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ECONOMIC EVALUATION OF BUILDING STONES OF SINDH

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ABSTRACT

Large deposits of good quality building stones of Precambrian to Miocene age are exposed in different parts of Sindh. Study of geotechnical properties of these rocks including compressive and shear strength, soundness and porosity show compatable values to the recommended ASTM range. In addition to the above parameters reserve estimation, accessibility, availability of labour and geographical controls have also been considered in the economic evaluation of these deposits. Optimum benefits from these deposits can only be achieved if materials are used according to their suitability, i.e. as building stones, grinding/miling stones, decorative stones or as raw material for cement, glass and steel industries.

INTRODUCTION

The occurence and uses of building stones have been known for centuries in the province of Sindh. They can be studied in old and new constructions, like Moenjodharo and Harapa as well as in the modern buildings. The potential areas of building stones are many and not far from the big cities except for the igneous rock exposures of the Nagarparker area. So far no quarries have been developed due to commercial and political reasons. Moreover, the lack of definite knowledge of their specific characteristics and dressing are also possible reasons for the lack of building stone resource development. The rocks studied during present investigation represent varities of limestone, sandstone and granite which differ in colour, texture and structure. During economic evaluation, due consideration has been given to the accessibility of the sites of reserves, geographical control of the locality, man power available in the area and quantity of the reserves, in addition to the physical characteristics of above mentioned rocks. The calculation of reserves is made on the basis of exposed rocks which can be

obtained by open quarrying. The total reserves also include possible workable depth of rocks below the surface through open quarry method. At present, building stones in Sindh and other parts of the country are randomly quarried and demand-consumption ratio is not considered. Due consideration has been paid to such factors during evaluation. The present investigation was undertaken to assess the quality and reserves of building stones from Pab Range, Morana, Gondbo, Orangi, Manghopir, Lahro, Surjan, Kirthar, Midway, Khadeji, Jamshoro, Lakhra, Makli, Halaji and Nagarparker have been investigated to classify the building stones for their proper usage.

During evaluation of the reserves due consideration was given to distance of the localities from Karachi which has facilities of transport through roads and railways to other parts of the country and by ship for export. Moreover, sizing, dressing and finishing facilities are also available. The nature and access to the localities, present quarrying activities, availability of labour and demand of the building stones have also been considered, evaluated and summarized (Table 1).

GEOTECHNICAL PROPERTIES

The determination of compressive strength, shear strength, soundness, and porosity of the rock samples from various localities of the present study is expected to help in the classification of building stones and their proper economic exploitation. Although geological investigations and mapping of the areas have been done by earlier workers (Ahmad, 1963, 1965; Asrarullah, 1963), no work with the above mentioned objectives has been done so far, at least in this region. The present study is the first attempt of this kind. In Sindh region, building stones are dominantly limestones and sandstones. Good quality building stones of igneous origin are also exposed in the south-eastern part of the province known as Nagaraparker area. The characteristics studied seem to be satisfactory tools to classify the rocks with respect to their durability and bearing capacity.

Compressive Strength

The comparison of data for compressive strength of building stones with allowable data of the US Bureau of Standards (ASTM 1988, C-170) reveals in general, higher values for the limestones of Pab Range and the limestones from Gondbo exceed the upper limits of the recommended values (Fig. 1). Most probably this increase in value of compressive strength of the sandstones from Pab Range is due to calcareous and siliceous cement. Likewise some of the samples from limestone beds of Gondbo which show a maximum of 35907 PSI compressive strength may be attributed to their origin and higher degree of recrystallization in tightly folded structures. The other beds of limestone exposed in this locality do not show much higher compressive strength values but have fairly high values (13545-27767 PSI). It appears that tectonic conditions and tight folding in this part of the locality has affected the compressive strength in general. The reserves of raw material in general are fairly high (5919097×10^6 million tons), and

TABLE 1. SUMMARY OF DISTANCE FROM KARACHI, COMMUNICATIONS, QUARRIES, LABOUR CHARGES AND DEMAND OF THE ROCKS OF STUDY AREA

