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Potential and properties of some rock aggregrates in Sarawak

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Abstract: The potential for stone quarries in Sarawak is discussed. Results of laboratory investigations into some of the engineering properties of rock aggregates from 65 locations in Sarawak are presented.

INTRODUCTION

The Geological Survey, since its inception in 1949, has carried out a large number of investigations of potential quarry sites in Sarawak (GSKL 017). Many of the quarries operating today resulted from these investigations. These investigation reports are unpublished and only available in the Survey library for reference by the public. Summaries of these reports are published occasionally in the Department Annual Reports, and in the various Memoirs and Reports covering specific areas. The purpose of this paper is to make some of these information available to the public.

The total production of stones in 1980 was reported to be 1,085,400 m^3 worth about M$10.2 million. Since 1975, the Geological Survey and the Central Materials Laboratory of the Jabatan Kerja Raya (JKR) have investigated the physical and mechanical properties of aggregates from the existing quarries as well as some of the potential quarry sites (Tarmac, 1974). The results of these investigations are compiled and reviewed in this paper.

GENERAL GEOLOGY

West Sarawak, west of Batang Lupar, forms part of the West Borneo Basement. This Basement is built up of Palaeozoic and Mesozoic rocks but, in west Sarawak, these rocks are concealed, in places, under a thick cover of Tertiary strata. The oldest rocks are considered to be the pre-Upper Carboniferous schists and Phyllites. Succedding sedimentary formations include Upper Carboniferous, Lower Permian, Triassic, Upper Jurassic, Cretaceous, and Lower Tertiary strata. Intrusive granitic rocks are mainly confined to west Sarawak. The oldest granitic rocks are the pre-Triassic granite-granodiorite at Gunung Jagoi and Gunung Kisam. Volcanic activities during Late Triassic gave rise to the basalt and andesite lava, and associated agglomerate and tuff of the Serian Volcanics, and minor dioritic intrusions. The basic volcanic and intrusive rocks in the Serabang and Sejingkat Formations, the minor acid volcanic rocks in the Pedawan Formation, the extensive, feature-forming adamellite at Pueh, Gading, Tanjung Datu, Tinteng Bedil and Buri, the Sebuyau granite-granodiorite, and the gabbro at Sematan resulted from igneous activities during Jurassic to Late Cretaceous. Tertiary igneous activities resulted in the widespread intrusions of stocks, dikes and sills of hypabyssal igneous rocks throughout west Sarawak.

Central-North Sarawak, east of Batang Lupar, is underlain by mainly regionally metamorphosed and unmetamorphosed sedimentary rocks of Cretaceous to Pleistocene age. The oldest igneous rocks are the gabbro, basalt and spilite of Cretaceous age in the Lupar Valley. The next phase of igneous activity occurred during late Eocene-Oligocene resulting in the granodiorite-granite-granophyre stock at Bukit Piring, and the andesite and rhyolite tuff in the Arip Valley. The last phase of igneous activity took place in Pliocene-Pleistocene times giving rise to dacite, andesite, and basalt lavas and pyroclastics, and associated minor microtonalitic stocks in the Upper Rajang and Tinjar area (Tan, Kho & Hon, 1981).

STONE POTENTIAL

Following the British Standards Institute of Group Classification of Aggregates (B.S. 812: 1967), 6 groups of rocks are quarried in Sarawak. Igneous rocks such as intrusive rocks (Granite, Porphyry) and volcanic rocks (Basalt) are generally good quality rocks suitable for use as roadstone and concrete aggregates. Sedimentary rocks such as limestone (Limestone) and well-cemented or metamorphosed sandstone (Gritstone, Hornfels) are moderately good quality stone and may be satisfactorily used as roadstone and concrete aggregates.

The stone potential in Sarawak is closely related to the regional geology. In west Sarawak, i.e. 1st Division and the part of the 2nd Division west of Batang Lupar, there is no shortage of good quality stone. Igneous rocks, both intrusive and extrusive, occur abundantly in this area and have not been fully exploited. Operating quarries like Ang Cheng Ho, Stabar, and Semengo are producing good quality stone from the Tertiary microtonalite; Sebuyau quarry is producing excellent quality stone from the Cretaceous granite; and Stebun and Ensabang quarries are producing good quality stone from the basalt and andesite of the Serian Volcanics. In addition, several areas with large stone reserves like Pueh, Gading, Stigang, Serambu, Grogo, Jagoi, Sibanyis, Semuja, and Muhoi in the 1st Division, and Triso, Mambai, Lintang, Tunggal, Tabong, Klambi, and Balang in the 2nd Division are known but have not yet been exploited, except for Klambi which was quarried until 1979 by JKR. In the 1st Division, the Bau Limestone has widespread distribution but has not been fully exploited. At present, only 3 quarries, viz. Sin Seng Ann, Paku, and Poh Kwong, are producing from this limestone. Areas with large reserves of limestone like Skunyit, Bah, Berinis-Serapat, Akut, Serabu, and Mentawa are known.

Central-North Sarawak suffers an acute shortage of good quality stone due to the unfavourable geology. Stones produced in this area are mainly good quality limestone from the following quarries, viz. Sekaloh, Niah, Garugok Batu, Selanyau-Upak, Holly Stone, and Betoh; moderately good quality sandstone from the Mile 22 Bintulu quarry; and moderately good to poor quality sandstone from the Mile 45 Oya and Sebankoi quarries. As a result of this shortage of good quality stone, the demand for constructional stone in certain parts of this area has to be met from river gravel and terrace gravel deposits, e.g. Limbang, Lawas, Sibu and Sarikei, although some igneous bodies are found in the 3rd and 7th Divisions, except for the ones at Piring and Arip, the others are too remote to be exploited at the present time. The Piring and Arip igneous rocks are close to the Sibu Bintulu road and can be exploited economically to supply the acute needs in the Bintulu area. The gabbro, basalt, and spilite at Bukit Batu are close to the Lubok Antu road and represent a source of good quality stone.

