CHAPTER III

GRANITE AS DIMENSION STONE

Granites provide an inexhaustible store house of a great variety of excellent construction material for building and decoration because of their high compressive strength, durability and property of taking very good polish. 'Cleopatras Needle' a shaft of stone now standing in Central Park, New York City, was fashioned 3500 years ago from Egyptian granite. Although its corners are rounded, the main structure shows only moderate evidence of weathering on the surface. In India, granites are widespread through Archean terrain. Temples, forts, palaces,

bridges and other large structures as well as local buildings bear witness to exceptional architectural qualities of banded gneisses and Bundelkhand granites of Rajasthan, the various gneissic rocks and granites of M.P., Bihar, Andhra Pradesh, Karnataka and Tamilnadu. At many places in Tamilnadu and Andhra Pradesh, the granites yield 8-9 m long and 5-10 m wide slabs which ancient architect fully exploited for pillars, beams flooring and roofing in many important buildings, particularly temples and palaces in South India. "Vidhan Saudha" (Sachivalaya) in Banglore is constructed of granite masonry.

Commercially granite includes all felspathic crystalline rocks of predominantly interlocking texture and with individual mineral grains visible to the naked eye or various igneous rocks with 'granitic texture'.

In Gujarat, stone industry has hardly paid any attention to these stones. Granite, granite gneisses and granophyres are quarried as dimension stone. Polishing of granite is completely neglected by stone industry. Vast resources of granite at the disposal of Gujarat State are still unexploited. The occurrence of granite around Idar (Sabarkantha district), Danta and Palanpur (Banaskantha district), Godhra (Panchmahals district) and Chhotaudepur (Vadodara district) and granophyre at Chamardi (Bhavnagar district) is shown in the Fig. 3.1.

GEOLOGICAL SETTING

The stratigraphic position of granites and granite gneisses in the geological setting of Gujarat is as follows:

Deccan Trap, Granophyres		Cretaceo-Eocene
Lameta and Bagh Beds Himatnagar sandstone		Cretaceous
- - - - - - - - - - - - - -	Unconformity	- - - - - - - - - - - -
Erinpura Granite		Post Delhi Intrusive
Ajabgarh Series Calc gneiss, Calc schist		Delhi System
- - - - - - - - - - - - - -	Unconformity	- - - - - - - - - - - -
Granite and Gneisses Aravalli system Champaner Series		Aravalli
- - - - - - - - - - - - - -	Unconformity	- - - - - - - - - - - -
Banded Gneissic Complex		Archean

Heron and Ghosh (1938) correlated granites around Idar, Palanpur and Danta with Erinpura granite. The close of Delhi period witnessed large scale intrusions of granite known as Erinpura granite first recorded at Erinpura, a town in the state of Rajasthan.

Gupta and Mukherjee (1938) considered granite around Godhra as equivalent to the Erinpura granite but Jambusaria and Patel (1968) stated that this granite is intrusive into Aravalli rocks and not in Delhi rocks. Recently Crawford (1975) reported that granites of North Gujarat (Palanpur, Danta and Idar) are equivalent to Malani suite of rocks or older with the help of Rb/Sr method. According to him granite from Godhra is younger than that from North Gujarat.

Granite gneisses around Devgadhbaria (Panchmahals district) and Chhotaudepur (Vadodara district) are similar to granite except that they show development of foliation due to metamorphism.

DISTRIBUTION

Granites occur in six districts of the State of Gujarat.

In eastern part of Banaskantha district, granites are exposed in the form of great domes and covers large hilly areas around Danta and Palanpur. Many of these granite peaks attain height from 600 to 900 m. Course grained, porphyritic biotite granites are predominent. Fine grained and non porphyritic granites also occur at places. Granites vary in colour from grey to pink according to the colour of predominant feldspar.

Plate 3.1: Granite quarry, Umedpura, Banaskantha district.

Plate 3.2: Photograph showing exposures of granite near Navavas, Mehsana district.

At present granites are quarried at two places. East and west of Danta adjoining portion of Idar area along Sabarmati river grey, fine grained, nonporphyritic and homogeneous granite occur (Plate 3.1). This granite was extensively quarried near village Umedpura for masonry work of Dharoi dam on river Sabarmati. This quarry is submerged under Dharoi reservoir. However there is ample scope for quarrying this type of granite occurring in surrounding areas. Granite occurring at Dantiwada dam site was also quarried near village Bhakhar as construction material. This granite is medium grained, grey to pink and equigranular.

Other granites available in Banaskantha district are coarse grained and at places biotitic. These granites cannot be used as dimension stone. However this granite along with fine grained variety can be used as paving blocks, curbing stone etc. for bringing about economy in granite stone industry.

