Proceedings of the Institution of Civil Engineers
Construction Materials 162
February 2009 Issue CM1
Pages 37–44
doi: 10.1680/coma.2009.162.1.37

ice
Institution of Civil Engineers

Elsewhere in *ICE Proceedings*

S. K. Fullalove, *Editor*

The following are summaries of papers published in other parts of *ICE Proceedings* during 2008 that readers of *Construction Materials* may find of interest. Summaries of all papers in ICE journals are freely available and fully searchable at the 'journals on-line' section of the ICE website. See www.ice.org.uk/journals for details.

Hong Kong – bastion of bamboo scaffolding

M. Ramanathan
Proceedings of the Institution of Civil Engineers, Civil Engineering, **161**, No. 4, November, 177–183,
doi: 10.1680/cien.2008.161.4.177

Hong Kong's skyline is dominated by some of the world's tallest buildings. Nevertheless, the city still uses bamboo scaffolding for much of its construction work – a traditional skill passed down over 5000 years. Bamboo is sustainable, lightweight and cheap and, as long as it remains fairly dry, a good construction material with significant mechanical properties. Researchers, engineers, environmentalists and bureaucrats have taken an increasing interest in the craft, such that regulations and practice continue to be improved and refined. However, to alleviate remaining design and safety concerns a structural design code is needed.

Heathrow Terminal 5: building substructures and pavements

T. Dawson, K. Lingham, R. Yenn, J. Beveridge, R. Moore and M. Prentice
Proceedings of the Institution of Civil Engineers, Civil Engineering, **161**, Special Issue 1—Heathrow airport Terminal 5, May, 38–44,
doi: 10.1680/cien.2008.161.5.38

This paper describes the design and construction of the vast piled basement structures for the three terminal buildings at London Heathrow's £4·3 billion Terminal 5 project, together with 1 million m^2 of associated aircraft pavements. The basements are up to 20m deep and involved the excavation and reuse of 6·5 million m^3 of gravel and clay. The aircraft pavement involved a number of innovations including development of a new high-strength concrete, which delivered a thinner construction and resulted in programme and environmental benefits.

Embodied energy and carbon in construction materials

G. P. Hammond and C. I. Jones
Proceedings of the Institution of Civil Engineers, Energy, **161**, No. 2, May, 87–98,
doi: 10.1680/ener.2008.161.2.87

The development of an open-access, reliable database for embodied energy and carbon (dioxide) emissions associated with the construction industry is described. The University of Bath's inventory of carbon and energy database lists almost 200 different materials. The data were extracted from peer-reviewed literature on the basis of a defined methodology and a set of five criteria. The database was made publicly available via an online website and has attracted significant interest from industry, academia, government departments and agencies, among others. Feedback from such professional users has played an important part in the choice of 'best values' for 'cradle-to-site' embodied energy and carbon from the range found in the literature. The variation in published data stems from differences in boundary definitions (including geographic origin), age of the data sources and rigour of the original life-cycle assessments. Although principally directed towards UK construction, the material set included in the database is of quite wide application across the industrial sector. The use of the inventory is illustrated with the aid of 14 case studies of real-world new-build dwellings. It was observed that there was little difference between embodied energy and carbon for houses and apartments until external works were taken into account (energy inputs for roads, connecting pathways, etc.).

A new model for simulating cracks in cementitious composites

S. C. Hee and A. D. Jefferson
Proceedings of the Institution of Civil Engineers, Engineering and Computational Mechanics, **161**, No. 1, March, 3–16,
doi: 10.1680/eacm.2008.161.1.3

A new model for simulating cracks in cementitious composites using embedded planes with local plasticity is presented. In the model it is assumed that the embedded planes of degradation (PODs) can not only undergo separation but can also regain contact, with the state of contact being controlled by a local contact model. A local plasticity model is included to capture permanent relative displacements associated with rough contact between the surfaces of embedded cracks. This model is a

significant development of the Craft model developed by the second author, which allows shear contact, or aggregate interlock, behaviour, as well as crack opening/closing behaviour, to be simulated more accurately. A fully consistent tangent stiffness matrix and stress recovery algorithm is derived. The model has been implemented in a constitutive driver program and also in the finite-element program Lusas. The model is assessed against a series of single-point stress–strain paths, and against data from normal-shear and cyclic tests. It is shown that the inclusion of local plasticity significantly improves the accuracy of the predictions of the model when judged against experimental data.