Ser. No.	Locality and rock type	Dist. from Karachi	Access to Locality	No. of Quarries	Lab./Tran. Charges	Demand	Needs
1.	Pab S.St.	20 miles	Paved road	5	Not high	High	Sci. Approach
2.	Morana L.St.	28	-do-	3	-do-	Very high	-do-
3.	Gondbo L.St.	24	-do-	5	Moderate	High	-do-
4.	Orangi L.St.	17	-do-	4	-do-	High	-do-
5.	Orangi S.St.	17	-do-	3	-do-	High	-do-
6.	Manghopir L.St.	12	-do-	4	Not high	Moderate	-do-
7.	Lahro L.St.	27	-do-	5	-do-	High	-do-
8.	Surjan L.St.	72	-do-	5	-do-	High	-do-
9.	Kirther L.St.	80	-do-	5	-do-	High	-do-
10.	Midway L.St.	100	-do-	5	-do-	High	-do-
11.	Khadeji L.St.	37	-do-	3	-do-	High	-do-
12.	Jamshoro L.St.	120	-do-	3	-do-	Very high	-do-
13.	Makli L.St.	75	-do-	2	-do-	Very high	-do-
14.	Haleji L.St.	75	-do-	5	-do-	Very high	-do-
15.	Nagarparker Granite.	700	-do-	6	-do-	Very high	-do-

can be utilized for several purposes such as milling stones, grinding stones and for special engineering works. Hence, it appears reasonable to consider that the building stones of the area under study are of fairly high quality with respect to their compressive strength. However, some of the limestone samples of the Orangi hills, Kirthar, Khadeji, Jamshoro and Lakhra localities show their compressive strengths to be less than the lower limit of the recommended values but such beds are few and identifiable in the field on the basis of their appearance, less compaction and hardness. It is, therefore, possible to separate the better and the poorer quality building stones during exploitation.