Due to the unfavourable geology in Central-North Sarawak, limestone and sandstone are expected to continue to be the only locally available constructional stone in this area. Limestone, however, is of limited distribution and is restricted to a few areas like Niah and Batu Gading, and limited reserves are known in the Sibuti area. Thus, the only locally, widely available constructional stone is sandstone. Although generally not as good as igneous rock and limestone, well-cemented or metamorphosed sandstone is a moderately good quality stone suitable for most road and concrete works. Test results on many sandstone samples from the various Tertiary formations indicate that the sandstone, when fresh, is a moderately good quality stone satisfactory for use as roadstone and aggregate.

During the period 1968–1980, a total of 27 quarries (13 private and 14 JKR) were in operation throughout the State. In 1980, however, the total number of operating quarries dropped to 21; of these 10 were operated by Government organisations.

LABORATORY INVESTIGATION PROCEDURES

Laboratory investigations of rock samples are designed to test their strength and durability. The standard tests carried out by the Central Materials Laboratory of the Jabatan Kerja Raya are the Crushing Value, Impact Value, Abrasion Value, and a determination of the Specific Gravity and Water Absorption. In some cases, Soundness Test and 10% Fines Test were also carried out.

Aggregate Crushing Value: The A.C.V. gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load (B.S. 812: 1967). This test is normally carried out on material passing the 1/2 inch (12.70 mm) and retained on the 3/8 inch (9.52 mm) B.S. sieve. A 4-inch deep bed of aggregate in a 6-inch diameter mould is submitted to a gradually applied load of 40 tons over a period of 10 minutes. The load is then released and the amount of material passing a No. 7 B.S. sieve (2.40 mm) is determined. This weight, expressed as a percentage of the total weight of the sample, is termed the A.C.V.

Aggregate with an A.C.V. below 30% is regarded as suitable for use in airfield pavement and road, and below 35% as suitable for use in concrete wearing surfaces.

10% Fines Test: The '10% fines value' gives a measure of the resistance of an aggregate to crushing, and is applicable to both weak and strong aggregates. This test is performed on the 3/8″–1/2″ aggregate, 4 inches deep in a 6-inch diameter mould. A load is applied and increased until 10% by weight of fines is formed. The load required to produce 10% of fines is the '10% fines value'.

Aggregate for structural concrete should have a 10% fines value of not less than 5 tons, and for concrete wearing surfaces, it should be not less than 10 tons (B.S. 882: 1965).

Aggregate Impact Value: The A.I.V. gives a relative measure of the resistance of an aggregate to sudden shock or impact. The test is carried out by subjecting an aggregate, which has been sieved through 1/2 inch and retained on the 3/8 inch B.S. sieve, to 15 blows of an 30–31 lb hammer falling through a height of 15″ (B.S. 812: 1967). After impact, the material passing the No. 7 B.S. sieve is expressed as a percentage of the total weight of the original sample and termed the A.I.V.

For structural concrete, the aggregate should have an A.I.V. of less than 45%, and for concrete wearing surfaces, an A.I.V. of less than 30% (B.S. 882: 1965).

Modified Aggregate Impact Value: This is not an accepted standard test. This test is the same as the A.I.V. test except for the following modifications:

(i) the aggregate is soaked in distilled water for 24 hours and then surface-dried before the impact test.

(ii) after impact, the aggregate is oven-dried for at least 12 hours before sieving.

Los Angeles Abrasion Value: This test is designed to measure durability of an aggregate against abrasion. A specified quantity of aggregate is placed in a 28-inch diameter by 20-inch long cylindrical drum mounted longitudinally on a horizontal shaft; fitted to the inside of the drum is a 3 1/2-inch wide shelf running from one end of the drum to the other. After adding a standard charge of steel balls, about 1 7/8-inch diameter, the drum is rotated at 30–33 r.p.m. for 500 revolutions. The aggregate is sieved through ASTM No. 12 (B.S. No. 10) sieve. The amount passing this sieve, expressed as a percentage of the total weight of the original sample, is the L.A.A.V. (ASTM C131).

The L.A.A.V. value of an aggregate for use as surfacing roadstone should be less than 40%, and for use as crushed base and structural concrete, it should be less than 50%.

Specific Gravity: The aggregate is soaked in distilled water for 24 hours, and weighed in water at the end of this period. It is then surface-dried and weighed in air, oven-dried for 24 hours, and finally weighed in air (B.S. 812: 1975). The apparent specific gravity S.G. is given by:

$$S.G. = \frac{Wo}{Ww - Ws}$$, where Wo = weight of oven-dried sample in air

Ww = weight of saturated sample in air

Ws = weight of saturated sample in water.

Specific gravity of an aggregate is an important factor in the design of some engineering structures, e.g. wharves. The specific gravity is a useful index of rock quality, and can indicate the degree of weathering or chemical alteration of the rock.

Water Absorption: The water absorption of an aggregate is usually determined in conjunction with the S.G. determination. The water absorption of an aggregate is determined by measuring the increase in weight of an over-dried sample when immersed in water for 24 hours (the surface water being removed) (B.S. 812: 1967). The W.A. is given by:

$$W.A. = 100\frac{(Ww - Wo)}{Wo};\ \text{where } Wo = \text{weight of oven-dried sample in air}$$

$$Ww = \text{weight of saturated sample in air}$$

For use in surfacing airfield pavement, an aggregate should have a W.A. of less than 2%.

