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S. K. Fullalove, *Editor*

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### **Channel Tunnel Rail Link section 2: Thames tunnel**

M. Burgess and H. Davies

*Proceedings of the Institution of Civil Engineers, Civil Engineering, 160, Special Issue 2—Channel Tunnel Rail Link section 2, November, 14–18, doi: 10.1680/cien.2007.160.6.14*

Tunnelling under the Thames estuary was considered to be the greatest risk to section 2 of the Channel Tunnel Rail Link project—now known as High Speed 1. However, it was delivered safely and ahead of programme by the application of risk management and sound engineering by the tunnel-boring machine manufacturer and contractors. This paper describes the award-winning design and construction of the 3.6 km long, twin-bore crossing.

### **Channel Tunnel Rail Link section 2: north Thames marshes**

N. O'Riordan and M. Kirk

*Proceedings of the Institution of Civil Engineers, Civil Engineering, 160, Special Issue 2—Channel Tunnel Rail Link section 2, November, 19–23, doi: 10.1680/cien.2007.160.6.19*

The 12 km north Thames stretch of section 2 of the Channel Tunnel Rail Link—now known as High Speed 1—involved constructing a high-speed railway formation across marshlands next to the Thames, alongside operating railways and crossing major roads. This paper describes the design and construction of the 12 km section which links the Thames tunnel to the London tunnels. The work included the push-launch of a 1 km long viaduct at Thurrock, which threads its way under and over the M25 bridge and tunnel crossings of the Thames respectively.

### **Channel Tunnel Rail Link section 2: London tunnels**

E. Woods, G. Battye, K. Bowers and F. Mimmagh

*Proceedings of the Institution of Civil Engineers, Civil Engineering, 160, Special Issue 2—Channel Tunnel Rail Link section 2, November, 24–28, doi: 10.1680/cien.2007.160.6.24*

The London tunnels of section 2 of the Channel Tunnel Rail Link—now known as High Speed 1—carry the new railway from the eastern edge of London into the centre at St Pancras, a distance of approximately 20 km. The scheme required civil engineering and particularly mechanised tunnelling to be pushed to the limits of technology. Successful delivery of the works required strong emphasis on proactive risk management and a single team approach throughout the design and construction phases. This in turn led to an unusual but effective procurement approach. Together these factors have resulted in the successful delivery of a major new transport asset with little disruption to the everyday life of Londoners.

### **Channel Tunnel Rail Link section 2: Stratford**

S. Dyson and I. Blight

*Proceedings of the Institution of Civil Engineers, Civil Engineering, 160, Special Issue 2—Channel Tunnel Rail Link section 2, November, 29–32, doi: 10.1680/cien.2007.160.6.29*

The last stop before London on the Channel Tunnel Rail Link—now called High Speed 1—is Stratford International in the heart of the London 2012 Olympic park. This paper describes the design and construction of the station box, a 1 km long, and up to 55m wide and 26 m deep, open concrete structure. It initially served as the construction and portal site for four of the London tunnel drives on section 2 and now provides the location for the Stratford International station and major track junctions. Excavated material from both the tunnels and the box has been used to regenerate the old railway freight yards into a site for a major new development.

### **Channel Tunnel Rail Link section 2: St Pancras Thameslink station**

M. Gates-Sumner and A. Chodorowski

*Proceedings of the Institution of Civil Engineers, Civil Engineering, 160, Special Issue 2—Channel Tunnel Rail Link section 2, November, 39–42, doi: 10.1680/cien.2007.160.6.39*

Section 2 of the Channel Tunnel Rail Link—now known as High Speed 1—included the construction of a new station for the existing Thameslink rail service under St Pancras International station. This paper describes the construction of the Thameslink box on the route of the existing tunnel along with a direct passenger interchange with the new international station. Two new tunnels were also constructed forming a potential connection to the existing East Coast main-line route.

