BRITTLE MATERIALS

THE mechanical properties of brittle materials, whether artificial, as glass, ceramics or concrete, or natural, as coal or rock, are less well known and understood than are those of ductile materials. The difficulty lies, in part, in the wide random variations in strength frequently observed in the same substance. This stems from the lack of ductility which renders brittle materials unable to accommodate local stress concentrations in the vicinity of chance cracks or flaws, which therefore precipitate breakage. In some cases inhomogeneity and anisotropy are obvious additional complications. None the less, the mechanical properties and particularly the strength of such materials are of immense technical importance, whether they are required to withstand loads or to be broken. Some materials, such as brick and concrete, have been studied extensively, and standard tests and specifications evolved, but there is little basic knowledge of the relationship between properties and structure. For many other materials, test methods have scarcely evolved beyond simulated user trials of finished articles. While much remains to be learnt about traditional materials, modern technology is pressing for information on new substances and on behaviour under extreme conditions of temperature, pressure or atomic bombardment.

In view of this lack of fundamental knowledge in relation to coals and rocks, the National Coal Board is undertaking at its Mining Research Establishment, Isleworth, Middlesex, a programme of research which, it is hoped, will lead to a system of classifying these materials according to their technically significant properties, and aid the development of improved mining techniques. In the course of this work it seemed that a mutual exchange of information on theories and techniques in various fields would be useful. The Mining Research Establishment, in consultation with the Building Research Station of the Department of Scientific and Industrial Research, therefore organized a conference on the Mechanical Properties of Non-Metallic Brittle Materials, which was held at the Royal Society of Arts, London, on April 1 and 2. It was attended by representatives from some forty industrial concerns, Government laboratories, research associations and university faculties, and from five West European countries.

The conference was opened by Mr. A. H. A. Wynn, scientific member of the National Coal Board. Mr. Wynn said that the complex structure of coal made it a particularly difficult substance to study. The Board hoped to learn from those who have a long tradition of scientific study of the mechanical properties of other brittle materials. Twenty-seven papers on eight different substances were to be presented, and it was clear that the research described had many common points of application.

The chairman of the first session, which was devoted to discussing strength in compression, tension, bending and shear, was Dr. L. C. Tyte, director of the Mining Research Establishment.

I. Evans and C. D. Pomeroy (Mining Research Establishment) discussed the random variability of the strength of coal in uniaxial compression and the dependence of mean strength on the size of specimen. A 'weakest link' theory, based on the probability of the propagation of cracks, was developed to explain the observations. Its implications regarding the physical nature of the breakage and the ultimate structural elements of the coal were considered. R. Jones (Road Research Laboratory) described recent work on the failure of concrete in compression and flexure. Ultrasonic pulse techniques showed precracking parallel to the direction of loading to occur in test cubes in compression at 40–70 per cent of the failing load. It was considered that the cracks arose from local bond failures between the aggregate and cement. The strength of gypsum plaster as a function of the percentage of voids was discussed by K. K. Schiller (British Plaster Board (Holdings), Ltd.). The voids depend on the excess quantity of water in the original mix. Theoretical relationships for the fractional reduction of strength due to porosity were derived and shown to be in good agreement with experimental results.

A. J. Newman (Building Research Station) described recent research on the influence of the method of testing upon the results obtained in compressive strength tests of bricks. This work led to the selection of the method of test now included in British Standards for bricks.

Mr. B. Sugarman (British Glass Industry Research Association) introduced Miss P. Walton's review of the micro- and macro-strength of glass. Specification of strength is difficult because of the large number of influences to which it is susceptible and the wide scatter of results under apparently identical test conditions. The strength of glass fibres is very dependent on the drawing conditions and, contrary to earlier results, is not necessarily a function of the dimensions. Strength is also affected by surface conditions, time under load and by immersion in water. Although glass can show a strength of about 400,000 lb./in.^{2} under basic test conditions, this may fall to some 4,000 lb./in.^{2} in use.

