Abandoned Limestone Mines in the West Midlands of England — A Strategy for Action

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ABSTRACT Abandoned limestone mines in the West Midlands of England present a risk of subsidence to urban areas. Over £25M has been spent in the last 7 years on investigation, monitoring and mine infilling. The role of the independent Black Country Limestone Advisory Panel in advising the Secretary of State for the Environment has been crucial in developing the necessary strategy for action.

INTRODUCTION

The geological situation in the West Midlands of England (Fig. 1) favoured easy exploitation during the Industrial Revolution of the raw materials for iron making. Rocks of Silurian age are overlain unconformably by Middle Coal Measures and thus thick seams of high quality Silurian limestones occur close to or directly underlie abundant seams of coal, iron ore and fireclays.

The presence of abandoned mines in the Silurian limestones of the West Midlands has been known for many years. Ground movements due to the collapse of the mines have occurred from time to time over the last 150 years, largely in open land. However, in 1978, collapse of part of the Cow Pasture Mine at a depth of 150m caused significant damage to industrial buildings in Sandwell. This changed the previous appreciation of the limestone problem and it became clear that the potential problems were on a scale which was beyond the means of private landowners or local authorities to remedy.

Assistance was sought from Central Government and legislation was enacted in 1980 to enable the grant-aiding of remedial works to prevent dereliction being caused by subsidence of abandoned mines. Whilst this legislation was triggered by the problems due to limestone mines in West Midlands County, it was recognized that there were wider applications, eg to similar limestone mines in the Wrekin District of Shropshire. It was also clear that there was insufficient information about the mines to allow priorities and the form of remedial action to be determined.

In consequence, a research study to assess the degree of risk of surface collapse and to consider what action was required was jointly funded by the Department of the Environment and the local authorities concerned.
FIG. 1 Location of abandoned limestone mines in the West Midlands.

THE OVE ARUP STUDY

This study (Ove Arup and Partners, 1983) comprised two separate but complementary activities:
(a) the search for data about the limestone mines; and
(b) an engineering study to develop a risk strategy.

The objective of the data search was to discover the extent of information concerning limestone mines that remains. The objectives of the engineering study were to investigate the extent and characteristics of the mines and the rocks surrounding them, to establish the degree of risk of ground movements occasioned by their collapse and to consider and recommend what remedial and other works should be undertaken.

38 mines were identified at depths of <10m to >200m. For some mines reasonably accurate plans were available but for others only the general location could be determined from the information available. Only if two or more independent pieces of information referred to the existence of a mine was it shown on the mine plans prepared at 1:2,500 scale.
Visual inspections were made of accessible workings in Dudley and Walsall and site investigations of flooded workings in Sandwell and Walsall were carried out using rotary core drilling, geophysical logging, ultrasonic surveying and closed circuit television.

Working had been by galleries and by room and pillar mining with room heights of 4-6m in the Upper Wenlock Limestone and 7-10m in the Lower Wenlock Limestone. 100 surface disturbances recorded in the past 150 years took the form of:
(a) crown holes - sudden collapses of the ground surface due to void migration from shallow workings at depths of <70m; and
(b) general subsidence - gentler but more widespread subsidence due to collapse of pillars or "pseudo-pillars" in the strata above the limestone from depths of >70m.

A statistical approach was adopted taking account of the stratigraphy and the age, depth and layout of the mines to define the potential for collapse. This was combined with an importance factor to derive the relative risk for the defined Consideration Zone (CZ ie the area above the mine within which structures and services are likely to suffer more than minor damage due to subsidence and thus consideration should be given to the need to investigate the ground in relation to surface movements that could be caused by abandoned limestone mines). CZs, bounded by the predicted 0.2% strain line, were produced as overlays to the detailed mine plans.

Options for future action indicated in the risk strategy were:
(a) minimum work;
(b) monitoring;
(c) investigation;
(d) treatment of the mine; and
(e) treatment of structures and services.

POLICY CONSIDERATIONS
A parallel study by the commissioning bodies of the policy considerations examined the roles of planning, building regulations, other legal issues and the land use and financial implications (DOE, 1983).

It was estimated that about 486Ha could potentially be affected by subsidence due to limestone workings including town centre areas with important surface uses which could not readily be replaced elsewhere. Within the total area thus affected, there were estimated to be about 12,000 jobs, a resident population of 9,000 and property valued (conservatively) at £152 million.

Codes of Practice covering planning and building regulations matters prepared during this study have since been adopted by the local authorities concerned. These codes have been modified for adoption by local authorities in Shropshire, where there are similar mining problems (Wrekin Council, no date) and have formed the basis for general policy guidance on the development of contaminated (DOE, 1987) and unstable land (DOE, 1990).

