Novel Applications of Geogrids in Areas of Shallow Mineworkings

R. J. Bridle & B. Barr
University of Wales College of Cardiff, UK

C. G. Jenner
Netlon Ltd., Blackburn, UK

ABSTRACT: The paper reports on aspects of an extensive research programme, including full-scale field trials and large -scale laboratory tests, to investigate the performance of geogrid reinforced pavements over voids. In the field trials 3m and 5m diameter voids were introduced into an 8m square test bed. Geogrids were placed over the areas to be voided and the 600mm deep pavement, which was constructed using Type 1 sub base material, was surcharged to a level of $5kN/m^2$. The laboratory tests were used primarily to study the effects of varying void diameter (ranging from 2m to 4m) and the number of layers of geogrids. The strains developed (together with creep strains and deflections) were measured by means of a novel strain monitoring system for a period of up to 4 days following the void formation. A tentative design procedure is proposed, based on the extensive experimental study.

1 INTRODUCTION

A significant amount of land reclamation and redevelopment has taken place in the UK during the last two decades. Much of this work has been carried out in the old industrial areas based to a large extent on the heavy industries of the past. In particular, a significant amount of land redevelopment has taken place in the traditional mining areas of the country.

One of the major difficulties encountered in the redevelopment of old industrial sites is the risk associated with unknown mining activities carried out in earlier times. In view of these serious difficulties the Department of the Environment in the UK commissioned Arup Geotechnics (1991) to prepare a report entitled "Review of Mining Instability in Great Britain". This report showed that up to forty mining subsidence incidents, due primarily to the collapse of old mineworkings, were encountered in any given year in the South Wales Coalfield area alone. The main type of subsidence reported was the development of crown holes (which are formed by the collapse of strata into a mine cavity) resulting in crater-type holes appearing at ground level.

In recent years there has been a considerable interest in the use of geotextiles to provide surface protection in areas of earlier shallow mineworkings. Much of the research work in this field to date has been of a theoretical or speculative nature (Poorooshasb (1991) and Kempton (1992)). The main objective of the work reported in this paper was to carry out a series of full-scale tests to investigate the use of geogrids to provide protection against sudden collapse of surfaces in lightly loaded areas such as landscaped recreation areas, footpaths, car parks and local access roads.

2 EXPERIMENTAL STUDIES

A full-scale test bed, 8m x 8m in plan and 1.2m high, was constructed in which geogrids (in one or two layers) were placed beneath 600mm of compacted Type 1 aggregate which was loaded in turn with a uniformly distributed surcharge of $5kN/m^2$. A section through the test bed is illustrated in Fig. 1. Voids of 3m and 5m diameter were developed in the test bed in a controlled manner and the strains developed in the geogrids were monitored by means of a novel strain monitoring system which is described elsewhere (Barr, Austin and Bridle (1994)). The strains were measured directly over a 100mm gauge length by means of extensometers containing Sangamo DCR 15 LVDT

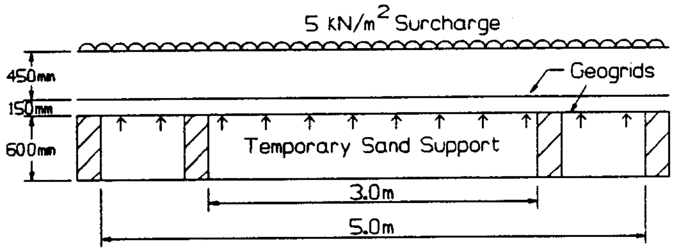

Fig. 1 Section illustrating test bed construction

displacement transducers with an extension range of ± 15mm. These transducers were connected via a 24-channel conditioning module, which distributed a highly stabilised 10 volt supply to the extensometer, to the Solatron-Schlumberger 3531D data acquisition system used in the study. The strains were monitored during the period of void formation and thereafter for a period of 2 to 4 days to record the development of any creep in the geogrids.

The test bed was constructed in an agricultural type building which had an open access along one side of the structure and a roof covering. This location had the benefits of good access for delivery of materials in bulk and reasonably good protection from poor weather. Furthermore, the site had plenty of adjacent land which could be used for stock piling large quantities of materials. (Approximately 150 tons of material was used in the test bed.)