Sodium Sulphate Soundness Test: The sodium sulphate soundness test is designed as an accelerated durability (weathering) test under simulated weathering. Crushed aggregates are sieved to provide specified quantities of several size fracrions. The graded aggregate is subjected alternatively to immersion for 16 to 18 hours in a solution of sodium sulphate at a temperature of $70° \pm 2°F$, and then drying in an oven. This procedure is repeated 5 times. The reduction in size of the particles as shown by sieve analysis after 5 cycles of exposure denotes the degree of soundness (ASTM C88-71a).

In aggregate for use in road and airfield surfacing, and in concrete, the value of this soundness test should be less than 12%, and in crushed stone base for road and airfield, this value should be less than 20%.

DISCUSSION OF TEST RESULTS

The limits of the various parameters for stone aggregates acceptable to JKR are given in Table 1. The test results for various rock types from 65 locations in Sarawak are given in Table 2, and the locations of these samples are given in Figure 1. Table 3 shows the average test values for the various rock types and their range of values.

Microtonalite and limestone are the most important construction aggregate and roadstone in the State. It can be seen from Table 3 that the microtonalite and limestone have values generally within the acceptable limits shown in Table 1, except that the A.C.V. and W.A. values of some of the aggregates are higher than that required for airfield pavement works. The Triassic volcanic rocks have values well within those acceptable to the JKR. The sandstone shows a wide range of values although the average values show that most of the sandstone are acceptable for roadstone and concrete works but not airfield pavement works.

The distribution of the range of values of the various rock properties according to the main rock types are shown graphically in Figure 2, and the relationship between the various rock properties in Figure 3.

The flakiness index and polished stone coefficient do not form part of the standard tests carried out on the aggregates. However, limestone has a low laboratory-

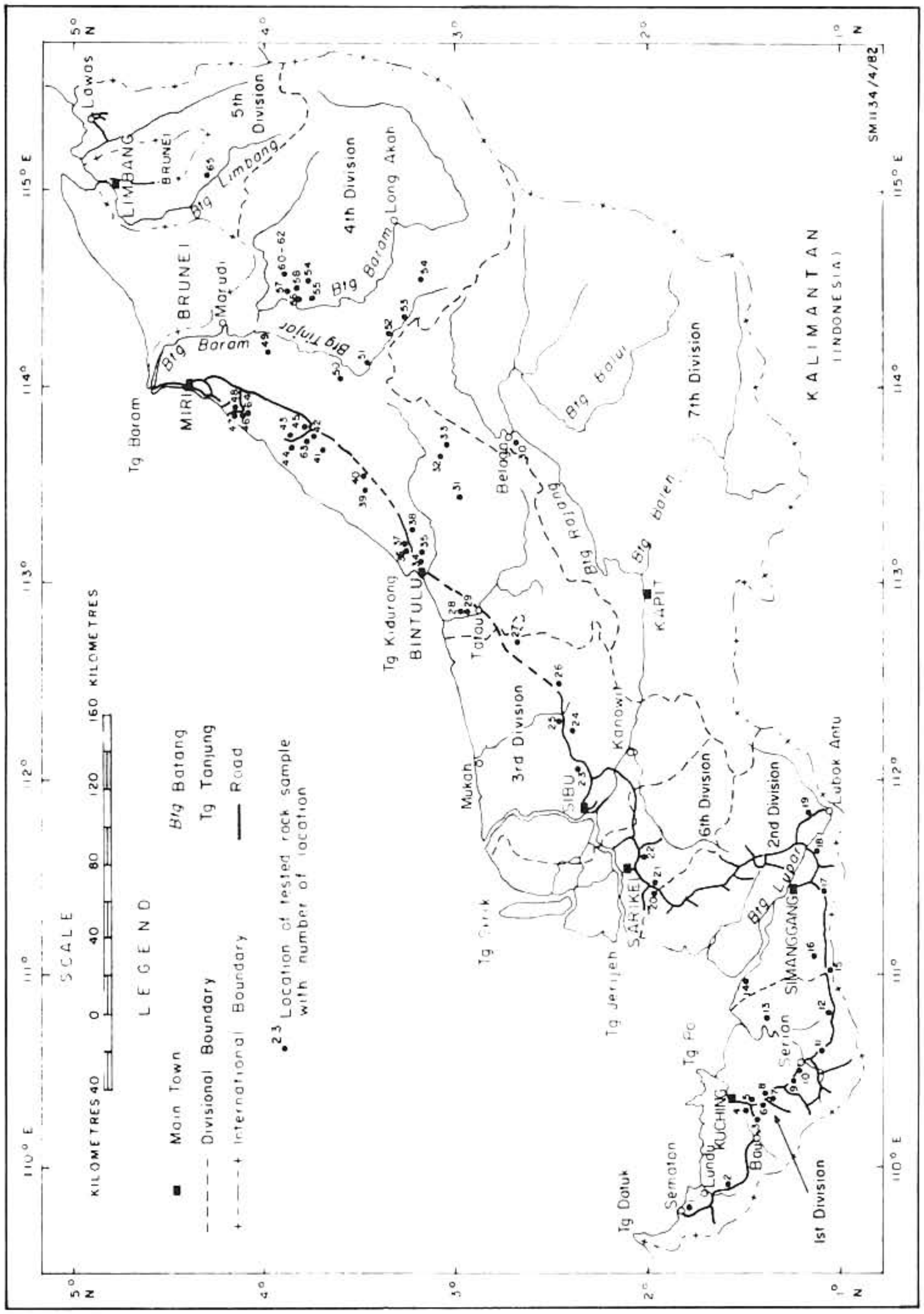

Fig. 1. Map showing locations of tested rock samples.

