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Renewed fissuring in the Magnesian Limestone beneath the A690 road at Houghton-le-Spring, City of Sunderland

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Renewed fissuring in the Magnesian Limestone beneath the A690 road at Houghton-le-Spring, City of Sunderland

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Front cover

Fissure exposed beneath near-side lanes of north-bound carriageway of A690, 20 June 2003. Walls of solid dolomitic limestone and open fissure beneath tarmac can be clearly seen

Bibliographical reference

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Foreword

This report was written following the observation, on 20 June 2003, that further cracking had occurred on the east-bound carriageway of the A690 at Houghton Cut, Co. Durham. The report provides an update to earlier reports on the same phenomenon prepared in 2001 and 2002 by the British Geological Survey.

Acknowledgements

The assistance of staff of Sunderland City Council, in particular members of the Highways Department, is gratefully acknowledged. Dr Stuart Edwards and Mr Richard Ayres of the School of Civil Engineering and Geosciences, University of Newcastle upon Tyne, are thanked for information on GPS monitoring studies of the Houghton-le-Spring area. Mr Harry Husband and Mrs Sheilagh Hudson of Hillside Farm are also thanked for information on their land.

Contents

Summary

This report describes exposures of voids associated with previously described fissures in the Magnesian Limestone beneath a major road (the A 690) in the City of Sunderland. Evidence of recent ground movements and their relevance to the nature and timing of ground movements beneath the road are discussed. In addition to recording observations made during repair work to the road, the report is intended to inform and guide the planning, management and maintenance strategies for the road and surrounding areas.

1 Introduction

The presence of prominent open fissures within dolomitic limestones of the Upper Permian Magnesian Limestone of the Houghton-le-Spring area, and their likely association with coal extraction from the underlying Coal Measures has long been known (Goulty and Kragh, 1989; Young and Culshaw, 2001).

The likely causes of cracking of the surface of the A 690 Sunderland-Durham road at Houghton Cut formed part of an investigation into the occurrence and nature of active ground fissuring in the Houghton-le-Spring area, conducted by BGS and partly funded by Sunderland City Council, in June 2000 (Young and Culshaw, 2001). An episode of active ground movement within the Houghton-le-Spring area in 2001 was described by Young and Lawrence (2002). In order to ascertain the extent and position of any voids associated with the fissures which cut the A 690 road, BGS was commissioned by Sunderland City Council to undertake ground penetrating radar and ground conductivity surveys across parts of the road during May 2002. Although the surveys clearly revealed the position of several fissures beneath the road no significant voids were detected beneath the road at the time of the survey (Cuss and Beamish, 2002).

Studies of fissuring within the Magnesian Limestone of N E England form part of the current investigations being undertaken by the BGS Urban Geological Hazards Programme. Results to date suggest that fissuring within the Magnesian Limestone is widespread in this area and is typically most abundant within the hangingwall zone of known faults mainly, though not exclusively, those with a roughly E-W orientation. Fissuring is actively occurring both in areas with a known history of such ground movement and in areas where such instability has not hitherto been reported. It is associated with damage to land, buildings and structures, including the A 690 road. Fissures may appear suddenly and may present significant safety hazards.

A critical review of field evidence and historical reports of damage demonstrated that such processes as landslipping, cambering and limestone dissolution do not offer realistic explanations for the observed fissuring. The nature of the fissuring and its close association with known faults within this abandoned coalfield where groundwater levels are known to be rising, is consistent with some form of reactivated subsidence of underlying coal workings, or reactivation of existing faults. The fissures in the A 690 road at Houghton Cut lie in the hangingwall zone of the prominent roughly E-W trending Houghton Cut fault (Young and Culshaw, 2001).

The geology of the Houghton-le-Spring area, and fissures and other features referred to in this report, are shown in the BGS reports cited above, to which reference should be made.

Although this report is primarily concerned with fissuring beneath the A 690 road, the ground movements described have considerable relevance to a number of planning and engineering issues over a much wider area. An understanding of these phenomena is especially relevant to the current debate over the management of the nearby Houghton Quarry landfill site.

2 Previous repairs to the A 690 road

Immediate repairs to both carriageways of the A 690 road [NZ 3442 5047] were undertaken by Sunderland City Council, following the initial discovery of the surface crack in April 2000.

