CHAPTER VIII

MARBLE AS DIMENSION STONE

Marble has been used throughout historic time as a building, ornamental and monumental stone because it affords strength, durability, architectural adoptibility and aesthatic satisfaction. The term 'Marble' is derived from Greek word meaning "to sparkle or flash", because the calcite crystals in marble sparkle as they reflect light.

Marble has enjoyed unique position as most decorative construction material all throughout the world and it still continues to be in great demand. The Taj Mahal at Agra,

built of white marble is one of the most magnificent and expensive memorials ever built. The famous Jain temples of Dilwara (Mt. Abu) (Plate 8.1), Kumbhariya, Palitana and Girnar were built from marbles of Ambaji area.

Marble is a metamorphic rock, resulting from the recrystallization of limestone. In stone industry all calcareous rocks taking good polish are grouped as marble. Serpentine rocks because of its attractive colour and capable of taking good polish are classified as marble.

Serpentine marble occurs near Chhuchapura (Vadodara district). It is famous as 'Motipura Marble' and can be termed as Verde antique. It is extensively quarried and used as ornamental stone of great beauty. Ambaji (Banaskantha district) has vast resource of marble which has been worked for centuries. Limestone from Andhav (Kachchh district) takes good polish and can be classified as marble. It is not unlikely that with reduced cost of production, Gujarat State can develop a good export trade in this ornamental stone (Fig. 9.1).

GEOLOGICAL SETTING

Geological setting of marble deposits is as follow:

Sandstone, Limestone of Katrol, Chori and Patcham Series (Andhav limestone)	Jurassic
- - - - - - - - - - - - - - Unconformity - - - - - - - - - - - -	
Erinpura Granite	Post Delhi Intrusive
Phyllite, Limestone, Marble (Ambaji), Calc suit, quartzite	Delhi system
- - - - - - - - - - - - - - Unconformity - - - - - - - - - - - -	
Mica schist, phyllites, slate, serpentine marble (Chhuchapura)	Aravalli system

DISTRIBUTION

In Banaskantha district the marble rocks occur on a five km long and one km broad low ridge made up of small hillocks, NE of Ambamata. It is pure white saccharoidal marble comparatively free from cracks, fissures or joints and bedding planes are rarely seen. It occurs around Ambaji, Jariba and Khokrihill. The area having undergone many episodes of metamorphism has resulted into the recrystallization

Plate 8.2: Photomicrograph showing granoblastic texture in Marble. (Crossed Nicols, X50)

Plate 8.3: Marble quarry, Ambaji, Banaskantha district.

of limestone into marble of different shades. Veinlets of quartz and calcite are quite common. Estimated reserve of marble in this area is about 1.7 million tonnes.

In Vadodara district the serpentine marble is well known as 'Motipura Marble'. It forms a small but conspicuous band near the Chhuchapura railway station (Vadodara-Chotaudepur Section of W.Rly.). Because of its variegated green and white appearance it is very popular as ornamental stone. This rock is highly and irregularly jointed. Estimated reserve of marble in this area is about 1.6 million tonnes.

In Kachchh district limestone occurs at Andhav about 80 km NNE of Bhuj on Bhuj-Khavda road. This limestone is locally quarried as building stone.

PROPERTIES

Ambaji marble is coarse grained, equigranular in texture and consists of calcite (Plate 8.2). This marble is white and greenish in colour, uniform in texture and is free from other impurities.

Motipura marble quarried near Chhuchapura, is green in colour due to the presence of serpentine. It is fine textured and hard. This marble gives flowery appearance because of its variegated green and white colour. It takes

very good polish.

However, this rock is interbedded with calc silicate rocks which do not take good polish. These calc silicate rocks are mainly consist of fibrous minerals like actinolite, tremolite etc. In presence of these minerals rock will not take uniform polish which results into less quarry yield at Chhuchapura quarry where wastage is more.