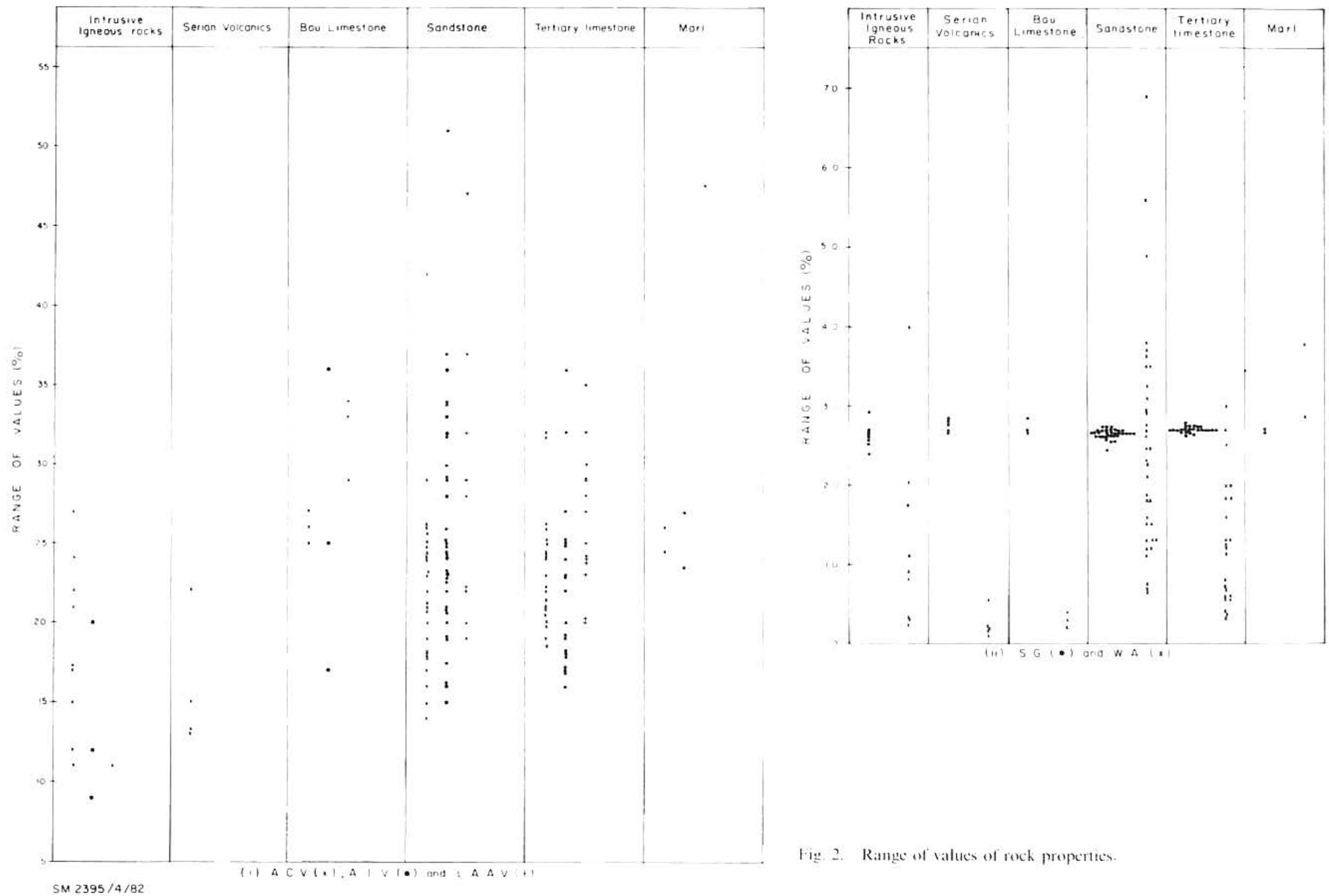

Fig. 2. Range of values of rock properties.