Developing unfired stabilised building materials in the UK

J. E. Oti, J. M. Kinuthia and J. Bai
Proceedings of the Institution of Civil Engineers, Engineering Sustainability, **161**, No. 4, December, 211–218,
doi: 10.1680/ensu.2008.161.4.211

This paper discusses laboratory tests on Lower Oxford Clay (LOC) stabilised using different levels of lime (L) or Portland cement (PC), with and without blending with ground granulated blast-furnace slag (GGBS). LOC is used by Hanson Brick Company Ltd in the manufacture of fired 'London' bricks at the Stewartby brick plant in Bedfordshire. The research investigated L–PC, L–GGBS and PC–GGBS blends to assess their potential for application in sustainable unfired clay building materials (bricks, mortar, etc.). Use of unfired materials reduces not only energy costs, but also environmental damage associated with the traditional firing process used in the manufacture of clay building components. Due to the high strength requirements of the building industry compared with, for example, stabilised highway pavement layers, a high maximum stabiliser dosage of 20% was used. For road construction, typical stabiliser dosages are 3–8% for lime and 3–5% for PC. In the current investigation, cylindrical test specimens were cured for 28 days at moisture contents of 25, 30, 35 and 40% before testing for unconfined compressive strength. Preliminary results show that the strength values for all stabilised material investigated was within the strength range of 737–2077 kN/m^2 at 28 days, with L–PC blends tending to achieve lower strength values than L–GGBS blends. Overall results suggest that there is potential in using GGBS-based binders for the manufacture of unfired building components.

Effect of core composition on seismic stability of earth dams

A. Shafiee
Proceedings of the Institution of Civil Engineers, Geotechnical Engineering, **161**, No. 6, December, 283–290,
doi: 10.1680/geng.2008.161.6.283

It is current practice to employ composite clay – a mixture of clay and aggregates that floats within the clayey matrix – as the core of embankment dams, which were previously constructed from pure clays. Experience has shown that significant pore pressure can build up during cyclic loading in composite clays. In this paper, the results of dynamic analyses performed on the Karkheh dam in Iran, incorporating different core materials, are presented. Pure clay and composite clay are used as the core materials and the results of the analyses are compared. It is shown that significant seismic pore pressure build-up in composite clays can significantly reduce the factor of safety against sliding for the fragment of the slip surface passing through the core, even though the overall factor of safety falls within a reasonable level.

Analysis of soil—reinforcement interaction in reinforced soil beds

H. B. Raghavendra
Proceedings of the Institution of Civil Engineers, Ground Improvement, **161**, No. 1, February, 9–15,
doi: 10.1680/grim.2008.161.1.9

A reinforced soil bed is a composite material composed of stiffer materials called 'reinforcement' embedded in the soil bed. Reinforcement inclusion in a soil bed results in a significant improvement in the bearing capacity and in reduced settlement. As a result, soil reinforced with strips, fabrics, sheets, grids and cells has become commonplace. Research is being carried out worldwide to study the effect of reinforcing elements in soil beds. The current paper describes an attempt to understand the soil–reinforcement interaction in soil beds that carry footing. The aim of the present study is to understand the changes brought about by the inclusion of reinforcement inside the soil system in terms of altered stresses and displacements at different increments of loading. The investigation uses the finite-element technique for the analysis and consists of a study of: (a) nodal displacement vectors, (b) deformed meshes and (c) failure initiation and progression. Based on the results of the above analysis, an attempt is made to understand clearly how the stiffer reinforcement enhances the load-carrying capacity, restricting the settlement. Results of the analysis are presented by means of illustrations between unreinforced soil beds and reinforced soil beds.

