Haines, 2008
Drilled Passive Venting Wells

- <30m
- Need to be closely spaced
- Single sized gravel
- Performance improved by:
  - Pipework
  - Vent-stacks
  - Membrane
- Issue of disposal of arisings
- Long-term maintenance?

Wilson, Card and Haines, 2008
Property Systems e.g. Virtual Curtain
Proprierty Systems e.g. Virtual Curtain
What’s the best way to check the vent or barrier works?

“To test is best”
Protecting the Building Envelope

Progressively build up fail safe protection measures:

A) Exclude ground-gases
   (Horizontal barriers or membranes)

B) Dilute and disperse, provide preferential pathway to atmosphere
   (Ventilated sub-floor void and membranes – NHBC)

C) Active venting systems with barriers – CS4 and above

D) Active positive pressurisation – CS4 and above

E) Monitoring and Alarm Systems – CS5
Design by which Risk Assessment?

• Situation A (Ciria C665) – Any development other than Situation B, eg factories, shops, commercial, warehouses, schools, cinemas, sports centres, stadiums, high rise housing, housing with basements, etc

• Situation B (Ciria C665 / NHBC) - Low rise residential building with minimum ventilated under floor void (min 150 mm)

• BS8485 – Solutions Scoring Methodology, non-managed property, public building (including managed apartments), commercial and industrial buildings

You must select the most appropriate risk assessment tools based on the conceptual model, sensitivity of end use, standard or non-standard design and regulatory setting.

“Ultimately the whole process should be one of transparency where all interested parties can see the approach taken, can understand the various steps and decisions made and be confident that a robust risk-assessed solution has been designed and installed commensurate with the construction and site constraints” BS8485 7.1
Protecting the Building Envelope

Type of development

- Low rise housing
  - Suspended floor slab
  - Ventilated underfloor void

- All other developments
  - High rise housing
  - Housing with ground bearing slabs/rafts
  - Commercial schools
  - Warehousing
  - Industrial

- Any development
  - Non-managed property, public building, commercial and industrial buildings

Adapted from Wilson, Card and Haines, 2008
Types of Development

• Standard NHBC residential Housing
• Non-standard residential housing
• Managed housing:
  – Flats & apartments, Housing associations etc.
• Public buildings:
  – Schools, Hospitals, Leisure Centre etc.
• Commercial:
  – Offices, Factories, Warehouses etc.
Types of Foundation

Depends on the ground conditions and the type of building

Types include:

• Strip footings
  – Sub-floor sleeper walls

• Piled:
  – CFA, Bored cast-in-situ, Driven, Vibro-piles (stone columns)

• Slabs:
  – Ground-bearing, Thickened-edge-beam, Suspended,
  – Block and beam

• Pad footings
### Types of Foundation

<table>
<thead>
<tr>
<th>Foundation or floor type</th>
<th>Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strip or pad foundations</td>
<td><img src="strip_or_pad_concrete_foundations.png" alt="" /></td>
</tr>
</tbody>
</table>

Structural loads from the building are supported on shallow strips or pads constructed from concrete. With this foundation type, either ground bearing or suspended floor slabs are used.
# Types of Foundation

<table>
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<tr>
<td>Piled foundations</td>
<td><img src="image" alt="Diagram of piled foundations" /></td>
</tr>
<tr>
<td>Structural loads from the building are transferred to competent strata at depth via several piles. Piles are commonly constructed of concrete although metal or sleeved piles are also available. Often the near surface ground is poor so the floor slab is normally fully suspended.</td>
<td></td>
</tr>
</tbody>
</table>
### Vibro replacement stone columns

This ground improvement technique involves the insertion of a vibrating mandrel into the ground. The resultant void is then filled with gravel that is then compacted using the mandrel. The stone columns then transfer the structural loads to competent strata at depth. If the ground improvement technique is used across the building footprint then this could enable a ground bearing floor slab to be used. If this is not done then a fully suspended floor slab will need to be used.