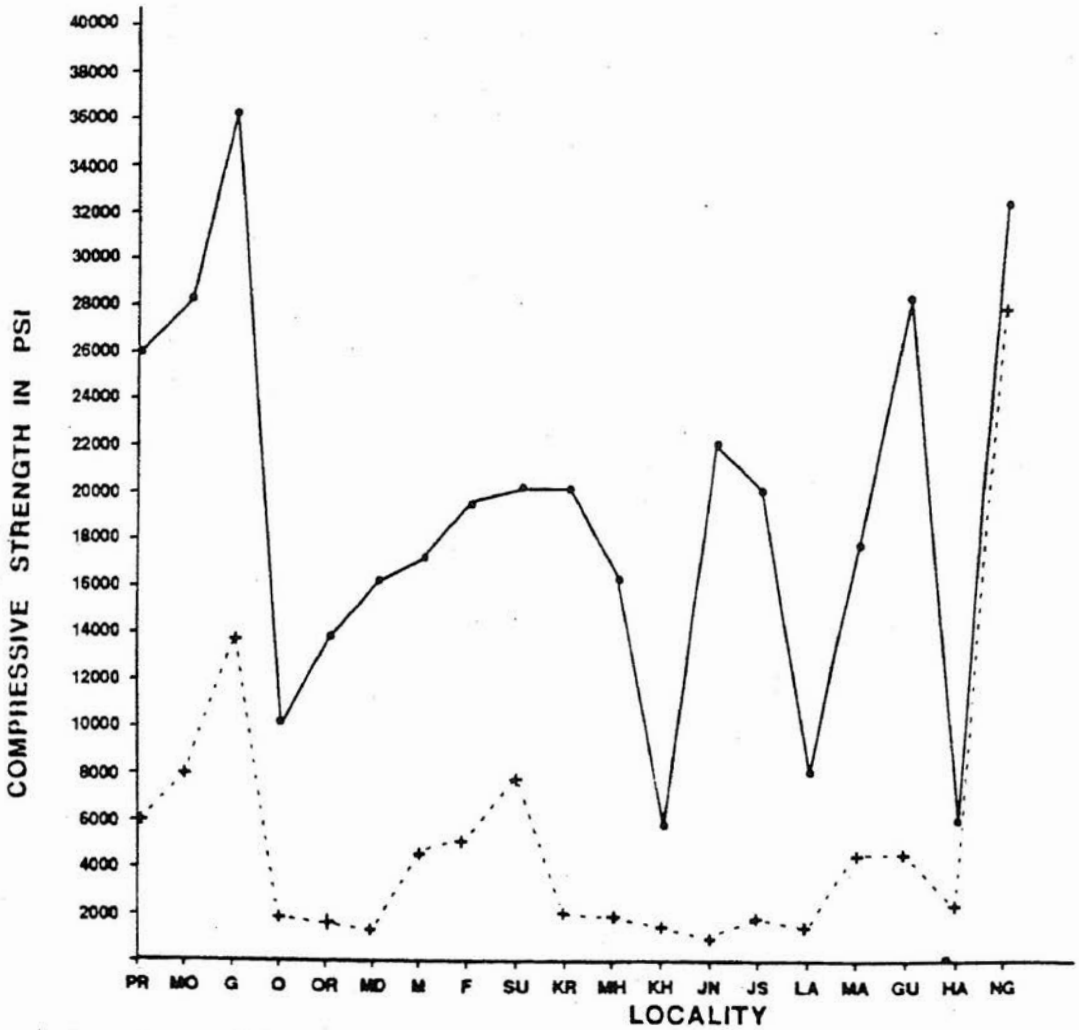

Fig. 1. Minimun and Maximum compressive strength of rocks from areas under study. PR=Pab Range, MO=Morana Hills, G=Gondbo, O=Orangi Hills, OR=Orangi Ridge, MD =Manghopir Dome, M=Manghopir Hills, F=Lahro Fault, SU=Surjan Anticline, KR= Kirther Ridge, MH=Midway Hotel, KH=Khadeji, JN=Jamshoro North, JS=Jamshoro South, LA=Lakhra Anticline, MA=Makli Hills, GU=Gujo, HA=Halaji NG=Nagaraparker.

The sandstone beds of Pab Range are fairly large and well exposed in quantity (30194618 x 10^6 million tons). They show much higher values of compressive strength than the average recommended values and are excellent for use in large civil engineering projects where the superimposed pressure is generally high. The sandstones of the Orangi hills and Manghopir dome show relatively lesser average value of compressive strength but fit well within the ASTM recommended range of values (ASTM 1988, C-170). They can be used for common public houses. The granite samples from Nagarparker also show high values of compressive strength well within the recommended limits for building and decorative stones.

Shear Strength

Rock samples from Pab Range are mainly limestone and calcareous sandstone with great variation in shear strength but within the recommended range of (ASTM 1988, C-170) values. The variation in the values of these limestones and sandstones are probably due to lithologic differences and the effects of tectonics (Fig. 2).