Bearing capacity of square footing on reinforced pond ash

A. K. Bera, A. Ghosh and A. Ghosh
Proceedings of the Institution of Civil Engineers, Ground Improvement, **161**, No. 1, February, 17–22,
doi: 10.1680/grim.2008.161.1.17

This paper presents the ultimate bearing capacity of square footing on pond ash reinforced with a single layer of geotextile reinforcement. The effect of different vital bearing-capacity parameters on the ultimate bearing capacity (q_{ru}) of square footing on reinforced pond ash has been studied. Parameters considered include depth of the reinforcement layer below the footing (u) and friction ratio ($f = \psi/\phi_d$)—that is, the ratio of the pond ash reinforcement interface friction angle (ψ) to the direct shear friction angle of pond ash (ϕ_d). The value of u/B (B being the width of footing) corresponding to the maximum ultimate bearing capacity is considered as optimum u/B in the current study. In the present investigation the value of optimum u/B ratio was found to increase with increase in friction ratio (f). With increase in friction ratio (f), bearing capacity ratio ($BCR_u = q_{ru}/q_u$) where q_u is the ultimate bearing capacity of square footing, of the same size as that for q_{ru}, on unreinforced pond ash) increases. In the present investigation BCR_u increases from

1·1180 to 1·4158 with a corresponding increase in friction ratio (f) of 0·7073 to 0·9230.

Efficacy of lime-stabilised fly ash in expansive soils

M. R. Rao, A. S. Rao and R. D. Babu
Proceedings of the Institution of Civil Engineers, Ground Improvement, **161**, No. 1, February, 23–29,
doi: 10.1680/grim.2008.161.1.23

The alternate swelling and shrinkage undergone by expansive clays due to moisture fluctuations causes substantial distress to structures built on such soils. Techniques such as sand cushions and cohesive non-swelling soil (CNS) cushions have been tried to arrest volume changes in these soils and hence prevent damage to structures. Sand cushions have been proved to be counterproductive. A CNS layer, though effective initially, became less effective after the first cycle of wetting and drying. Research carried out by the authors using a lime-stabilised fly ash cushion has shown that it is quite effective in arresting volume changes in expansive soils. A fly ash cushion, stabilised with 10% lime and with thickness equal to half that of the active zone in an expansive soil bed, reduces heave by about 68% initially. With subsequent cycles of swelling and shrinkage the percentage reduction in swelling is as much as 99·2%. Studies carried out on leaching have shown that only a small percentage of lime added to the fly ash leaches, even after five cycles of wetting and drying. This shows the efficacy of the lime-stabilised fly ash cushion in minimising heave of expansive soil beds.

Testing coir geotextile drains for soft ground improvement

K. S. Beena and K. K. Babu
Proceedings of the Institution of Civil Engineers, Ground Improvement, **161**, No. 1, February, 43–49,
doi: 10.1680/grim.2008.161.1.43

The results of an experimental investigation to explore the effectiveness of coir geotextile vertical drains for ground improvement are reported. The time settlement behaviour of clayey soil, as influenced by coir geotextile drains, is summarised and the construction and installation details are also discussed. Two types of coir drains, a circular type and a rectangular type, using two varieties of coir geotextiles were tested in three configurations, namely a single drain and triangular and rectangular patterns. It was observed that the time for consolidation was very much reduced due to the installation of coir drains irrespective of the type of coir geotextile used, type of coir drain and the layout of the drains. Furthermore, in addition to ease of construction these drains are eco-friendly and will not pose any environmental problems.

Subgrade modulus of geocell-reinforced sand foundations

S. K. Dash, P. D. T. Reddy and S. T. G. Raghukanth
Proceedings of the Institution of Civil Engineers, Ground Improvement, **161**, No. 2, May, 79–87,
doi: 10.1680/grim.2008.161.2.79

This paper presents the subgrade modulus aspect of geocell-reinforced sand foundation beds, where most of the reported work deals with bearing capacity. Through a series of laboratory model tests the influence on the subgrade modulus of different parameters, such as the geometry and position of placement of the geocell layer, has been examined. With the provision of geocell reinforcement, the subgrade modulus of sand bed can be increased as high as eight times compared with the unreinforced case. A multiple-variable data regression is performed on the experimental data to establish a relation between the effect of reinforcing in terms of subgrade modulus improvement factor and the parameters that control the scheme of reinforcement. This equation will be of use in predicting the subgrade modulus of geocell-reinforced sand beds, and also in efficient utilisation of geocell reinforcement in increasing the performance of sand foundations.

