Proceedings of the Institution of Civil Engineers
Construction Materials 161
February 2008 Issue CM1
Pages 41–46
doi: 10.1680/coma.2008.161.1.41

ice
Institution of Civil Engineers

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Concrete takes the lead in sustainable construction

C. Georgopoulos
Proceedings of the Institution of Civil Engineers, Civil Engineering, **160**, No. 2, May, 53,
doi: 10.1680/cien.2007.160.2.53

If sustainability is measured simply in terms of embodied carbon dioxide emissions, concrete is ahead on points. But if you factor in cost, durability and other unique properties of concrete, Costas Georgopoulos of The Concrete Centre says it is the clear winner for sustainable construction.

Attitudes towards earth building for Zambian housing provision

J. Hadjri, M. Osmani, B. Baiche and C. Chifunda
Proceedings of the Institution of Civil Engineers, Engineering Sustainability, **160**, No. 3, September, 141–149,
doi: 10.1680/ensu.2007.160.3.141

Zambian cities are experiencing a massive influx of people from rural areas resulting in high demand for housing and the growth of squatter settlements. Insufficient use of low-cost traditional construction techniques in the Zambian residential construction industry has resulted in expensive housing stock for the majority of the poor. There is therefore an urgent need to assess alternative building materials and techniques that are both affordable and sustainable. This research examines the viability of earth as a building material and associated construction techniques for urban housing provision in Zambia. Attitudes towards earth building among end-users, designers, contractors and government regulators were assessed using quantitative and qualitative research approaches. The study concludes that urban residents associate earth houses with poverty and low socio-cultural status; construction professionals are reluctant to specify and select earth materials due to their technical and performance limitations; and government regulators acknowledged that there are currently no appropriate earth building standards and codes in place. Nevertheless, Zambian designers and contractors expressed their willingness to use the material if its performance is improved. Furthermore, government reported that new codes of practice and standards could be developed if stimulated by research findings.

Life-cycle costing of metallic structures

L. Gardner, R. B. Cruise, C. P. Sok, K. Krishnan and J. Ministro Dos Santos
Proceedings of the Institution of Civil Engineers, Engineering Sustainability, **160**, No. 4, December, 167–177,
doi: 10.1680/ensu.2007.160.4.167

Structural material selection has traditionally been based on initial material cost. However, growing pressure on the construction industry to consider the longer-term financial and environmental implications of projects is encouraging a more holistic view. Thus, materials with higher initial costs, but which offer cost savings over the life cycle of a structure, are gaining increasing recognition. The life-cycle costs of structures of two such metallic materials, namely aluminium alloy and stainless steel, are compared with those of ordinary structural carbon steel in the present study. Two structural applications—a typical office building and a bridge—are analysed, while offshore applications are briefly discussed. The ratio of initial material cost per tonne was assumed to be 1.0:2.5:4.0 (carbon steel:aluminium alloy:stainless steel). Following a preliminary structural design to current European design standards taking due account of the material densities and structural properties (principally strength and stiffness), it was found that on an initial cost basis, carbon steel offers the most competitive solution for both the building and the bridge. However, considering the additional life-cycle costs including maintenance costs, end-of-life costs and the residual value of the structure (appropriately discounted to present values), the results indicate that carbon steel offers the most competitive life-cycle solution for the office building but delivers the most expensive life-cycle solution for the bridge. Overall, it is concluded that on a whole-life basis aluminium alloy and stainless steel may offer more competitive solutions than carbon steel for bridges and exposed areas of building structures.