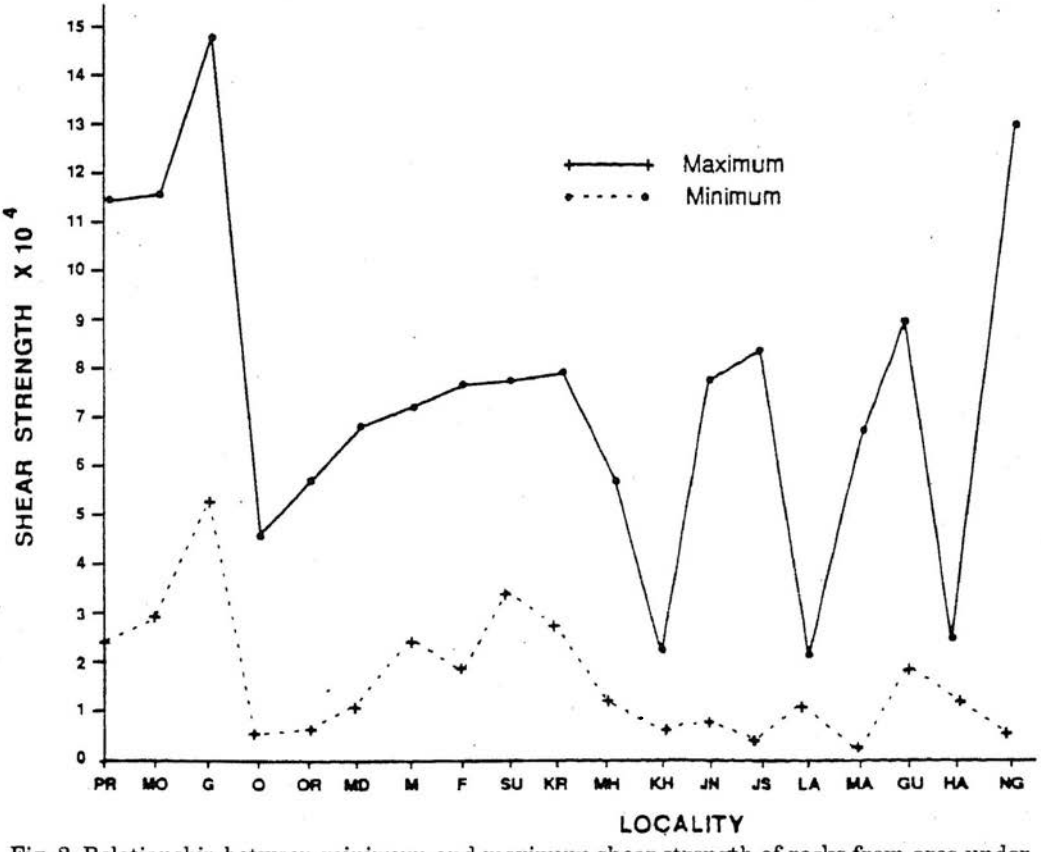

Fig. 2. Relationship between minimum and maximum shear strength of rocks from area under study. Location points same as in Fig. 1.

The limestone samples fron Morana hills show better average of shear strength value (64,800 PSI) but the average value in limestone samples of Gandbo locality is much more higher (101437 PSI). The lower average value of shear strength in Orangi hills as compared to Orangi Ridge is probably due to more argillaceous nature of the limestones and the sandstones.

The rock samples from Manghopir dome show higher average value of shear strength (42937 PSI) as compared to Orangi hills and Orangi Ridge, although, rocks of the same formation extend in these localities. This change is probably an indication of improvement in quality of building stones due to lithologic changes and variable effects of tectonics (Hawks & Mellor, 1970). Further continuation of the rocks of these three localities towards Hub Dam site near Lahro show more increase in average shear strength (47000 PSI) of the rocks as compared to Orangi and Manghopir.

Localities of the Surjani, Kirthar and Mid Way Hotel represent same rock exposures at different distances but the rocks show variable values of shear strengths within the recommended limits of ASTM. The rock samples of these localities show average shear strength values of 57600, 52200 & 30500 PSI respectively. The variations in values are most probably due to the presence or absence of microfissures. It is remarkable to note that the average values are higher than the recommended values of the U.S. Bureau of Standards. Further extension of this formation in Khadeji show lower average value (16062 PSI) for the rocks and is an indication of decrease in the quality of building stones as compared to Kirthar and Surjani localities.

The great variation in shear strength between maximum and minimum values in the rocks of Lakhra anticline is due to varying amount of argillaceous constituents in the limestone. However, the average value is within the recommended limits of ASTM (19250 PSI). Similarly, the rock samples from Makli, Gujo and Haleji show average shearing strength values of 43056, 79571 & 23583 PSI respectively and are considered better quality limestones as compared to Khadeji locality. The average shear strength value of Nagarparker granites is high (12500 PSI) and the rocks are considered excellent as building and decorative stones.

Soundness

Since the value of soundness is an indication of weathering rate of rocks in different climatic conditions, it was considered important to evaluate this character of rocks under study. The limestones and sandstones of Pab Range show variation in the percentage of soundness value but an average of 2.85% is common in the rocks of this locality (Fig. 3). The rock samples from Morana show more variation in maximum and minimum percentages of soundness as compared to Pab Range locality probably due to the presence of high content of argillaceous material in the rock.