Construction and demolition materials management in Hong Kong

A. T. Yeung
Proceedings of the Institution of Civil Engineers, Municipal Engineer, **161**, No. 1, March, 43–49,
doi: 10.1680/muen.2008.161.1.43

The management of construction and demolition materials is a problem being tackled by many government agencies worldwide. The problem is particularly acute in Hong Kong due to rapid economic development and urban renewal over recent decades, and the situation is aggravated by the dense population on a small plot of usable land. The Hong Kong Special Administrative Region (HKSAR) government is implementing many initiatives in both public and private sectors to handle the ever-increasing municipal problem. Some of these strategies and practice are reviewed in this paper. The effectiveness of these initiatives is being closely monitored by the HKSAR government and adjustments are being made from time to time as required.

Robustness of light steel frames and modular construction

R. M. Lawson, M. P. Byfield, S. O. Popo-Ola and P. J. Grubb
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **161**, No. 1, February, 3–16,
doi: 10.1680/stbu.2008.161.1.3

The robustness or structural integrity of light steel framing and modular constructions is important because these are relatively new structural forms, in which the components have different forms of inter-connectivity in comparison with primary steel frames. There is an increased need to understand the sensitivity of these forms of construction to so-called 'accidental actions', including terrorist threats. Various forms of construction using light steel and modular technologies are identified and their implications for robustness are reviewed. A series of stressed skin tests on modular constructions is presented. These show that modules are able to span as deep beams with one longitudinal support removed with minimal displacements, indicating that the torsional stiffness of the 'box' provides a high level of robustness. Removal of a corner support again demonstrates the role that torsional action of the box plays in redistributing loads away from damaged sections of a structure. For light steel framing, multiple interconnections provide

robustness by tying action and alternative load paths in the event of one or more elements being severely damaged. For modular construction, a scenario-based approach is required in which modules are selectively removed and the horizontal and vertical forces in the connections between the modules can be calculated explicitly.

Achieving durable repaired concrete structures: a performance-based approach

S. Matthews and J. Morlidge
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **161**, No. 1, February, 17–28,
doi: 10.1680/stbu.2008.161.1.17

Societal drivers are encouraging the life extension of existing buildings and infrastructure and some 50% of Europe's annual construction budget is spent on remediation and refurbishment. Owners require greater certainty in the performance of concrete structures in order to manage their assets more effectively. This has generated a requirement for more durable and effective measures for the protection and repair of concrete structures. To help address these issues, a European-funded thematic network Conrepnet was launched in 2003. The network has looked at the performance of previously repaired concrete structures, reviewed current industry practices and research activities, examined the concept of a performance-based approach and developed a vision and for its application. While the outcomes of the first two areas are of considerable interest by virtue of the findings from three questionnaire surveys, it is in the latter area that the greatest impact may arise and, accordingly, was the main focus of the network.

Neural network modelling of RC deep beam shear strength

K.-H. Yang, A. F. Ashour, J.-K. Song and E.-T. Lee
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **161**, No. 1, February, 29–39,
doi: 10.1680/stbu.2008.161.1.29

A $9 \times 18 \times 1$ feed-forward neural network (NN) model trained using a resilient back-propagation algorithm and early stopping technique is constructed to predict the shear strength of deep reinforced concrete beams. The input layer covering geometrical and material properties of deep beams has nine neurons, and the corresponding output is the shear strength. Training, validation and testing of the developed neural network have been achieved using a comprehensive database compiled from 362 simple and 71 continuous deep beam specimens. The shear strength predictions of deep beams obtained from the developed NN are in better agreement with test results than those determined from strut-and-tie models. The mean and standard deviation of the ratio between predicted capacities using the NN and measured shear capacities are 1·028 and 0·154, respectively, for simple deep beams, and 1·0 and 0·122, respectively, for continuous deep beams. In addition, the trends ascertained from parametric study using the developed NN have a consistent agreement with those observed in other experimental and analytical investigations.

Cyclic response of concrete-encased composite columns with low steel ratio

C. S. Shim, Y. S. Chung and J. H. Han
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **161**, No. 2, April, 77–89,
doi: 10.1680/stbu.2008.161.2.77

Improved economy and speed of construction can be achieved through the use of prefabricated structural members. As a step in the advancement of prefabricated substructures, a precast composite column system for seismic regions is proposed in this work. In order to enhance the seismic performance of the reinforced concrete (RC) pier, it is customary to cover the plastic hinge areas of the RC column with close transverse reinforcements. Concrete-encased composite columns with core structural steel can be regarded as another useful method to reinforce RC columns. Eight concrete-encased composite specimens with a low steel ratio were fabricated in this work. The quasi-static test was carried out to investigate the cyclic response of composite columns embedded with single structural steel and multiple structural steels. The specimens were composed of a concrete-encased section and structural steel, the steel being an H-shaped or a circular tube.