The double-curvature masonry vaults of Eladio Dieste

R. Pedreschi and D. Theodossopoulos
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **160**, No. 1, February, 3–11,
doi: 10.1680/stbu.2007.160.1.3

The Uruguayan engineer Eladio Dieste developed an innovative construction method for wide-span roof structures. Known as Gaussian vaults, their double-curved geometry is based on the catenary resulting in mainly axial compressive forces. Whereas most thin wide-span roofs have been built using concrete, Dieste used brick, and unlike traditional masonry vaults, they are only one brick-layer in thickness. Typically the vaults have a low rise, the span-to-rise ratio is normally 8–10 and buckling is the likely mode of failure. Dieste used the curved surface of the vaults to resist buckling and developed design procedures to ensure their safety. In the present paper a brief background to Dieste's work is presented including his methods of analysis and the application is considered with reference to one of his larger projects, the warehouse at the docks in Montevideo, with a span of 45 m. Through an iterative mathematical procedure, Dieste formulated the critical loads of catenary arches into graphs. The method is compared with a finite-element study, which also considers the elastic deformations under self-weight, asymmetric loading owing to wind and ultimate failure owing to buckling.

Axial load behaviour of concrete-filled steel tubular columns

S. De Nardin and A. L. H. C. El Debs
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **160**, No. 1, February, 13–22,
doi: 10.1680/stbu.2007.160.1.13

This paper reports an experimental study of concrete-filled steel tubular columns. Six short columns subjected to concentric load were tested. Columns of square, circular and rectangular cross-sections with two steel tube thicknesses were considered. The experimental results showed that the ductility of high-strength concrete increases when confined by a steel tube, but the load-carrying capacity remains the same. The confinement effect does not increase the capacity of the columns because the axial strain of the high-strength concrete core is low up to the point where the column reaches its ultimate load. A model to predict the load against strain behaviour was proposed and the pre-peak and post-peak behaviours of concrete-filled steel columns axially loaded could be predicted from the behaviours of steel tube and concrete core.

Testing and analysis of a traditional oak frame

T. Hill, J. Shanks, J. Stott and P. Walker
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **160**, No. 1, February, 23–29,
doi: 10.1680/stbu.2007.160.1.23

Despite the widespread historical use of green oak framing, using all-timber connections, their engineering performance is poorly understood. Restoration of existing structures and design of new buildings are both often reliant on the skills of the carpenter and historical precedents. Structural engineers frequently struggle to validate green oak frame designs using modern codes of practice. The present paper presents findings from a study undertaken to investigate the structural performance of arched-braced green oak sub-frames. The sub-frames were part of a traditional roof structure in a barn that had fallen into disrepair and was to be replaced. To inform the design process and improve engineering understanding, five identical arched-braced sub-frames were commissioned for load testing under laboratory conditions to failure. The experimental results from the sub-frame tests, including deformation and load capacity, are presented. Experimental load capacities are compared with a novel collapse load analysis.

Strut–tie analysis of beams with external tendons

B. El-Ariss
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **160**, No. 1, February, 31–35,
doi: 10.1680/stbu.2007.160.1.31

Strengthening of concrete beams by means of external tendons has been increasingly used. Analysis of such beams is more difficult than that of beams with internal bonded tendons because the stress in external tendons depends on the deformations of the whole beam. In the current paper, a simple model based on the strut-and-tie method is presented to predict the capacity of simply supported externally prestressed concrete beams subjected to equal concentrated loads at third-points. The model defines the struts and ties that form a load transfer mechanism in the beams. It predicts the ultimate loads the beam can carry and the force in the tendons at failure using the section method and equilibrium equations. When comparing the results obtained using the proposed model with others in the literature, the model was found to be conservative. The proposed model is intended to help designers in the inspection and structural assessment of beams.

Analysis of bending tests on CFRP-stiffened pultruded GRP beams

G. J. Turvey
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **160**, No. 1, February, 37–49,
doi: 10.1680/stbu.2007.160.1.37

The equations for the mid-span deflection and end rotations of carbon fibre reinforced plastic (CFRP) stiffened pultruded glass reinforced plastic (GRP) shear deformable beams with semi-rigid end connections are introduced. Two series of three-point flexure tests on simply supported pultruded GRP beams are described. In the first series the beams were tested in the unstiffened state and in the second series the beams were tested with pairs of CFRP strips of varying length bonded to their soffits. A third series of three-point flexure tests on a similar pultruded beam with the CFRP strips bonded over the whole span and with bolted stainless steel and GRP cleat end connections is also described. The shear deformable semi-rigid beam equations are used to predict the loads, deflections, end rotations and surface strains recorded in the three test series. It is shown that the correlation between the measured deflections, rotations and strains is generally good, given the nature of uncertainty surrounding some of the material properties. For example, the largest percentage difference between measured and predicted deflections was about 6% for the first two test series and 12% for the third series. It is concluded that this level of correlation between actual and predicted deformations vindicates the use of refined beam analysis for the more efficient design of CFRP stiffened pultruded GRP beams with practical end connections.

