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Proceedings

Engineering Group of the Geological Society, 1983–84

12–15 September 1983. **The engineering geology of tidal rivers.** Held at the University of Hull. Local secretary, Dr P. Young.

12 September.

The impact of construction on tidal river systems: An overview. Published in *Q. J. eng. Geol. London*, **17**, 193–8.

Impact of engineering structures on tidal flow and sediment distribution in the Thames. Published in *Q. J. eng. Geol. London*, **17**, 207–18.

Thames tidal flood risk—the need for the Barrier. Published in *Q. J. eng. Geol. London*, **17**, 199–206.

Deep foundations—the River Hull Tidal Surge Barrier. Published in *Q. J. eng. Geol. London*, **17**, 291–300.

Engineering solutions to geological problems in the design and construction of the Humber Bridge. Published in *Q. J. eng. Geol. London*, **17**, 301–6.

A buried valley in the Orwell Estuary. Published in *Q. J. eng. Geol. London*, **17**, 283–88.

Engineering geological and geophysical investigation of the Barking Creek Tidal Barrier Site. Published in *Q. J. eng. Geol. London*, **17**, 259–68.

A geophysical survey of the Crouch/Roach river system with special reference to buried channels. Published in *Q. J. eng. Geol. London*, **17**, 269–82.

Sediment transport at inlets and the formation of subtidal inlet deltas. E. H. Owens. The paper reviews the state of knowledge of inlet sediment dynamics for river systems with a tidal range greater than 2 m. The primary implications for engineering or structural activities in the vicinity of an inlet are related to shoreline protection structures at inlet margins, and dredging activities within the inlet area as a whole.

Hydraulic/soil mechanical experiments in a large wave facility. J. Lindenberg, P. Vellinga & K. den Boer. The paper describes the Deltaflume, a large 230-m flume in which regular and random waves up to 3 m can be generated. Three projects outlined the behaviour of a sand foundation beneath a wave-loaded caisson, the necessary width of a row of dunes to withstand long-term erosion, and the block revetment for a secondary dam in Eastern Scheldt.

14 September.

The characteristics of alluvial deposits: some engineering implications. Published in *Q. J. eng. Geol. London*, **17**, 219–34.

The stratigraphy and properties of the Clyde Alluvium. Published in *Q. J. eng. Geol. London*, **17**, 243–58.

Settling and consolidation of cohesive sediment in the laboratory. G. C. Sills & R. C. Thomas. Laboratory experiments are in progress in which cohesive sediment settles from a suspension. Its subsequent consolidation is monitored by means of density profile measurement, using a non-destructive X-ray technique, coupled with pore pressure and stress measurement. The behaviour is dependent on deposition history and water chemistry and these have been varied in recent experiments with difference input rates of the sediment and different salinities.

A geological appraisal of the site of the foundation failure of the giant oil tanks at Fawley, Hampshire. Published in *Q. J. eng. Geol. London*, **17**, 307–18.

Geotechnical aspects of Greenodd Bypass. Published in *Q. J. eng. Geol. London*, **17**, 339–48.

Peat: morphology and properties. N. Hobbs. In view of its exceptionally high water content, peat is often considered an extraordinary material. In many respects, however, correlations between its various properties and behavioural parameters are little different from those of clay soils, except in regard to strength. The properties and parameters of some UK peats are compared with those from Canada and other countries, emphasizing the high cation exchange capacity.

Analysis of the geotechnical properties of Somerset alluvium from data accumulated from the M5 motorway investigations. Published in *Q. J. eng. Geol. London*, **17**, 235–42.

Tunnelling through warp: an estuarine clay. Published in *Q. J. eng. Geol. London*, **17**, 349–50.

Reclaiming Pyewipe mudflats, Grimsby, using colliery spoil. D. T. Kilpatrick & P. West. This paper describes some of the work carried out on the investigation of the mud, the colliery spoil and the hydraulics of the reclamation. The difficulty of site investigation in an area where neither boats nor vehicles can operate is described. The settlement characteristics of the mud under 10 m of spoil were ascertained and the profile of the upper surface of the boulder clay and its characteristics confirmed.

Technical note on the design and construction of the Afon Ganol Valley section of the North Wales Coast Road (A55). Published in *Q. J. eng. Geol. London*, **17**, 335–38.

15 September. **Annual General Meeting**

The flood plain deposits of the Lower Thames. A. Marsland. The flood plain consists of soft clays, peats, silts and sands resting on gravels. The wide range of soils in a single profile and between locations makes it difficult to assign soil parameters for design purposes; careful categorization is required. The presence of organic matter means that *in situ* testing is highly desirable. High pore water pressures in the basal gravel can lead to instability of excavations unless this is relieved by ground water lowering.