<table>
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<th>Diagram</th>
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<tbody>
<tr>
<td>Vibro replacement stone columns</td>
<td><img src="image" alt="Diagram" /></td>
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<tr>
<td>columns constructed from gravel</td>
<td></td>
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### Types of Foundation

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<tr>
<td>Ground bearing slab (<em>cast in situ</em>), raft or semi-raft</td>
<td></td>
</tr>
<tr>
<td>Ground bearing floor slabs are solid construction of concrete on hardcore supported directly by the underlying ground. Ground bearing slabs can either be reinforced or without reinforcing, so can behave as either flexible or rigid structures. Structural loads can either be supported by separate foundations (see strip or pad foundations above) or by a sufficiently reinforced floor slab (raft foundation). Ground bearing floor slabs can be prone to differential settlements that could potentially lead to cracking of floor slab. While flexible structures will have a certain level of tolerance to differential movement (caused by settlement and/or heave) failure of rigid unreinforced structures is more likely. This may create open cracks that form a pathway for vapours to intrude into the building. In clay soils heave and shrinkage caused by trees can affect the integrity of the slab and a suspended floor slab is more likely to be adopted. Ground bearing floor slabs are commonly used in large commercial and industrial buildings.</td>
<td></td>
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</tbody>
</table>
BRE 414 Beam & Block

1 Foundation.
2 Concrete cavity fill
3 Open void solum laid to fall and drained (Ventilation provided with periscope vents and straight-through ventilator)
4 Damp-proof course
5 Straight-through ventilator
6 Periscope ventilator
7 Damp-proof course
8 Beam-and-block floor
9 Gas-resistant membrane
10 Cavity tray
11 Screed and insulation
12 Seal (areas of high wind exposure)
Protecting the Building Envelope

A) Dilute and disperse (provide preferential pathway to atmosphere)

B) Exclude ground-gases
Principle of Passive Dilute and Disperse in Ventilated Void

After CIRIA 149, 1995
Concept of Dilute and Disperse in Ventilated Void

Fresh air flow required (total under whole building), \( Q \) is given by:

\[
Q = q\left(\frac{100-C_e}{C_e}\right)
\]

Where:

- \( q \) = surface emission rate of gas from the ground (total under whole building) – see Section 4.
- \( C_e \) = equilibrium gas concentration in the void (in this case expressed as the % value not the mathematical value i.e. for 1 percent use 1 in the equation rather than 0.01).

Wilson, Card and Haines, 2008
Gas-Proof Membranes

High quality membranes are only as good as their installation!

Wilson, Card and Haines, 2008

<table>
<thead>
<tr>
<th>Membrane</th>
<th>Methane permeability (ml/m²/24h/atm)</th>
<th>Time to fill room to 5 percent v/v methane through intact membrane (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polypropylene 1mm thick (4000 gauge)</td>
<td>0.15</td>
<td>3.7 million</td>
</tr>
<tr>
<td>Polyethylene 0.4mm thick (1600 gauge) reinforced</td>
<td>31</td>
<td>17675</td>
</tr>
<tr>
<td>Low density polyethylene sandwich with aluminium foil core, 0.4mm thick (1600 gauge) reinforced</td>
<td>&lt;0.001</td>
<td>547 million</td>
</tr>
</tbody>
</table>
New Development Changes the Ground-Gas Regime

Car-parks may require gas venting measures to protect adjacent buildings
Former Landfill – Now Retail Park
Former Gas Works site
Legal and Financial Issues

Gas protection measures in private housing e.g. membrane and sub-floor void, these need to be identified in house deeds or lease or restrictive covenants

Where protection measures require regular maintenance, repair or replacement (particularly active systems):

• Not generally suitable or appropriate for new build private houses

• Financial provision needs to be in place e.g.
  – Sinking fund, Bond

• Financial provision needs to be protected by legal instruments e.g.
  – Section 106 agreements signed between the LA and the developer.
  – Management Company’s Articles of Association
Case Study - Managed Housing on Former Landfill

• Former landfill in sandstone quarry proposed for car-park and residential redevelopment.

• Methane concentrations up to 30%

• Car-park area constructed with pre-formed venting layer connected to aspirating venting stacks.

• Planning permission granted for managed residential property
Case Study – Residential Housing on Gassing Landfill

- Fully ventilated undercroft car parking
- Fully propriety sealed communal areas, entrance ways, lifts, stairwells, and service entries
- Monitoring and maintenance agreement
- Section 106 repair fund
- Alarm systems
Fully Ventilated Under-croft Car-Park
Case Study – What not to do

• Late 1980’s residential housing in a former quarry, partially backfilled with ‘inert waste’

• Planning conditions required:
  • Gas-proof membranes
  • Ventilated sub-floor void
Case Study – What not to do

Ground conditions improved prior to construction by vibro-compaction (stone-columns)

Site now subject to a Part 2A investigation

• Original gas regime significantly altered
• Vertical pathway to beneath houses
• Inadequate sub-floor ventilation
• Gas-proof membrane – not gas-proof
Sub-floor void of existing housing
Thank you
Questions?