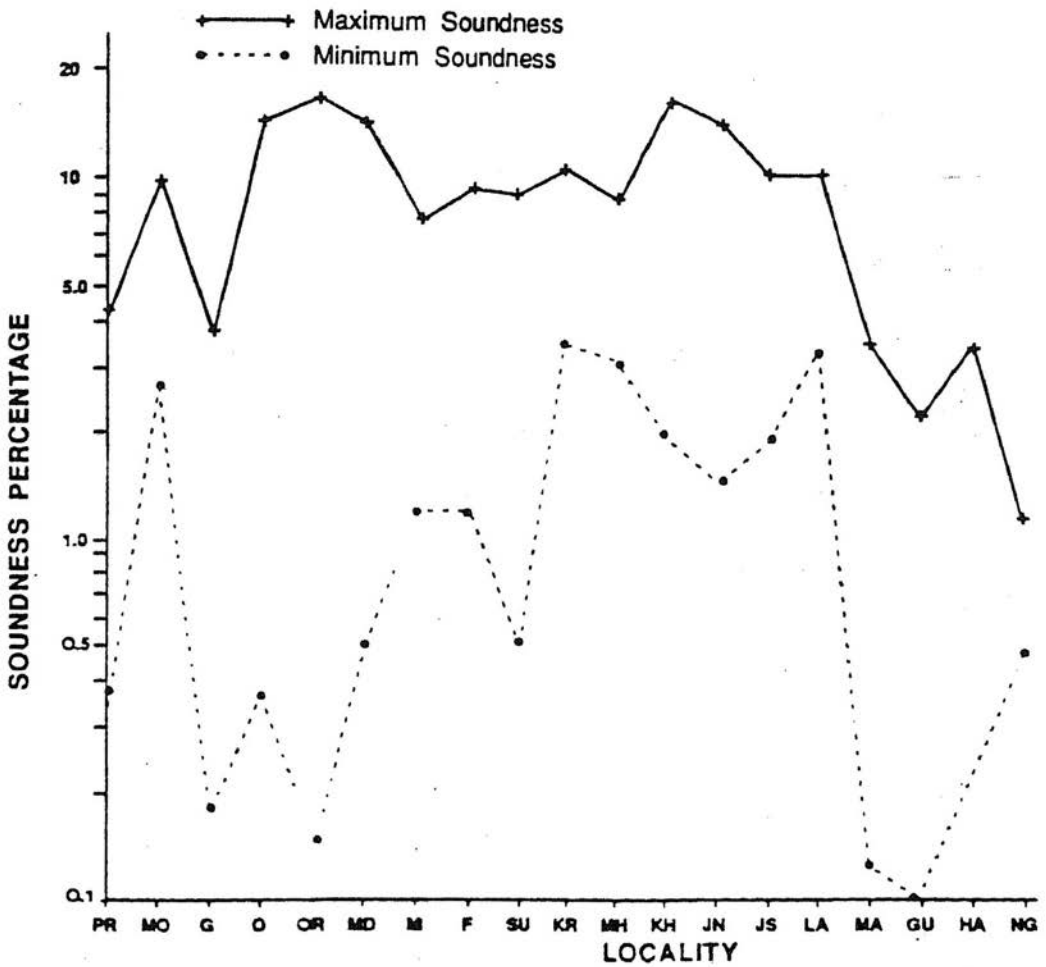

Fig. 3. Relationship between minimum and maximum percentage of soundness in rocks from the study area. Location points same as in Fig. 1.

The samples from Gandbo locality are mainly the varities of limestone and are highly resistant to weathering. The average soundness value in the rocks of this locality is less than Pab and Morana and most probably due to high compaction, fine grained texture and low content of clays.

The limestones and sandstones from Orangi locality show higher percentages of soundness and the average value observed is 7.71% which is more than the average values found in the rocks of Pab, Morana and Gandbo. The difference is mainly due to higher content of argillaceous material in the rocks and the presence of clayey matter in the micro-cracks.

The rocks of Manghopir locality are actually an extension of the rocks of Orangi locality but the average soundness percentage value is less. This indicates an improvement in the quality of building stone of this locality due to the effects of tectonic activity which activated re-arrangement of grains and minimized the pore spaces of the rocks.

The continuation of rocks of the same formation from Manghopir towards Hub Dam site in Lahro show higher percentage of soundness value, probably due to the fact that the rocks were not subjected to the same intensity of tectonic effects in this locality as in Manghopir.

The localities of Surjan, Kirthar, Midway Hotel and Khadeji represent the same rock exposures around Thano Bula Khan at variable distances but the average percentages of soundness values in these localities are 1.43%, 7.63%, 6.37% & 6.54% respectively. This possible reason for the differences in average value can be similar to those described for the rocks of Manghopir locality.

The samples from Jamshoro North and South are mainly varities of limestone and show variable percentages of soundness values. The variation in the percentage of soundness is most probably due to chalky and argillaceous nature of the limestone which are well exposed in the southern limb. The limestone samples from Lakhra locality are also showing variation in soundness values similar to Jamshoro.

Samples of limestone from Makli locality represent a slightly better quality of limestone in which the soundness value has an average of 2.297%, probably due to fine grained texture & higher degree of compaction. Similar values of soundness were found in the rocks of Goju and Haleji. Likewise, the granite of Nagarparker show an average soundness value of 0.75% and is considered as excellent rock both as building stone and as decorative stone.

