

Architectural Significance of Granite and Other Durable Rocks in the Context of India – An Analytical Study

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Abstract: *Architectures created through the cutting of naturally occurred massive rocks include different structures, buildings, tombs, monuments, caves and sculptures. On account of hard and tough property, the granite is considered as strong construction stone in human history. Granite is very common in the continental crust of our mother earth. It is characterised as coarse grained plutonic intrusive igneous rock and is composed of quartz, alkali feldspar and plagioclase. Typical mineralogical character and textural varieties of granite facilitates to develop a wide range of colours, which include white, pink and grey etc. Granite rocks established itself as praiseworthy architecture stone since historical past because of its distinctive character like durability, appreciable finishing, fascinating polish nature and above all its magnificent colour diversities. As architectural stone, the granitic rocks demand attraction owing to the combination of style and elegance. The application of granitic rocks is witnessed in the ancient world through the mesmerising major architectures in India and around the world like Mount Rushmore, Washington Monument, Great Pyramid of Giza; Ajanta and Ellora caves, monolithic structure in the Zagwe-built Lalibela in Ethiopia along with in most of the long-lived old Indian temples, old forts and monuments etc. The monolithic free-standing architecture is generally rock-cut structures as depicted in the Ellora Kailasanathar Temple. The biggest monolithic statue in world, the Gommateshwara statue of Bahubali at Shravanabelagola present in the Indian state at Karnataka was carved in the 983 CE from a single block of granite rock. The radioactivity stuff in the granite is an important concern to the people in recent world. Even though the impact of radioactivity is proved mostly very less harmful to mankind, current research indicates that few granite products are showing radioactive substance index beyond permissible limit of the specified standard, which is responsible for environmental pollution during the use for long. Therefore, due attention is required towards the pertinent issue of radioactivity in the granite stones. Apart from granite, many of the architectures in India are created by the other rock types that include rocks like sedimentary, metamorphic and igneous rocks.*

Keywords: Architecture, Granite, Ancient History, Polishing Nature, Radioactivity

I. INTRODUCTION

People are in use of granite since time immemorial for multiple constructions and building beautiful architectures. For construction of building, bridges, paving, fort, monuments along with many other interior and exterior projects, granites are in use widely. For indoors, polished granite slabs and tiles are used in countertops, tile floors, stair treads; building veneer; cemetery monuments and various other design elements. Granite is widely used for architectural facades, construction materials, ornamental stone and monuments. The forts, monuments and palaces are made of all type of rocks like sedimentary, metamorphic and igneous rocks in India. The noteworthy rocks used in the architectural heritage under major rock types are as follow:

1. Sedimentary rocks include different types of sandstones, clay stones and limestone etc.,
2. Metamorphic rocks include all type of marbles and quartzite etc. and
3. Igneous rocks include granite and basalt, etc.

1.1 Forts, Monuments and Temples in India

In India the monuments, forts or temples are made up of all type of rocks - sedimentary, metamorphic and igneous. The sedimentary rocks include the different type of sandstones, clay stones, limestone etc., the metamorphic rocks include all types of marbles, quartzite etc., and the igneous rocks include granite and basalt. As for example, the Taj Mahal is mainly made up of *Makrana* Marble from Rajasthan which is unique because of its purity and luster. The Red fort of Delhi and Agra both are made by red sandstone which are of Vindhyan age and brought from present day Mirzapur and Sonbhadra District. Hawa Mahal of Jaipur and other monuments of Jaipur are made by locally found Marble which is of pink colour and that's the reason why Jaipur is called as pink city of India. Deewan-e- Khas and Deewan-e-Aam in Agra are made by white marble. Maximum forts in North India are made up of various sandstones, but same in Maharashtra are made by basalt as basalt is easily found there. The famous Ajanta Ellora caves, Elephanta caves are carved out of massive basalt. Rameshwaram Temple also contain majority of sandstones and marble. But the utility of granite was in vogue in India through the ages. A brief detail of the few granite temples or monuments in India are as follow:

1.2 Temples and Monuments made up by granite rocks in India

A. Brihadeswarar Temple, Thanjavur, Tamil Nadu

Brihadeswarar Temple in Tanjore or Thanjavur, Tamil Nadu, established in 1010 C.E., is dedicated to Lord Shiva. The temple is said to be made of some 60,000 tons of granite. Featuring historic frescoes, mural paintings, and painstakingly detailed sculptures, this temple is equally fascinating to architecture, art, and history enthusiasts.