Repairs involved removing the uppermost few centimetres of tarmac and placing a flexible membrane prior to resurfacing with fresh tarmac. During this work the crack was found to

continue into the road sub-base (Young and Culshaw, 2001, Figure 42). Road maintenance staff on site during the repair work reported that a steel rod had been inserted into the crack to a depth of at least 1.0 m beneath the surface.

Since the original repair to the carriageway in April 2000, slight subsidence, or settlement of the newly placed tarmac has occurred. On at least one occasion additional tarmac has been placed to infill slight depressions in the repaired road surface.

No additional damage to the road was apparent at the time of a sudden collapse of the pavement adjoining the north-bound carriageway in May 2001, described by Young and Lawrence (2002, p 3). A pedestrian suffered minor injuries as a result of falling into the 0.75 metre deep hole in the pavement caused by this collapse.

3 Recent evidence of fissuring beneath A 690 road

On 20 June 2003, Sunderland City Council Highways Department staff observed significant depressions in the previously repaired tarmac in the nearside lane of the north-bound carriageway of the road and ordered an immediate investigation by removing a section of tarmac. This showed a substantial void immediately beneath the tarmac at a depth of about 0.2 m from the surface (Figure 1).

The writer arrived on site very shortly after being contacted by Highways Department staff. Geological features exposed during excavations in the two western lanes of the north-bound carriageway on the afternoon of 20 June, and in further excavations in the easternmost lane of this carriageway undertaken on 23 June, are described briefly and illustrated below.

At the time of this examination a trench up to 2 m wide and approximately 1.5 m deep had been excavated along the line of the original fissure, across the two westernmost lanes of the north-bound carriageway (Figures 2 - 3). So far as could be established the road at this point comprised up to 0.5 m of tarmac resting upon at least 0.5 m of dolomitic limestone rubble. Distinguishing limestone sub-base from broken limestone *in situ* beneath the road proved difficult. However, over much, perhaps the whole, of the excavated trench solid, *in situ*, limestone was present at depths of between 0.75 to 1.0 m from the road surface.

Immediately beneath the kerb, at a depth of roughly 0.2 m from the surface an open void up to 0.5 m wide, 1.0 m deep and extending for several centimetres beneath the pavement was clearly visible (Figure 1).

Over the remaining length of the trench a prominent fissure could be traced across the full extent of the excavation in solid limestone (Figure 3). This, the only fissure exposed in the excavation, is clearly the same fissure that became apparent in April 2000. Solid limestone walls were separated by up to 0.3 metres of dolomitic limestone rubble, though it was impossible to determine whether this was a natural filling to the fissure or whether it comprised sub-base materials pushed into the fissure during excavation.

Excavation at the extreme eastern end of the trench, immediately adjoining the eastern lane of the carriageway, exposed an open void, almost totally free of any filling. Here the void, up to 0.2 m across, was seen to be effectively bridged by the tarmac covering (Figure 4). The void proved to be over 3.0 m deep and was up to a maximum of 0.5 m wide, approximately 1.5 m from the surface. Detailed examination proved difficult but, so far as could be established, the sides of the fissure comprised solid dolomitic limestone with no evidence of dissolution or accumulation of 'flowstone' deposits. No distinguishing features were observable within the limestone walls and thus it was impossible to estimate any relative displacement across the fissure. A small amount of broken limestone rubble was observed on the floor of the void, though it was impossible to establish whether this was a natural partial filling or material

introduced during excavation.

Excavation of the easternmost lane of the north-bound carriageway was carried out on 23 June and examined by the writer immediately prior to infilling and restoration.