In Kheda district big boulders of grey granite covering granite masses around Balasinor occurred as scattered rounded hills in the midst of recent alluvium. This granite is fine grained to medium grained and shows both equigranular and porphyritic texture. These granites were quarried in the past. Equigranular fine to medium grained granite can be

quarried for its use as dimension stone but at present no attention has been given to this valuable natural resources.

In Mehsana district granite masses occur in Taranga hills abruptly rising from the plains north of Kheralu (Plate 3.2). This granite is grey in colour and fine to coarse grained in texture. This highly jointed granite is available in large quantity. It is easy to work on this granite as hills form natural quarry face (Plate 3.2). Government of Gujarat has developed a quarry near Nathizar for metal and rubble but the production is not regular.

In Panchmahals district, granite outcrops occur around Godhra which do not rise much above the general ground level. Granite is weathered into grey knollw and flat domes. In the main outcrop the granite is characteristically variable in texture from coarse to fine grain. The colour of granite varies from grey to pink depending upon the colour of the dominant felspathic constituent. At present granite is quarried near village Parvadi, near Godhra. This granite is grey, fine grained and equigranular. This is used in construction of Kadana dam on river Mahi and Panam dam on river Panam. In this quarry boulders of granite are worked upon to produce dimension stones. Granite gneisses occurring near Devgadhbaria are similar to granites in appearance but

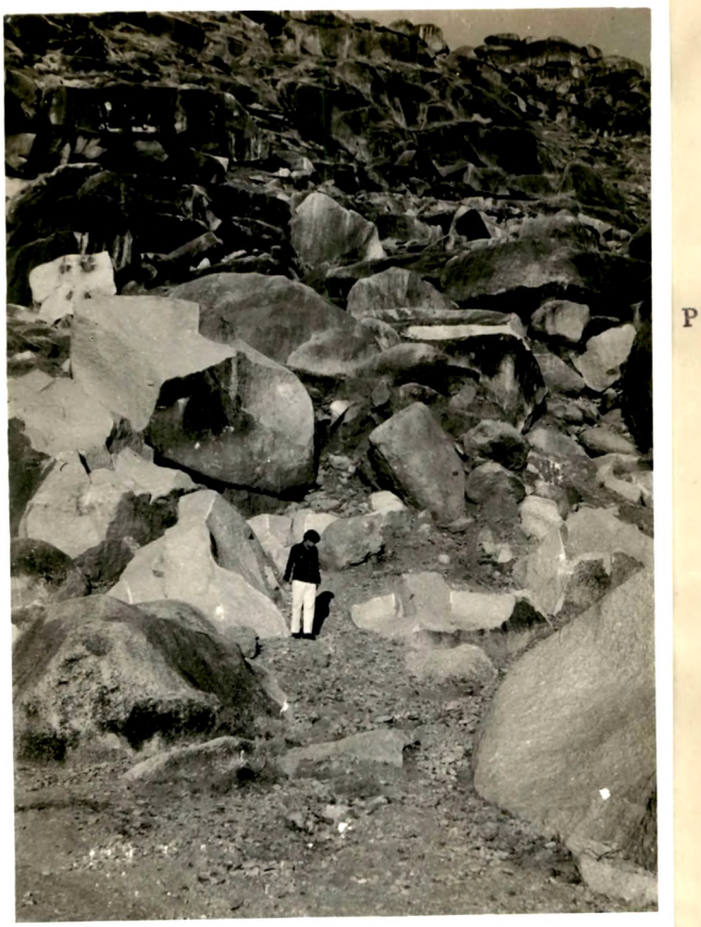

Plate 3.3 :

Exposures of granite around Idar, Sabarkantha district.

Plate 3.4: Photomicrograph of medium grained Granite. (Crossed Nicols, X50).

well developed feldspars. This stone can be used as paving block, curbing stone, veneer etc. It is not advisable to use this rock, as building stone.

In Sabarkantha district granite occurs mainly around Idar. The outcrops of this rock are of very scattered nature, rising abruptly from the alluvium in the form of small groups of rugged, pinnacted hills and rising 15 to 18 m above the plain. One of the largest of the groups is seen encircling the town of Idar (Plate 3.3). Granite varies from fine to coarse grained and grey to pink. Biotite granite occurring near Babsar is very rich in biotite content and should not be used as dimension stone.

At present granite is quarried near Idar. This granite is pink, medium grained and porphyritic. Quarry owners are working on boulders which occupy hill slopes (Plate 3.3). Quarrying is done on very small scale. Granite is locally used as building stone. This stone can very well be used as monumental stone.