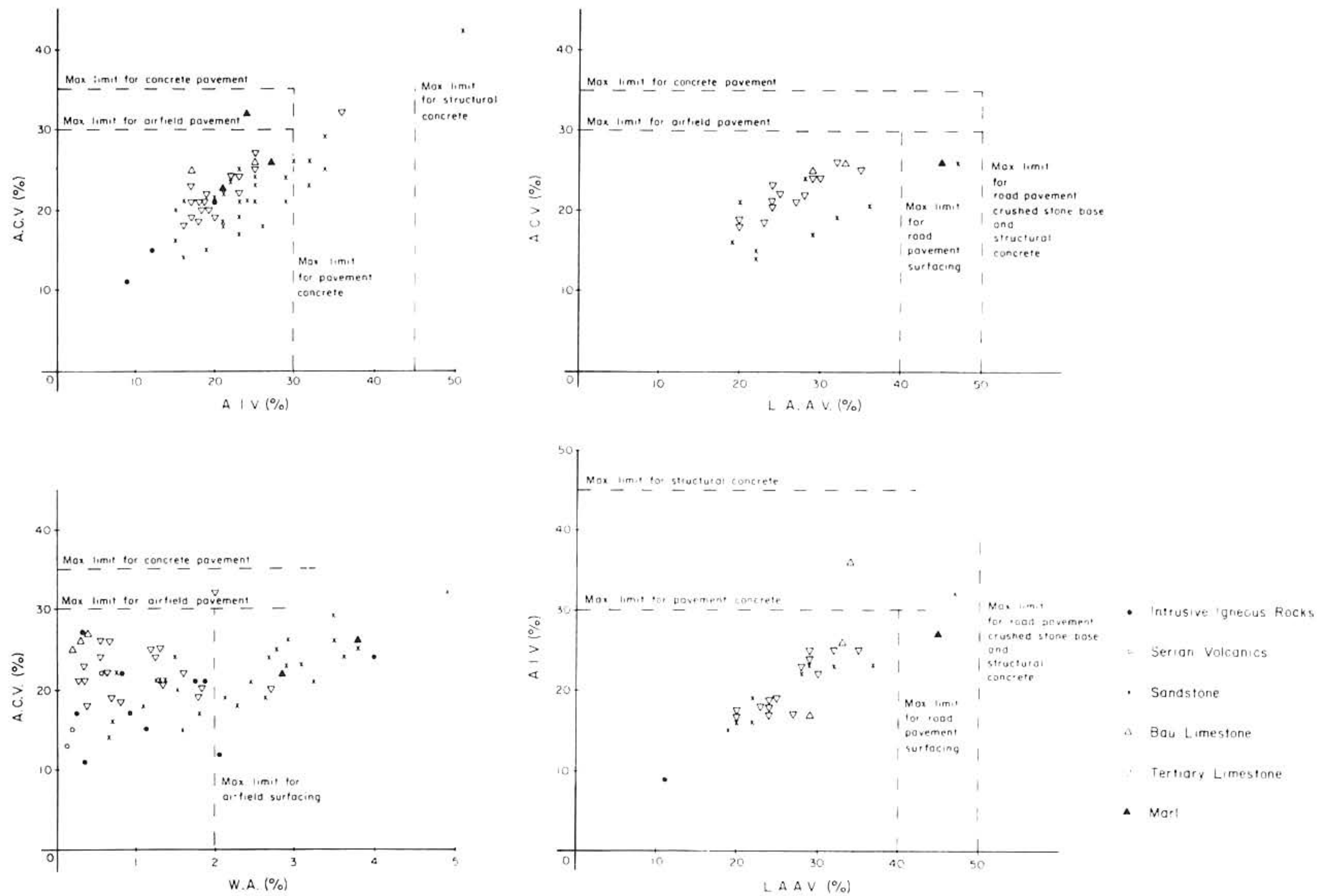

Fig. 3. Relationship between the various rock properties for different rock types in Sarawak.

TABLE 1

TEST LIMITS OF STONE ACCEPTABLE TO JKR

Parameter	Acceptable Limits					
	Road Pavement		Airfield Pavement		Concrete	
	Surfacing	Crushed Stone Base	Surfacing	Crushed Stone Base	Pavement	Structural
Aggregate Crushing Value	[illegible]	-	30% Max	30% Max	35% Max	-
Aggregate Impact Value	[illegible]	-	-	-	30% Max	45% Max
Los Angeles Abrasion Value	40% Max	50% Max	-	-	-	-
Water Absorption	-	-	2% Max	-	-	-
Soundness of Aggregate (5 cycles with sodium sulphate solution)	12% Max	20% Max	12% Max	20% Max	12% Max	12% Max
10% Fines Value	70 tons Min	-	-	-	10 tons Min.	5 tons Min.

(Figures supplied by JKR Sarawak)

determined polished stone coefficient, and it has been fairly well established that many skidding accidents had occurred on polished limestone road surfaces (Ting & Chew, undated). Therefore, the use of limestone in bituminous wearing courses is not encouraged. Another problem with limestone is its low resistance to attack by polluted waters. Due to this susceptibility to chemical attack, the use of limestone in concrete aggregate for substructure and foundations, and in superstructures liable to chemical attacks is not allowed by the JKR in Peninsular Malaysia (Ting & Chew, undated).

CONCLUSIONS

There is no shortage of good quality stone in the west Sarawak region, west of Batang Lupar. In this area, there were 12 operating quarries in 1980; 4 were quarrying microtonalite, 3 were quarrying limestone, 2 were quarrying basalt-andesite, 2 were quarrying metasandstone, and 1 was quarrying granite. 27 potential quarry sites with considerable stone reserves had been investigated up to 1981. In addition, areas with large reserves of good quality stone are known, in particular the various outcrops of both intrusive and extrusive igneous rocks, and limestone of the Bau Limestone.

The Central-North Sarawak region, east of Batang Lupar, remains a problematical area for good quality stone. In 1980, there were 9 operating quarries. Six of these quarries were working on limestone; of these 3 were located at Gunung Subis, 1 at Sibuti, and 2 in the Batu Gading area. The other 3 quarries were in sandstone. Other than these 9 quarries, a number of gravel pits exploiting river gravel and terrace gravel were operating in the 3rd, 5th, and 6th Divisions. Good quality stone from local sources is expected to be in short supply. The only easily accessible sources of good quality stone are the igneous rocks at Piring, Arip and Lubok Antu, and the limestone in the Batu Gading area. Sandstone appears to be the only readily available local