Strengthening a steel bridge with CFRP composites

S. S. J. Moy and A. G. Bloodworth
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **160**, No. 2, April, 81–93,
doi: 10.1680/stbu.2007.160.2.81

The present paper reports the successful strengthening of Acton Bridge on the London Underground system using carbon fibre reinforced polymer (CFRP) plates. The adhesive used to bond the plates to the steel had to cure while trains continued to run over the bridge. Concerns arising from this were the effect of cyclic load during curing on the final bond strength and whether adhesive flexibility affected the reinforced section properties. Tests to investigate these concerns are also reported. These tests involved reinforced beams subjected to cyclic loading of different intensities in bending during adhesive cure and tested statically at intervals to determine the build up of stiffness. The tests showed that, generally, adequate bond develops but at higher load intensities the strength of the bond is reduced and above limiting values of slip or developed shear stress at the steel/CFRP interface no bond will develop. A further conclusion was that adhesive flexibility does reduce section properties but by less than about 7%. Lap-shear tests conducted on specimens cut from the reinforced beams confirmed the bending test results. These showed that the biggest reductions in bond strength were at the ends of the beams where slip and shear stress were greatest.

Stiffness and damping of infilled steel frames

M. Mohammadi Ghazimahalleh
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **160**, No. 2, April, 105–118,
doi: 10.1680/stbu.2007.160.2.105

This paper presents the results of an experimental and numerical investigation on 15 masonry, concrete and multilayer infill specimens. Two types of frames are considered. The first one, having pinned connections, has a small-scale and is composed of very stiff beams and columns. The second has a medium-scale and has rigid connections. The frames represent lower storeys of high- and medium-rise buildings, respectively. The effects of reinforcement and bond beam on masonry infill panels are investigated. It is shown that the efficiency of horizontal reinforcements and bond beams on the behaviour of infill panels depends on the dominant cracking pattern. The results show that adding the steel fibres to the material of infill corners can considerably increase the ultimate strength of concrete panels. It is also concluded that the behaviour of multilayer or fibrous concrete panels is better than single-layer panels and they are preferred when strengthening buildings against lateral loads. A new explanation for infill stiffness, named practical stiffness, is proposed and a new formula is suggested to estimate stiffness of the specimens. Eventually, damping ratios of all specimens are presented. The results show that damping ratios of specimens are indicators of structural damage.

Stainless steel structures in fire

L. Gardner
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **160**, No. 3, June, 129–138,
doi: 10.1680/stbu.2007.160.3.129

The initial material cost of structural stainless steel is about four times that of structural carbon steel, largely owing to the expense of the alloying elements and the relatively low volume of production. Given broadly similar structural performance, additional areas of benefit need to be identified and exploited in order to establish stainless steel as a viable alternative material for construction. In addition to the familiar benefits of corrosion resistance, low maintenance, high residual value and aesthetics, one such area is fire resistance. Stainless steel generally displays superior strength and stiffness retention at elevated temperature when compared to carbon steel, but also exhibits greater thermal expansion. The current paper describes experimental, numerical and analytical investigations into the elevated temperature response of stainless steel structures. Comparisons are made with the behaviour of carbon steel structures in fire and proposals for improved structural fire resistant design guidance for stainless steel are described.

