Advances in Aggregates and Armourstone Evaluation
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Advances in Aggregates and Armourstone Evaluation

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environmental damage is also needed to add to the management of the marine sand and gravel resources. Predictions of the available marine aggregates quarrying opportunities on land that are better circumvented. The technical potential of secondary and recycled aggregates is being actively investigated in response. More recently, the environmental sustainability debate has intensified under stricter management plans founded on scientific understanding of physical processes, urbanization pressures and human responsibilities within each coastal region. Not surprisingly, such high material demand is not without environmental consequences.

Ever since the UK Department of the Environment published its Minerals Planning Guidance Note MPG6, 1994 ('Guidance for Aggregates Provision in England'), the projected resources and huge demands for these construction materials have been increasingly scrutinized by government strategic planners. In particular, MPG6 expressed a need to ease pressure on primary sources of aggregates (crushed rock, marine-dredged and land-won sand and gravel) by increasing the use of secondary aggregates (e.g. pulverized fly ash, slags, slate and china clay wastes) and recycled aggregates (crushed concrete and demolition waste). The technical potential of secondary and recycled aggregates is being actively investigated in response. More recently, the environmental sustainability debate has intensified under pressures to conserve the landscape and to minimize sea-bed disruption in sensitive areas.

Research is vital in helping to underpin a dredging industry seeking (i) effective exploration methods, (ii) accurate evaluation of survey results and (iii) sensitive management of the marine sand and gravel resources. To complete the picture, firm data on what 'could' be extracted from the sea-bed without causing long-term environmental damage is also needed to add to the quarrying opportunities on land that are better circumscribed. Predictions of the available marine aggregates resources, and the likely demands from the various user sectors are urgently needed to assist responsible planning within the industry.

Users of concreting aggregate and constructional fill, the coastal authority 'beach rechargers' and many overseas users often compete for the same marine aggregate supply. However, with the exception of some sand deposits, these resources are considered to be non-renewable, and the wisdom of extraction in certain locations has consequently become a complex matter to resolve. The circulation of sediment within nearshore cells generally remains poorly understood; as a result it is not always clear at what point sediment extraction at sea is no longer detrimental to the health of nearby beaches. Leaving aside the environmental problems of high material demand, another set of problems afflicting the construction materials sector of the extractive industries concerns the testing and specification of materials quality. This has been recently highlighted by the activity surrounding the introduction of Eurostandards required for the specification and testing of aggregates in their various unbound (e.g. construction fill) and bound (e.g. bituminous roads and concrete) applications, as well as for armourstone and building stone. The search for a single favoured European test method for each important aggregate or armourstone property has been ongoing where the sole aim has been one of reducing trade barriers. The micro-Deval test used to determine the resistance of aggregate to wear is one such chosen test which, until recently, was little known outside France. A comparison between competing alternative test methods is necessary before rational decisions can be reached amongst the various European nations, each of which have their different established practices, and their numerous varieties of rock types and prevailing climates. Published quantitative studies that compare chosen new or unfamiliar tests with older nationally established tests form essential data sources. It is these that give the industry the confidence to adopt new practices. More pressing perhaps, is the need for specification of tests that can predict in-service performance more successfully.

A further problem that is readily apparent when materials quality is a key issue is the question of reliability. For example, what is the probability that site concrete will be made from significantly contaminated aggregate, on the basis of routine testing of a continuously delivered product? Clear explanations of how to apply statistics to rock quality data is wantonly lacking at present and many results are presented in a manner that can easily confuse or mislead. The potential benefits to industry from clear explanations would include realistic confidence bounds, enabling structures to be built that are more economic and safe.
One sector of construction activity that is the subject
of great uncertainty and risk for the designer and/or
contractor is that surrounding armourstone operations.
The risk is linked not only to the sheer scale and rigours
of armourstone production, handling, transportation,
construction and unpredictable weather conditions, but
also to the high variation in the possible shapes, sizes
and rock types for the blocks themselves. The physical
awkwardness of this massive material and the relative
lack of expertise with its design and construction has in
recent years motivated greater study of this increasingly
important quarry product, in spite of its relatively small
volume share in the market. What makes one quarry
better than another in terms of the quality of armour-
stone it produces is a question facing many users
evaluating the various sources. Even though challeng-
ing to a geologist, the question remains totally baffling
to the non-specialist because of the current lack of
systematic guidelines.

European standardization has helped focus the minds
of potential producers of armourstone, who appear eager
to analyse predicted armourstone demands and the latest
trends on how it will be specified. In contrast to the
material needs of the developed countries of Northern
Europe, the coastal engineering materials needed in
many parts of the world may be produced under very
different economic and environmental constraints. For
example, the massive quantities involved (such as for a
substantial breakwater) requires that material transport
costs have to be minimized, thereby putting pressure on
the need to open a local quarry dedicated to the project.
The key technical and planning issues are then down to
assessing the suitability of alternative local sources
and to the efficient planning and development of the
new quarry should one be necessary. The lack of case-
history accounts and guidance on the technical princi-
pies governing the successful operation of a dedicated
quarry has contributed to numerous cases of costly
delays, over-production resulting in wasted quarried
rock, and environmental problems.

These examples illustrate the background facing a
major part of today's natural construction materials
industry, albeit with a slant to coastal engineering mat-
ernals. As implied by the word 'advances' in the title, this
book is based on recent research. It contains a unified
selection of research papers presented to the Extractive
Industries Geology Conference (EIGC) at Warwick, UK
on 15 and 16 April 1996, held under the umbrella of the
Geological Society's first biennial Applied Geoscience
Conference.

