AGGREGATE PROPERTIES OF SOME HONG KONG ROCKS

GEO REPORT No. 7

T.Y. Irfan, A. Cipullo, A.D. Burnett & J.M. Nash

GEOTECHNICAL ENGINEERING OFFICE
CIVIL ENGINEERING DEPARTMENT
HONG KONG

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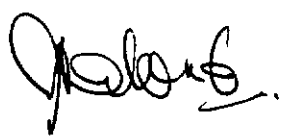
PREFACE

In keeping with our policy of releasing information of general technical interest, we make available some of our internal reports in a series of publications termed the GEO Report series. The reports in this series, of which this is one, are selected from a wide range of reports produced by the staff of the Office and our consultants.

Copies of GEO Reports have previously been made available free of charge in limited numbers. The demand for the reports in this series has increased greatly, necessitating new arrangements for supply. In future a charge will be made to cover the cost of printing.

The Geotechnical Engineering Office also publishes guidance documents and presents the results of research work of general interest in GEO Publications. These publications and the GEO Reports are disseminated through the Government's Information Services Department. Information on how to purchase them is given on the last page of this report.



A. W. Malone
Principal Government Geotechnical Engineer
April 1995

EXPLANATORY NOTE

This GEO Report consists of eight Technical Notes on selected aggregate properties of various granitic and volcanic rocks in Hong Kong. These Technical Notes were prepared by the Planning Division of the former Geotechnical Control Office as part of the Fresh Rock Testing Programme which was initiated in 1985.

The Technical Notes are presented in separate sections in this Report. Their titles are as follows :

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SECTION 1 : AGGREGATE PROPERTIES OF MEDIUM-GRAINED GRANITE FROM TURRET HILL QUARRY

T.Y. Irfan & J.M. Nash

This report was originally produced as GCO Technical Note No. TN 2/87

FOREWORD

In order to help provide the Materials Division and the Hong Kong Geological Survey with much needed data on the characterization and possible usage of each of the Territory's major rock types the Office initiated the Fresh Rock Testing Programme in 1985.

This report forms part of the Fresh Rock Testing Programme and is one of a series of reports which presents the results of selected aggregate and index laboratory testing carried out on fresh block samples of discrete rock types.

The rock type described in this report is a medium-grained, inequigranular, megacrystic, GRANITE from the Turret Hill Quarry, Shatin.

The authors wish to acknowledge the role played in the field sampling and sample preparation by TO's W.C. Lee and M.K. Chan and in the laboratory testing by K.H. Lee and other laboratory staff. The cooperation and assistance of the Quarry Management and the Materials Division is also acknowledged.

A D Burnett

(A.D. Burnett)
Chief Geotechnical Engineer/Planning

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1. INTRODUCTION

One of the objectives of the Fresh Rock Testing Programme outlined in the Technical Note "Laboratory Characterization Testing of Fresh Rock (Irfan & Purser, 1985) is to determine the aggregate properties of rocks commonly used in Hong Kong for concrete and roadstone aggregate and to recommend alternative rock types based on the results of testing. Major rock types recently mapped during the course of the new Geological Survey of Hong Kong are sampled and subjected to limited selected physical index and aggregate tests. It was decided to publish the results of the agregate testing at each sampling locality in the form of technical reports at the request of CGE/M and on recommendation of the Aggregate Working Group. This Technical Note on the aggregate properties of medium-grained granite from Turret Hill Quarry forms the first report in the series.

This report gives the results of selected aggregate and rock index tests carried out on fresh granite samples from a particular locality in the quarry and discusses the results and suitability of the rock as aggregate in comparison with the typical aggregate acceptance values. Only the selected rock material properties are considered when assessing the suitability of the rock. Other rock factors as well as environmental, operational and haulage factors will be the dominant factors in determining the suitability for development of a particular source of suitable material.