### **Reducing differential settlements of approach embankments**

S.-L. Shen, Z.-S. Hong and Y.-S. Xu

*Proceedings of the Institution of Civil Engineers, Geotechnical Engineering*, **160**, No. 4, October, 215–226,

doi: 10.1680/geng.2007.160.4.215

This paper presents a case history of an approach road remediation project on a low embankment over soft Ariake clay, located in the coastal Saga Plain of Japan. After the road had been opened to traffic for two-and-a-half years, large settlements were observed, and there was significant differential settlement between piled structures and approach road embankments on soft clay. This differential settlement had a significant impact on vehicle ride quality, and necessitated a remediation programme. In the remediation project, a new method called the column approach (CA) method was adopted to support a transitional zone at the interfaces of piled structures and road embankment. With the CA method a transitional zone was designed at these interfaces to be supported by soil-cement columns of varying lengths to smooth out the settlement profile within these zones. Field monitoring was conducted following completion of remediation. The CA method was also compared with two other Japanese code-designated methods: overlaying a new pavement on the existing pavement at a certain time interval, and constructing a concrete cushion slab under the road pavement. Both practical and economic aspects are examined in the case study presented. This study shows that, when the differential settlement is over 0.3 m, overlay remediation is not economic, and the approach cushion method does not perform well. The CA method not only reduces the differential settlement effectively, but also reduces the total construction cost, although the initial investment is relatively high.

### **Embankment supported on piles with biaxial geogrids**

M. S. S. Almeida, M. Ehrlich, A. P. Spotti and M. E. S. Marques

*Proceedings of the Institution of Civil Engineers, Geotechnical Engineering*, **160**, No. 4, October, 185–192,

doi: 10.1680/geng.2007.160.4.185

The case study consists of a piled embankment built over a very soft, organic compressible clay layer 10 m deep. The height of the embankment supported on piles was about 1.3 m, and the piles, which measured 0.18 m × 0.18 m, were spaced 2.5 m apart in a square pattern, with 0.8 m wide square pile caps covered with a bidirectional 200 kN/m geogrid polyester reinforcement. A region of the piled supported embankment was instrumented to provide a better understanding of the overall embankment–reinforcement–pile cap system. Three-dimensional and two-dimensional pile layouts were adopted. An excavation of 1 m under the geogrid was carried out to induce rapid load transference to the geogrid. The settlement in between pile caps was 0.10–0.4 m, whereas settlements in the region under similar embankment heights were much higher, thus demonstrating the efficacy of pile-supported embankments with geogrids in controlling settlements. Strains at the reinforcement were also measured, and showed values in the range 0.25–2.05%.

### **Volume loss experienced on open-face London Clay tunnels**

P. S. Dimmock and R. J. Mair

*Proceedings of the Institution of Civil Engineers, Geotechnical Engineering*, **160**, No. 1, January, 3–11,

doi: 10.1680/geng.2007.160.1.3

This paper describes the nature of ground movement observed during construction of the Jubilee Line Extension at St James's Park and beneath Elizabeth House for different stages of tunnelling in London Clay, using open-face shield construction and sprayed concrete linings respectively. Volume loss is defined as the volume of ground loss as a proportion of the final tunnel volume and is measured in the plane of the tunnel. Volume losses corresponding to different phases of tunnelling at St James's Park and beneath Elizabeth House are identified in the paper. A companion paper presents a new approach to estimating volume losses for each phase of open-face tunnelling in London Clay.