Andhav limestone is hard, massive, very fine grained and golden yellow in colour. It takes good polish and looks more elegant than marble because of its fine texture and wooden colour. It can be popularised as dimension stone.

Experimental polishing of Andhav limestone was done in the laboratory. First of all, limestone was cut into 1 cm thick pieces with the help of rock cutting machine. Each piece was polished on both surfaces on mild steel plate using 90/300/600 mesh was done on iron plate covered with rough woolen cloth. Polishing media used was suspension of green chromic oxide powder. However polishing cost can be lowered by using silica sand of different mesh sizes as polishing media.

All marbles can be easily polished because it is uniform in mineral composition. Its main constituent calcite is having hardness of 3 on Moh's scale reduces the cost of polishing. Marbles are popular because of their low cost of polishing as compared to those of granite.

Ambaji marble is free from impurities while serpentine marble of Chhuchapura contains iron sulphide in the form of pyrite crystal which on weathering causes discoloration. In Chhuchapura marble, there were inherent cracks and limonite industries in the blocks. As a result of this flaw, production of bigger size slab is very slow.

For exterior use, solubility due to rainwater which causes pitting in marble deserves careful consideration. The rate of solubility is low except near industrial towns where various acids in smoke are absorbed by rainwater. Marble with low absorption and consequently having low rate of solubility are best for exterior use.

The sulphate attack on carbonate rocks proceeds in a dual way, as solution by the action of sulphuric acid or sulphurous acid and by the conversion of carbonates to either calcium sulphite or calcium sulphate. Calcium sulphite has approximately the solubility of calcite in

pure water but is neither influenced by temperature nor by the CO_2 content of the solvent. Calcium sulphate is much more soluble than both. In industrial areas sulphate content is more which will result into weathering of marble. In such atmospheric condition it will not be advisable to use marble.

Lewin (1968) suggested the use of NaF for protecting carbonate rocks from solubility. He found that NaF reacted with the thermodynamically less stable interstitial calcite particles, downward to the depth of maximum fluid penetration; metasomatic replacement took place to form the water insoluble and harder CaF_2, the mineral fluorite. Such conversion of tiny intergranular calcite particles reduces microchannels and diminishes the absorption. The new growth and intergrowth forms a tight network which is stronger and more cohesive than the parent calcitic substance.

Replacement of calcite with barium hydroxide, in the presence of urea as a catalyst, converts calcite to insoluble barium carbonate, the mineral witherite, contact with sulphate converts barium carbonate to the still less soluble barium sulphate, barite.

The treatment of marble with NaF and $Ba(OH)_2$ appears to be promising, serving a dual role as a sealer and hardner.

Compressive strength of marble from the Gujarat State varies from 725 to 958 kg/cm^2. According to Hawkes and Mellore (1970) this rock is classified as strong. The results of laboratory investigation revealed that marble from Gujarat is notably impervious to moisture (Table 8.1).

The ISI specification of Marble (IS 1130 - 1969) is as follows :

Percentage water absorption	:	Max. 0.4 by wt.
Hardness	:	Min. 3 Moh's scale
Sp. Gravity	:	Min. 2.5

Marble from Gujarat satisfying all the specifications suggested by Indian Standard can be used as dimension stone.

Chemical analysis of marble was carried out to determine its CaO content which will be useful for finding out utilization of wastage of marble quarries (Table 8.2).

At Chhuchapura, marble is interbedded with calc-silicate rocks which do not take good polish. Chemical analysis of these calc silicate rocks revealed that SiO_2 content is more than that present in marble which is responsible for its incapability to take uniform polish (Table 8.3 - 232b).

QUARRY METHOD

All the existing quarries of Marble are shown in Fig. 8.1 and list of quarries is given in Table 8.3. At present only metal road or cart track leads to the quarry site. Government of Gujarat should construct for roads upto quarry sites for speeding the transportation of Marble blocks and for the working of quarry operation round the year (Fig. 1.2).