2. SITE DESCRIPTION AND SAMPLING

The sampling site is the disused Turret Hill Quarry located on the southwestern flank of Turret Hill (Nui Po Shan), east of Shatin (Figure 1). The site was originally used as a borrow area in the mid-1960's and 70's which was then turned into an aggregate quarry in the late-1970's. Rock extraction ceased at the quarry at the end of 1984 when the contractor had completed the formation of rock slopes (Plate 1) in accordance with the Contract. This sampling site was chosen for Fresh Rock Testing Programme bacause of its ease of access and nature of fresh rocks present. The sampling locality is situated at the estern end of the quarry on third bench from the toe (Plate 2). Block samples of easily manageable size were collected from the face in granite for testing.

3. GEOLOGY

3.1 Site Geology

The quarry is shown to be located in medium-grained granite, (gm), on the new 1:20 000 geological map (Figure 1). Addison (1986) reported that this granite is intruded by thin sheets and dykes of fine-grained granite in the quarry area. A monzonite intrusion is present at the eastern end of the quarry. A northwest-southeast trending fault traverses granite near the northern side of the quarry. At the sampling locality, the medium-granite is fresh and moderately to widely jointed. Some major joints are reddish brown stained. Occasional vugs of quartz and mica occur in the rock.

3.2 Description of Test Sample

Engineering geological description (c. BS 5930 : 1981). The rock is very

strong, light pinkish grey, crystalline, fresh, medium-grained GRANITE with an average grain size of 3 to 5 mm and inequigranular texture.

Detailed description. The rock consists of subhedral grains of quartz, alkali feldspar, plagioclase feldspar and biotite. Quartz forms about 35% of the rock and biotite less than 5%. Alkali feldspars are generally light pink in colour. No modal analysis was carried out. Detailed description of the medium-grained granite is given in Addison (1986). The minimum and maximum sizes of grains are 1 mm and 7 mm respectively (average size of 3 to 5 mm).

4. AGGREGATE TESTING AND CHARACTERIZATION

4.1 Sample Preparation and Testing Methods

The block samples collected from the site were broken by using a sledge hammer and rock breaker into smaller size specimens. These were then fed into a laboratory jaw crusher (Plate 3) to prepare 10-14 mm and nominal 20 mm size aggregates (Plate 4).

Selected physical rock index tests were performed on the irregular lumps of rock using the methods recommended by ISRM (1978). These included the determination of bulk density (dry and saturated), mineral grain specific gravity, porosity (total and effective) and water absorption. Point load index testing (ISRM, 1985) was carried out on irregular lumps to determine the strength of the rock.

The aggregate testing included aggregate crushing value, ACV, aggregate impact value, AIV, water absorption, flakiness index, I_F, and elongation index I_E, on standard size (10-14 mm) aggregates according to the methods recommended in BS 812 (BSI, 1975) and Los Angeles abrasion value, LAAV, on 20 mm nominal size aggregates according to ASTM C-131 (ASTM, 1981).

4.2 Classification and Characterization of Aggregate

Numerous classification and descriptive schemes exist to characterize aggregates. A number of commonly used schemes were critically reviewed and found unsatisfactory from many points of view by the Geological Society Working Party on Aggregates (Collis & Fox, 1985). This Working Party recommended a new classification system called CADAM (Classification and Description of Aggregate Materials) to be used for both commercial and contractual purposes. This CADAM scheme is adopted here to describe and classify the Hong Kong aggregates. Table 1 shows the classification of aggregate in this study by the proposed CADAM scheme. A more detailed petrographic evaulation of the aggregate is given in Table 2.

4.3 Test Results

The results of standard tests carried out on irregular specimens are given in Table 3. The results of tests carried out on laboratory crushed aggregates are shown in Table 4. Limited test results are available on 10 mm and 20 mm nominal size aggregates from the quarry carried out in 1979 and 1980. These are given in Table 5.