Vertical drains used to facilitate road construction for a Medway riverside industrial area. Published in *Q. J. eng. Geol. London*, **17**, 327–3.

The coastal and estuarine geology of North Wales in relation to the design and construction of the A55 coast road. M. Springett. Overlying the bedrock are glacial and fluvioglacial deposits and lacustrine clays, while alluvial deposits occur in the Conway estuary. The paper considers the effect of the geology and the infill of the valleys on the design and construction of embankments, cuttings and estuary tunnel through the alluvial materials. Various techniques were considered including piling, rock replacement, sand drains, cut-off walls and dewatering.

Frigg IV pipeline – River Tay crossing. E. R. Fitch. The paper discusses the problems encountered when placing a 4 km long large diameter pipeline across the River Tay. Following a study of bathymetry of the estuary bed and adjacent foreshore, various construction methods were considered. The reasons for and against the various methods were outlined.

Pipeline construction in backswamp estuarine alluvium. W. L. Cornelius. Various problems were envisaged when laying a large-diameter pipeline between Newport and Cardiff through the alluvial deposits in the Marshfield area: the passage of heavy plant along the pipeline spread, trench instability, flotation of the pipe within the weak backfill material, and numerous drainage reens some over 2 m deep. Following discussion with the contractor, a novel method of construction was adopted.

Relevelling a gasholder at Rhyl. Published in *Q. J. eng. Geol. London*, **17**, 319–26.

Reinforced soil walls in marine environments. N. W. M. John, P. B. Johnson & R. Ritson. To overcome the corrosion problems associated with metal reinforcement of reinforced soil, an alternative fabric system has been adopted. Two fabric reinforced soil walls have recently been completed in marine environments. The Southampton wall, 20 m long and 4 m high, was constructed where the tidal range is about 4 m. The instruments were installed and read for 18 months. A longer embankment was constructed in Jersey.

Engineering Group Meetings

8 November 1983. **Geothermal energy.** Held at Burlington House, London. Chairman: Pierre Ungemach, Head of the Research and Development Programme on Geothermal Energy, Commission of the European Communities.

Introduction.

Exploration for geothermal energy in Vanuatu, South Pacific. W. G. Burgess, A. H. Bath & J. N. Carney (IGS Hydrogeology Unit). The first phase of a study of the geothermal potential of Efate Island comprised geological mapping of 250 km^2 and hydrochemical investigation of all the thermal springs. Pleistocene basaltic intrusions are the probably heat source for the hydrothermal system'the surface expression of which as thermal springs and hot ground is controlled by dominant NNE and ESE faults. Uncertainties about the extent of the hydrothermal system at depth can only be resolved by detailed geophysical study, which should at least include an electrical resistivity reconnaissance and improved gravity measurements.

Factors affecting the selection of sites for geothermal wells in hydrothermal areas. J. R. Shaw (Merz & McLellan). Geothermal areas are generally first identified from surface manifestations. Different routes have been taken from this point to try to exploit successfully the potential resource. The most important single step is in proving by drilling that steam will flow in large quantities to the surface. Drilling is expensive and many techniques have been tried to improve the chances of drilling success. These techniques are discussed together with other factors which affect the location of exploratory holes.

Problems in handling reinjection in clastic sedimentary reservoirs, with particular reference to two case studies in the Paris Basin. P. Ungemach (Commission of the European Communities). Problems associated with reinjection of heat-depleted geothermal brines are reviewed with particular emphasis placed on well damage and formation plugging caused by solids in suspension in the injected brine. Reference is made to early reinjection experiences and tests carried out in clastic sedimentary deposits in the European Community, in the Paris Basin, and the Po Valley.

The engineering geology of the hot dry rock geothermal reservoir in Cornwall. A. J. Beswick (Camborne Geothermal Project). The Camborne School of Mines is investigating methods to enhance the permeability of granite to enable geothermal energy to be extracted from deep crystalline rocks. The first task, completed in 1981, was the development of the experimental site, which included earth and rock clearance to make room for the drilling rig, stabilization of the quarry faces, etc. Following site preparation, two 316-mm holes were drilled in the granite into the reservoir region at 2000 m below surface and the reservoir developed using explosive shots and hydrofracturing. Some of the problems encountered during the drilling and development of the reservoir are discussed.