### **Rock socket piles at Mall of the Emirates, Dubai**

L. Alrifai

*Proceedings of the Institution of Civil Engineers, Geotechnical Engineering*, **160**, No. 2, April, 105–120,

doi: 10.1680/geng.2007.160.2.105

The first snow centre in the Middle East, Ski Dubai, was constructed as part of the Mall of the Emirates retail and leisure complex in Dubai, United Arab Emirates. Opened in December 2005, the project comprises an 80 m high indoor ski slope and associated structures. The higher end of the slope spans over a three-level car park. The site is underlain by a variable sequence of very loose/loose silty sands, which in turn overlies solid geology comprising very weak/weak carbonate sandstone. It has been considered that the most appropriate foundation option to support the structure safely is a piled foundation. Bored and cast-in-place piles socketed into the rock were proposed. Detailed analyses of single piles and pile groups under axial and lateral loading conditions were undertaken. The seismicity and liquefaction potential were considered in the design in accordance with the requirements of Dubai Municipality. The preliminary test piles, which were carried out prior to the installation of the working piles, checked the pile capacity and load–settlement behaviour, confirmed the effectiveness of the piling technique used, and provided greater assurance of the satisfactory performance of the foundations. The results of the preliminary pile-testing programme were compared with those obtained from theoretical predictions based on the empirical relationships between pile capacity and the unconfined compressive strength. On the basis of this review, a guide for the design of rock socket piles in weak carbonate rocks suitable for use in Dubai is proposed.

### **Controlling clay pore pressures for cut-and-cover tunneling**

T. O. L. Roberts, H. Roscoe, W. Powrie and D. J. E. Butcher

*Proceedings of the Institution of Civil Engineers, Geotechnical Engineering*, **160**, No. 4, October, 227–236,

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To facilitate construction of the Channel Tunnel Rail Link

through Ashford in cut-and-cover tunnels and retained cut, it was necessary to control pore water pressures in the relatively low-permeability, laminated Weald Clay. This was achieved by means of an ejector well dewatering system. This paper describes and discusses the investigations carried out to characterise the in situ permeability of the Weald Clay, the design and performance of the ejector well system installed, and the associated soil surface settlements. The correlation between the changes in pore pressure and settlements at the site is compared with that given by Preene *et al.* This comparison is used to evaluate the method, and to provide some insights into the selection of appropriate parameter values of soil permeability and stiffness.

#### **Performance of push-in pressure cells in overconsolidated clay**

D. J. Richards, J. Clark, W. Powrie, and G. Heymann  
*Proceedings of the Institution of Civil Engineers, Geotechnical Engineering*, **160**, No. 1, January, 31–41,  
**doi:** 10.1680/geng.2007.160.1.31

Low-profile push-in pressure cells (spade cells) are commonly used to measure total horizontal stresses in both normally and overconsolidated clays. It is known that spade cells over-read the in situ stress in such deposits as a result of the complex localised stresses created during installation. Previous investigations into the magnitude of over-read are limited in number and have produced scattered results. During construction of the Channel Tunnel Rail Link at Ashford, Kent, a spade cell was installed horizontally in an overconsolidated clay, aligned to measure initial vertical stress, and the change in vertical stress due to excavation of material above the cell. The results of this experiment are presented and interpreted with reference to a finite element analysis and a comparison of spade cell and self-boring pressuremeter test data of horizontal stresses at the same site, to assess the performance of this type of spade cell in the Atherfield Clay.

#### **Characteristic and design soil parameters: use of statistics**

S. R. Lo, and K. S. V. Li  
*Proceedings of the Institution of Civil Engineers, Geotechnical Engineering*, **160**, No. 3, July, 141– 146,  
**doi:** 10.1680/geng.2007.160.3.141

This paper emphasises that the geotechnical parameter governing the occurrence of a limit state is not the point value as measured by a laboratory or field test, and this has important implications for the determination of soil parameters with statistical methods. Two confusing concepts in statistical soil mechanics are discussed: the modelling of innate variability by a random field model, and the distinction between population mean, mean value of a failure domain and sample mean. These two concepts are intrinsically related. This paper demonstrates that most of the confusions or dilemmas associated with the characteristic value and the use of partial material factors may be removed by considering appropriate probabilistic or statistical concepts. It needs to be emphasised that 'considering' does not equate to 'routinely using'. For a sandy soil, it is argued that the methodology of taking a prudently assessed critical state friction angle as the design

value is statistically consistent with the definition of the design value in Eurocode 7.