TABLE 2

LABORATORY TEST DATA FOR VARIOUS ROCK TYPES IN SARAWAK

NO.	LOCATION	GROUP CLASSIFICATION OF AGGREGATE	AGGREGATE CRUSHING VALUE* (%)	AGGREGATE IMPACT VALUE* (%)	MODIFIED AGGREGATE IMPACT VALUE* (%)	LOS ANGELES ABRASION VALUE* (GRADING B) (%)	SPECIFIC GRAVITY	WATER ABSORPTION* (%)	10% FINES VALUE (TONS)	SOUNDNESS (SODIUM SULPHATE 5 CYCLES) (%) COARSE	FINE	REMARK
1.	G. Angus, Serian	Gabbro	11	9	10	11	2.91	0.34	-	-	-	
2.	Snibong, M24½, Bau-Lundu Road	Hornfels-Porphyry	14	16	-	14	2.68	3.18	-	-	-	Snibong Quarry
3.	Bt. Skunyit, Batu Kitang	Limestone	26	25	24	33	2.71	0.30	-	-	-	
4.	Bt. Stapok, Batu Kawa Road	Porphyry	22	-	-	-	2.62	0.82	-	-	-	Ang Cheng Ho Quarry, microtonalite
5.	Stabar, M8½, Kuching-Serian Road	Porphyry	24	-	-	-	2.40	4.0	-	-	-	Stabar Quarry, microtonalite
6.	M9½, Kuching-Serian Road	Porphyry	12	-	-	-	2.53	2.04	-	-	-	Abandoned San Quarry, microtonalite
7.	G. Angor, M12, Kuching-Serian Road	Limestone	27	-	-	-	2.72	0.4	-	-	-	Poh Kwong Quarry
8.	Bt. Berinis & Serapat, M13 Kuching-Serian Road	Limestone	25	17	23	29	2.68	0.20	-	-	-	
9.	G. Pendu, M33, Kuching-Serian Road	Limestone	-	36	-	34	2.71	0.2	-	-	-	
10.	Stebun, M38, Kuching-Serian Road	Basalt	13 13	- -	- -	- -	2.82 2.79	0.12 0.17	- -	- -	- -	Basalt, andesite and angglomerate in Stebun Quarry
11.	Semuja Pass, M42, Kuching-Serian Road	Basalt	22	-	-	-	2.69	0.56	-	-	-	Basalt, andesite and agglomerate. Abandoned JKR Quarry
12.	Munggu China, M60, Kuching-Serian Road	Basalt	15	-	-	-	2.85	0.21	-	-	-	Basalt, andesite, agglomerate in Ensabang Quarry
13.	Lot 358, Sedilu, Gedong L.D. Simunjan	Porphyry	15	12	14	-	2.67	1.11	-	0.09	0.65	Microtonalite
14.	Sebuyau	Granite	27	-	-	-	2.66	0.33	-	-	-	Sebuyau Quarry
15.	Abok, M76, Kuching-Simanggang Road	Porphyry	17	-	-	-	2.56	0.92	-	-	-	Microgranite with garnet. Abandoned JKR Quarry
16.	Bt. Melanjan, Pantu	Porphyry	21	20	27	-	2.64	1.75	-	-	-	
17.	Bt. Klambi, M108, Kuching-Simanggang Road	Granite-Porphyry	17	-	-	-	2.67	0.25	-	-	-	Abandoned JKR Quarry, Granodiorite-microdiorite
18.	Bt. Balang, M127, Kuching-Sibu Road	Hornfels	21	24	28	-	2.63	1.88	-	-	-	Marup Quarry, metasandstone
19.	Bt. Balai Nyabong, M14½, Lubok Antu Road	Flint	-	23	30	36	2.65	0.59	-	2.28	4.42	Chert
20.	Bt. Tekarup, M204, Kuching-Sibu Road	Gritstone	- 16	28 15	48 18	- 19	- 2.67	3.70 0.70	- -	- -	- -	Sandstone
21.	M206, Kuching-Sibu Road	Gritstone	26	32	48	47	2.67	2.92	-	-	-	Sandstone
22.	Bt. Kejuru, Sarikei	Gritstone	-	36	75	-	-	5.61	-	-	-	Sandstone

* In these tests, a numerically lower result indicates a better rock.

TABLE 2 (Cont'd)