The geothermal resources of the United Kingdom. I. N. Gale & K. E. Rollin (BGS Hydrogeology Unit). The Geothermal Accessible Resource Base (ARB), which is defined as the quantity of heat stored to a depth of 7 km, has been calculated for the United Kingdom using a three-layer temperature dependent conductivity model in conjunction with a heat flow map. That part of the ARB that can be exploited at some future date is the geothermal resource. The hot dry rock accessible geothermal resources in permeable rocks in deep sedimentary basins have been calculated. The principal hot water reservoirs are the Permo–Triassic Sandstones. The identified resource of these deposits is that part of the geothermal resource which can be developed economically at a specific time in the future, the size being controlled by the reservoir properties, the fluid temperature in the reservoir and the temperature at which it is rejected after use. The distribution of the identified resource in relation to potential heat loads is discussed and predicted thermal yields at centres of population are given.

13 December 1983. Held at Burlington House, London. Convenor: Dr I. Sims. **Mineralogical aspects of artificial aggregates and additives for concrete**

The chemistry and mineralogy of granulated blastfurnace slag. S. R. Critchley, P. W. Scott & F. C. F. Wilkinson (Department of Geology, University of Hull). Granulated blastfurnace slag is produced by very rapid quenching, shortly after the molten slag leaves the blastfurnace. After further grinding, the slag with its pozzolanic properties is used as a cement replacement material in concrete. Chemically it comprises CaO (approx. 40%) and SiO_2 (approx. 35%)

dominantly, with lesser amounts of MgO, Al_2O_3 and other minor elements. The composition varies from different sources and also changes as a reflection of variations in iron-making practice. The major phase present is glass with a similar composition to the bulk chemistry. Varying proportions of melilite, merwinite, oldhamite and native Fe also occur.

The identification of artificial additives in hardened concretes and mortars. G. P. Hammersley (Ground Engineering, John Laing Construction Ltd) A. B. Poole (Applied Earth Science Unit, Queen Mary College, London University). The identification of mineral additives in hardened concretes and mortars is often difficult, particularly when they are present in low concentrations. Various optical and other techniques of mineral identification are reviewed and their suitability for the determination of particular additives evaluated.

Mineralogical changes on firing different rock types in colliery spoil. R. J. Collins (Building Research Establishment). A sample of the output of coarse washery discard and run-of-the mine dirt was taken at Desford Colliery, South Midlands, and sorted according to size and rock type. The mineralogy and physical properties of fifteen types of rock, both before and after firing at 1200°C, are compared. A careful consideration of sieving, density, self-grinding and other techniques could thus be used for up-grading spoil both before and during processing.

Volatile evolution in the formation of lightweight aggregates from clay raw materials. A. J. Bloodworth (British Geological Survey). A DTA furnace has been linked to non-dispersive infrared H_2O, SO_2, CO_2 and CO detectors enabling volatile evolution profiles to be obtained of potential clay raw materials for lightweight aggregates over a 20–1100°C temperature range. Evolved gas analysis allows a greater understanding of the mechanisms of bloating in clays of this type and can facilitate both identification and quantification of volatile evolving components such as sulphides, sulphates, carbonates, clays and organic matter.

10 January 1984. Joint Meeting of the Engineering Group and the Institution of Highways and Transportation held at Burlington House, London. **M25 motorway.** Convenor: G. West, Ground Engineering Division, Transport and Road Research Laboratory, Crowthorne, Berkshire.

Introduction by Chairman of the Engineering Group of the Geological Society, Dr A. B. Hawkins.

General planning concepts and geotechnical considerations. J. S. Salt & J. Wrightman (South East Regional Office, Department of Transport). London is not just a large city but an old one. The growth of the city and its traffic has demanded an orbital route, M25, which must both serve and be restrained by previous development. The paper sets out a brief history of the planning of M25 and the factors which have influenced overall route location. Also illustrated are the nature of restraints to the alignment and the ground engineering problems these create. Periglacial relicism, old backfilled gravel workings, cuttings in water bearing fine sands, and the assessment of the types and use of soils in shallow cuttings are some of the features met. How these were investigated, treated in design and the costs of different solutions were illustrated.

Site investigations for motorway construction in Kent on Gault Clay. C. Garrett (Kent County Council Highways Laboratory). During the past two decades numerous site investigations were carried out for the M25 and the associated M26 motorway in Kent which are located entirely on the Gault Clay outcrop. Prior to the building of these motorways few major engineering structures had been built in or on the Gault Clay outcrop which is relatively sparsely inhabited, being generally pastureland and woodland. Hence little evidence existed at that time concerning the geotechnical properties and behaviour of the Gault Clay which is infamous as a result of its particularly high swelling and shrinkage movements. In addition the near surface layers of the Gault Clay exhibit periglacial features such as solifluction and cryoturbation dating from the most recent Ice Age and which significantly affect the clay's mass properties. The paper gives details of the geotechnical properties and behaviour of Gault Clay and describes the special site investigations carried out into modification and stabilization of the clay using lime, horizontal and vertical pile tests for bridge structures and the detailed investigation and monitoring related to the construction of cantilevered bored-pile retaining walls.

