Bulk Infill Stabilisation of Sub-Surface Voids

PURPOSE
Shallow voids pose a risk to surface building and subsurface infrastructure because collapse of the ground overlying the voids can result in voids migrating to the surface, leading to crown-hole development. This poses a risk to both foundations, structures themselves, and below-ground infrastructure. One option for remediation is bulk filling of these voids by drilling and grouting.

The depths and thickness of the voids should be identified by desk study and subsequent detailed Ground Investigation supervised by a suitably qualified Geotechnical Engineer/Engineering Geologist. Generally, if there is more than 10x the extracted thickness (i.e., the original height of the mining void) of rock cover, then there is low risk of the void migrating to the surface. If the rock is heavily fractured, or vulnerable to weathering, then greater cover may be required.

Treatment to mining voids in the UK requires the permission of the Coal Authority. Special Publication 32 "Construction over Abandoned Mine Workings", 1984 provides information and guidance for engineers and geologists who engage in mine treatment. The application requires details of the buildings, the design of the grouting strategy including the hole spacing and grout mixes and the method of drilling (including flushing details).

PLANNING
- Identify the correct treatment strategy: This is highly dependent on the subsurface geology i.e., presence of faults, thickness of superflours, influence of ground water, dip of strata, surface topography, depth to coal seam. Undertake any further exploratory drilling and testing if further information is required.

- Determine treatment area: Treatment is required around any proposed structure or high load bearing ground that has less than 10x thickness of rock above the top of the worked coal seam.

- Determine off-set around building. Void migration to the surface can spread laterally, so it is necessary to allow for this angle of draw. Generally, an angle of 15 degrees is taken in rock, and a function of the angle of shearing resistance in soil. Generally, an off-set of 2-8m will be required.

- Determine primary treatment grid: Holes for drilling and grouting are generally spaced on a square grid. Where workings are generally absent or if there is uncertainty about their extent, a wide hole spacing of 6m is often used as a primary grid.

- Where voids greater than 500mm are encountered, it may be necessary to install a perimeter around the treatment area to prevent grout loss outside the intended treatment area. These would normally be drilled at 1.5m centres and be filled with gravel prior to grouting with a more viscous mix, usually 5:1 PFA/OPC mix.

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METHOD

• Drilling holes: Each of the holes within the treatment grid will then be drilled and grouted. The hole diameter is usually 75mm for infill holes and 100mm for perimeter holes or holes where gravel is required. The drilling process involves rotary percussive rigs, firstly installing casing seated into rockhead, then drilling to 1m below the base of the seam.

• Grout injection: Commencing at the lowest dip side, grout is injected through a flexible tube called a tremie from the base of the drilled hole to the surface. The grout mixture is commonly 10:1 ratio of PFA/OPC. Where grout take is very high, sand may be added to the mix. Where voids greater than 500mm are encountered, gravel may be added.

• Depending on various factors including grout take, nature of backfill, collapse of overlying ground, it may be necessary to drill a secondary grid, at closer hole spacings. Normally, this would be at 4.25 or 3m centres.

TESTING & REPORTING

• Pressure testing: 2% of the total number of holes drilled on a site will usually be pressure tested. A gauge pressure of 10kN/m² per metre of overburden pressure (up to a maximum of 200 kN/m²) is typically used. The test is considered a pass if the pressure holds for 2-3m which indicates no further grout can be injected.

• Material Testing: Grout cubes will be taken at regular intervals, which are crushed in the laboratory to ensure compliance. The required grout strength is in the order of 0.7 - 1N/mm².

• Reporting: A completion report is usually prepared for inclusion in the Health and Safety File, which is also submitted to the Coal Authority for their records. This will include a plan of the treatment and any perimeter holes, drilling logs, grouting logs and any material test results.

Figure 1. Diagram outlining an example of a treatment grid used in drilling and grouting. The closely spaced 4.25m square grid outlines an area of potential high grout take, whilst the wider 6m square grid outlines an area of potential lower grout take.