Enhancing ductility of non-seismically designed RC shear walls

J. S. Kuang and Y. B. Ho
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **160**, No. 3, June, 139–149,
doi: 10.1680/stbu.2007.160.3.139

Experimental investigation is conducted on the seismic behaviour and ductility enhancement of non-seismically designed reinforced concrete shear walls with various configurations of confinement links. Large-scale squat shear wall specimens are tested under reversed cyclic loads. Emphasis is placed on the effects of the boundary confinement and configuration of confinement links on the improvement of seismic performance and ductility. It has been shown that modification in reinforcement detailing specifications for non-seismic design should be made in order to improve seismic behaviour and enhance ductility capacity, as well as the energy dissipation ability, of reinforced concrete shear walls with non-seismic design for fulfilling the requirements of low to moderate seismicity. This can be achieved by adopting the specific reinforcement detailing, which is proposed based on the results of the experimental study. The proposed reinforcement details include only minor modifications to the detailing techniques of currently practiced non-seismic design, which can lead to an important improvement of ductile response behaviour of the shear walls, but do not result in significant increases in construction cost and difficulty.

Cracking and tension zone behaviour in RC flexural members

K. L. Kong, A. W. Beeby, J. P. Forth and R. H. Scott
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **160**, No. 3, June, 165–172,
doi: 10.1680/stbu.2007.160.3.165

This paper presents the results of an extensive programme of research carried out jointly at the University of Leeds and the University of Durham to clarify various aspects of cracking behaviour particularly in the tension zones of flexural members. The results show that concrete cover is the only parameter affecting the transfer length at load levels close to cracking and up to service load. An attempt has also been made to show the bond mechanism at the bar–concrete interface using the technique of ink injection. Unfortunately, this technique failed to reveal internal cracks between two major cracks when the stress in the reinforcement was increased up to approximately 200 MPa; whether this was attributed to their absence or to faults in

the testing procedure was unclear. The current paper also proposes an empirical formula to predict the transfer length in slabs. The input data required are more simple and convenient to collect than using a crack width microscope and the predictions from the formula are just as accurate.

Inclined reinforcement around web opening in concrete beams

K.-H. Yang and A. F. Ashour
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **160**, No. 3, June, 173–182,
doi: 10.1680/stbu.2007.160.3.173

Twelve reinforced-concrete continuous deep beams having web openings within interior shear spans were tested to failure. The main variables investigated were the opening size and the amount of inclined reinforcement around openings. An effective inclined reinforcement factor combining the influence of the amount of inclined web reinforcement and opening size is proposed and used to analyse the structural behaviour of continuous deep beams tested. It was observed that the end support reaction, diagonal crack width and load capacity of beams tested were significantly dependent on the proposed effective inclined reinforcement factor. As this factor increased, the end support reaction and increasing rate of diagonal crack width were closer to those of companion solid deep beams. In addition, a higher load capacity was exhibited by beams having an effective inclined reinforcement factor above 0·077 than the companion solid deep beam. A numerical procedure based on the upper-bound analysis of the plasticity theory was proposed to estimate the load capacity of beams tested. Comparisons between the measured and predicted load capacities showed good agreement.

Catenary action in steel-framed buildings

M. Byfield and S. Paramasivam
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **160**, No. 5, October, 247–257,
doi: 10.1680/stbu.2007.160.5.247

The current paper is of relevance to engineers engaged in the design of buildings in which severe column damage resulting from malicious actions is a design scenario. The tying force method as used for providing robustness to steel-framed buildings relies upon catenary action to redistribute loads following column damage. Fortunately severe column damage is extremely rare and for this reason it is not well understood if this load redistribution mechanism is reliable. The current paper presents results of an investigation into the tying force method by way of a case study of a steel-framed building in which support to a perimeter column is removed. Results indicate that industry standard beam–column connections possess insufficient ductility to accommodate the large floor displacements that occur during catenary action and the factor of safety against collapse is shown to be less than 0·2.