Since 3m and 5m diameter voids were to be investigated, an attempt was made to carry out two tests sequentially with the 3m void being created first followed by the 5m void. Two concentric walls and the associated tunnel used for void formation were built within the test bed by means of three layers of blockwork. Gaps were left at regular intervals in the inner 3m diameter wall in order to aid its removal upon completion of the test on the 3m diameter void. The whole of the bottom half of the test bed (up to the level of three layers of blockwork) was then filled with compacted sand to simulate formation level.

The bottom layer of geogrid was laid at the formation level in three strips with the central strip located along the central portion of the void area. The two adjacent strips were overlapped by 300mm with each edge braided. The bottom 12 strain monitoring gauges were then placed in position in two radial directions as shown in Fig.2. The LVDTs used for strain monitoring were protected by hand placement of sand and aggregate and then the first 150mm of aggregate was placed in position and compacted. (The strain monitoring system used in the experimental work reported here is described in detail in a companion paper by Barr, Austin and Bridle (1994)).

The above procedure was then repeated for the

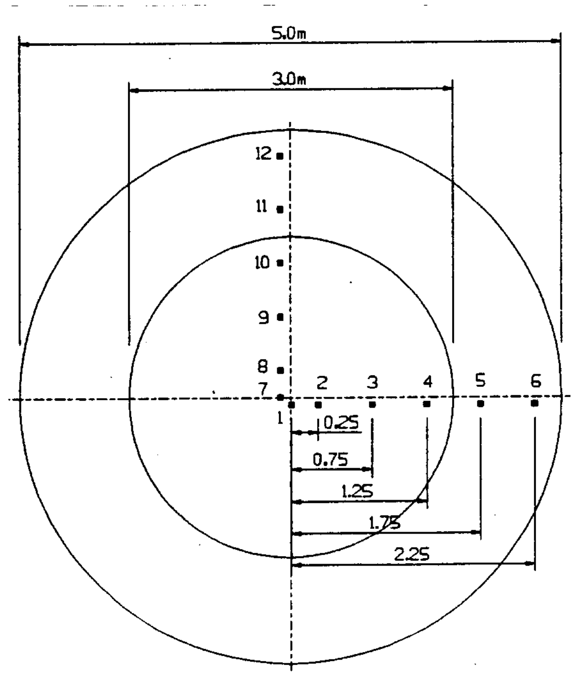

Fig. 2 Location of strain gauges on bottom grid

second layer of geogrid (when used) placed 150mm above the first layer in the test bed. Again the geogrid was laid in three strips with the central strip located along the central portion of the void area. The top 12 strain monitoring gauges were placed and protected as described above. Thereafter the final 450mm of aggregate was placed in position to complete the test bed. The surcharge of 5kN/m^2 was applied by means of kerbstones placed on the test bed.

Once the imposed loading had been placed in position, the access tunnel was cleared and the blockwork at the front end of the tunnel, supporting the sand in the central 3m void area, was removed. Various methods of excavation of the sand in the void area were used. The first method was a suction method which proved to be a slow and laborious method. Hand tools were also tried but these also proved to be too slow and laborious. Eventually a rapid method of excavation was achieved by means of a combination of water-jetting and hand tools.

A complete record of strains and deflections of the test beds were taken throughout the period of void formation and thereafter for a period of 2 to 4 days. The layout of the gauges is shown in Fig.2. Gauges 1 to 6 were placed along a radius perpendicular to the direction of the access tunnel and gauges 7 to 12 along a radius in the direction of the tunnel. Gauges 1 and 7 were at the centre of the void, gauges 2, 3, 4, 8, 9 and 10 were within the 3m diameter void and gauges 5, 6, 11 and 12 were between the 3m diameter and the 5m diameter walls. Gauges 13 to 24 were placed in corresponding locations at the second geogrid level.