Ambaji Quarry(Plate 8.3): Quarrying is done manually. Overburden is stripped with the help of picks and dumped on one side. In selecting the place for opening the pit care is taken to avoid the areas where rocks are much fractured and jointed, so that big blocks may be obtained from the mines.

Two rows of 1.25 cm diameter holes are manually drilled at right angles to each other upto 2 m depth with a spacing of 5 cm. The holes are generally inclined in the direction of the dip partly as the cleavage planes are in the same direction and partly because the miner finds it convenient to drive. Round wedges are then hammered into these holes in order to split and dislodge the blocks of the marble.

Plate 8.4:

Marble quarry,Chhuchapura,
Vadodara district.

Plate 8.5: Photograph showing outcrop of Andhav Limestone,
Andhav , Kachchh district.

The block thus obtained, is then turned into regular shape. Squaring or dressing is done by wedging out along the rift. Splitting a big block into two is done by fracturing the blocks at right angles to the rift by driving holes of 1.25 cm at interval of 20 to 25 cm and about half the thickness of the block and then separating the space between two holes with a wedge.

At places manually operated cranes are erected. The ropes are directly tied to the block. The blocks are then chisel dressed on the surface before they are sent to the factories for cutting into slabs and for polishing.

The mines are located within 3.2 km to 6.4 km from the nearest power point at Ambaji. If the electric line is extended upto mines, mining operation can be mechanised and the production can be increased. Modern method such as wire saw method can be used for quarrying marble.

Chhuchapura Quarry (Plate 8.4): The area with a flat topography has a very little overburden. The green marble band, which is highly and irregularly jointed is exposed and free face is developed manually by pick and chisels. Thereafter a row of holes spaced 7.5 to 10 cm apart upto a depth of about 2 m are drilled with pneumatically operated Jack hammers. Round wedges are hammered into the holes

manually to split and dislodge the block.

Two hand operated cranes are installed on the surface at the edge of the quarry. These cranes are used for lifting the irregularly shaped mined blocks to the surface from the quarry face. The blocks are then manually dressed.

Dressed blocks are hauled to the factory by track as shown in photography for further processing. A sump has been excavated at the bottom of the quarry for collecting seepage water which is pumped by a centrifugal pump driven electrically and this water is the only source of supply for the requirement of the factory. Due to irregular and highly jointed nature of block, large size blocks are difficult to get. As a result of this mining losses are very high. Only 30% of the material mined are sent to the factory for further processing.

Quarrying is followed in dip direction without forming any benches in hanging wall or footwall. This quarry have gone fairly deep i.e. about 50 m with overhanging wall as a result of which the workings have become very unsafe.

Andhav Limestone (Plate 8.5): Quarry method is not well developed for quarrying dimension stone, however, locally this stone is being quarried for building stone

with the help of wedges and hammer. It is horizontally bedded slabs with thickness 10 to 20 cm and upto a maximum size 2x2 m to 3x3 m can be easily quarried without wastage.

POLISHING

Polishing of marble is easy compared to that of granite. First operation in polishing of marble is edge cutting and sawing which is done with the help of edge cutting machine and gangsaws operated electrically.

Sawing operation done by gangsaws consists of 3.175 mm thick and 10 mm wide blunt flat steel plates fixed in a rectangular frame. The spacing between the adjacent saw plates depends on the thickness of the slabs required. Minimum thickness which can be cut being 22.25 mm. The marble blocks are placed below the gangsaw. The saw frame is given horizontal reciprocating motion, the bottom edges of the steel plates rub against the upper surface of the marble blocks. Ordinary sand layer is put on the block and water is sprinkled automatically. In case of Chhuchapura quarry, water which is obtained from the quarry is reclaimed and recirculated. The abrasive action of the ordinary sand created by the reciprocating motion of the blunt steel plate cuts the marble. Gangsaws can take block for cutting upto 2.44 m x 1.22 m x 1.22 m.

The slabs with irregular sides and having cracks or flows in them are trimmed or cut into various rectangular or square sized blocks by the edge cutting machine. In Chhuchapura quarry, there were inherent cracks and limonite inclusions in the blocks in many cases. As a result of this flaw, production of bigger size slab is difficult.