Cyclic behaviour of beam–column connections in steel portals

C.-M. Yang and Y.-M. Kim
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **160**, No. 5, October, 259–272,
doi: 10.1680/stbu.2007.160.5.259

This paper presents an experimental study on the cyclic behaviour of bolted and welded beam-to-column connections in a steel portal frame. The test focuses on: (a) an experimental analysis for investigation of the behaviour of beam-to-column connections under cyclic loading, (b) the failure modes of each connection under cyclic loading; and (c) the capacity of the high-strength bolted angle connections compared with the fully welded counterpart. The behaviour of the high-strength bolted frame under cyclic lateral loading is studied, and it is compared with that of the welded frame subjected to the same loading. The results obtained from six tests on steel portal frames showed that the initial connection stiffness of the specimen composed of top-seat angle and double web angle (TSD) was developed for about 48% of the specimen with welded connection (FW), and the specimen composed of double web angle (DWA) was about 15%. Based on these tests, conclusions are presented.

Long-term response of concrete-encased composite columns

R. Chacón, E. Mirambell and A. Marí
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **160**, No. 5, October, 273–285,
doi: 10.1680/stbu.2007.160.5.285

During the last few decades, owing to their several advantages, composite columns have gained acceptance for high-rise buildings as an alternative to steel or reinforced concrete columns. When a composite column is subjected to an eccentrically applied sustained axial load, its structural response must undergo both a short-term and long-term analysis. The study presented in the current paper aims to evaluate the short- and long-term response of concrete-encased composite columns. A numerical model previously developed and experimentally verified is systematically used within this work. This model is capable of developing non-linear and time-dependent analyses on reinforced concrete frame structures. In order to verify the obtained numerical results for this particular case, a series of experimental results on concrete-encased composite columns are compared with those derived numerically. Once verified, the model is used as a simulation tool to analyse in depth the structural short- and long-term response of composite columns. Finally, based on the present study, conclusions about design criteria for concrete-encased composite columns are drawn.

Shear of prestressed concrete beams with steel fibres

J. Thomas and A. Ramaswamy
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **160**, No. 5, October, 287–293,
doi: 10.1680/stbu.2007.160.5.287

This study outlines the details of non-linear analysis using the modified compression field theory (MCFT) of 11 shear–critical partially prestressed concrete T-beams having steel fibres over partial or full depth. Prestressed T-beams having a shear span-to-depth ratio of 2·65 and 1·59 that failed in shear have been analysed using Response-2000. Response-2000 is an implementation of MCFT within the framework of sectional analysis originally developed for reinforced concrete beams having no fibres. The modelling of the various effects of fibre in the concrete matrix using Response-2000 has been illustrated in the current study. The MCFT-based model used for the present analysis

accounts for the non-linearities, such as effect of addition of fibres in the post-peak regime of the compressive stress–strain response, the post-cracking tensile stiffness and response of concrete. The load sustenance through the bridging action of steel fibres at the crack interface has been accounted for in the model. The reinforcements such as deformed bars, prestressing wires and steel fibres have been modelled discretely. The capability of the model to capture cracking behaviour, loads and deflections in various types of shear failures in prestressed concrete beams has been illustrated.

Progress of advanced composites for civil infrastructure

L. Canning, J. Hodgson, R. Karuna, S. Luke and P. Brown
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **160**, No. 6, December, 307–315,
doi: 10.1680/stbu.2007.160.6.307

The current paper describes the use of fibre reinforced polymer (FRP) composites as primary structural members. In particular FRP composite bridge decks are discussed and the Asset project, which comprised the development of a FRP composite bridge deck system, is described in detail. The analysis, design and testing undertaken within the project are also discussed in detail. The culmination of the project, the reconstruction of West Mill Bridge in Oxfordshire, is described and conclusions made on the particular advantages of using FRP composites for bridge decks.