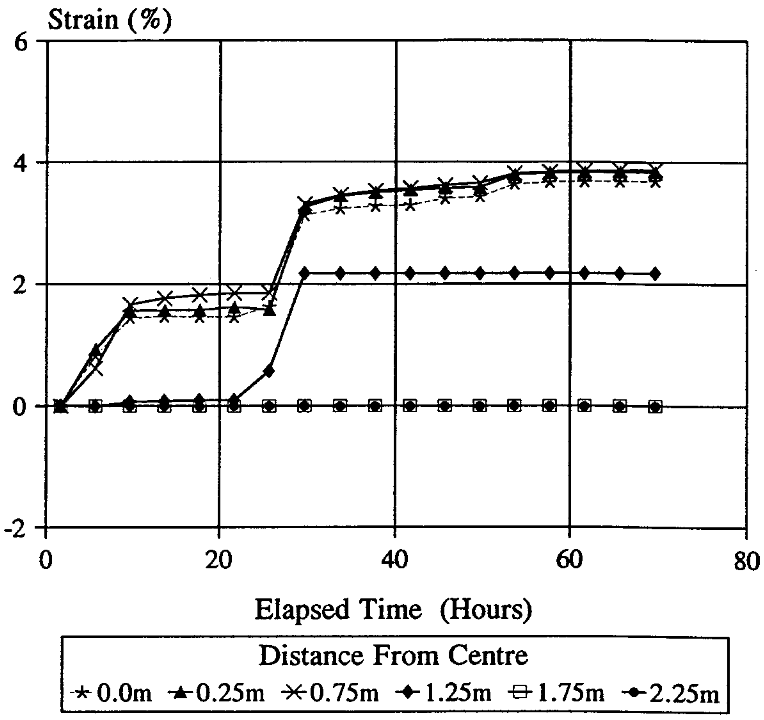

Fig. 3 Strains in base layer of Geogrid for 3.0m diameter void

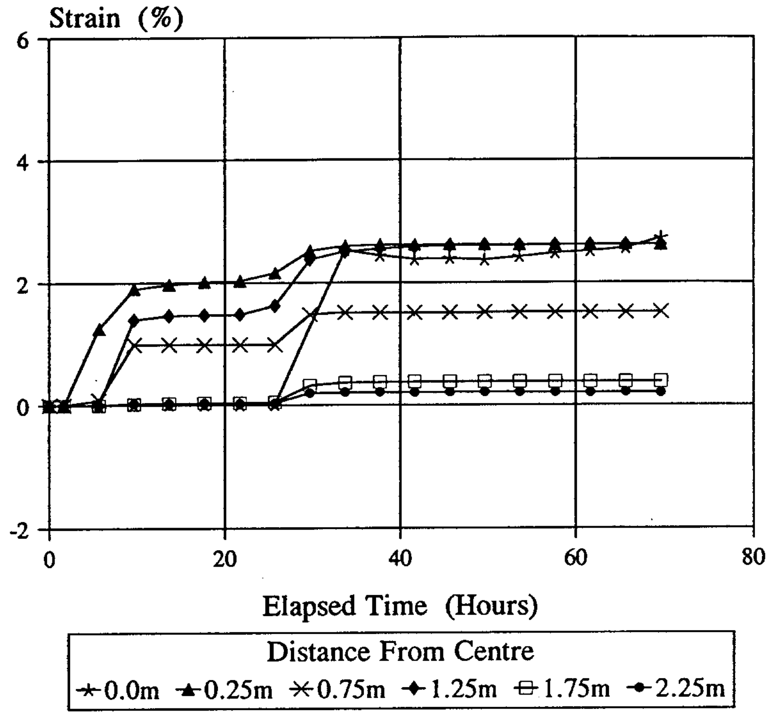

Fig. 4 Strains in upper layer of Geogrid for 3.0m diameter void

3 MEASURED STRAINS

The strains induced in the geogrids during and after the evacuation of the void are shown in Figs. 3 and 4. The formation of the void was achieved over a period of 30 hours and the monitoring was continued from the start of the evacuation for a period of some 70 hours. The strain at the centre of the lower grid developed gradually as the void was excavated and after the first day of void formation these strains had reached approximately 1½→2%. The strains in the upper grid followed the same pattern with a similar strain at the centre but lower values as the distance from the centre increased. The Figs. 3 and 4 show a small increase in strain overnight and then the significant increase as the void formation was completed.

