Timely owner awareness of the importance of geotechnical engineering in dispute resolution

La conscience à propos du propriétaire de l'importance de génie géotechnique pour la résolution des disputes

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ABSTRACT

Case histories involving backfilled sites on a range of different materials, landslide sites, and a retaining wall demonstrate that problems can arise if there is an inadequate understanding of the ground conditions. Water is a common theme that results in many of the difficulties which occur. The lack of early introduction of geotechnical specialists often leads to costly remedial works followed by legal proceedings. Timely involvement of geotechnical engineers is strongly encouraged so that disputes are avoided.

RÉSUMÉ

Quelques évolutions du cas géotechniques y compris des chantiers 'remblai' qui sont construit sur une gamme de matériels différentes; des chantiers qui sont affectés par des glissements de terrain; et un mur rétinien démontent que les problèmes se présentent si les conditions du sol ne sont bien compris. Souvent c'est la présence d'eau qui est la cause d'un grand nombre de ces problèmes. L'absence des spécialistes géotechniques au début des projets peut mener à les mesures remédies très cher et les procès légales. L'introduction à propos des ingénieurs géotechniques est fortement encouragée pour que les disputes soient évitées.

Keywords : Failures, Liability, Foundations, Backfill, Slopes, Retaining Walls

1 INTRODUCTION

In spite of now being in the 21st century, owners, developers, and too many non-specialist civil engineers, lack adequate understanding of the importance of geotechnical engineering. Too often they only begin to recognise its relevance after a failure involving a feature such as a foundation, a slope, or a retaining wall, has occurred.

A series of case histories is presented which involve failures or potential failures that arose as a result of inadequate understanding of the need to address ground-related matters. Disputes often took place before the parties finally turned to the specialist geotechnical engineers to explore and identify the cause of the problem and assist towards its resolution.

Traditionally each party appointed and instructed their own chosen expert and a strongly orientated adversarial approach developed. More recently, the benefits of engaging a single technical expert who is chosen to jointly represent all the parties has become recognised.

The first set of case histories comprises various backfilled sites which encompass a range of different materials. They exemplify the varying problems that can arise, particularly with respect to foundations.

The second set concerns problems associated with slope instability which arose either because of removal of material from the toe of a slope or undue loading at the head of a slope.

The final case describes a retaining wall which began to suffer excessive lean many years after its original construction. The timely appointment of a specialist geotechnical engineer as a single joint expert ensured prompt technical resolution, in spite of the complexity of the issues involved, without recourse to litigation.

Water was found to be a common factor in giving rise to ground related problems for each category of the case histories described.

2 BACKFILLED SITES

2.1 *Stiff clay backfill*

Shortly after houses were built on a new development, some of them began to suffer undue settlement. Tilt was recorded in excess of 200mm. The houses were located on a backfilled opencast coal mining pit with the depth of backfill being about 10m. Shallow pillar and stall type mine workings underlay the opencast pit. The backfill had been placed without controlled compaction. Grout injection had been carried out before the houses were built to stabilise the shallow mine workings. Vibro stone columns were introduced into the fill in an endeavour to improve its bearing capacity and reduce the settlement that might otherwise arise. Figure 1 shows a typical cross-section of the site.

When the settlements occurred, an geotechnical specialist was appointed to review the matter, advise on whether either the stone columns or the grouting might be defective and give guidance on possible remedial works. The first stage was to conduct an investigation of the fill and the underlying solid strata. It was established that the fill consisted of loosely compacted lumps of stiff clay. The depth to the most shallow coal seams was confirmed together with an indication that there were few if any open voids remaining. It was decided to

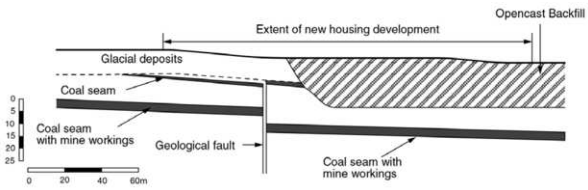

Figure 1. Cross section through clay backfill site

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carry out regrouting as part of a remedial works. It was established that the additional amount and pattern of the further grout takes bore no comparison with the pattern of settlement. Accordingly it was deemed that inadequate grouting was not the cause of the problem.