Testing a new reinforced brick masonry shell system

J. A. O. Barros, P. B. Lourenço, J. T. Oliveira and E. Bonaldo
Proceedings of the Institution of Civil Engineers, Structures and Buildings, **160**, No. 6, December, 339–354,
doi: 10.1680/stbu.2007.160.6.339

The main aim of the current paper is to describe the experimental research carried out at the University of Minho, Portugal, regarding the development of an innovative reinforced brick masonry shell structural system. The concept of the system is based on the work of the engineer Eladio Dieste, and focuses on the prefabrication industry. The structural system is composed of a layer of clay bricks, reinforced concrete joints and a reinforced concrete cover layer. The constituent materials of the structural system were selected according to the necessary requirements in terms of mechanical properties and prefabrication technology. To analyse the interaction between the intervening materials, flexural, shear and biaxial tests with representative panels were carried out. To validate the developed structural system, a full scale shell was built and tested under monotonic vertical load applied at a quarter of its span. The shell performance revealed that the developed structural system is suitable for the proposed application.

Performance of foamed bitumen-stabilised mixtures

K. Khweir
Proceedings of the Institution of Civil Engineers, Transport, **160**, No. 2, May, 67–72,
doi: 10.1680/tran.2007.160.2.67

Mixtures stabilised with foamed bitumen are commonly made with recycled aggregate, typically reclaimed asphalt planings. These mixtures are influenced by many factors, which require full consideration during the production and construction stages. Untreated recycled material is often unsatisfactory owing to the particle size distribution and high water content. Addressing the grading problem may require the addition of other materials; defining material type and quantity is significant. Foamed bitumen stabilised material is often modified with a hydraulic binder, not only to dry up the mixture, but also to enhance its performance, particularly in its early life. Moisture levels within the material during compaction are very important in aiding the workability of the mixture. Also, the compaction process is very dependent on the compaction energy. The stabilised mixture should be protected from the ingress of water during its early life. Foamed bitumen stabilised mixtures perform successfully when laid as a base layer, and a conventional binder course and surface course can be laid immediately on top. This paper is based on more than ten years of the author's experience in this field. In particular, it highlights the significance of the addition of hydraulic binder, moisture content, compaction level and curing time. Graphical relationships are established to aid mixture design, and can be used to predict mixture performance. Also, analyses of laboratory and site curing times are compared.

The introduction of flexiblity into a road ironwork installation

B. V. Brodrick, A. C. Collop, S. F. Brown and R. Cooper
Proceedings of the Institution of Civil Engineers, Transport, **160**, No. 3, August, 93–100,
doi: 10.1680/tran.2007.160.3.93

This paper describes research undertaken to examine the option of replacing the upper portion of a rigid traditional brick access chamber with a flexible material, so that the system is more compatible with the surrounding flexible (asphalt) pavement construction, and is therefore less likely to exhibit premature failure. It focuses on one example of a suitable material, the influence of the confinement of this material within the surrounding pavement, and the importance of using a compatible backfill that acts as a bridge between the pavement and the ironwork. Full-scale experiments have been undertaken using a laboratory-based rolling-wheel test facility. Results show that flexibility incorporated into a road ironwork chamber can smooth out the step change in stiffness between a flexible pavement and a rigid chamber. Replacement of the upper portion of a chamber with a suitable flexible section results in the structure being more compatible with an asphalt pavement. It was also confirmed that the backfill around the chamber should be well compacted to provide good confinement, and the reinstatement material around the frame is a key element in the overall performance of a flexible chamber installation.

Geocomposite technology: reducing railway maintenance

P. K. Woodward, D. Thompson and M. Banimahd
Proceedings of the Institution of Civil Engineers, Transport, **160**, No. 3, August, 109–115,
doi: 10.1680/tran.2007.160.3.109

The XiTRACK three-dimensional track reinforcement technique has been very successful in overcoming difficult, long-standing track problems on the railway. This success led to the specification of the technique for use at Deep Wharf level crossing, Purfleet. This was the first time that the technique had been used to reinforce the track structure at a level crossing. The main technical challenge was the application of the technique to stabilise the track over very poor ground, namely the very soft

alluvial soils present at the site. A review of other proposed methods, such as concrete foundations and/or piles, illustrated the cost-effectiveness of the reinforcement method: in particular, the rapid installation of the system (the polymer cured within 15 s) minimised track downtime and thus enabled considerable cost savings to be achieved. The design process adopted was used to predict track behaviour before and after treatment, which enabled the design of the most appropriate polymer rheology and polymer distribution and loading levels to achieve optimum performance and ensure that the technique worked. This paper describes the work performed at Purfleet using the technique, including measured acceleration time histories before and after treatment.