The complexity of the breakage phenomena occurring in apparently simple compression tests was brought out in a paper by Prof. Th. R. Seldenrath and J. Gramberg (Technical University, Delft). Cylindrical specimens of fine-grain rocks such as lithographic limestone, when uniformly loaded, fail by splitting parallel to the direction of loading. Glass sometimes fails in a similar manner, but in other instances shatters into many fragments. Coarse-grain rocks, such as marble, collapse with the formation of typical 'shear cones'. The lateral dilatation of the cylindrical specimens is a maximum at about a quarter of the specimen height from either end and less in the central plane.

Triaxial compression tests at confining pressures up to 4,000 lb./in.^{2} on coal and coal-measure rocks, respectively, were described by S. A. F. Murrell and N. J. Price (Mining Research Establishment). The introduction of a confining pressure increases the compressive strength and changes the mode of fracture of coal from explosive bursting to shear failure. At high pressures, coals of markedly different properties under uniaxial compression possess almost equal strengths, and anisotropy also disappears.

The chairman commented on certain common features revealed in the papers. Materials of high intrinsic strength are weak in practice, strength is not reproducible but shows a statistical variation,

and mean strength diminishes with increasing size of specimen. These observations are consistent with a material permeated by cracks, whether visible or not. Theoretical approaches are based on this assumption, following Griffith's classical work on glass. Collateral evidence of the influence of cracks is provided by the triaxial loading tests.

For the second session, on elasticity and creep, the chairman was Dr. F. M. Lea, director of the Building Research Station of the Department of Scientific and Industrial Research.

Prof. A. D. Ross (King's College, London) outlined the relative contributions of elasticity, creep and shrinkage to the total strain in concrete, emphasizing the significance of the latter two factors. Rheological models and theories advanced to explain the observed phenomena were discussed. Prof. R. H. Evans (Leeds) dealt with the properties of concrete and other building materials when subjected to rapid rates of loading. Values for the modulus of elasticity obtained by static and dynamic tests differ, and anomalous values are found for many materials at very low loads. These are attributed to internal stresses.

Various aspects of the strength of ceramic materials were described in a paper presented in three parts, from the British Ceramics Research Association. A. Dinsdale and W. T. Wilkinson critically examined methods of measuring impact strength. The results for any one material and type of test show a wide variation, and tests differ in their ability to discriminate between materials; none is fully satisfactory. The system most likely to yield results that can be interpreted in terms of an inherent property of the material involves the use of unrestrained test pieces. Fatigue from repeated blows is observed when the impact points are distributed but not when they coincide. Sonic testing of ceramic refractory materials was described by W. R. Davies and J. F. Clements. The ratio of the dynamic modulus of elasticity to the modulus of rupture is practically constant and can be used both to estimate transverse strength, and as a possible index of resistance to thermal shock. Sonic resonance methods have been used to detect cracking and 'spalling' due to thermal shock. K. Pate and W. Noble described stress–strain relationships in heavy clay products. Thermal expansion, elasticity and elastic hysteresis were considered, together with the partially irreversible changes occurring during cyclic wetting and drying. It was concluded that no single test is sufficient to assess durability.

H. W. Davidson and H. H. W. Losty (General Electric Co., Ltd.) described a study of the elastic and plastic properties of carbon and graphite. They found it possible to rationalize these properties and the changes with temperature, in terms of the movement of layer planes within the graphite crystallites without reference to the gross grain structure, and to account qualitatively for the behaviour on graphitization and neutron irradiation.

N. B. Terry and W. T. A. Morgans (Mining Research Establishment) described studies of the rheological behaviour of coal. The coals examined show transverse isotropic elasticity, with dynamic moduli higher than the static moduli. Measurements of creep and internal damping have led to the suggestion of a type of mechanical model that would simulate coal. The elastic anisotropy was attributed to microcrack structure. F. J. Hiorns (British Coal Utilization Research Association) used vibrating strips of coal to study the dynamic Young's modulus and internal friction over the temperature-range 20°–180° C., including water absorption effects. Complex changes with water content were reported.