Figure 1: Granite made Brihadeeswarar Temple, Thanjavur, Tamil Nadu (Source: Wikipedia)

The temple has been designated as a World Heritage Site¹ by UNESCO². It is one of the largest temples in South India and an example of Dravidian architecture. It is built by Tamil king Raja Raja Chola I, between 1003 and 1010 AD. Built out of granite, the *vimana* (the structure over the *garbhagriha* or inner sanctum in the Hindu temples of South India) tower above the sanctum is one of the tallest in South India. The temple has a massive colonnaded *prakara* (corridor) and one of the largest Shiva *lingas* (in India, the complex also includes stone images of *Nandi*, *Parvati*, *Kartikeya*, *Ganesha*, *Sabhapati*, *Dashinamurti*, *Chandeshvara*, *Varahi* and others. On the walls of these temples, one can see series of 2mm diameter of holes in the granite stones made 1003 years back. The craftsmen in

those days carved out a series of 2 mm holes in the granite, the hardest stone without modern day drilling machine. It is worth-visiting among many other beautiful temples in Tanjore.

B. The Iconic Vithala Temple Complex, Karnataka:

Built during the 14th century, this temple displays the grandeur and complex craftsmanship of the period. The Stone Chariot temple is carved out of a single block of granite and resembles the Konark Sun Temple chariot.



Figure 2: Single block Granite Vithala Temple Complex, Karnataka (Source: Wikipedia)

There is a strong influence of Dravidian architecture throughout this temple. Ornate *Mantapas* (porches) and Musical Pillars are some of the worth-seeing sights here, along with the Stone Chariot temple. The musical pillars literally have musical instruments carved into the stone and during the period they were fully functional instruments in use.

C. The Gommateshwara Statue, Karnataka

The Gommateshwara statue is a colossal statue of Jain Bahubali (meaning ‘the One with Strong Arms’), found in Karnataka, India. Bahubali was the son of Rishabhanatha, the first *Tirthankara* of Jainism. The statue is located in the town of Shravanabelagola, Karnataka. The massive statue is located on the top of Vindhyagiri, one of the two hills in Shravanabelagola (the other being Chandragiri). The statue was carved out of a single piece of granite and reaches a height of 17 meters (about 56 feet), making it one of the largest monolithic statues in the world. It was built around 983 AD by Chavundraya, who served under Rachamalla II, the ruler of the Ganga Dynasty.

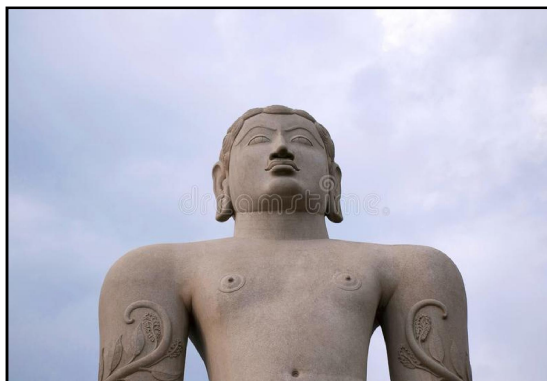


Figure 3: Gommateshwara Statue carved out of a single piece of granite at Shravanabelagola, Karnataka (Source: Wikipedia)

1. UNESCO is the United Nations Educational, Scientific and Cultural Organization is a specialized agency of the United Nations based in Paris.

2. World heritage site is a landmark or area which is chosen by the UNESCO as having cultural, historical, scientific or other form of significance, and is legally protected by international treaties.

