A. TYPES AND PROPERTIES OF DIMENSIONAL STONES FROM NWFP (PAKISTAN)- AN OVERVIEW

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1. Introduction
Stone is a general name given to natural solids formed from one or many minerals, with different properties and uses. Dimensional stones (DS) are defined as rock materials obtained for making slabs or blocks of specific size or all those stones which can be cut, polished and used for interior/exterior decoration of buildings. On the average, the use of DS increases by ~6.86% per annum. Annually, 60 million tonnes of DS are produced of which the contribution of China, Italy, Spain and India is more than 50%. Unfortunately, in contrast to the abundance of DS reserves, Pakistan’s share in its production is only 0.58%. The marble reserves of Pakistan amount to ~29.023 billion tons of which more than 90% are located in the North West Frontier province (NWFP), particularly in the districts of Bunir, Mardan, Nowshera, Chitral and Swabi, and Mohmand, Bajaur and Khyber Agencies.

2. Various Types of Marble/Dimensional Stones
In addition to the quantity, a variety of marbles (shown in Figure 3) are found in this region. Some of the known types of marble include granite, limestone, sandstone, slate, and onyx.

Granite, is a light colour, visibly coarse-grained igneous marble, similar to metamorphic rocks in appearance. It is
composed of calcite, feldspar and quartz, with small amounts of mica, zircon, appetite, magnetite and limonite. Limestone mainly comprises calcite, along with dolomitic and siliceous lime-stones. It is a type of calcareous rock, some of which can be polished as marble. Sandstone comprises calcareous and siliceous-cemented sandstones in the form of conglomerates (rounded pebbles and cobbles cemented in a matrix of sand), breccia (cemented angular particles), siltstone (fine quartz and clay particles) and quartzite (metamorphosed siliceous cemented sandstone). Slate is a fine-grained metamorphic rock derived from shale or siltstone that splits into thin layers and is composed mostly of quartz, chlorite, mica and clay minerals. Onyx (means fingernail) appears as comprising sharply contrasting bands of colour in the stone. It is compact rock of carbonate nature, formed through chemical precipitation usually in underground cavities in the form of big lenses and patches. Its specific gravity ranges from 2.6 to 2.8, commonly green in colour with fine texture, bands and patches of red, brown, tan, cream, green and white colour.

Marble is defined as an important dimensional stone which may be metamorphosed limestone \((\text{CaCO}_3)\) or dolomite \((\text{CaMgCO}_3)_6\) or combination of both. Generaly, all decorative calcium rich rocks that can be cut and polished are called marbles. Petrographically, marble has massive deposits rather than thin-layered deposits and consist of a variety of calcite grains.

3. Properties of Dimensional Stones

Properties of Marble are very important because there are certain phenomena in which a marble looses its properties. For example, in dry and acid free atmosphere, the marble sustains its hardness for relatively longer and remains durable. Purest form of marble is white with visible crystalline structure. Calcite marble, that are exposed to moisture maintains a relatively smooth surface during weathering; but dolomite limestone may weather with an irregular sandy surface. The density of marble ranges from 2.7 to 3.2 \(\text{gm/cm}^3\), with porosity ranging from 0.0002 to 0.5%. If it gets denser, its cutting becomes difficult. Its resistance to abrasion or scratching depends upon the strength of the rock which is important for drilling and use. On MOH scale, marble is on number three. Hard marble is considered ideal for paving steps and floors while soft marble is used for sculpture and decorative purposes. Marble with lower water absorbent properties is preferred as it has inverse relationship with strength. Colour is also important in the marble market as pure marble is white in colour and different minerals, give various colours to marble. For example, the black colour comes from biotite, hornblende and carbon, where as the brown and yellow colours are due to limonite. Red colour may be due to hematite and green colour is associated with mica, chloride, silicate and serpentine.