Mechanistic-empirical evaluation of airfield test pavements

K. Gopalakrishnan
Proceedings of the Institution of Civil Engineers, Transport, **160**, No. 4, November, 191–200,
doi: 10.1680/tran.2007.160.4.191

The impact of new-generation aircraft (NGA) such as the Boeing 777 and Airbus A380 on airfield pavement performance is of serious concern to airfield authorities worldwide. Recognising the need to develop advanced pavement design procedures based on sound theoretical principles, and with models verified from appropriate full-scale NGA test data, the Federal Aviation Administration constructed the National Airport Pavement Test Facility (NAPTF). In this paper, a mechanistic-based approach is presented to predict the allowable six-wheel and four-wheel NGA gear passes for airfield flexible pavements based on full-scale traffic test results from the NAPTF. A finite-element pavement structural model that can account for the non-linear stress-dependent behaviour of pavement geomaterials was used to compute the mechanistic responses of NAPTF test sections. Both the subgrade deviator stress and subgrade stress ratio were found to be good estimators of airfield pavement rutting performance. Although the results are applicable specifically to the six-wheel and four-wheel NGA gears used at NAPTF, the method can easily be extended to any prototype NGA gear loading with additional data from such full-scale traffic tests.

Estimating time to failure of cast-iron water mains

B. Rajani and S. Tesfamariam
Proceedings of the Institution of Civil Engineers, Water Management, **160**, No. 2, June, 83–88,
doi: 10.1680/wama.2007.160.2.83

Water distribution networks form essential components of water supply systems in most urban centres. Water mains buried in the soil/backfill are exposed to different deleterious reactions and—as a result—their design factors of safety may significantly degrade with time, leading to structural failure. In most cases, a combination of circumstances leads to the failure of a pipe. Factors contributing to pipe failure include: operational conditions; design parameters; external loads (traffic, frost, etc.); internal loads (operating and surge pressures); temperature changes; loss of bedding support, pipe properties and condition; and corrosion pit geometry. These are recorded rarely, if at all, and it is therefore very difficult to ascertain the precise causes of failure. Even if all this information were available, any attempt to estimate the pipe condition state would involve considerable uncertainty owing to large spatial and temporal variability that is inherent in this information. Estimation of time to failure is further exacerbated by the uncertainties in determining future corrosion rates. In this paper, corrosion models and a previously developed analytical model based on Winkler-type pipe–soil interaction are used to estimate time to failure. Since available data are insufficient to establish credible probability distributions, uncertainties in the input data/ parameters are handled using possibility theory and fuzzy arithmetic. Sensitivity analyses are carried out to identify the critical data/parameters that merit further investigation.

Ways to facilitate the use of recycled aggregate concrete

V. W. Y. Tam, K. Wang and C. M. Tam
Proceedings of the Institution of Civil Engineers, Waste and Resource Management, **160**, No. 3, August, 125–129,
doi: 10.1680/warm.2007.160.3.125

A huge amount of solid waste is generated annually from construction and demolition activities. This has led to the promotion of waste recycling as a major measure to reduce waste and to mitigate the harmful effects of construction activities on the environment. Among these wastes, concrete apportions more than half of the total. While recycled concrete waste has been used in low-grade utilisations, high-grade applications are rarely discussed. Although the Hong Kong Special Administrative Region Government has actively been promoting recycling of construction solid waste by issuing technical circulars, specifications and practice notes and setting up a recycling plant to encourage the adoption of recycled aggregate (RA), these measures have not facilitated wide adoption of recycled aggregate concrete (RAC). In fact, the quality of RA and RAC is less than that of virgin material or ordinary concrete and concrete suppliers are thus reluctant to use these materials. Utilising a series of laboratory tests, this paper aims to set out some guidelines to facilitate the use of RAC in the construction industry.