D. The Barabar Hill Caves in Bihar

The Barabar Hill Caves are the oldest surviving rock-cut caves located in the region of Jehanabad district of Bihar. The caves were built during the Mauryan Era (322–185 BCE). Most caves at Barabar consist of two chambers, carved entirely out of granite, with a highly polished internal surface, the “Mauryan Polish³” also found on sculptures, and exciting echo effects. On the Barabar hill lies a huge rock of about 30 m x 150 m, on which four caves were excavated. It must have been quite hard work to excavate such large inner spaces from stiff granite rock by means of chisels only. These rock-cut caves date back to the 3rd Century BCE, Maurya period, of Ashoka (reigned 273 – 232 BCE) and his grandson, Dasharatha Maurya.

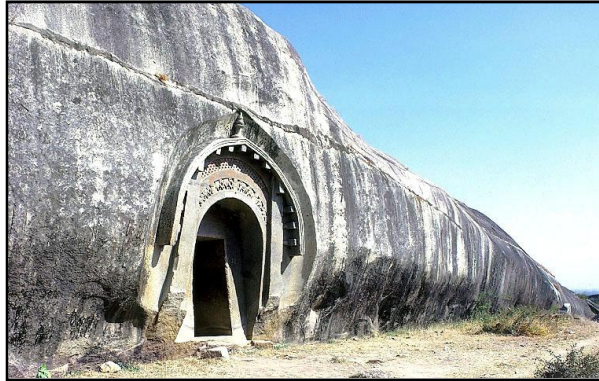


Figure 4: Cave temple on Barabar Hill carved out from granite rock in Bihar (Source: Wikipedia)

The caves were founded by Makkhali Ghosala, a contemporary of Gautama Buddha, for the aesthetics from the Aivika section. At the site, there are several rock-cut Buddhist and Hindu sculptures and Ashokan inscriptions.

E. The Rock-cut Temple at Kalugumalai in Thoothukudi District

Kalugumalai Vettuvan Koil stands as the only one example for the early Pandyan monolithic art. The divine sculptures represent various forms of Siva, Umamahesvara, Dakashinamurthi, Vishnu, Brahma, Karthikeya Surya and Chandra are very neat and fine execution of sculptural art.

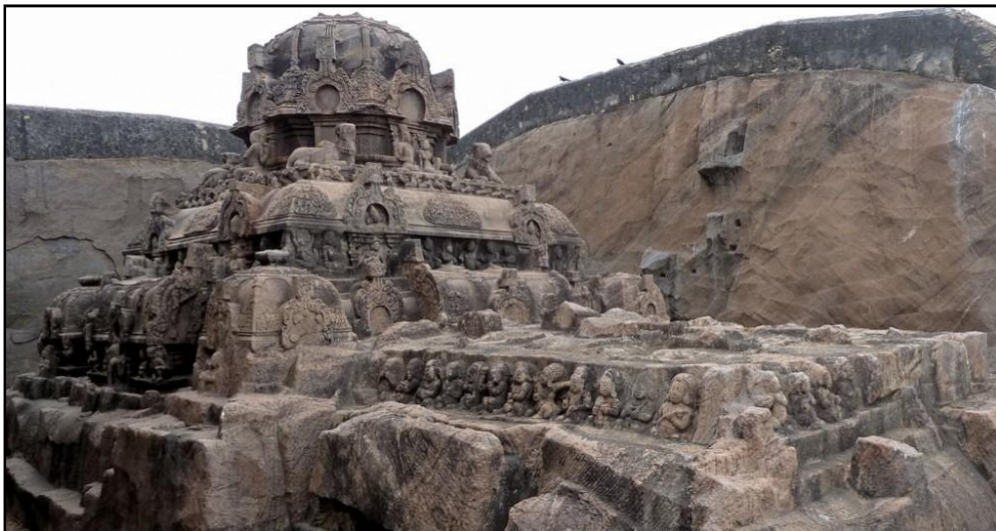


Figure 5: The granite rock cut temple at Kalugumalai in the Thoothukudi district in Tamil Nadu (Photo: Wikimedia Commons)

3. Mauryan polish is considered to be one of the essential characteristics of the sculptures of Mauryan Empire in India, in the 3rd century B.C. It a remarkable polish of the statuary which gives a shiny aspect to the stone material, generally of granite or sandstone.

