Application of ground-penetrating radar to investigate the effects of badger setts on slope stability at St Asaph Bypass, North Wales

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Abstract

At the St Asaph Bypass, surface cracking developed along the crest of a modern highway cutting, above a cluster of badger setts excavated in the sandy soils of the cutting slope. This prompted concerns about the extent of the underlying tunnel systems and the possible existence of deep cavities lacking surface expression that might cause a potential slope instability problem. The full threat posed to the integrity of the cutting and to the safety of road users remained uncertain. In addition, intrusive investigations were deemed inappropriate and a non-invasive solution to the problem was required.

Ground-penetrating radar was used along a 50 m stretch of the cutting to determine the full extent of the badger setts beneath the surface. The geophysical survey identified 324 m of tunnels and demonstrated that the tunnel network was generally shallow (*c.* 0–2 m). Pronounced radar reflections characteristic of air voids were identified in the data and interpreted as the badgers' access tunnels and living and nursery chambers whereas the more subdued features were interpreted as collapsed and abandoned diggings. This case history illustrates the benefits of using ground-penetrating radar to provide an understanding of slope stability and local ground conditions in areas of environmental sensitivity when non-intrusive investigations are required to provide reassurances in relation to public safety.

Keywords: badger setts, case history, radar, geophysics, highways, slope stability

Introduction

Animal diggings pose a common problem wherever poorly consolidated sandy soils form the slopes of embankments and cuttings along transportation corridors. Engineered slopes with well-drained, firm and undisturbed ground frequently combine with landscaped areas of broad-leaved woodland that adjoin open pasture-land to create ideal habitats for a wide variety of burrowing animals in general and badgers in particular (Cresswell *et al.* 1990). The engineering geological concerns relating to animal diggings principally involve their potential to induce ground movements that may adversely affect roads, railways, buildings and flood-defences, with potential consequences for neighbouring communities and the local economy.

Constructed in 1970, the A55 St Asaph Bypass includes a major earthworks cutting, 500 m in length (Figs. 1 and 2) (Nichol 2000). The site lies some 0.6 km north of St Asaph and at the northeastern end of the cutting [National Grid Reference SJ 040750]. Here, the slope profile contains numerous entrances and spoil heaps associated with badger setts. The presence of these diggings together with the development of longitudinal cracks along the crest of the slope prompted concerns about slope instability and the potential threat posed to the highway.

Badgers are a protected species under the Protection of Badgers Act, 1992. It is an offence to disturb or destroy a badger sett, even if this action is unintentional. It was therefore necessary to remotely assess the true scale of the problem before recommending whether physical intervention, such as sett relocation was required.

The use of ground-penetrating radar (GPR) techniques has become well established for highway engineering applications and the potential for GPR mapping of tunnels excavated by fossorial species was identified by Stott (1996) in describing experiments to investigate the structure of rabbit warrens near Adelaide, South Australia. However, as far as can be determined, the use of GPR techniques to map extensive, complex tunnel systems within engineered slopes along transportation corridors has not previously been attempted. In this paper non-invasive GPR investigations were carried out to determine the extent of excavation and redistribution of the soil by badgers within a major road cutting and also to provide a better understanding of the potential for future ground movements.

Geological setting

Geologically, the central feature of the district is the down-faulted rift valley of the Vale of Clwyd (Warren *et al.* 1984). Within the graben tract at St Asaph, the local bedrock consists of sandstones, siltstones and mudstones of Upper Carboniferous (Westphalian) age that crop out between the two Permo–Triassic basins around St Asaph. The rockhead strata are overlain by heterogeneous till deposits associated with the last