Concrete was partially in-filled inside a circular steel tube. The test parameters used are the amount of transverse reinforcement, structural steel and loading pattern. Seismic performance was investigated by measuring the ductility and the energy-absorption capacity of composite columns. The effects of embedded steel members and transverse reinforcements on the cyclic performance were estimated through the observation of local behaviour. It was observed from test results that structural steels increased the deformation capacity of RC columns. In order to satisfy required ductility in seismic regions for composite columns with low steel ratio, it is adequate to follow the detail requirements of transverse reinforcement for RC columns to satisfy required ductility in seismic regions.

Passive fire protection of concrete structures

G. A. Khoury
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **161**, No. 3, June, 135–145,
doi: 10.1680/stbu.2008.161.3.135

Passive fire protection of concrete structures is chiefly aimed at combating explosive thermal spalling, which relies on two underlying mechanisms: (a) the build-up of pore pressures and (b) the development of thermal stresses. The former could be alleviated, or eliminated, by the use of polypropylene (PP) fibres in the mix. Thermal stresses could be reduced by the use of thermally stable aggregates of low thermal expansion—not always practical when the choice of aggregates is limited at the location in question. The second, more effective, but much costlier solution is the use of thermal barriers that reduce the heat flow into the substrate concrete and hence reduce concrete temperature (and the resulting pore pressures and thermal stresses). Thermal barriers, therefore, address both underlying mechanisms of explosive thermal spalling. Criteria for determining the thickness of thermal barriers are currently based on specified maximum temperatures at the barrier/concrete interface. This is fundamentally flawed. The current author proposes

that authorities should consider instead other criteria, which would include the heating rate at the interface (because explosive spalling is more a function of heating rate than maximum temperature) as well as permeability (strength), silica fume content, initial moisture content and, if possible, aggregate type. This approach is scientifically more correct and provides a more conservative (i.e. safer) result. In new designs, a judicial cost-effective use of both thermal barriers and PP fibres is recommended.

Failure of rectangular masonry buttresses under concentrated loading

J. Ochsendorf and L. De Lorenzis
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **161**, No. 5, October, 265–275,
doi: 10.1680/stbu.2008.161.5.265

The stability of masonry vaulted structures relies upon the ability of buttresses to sustain the thrust exerted by arches and vaults. Nevertheless, the stability of buttresses has been the subject of limited studies to date. This paper extends a previous investigation on masonry buttresses under arch or vault loading, where the horizontal force leading to overturning failure accounting for fracturing of the buttress before collapse was computed. The previous analytical solution, obtained by treating masonry as a continuum with no tension resistance, is compared with predictions from discrete element analyses. The latter consider masonry as an assemblage of rigid blocks with no-tension frictional joints and are based on time-stepping integration of the equations of motion of the individual blocks. Results of laboratory tests on models are also presented and compared with the analytical predictions. Collapse criteria by sliding and material failure are established and the effect of buttress leaning is also accounted for.

Modelling of bonded post-tensioned concrete slabs in fire

E. A. M. Ellobody and C. G. Bailey
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **161**, No. 6, December, 311–323,
doi: 10.1680/stbu.2008.161.6.311

This paper presents a finite element model highlighting the behaviour of bonded post-tensioned one-way spanning concrete slabs in fire conditions. The model was verified against ten fire tests on bonded post-tensioned concrete slabs at ambient and elevated temperatures. The slabs were simply supported and post-tensioned with 15·7 mm nominal diameter seven-wire mono-strand tendons. The mechanical and thermal material non-linearities of the entire slab's components, consisting of the concrete, plastic and galvanised steel ducts, prestressing tendon and the anchorages, have been carefully inserted into the model. The interface between the tendon and surrounding grout was also considered, allowing the bond behaviour to be modelled and the tendon to retain its profile shape during the deformation of the slab. The temperature distributions throughout the slab, together with the slab's development of displacement and stress, as it was heated, were predicted by the model and verified against test data. A parametric study was conducted to investigate the effects on the global structural behaviour owing to the change in the aggregate type, duct type, load ratio, boundary conditions and different fire scenarios. The study has shown that the bonded post-tensioned concrete slabs investigated in this study are capable of achieving the designed 90 min fire resistance. It is also shown that the fire resistance given by BS 8110-2 and BS EN 1992-1-2 are acceptable for the design of bonded post-tensioned one-way spanning concrete slabs under fire conditions.