#### **Loss of soil structure for natural sedimentary clays**

Z. Hong, S. Shen, Y. Deng, and T. Negami  
*Proceedings of the Institution of Civil Engineers, Geotechnical Engineering*, **160**, No. 3, July, 153– 159,  
**doi:** 10.1680/geng.2007.160.3.153

A number of oedometer and triaxial consolidated undrained triaxial shear tests were performed on both undisturbed and reconstituted specimens of natural soft clays. Based on a comparison of strength behaviour between undisturbed and reconstituted specimens of soft clays, a new interpretation of the loss of soil structure is proposed. This new definition indicates that the resistance of soil structure disappears completely when the consolidation stress is larger than the yield stress in oedometer compression (i.e. the post-yield stress state). The difference in behaviour of compression and strength between reconstituted and undisturbed specimens in the post-yield stress state is explained as being caused by the difference in water content, whereas the mechanical behaviour in the pre-yield stress state (i.e. consolidation stress smaller than yield stress in oedometer compression) is affected by both the water content and the resistance of the soil structure. Experimental data from mercury intrusion porosimetry for a strongly structured diatomite are also used to verify the dramatic change of microstructure in the vicinity of the consolidation yield stress.

#### **Remediating a soil-nailed excavation in Wuhan, China**

Y. Yang, PhD  
*Proceedings of the Institution of Civil Engineers, Geotechnical Engineering*, **160**, No. 4, October, 209– 214,  
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Soil nailing was employed to stabilise the sides of a basement excavation in an urban district of Wuhan City, China. During the course of the excavation, excessive movements were observed, and collapse occurred along one of the basement sides. A remedial earth-retaining system was developed to provide additional stability to the ground retained by the soil-nailed wall. In the revised system, the soil-nailed wall retained the upper soil while propped piles at the toe of the wall augmented the overall stability of the sides. The case study presented in this paper demonstrates the effectiveness of the earthretaining system in controlling movements.

#### **Improving a gypsum sand roadbed soil by increased compaction**

S. S. Razouki and A. N. Ibrahim  
*Proceedings of the institution of Civil Engineers, Transport*, **160**, No.1, February, 27– 31, **doi:** 10.1680.tran.2007.160.1.27

A silty sand of the SM group according to the Unified Soil Classification System and of the A-1-b group according to the American Association of State Highway and Transportation Officials (AASHTO) soil classification system, with about 28% gypsum content, was tested in the laboratory for California Bearing Ratio (CBR) under four different compaction efforts. Twenty-four pairs of CBR soil samples were completed at the optimum moisture content derived from a modified AASHTO

compaction test. To achieve different compaction efforts, four groups, each of six pairs of samples, were compacted using 10, 30, 50 and 70 blows per layer respectively. The individual pairs in each group were then soaked for different periods of time—4, 7, 15, 30, 60 and 120 days—while subject to a surcharge load of 40 lbf (178 N). The CBR test results show the significant effect of compaction effort on CBR value. An increase in soaking period causes a significant decrease in the CBR for each degree of compaction effort. Samples made under low compaction efforts are affected more by soaking than those made under high compaction efforts.

#### **Hydraulic conductivity of tyres in landfill drainage systems**

A. P. Hudson, R. P. Beaven, W. Powrie and D. Parkes  
*Proceedings of the institution of Civil Engineers, Waste and Resource Management*, 160, No. 2, May, 63–70,  
**doi:** 10.1680/warm.2007.160.2.63