P. Murray, J. Williams and D. T. Livey (Atomic Energy Research Establishment, Harwell) gave data on the effects of porosity and microstructure on the mechanical properties and resistance to thermal shock of high-temperature materials (pure oxides). The importance of low porosity and fine grain size was emphasized. Improvement in resistance to thermal shock depends mainly on increased strength, which demands low-porosity fine-grain material. Treatment to minimize the effects of surface microcracks may lead to significant improvements in strength.

The chairman, in opening the discussion, directed attention to the commonly observed differences between instantaneous and long-period moduli, and warned that the success of similar 'spring and dashpot' models in representing the behaviour of different materials did not necessarily mean that the phenomena arose from common causes. He remarked also on the broad scatter of results characteristic of impact testing and wondered if theoretical approaches similar to those used in respect of compression and tensile strength could be applied.

Mr. H. T. Ramsay, director of the Safety in Mines Research Establishment, took the chair for the third session, on dynamic loading, impact and fragmentation.

E. N. Fox (Cambridge) has studied the strength of concrete beams subjected to short-duration flat-topped stresses, applied by using the stress–yield characteristics of a steel wire arresting a falling weight. For pulses of 10–100 m.sec. duration the results exhibited considerable scatter but indicated the strength to be, on average, about 35 per cent greater than the static strength. H. Green (Building Research Station), dealing with impact testing of concrete, emphasized the importance of the restraints imposed on the specimen and found that apparatus based on the ballistic pendulum is more satisfactory than drop-weight methods. The resistance of 4-in. concrete cubes to repeated blows is influenced by the shape and surface texture of the coarse aggregate used in the concrete.

R. Teale (Mining Research Establishment) described experiments in which cubes and ridges of rock of various cross-sections, attached by one face, were broken from the parent blocks by wedging and by lateral overturning forces. Wedging is inefficient because of frictional losses. The overturning forces increase as the 1·7 power of the linear dimensions and are roughly proportional to the compressive and shear strengths of the rocks. For ridges, shallow and deep modes of breakage are observed, depending on the width/height ratio. Studies of the penetration of a roller bit into concrete containing a strong rock aggregate were described by N. J. Price and R. Shepherd (Mining Research Establishment). The crushing strength of the concrete was its most significant property affecting penetration; the percentage and the particle size of the rock aggregate were not critical.

S. Paterson (Imperial Chemical Industries) reported studies of the energy partition in shattering stone blocks with an explosive charge. 'Balanced' charges communicate 10 per cent or less of their energy to the target block, not more than 2 or 3 per cent being energy of mass movement, while the remaining 90 per cent resides in the explosive products.

R. J. Hamilton and G. Knight (Mining Research Establishment) found the size distribution of the fine debris (100μ to 1μ in size) produced in the mechanical breakage of coal and rock to be constant in form for each material, but the quantity depends on the breakage process. Stronger materials on shatter produce less total dust than weaker ones, but a greater proportion is dispersed into the atmosphere. H. C. Grimshaw (Safety in Mines Research Establishment) reported similar size distributions from rocks shattered by explosives. Increasing the weight of charge increases the production of fine dust but has little effect on the size distribution. Water infusion reduces the amount of fine dust.

The chairman commented that a number of the papers gave rather unexpected results and confirmed the value of small-scale laboratory work before designing large machines. The constancy of size distributions for very varied breakage processes remains a surprising feature and the results reported, which extend to particles of respirable size, are highly significant for the mining industry.

The chairman of the fourth session, on the action of tools, was Dr. W. Idris Jones, director-general of research in the National Coal Board.