THE LIMESTONE PROGRAMME 1983-90
On publication of the reports of these studies, a commitment was given by the Secretary of State for the Environment to make funds
available through derelict land grant for investigation, monitoring and treatment of the limestone mines where appropriate (Brook & Cole, 1986; Cole et al., 1986). Further research has examined methods of monitoring the condition of the mines using acoustic emission techniques (eg Miller et al., 1988) and monitoring of ground movements (Longworth, 1988). In addition, full-scale pumping trials for a novel method of infill were carried out by the Building Research Establishment (Ward & Hills, 1987; Ward, 1988).

Subsequent investigations of the mines have been reported by eg Braithwaite & Cole (1986), Jackson & Braithwaite (1988), Brook (1988). Almost all have now been investigated to some degree and many of the previous uncertainties have been resolved. Whilst there have been minor extensions to CZs, substantial areas have been removed because investigation has shown the mines to be fully collapsed or the limits of mining have been defined more accurately than was previously possible.

Techniques for infilling the mines to preclude the possibility of surface damage have also been progressed (eg Stevens & Seago, 1987; Braithwaite & Cole, 1988; Cole & Stevens, 1989). The use of rock paste made from colliery spoil or pulverised fuel ash as infill material has proved to be much cheaper than conventional grouting techniques. Following a trial infill of part of the Castlefields Mine, Dudley, in 1985, rock paste has been used successfully to infill the Littleton Street mine in Walsall. 600,000 tonnes of colliery spoil from three derelict spoil heaps were injected into the mine as a thick paste at an average rate of 6,500m$^3$ per week at a total cost of £6 million, enabling 15.5Ha of CZ to be removed.

THE BLACK COUNTRY LIMESTONE ADVISORY PANEL

To assist him in his decision-making, in November 1983, the Secretary of State for the Environment established a panel of outside experts. This Black Country Limestone Advisory Panel, chaired by Sir Edward Parkes, was established to:

- "advise the Secretary of State for the Environment on proposals for monitoring, site investigations and remedial works in relation to old limestone mines in the Black Country; and to consider other related issues as necessary".

After an initial period of familiarization with the limestone problem, the Panel's main role has been in the provision of:

(a) advice and recommendations on the annual round of programme submissions for derelict land grant by the local authorities;
(b) detailed comments, advice and recommendations on individual schemes subsequently submitted for pre-tender approval;
(c) independent views on engineering and risk assessment; and
(d) advice on a long-term strategy to achieve acceptable cost-effective solutions to the limestone problem.

Research recommended by the Black Country Limestone Advisory Panel

Land use affected by limestone workings

Land use and planning aspects of the limestone problem were briefly examined during the 1983 policy study by individual local authorities in the preparation
of their strategies for action. However, the Panel advised the Department of the need for an independent assessment of the value of potentially affected land in relation to the overall strategy for land use and economic development within the region.

Therefore, the Department commissioned Roger Tym & Partners (1985) to carry out research to:

- "provide an evaluated information base to assist the Limestone Advisory Panel and the Department in assessing the programmes and bids submitted by the local authorities”.

Having assessed the regional social, economic and planning context, this study examined land use and activities within 13 CZs comprising a total of 364Ha. The value of properties on the basis of the market as it then existed was about £100 million (excluding the value of roads, properties owned and operated by Statutory undertakings and churches, schools, hospitals and museums) and the estimated increase on completion of satisfactory remedial works was just over 11%. The CZs were then ranked on the basis of priority to confirm existing use and to create development opportunities.

**Risk analysis and cost-benefit study**  Recognizing the limitations of the relative risk assessment carried out during the Ove Arup study and the need to combine it with the land use information described above, the Panel recommended the development of a computerised system to provide an expert analysis of data about the limestone mines in relation to risk assessment and cost-effectiveness of treatment. This was developed by Blockley and Henderson (1988) using FRISP (Fuzzy Relational Inference Language with Support Logic) to provide a measure of uncertainty.

**Technical audit of limestone investigations**  The Ove Arup study had developed techniques of investigation designed to gain the maximum amount of information from a limited number of boreholes. These techniques were applied by the local authorities in their strategies for staged investigations of the mines to determine their extent and condition and to provide information for the design of remedial measures. Once a sufficient number of investigations had been completed, the Panel advised of the need for an independent technical audit of investigation techniques to ensure that cost-effectiveness was being achieved.

The findings of this independent assessment (Geoffrey Walton Practice, 1988) endorsed the general approach adopted but recommended a reconsideration of certain aspects and identified a number of actual and potential savings. These areas of savings were recognized by the local authorities and their consultants and some had already been identified and implemented.