It was recognised that the stone columns could be acting as vertical drains introducing water into the fill thereby giving rise to inundation collapse. To resolve this it was decided to install piles to underpin the houses, which had solid raft foundations, and then jack them back to level.

Legal proceedings ensued which led to a High Court hearing and in due course judgement was given. In this example there was a complete absence of timely awareness of the technical problems at the outset and a complete lack of enthusiasm by the parties concerned to settle the matter in a timely manner.

2.2 *Sand backfill*

Many years after houses were built on both sides of a road in the West Midlands, a number of the properties began to suffer settlement giving rise to structural cracking. Research revealed that the houses were located over backfilled sandstone quarries. Investigation demonstrated that the fill was predominantly loose sand with the groundwater level being close to the base of the old quarry. Repairs involving pile underpinning were put in hand before the degree of damage became excessive. Specialist geotechnical advice was sought regarding the cause of the settlement and why it should have arisen many years after the houses were built.

Some months before the damage had arisen, heavy lorries had trafficked the road in connection with a new housing development. Loose sand is susceptible to settlement on severe vibration. However, although the residents reported that their houses experienced vibration, the timing did not coincide with the damage. Excessive water was discharged from a site uphill where a new housing development was being constructed and the water flowed down the road past the existing houses. Again, detailed review showed that the two events did not coincide. Heavy rainfall occurred in the months immediately preceding the subsidence and initially appeared to be a probable cause. However examination of the rainfall records for 30 years revealed there had been other periods of high rainfall but that no subsidence had been reported. Almost at the same time as the damage to the house was noted, it was recorded that the adjacent road was starting to deteriorate. A number of weeks afterwards it was established that a major water main in the road was leaking. In due course this was repaired. Water from the leak could readily have inundated the loose sand fill causing collapse compression. The timing matched the occurrence of damage to the houses. Figure 2 shows the juxtaposition of the houses and the water main.

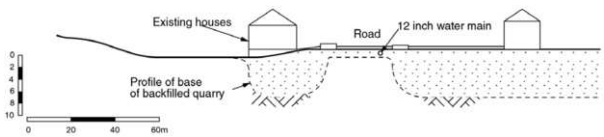

Figure 2. Cross section through sand backfill site

Legal proceedings were commenced and a meeting was held between the geotechnical experts appointed by the parties concerned. Common views were found to exist on many of the issues which led to a resolution of the matter.

This example demonstrates the lack of timely awareness of the nature of the ground conditions when the houses were originally built and that this can create a problem that is hidden for many years before it manifests itself.

2.3 *Limestone backfill*

During the construction of a golf-driving centre in the Northeast of England there was a torrential rainstorm. Subsidence occurred which affected the partly constructed facility. Repairs were put in hand but before the works were completed there was a further rainstorm and a repeat of the subsidence.

At this stage the developer decided to obtain specialist geotechnical advice on the nature of the site. Careful investigation established that the material which had previously been considered to be natural ground was in fact fill to an old limestone quarry. There appeared to be some conflict between the extent of the quarry as shown on historical records compared with that depicted on the geological map of the area. A cross-section showing the actual ground conditions is given on figure 3.

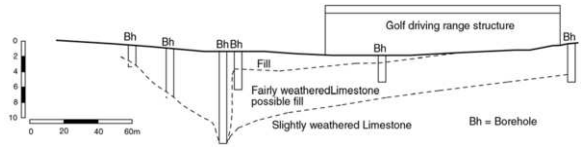

Figure 3. Limestone backfill site

Although washout arising from the rainstorm was a possible cause of the subsidence, it was deemed that the fill had undergone collapse compression. Piling remedial works were therefore introduced.