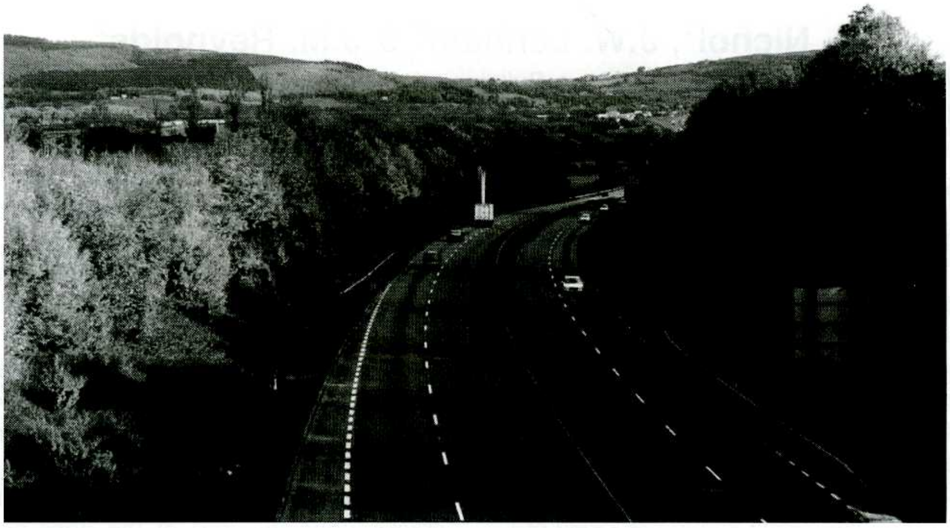

Fig. 1. A55 St Asaph Bypass cutting. View looking eastwards.

glaciation affecting the area during Late Pleistocene (Devensian) time.

Between the rivers Clwyd and Elwy the A55 highway passes in deep cutting through an intervening ridge. The principal glacial deposits forming the ridge are clayey tills, sands and silts.

The site

The site adjoins the A55 eastbound carriageway and comprises the earthworks slope of the highway cutting and a platform area above the crest. The slope has been planted with deciduous trees at regular 1.5 m spacing, whilst the platform has been left bare. The tree canopy effectively restricts growth of ground cover across the site. The cutting slope has an average gradient of 24° and a mean down-slope length of 15 m and the flat platform at the top of the slope varies from 3–6 m wide and is bounded to the north by a fence bordering an open field.

The geological profile of the site consists of pale brown heterogeneous sandy and silty soils overlying brown clayey soils. Descriptions and engineering properties of the soil units are summarized in Table 1. The particle size distribution of a representative sample of the spoil material is presented in Figure 3, indicating the characteristics of the ground in which the badgers have tunnelled.

The surface expression of the badgers' workings appears restricted to a 50 m stretch at the eastern end of the cutting. Most of the diggings are situated along the upper part of the slope, where flattened trackways between the trees link entrances, foraging patches and latrines. Several smaller entrances also exist on the level platform at the top of the slope but no surface indications of badger activity were noted in the adjacent field. On the slope, excavations by badgers have created conical spoil mounds measuring up to 3 m wide and 1.5 m high. Typically, each spoil mound surrounds a single entrance but, in places, individual mounds have coalesced to form larger heaps (Fig. 4), resulting in localized slope steepness of up to 38°. Anecdotal evidence from local badger conservationists suggests that there may have been a sett in this area for over 100 years and certainly, the site has been relatively undisturbed since 1970. Conceivably, the underground tunnel system has evolved over a long period of time and could be more complex than suggested by the distribution of features on the ground surface at the present day.

Ground-penetrating radar survey

Introduction

In GPR applications, radio-frequency pulses are transmitted vertically into the subsurface from an antenna placed on the ground. The subsurface propagation velocity and attenuation of radar waves are a function of soil conductivity, which is controlled by bulk composition and moisture content. Interfaces between media of differing dielectric properties give rise to partial reflection of the down-going radar wave; these reflections return to the surface where they are received and digitally recorded. The amplitude and time delay of reflected energy arrivals provide quantitative information on the composition and structure of the ground. Radar systems measure the two-way-travel time (TWTT) elapsed between transmission of the down-going pulse and