5. DISCUSSION ON TEST RESULTS

The rock index tests given in Table 3 show that the fresh, medium-grained granite from the Turret Hill Quarry site is a very strong rock with a point load strength value of over 10 MPa (or uniaxial compressive strength of over 250 MPa using a conversion factor of 25; ISRM 1985) and has very low water absorption and porosity properties.

The test results given in Tables 3 and 4 are those of the tests carried out on a few block samples chosen from one locality in the quarry. The test results may therefore not be representative of the whole rock type occurring in the quarry or the Territory. With this in mind, a comparison of the aggregate test results carried out on laboratory crushed specimens (Table 4) is made with the limited test results available on the quarry run material (Table 5). The results are similar in terms of aggregate impact value, water absorption, elongation index and relative density except in the flakiness index where a lower value was obtained on laboratory crushed specimens.

5.1 Suitability of Rock as an Aggregate

The test methods adopted and their limiting values for determining the suitability of rock for various aggregate uses, both vary considerably from specification to specification in response to application, climate, availability of materials, etc. In Hong Kong, both the test methods and acceptance values for aggregates to be used in concrete and as roadstone are generally those recommended in the British Standards (Government of Hong Kong, 1977), namely BS 882, BS 1621, BS 812. In general, fresh granitic rocks have been traditionally used for both concrete and as roadstone in Hong Kong although volcanic rocks have occasionally been used for some special aggregate purposes (e.g. as friction course for Kai Tak Airport runway extension).

A comparison of the test results in Tables 4 and 5 with typical UK aggregate acceptance values (Table 6) indicates that the aggregates produced from the medium-grained granite in the quarry are within the acceptable limits for use in concrete and as roadstone. However, in terms of both aggregate impact value (or aggregate crushing value) and Los Angeles abrasion value, they have rather high values making the aggregate from the medium-grained granite less desirable, compared to the fine-grained granites or basaltic rocks, for wearing courses and some special purposes such as heavy duty concrete floor.

No soundness tests to determine the durability of the aggregate have been carried out for the reasons that the rock tested was fresh and the aggregates from fresh granites are known to be durable. However, it is recommended that the soundness tests should be carried out if the proportion of discoloured (weathered) rock is significant.

No tests have been carried out to determine potential alkali-silica reactivity since this is not expected to be a problem in the case of aggregate from coarsely crystalline granitic rocks.

6. CONCLUSIONS

The laboratory test results carried out on aggregate produced from fresh, medium-grained granite samples collected from the Turret Hill Quarry are

within the commonly accepted limiting values for general use in concrete and as roadstone.

The aggregate impact value (or crushing value) and the Los Angeles abrasion value test results are rather high and near to the specified limiting values thus making the aggregate from this rock type less desirable for special uses such as wearing courses and heavy duty concrete floors compared to aggregates from the fine-grained granites or basaltic rocks.

In this investigation, the tests were all carried out on fresh rock samples. Aggregates produced from slightly weathered granite grade are, however, also generally suitable for various uses (see Choy & Irfan, 1986 and Collis & Fox, 1985), but they may have lower strength and abrasion characteristics. Their suitability, particularly in-service performance, should also be assessed for particular aggregate use by durability and soundness tests and petrographic examination.

The test results for the current laboratory crushed samles are comparable to the documented test data for quarry run aggregates available from the quarry when it was operational. However, for the latter case the state of weathering of the samples tested and their exact geological characteristics are not known.