Plant selection – geological considerations M25 Yeoveney–Poyle, Chertsey–Wisley, Leatherhead interchange. H. M. Bedelian (Balfour Beatty Construction Limited). Plant selection, especially on Bulk Earthworks is dependent on many factors, mainly quantity, haul distance, physical constraints, use of existing fleets as well as type of material. Though all these aspects are interdependent, the paper analyses how the type of material anticipated, and in particular its geological properties led to the selection of plant on the M25 contracts at Yeoveney–Poyle, Chertsey–Wisley and Leatherhead Interchange. The specification requirements were examined to demonstrate how these led to the eventual choice. Finally, an attempt was made to show how the material and conditions actually encountered affected the original decisions.

M25 motorway: Thames Valley stages — construction through backfilled and water-filled gravel pits. P. J. Williams, W. S. Atkins & Partners. The paper deals with design and construction aspects of the ground-works for the 8 km of the M25 Motorway through the Thames Valley from Egham in Surrey to Thorney in Bucks. Well over half of the area of the land traversed by the motorway and the three interchanges had formerly been worked for gravel. These worked areas were left as water filled pits, or had been backfilled with various types of waste or gravel washings. The paper describes the alternative processes considered for preparing and stabilising the ground up to former groundlevel, the solutions adopted, and the behaviour during construction. The groundworks have to cater for embankment heights which vary from near ground level to a maximum of 20 m at the four-level M4 interchange.

Research at the Bell Common Tunnel. I. F. Symons & Dr A. Charles (Transport and Road Research Laboratory and Building Research Establishment). The cut and cover tunnel on the M25 at Bell Common, Epping is formed by two embedded secant pile walls propped by the roof and retaining London Clay overlain by Claygate Beds. In stiff overconsolidated clays there is uncertainty concerning the initial *in situ* lateral stress and the changes induced by construction, which inhibits reliable predictions of the performance of this type of structure. To investigate this a section of the retaining wall and adjoining ground has been instrumented to monitor stresses and deformations. The presentation outlines the observations made during tunnel construction.

Earthworks problems during construction M25 (A10–M11) Contract I. J. S. Rushton, Tarmac National Construction. This 2.9 km long section of the M25 had a tender value of £28.62 million due mainly to the very high structural content including a cut and cover tunnel, large pumping chamber and three reinforced earth walls. The total earthworks quantity of 700 000 cubic metres was spread over the three year contract period, and because of the restricted site, the wide variety of materials and the constraints of the programme, the earthworks were a dominant feature of the works. The paper discusses the major earthworks difficulties posed by the scheme and the methods adopted by the Contractor to deal with them.

Conclusion by President of the Institution of Highways and Transportation, Mr M. Hardy.

11 January 1984. Joint Meeting of the Engineering Group and the British Geotechnical Society held at the Institution of Civil Engineers. **Recent applications of grouting.** Introduced by J. C. Woodward (Wimpey Laboratories Ltd), Dr D. A. Greenwood (Cementation Specialist Holdings Ltd) and Dr G. S. Littlejohn (Colcrete Ltd).

The presentation by Woodward highlights aspects of three novel grouting jobs overseas–a 14 km long diaphragm wall in Jordan, reinstatement of ground anchors to hold down a dry dock in Alexandria and installation of 65-m-long 400-tonne pile anchors for a jetty in Eire.

The diaphragm wall in Jordan was required as the 7 m deep cut-off below earth dykes impounding solar evaporation ponds in the southern end of the Dead Sea. The thin diaphragm connected the clay core of the main north–south dyke to a clay aquiclude below interbedded layers of permeable rock salt, and consisted of a 2.5 mm thick polyethylene sheet surrounded by a cement–clay grout in a 225 mm wide slot. Special techniques had to be developed to cut the slot, place the sheet and mix grout using highly active Dead Sea brine.

The 267 m × 42 m dry dock in Alexandria was constructed in 1962 and required 444 rock anchors each loaded to 178 tonnes to hold down the dock floor. In recent years loss of load has occurred in these strand anchors and it became necessary to reinstate about 20% of the load with new 63-tonne bar anchors. A complicated system of drilling and grouting had to be devised to install the anchors, working from temporary platforms above tide level outside the dock while the dock was dewatered for ship repair activities.