Porosity

The total porosity of the limestones and sandstones are mostly within the recommended limits (15%) of ASTM. However, there are some beds in Gandbo, Manghopir and Surjan localities which show higher values, but they can be identified with the help of textural characteristics and argillaceous composition (Fig. 4). The limestone beds showing higher percentage of total porosity can be used as building stones in arid regions, because of their higher compressive and shear strength to withstand civil engineering construction works (Winkler, 1973). Alternatively, the limestones which show higher porosity can be utilized in the manufacture of cement because of their suitable chemical composition as the reserves are also sufficient for the establishment of cement factory.

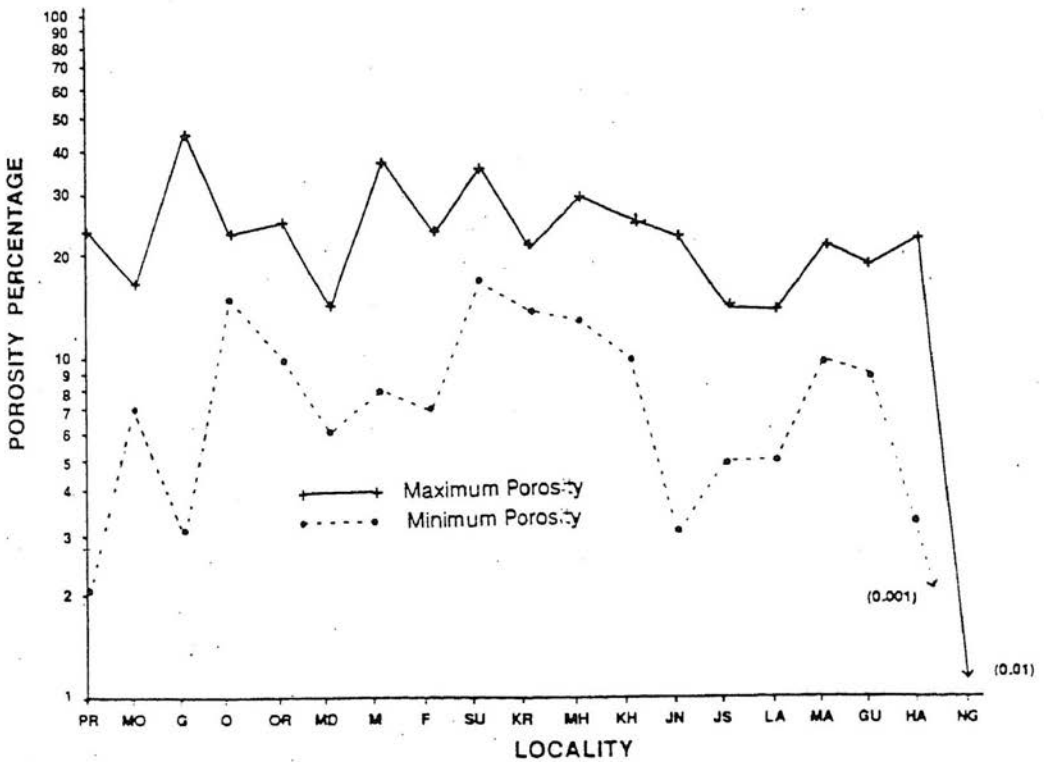

Fig. 4. Minimum and maximum porosity percentage in rocks from study area. Location points same as in Fig. 1.

RESERVES

The present estimation of the reserves is for limestones, sandstones and granites of the province of Sindh. It appears that, one day, full attention will be paid to the possibilities of using building stones and the building material. In view of this, it will not be wise to ignore building stones of the province when the country is passing through an industrial evolution and there is urgent need to have houses and buildings for the people. In this regard, private companies can be encouraged to explore the possibilities of using building stones which occur throughout the country.

The aim of reserve calculation during the present work is to show all the reserves of building and decorative stones in the province of Sindh and their possible utilization and exploitation on a rational basis (Table 2).

The demand of Pab sandstones in the country and abroad is very high. Presently the sandstones are being used as grinding stone and milling stone in Karachi and other parts of the country. It is also exported to Arabian countries. Pab sandstone and the

TABLE 2. RESERVES, CHARACTERISTIC AND PREFERABLE USES OF THE BUILDING STONES UNDER STUDY.