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Table 1 - Description and Classification of Aggregate by the CADAM System

AGGREGATE FORM	Crushed Rock		~~Gravel~~	~~Natural~~		~~Sand~~	~~Natural~~		~~Land-won~~	
				~~Crushed~~			~~Crushed~~		Marine Dredged	
				~~Mixed~~			~~Mixed~~			
CLASS (or MISCELLANEOUS)	~~Carbonate Class~~		~~Quartz Class~~	Silicate Class					~~Miscellaneous Material~~ (correct name to be given below)	
				Igneous		~~Sedimentary~~		~~Metamorphic~~		
Petrological name (if known)	GRANITE									
GEOLOGICAL AGE/ COLOUR/ GRAIN SIZE FISSILITY	Mesozoic/Light pinkish grey/fresh/coarse-grained/No fissibility									
Comment (if any)										

Compiled by : T. Y. Irfan Date : _____

SGE/EG, GCO

CADAM - CLASSIFICATION and DESCRIPTION of ACGREGATE MATERIAL

LOCATION AND SAMPLE DETAILS	Quarry/Pit address : Turret Hill Quarry, Shatin, N.T. Operator : Disused (Contract Qu) Sample : Type Blocks Size 50 kg Preparation Lab. Crushed Supplied by E.G. Section	Grid Ref. 84020E 82760N	Date Rec'd
		Date of sampling 16/5/85	Sampling Cert. No. 3663EG003

Table 2 - Petrographic Evaluation of Aggregate

PETROGRAPHIC EVALUATION OF AGGREGATES

SAMPLE REF LOCATION/GRID REF SAMPLING DATE	HK 3663 EG 003 Turret Hill Quarry, Shatin 84020E 82760N 16.5.1985	SAMPLE SIZE/WEIGHT Bulk sample 50 kg Sub-sample 1 kg (10 - 14 mm)
AGGREGATE PROPERTIES Particle Shape (BS 812:1975)	Mainly irregular, some angular shaped, small percentage of elongated particles	
Surface Texture (BS 812:1975)	Crystalline	
Coating	None	
Cleanliness (Dust etc)	Some dust resulting from aggregate crushing	
GEOLOGICAL PROPERTIES Rock Type (GSS Classification)	Medium-grained GRANITE (gm)	
Mineralogy		
Major Constituents	Quartz, Alkali Feldspar, Plagioclase Feldspar, some Biotite (5%)	
Minor Constituents	Chlorite, muscovite	
Cementing Materials	Crystalline, no cementing minerals	
Expansive Minerals	Chlorite (?), small amount	
Weathering of Particles	Fresh, no staining	
Organic Material Content	None	
GENERAL COMMENTS	Granite is inequigranular and megacrystic	Compiled by JMN/TYI Date
ADDITIONAL INFORMATION		

Table 3 - Rock Index Properties of Medium-Grained Granite from Turret Hill

Rock Index Property			Average Value	Range
Mineral Grain Specific Gravity,		(g/cm^3)	2.64	2.60 - 2.66
Bulk Density	Dry	(g/cm^3)	2.60	2.58 - 2.61
	Saturated	(g/cm^3)	2.62	2.60 - 2.63
Water Absorption (Saturation Moisture Content)		(%)	0.52	0.51 - 0.52
Porosity	Total	(%)	1.76	1.73 - 1.78
	Effective	(%)	1.34	1.33 - 1.35
Point Load Strength		(MPa)	10.1+	

Legend :

+ Limited test results on 4 irregular lumps

Table 4 - Test Results on Laboratory Crushed Aggregates (10-14 mm) from Turret Hill

Aggregate Property			Test Value
Aggregate Crushing Value,	ACV	(%)	23
Aggregate Impact Value,	AIV	(%)	24
Los Angeles Abrasion Value,	LAAV	(%)	29
Water Absorption		(%)	0.5
Flakiness Index,	I_F	(%)	7 (20)*
Elongation Index,	I_E	(%)	41 (30)*

Legend :

* 14 - 20 mm aggregate

Table 5 - Aggregate Test Results+ from Turret Hill Quarry, 1979-1980 (20 mm aggregate)

Aggregate Property			Test Value	
			1979	1980
10% Fines Value		(kN)	140	110
Aggregate Impact Value,	AIV	(%)	n.d.	27
Aggregate Abrasion Value,	AAV	(%)	5	n.d.
Water Absorption		(%)	n.d.	0.5
Flakiness Index,	I_F	(%)	14	28
Elongation Index,	I_E	(%)	33	42
Relative Density		(g/cm^3)	2.61	2.61