Whole or shredded scrap tyres are sometimes proposed as an alternative to conventional aggregates in landfill drainage systems. Landfill basal drainage systems are, however, subjected to large overburden stresses from the overlying waste, which may compress a tyre drainage layer, thereby reducing its porosity and hence its effectiveness. Previous work has indicated that tyre drainage layers will remain effective under high stresses, but tests have in the main been restricted to small (<100mm) shred sizes. The use of coarser shreds or even whole tyres for landfill drainage systems may be advantageous as they are more economical to produce and may be less prone to clogging than smaller shreds. In the current paper, the results of large-scale (2m diameter) tests to investigate the variation in hydraulic conductivity (permeability) with stress of 50, 200 and 450mm nominal size tyre shreds are compared with data from the literature for smaller-size shreds and whole tyres. Tests were carried out at vertical stresses up to 600 kPa, representing landfill depths of up to about 60 m. Potential errors in laboratory test procedures are highlighted and the influence of scale and the relative test chamber to particle size on the results is discussed. It is concluded that a chamber to particle size ratio of at least 6 is needed with a rigid walled permeameter, if errors owing to peripheral flow effects are to be avoided. Relationships between shreds size and drainage properties are investigated: no clear correlation between tyre shred size and drainage properties in the particle size range 50–450mm is found. Whole tyres, however, generally have a slightly higher hydraulic conductivity, while samples containing a significant proportion of material less than 20mm in size have generally a lower hydraulic conductivity at a given vertical stress than clean samples of larger shreds.

#### **Stabilised mineral–biomass mixtures in groundwork: fundamentals**

P. Tyrologou, A. W. L. Dudeney, J. P. Harrison and C. A. Grattoni  
*Proceedings of the institution of Civil Engineers, Waste and Resource Management*, 160, No. 2, May, 71–76,  
**doi:** 10.1680/warm.2007.160.2.71

This paper considers the fundamentals of mechanical structures

and fluid flow characteristics in lime-stabilised mineral–biomass mixtures for potential novel applications in low-value bulk industrial products or wastes. As contained organic matter is expected to be essentially stable indefinitely under anaerobic conditions, the composites represent a form of solid carbon sequestration. Laboratory specimens containing designed combinations of coarse mineral (4 or 10mm quartz) and fines (wet digested sewage sludge, pulverised–fuel ash and quicklime) were evaluated as possible precursors to composite emplacements in engineering groundwork. The volume proportion of coarse mineral to mixed fines was nominally 3:2, a value that allowed complete sludge infilling between coarse particles while ensuring particles remained in point contact to form a supporting matrix. The results showed that compositions of digested sewage (25% solids) and fuel ash in the approximate mass ratio 2:1, together with 3% quicklime, underwent pozzolanic strengthening to give an unconfined compressive strength of typically 250–30 kPa after several months' ageing. This is similar in strength to stiff soil or soft rock and, in principle, indicates sufficient mechanical integrity for use as foundations beneath light building development or as a bulk fill underlying open amenities. Porosity (4–10%) and hydraulic conductivity (10<sup>-5</sup>–10<sup>-7</sup> m/s) were moderate to low. Interstitial water contained significant concentrations of ammonia and heavy metals, suggesting that effective isolation from the outside environment would be required in field applications.

#### **Stabilised mineral–biomass mixtures in groundwork: pilot study**

B. K. C. Chan and A. W. L. Dudeney  
*Proceedings of the institution of Civil Engineers, Waste and Resource Management* 160, No. 2, May, 77–84,  
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Based on fundamental characteristics previously determined, two types of pilot studies were carried out to inform possible future full-scale field application of stabilised mineral–biomass mixtures as components of brownfield restoration projects. To gain a preliminary confirmation of properties, four vertical cylinders containing mixed compacted material were used to represent cylindrical volumes within supposedly continuous mixed emplacements. A 100 t field emplacement based on an alkaline model was constructed within a clay lining. This was regulated by an Environment Agency waste management licence. During 18 months' monitoring, optical surveys detected no significant mechanical movement and the emplacement remained essentially dry despite periods of heavy rain and flooding. No landfill gas was detected in boreholes within the compact mass. Pore water recovered during final excavation contained low but significant levels of ammonia and heavy metals, thus justifying lining. The results should form the basis of development to a full-scale prototype emplacement (105 t, 1 ha) as a means of assessing this technology for reusing bulk surplus industrial products under regulation.