Locality/ Rock type	Reserves in Million tons Building Stone x 10^6	Decorative Stone	Characteristics	Possible uses
Pab Limestone	1849462	974231	High compressive strength, low porosity & weathering. Takes good polish. Colour white and grey.	Building stone
Pab Sandstone	30196418	2468675	High compressive strength, low porosity & weathering. Takes excellent polish. Colour grey.	Building & Milling stone
Morana Hills Limestone	4483621	3769159	High comp. strength, low-medium porosity and weathering. Takes excellent polish. Colour grey, pink and brown.	Decorative Stone
Gondbo Limestone	5919097	1693120	High comp. strength, low-medium porosity, low weathering. Takes excellent polish. Colour grey & brown.	Building & decorative stone
Orangi Hills Limestone	2876652	1477552	Low-high comp. strength, low-medium porosity & weathering. Takes good polish. Colour grey.	Building & road stone
Orangi Hills Sandstone.	37659721	1459752	Medium comp. strength, porosity & weathering. Takes poor polish. Colour grey & pink.	Building & wall stone
Orangi Ridge Limestone.	9267325	2311846	Medium comp. strength, porosity & weathering. Takes fair polish. Colour yellow, brown & pink.	Road stone & building stone
Manghopir Sandstone.	9267325	2311846	Medium comp. strength & porosity, low weathering. Takes polish. Colour grey and brown.	Wall stone & building stone
Manghopir Limestone	30112796	256876	Medium-high comp. strength, low por. & weathering. Takes good polish. Colour pink & yellow.	Cement making, building & road stone
Lahro Limestone	22703874	1234098	Medium-high comp. strength, low porosity, low-medium weathering. Takes good polish. Col. yellow, brown, light green.	Building & road stone

Surjan Limestone	9669647	49763	High comp. strength, medium porosity, low weathering. Takes good polish. Colour white, cream & pink.	Building/road stone cement making
Kirther Limestone	125158721	26092708	Medium-high comp. strength, medium porosity, low weathering. Takes poor polish. Colour pink, cream & brown.	Building & road stone
Midway Hotel Limestone	89295536	7067174	Low-high comp. strength, medium porosity, low weathering. Takes poor polish. Colour cream & off white.	Building/road stone cement making
Khadeji Limestone	29638606	21745152	Medium comp. strength & porosity, low-med weathering. Takes good polish. Colour yellow and pink.	Building, road & wall stone
Jamshoro Limestone (N)	12464957	57389138	High comp. strength, low porosity & weathering. Takes good polish. Colour white.	Cement making, road & building stone
Jamshoro Limestone (S)	48932127	687500	Medium-high comp. strength, low porosity & weathering. Takes good polish. Colour off white, yellow & brown.	White cement & steel making,building stone
Lakhra Sandstone	4621875	2385	Low-medium compressive strength, low porosity, low-med. weathering. Takes poor polish. Colour yellow & brown.	Wall & building stone
Makli Limestone	984850	208563	High comp. strength, low-medium porosity, low weathering. Takes good polish. Colour cream & yellow.	Building/road stone, cement making
Gujo Limestone	15265	2365	Very high comp. strength, low porosity & weathering. Takes fair polish. Colour grey.	Building & road stone
Nagarparker Granite&	15689700	25689700	High comp. strength, low porosity & weathering. Takes excellent polish. Colour pink & grey.	Decorative stone
Halaji Limesrone	621853	5562	Med. comp. strength, low-med. porosity, low weathering. Takes good polish. Colour yellow.	Building & road stone

associated rocks have been used in the old constructions of Karachi. Commercially, these rocks are used more for grinding than as the finished products. If the development and marketing of these rocks is done on scientific grounds, it would prove to be a good source of foreign exchange for the country. Very little of the exposed rocks have been quarried so far. The bulk reserves of the sandstones which have been estimated during the present work are 30196418×10^6 million tons. The reserves of grey variety decorative sandstones are 1974940 million tons. The other variety of decorative sandstone known as grey banded, hard, compact sandstone is high in compressive strength and low in porosity and has estimated reserves of 493735 million tons.