NO.	LOCATION	GROUP CLASSIFICATION OF AGGREGATE	AGGREGATE CRUSHING VALUE* (%)	AGGREGATE IMPACT VALUE* (%)	MODIFIED AGGREGATE IMPACT VALUE* (%)	LOS ANGELES ABRASION VALUE* (GRADING B) (%)	SPECIFIC GRAVITY	WATER ABSORPTION* (%)	10% FINES VALUE (TONS)	SOUNDNESS (SODIUM SULFATE 5 CYCLES) (%)		REMARK
										COARSE	FINE	
23.	Lot 1728, Pasai-Siong L.D., Sibu	Gritstone	17	23	30	29	2.69	1.8	-	-	-	Sandstone
24.	S. Bua, Btg. Oya	Gritstone	14	16	20	22	2.65	0.66	-	0.24	4.45	Sandstone
25.	M45 Quarry, Sibu-Oya Road	Gritstone	-	33	-	-	2.57	1.8	-	-	-	Sandstone, JKR Quarry
26.	Bt. Balong Babi, M62 Sibu-Oya Road	Gritstone	21	16	20	20	2.63	1.3	-	-	-	Sandstone
27.	S. Sabatu, Ulu Arip	Limestone	24	22	24	30	2.7	1.24	-	-	-	
28.	Bt. Ransi, Tatau	Limestone	-	24	32	-	2.72	1.2	-	-	-	
29.	S. Separai, Tatau	Limestone	-	24	32	-	2.72	1.2	-	-	-	
30.	Bt. Tap, S. Mazau, Belaga	Gritstone	22	21	-	-	2.62	0.74	-	-	-	Sandstone
31.	S. Binyo, Pandan area, Bintulu	Gritstone	19	23	30	32	2.71	2.62	-	-	-	Sandstone
32.	S. Sikitong, Tubau area, Bintulu	Gritstone	24	22	-	28	2.72	1.5	-	-	-	Calcareous sandstone
33.	Bt. Pesu, Tatau area, Bintulu	Gritstone	15	19	19	22	2.69	1.58	-	0.15	0.8	Sandstone
34.	Bt. Lajag, Bintulu	Gritstone	-	25	34	-	2.73	2.3	15.4	-	-	Sandstone
			-	37	50	-	2.62	2.48	-	-	-	
35.	Bt. Sepadok, Bintulu	Gritstone	29	34	62	-	2.69	3.5	-	-	-	Sandstone
36.	S. Belungai, M20½, Bintulu-Miri Road	Gritstone	25	23	33	-	2.63	2.77	-	-	-	
	- " -		23	25	32	-	2.63	2.91	-	-	-	Sandstone from drill core
	- " -		21	20	31	-	2.67	2.46	-	-	-	from depths 3.66 m to 53.67 m
	- " -		24	25	37	-	2.65	2.68	-	-	-	
	- " -		24	29	65	-	2.65	3.63	-	-	-	Sandstone - surface sample,
	- " -		21	29	49	-	2.66	3.25	-	-	-	slightly weathered
	- " -		18	21	27	-	2.68	2.12	-	-	-	
37.	Bt. Bekuyat, M22, Bintulu-Miri Road	Gritstone	20	15	25	-	2.70	1.51	-	-	-	Sandstone, M22 Bintulu
	- " -		18	26	32	-	2.67	2.27	-	-	-	Quarry
38.	Bt. Bala, M22½, Bintulu-Miri Road	Gritstone	26	30	31	-	2.55	3.5	-	-	-	Sandstone
39.	Bt. Tiban, M37, Bintulu-Miri Road	Gritstone	21	23	32	37	2.66	1.3	-	-	-	Sandstone
40.	Bt. Sekuyong, M42, Bintulu-Miri Road	Limestone	-	19	24	-	2.74	1.3	16.4	-	-	
	- " -		-	19	21	-	2.76	1.0	19.6	-	-	
41.	S. Lembong, Suai	Limestone	18	16	17	20	2.70	0.39	-	0.41	3.39	
42.	Lot 7, Niah Land District	Limestone	19	20	-	-	2.64	1.84	-	-	-	
43.	Lots 70, 423, Niah Land District	Limestone	21	18	21	24	2.74	1.33	-	-	-	
44.	Lot 304, Block 12, Niah Land District	-	26	27	55	45	2.67	3.78	-	-	-	Marl

* In these tests, a numerically lower result indicates a better rock.

TABLE 2 (Cont'd)

NO.	LOCATION	GROUP CLASSIFICATION OF AGGREGATE	AGGREGATE CRUSHING VALUE* (%)	AGGREGATE IMPACT VALUE* (%)	MODIFIED AGGREGATE IMPACT VALUE* (%)	LOS ANGELES ABRASION VALUE* (GRADING B) (%)	SPECIFIC GRAVITY	WATER ABSORPTION* (%)	10% FINES VALUE (TONS)	SOUNDNESS (SODIUM SULPHATE 5 CYCLES) (%) COARSE	FINE	REMARK
45.	Niah, S. Sekaloh	Limestone	26	-	-	-	2.68	0.56	-	-	-	Near Niah Quarry
			25	-	-	-	2.74	1.20	-	-	-	
46.	Lots 124, 147 & 525, Sibuti Land District, M2½, Bekenu-Tusan Road	-	22	21	35	-	2.7	2.86	-	-	63.8	Marl
		Limestone	-	27	-	-	2.71	2.5	-	-	-	
	- " -		-	25	-	-	2.71	2.0	-	-	-	
	- " -		-	32	-	-	2.76	3.0	-	-	-	Silty limestone
47.	Lots 508, 656, Sibuti Land District, M3, Bekenu-Tusan Road	Limestone	32	24	-	-	2.69	2.0	-	-	-	
48.	Bt. Batu, Bekenu	Limestone	25	25	36	35	2.70	1.3	-	-	-	Selanyan-Upak Quarry
	- " -		18.5	18	25	23	2.71	0.8	-	-	-	
	- " -		22	23	28	28	2.70	1.6	-	-	-	
49.	Bt. [illegible], Bekenu	Limestone	22	19	20	25	2.70	0.62	-	-	-	
50.	S. Bok, Btg. Tinjar	Gritstone	42	51	-	-	2.44	6.9	-	-	-	Sandstone
51.	S. Sait, Btg. Tinjar	Gritstone	23	32	62	-	2.69	3.1	11	-	-	Sandstone
52.	S. Mechant, Btg. Tinjar	Gritstone	25	34	70	-	2.65	3.8	12	-	-	Sandstone
53.	Btg. Tinjar	Gritstone	18	21	65	-	2.66	1.1	19	-	-	Sandstone
54.	S. Paong	Quartzite	21	25	32	-	2.65	1.3	18	-	-	
55.	S. Batu, Long Lama	Limestone	26	25	24	32	2.69	0.68	-	-	-	
56.	Bt. Besungai (N), Long Lama	Limestone	-	25	29	29	2.7	1.14	-	-	-	
57.	Batu Gading	Limestone	25	24	-	-	2.68	0.6	-	-	-	Holly Stone Quarry
58.	S. Temala, Long Lama	Gritstone	32	36	61	-	2.61	4.9	8	-	-	Sandstone
59.	S. Menyakit, S. Temala	Limestone	24	23	20	29	2.71	0.55	-	-	-	
60.	S. Maloi, S. Temala	Limestone	23	17	19	24	2.72	0.34	-	-	-	
61.	M3, Sarawak Plywood Timber road	Limestone	21	18	19	24	2.74	0.36	-	-	-	
62.	S. Sepayang - S. Setuang	Limestone	21	17	22	27	2.74	0.34	-	-	-	
63.	S. Mirah, Batu Niah	Limestone	20	19	-	-	2.64	1.84	-	-	-	
64.	S. Puteh, Bekenu	Limestone	19	17	19	20	2.69	0.72	-	-	-	
65.	S. Selidong, Btg. Limbang	Limestone	20	19	20	-	2.75	2.7	-	-	-	