In Vadodara district, granite and granite gneiss are exposed over large areas around Chhotaudepur. The rocks are mostly whitish grey to pink depending upon the colour of the predominant feldspar and are fine to coarse grained.

Plate 3.5: Photomicrograph of coarse grained Granite. (Crossed Nicols, X50).

Plate 3.6: Granite quarry, Parvadi, Panchmahals district.

The granite occurring south-east of Chhotaudepur is more pink and more gneissic. Granite quarried near Tejgadh is white, equigranular and fine grained. This stone has been used in the construction of railway bridge. Granite is also quarried near Narpar. Stone from this quarry is used in the masonry work of bridge across Orsang river.

The gneisses in this area are similar to granite except that foliation is developed due to metamorphism. This type of rock occur around Dhanpur, Hatipagla, Ghanta, Kundal and Motipura.

In Bhavnagar district group of isolated hills abruptly rise from the alluvial plains near Chamardi, NNW of Bhavnagar. The typical rock of the Chamardi hill is a light coloured granophyre having predominance of feldspar. This rock is quarried at Chamardi for use as dimension stone.

PROPERTIES

Granites in Gujarat are grey to pink, homogeneous and fine to coarse grained (Plates 3.4 and 3.5). They are of two varieties viz. equigranular and porphyritic. They consist of quartz and feldspars (Orthoclase, microcline) in nearly equal amount and mica and chlorite in small amounts.

Granophyre of Bhavnagar district is generally coarse grained but a fine grained variety is also found which cuts through the coarse variety. The texture is micrographic, the quartz and feldspar (orthoclase) retaining their parallel orientation. The quartz and feldspar show intergrowth at places.

Granite, to be used as dimension stone must be fine to medium grained and equigranular (Plate 3.4). However fine to medium grained porphyritic granite can also be used as dimension stone which will give attractive appearance after polishing.

Granite is very hard and difficult to cut and dress as all its mineral constituents except mica and chlorite are very hard. The presence of the predominant minerals quartz and feldspars having hardness of 7 and 6 in (Meh's) scale, results in high cost of polishing. This may be one of the factors why granite is not popular in Gujarat State as compared to marbles. However granite is most durable rock because quartz and feldspars are highly resistant to weathering. Granite will not breakdown easily due to physical weathering as its texture is homogeneous. Quartz remains unaltered but feldspars are often altered to kaolinite and micas to various clay minerals as per following chemical

reaction suggested by Trefethen (1960).

$$2KAlSi_3O_8 + CO_2 + 2H_2O \longrightarrow H_4Al_2Si_2O_9 + 4SiO_2 + K_2CO_3$$

Orthoclase — Kaolinite

The silica liberated is either soluble or colloidal silica which may subsequently become quartz on crystallization. Similarly Albite and Anorthite will alter to Kaolinite.

$$2NaAlSi_3O_8 + CO_2 + 2H_2O \longrightarrow H_4Al_2Si_2O_9 + 4SiO_2 + Na_2CO_3$$

Albite — Kaolinite

$$CaAl_2Si_2O_8 + CO_2 + 2H_2O \longrightarrow H_4Al_2Si_2O_9 + CaCO_3$$

Anorthite — Kaolinite

Feldspar will, however, disintegrate slowly if exposed to acid bearing atmosphere, due to the presence of smoke of coal. Under normal atmospheric conditions, granite will endure for centuries without significant change in colour or durability.

Generally mica is very less in granite hence its effect on weathering is negligible. Some granites are rich in mica constitute (about 60%) and are dangerous for their use as dimension stones, due to alteration of mica to clay minerals

on weathering. Mica is soft and easily attacked by water. However, muscovite is more stable than biotite. Biotite Granites around Babsar (Sabarkantha district) are rich in biotite content. It is not advisable to use them for irrigation project. Engineering properties of granite are given in Table 3.1. Granites having compressive strength of granite ranging from 673 to 1700 kg/cm^2, which are according to Hawkes and Mellore (1970), strong to very strong rocks (Appendix A). For building purposes, crushing strength of granite is in excess of that required after allowing liberally for a safety factor. Even in bridges, dams and the bases of tall monuments and other structures where granites must sustain heavy pressure, strength of granite far exceeds the requirement of safety. The results of laboratory investigation revealed that granites of Gujarat are notably impervious to moisture (Table 3.1). The specific gravity of granite tested is in accordance to ISI specification. This property is mainly important for architecture and builders. Structures must be designed to support the weight of the stone per unit area.