Simplified fire design for composite hollow-section columns

J. M. Aribert, Ch. Renaud and B. Zhao
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **161**, No. 6, December, 325–336,
doi: 10.1680/stbu.2008.161.6.325

In the context of Eurocode 4 Design of Composite Steel and Concrete Structures, Part 1–2: Structural fire design, this paper proposes a new simplified design method to determine the fire resistance of columns with concrete-filled steel hollow sections. This method was introduced into the French national annex of the Eurocode in October 2007 in place of the informative Annex H. After mentioning several theoretical shortcomings of Annex H and its lack of accuracy leading to unsafe design of columns with usual slenderness, an advanced finite-element model already developed by the current authors is briefly presented. A comparison with fire tests carried out in France, Germany and Canada illustrates the good accuracy of the model. The new design method is then explained progressively.

Column–joint assembly in RC columns strengthened by steel caging

J. M. Adam, S. Ivorra, F. J. Pallares, E. Jiménez and P. A. Calderón
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **161**, No. 6, December, 337–348,
doi: 10.1680/stbu.2008.161.6.337

The strengthening of reinforced concrete columns by steel cages is one of various techniques available to increase ultimate column loads. Different researchers have shown the importance of the beam–column joint on the behaviour of columns strengthened by steel cages. This paper presents a parametric study using finite element models carried out with the aim of analysing the influence of the beam–column joint on the behaviour of axially loaded reinforced concrete columns strengthened by this technique. A design rule is proposed to provide a means of estimating the ultimate load capacity of column–joint assembly and recommendations are given concerning the design of the steel cage.

Continuous concrete beams reinforced with CFRP bars

A. F. Ashour and M. N. Habeeb
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **161**, No. 6, December, 349–357,
doi: 10.1680/stbu.2008.161.6.349

This paper reports the testing of three continuously and two simply supported concrete beams reinforced with carbon-fibre-reinforced polymer (CFRP) bars. The amount of CFRP reinforcement in beams tested was the main parameter investigated. A

continuous concrete beam reinforced with steel bars was also tested for comparison purposes. The American Concrete Institute (ACI) 440·1R-06 equations are validated against the beam test results. Test results show that increasing the CFRP reinforcement ratio of the bottom layer of simply and continuously supported concrete beams is a key factor in enhancing the load capacity and controlling deflection. Continuous concrete beams reinforced with CFRP bars exhibited a remarkable wide crack over the middle support that significantly influenced their behaviour. The load capacity and deflection of CFRP simply supported concrete beams are reasonably predicted using the ACI 440·1R-06 equations. The potential capabilities of these equations for predicting the load capacity and deflection of continuous CFRP reinforced concrete beams have, however, been adversely affected by the debonding of top CFRP bars from concrete.

Analysis of buckling in dual-gauge tracks

M. Cuadrado, C. Zamorano, P. González, J. Nasarre and E. Romo
Proceedings of the Institution of Civil Engineers, Transport, **161**, No. 4, November, 177–184,
doi: 10.1680/tran.2008.161.4.177

Two types of track gauges are currently in use in the Spanish railway network: the traditional 'iberian' wide gauge of 1668 mm used in the conventional network and the international 1435 mm gauge used for the high-speed lines. The dual-gauge track, in which a third rail is added to the classical two-rail layout, has recently been proposed for the design of new lines. This solution implies a substantial modification of the classical ballasted track structure and thus requires an analysis of mechanical phenomena occurring on the rail-sleeper grid of the track. In particular, this study focused on lateral track buckling, produced by the axial compression stresses on the rails induced by increases in temperature. Whenever the axial compression force exceeds a critical threshold, the track could become unstable as significant lateral deflections may appear thus leading to unacceptable riding safety levels. In this case, the addition of the third rail increases the steel section and therefore the axial compression, which may lead to track instability. This study assessed this phenomenon in detail by means of a three-dimensional, nonlinear, numerical finite element model, based upon the latest reports of the European Railway Research Institute. Several conclusions have been derived from this study as regards the increasing risk of instability in a dual-gauge track.