The dressing pattern and ornamentation of these sculptures represent not only the significance of Pandya's art but also the influence of Pallava, Chalukya and Rastrakuta art traditions. The Vettuvankoil is a small temple, which consists of small sanctum sanctorum facing east. This monolithic temple, consisting of several architectural images and beautiful plaster of great beauty in its Vimana, is at the top of the hill at Kalugumalai⁴. It must be mentioned here that it is the only rock cut monolith available in the Pandya region. This temple is datable to 08th Century A.D. The artisans have cut out along hill of granite by cutting the latter into three parts. The dimension of such a boulder is 30 feet in depth, 47 feet in length and 24 feet in width.

II. CHARACTERISTICS OF GRANITE

2.1 Mineralogical Characteristics

Granite is a plutonic counterpart of igneous rock, formed in deep of earth's crust. It is consisting of three minerals include Quartz, Mica (mostly muscovite) and Feldspar (usually orthoclase). The main chemical composition of the granite are SiO₂ (65% to 70%); a little of Al₂O₃, CaO, MgO and Fe₂O₃ and thus it is acidic in nature. Hence, SiO₂ is the predominant constituent; granite is acid resistant as well as erosion resistant.

Granite is one of the hardest dimensional stone. Granite is durable because its porosity and water absorption are small and also weather resistant. Due to its strong mineralogical character, everlasting durability and beautiful colour and polishing nature, granite is considered as the best building material. Indian granite has huge durability and strength. The majestic colour of granite is caused by dark mica and starry quartz sand. Granite is poor fire resistance. The quartz in the granite will have crystalline transition in 573^oC temperature; which will facilitate the breakdown of the granite rock in the contact of fire. The physical and mechanical properties along with mineralogical composition are shown in Table 1.

	Features	Baltic Brown
Physical and Mechanical	Grain size (mm)	0.6-20
	Water absorption (%)	0.22
	Specific bulk density (KN/m ³)	26.8
	Uniaxial compressive strength (MPa)	194
	Flexural strength (MPa)	12.7
Mineralogical Composition (%)	Alkali feldspar	57
	Quartz	21
	Plagioclase	15
	Biotite	3
	Other	4

Table 1: Physical and Mechanical Properties of Granite with Mineralogical Composition (Source: Research Gate)

2.2 Radioactive Toxicity Character of Granite

The mining of granitic rocks from the earth they naturally include some radioactive elements, and may infrequently emit the radon gas. The exposure of radon gas over the years may cause cancer, the primary health concern with this gas (wikipedia). Radon is considered as a natural radioactive gas, which is not visible, has no smell or taste. The presence of radon in home can cause a danger to the health of family members. Most importantly, radon can be the reason of lung cancer among the non-smokers. Radon is the second-leading cause of lung cancer in America, and claims about 20,000 lives annually (Source: Environmental Protection Agency). It may be advised to consider testing before purchasing the granite countertops for home. It is to be ensured that the amounts of radon gas getting emitted from the granite countertops are safe for health.

Granite is a popular choice for today's luxury homes and offices because of its enduring beauty and especially because no synthetic material can yet be comparable with its elegance and durability. Research reveals that there are

4. Kalugumalai is located in the Thoothukudi district in Tamil Nadu. The place houses the rock-cut Kalugasalamoorthy Temple, monolithic Vettuvan Koil and Kalugumalai Jain Beds

some granite products, whose radioactive substance index exceeds the specified standard are responsible for pollution to the environment during use for pretty long years. To avoid the adversity of radioactive pollution of granite, the Grade-A granite products to be used and people should ensure during buying the granite slabs for household uses. People should insist the dealer for qualification certificate of radioactivity test prior to buy the granite slabs. Without this precaution, the use of this beautiful stone will be causing harm to the people.

III. DISCUSSION

3.1 Architectural Importance of Granite

Granite is a natural stone. It is documented that it was quarried long ago in ancient Egypt for building construction purposes. Considering its typical architectural beauty, granite has been used for world's most famous memorials and monuments. Here are the examples of few world class architectures:

1. The world's most recognisable granite monument, wherein annual influx of tourists around 3 million, Mount Rushmore National Memorial at USA was dedicated in 1934.
2. The Vietnam Veteran Memorial located at Washington D.C. was dedicated in 1982.
3. Diana, the Princess of Wates Memorial Fountain located at London Hyde Park was dedicated in 2004, that visited by around 1 million tourists annually.