Four papers, all from the Mining Research Establishment, dealt with the action of wedge-type tools on coal. M. J. Dumbleton, M. J. O'Dogherty and R. Shepherd described laboratory experiments in 'ploughing' the face off a block of coal, and related the cutting force to the blade angle, depth of cut, strength properties and orientation of the coal specimen. Theoretical aspects of this process were considered by I. Evans, who assumed that the material fails in tension. C. D. Pomeroy gave experimental results for the effect of lateral pressure on the coal specimen on the ploughing forces. The entry of a wedge into specimens with one free face was the subject of a paper by I. Evans and S. A. F. Murrell.

J. H. Brown and C. D. Pomeroy studied friction between coal and metal surfaces.

The chairman commented on the absence of papers on materials other than coal in this session, but considered that the coal industry's problem is probably unique in requiring breakage to handleable size but not smaller. Considerable knowledge exists of metal cutting processes which might be applicable to coal and other brittle materials. There are considerable problems in establishing the relevance of basic measurements to more complicated processes such as ploughing, and further problems in proceeding from the laboratory to underground mining conditions.

The proceedings of the conference will be published in book form. W. H. WALTON

INTERNATIONAL CONGRESS OF APPLIED PSYCHOLOGY

THE thirteenth International Congress of Applied Psychology was held at the University of Rome during April 9–14. Opening discourses by Prof. Canestrelli, the president, and by Profs. A. Gemelli and H. Piéron gave a conspectus of the scope of the congress and an account of the historical development of applied psychology. More than six hundred participants attended from thirty countries, and some 250 papers were presented. These covered a much wider range of subjects than at previous meetings, a novel feature being the special attention given to medical and, particularly, to legal psychology.

Plenary discussions were devoted to psychological aspects of training industrial managers, medical men, teachers and men of law. The other sessions were occupied, according to this four-fold division, with symposia and individual papers on more general industrial, medical, educational and legal questions.

The sessions on occupational psychology were less concerned with traditional problems of selection, training and environmental conditions of work than with newer questions, such as the specification of criteria for judging the worker's efficiency, the design of tools and machines, the human consequences of automation, industrial mobility, and the vocational rehabilitation of disabled workers. The medical meetings were mainly occupied with personality in physical illness, causes of abnormal behaviour in childhood, effects of hospitalization, analysis of the ideas of normality and abnormality, and socio-psychological aspects of critical physiological phases (for example, pregnancy, ageing) and of psychosomatic medicine. Themes in the educational sessions included the teacher–pupil relationship as a factor in scholastic success, educational and vocational guidance, practical applications of learning theory, 'group dynamics' in the classroom, and the adjustment of school programmes to varying levels of mental development. Finally, the sessions on legal psychology were directed to the problem of evaluating testimony, psychological examination of the accused, the study of criminal gangs, and the readjustment of discharged prisoners.

No participant could attend all the meetings, some of which were held simultaneously. One can therefore do little more than give a personal impression of a rather arbitrary selection of papers widely differing in form and content.

In the industrial section Dr. M. Roche, from Paris, made out a strong case for placing the training of driving instructors on a sound pedagogical basis, so as to ensure that only those who are themselves adequately qualified instructors should be permitted to teach others. Prof. G. Westerlund reported a large-scale statistical and 'inter-disciplinary' study of industrial accidents in Sweden. He suggested that accidents are more likely to occur when the worker is new to his job or environment, when his training is inadequate, and when equipment is used to an end for which it was not designed.

Dr. E. V. Gurijanov, of the Academy of Educational Sciences in the U.S.S.R., gave an impressive account of researches at the Laboratory of Labour Psychology, of which he is director. Their aims, he said, were not only to raise the individual's productivity, but also to create the most favourable conditions for the human operator, to improve his vocational skills and aptitudes, and encourage him to adopt 'a creative attitude' towards the solution of industrial problems.

Of more theoretical interest were papers by Mr. P. Bertelson and Mr. R. D. Shepherd, respectively, who studied the response times to stimuli varying in the probability of their appearance. Mr. Bertelson considered the effect of redundance of signals in a sequential task, while Mr. Shepherd was specially