The ISI specification of structural granite (IS 7124-1973) is as follows:

(i) Compressive strength should not be less than 1000 kg/cm^2.

(ii) Specific gravity should not be less than 2.6.

(iii) Percentage water absorption should not be more than 0.5 per cent.

Granites of Gujarat satisfy all the specifications suggested by Indian Standard and therefore can be used as dimension stones.

QUARRY METHOD

All the existing quarries of granite are shown in Fig. 3.1 and list of quarries is given in Table 3.2. All the existing quarries are approachable in all seasons by carttruck or motorable road (Fig. 1.2).

Granite topography is characterised by rounded hills covered by boulders. These features are taken advantage of in quarrying operation (Plate 3.6).

Overburden is either very less or completely absent. Overburden of 0.3 to 1.5 m can be easily removed manually by shovel. At places exposed rock is inferior due to weathering which is removed by chisel and hammer at the time of dressing.

Primary break or cut is made by drilling and broaching methods to separate block from the parent mass. Holes of

1 to 2 cm in diameter are drilled with the help of hand chisel along a straight line. The distance between the holes vary from 5 to 15 cm. Chisels are left in the holes to act as wedges to develop and extend fine cracks along rift, grain or joints for splitting the rock. Depth of the hole vary according to the size of boulder, spacing of joints etc. At places where boulders are worked holes are drilled with point and hammer and blasted off putting light charge of gun powder to develop fine cracks without shattering effect. Quarry operators do not have any regular measurements or method for drilling of hole, requirement of explosive per hole etc.

Granophyre at Chamardi is also quarried like granite boulder. They do not use any special technique for quarrying.

At Umedpura (Banaskantha district) holes are drilled with Jack hammer to produce large quantity of rubble. The face height is kept at 3 m and 3 m deep holes are drilled 1 to 1.3 m apart depending on the spacing of joints.

To separate the block from the bottom, floor breaks are made by driving wedges in horizontal drill holes at the base of the block. Separating the block from the bottom is not necessary when blocks are blasted off. Subdivision of the blocks into specified sizes and shapes and their

dressing is done by chisel and hammer near quarry site by skilled workers who are in this profession over generations.

The present author would like to suggest some improvements in quarry method. Drilling and blasting should be carried out systematically to reduce the undersize material and to increase the recovery of dimension stones. Ammonium nitrate and fuel oil mixtures hardly costing 1/3 of high explosive and having a heaving effect rather than shattering effect should be used so that undersize material will be less. This explosive which can be stored safely gives an additional advantage. Holes for the blasting should not be drilled vertical. Inclined holes with an angle of 15° to 20° to horizontal will give more recovery of stones due to increased blasting efficiency.

Jet piercing method suggested by Bowles (1956) should be used for making primary cut into the stone. 18 cm channel is cut into the rock with a flame drill. Combution of oxygen and fuel oil fed through nozzle generates a temperature over 5000°F. A stream of water join the flames and the combined effect is to disintegrate the rock into fragments, which are blown away from the cut.

The vertical channel is made from open face by guiding the nozzle up and down in an arc. The process has been in use for too short a time to permit reliable determinations of rate or cost of cutting. The noise made is so deafening that the operation has to be carried out only during night shifts.

However, the most modern method of making primary cuts is by using wire saw also mentioned by Bowles (1956). This equipment consists of three strand or single strand wire that runs as a belt under tension. When fed with sand, aluminium oxide, silicon carbide, or other cutting agent, carried in a stream of water, it cuts a narrow channel by abrasion. This method is very good for granites of North Gujarat i.e. Mehsana, Banaskantha and Sabarkantha districts where quantity of this stone is enormous.

Wire saw method has an advantage over other methods. Wire cutting conserves much valuable stone and wastage is very less. Most important advantage is that the surface resulting from wire saw cuts is very smooth. This is useful in surface finishing by reducing the cost of finishing and polishing of the stone.

POLISHING

Polishing of granite is completely neglected by stone industries in Gujarat. Polishing will give ornamental value to granite. Vast resources of granite available in Gujarat can justify the establishment of a granite polishing factory. Polishing of granite is done in the States of Andhra Pradesh, Karnataka and Rajasthan. Rajasthan Government has established a granite polishing factory at Jalore. Polished granite has added advantages over polished marbles. Polished surface of granite looks like a mirror and the polish is long lasting. Granite is acid resistant and being hard, it cannot be easily scratched. The cost of polishing granite being comparatively higher than that of marble, prevents its liberal use. The main market for the polished granite slabs is outside India, particularly in western countries. It is mainly used as a tombstone with inscription.