Creep in conventional and modified asphalt mixes

A. Aksoy and E. Iskender
Proceedings of the Institution of Civil Engineers, Transport, **161**, No. 4, November, 185–195,
doi: 10.1680/tran.2008.161.4.185

The aim of this study was to evaluate permanent deformation of conventional and styrene butadiene styrene (SBS) polymer-modified asphalt concrete. Two types of polymer modification were selected. First pre-modified (PM) bituminous binder with SBS was used and identical samples were produced at optimal bitumen content. In addition SBS powder was incorporated and modified samples were prepared with laboratory-modified binder (M). Samples were prepared with great care. Static creep and repeated creep tests were conducted at both low (0 ℃) and high (40 ℃) temperatures. A Nottingham Asphalt Tester (NAT) was used for creep tests. Permanent deformations were evaluated with both identical samples for the same mixture type and different types of mixtures were interrogated with average deformations. Efficiency of SBS polymer additives was clearly observed with high temperature (40 ℃) in both static creep tests and repeated creep tests. The PM mixtures showed a slightly increased resistance to the permanent deformation in comparison with the M mixtures. Static creep and repeated creep tests were found to be a good indicator of the rut resistance at high temperature (40 ℃) for both conventional and polymer-modified mixtures. The superior performance of polymer modification in terms of rutting was clarified. The modified samples protected structural integrity at high temperature.

Fatigue analysis of stabilised cement with image processing

A. B. Göktepe, A. H. Lav, S. Altun, C. Akgüner and A. Sezer
Proceedings of the Institution of Civil Engineers, Transport, **161**, No. 4, November, 197–206,
doi: 10.1680/tran.2008.161.4.197

During this investigation, both microstructural and fatigue analyses were carried out to determine the structural integrity of a flexible pavement system with a 4% cement-stabilised base course. Scanning electron microscope analyses as well as material characterisation studies, which included Texas triaxial, resonant-frequency, ultrasonic pulse, and accelerated load facility tests, were conducted to collect the requisite data. Additionally, dynamic finite element analyses were employed to determine the critical strains necessary to calculate the fatigue performance. Correlations between selected microstructural parameters and the fatigue performance of treated pavement structures were established by multilayer feed-forward neural networks. The results, which demonstrated a meaningful relationship between microstructural information and fatigue characteristics of a flexible pavement, may be used to predict the fatigue performance of such systems.

Using eggshell waste in red wall tiles

M. N. Freire, S. J. G. Sousa and J. N. F. Holanda
Proceedings of the Institution of Civil Engineers, Waste and Resource Management, **161**, No. 1, February, 23–27,
doi: 10.1680/warm.2008.161.1.23

Large quantities of eggshell waste are discarded in the food processing industry. This work investigates the incorporation of eggshell waste as a raw material into a wall tile body, replacing natural carbonate material by up to 15 wt%. Formulations containing eggshell were uniaxially dry pressed and fired at 1150℃ using a fast-firing cycle. Physico-mechanical properties of the fired tiles (e.g. linear shrinkage, water absorption, apparent density, flexural strength) were then determined. Development of the microstructure was followed by scanning electron microscope (SEM) and X-ray diffraction (XRD) analyses. The results showed that eggshell waste could be used in wall tiles, in the range 5–10 wt%, as a partial replacement for traditional carbonate-based materials with only a slight decrease in the end product properties.

Comparison of timber and metal formwork systems
R. Yip and C. S. Poon
Proceedings of the Institution of Civil Engineers, Waste and Resource Management, **161**, No. 1, February, 29–36,
doi: 10.1680/warm.2008.161.1.29

Formwork is one of the most important temporary works for reinforced-concrete superstructures in building projects. The use of traditional timber formwork has dominated the construction industry in Hong Kong for many years. Now, however, low-waste technologies for superstructure construction are becoming more common. The study reported here compares the advantages and disadvantages of using traditional timber formwork and a large panel steel formwork system integrated with precast concrete semi-slab (composite formwork system) in superstructure construction in Hong Kong. The study compares these two different formwork systems used in two identically designed school projects in Hong Kong. The comparisons are focused on construction cost, time required for completion of work and construction waste generation. By conducting a detailed cost comparison, this paper shows that, despite the fact that the composite formwork system is able to produce less construction waste, the traditional timber formwork system is still more favourable economically. However, if the composite formwork could be reused in other standard school projects after completion of the project, economic advantages would be realised.