Early steps towards legal proceedings were taken with goetechnical experts being appointed by the respective parties. There was general agreement that the mostly likely cause of the subsidence was collapse compression. However there was a lack of agreement as to whether it could have been foreseen and whether there were shortcomings in the original investigation. In an endeavour to resolve the matter the parties agreed to hold a one day mediation hearing rather than proceed to a lengthly and costly High Court hearing. This led to a mutually satisfactory resolution.

Again this example demonstrates the lack of proper understanding of the ground conditions at the outset of a development. This is turn arose by the failure to introduce a geotechnical specialist until severe problems had occurred.

2.4 *Mass concrete backfill*

Some 10 years after completion of backfilling an opencast ironstone mined site with ‘boulder clay’ material a developer expressed an interest in constructing houses on the land. The backfilling had been carried out with no compaction and therefore temporary surcharge was introduced to reduce, if not eliminate, the risk of settlement affecting the proposed development.

About two years after construction, one pair of semi-detached houses started to show signs of cracking. The cracks were at their widest at ground level adjacent to one of the gable end walls and rose diagonally towards the party wall, gradually reducing in width towards the eaves of the house. In due course the cracks began to widen to about 10mm and the developer decided that piles should be installed to underpin the house structure in an endeavour to prevent further more extensive damage occurring.

The developer decided to initiate legal proceedings against the original designer of the houses in order to recover the monies expended on the remedial works. Experts were appointed but no agreement could be reached on the key issues. Accordingly the matter progressed to a High Court hearing.

During this hearing one of the factual witnesses for the developer revealed that about 18 cu.m of mass concrete had

been placed on the site of the structure that had suffered damage. Further information also came to light which showed that there had been a large heap of topsoil up to 6m high which was located close to and overlapping one end of the pair of houses.

Trial pit examination revealed that in this area the house A was founded on particularly deep beam foundations while house B was on normal depth foundations. It was apparent that there had originally been a depression which had been backfilled with topsoil and then mounded over. During development all the old topsoil had been removed and the backfilling dug out with the resulting recreated depression backfilled with mass concrete. Accordingly one of the pair of houses was founded on deep mass concrete fill while the other was on clay backfill. The very marked difference in the stiffness of the ground had resulted in the houses effectively 'breaking their back'. A cross section through the pair of houses is shown on figure 4.

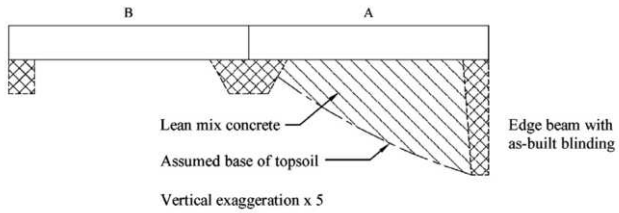

Figure 4. Cross section showing mass concrete backfill

With this understanding to hand the Court hearing came to an abrupt conclusion. The example demonstrates not only the problems which arise from the lack of early appointment of a geotechnical specialist but also the failure to make available appropriate records in a timely manner so that a resolution could be achieved before the matter progressed to Court.

3 LANDSLIDE SITES

3.1 *Road access cutting*

To form an access road to a site for a new development at a brewery, a cutting was made across a sloping valley side. Rainfall was reasonably heavy and the toe of the new cutting began to be unstable. A walkover by a geotechnical specialist revealed that fissures had opened up about 100m up-slope from the cutting. It was evident that a relatively substantial landslide was in the process of occurring. Stabilisation works required a knowledge of the depth to the plane of sliding and the relevant groundwater pressures. This information could only be obtained by detailed borehole examination and groundwater monitoring. Temporary stability was achieved by placing a toe berm. After investigations and monitoring lasting almost one year were complete a full understanding of the conditions controlling the slope movement was obtained. Remedial works involving a deep drainage trench were constructed to lower the groundwater pressures permanently and thereby prevent future slope movement. A section through the landslide is given on figure 5.