Polishing method used at Jalor (Rajasthan) can be adopted for polishing of granite in Gujarat. The polishing of the block is carried out by a rotary polishing machine coupled with 3 H.P. electric motor. The axis of rotation is vertical while a disc attached to the end of central rod is rotated in a horizontal plane over the dressed surface

of the block. The polishing is carried out in different stages using different grinding and polishing media with the discs of different metals.

Grinding the surface is carried out by using a mild steel plate of 15 cm diameter and 1.25 cm thickness. Chilled steel shots are used as grinding medium and the surface is wetted by water to obtain smooth surface for polishing. The steel shots are prepared in workshop of the factory itself by heating the steel plates (rejected steel plates can be used for chasis springs of the vehicles) to red hot and then suddenly cooling them by dipping in cold water. This makes the plate quite brittle. Now these small plates are broken to tiny shots by hammering. The grinding operation is time taking and consume about 3/8 of the total polishing time.

The ground surface is first polished with the help of 10 cm diameter mild steel plate of 6.25 mm thickness using 60 mesh carborundum powder as polishing media and water as wetting agent. This operation takes about 1/4 of total polishing time.

Further polishing is carried out using a mild steel disc of 10 cm diameter and 6.25 cm thickness and carborundum powder of 120 mesh and 220 mesh as polishing media respectively.

This is followed by polishing using copper disc of 10 cm. diameter and 6.25 cm thickness and 400 mesh silicon carbide powder as polishing media and water as wetting agent.

When the surface of the slab becomes fully smooth and starts taking shine, further polishing is carried out by using puffy powder (tin oxide, probably containing some lead oxide) as polishing media and lead disc of 7.5 cm diameter and 6.25 mm thickness.

Final polishing is done by using disc of 15 cm diameter and 2.5 cm thickness to add gloss. The polishing time by manual operation is double that of time taken by machine.

USES

At present, granite is mainly used by Public Works Department of the Gujarat State in the construction of irrigation projects and bridges.

Granite is used in masonry work as rubble and facework in the construction of a weir across Mahi river at Wanakbori, Dantiwada dam on Banas river and Dharoi dam on Sabarmati river. It is used for facework at Kadana dam on Mahi river and Panam dam on Panam river. Granite is also used in the

construction of bridge on Orsang river. Locally this stone is used as building stone. Granite after polishing can very well be used as monumental and ornamental stone. Granophyre of Chamardi is being used as building stone and guard stone locally. It can be used as paving blocks, curbing stone, kilometer stone etc. It can be used as veneer for external as well as internal decoration of the buildings. It can also be used as paving blocks, curbing stone etc. but this use should be limited to inferior quality of rock which do not require any selection criteria whereas for monumental, ornamental and veneer even grain uniform texture and an attractive colour is required. Knots or hairlines are not permitted for this type of use. The crushed aggregate of granite produced during quarrying and dressing of stone can be used as road aggregate to balance the economy of stone industry.

Table 3.1 : Engineering Properties of Granite.

Sr. No.	Location	Compressive strength kg/cm^2	Water Absorption %	Specific Gravity	Durability
		IS 1121 - 1974	IS 1124 - 1974	IS 1124 - 1974	IS 1126 - 1974
1.	Bhakhar (1)	1199	0.62	2.63	0.18/30 cycles
2.	Umedpura (2)	952-1400	0.13-0.52	2.62-2.65	0.09/30 - 0.25/30 cycles
3.	Chamardi (3)	906	0.27	2.87	0.21/30 cycles
4.	Navavas (4)	1292	0.09	2.67	0.095/30 cycles
5.	Kothamba (5)	946.3	0.19	2.69	-
6.	Parvadi (6)	960-1420	0.17-0.36	2.62-2.65	0.17/30 cycles
7.	Idar (7)	1140	0.07	2.64	0.31/30 cycles
8.	Mohor (8)	673	0.33	2.63	-
9.	Nurpur (11)	1413	0.37	2.60	-
10.	Tejgadh (12)	1041	0.23	2.70	-

Table 3.2 : List of Granite Quarries (Fig. 1.2).

District		Location
Banaskantha	(1)	Bhakhar
	(2)	Umedpura
Bhavnagar	(3)	Chamardi
Mahesana	(4)	Navavas
Panchmahals	(5)	Kothamba
	(6)	Parvadi
Sabarkantha	(7)	Idar
	(8)	Mohor
Vadodara	(9)	Dolaria
	(10)	Dungarvat
	(11)	Nurpur
	(12)	Tejgadh

Plate 4.1 : Ukai Dam (Surat district) showing use of Deccan Trap as Rubble.