From among the eight EIGC sessions, the book draws
upon four sessions: marine sand and gravel resources,
armourstone evaluation, aggregate testing and engineer-
ing and mining rock waste. The recurrent themes which
feature most prominently in this volume are: construc-
tion material resources, production, demand, testing,
evaluation, specification and performance.

Papers selected for the book were presented by
speakers invited by the plenary session convenors and
include papers imparting both American and European
expertise.

This book aims to highlight a range of pressing
research issues in natural construction materials of direct
relevance to an industry facing growing pressures for
environmental sustainability and standardization of
product quality within Europe. It is presented as a
catalyst for furthering research and it is hoped that it will
serve as an excellent reference on certain aspects of
aggregates and armourstone.

Part 1 is on marine sand and gravel resources. One
paper deals largely with sources of glacial and/or fluvial
Quaternary origin that extend across the Northern
European shelf and gives details of their production
volumes from dredging. These sources are clearly identi-
fied and explained in relation to the major post-glacial
sea-level rise of some 5000 years ago which submerged
these terrestrial deposits. Another paper illustrates the
use of geophysical exploration and interpretation tech-
niques in sea areas around Hong Kong. Such methods
can also help mitigate environmental impacts. The ways
in which the dredging industry is harnessing an under-
standing of Quaternary depositional processes in its
management of current and future licensed areas is also
presented. A summary of the collaborative project with
cosponsors (including the DoE, MAFF, NRA, Crown
Estates, English Nature and representatives of the
dredging industry), which led to the CIRIA report on
beach recharge materials is also presented. Future
demands for coast protection sand and shingle, as
compared with demand for construction aggregates, can
be seen alongside the resources for the offshore regions
around England and Wales.

Part 2, on armourstone evaluation, continues the
costal theme, with a keynote paper on the outlook for
coastal protection materials. The main physical and
economic factors driving the use of armourstone and
beach recharge materials are explained while a warning
is sounded that despite high estimated demands, the
extractive industry must also respond sensitively to
environmental considerations.

The producers and users of armourstone have, since
1991, generally benefited from the availability of the
CIRIA/CUR Manual on the use of rock in coastal and
shoreline engineering and its armourstone specifica-
tion but, have now to become accustomed to a new
European specification for armourstone rock quality.
This situation, and the many difficult issues surround-
ing armourstone quality testing and specification, are
reviewed in a paper which gives the rationale for recent
specification developments and describes the extensive
comparative analysis of both familiar and new abrasion
tests and intact strength tests which have influenced
the new specifications. The testing and specification of
European standard armourstone gradings and possible
ways of controlling them at source are described in another paper which focuses on the annual pattern of armourstone usage in the UK in recent years. This provides the kind of market research data that potential producers and others have long been trying to obtain, but often with little success.

To rely on a single factor to evaluate the suitability of a rock source is clearly foolish. In one paper, from the USA, a rock-engineering systems approach is applied that considers most conceivable factors of influence. It gives a systematic and comprehensive rating system for assessing the suitability of armourstone sources. Indeed, it provides an 'expert system' for others with less experience. This paper is complemented by one which presents a case-history examination of the key technical and logistical factors leading to the opening and efficient running of a dedicated armourstone quarry in Malaysia.

The final paper of Part 2 describes a field and laboratory study to compare the long-term wear performance of different rock types for use as beach recharge shingle, thereby providing a link with Part 1. The approach and results presented bear upon assessing the degree to which quarried or sea-dredged rock sources are technically suited for such purposes in sites of differing prevailing weather conditions.

Part 3, on aggregate testing, has two papers on the micro-Deval test for aggregate wear. One pulls together the recent favourable Canadian experience of the micro-Deval test when applied to specification for several end uses which, perhaps surprisingly, include concrete. The second paper closely compares the micro-Deval test with the British Aggregate Abrasion Value test in the context of highway surfacings. Another paper focuses on the Polished Stone Value test for aggregates in the gritstone trade group, showing how increases in PSV are often at the expense of other important aggregate properties. A much-awaited and authoritative statistical study of aggregate testing data is also provided. The basis upon which engineers apply judgement from consideration of their test results is thoroughly overhauled, with the help of examples of typical materials-testing problems whose interpretation is often the task of the engineer.

Preliminary results from an investigation of concrete made using slate waste, china clay waste and pulverised fly ash are also presented. Strength results and polished sections of these new mixes show how substantial technical achievements can be made with cheap processing, novel mix-design and the use of admixtures.

Finally, reflecting the breadth of the conference session on aggregate testing, a technical note is presented on a new method for abrasion testing, a subject which recurs throughout this book. A test procedure is outlined for assessing wear rates of planar rock or concrete surfaces subjected to grinding-wear typical of foot traffic. The test has been used to examine the surface laitance of pre-cast concrete slabs and calculation is by means of a reference material whose response enables the calculations to yield a more reliable index for comparing geomaterials.

The editor expresses his appreciation to all those who attended the conference sessions, to Dick Thomas for his keynote address, to session convenors Andy Bellamy and Bill French, to session chairmen Richard Fox, Alan Clark and Professor Peter Fookes, to all the authors who prepared and presented papers in this volume, especially Dave Lienhart, Chris Rogers and Jan van Meulen who came from overseas, to the reviewers of the submitted papers and to the organizing committee of the Extractive Industry Geology Conference 1996. Their efforts have enabled this volume to reach the quality for which the Geological Society Engineering Geology Special Publication Series is respected.

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