**Reports by the Black Country Limestone Advisory Panel**

The Advisory Panel has reported to the Secretary of State for the Environment on a number of specific issues and, since September 1989 has also reported progress on an annual basis (BCLAP, 1989; 1990).

**Cow Pasture Mine, Sandwell**  Subsidence at the Cow Pasture mine in Sandwell had been responsible for the change in the appreciation of the limestone problems in the West Midlands. Following the Ove
Arup study, further investigation of this mine revealed that it was largely open and remained vulnerable to further subsidence. It was also clear that treatment of the mine would involve considerable expenditure.

Following further work by the local authority and its consultants and by the Department, the Panel reported to the Secretary of State (BCLAP, 1986) on the most cost-effective means of dealing with the problems caused by the Cow Pasture mine. Options considered included:

(a) infilling at a cost of up to £14 M;
(b) inducing subsidence at up to £6-7 M;
(c) structural protection at £2.3-3.5 M (up to £2.5 M now and £1 M over the next 15-20 years);
(d) relocation of surface development at £11-13 M; and
(e) monitoring and compensation at up to £2-3 M (spread over the next 15-20 years).

The Panel's recommendation of a programme of monitoring and damage-repair as the most sensible and cost-effective approach enabled the Department to devise and implement a package of central and local government and private sector measures to help alleviate the element of blight on property transactions in the area caused by the existence of the limestone mines. In particular, assurances were received from insurers and building societies that they will not discriminate in their offers of subsidence cover and mortgages solely on the grounds that property is in a limestone area.

This package was successfully tested in 1988-89 when further collapse of a different part of the Cow Pasture mine caused subsidence of up to 1.3m leading to severe damage to residential and industrial properties. 12 houses were written off for insurance purposes, with payments to individual owners dependent on the extent of their cover. The difference between the insurance payments and the value of the properties is being made up by local authority purchase of the properties which will then be demolished.

A strategy for limestone mines  In 1988, the Panel reviewed the achievements of the limestone programme and considered what still needed to be done (BCLAP, 1988a). It recommended a strategy which involves defining the extent and stability of the mine workings by staged investigations; initiating treatment methods; programming the works by priorities based on the risk to public safety and property and on the potential use of the overlying land; and completing the programme as quickly as resources and knowledge will allow. The mid-1990s target for completion of treatment of all mines to be treated (at a cost at 1987 prices of up to £40 M) was amended to the middle to late 1990s by the Secretary of State in endorsing the Panel's strategy.

Technical audit of limestone mine investigations Following the technical audit which it had recommended and the response to it by the local authorities' consultants, the Panel reported on the benefits which would ensue (BCLAP, 1988b). This report included guidelines for the preparation of bids for derelict land grant to assist in future decisions and ensure that the potential cost-savings which had been identified by the technical audit could be achieved.

Other reports by the BCLAP Progress with the limestone
programme is now reported on an annual basis and further consideration is being given to specific issues. In particular, a report on monitoring of the limestone mines is currently being finalised and consideration is being given to the development of an overall treatment strategy in the near future, as the investigation phase is nearing its completion.

THE LIMESTONE PROGRAMME - THE CURRENT POSITION

As a result of works carried out to date, a number of mines can now be removed from further consideration. Of the 486Ha identified in the Ove Arup study, 90-100Ha have been removed from CZs, including:

(a) 3 mines in Sandwell have been deleted following reappraisal of the historical evidence;
(b) 6 mines in the Dudley Port area of Sandwell have had their CZs deleted following investigation by drilling as they were found to be fully collapsed;
(c) Blackham mine in Sandwell has had its CZ reduced as drilling found the upper mine to be collapsed;
(d) Moss Close mine has had its CZ reduced since drilling showed that the mined area was substantially less than the leased area on which the CZ had been based;
(e) infilling of the Littleton Street mine is complete and the CZ can now be removed;
(f) parts of several other mines have been infilled, including emergency infilling of limited areas where chimneys had been identified approaching the surface;
(g) infilling of the Moss Close and Arboretum mines and of parts of the James Adams mine is under way; and
(h) design for the infilling of the Wolverhampton Street mine (16Ha at a cost of £10 M) is under way.

Since the scale of the limestone problem was recognized in the late 1970s, over £25 M has been spent on investigation, monitoring and treatment of the limestone mines with a further £1.5-2.0 M on research. Current expenditure is at the rate of £6 M per annum and the programme is now moving from the investigation to the treatment phase of the overall strategy.

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Any views expressed are, however, those of the author alone and do not necessarily represent the views of the Department of the Environment or any other organisation.

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