The strain in the lower grid increased to almost 4% at the centre at the time that the void was completed but did not increase significantly in the subsequent two and a half days. The upper grid again developed a similar pattern but with maximum central values of approximately 2½%.

The strain pattern in the lower grid showed a significant reduction in strain at 1.25m from the centre of the void whereas the upper grid had a more uniform strain distribution over the full area of the void. There were also very small strains developed outside the void area in the upper grid but these strains were not evident in the lower grid.

4 DISCUSSION

There are a number of interesting points that arise from this work with regard to the performance of geogrids in the soil rather than in the laboratory. In-isolation sustained load tests on the geogrid show that it would be expected to strain to almost 7% in 24 hours if it had been loaded to 4% strain initially. The performance in soil was such that this tendency to creep was greatly reduced and almost eliminated. It is appreciated by the authors that the "post void formation" duration of monitoring was quite short for an examination of creep behaviour but the purpose of the testing was to look at short term protection.

During the void formation and the subsequent monitoring, the underside of the lower grid could be observed safely from the access tunnel and the development of interlock of the stone particles into the grid apertures was evident. This interlock may well be the key to the improved performance of the structure in comparison to that which would be predicted by theory. Whilst a thicker construction could be expected to benefit from arching within the subbase material, the 600mm thickness compared with the 3m diameter void makes the contribution of arching unlikely. The apparent stiffening of the geogrid/ granular layer due to confinement of the aggregate by the mechanical interlock mechanism appears to be the major contributor to the enhanced performance.

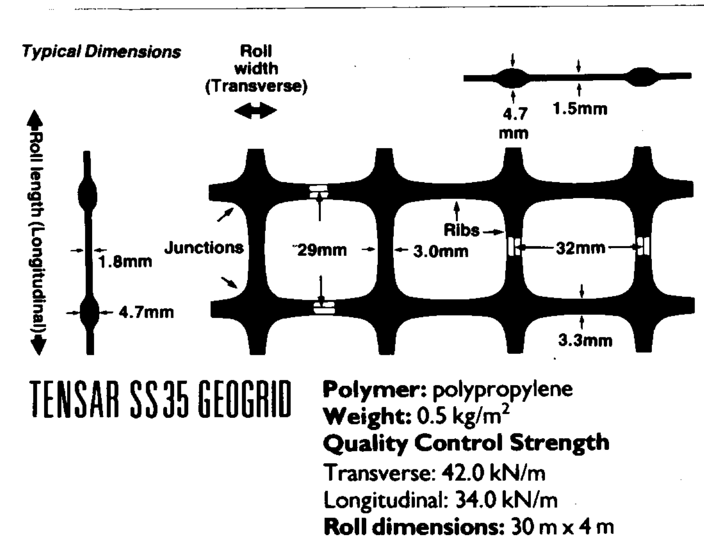

Fig. 5 Details of geogrid used in study

5 CONCLUSION

The results of this full scale work (together with additional laboratory studies to investigate the effect of void diameter) have enabled some tentative design procedures to be proposed which are based on a relatively straightforward tension membrane theory with a parabolic deflected shape. The back analysis of previous single grid layer tests showed that the limiting void diameter can be accurately predicted from the equation:

$$T = \frac{wL^2}{8d}$$

where T = short-term strength of the geogrid (kN/m)
w = total overburden (DL + Surcharge) (kN/m^2)
L = diameter of void (m)
d = central deformation of void (m)

The short-term strength of the geogrid should be taken as the Quality Control Strength quoted in Fig. 5, which provides a brief description of the properties of the geogrid used throughout the experimental study reported in this paper. The adoption of this short term strength recognises the contribution of the interlock mechanism.

The double grid construction will provide support for longer periods of time or for larger diameter voids. This work has been carried out on the geogrid referenced only and therefore cannot be proposed as a general solution until the reinforcing mechanisms are accurately identified.

Further work on the identification of those mechanisms and the relevant geogrid properties has been carried out and will be reported later.

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