Transportation cost which depends on the specific weight (2.2 to 3.2 tons/m\(^3\)) of marble also influences marble market value. On the other hand, highly permeable and porous rocks with porosity >0.5% are considered lower in quality. Fine grained marbles are harder than the coarse grained marbles. Marbles comprising small crystals are transparent and easy in polishing. The strength depends upon the phase(s)
present, porosity, hardness, crystal
distribution and impurities. Usually uniaxial
compressive strength of true marble is 500-
1500kg/cm$^3$. Durability is the ability of a
stone to endure and maintain its essential
and distinctive characteristics e.g.
resistance to decay, strength and
appearance. Durability is based upon the
stone's natural properties and the
environmental conditions to which it is
subjected to. Aesthetic durability or
dimensional stability is the ability of a stone
to resist cosmetic changes i.e. the Color
Stability. Changes in color can occur in two
ways; a) when some stones are used in
exterior applications and exposed to
direct sunlight, they fade or change color.
Dark colored stones and those that contain
organic matter will generally fade to a
much lighter color. b) Some stones have
moisture sensitive mineral contents that will
cause the stone to develop rust spots, or
other color variations, or contain moisture
sensitive substances that will cause blotchy
and streaking discolorations. Certain
limestones contain bituminous materials
that are soluble when exposed to moisture.
The quality and durability of marbles are
often used interchangeably when dealing
with stone problems and can be classified
into two categories namely; innate qualities
and man-made qualities. Innate qualities
include the physical properties and natural
characteristics of stones. American Society
for Testing and Materials (ASTM) has
developed standard definable and
controllable test methods for evaluating
these properties for a specific application.
Man-made qualities are those resulting
from the fabrication process at the factory
level. They include size, thickness,
squareness, flatness and surface finish etc.
These qualities can be objectively
evaluated in relation to established industry
standards. For instance, squareness is
determined by the four angles of the tile. If
any of the four angles deviates from 90°, it
will affect the other three angles. If the tiles
are not square, the joints and seams in an
installation cannot be aligned. The Marble
Institute of America (MIA) has classified
marble and stones into three groups
depending upon the soundness of their
fabricating qualities. The classification
indicates what method of fabrication is
necessary.

4. Weathering
Weathering is a complex interaction of
physical, chemical and biological
processes that alters the stone in some
general or specific way. The physical
properties of stones differ widely between
stone groups and even within the same
stone type. The mineral composition,
textural differences, varying degrees of
hardness and pore/capillary structure are
the main reasons why neither all stones
nor all the surface of the same stone
shows signs of alteration uniformly. These
minerals can be broken down, dissolved or
converted to new minerals by a variety of
processes, which are grouped as
mechanical processing and chemical
processing.

a. Weathering by Mechanical Processes
Mechanical processes include frost action,
thermal expansion, wetting and drying, and
salt decay. These processes generally lead
to weakening of the stone, increasing its
permeability that allows relatively more
water penetration and increases the areas
for the chemical weathering processes to
take place. Frost action or commonly called
freeze/thaw cycles occur when water within
the pore structure or cracks freezes to ice. When water freezes, it expands between 8 to 11%, with a force ranging from about 128 to 150tons/sq.ft. Thermal expansion is a known phenomenon and different minerals expand and contract at different rates. It is also known that the temperature of stone can vary between 30 and 50% higher than the average air temperature. Water in the pores makes thermal stressing more effective, which eventually leads to surface flaking. Additionally, stone expands when it absorbs water and shrinks as it dries, so exposure to moisture or contact with water affects its durability. Salts are some of the most damaging agents to stone and manifest themselves in a process commonly referred to as Efflorescence. The most common form of efflorescence is the appearance of salts at the surface in the form of a whitish to gray powdery fluffy blooms. Sub-efflorescence is similar to efflorescence, however instead of the salts being transported to the surface they crystallize and buildup within the pore/capillary structure beneath the surface. As salts accumulate, internal pressures develop which generate spalling and flaking, and may eventually lead to deep deterioration of the stone.

b. Weathering by Chemical Processes
Weathering by chemical processes involves complex chemical reactions that alter the internal structure of minerals by removing and / or adding elements through dissolution, oxidation, hydration and hydrolysis. Water, in all of its occurrences (rain, fog, raising ground moisture and ocean) and its chemical composition is the most important element in this process. It acts as a solvent and also as a chemical reactant. Carbon dioxide (CO₂), oxygen and climatic conditions influence the type and rate of weathering, alterations and decay of stone.