The bulk reserves calculated from the main limestone quarries of Morana Hill range in colour from greenish-grey to pink and are presently in operation. The demand is still not fulfilled. The bulk reserves estimated from three quarries are 2315872×10^6, 943875×10^6 and 1223874×10^6 million tons. The reserves of greenish-grey, pink to brown and pink limestones which are being used for exterior decoration are 1739612, 869806 and 1159741 million tons. These rocks could be exported as decorative stones if quarrying and dressing of the rocks are done on scientific grounds. Presently, there is no arrangement for dressing of the rocks at the quarry sites. They are transported away to Baluchistan or Punjab for the purpose of dressing before their marketing. If dressing provision for the rock is made at the quarry site, savings can be made, due to availability of local labour at low costs. The extra transportation cost for the waste material can also be minimized. Mechanized mining and dressing of the material at site would further increase production and thus export of the material will be facilitated. Presently in the public sector these rocks are being used in the construction of boundary walls which is not a rational use of these rocks. The quarries of the rocks are connected with fifteen miles paved and about three to four miles unpaved road with the city of Karachi. The bulk reserves estimated as building stones are 4483621×10^6 million tons.

The Orangi Hill sandstones are pink and medium grained. Presently three quarries are being worked in the locality and the material quarried is used in the construction of the roads of Karachi. These quarries are connected with Karachi city by five miles paved and two miles unpaved road. Transportation and labour charges are not very high. The bulk reserves are 3765971×10^6 million tons and the reserves for decorative stones are 1459752 million tons.

The rocks of the Orangi Ridge are mainly yellowish to brown limestones and pinkish to reddish sandstones. These rocks are at a distance of about seventeen miles from the main city of Karachi and about one to two miles from Qasba Colony. Transportation charges are not high and manpower is easily available.

The methods applied for quarry operation are mostly unscientific and a major part of the rock is wasted. At present, the rocks are quarried mainly for road metalling and for local uses as building stones. Taking into consideration the texture, structure

and the physical characteristics of the rocks, the building stones may be developed on scientific grounds. The better use of building stones, both limestone and sandstone, is when used for exterior wall decoration. After proper polishing it can also be used for the internal decoration of mosques and some parts of the houses and buildings in Karachi.

The building stones and the decorative stones are at variable distances but they are accessible from Karachi. The reserves, both of the building stones and decorative stones are highly promising for local uses and export purposes. The exploitation of the reserves in various parts of the province would facilitate development work program of the province and shall create job opportunities both for the locals and the skilled unemployed manpower. It would prove a good source of earning foreign exchange for the country with the conditions that mining methods and techniques are improved to avoid wastage of the rocks and improved safety factors of the workers.

MINING TECHNIQUES

Mining techniques are old and unscientific due to the lack of scientific information. The explosives mainly used are gelatinous, seismic, semi-gelatinous, powdered, wabocord, detonators etc. The above mentioned explosives produce shock waves which travel with very high velocity and disturb the internal structures resulting in small and large cracks on the surface of the rocks. The rocks with discontinuities more than 30 per meter are not suitable as raw materials for building stones.

During the mining safety measures such as ohmmeter, leakege testers, control instruments, short firing cables, connecting wires, lightening detectors and crimpers should be used to reduce the wastage of the rock. This can be achieved provided that the training facilities and blasting services divisions are established.

CONCLUSIONS

1. The reserves of good quality building stones are fairly large and transport charges would not be very high due to easy approach to the sites, cheap labour and proximity with the cities of Karachi and Hyderabad.

2. The rocks having a compressive strength greater than 20,000 PSI from Gandbo and other localities can be used as miling stones and grinding stones in addition to their use in special civil engineering construction works.

3. Limestone with higher content of calcium and low compressive strength are suitable as raw materials for cement, glass and steel industries. They can also be used

for chemicals, improvement of agricultural land and as carving stones for decoration purposes due to their appealing colours and textures.

4. The soundness values of rocks under study are within recommended limits with few exceptions. Hence the effects of weathering would be very low and the rocks can be used for civil engineering works in varied types of climatic controls.

5. The change in textural and mineralogical characteristics of the rocks due to recrystallization, diagenesis and the effects of tectonism appear to affect the geotechnical properties of the rocks of different localities under study.

6. The degree of recrystallization and diagenesis appear to have affected the porosity of the rocks.

7. The exploitation of the building stones can be done by open quarry method and the waste material can be used for agricultural and other purposes.

8. The lithographic limestone from Morana and the Gondbo of Kirthar Formation take excellent to good polish. Likewise, the fossiliferrous limestone from Khadeji and Haleji take good polish and therefore they can be exploited as decorative stones instead of their uses as building stones.

9. The granites of Nagarparker are good decorative stones and their exploitation can be economical.

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