Legend :

\+ Test results from Materials Division File Q 3/2/8

n.d. Not determined

Table 6 - British Standard and Other Acceptance Values for Test Results on Roadstone and Concrete Aggregates

Test	Test Value	Use	Authority
Aggregate Crushing Value, ACV (%)	Maximum 30	C.R.	Higginbottom (1976)
Aggregate Impact Value, AIV (%)	Maximum 45+ Maximum 30*	C.R.	BS 882:1983
10% Fines Value (kN)	Minimum 50+ More than 100* More than 150*	R.C. R. C.	Hosking & Tubey (1969) BS 882:1983 BS 882:1983
Aggregate Abrasion Value, AAV (%)	Maximum 10 (diff. cond.) Maximum 12 (av. cond.)	R.	DoT (1976)
Los Angeles Abrasion Value, LAAV (ASTM C-131)	Maximum 30 (diff. cond.) Maximum 40 (av. cond.) Maximum 35*	C. C. R.	Australian Standard 2758.1 (1985) Shergold (1948)
Water Absorption (Porosity) (%)	Less than 3+	C.R.	Higginbottom (1976) BS 5337:1976
Bulk Density (g/cm^3)	More than 2.60	C.R.	Higginbottom (1976)
Flakiness Index, I_F	Less than 35***	C.R.	BS 882:1983
Magnesium Sulphate Soundness (%)	Maximum 18 (5 cycles)	C.R.	ASTM C33-81
Sodium Sulphate Soundness (%)	Maximum 12 (5 cycles) Maximum 12 (5 cycles)	C.R. C.	ASTM C33-81 Australian Standard 2785.1 (1985)

Legend : R - Road aggretates, C - Concrete aggregates, * For wearing surfaces,
** For heavy duty concrete floor, *** For C20 and over concrete grade, + General use

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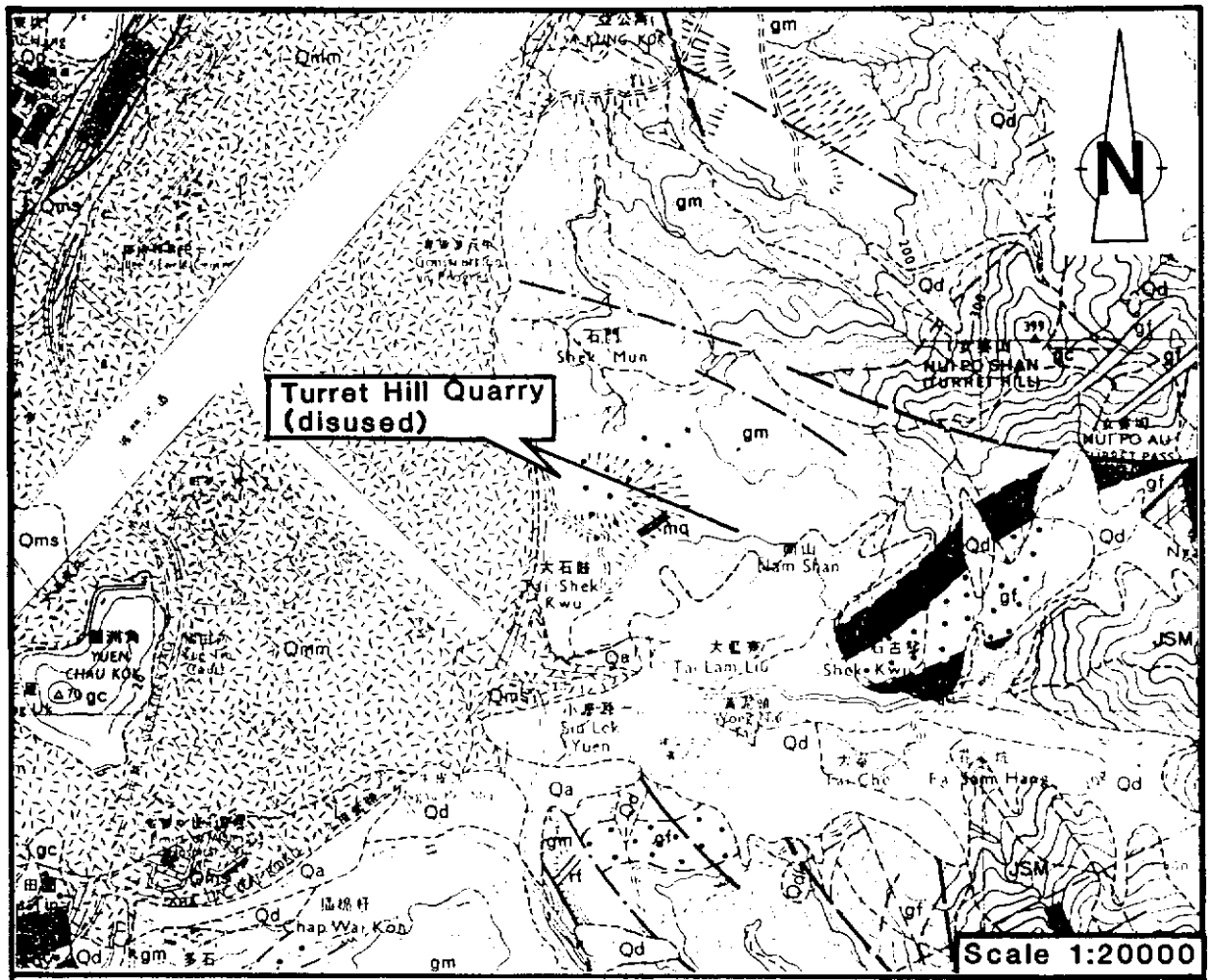