The 400-tonne anchors installed at the new coal loading facility at Moneypoint power station are probably the longest used in Europe for anchoring marine piles. Each anchor consisted of twenty-seven 15 mm dyform strands covered with polypropylene and provided with additional corrosion protection through an outer plastic sheath. The mudstones and sandstones required extensive pre-grouting in the 10 m pond zone and above, due to porosity and jointing in the rock. Special detailing was required at the anchor head and pile top to take the high loading.

Dr Greenwood suggests that there was a continuous relationship between hydrofracture of soils or soft rocks by grouts designed to permeate, and compaction grouting which consolidates them. The rheological properties of grouts may be controlled to offer the possibility of deliberate choice of fracture range to suit individual job circumstances.

The conditions for grout penetration by permeation and by hydrofracture and for retention in place are briefly reviewed as a basis for describing the concepts of squeeze grouting and grout jacking. These include control of grout viscosity and shear strength/bleed capacity to ensure respectively, localization of consolidating pressure by grouting and ultimate wedging action. As grouts get stiffer equipment must be adapted to suit both mixing and pumping, and pipeline features must be appropriately detailed. Finally some illustrative examples of the application of these techniques are described.

The presentation by Dr Littlejohn covers permeation and hydrofracturing techniques as employed at Asprokrommos Dam, Cyprus and the Hong Kong Metro, chemical injection of silty sands beneath piles in Jeddah, roadway support in longwall mining via pump packing, freespan support of pipelines offshore using seawater grouts and the potential for foamed grouts in applications such as annulus grouting in sewer renovation and trench reinstatement in highway maintenance.

Joint Meeting of the Engineering Group and the Marine Studies Group

7 February 1984. **Routeing of pipelines and cables on the sea bed.** Held at Burlington House. Convenor: Dr J. B. Wilson.

Geological factors influencing pipeline and cable route selection. N. G. T. Fannin (B. G. S. Edinburgh). The British Geological Survey is conducting a reconnaissance mapping programme on the continental shelf and upper slope and this provides a framework for detailed surveys. Bedrock and sediment topography are critical factors while other characteristics such as sediment texture, stability and geotechnical properties are important. A third group of events which occur on a geological time-scale such as seismicity and catastrophic gas emission must also be taken into account. Thus both an understanding of the geological present and of geological history and environment of deposition is required so that the engineer can identify the most cost-effective design criteria.

Seabed investigation for pipeline and cable routes. A. R. Biddle (Consulting Geotechnical Engineer, Amersham, Bucks). The presentation concerns the planning and coordination required to maximize the benefits of seabed geophysical surveys and geotechnical investigations. The main points were: (i) Any offshore site investigation should be carefully planned. (ii) The clients coordinator should set the objectives of the site investigation project and consult all appropriate specialists to ensure that the programme is comprehensive. For a pipeline or cable survey, the specialists will include at least a positioning surveyor, an oceanographer, a pipeline or cable design engineer, a geotechnical engineer, a geophysicist and a geologist. (iii) Anomalies in the seabed must be evaluated as either "Engineering Constraints" for which an appropriate solution is found or as "Hazards" for which no confident solution can be decided because of insufficient knowledge about the phenomenon. In this latter case, engineering judgement has to be made on the degree of risk that the hazard poses to the project and a decision taken either to accept that risk or to avoid it by moving the pipeline route. (iv) As the work involves synthesis and interpretation of data from many specialist disciplines it is becoming known as an "Integrated Site Investigation". Most seabed surface phenomena are poorly understood and require an iterative investigation procedure for evaluation. Teamwork is required by all involved to ensure that the many facets to each problem are covered. (5) A specialist can only contribute his best if thoroughly briefed on the construction project and the survey objectives. Inappropriate work can result from calling in an expert at a late stage without putting the problem in context and fully explaining the background. It is best to involve the specialist team from the outset. Examples are shown of seabed features that pose hazards to the designer and which must be evaluated by the geotechnical engineer to assess their significance in routeing decisions.

The application of marine geophysical and geotechnical techniques to the routeing of pipelines and cables. T. A. Clark & D. I. Taylor (Osiris–Cesco Ltd, Deeside, Clwyd). The paper reviews techniques and methods for data acquisition to enable the design and routeing of pipelines and cables underwater. Following a desk study, selection of the most applicable investigation techniques is undertaken. Field studies normally commence with preliminary seabed and sub-surface surveys of the proposed route followed by more detailed survey along the preferred corridor route. Seabed sampling is then undertaken to confirm material types and properties and for geophysical correlation. Sampling equipment deployed will depend on the water depths, depth of interest below seabed and anticipated material types. Case studies are presented in which the authors had particular involvement.