The eastern wall of the excavation, immediately beneath the crash-barrier in the central reservation, revealed a continuation of the fissure as an open void immediately beneath the tarmac (Figure 5). From a width of around 0.1 m beneath the tarmac the void continued downwards as a fissure dipping southwards at 50° and widened rapidly to a maximum of 0.66 m at a depth of about 1.0 m from the surface. The walls were seen to comprise solid dolomitic limestone. Although coated with dolomitic dust, perhaps the result of excavation, the walls appeared clean and fresh with no sign of dissolution or accumulation of 'flowstone' deposits. A few blocks of limestone were present on the floor of the void, though here again it was impossible to establish whether this was a natural partial filling or material introduced during excavation. Here, too, it was not possible to determine any displacement across the fissure. The void was seen to continue downwards for at least a further metre or so below the level of the excavation and clearly continued eastwards beneath the central reservation and westernmost portion of the south-bound carriageway. The precise extent of this extension could not easily be measured, though the void appeared to extend eastwards for at least 1.0 to 1.5 m and appeared to extend slightly southwards from the alignment of the course of the original fissure, though this too proved difficult to measure. A notable feature of the void was the gentle circulation of cool air within it, suggesting a connection with void spaces beyond those observed. The workmen undertaking the repairs commented that when first cut this void appeared to suck dust into it.

It is understood from City Council staff that the excavations were reinstated by filling with dry broken rock compacted to the level of the base of the tarmac. A flexible membrane was placed over the rubble fill and tarmac was placed above this to make good the road surface.

Young and Culshaw (2001, pp 17-18) drew attention to two very faint en echelon cracks seen in June 2000, approximately 40 m south of the original crack in the road surface. At this time the cracks were difficult to observe and were restricted to the easternmost two lanes of the north-bound carriageway. Young and Lawrence (2002, p 3) noted that at the time of their 2001 investigation this cracking was much more pronounced: the two faint cracks by then appeared to have united into a single much more prominent crack which could be readily traced across all three lanes of the carriageway.

This crack has clearly grown comparatively rapidly and, at the beginning of June 2003, had become almost as conspicuous as the original crack discovered in April 2000. This crack, like its neighbour to the north, can be clearly linked to a conspicuous fissure exposed in the western wall of the road cutting. In view of the apparently rapid recent development of voids in the original fissure, it is not unreasonable to suppose that similar ground movements could have widened any fracture beneath this crack. Investigation of the nature of this fracture, and the possible extent of any associated voids is recommended as a matter of urgency.

This crack cannot currently be detected in the south-bound carriageway. This may reflect foundation conditions and materials beneath the road at this point. The north-bound carriageway lies close to the rock surface excavated during the widening of the A 690 road in the 1970s. Any fissure developed within the solid rock here is thus likely to affect the road surface. The south-bound carriageway at this point lies on made ground introduced as part of the re-grading of the road profile during the 1970s alterations. It is reasonable to suppose that the made ground, perhaps here amounting to >2 m, may currently be effectively preventing the upward migration of any fissure to the road surface.

4 Evidence of recent ground movement in the Houghton-le-Spring area

Following the repairs outlined above, a brief examination was made of land along the line of the Houghton Cut Fault for several hundred metres to the east and west of the A 690 road. The prominent fissures west of the road described by Young and Lawrence (2002) locally showed very slight disturbance of the soil along the sides of the open fissures, in places with some signs of very slight disturbance to this year's growth of vegetation.

To the east of the road, on the hillside above Hillside Farm, a circular hole up to 0.5 metres across and at least 1.0 m deep was observed within the linear depression 'B' on Figure 3 of Lawrence and Young (2002) [NZ 34475047]. The owner, Mr Husband, reported that this hole had appeared within the past two to three months, though he could not be more precise about the timing of this or of a rather larger hole up to 1.0 m across and at least 1.0 m deep, which had also developed suddenly within the past two months, approximately 450 m further east almost on the surface outcrop of the Houghton Cut Fault [NZ 3375 5049].

Significant recent collapses at Middle Haining Farm [NZ 3552 5095 and NZ 3555 5097], close to those previously described by Young and Culshaw (2001, pp. 14 - 15), approximately 1 km east of Houghton Cut, were seen by the writer following reports from staff of Sunderland City Council in April 2003.

There is thus some evidence that ground movements have been active locally along the line of the Houghton Cut Fault within the past few months, though precise timing of any events are not known.

Whereas data from the network of GPS monitoring equipment installed in the Houghton-le-Spring area by the School of Civil Engineering and Geosciences, University of Newcastle upon Tyne, reveal evidence of active ground movement, insufficient data have so far been collected to allow for detailed comment on the timing, amount or direction of movement.