* In these tests, a numerically lower result indicates a better rock.

TABLE 3

AVERAGE VALUE AND RANGE OF VALUES FOR THE DIFFERENT TEST DATA OF DIFFERENT ROCK TYPES

ROCK TYPE	AGGREGATE CRUSHING VALUE (%)				AGGREGATE IMPACT VALUE (%)				MODIFIED AGGREGATE IMPACT VALUE (%)				LOS ANGELES ABRASION VALUE (%)				APECIFIC GRAVITY				WATER ABSORPTION (%)				10% FINES VALUE (TONS)			
	AVERAGE VALUE	NO. OF SAMPLES	MAX	MIN	AVERAGE VALUE	NO. OF SAMPLES	MAX	MIN	AVERAGE VALUE	NO. OF SAMPLES	MAX	MIN	AVERAGE VALUE	NO. OF SAMPLES	MAX	MIN	AVERAGE VALUE	NO. OF SAMPLES	MAX	MIN	AVERAGE VALUE	NO. OF SAMPLES	MAX	MIN	AVERAGE VALUE	NO. OF SAMPLES	MAX	MIN
TERTIARY INTRUSIVES - microtonalite, micro-granite (PORPHYRY)	18	7	24	12	16	2	20	12	20	2	27	14	-	-	-	-	2.58	7	2.67	2.40	1.55	7	4.0	0.82	-	-	-	-
TRIASSIC VOLCANICS - basalt, andesite, agglomerate (BASALT)	16	4	22	13	-	-	-	-	-	-	-	-	-	-	-	-	2.79	4	2.85	2.69	0.26	4	0.56	0.12	-	-	-	-
Sandstone of Cretaceous to Tertiary age (GRITSTONE)	22	26	42	14	26	33	51	15	39	29	75	18	26	8	37	19	2.65	31	2.76	2.44	2.49	33	6.9	0.7	14.9	8	19.6	8
BAU LIMESTONE (LIMESTONE)	26	3	27	25	26	3	36	17	23.5	2	24	23	32	3	34	29	2.70	4	2.72	2.68	0.27	4	0.4	0.2	-	-	-	-
TERTIARY LIMESTONE (LIMESTONE)	23	20	32	18	22	24	32	16	24	17	36	17	26	14	35	20	2.71	26	2.76	2.64	1.23	26	3.0	0.34	-	-	-	-
TERTIARY marl	24	2	26	22	24	2	27	21	45	2	55	35	45	1	-	-	2.68	2	2.7	2.67	3.32	2	3.78	2.86	-	-	-	-
CRETACEOUS INTRUSIVES gabbro & granite (GABBRO & GRANITE)	19	2	27	11	9	1	-	-	10	1	-	-	11	1	-	-	2.79	2	2.91	2.66	0.33	2	0.34	0.33	-	-	-	-
CRETACEOUS CHERT (FLINT)		-	-	-	23	1	-	-	30	1	-	-	36	1	-	-	2.65	1	-	-	0.59	1	-	-	-	-	-	-

source of constructional materials in many areas. The thick-bedded to massive sandstone of many of the Tertiary formations has been tested, and found to be of moderately good quality suitable for use as roadstone and concrete aggregates. Thus the sandstone, when fresh, may be a source of moderately good quality stone to supply the needs in such areas. 25 potential quarry sites with moderate reserves of stone had been investigated in the Central-North Sarawak region.

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REFERENCES

ASTM C88–71a. Standard Method of Test for Soundness of Aggregates by use of Sodium Sulphate or Magnesium Sulphate. *American Society for Testing and Materials.*

ASTM C131. Standard Method of Test for Abrasion of Concrete Aggregates. *American Society for Testing and Materials.*

BRITISH STANDARD 812, 1967. Methods of Sampling and Testing of Mineral Aggregates, Sands, and Fillers. *British Standards Institute.*

BRITISH STANDARD 882, 1965. Specifications for Aggregates from Natural Sources for Concrete. *British Standards Institute.*

GSKL 017. An open-file collection of unpublished reports on investigation of roadstone conducted by the Geological Survey.

TAN, D.N.K., KHO, C.H., & HON, V., 1981. Regional Geology: Sarawak, *Geological Survey Malaysia Annual Report* 1979, p. 97–118.

TARMAC, 1974. Investment Opportunities in the Quarrying Industry—The State of Sarawak. VIII: Appendices. *Tarmac Roadstone Overseas* (unpublished).

TING, W.H. & CHEW, S.H., (undated). *Investigation and Evaluation of Crushed rock aggregate found in west Malaysia* (unpublished).

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