Geotechnical problems associated with offshore pipelines. P. T. Power (Fugro Ltd, Hemel Hempstead, Herts). The presentation considered those aspects of pipeline design, installation and operation that are affected by geotechnical conditions. Amongst the topics covered are: on-bottom stability, trenching requirements, span correction and other 'intervention' works, thermal effects and settlement and floatation of pipelines. Examples from actual and hypothetical pipeline projects are used to illustrate some of the problems.

Estuary crossings: the problems of high potential scour. C. K. Patrick, (University of Lancaster). The estuaries entering Morecambe Bay dry out at Low Water, have high tidal ranges (up to 10 m), very mobile beds and rigid margins, and high river flood discharges. These combine to produce complex scour behaviour which must be allowed for when designing pipe-crossings. The mechanisms of scour are inadequately understood and background data are poor, so that great care should be taken in feasibility studies. Two case studies are described which indicated the problems involved in establishing adequate design information and ways in which they can be overcome.

Subsea consideration for the Ekofisk pipelines. W. L. Heidbreder (Phillips Petroleum Company, Stavenger Norway). A discussion of the general factors involved in pipeline routeing is presented followed by a description of their application to the design and routeing of the Ekofisk to Teeside oil pipeline, the Ekofisk to Emden gas pipeline and the Greater Ekofisk Area infield pipelines. Anticipated and actual problem areas during design and installation are compared. After ten years of operation, several interesting occurrences which relate to the discussed principals of routeing hazards and soil properties have been observed. These findings, their cause and solutions are presented.

Aspects of route selection for the Brae to Forties 30 inch oil pipeline. I. Gold (Marathon Oil (UK) Ltd, London). The objective of the Brae to Forties pipeline route design was to establish a safe economic route consistant with minimizing effects on environmental parameters and the proposal not to trench the pipeline. This required detailed seabed investigations along a corridor agreed with respective block operators. The route evolved avoided such features as pockmarks. Vigorous control was required in the establishment and use of a positioning system to ensure the accuracy of the lay. Subsequent examination confirmed uniform settlement and support with no significant spans. Its good integrity vindicates the decision to adopt "state-of-the-art" techniques for route design and pipeline positioning.

The planning of submarine cable routes to reduce cable faults. R. S. Aitken & J. Butler (British Telecom International, Southampton). Every year submarine cable owners suffer many faults to their underwater plant. The paper examines the cause of such faults, be they the result of seabed conditions or the actions of other sea users. The second part of the paper describes how British Telecommunications investigates seabed conditions to enable cable to be protected.

Some rare underwater phenomena as they have affected cable systems. R. L. Williamson (Standard Telephones and Cables PLC, London). The ocean floor normally provides submarine cable systems with a benign environment which is stable in temperature and free from physical disturbance. Because of this cables in depths exceeding 1000 m do not need to be armoured and, even so, damage to them is almost unknown. However, there are exceptions and the paper gives an account of a few instances in which localized deep ocean currents and other phenomena have necessitated repair and re-routeing. Areas discussed included the Bashi Channel and the Gulf of Cadiz.

Route engineering and installation of submersible plant for submarine communications systems. A. H. Clinton (Cable and Wireless PLC, London). The high cost of submersible plant, its relative inaccessibility when installed and the severe disruption to telecommunications services that arise from interruptions to a high capacity international cable system demand that planning, survey and installation are executed to high standards. The presentation describes the principles of surveying, route selection and installation for a submarine cable. The submersible components are engineered for high reliability. This reliability must be complemented by maximum security along the route chosen and a long uninterrupted life for the system.

Geological aspects of the CEGB–EDF cross-Channel cable route. B. N. Fletcher (B. G. S., Keyworth, Nottingham). A 2000 MW DC link with the French electricity system is planned, with both sides connected by eight cables (four

500 MW pairs). An existing cable links Lydd with Equihen. Experience showed the need to bury cables in seabed trenches. Surveys between Dungeness and the French coast, near the existing cable, showed rock outcrop (Wealden Beds, Purbeck Beds, Portland Beds, Kimmeridge Clay) with small steep scarps unsuitable for a trenching machine. Further surveys identified a suitable route between Folkestone and Sangatte, mainly over Turonian and Cenomanian Chalk. It crosses Gault Clay and Folkestone Beds near the landing point at Folkestone.

8 May 1984. Joint meeting of the Engineering Group and the Geological Information Group **Applications of microcomputers in engineering geology.** Held at Burlington House, Piccadilly, London W1. Convenor: Dr P. Young.