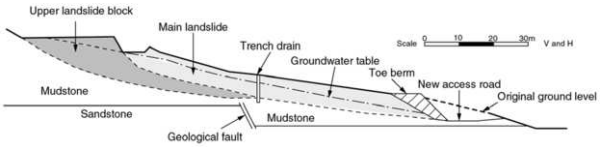

Figure 5. Section through slope with cutting for road access

From the outset, the developer client appreciated that all efforts should be focused on understanding and resolving the problem. There was close co-operation between the developer, the geotechnical specialist and the contractor. The developer decided against making a claim for the recovery of the cost of the works. This exemplifies the situation where, although recognition of the actual nature of the ground conditions was somewhat belated, there was expeditious resolution of the matter.

3.2 *Slope regrading for housing*

Fill was placed on the uppermost part of a slope to form a site for new housing. When they were partly completed there was a period of heavy rain. The houses began to crack so the developer decided to seek specialist geotechnical advice. Boreholes were put down to allow sampling and testing and groundwater monitoring was undertaken. The original natural ground level was found to be masked by up to about 10m of ash fill as can be seen in figure 6. The clay marl was found to contain polished discontinuities, indicative of relict slope movement. Accordingly the slope failure on the new housing development site was deemed to be a renewal of a former landslide. This assessment was matched by the theoretical analysis of the slope. Remedial works involved regrading the slope to its former profile and introducing gravel filled berms. It was not possible to retain the row of houses that had been planned for this area but the remaining parts of the development were secured.

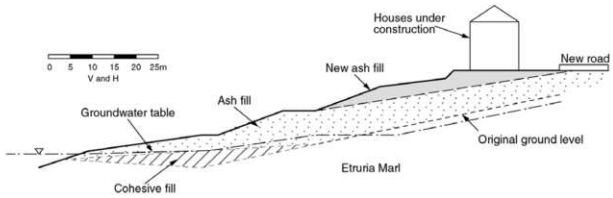

Figure 6. Section through slope regraded for housing

A claim was made by the housing developer against the original technical adviser to recover the losses suffered. Meetings between geotechnical experts were held but the issue of whether the problem could have been foreseen and whether the original adviser had acted with reasonable skill and care remained. The legal representatives duly made preparations for a High Court hearing. In the event a settlement was reached 'on the steps' moments before the parties entered the courtroom. Considerable costs were incurred but the potential for saving some monies by not proceeding with the hearing was achieved. It demonstrated the value of reaching a resolution even at a relatively late stage.

3.3 *Cutting for housing development*

A 4m cutting high was formed for a new housing development at the toe of a slope and a 1m high gabion wall was installed. An existing house, with a rear extension, and a garden were sited behind the crest of the slope. The garden was bounded by a masonry retaining wall. The overall drop in level to the new housing development was about 7m.

Shortly after the cutting was formed part of the garden was found to have subsided by at least 100mm with cracking in the masonry boundary walls. Cracks up to 6mm width were observed to the rear extension. The insurer of the house owner engaged a geotechncial specialist to advise on the problem. The initial interpretation was that the movement was typical of incipient slope failure. Aerial photographs revealed that the original slope was uneven, indicative of the area having

suffered relict slope movement. Figure 7 shows a cross section through the site.

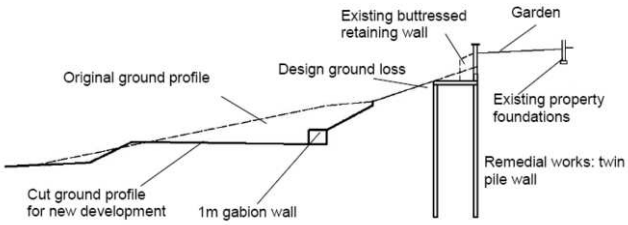

Figure 7. Section showing cutting for housing development

A site investigation identified that ground conditions were loose silty fine sand with layers of soft to firm clay. The groundwater level was found to have seasonal variation of about 2m with the higher, winter, level at 7.5m depth. Perched water, also with a seasonal variation, was identified as overlying the uppermost clay layer, being above the level of the toe of the slope. Laboratory testing established that the clay had a residual strength value, ϕ'_r, of 14° with c' of zero. Analysis showed that the factor of safety fell marginally below unity for a moderately pessimistic assessment of the highest likely water level. Access to the toe of the slope was denied and therefore it was decided to install a twin-pile wall positioned immediately behind the crest of the slope.