5 Timing of the recent fissuring beneath the A 690 road

Geophysical surveys conducted in May 2002 by Cuss and Beamish (2002) identified the position of several fissures, including that which forms the main subject of this report, though no evidence for substantial voids was obtained. As voids of the size revealed during the repair work described here would have been readily detected by the methods employed, it is reasonable to suppose that these recently exposed voids must have developed at some time since May 2002. Moreover, it seems reasonable to assume from their position immediately beneath the otherwise unsupported tarmac of the road, that these voids are unlikely to have existed for any significant period. The constant passage of large volumes of heavy traffic on this busy road would almost certainly result in the collapse of the tarmac bridging the voids, or cause severe depressions in the road surface.

The evidence from recent collapses at Hillside and Middle Haining farms, apparently all during April or May 2003 suggests a phase of active movement in rocks adjoining the Houghton Cut Fault. It is possible that the voids revealed within the road may have developed at this time, though there is no means of fixing the time of this movement.

6 Conclusions

Active ground movement, with associated surface fissuring, continues to be active in the vicinity of Houghton Cut.

These movements have resulted in the comparatively rapid development of large open voids at shallow depth, immediately beneath the carriageway of the A 690 road.

Open voids have been observed to extend at least part way beneath the south-bound carriageway of the road.

A further fissure, 40 m south of the original fracture, is continuing to develop and become more conspicuous within the north-bound carriageway.

Evidence both from the Houghton-le-Spring neighbourhood and elsewhere on the Magnesian Limestone outcrop suggests that such ground movement is likely to continue with the sudden appearance of open fissures at the surface, or in some instances concealed beneath road surfaces.

Careful monitoring of fissuring at Houghton-le-Spring is likely to contribute greatly to understanding the causes of fissure development and has the potential to assist in their prediction and remediation.

7 Recommendations

The prompt action taken by the City Council to investigate and repair the north-bound carriageway of the road has undoubtedly avoided a potentially serious threat to public safety. However, in the light of recent observations made in the road and the adjoining area, the following recommendations are proposed:

1. Investigation of the extent of any voids, and their remediation, beneath the south-bound carriageway is strongly recommended as a matter of urgency.
2. Repeat walk-over surveys of the area covered in Young and Culshaw's 2001 report should be undertaken at 6-12 month intervals to record any changes at the surface.
3. Appropriate geophysical surveys of the fissures within Houghton Cut should be undertaken to identify any changes which may have occurred since Cuss and Beamish's report of 2002.
4. GPS monitoring of ground movements in the Houghton-le-Spring area should be continued.
5. Collation of all relevant geological, groundwater, geophysical (including micr-seismicity), mining, geotechnical and other data and reports held by local authorities, the Coal Authority, the Environment Agency and others should be undertaken.
6. Mapping of fissuring and damage should be extended to include the whole of Sunderland (and preferably beyond), to include both the Magnesian Limestone and Coal Measures outcrops, to establish the full extent of these ground movements.
7. Determination of the processes that are causing these ground movements and the time frames over which they act.
8. Research into the suitability of PSInSAR as a means of identifying and quantifying these ground movements.
9. Research into existing and possible new methods for road pavement and sub-base design appropriate to these ground conditions.

10. Evidence of such ground movements should be taken into account in any evaluation of sensitive environmental issues in the surrounding area, including those surrounding the Houghton Quarry landfill site.

11. The necessary research and investigations be coordinated by BGS in collaboration with Sunderland City Council, with appropriate input from BGS's existing university research partners.

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Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

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Figures

Figure 1. Void beneath pavement, adjoining north-bound carriageway of A 690 road, exposed during repair work 20 June 2003.

Figure 2. Excavation of fissure across north-bound carriageway of A 690, 20 June 2003.

Figure 3. Fissure exposed beneath near-side lanes of north-bound carriageway of A690, 20 June 2003. Walls of solid dolomitic limestone and open fissure beneath tarmac can be clearly seen.

Figure 4. Detailed view of the open fissure immediately beneath the tarmac, seen in Figure 3.

Figure 5. Open fissure immediately beneath tarmac, exposed in excavation of the outside lane of the north-bound carriageway of A 690 road, during repair work 23 June 2003.

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