Introduction by Dr A. B. Hawkins

Microprocessors and microcomputers: a review and implications for geologists. J. J. Hill & R. P. Young (University of Hull). A review of literature showed an increasing use of microcomputers in geology. This paper aims at providing an introduction to, and review of the microcomputing field. The basic terms in use are explained and the main microcomputer systems and processor chips are surveyed. The distinction is made between systems which use embedded microprocessors which are transparent to the user and systems which provide enhanced capabilities by software development and interfacing to a personal microcomputer. Finally, a review of current and potential applications in Engineering Geology and Engineering Geophysics was given.

Field measurements with microcomputers in soils and rocks. D. J. Corke, P. S. Finn & A. Price Jones (Soil Mechanics Ltd). This paper describes four field applications of microcomputers in engineering geology/geotechnical engineering, each illustrated with a typical case history.

Inclinometer monitoring. Rapid field processing of inclinometer readings is a powerful tool in cases of active ground movement. A microcomputer system is described which allowed readings to be processed and plotted on site within minutes. Using a modem connection, the microcomputer can be linked to larger computers for rapid transfer of data.

Pressuremeter testing. Field use of microcomputers to monitor and analyse pressuremeter tests is described. The system, based around an HP86, uses computer graphics to display results as the test is in progress, enabling optimal control. A separate, microbased "Autonomous Data Unit" allows simultaneous manipulation of the data without interfering with the data logging.

Dynamic measurements. The dynamic design of foundations on rock frequently requires *in situ* measurement of P-wave and S-wave velocities and damping ratio. Field use of an HP85 microcomputer system to record downhole measurements for both impact signals and constant frequency oscillations is described. The system provides a graphical display and print out results on site.

In situ *stress measurement.* An automatic data logging and reduction system has been incorporated with the CSIRO cell to carry out *in situ* measurements of rock stresses at depths up to 300-m. The system, based around an HP85 microcomputer, enables the plotting of data and reduction of strain measurements to give the complete stress tensor immediately following overcoring.

A device to facilitate the in situ *testing and sampling of terrestrial soils.* C. Nunn (Zetelogic Ltd). A novel device is now being introduced which has direct application in the terrestrial site-surveying industry and whose technology also has application spin-offs in Engineering Geology, Engineering Physics and geological fields.

Static and dynamic penetrometers (upgraded versions of the Dutch Cone, DC, and Standard Penetration Tool, SPT) are combined in one device, operated via a logging cable down geotechnical site-evaluation boreholes. The DC probe is penetrated at constant velocity, the cone load and side friction being measured to determine static soil strength parameters. The SPT core tube penetrates with constant initial impact energy, the varying deceleration and cumulative displacement being measured to determine dynamic strength parameters and textural profiles of the soil. The complex interactive control used to generate accurate and meaningful data from the downhole environment invokes the use of single chip microcomputer unit (MCU) technology. One MCU controls analog/digital conversion, digital data transmission and reception, real-time phasing functions, digitally controlled power circuits and multiplexing of static and dynamic sensors, including accelerometers and strain gauges, axial load cells and optical shaft encoder. On-chip EPROMS contain macro and micro controlled algorithms. On-chip RAM is utilized as buffer memory and stores micro routines transmitted from the surface computer. The surface system is a superior specification M68000 user-friendly computer used to coordinate and display raw and computer hole data.

Microcomputer-based seismic instrumentation systems. R. P. Young, J. J. Hill, A. D. Green & R. N. Haigh (University of Hull). Developments in microprocessor technology are having considerable influence on the way engineering seismic data is collected, processed and analysed. Two seismic instrumentation systems are described in this paper.

A 24-channel, radio telemetric, seismic monitoring system has been developed, consisting of six portable outstations which can be positioned up to 5 km from a base station located in a landrover or site office. Each microcomputer controlled outstation has one air overpressure and three ground vibration channels for recording up to sixteen seconds of pre- and post-trigger data. Communication between each outstation recorder and base is via a UHF duplex telemetry link which is used to activate and programme each outstation, to maintain synchronization and to transfer data from each outstation, to maintain synchronization and to transfer data from each recorder to the microcomputer-controlled base station. Here the captured seismic event can be stored on cassette, displayed on a 5-inch monitor, or transferred to a microcomputer for processing.

A microcomputer enhanced engineering seismograph, GEOSEIS–MERLIN, has been developed as a portable repackaged Apple unit with a 5″ monitor, internal printer and disk drives or bubble memory to give on site processing and results. The unit includes a multi-channel, 12-bit ADC card with programmable gain amplifiers and the system is designed to operate in the field as a self-contained, six-channel, seismic processing system. Menu-driven software operations include: data capture, concatenation and editing of files, display of seismic time data, seismic refraction analysis of up to 24 channels, power spectral computation, display of power and attenuation spectra, spectral smoothing and digital filtering of waveforms. The system can calso be used as an interface to existing seismographs or to the radio telemetric seismic monitoring system.