Demolition waste: are we doing our best?
M. Bjerregaard
Proceedings of the Institution of Civil Engineers, Waste and Resource Management, **161**, No. 2, May, 45–49,
doi: 10.1680/warm.2008.161.2.45

This paper questions whether the right issues are being addressed when designing projects that involve both demolition and construction on the same site. With current UK industry focus on achieving high recycling rates, the effect that these recycling rates have on other impacts that could result from demolition and construction works is not being assessed. This paper discusses the benefits and challenges involved in adoption of the UK demolition protocol. It is suggested that industry needs to build on the protocol's approach in order to integrate sustainability into the design and implementation of projects—and recycling rates are only one of the factors to be taken into account. To support this further development, a call is made for a more holistic approach with quantifiable comparison tools; project teams could then make informed decisions regarding health and safety, recycling rates, inclusion of local employment, support for local businesses, carbon footprints, fuel consumption, and so on.

Design and specification of tyre bales in construction
J. D. Simm, M. G. Winter and S. Waite
Proceedings of the Institution of Civil Engineers, Waste and Resource Management, **161**, No. 2, May, 67–76,
doi: 10.1680/warm.2008.161.2.67

Around 48 million used tyres are generated in the UK each year and their disposal, no longer permissible via landfill due to the provisions of the European Union Landfill Directive, is thus a considerable problem. By no means restricted to the UK and other parts of Europe, this problem has a truly international complexion as other regions seek to address the problem of used tyre disposal. The compression of whole tyres into rectilinear tyre bales for use in construction is one possible means of addressing the problem. This paper assesses the recently published British Standards publicly available specification (PAS) 108 for the production of tyre bales for use in construction. Issues with respect to input materials (tyres), the production of tyre bales and the use of tyre bales are covered. Information on the properties and behaviours of tyre bales are described, as are suggested methods of measurement. General construction considerations and specific applications for tyre bales are highlighted along with end of service life options.

Resource recovery through catalytic cracking of waste plastics
P. A. Parikh and Y. C. Rotiwala
Proceedings of the Institution of Civil Engineers, Waste and Resource Management, **161**, No. 2, May, 85–87,
doi: 10.1680/warm.2008.161.2.85

Various technological methods are being developed to overcome the drawback of plastics, namely, their non-biodegradability. Conversion of waste plastics into fuels is one of the best means of conserving valuable petroleum resources in addition to protecting the environment by limiting the volume of non-degradable waste. Catalytic—rather than thermal—decomposition of plastics allows higher selectivity of products in the boiling point range of liquid fuels, for example, diesel and gasoline. In this context, an attempt has been made to review the relevant literature dealing with catalytic decomposition of waste plastics into liquid fuels. The paper also addresses the effects of different properties of catalysts, for example pore system, pore size, crystal size, Si/Al ratio of zeolites, and acidities, on product distribution.

Assessing performance of a permeable biobarrier
R. D. Wilson, W. C. Yip and C. N. Naas
Proceedings of the Institution of Civil Engineers, Water Management, **161**, No. 6, December, 375–379,
doi: 10.1680/warm.2008.161.6.375

While the past 15 years have seen rapid development of permeable reactive barriers and other in situ systems for the treatment of groundwater contamination, assessing performance has not received the same attention. In some cases the long-screened monitoring wells installed as part of initial site investigations are used to monitor treatment, while in others a few additional wells may be installed to serve as sentinels. Performance is assessed based on differences in contaminant concentrations, which is unreliable where plumes are spatially complex and/or temporally unstable. In this work, a standard concentration performance metric is compared with that based on mass flux, using data collected during an evaluation of a discontinuous aerobic biobarrier treating a near-source (and spatially complex) BTEX plume. The data were derived from high-resolution multilevel samplers installed up- and down-gradient of the treatment system. Concentrations in screened

monitoring wells of various lengths were approximated by interval-weighted concentrations from these multilevels. The accuracy of the different performance assessment methods was measured based on estimated uncertainty generated as a result of observed spatial plume complexity. While more data intensive, mass flux proved to be a more reliable performance metric. Assessment using data from few long-screened wells could not reliably match that of the flux fences, but did come within acceptable limits when the number of wells approached the number of multilevels.