It had been hoped that recognition of the cause and acceptance by the causative party would be forthcoming. The absence of this resulted in legal proceedings being commenced. Substantial costs were incurred before the matter was resolved. This demonstrates the disbenefit arising from lack of understanding of the ground conditions by the party who carried out the excavation and the failure to accept responsibility in a timely manner.

4 RETAINING WALL SITE

4.1 *Masonry retaining wall*

Some 100 years ago a retaining wall up to 5m high was built next to an existing road. The area behind was backfilled and a level site formed for terraced housing. The wall was based on shallow foundations. A pipeline was constructed, presumably before the houses and wall were built, to carry the outflows from the properties. There was also a shallow depth drain running along the front of the houses to collect the surface water run-off. Figure 8 depicts the key features.

About 30 years ago the wall developed a slight outward lean. Monitoring revealed that the movement was progressive and about 25 years later it had reached a lean of about 1 in 10. A survey of the pipeline established that it had various cracks, particularly immediately upstream of the retaining wall. The house owners began to be concerned about the security of their properties which were in danger of becoming damaged if the wall were to move further or, indeed, collapse.

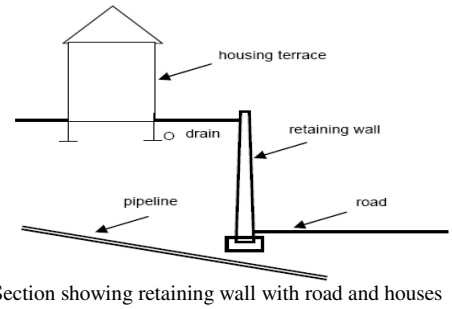

Figure 8. Section showing retaining wall with road and houses

Following discussions between their legal representative and the equivalent representatives for the owners of the pipeline and the road, a geotechnical specialist was appointed to act jointly for all the parties to establish the cause of the problem. An investigation found that the soil conditions beneath the wall foundations comprised sand with occasional bands of clay. Analysis of the wall indicated that it could have a marginal factor of safety against instability, the actual value depending on the water level behind the wall. Various possible causes were considered which included leaking house drains introducing water into the ground behind the wall, the pipeline which was known to be defective and would therefore be leaking, weakening the soil beneath the retaining wall foundation, and vibration from traffic disturbing the wall foundations.

The parties recognised that the uncertain precise cause of the damage could give rise to an uncertain outcome of any Court hearing and therefore decided not to takes steps towards costly litigation. Instead progress was made in determining the works necessary to rectify the problem. The pipeline was lined to prevent it from leaking and a tie-back system for the masonry retaining wall was planned to prevent any further outward movement. This example demonstrates how timely introduction of a geotechnical specialist and mutual co-operation between the parties concerned can lead to a particularly satisfactory outcome for all involved.

5 CONCLUSIONS

1. Case histories involving backfilled sites, landslides and a retaining wall each demonstrate the problems which may arise when there is a lack of proper understanding of the ground conditions.
2. In almost all the cases, water was a critical factor which triggered failure or incipient failure. The absence of appropriate appreciation of this key feature may be the underlying reason for the difficulties that occur.
3. Costs associated with remedial works can be high and disputes typically result when the respective parties are not able to agree who should bear the responsibility.
4. The introduction of geotechnical specialists normally assists in leading to a resolution. Conversely the absence of specialist input can result in undue costs associated with legal proceedings.
5. The involvement of geotechnical specialists as technical experts in litigation matters offers an excellent opportunity to make owners aware, albeit belatedly, of the importance of ground engineering.
6. It would, however, be preferable that more timely awareness was gained by owners and the like so that the incidence of ground related failures was minimised.