Examples of tomographic and Fourier microcomputer processing of seismic records. B. M. New (Transport and Road Research Laboratory). A technique for processing seismic data has been developed that provides a 'representative velocity' tomogram which may be interpreted in terms of the engineering properties of the subject rock mass. This transmission system is intended for use in cross-borehole surveys and has been successfully tested between sub-parallel mine roadways in a massive granite body.

The velocities of compressional waves between numerous source and transducer locations are analysed and the interactive character of the observations is used to build a two-dimensional array of computed 'representational velocities' appropriate to specific areas within the intervening rock mass. Evaluation of the processed data is undertaken using site specific and more general rock mass classification systems. The processing is carried out on a CBM Pet microcomputer and the program is readily adaptable to most field configurations. The program also allows various mapping and influence parameters to be varied and optimised to obtain the best resolution of rock mass inhomogeneities.

Fast Fourier Transform routines for the calculation of the energy spectral density (and other frequency domain functions) of ground vibrations, induced by blasting during civil engineering works, are also briefly discussed.

Microcomputers in laboratory testing and the assessment of site investigation data. M. S. Atkinson, A. M. Coatsworth & P. J. L. Eldred (Soil Mechanics). This paper describes two applications of microcomputers in the laboratory and in the assessment of site investigation data in the field of engineering geology/geotechnical engineering.

Laboratory testing. The use of microcomputers in commercial soil testing laboratories for the logging of data, routine calculations and plotting of data is becoming commonplace. However, computer controlled testing is rare. Using computer controlled triaxial apparatus, a particular construction situation in geotechnical engineering can be modelled by a similar process in the laboratory, whereas standard tests follow some arbitrary loading procedure. Control of a triaxial cell by a microcomputer and some practical uses to which it has been put are described.

Assessment of site investigation data. Processing of field and laboratory test results, both during and after a site investigation, can be a time consuming task. Whilst acknowledging that some manipulation and plotting of data by hand can lead to a greater understanding of the soil, the use of microcomputers can aid and speed up the task. Alternatively, the data can be examined in a greater variety of ways. A computer program for sorting and plotting such data and some of its practical uses are described.

Microcomputer technology offers a new approach to the automation of physical testing. M. McNair (ELE International Ltd). The major problem in the automation of physical measurement with microcomputers is the interfacing of transducer devices and developing a means to monitor them. Although many solutions are available, they generally involve microcomputer technology and the range of choices is very confusing, especially to those unfamiliar with this type of computer application.

The ADU has been designed to overcome these problems by combining adaptable hardware and software in one unit. It is an intelligent data logging device that can accept a wide range of transducers and monitor them in virtually any manner desired. The ADU is simply programmed from most popular makes of microcomputers. All readings gathered are stored in its own solid-state memory until required by the user. Since all the necessary data logging functions are in the ADU, the problem is drastically simplified. All the user has to do is to specify the tests to be carried out and retrieve the readings when required. Process control can be added as an option for applying intelligent control to pressures, loads, rates of flow, etc.

The ADU is a universal tool that offers particular advantages to the engineering geologist for automated field and laboratory testing. Typical rock mechanics applications would be: strain gauge measurements, monitoring settlements and ground movement.

Does the output stage let you down? D. A. Greenwood (Micro Training and Advisory Services Ltd). Report writing forms an essential final stage of any geological investigation and in many cases, represents the 'end-product' as far as the client is concerned. Such a report frequently calls for original text, standard text items and summaries of numerical information in tables, logs, charts, plots, etc.

Conventional methods of preparation via the typing pool and drawing office are relatively uncoordinated and often involve the reworking of the same data as drafts are produced, edited and approved by senior staff. There is also a considerable burden of proof-reading and checking back to original field data.

Much of this work could be streamlined by transferring it to a microcomputer, set up as a managerial/secretarial work-station employing standard word processing, data handling and graphics packages. The latest generation of microcomputers also have communications and terminal emulation facilities offering the further possibility of transferring data between microcomputers, or to or from main-frame systems. Links also exist to photo-typesetting, enabling high quality "prestige" printed reports to be produced from word-processed documents.

As microcomputers become completely portable, it will be feasible to key-in much of the original data in the field, either directly as text or indirectly via specially written data capture programs.

Closing remarks by Dr A. B. Hawkins.