LEGEND :

SOLID GEOLOGY

Qmm, Qa, Qd, Qdt	Quaternary Superficial Deposits
mq	Quartz Monzonite
JSM	Crystal and Lithic Tuff, Tuff-breccia and Tuffite
gc	Coarse-grained Granite, > 6mm
gf	Fine-grained Granite < 2mm
gm	Medium-grained Granite, 2-6mm
	Inequigranular Texture

GEOLOGICAL LINES

- Geological Boundary, Superficial Deposits
- Geological Boundary, Solid Rock
- Fault
- Photogeological Lineament

NOTE :

The geological map is extracted from the published sheet 7 of the 1 : 20000 geological map series of Hong Kong. Not all the geological symbols are given in the legend

Figure 1 - Location Map Showing Geology of the Site and the Adjacent Areas

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Plate 1 - General View of Turret Hill Quarry

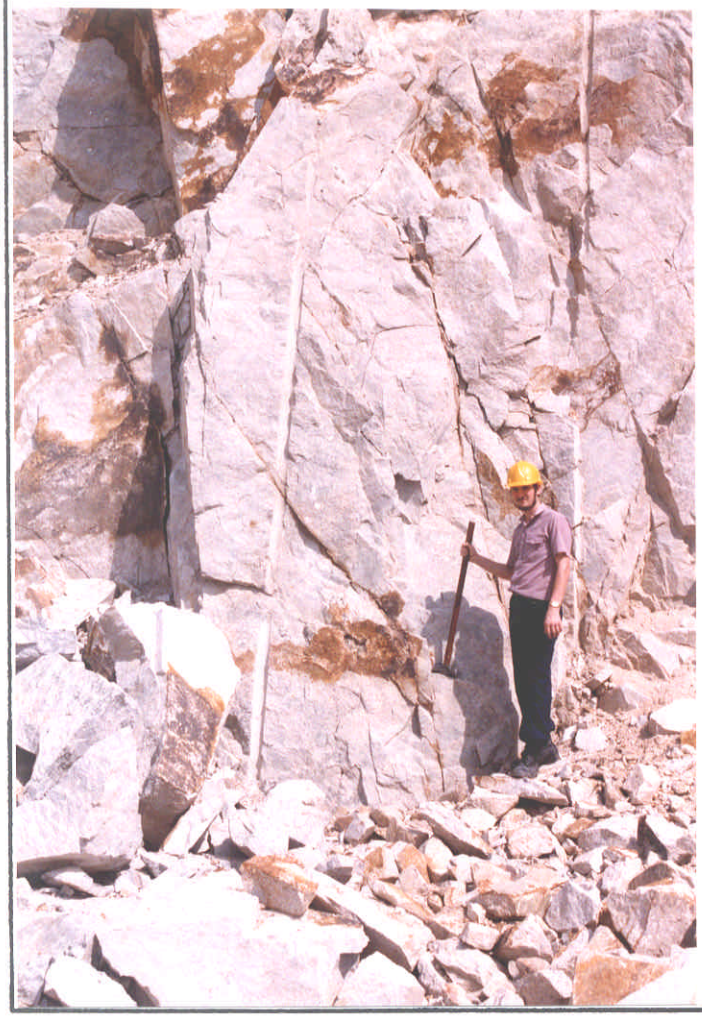

Plate 2 - Sampling Site

Plate 3 - Laboratory Jaw Crusher

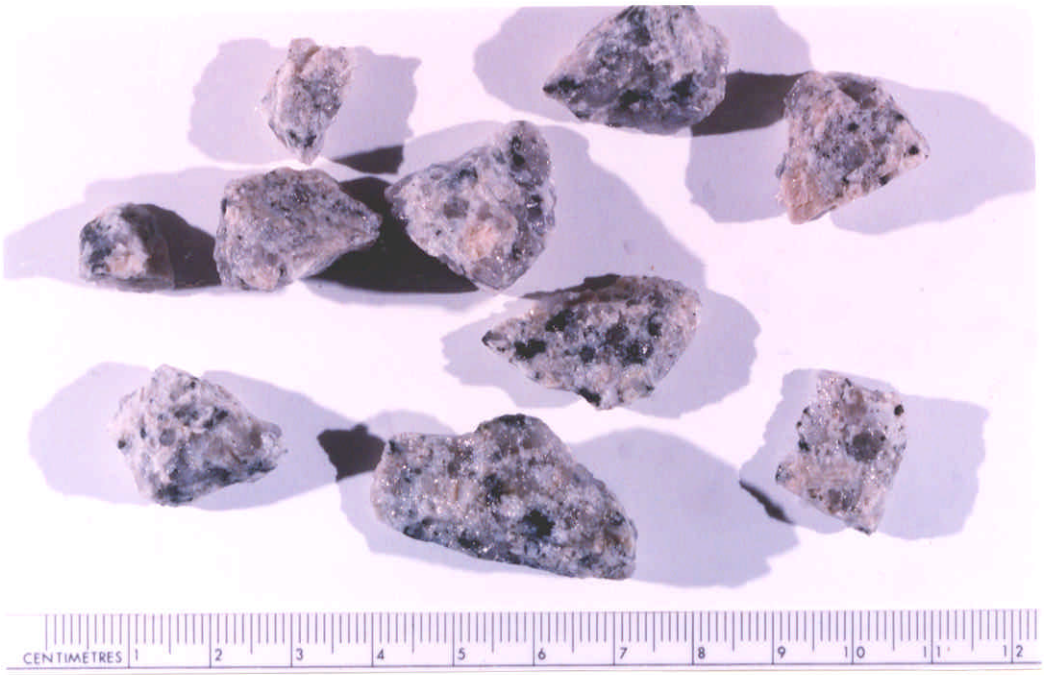

Plate 4 - Crushed Rock Aggregate from Medium-Grained Granite