The cutting machine consists of 25 cm diameter and 3.17 mm thick steel disc on which 9.52 mm thick and 2.5 mm wide cutting material is moulded all round the circumference of the disc. The cutting material consist of emery powder and sulphur in equal quantities which are heated and moulded on the wheel in the factory itself.

Polishing tool consists of steel disc rotating in a horizontal plane over the marble slab to be polished. At the underside of the disc five triangular segments of carborundum blocks are fixed. It is bench mounted and electrically operated. Polishing is done in 5 stages commencing with coarse wheel and finishing with fine grained wheel. The wheel Nos. are 36, 60, 80, 120 and 320 from coarse to fine grained. In Gujarat mainly unpolished blocks are sold, although polishing units are part of the processing units.

There is need for mechanizing the quarry operation as well as for the improvement in processing unit. Wire saw equipment and processing unit can be established at Ambaji quarry site if power is supplied to quarry area. For cutting of marble if diamond blades are used then cutting operation will be faster than that with gangsaws and the surface will be smoother. It will be also helpful for edge cutting.

USES

At present marble is used as ornamental, building and sculpture stone. Production data of Marble is shown in Table 8.4. Marble of Ambaji was used in Jain temples of Kumbhariya, Palitana and Girnar. Marble is used in steps, sills and in flooring of buildings. Marble from Chhuchapura area are mostly used as ornamental stone because of its dark green colour and flowery pattern. They are also used as table tops.

Andhav limestone because of its wooden colour and attractiveness can be used as veneer, building stone and ornamental as well as monumental stone.

In order to obtain some return on quarry waste operator can develop by product markets. At present,

quarry waste is mainly used in tiles industry and as terrzzo chips for flooring. Marble has the same chemical composition as limestone which has extensive and varied market. Quarry waste can be used in chemical and metallurgical industries. Quarry waste also can be used in lime burning. It can be also grund to an impalpable powder for use in whiting and as constituent of stock feed and fertilizers. Quarry waste from Chhuchapura area can be used in crushed form as concrete-aggregate and roadstone.

Table 8.1 : Engineering Properties of Marble

	Location (Fig.8.1)	Compressive strength km/cm^2	Water absorption %	Sp. Gravity
228	Ambaji	958	0.18	3.72
229	Koteshwar	956	0.17	2.92
230	Kumbhariya	657	0.12	2.71
231	Andhav	953	0.39	2.66
232	Chhuchapura	725	0.16	2.75

Table 8.2 : Chemical Analysis of Marble

	Location	SiO_2 %	$Al_2O_3.Fe_2O_3$ %	CaO %	MgO %	Loss igni. %	Total %
228	Ambaji	3.6	0.3	53.0	1.0	42.5	100.4
229	Koteshwar	2.5	0.7	52.5	2.8	38.9	100.6
230	Kumbhariya	1.3	0.6	51.9	3.2	43.2	100.2
231	Andhav	3.0	2.6	52.7	0.8	41.6	99.9
232	Chhuchhapura						
	(a) Marble	9.88	4.0	37.29	12.94	35.66	99.77
	(b) Calc Silicate Rock	23.36	4.5	30.56	17.00	24.60	100.02

Table 8.3 : List of Marble Quarries (Fig. 1.2)

District		Location
Banaskantha	228	Ambaji
	229	Koteshwar
	230	Kumbhariya
Kachchh	231	Andhav
Vadodara	232	Chhuchhapura

Table 8.4 : Production Data of Marble in Gujarat State

Year	Block (Metric Tonnes)	Rubble/Chips (Metric Tonnes)
1968	713	-
1969	748	-
1970	408	306
1971	659	885
1972	827	2179
1973	692	1220
1974	1014	1266
1975	1274	637
1976	1669	2686
1977	1704	2980
1978	1970	3754

(Source: Directorate of Geology & Mining)