Apart from granite and other igneous rocks were also used for construction of historical monuments, memorials and forts throughout the world. Every fort and monument has its own architectural styles, religious entities, period of construction. To match that architectural style suitable stones are playing a key role. The monuments can be classified based on their periods of construction. Period wise monuments constructed are given in Table 2.

Period	Monuments
Ancient India	Indus Valley Period; Magadha Empire and Gupta Empire
Mughal	Medieval India
Modern India	Recent Monuments

Table 2: Monuments constructed during historical period in India (Source: Wikipedia)

Architectural styles are also having important role to play for classification of monuments, memorials and forts. South Indian monuments are depicting the architecture of Dravidian period and monuments of Mughal periods are typical of Turkish-Persian architecture. The famous historical fort and monuments of India in different periods with their building materials are shown in Table 3.

Sl. No.	Fort/Monuments/Temple/Memorial	Rocks used
1	Brihadeswarar temple	Granite
2	Taj Mahal, Agra and Victoria Memorial Hall, Kolkata	Makrana Marble
3	Red fort of Delhi and Agra	Red sandstone which are of Vindhyan age
4	Hawa Mahal of Jaipur and other monuments of Jaipur	Locally found Marble
5	Deewan-e Khas and Deewan-e Aam	White coloured marble
6	Maximum forts in North India	Various sandstones
7.	Forts in Maharshttra	Basalt
8	Famous Ajanta Ellora caves & Elephanta caves	Massive basalt
9	Rameshwaram Temple	Majority of Sandstones and Marble
10	Lotus Temple	Marble
11	Qutub Minar	Red sandstone and marble
12	Sanchi stupa	Sandstone
13	Humayun Tomb	Red Sandstone
14	Most acclaimed masterful model in Mount Abu	Marble
15	Konark, Orissa Khajuraho, M.P., Sanchi, M.P. Pandawa Mahal	Sand stones

16.	Vivekananda Rock Memorial, Kanyakumari, Tamil Nadu	Granite
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Table 3: Famous historical forts and monuments of India built in historical periods and rocks used (Source: Wikipedia)

IV. USE OF OTHER ROCKS IN CREATION OF MONUMENTS, FORTS AND TEMPLES

Architects have used stone as a medium in different decades. Stones like limestone and sandstone were used in the past because they are easily cut from the ground. Harder stones, like granite, are more common today and are able to withstand weathering for longer period. Granite has been used in building monuments since the great pyramid at Giza was lined with blocks of it. It has been mined since the 19th century in America. The Washington Monument in Washington D.C. is largely composed of granite. The world's most ancient monuments are made of limestone. The pyramids at Giza were built by using limestone. It is a sedimentary stone composed of fossilized organic sea creatures like clams, corals, brachiopods and bryozoans. Limestone is soft, easily cut and carved and widely available and thus was used since ancient period. It is particularly susceptible to weathering and will erode when exposed to water and wind. This is probably why the pyramids were lined with granite, a harder casing stone. Sandstone, like limestone, is a sedimentary rock. Sandstone is made of fossilized and solidified sand. The particles of sand must be between 0.1mm and 0.2mm in diameter to qualify as sandstone. Smaller particles that solidify are called shale or siltstone. Sand is usually a mixture of quartz and feldspar grains with calcite, gypsum or clay connecting the stone. The Ankor Wat temple in Cambodia is made entirely of sandstone.

V. CONCLUSION

The building and ornamental stones are part of our culture and civilization in India. Permeable rocks may cause harm to the structures as water seepage takes place. Weak rock types are not suitable for the creation of architectures. So, the weak minerals like mica, talc, calcite, pyrite, chlorite, magnetite and clay minerals are generally not used for the construction bigger architectures. The durable rock types like sandstone, limestone, dolerite, soapstone (metamorphic rock), Makrana marble, limestone and basalts along with granites used for the construction of age old architectures.

Various civilizations have witnessed the structure of religious buildings and palaces carved out of these beautiful stones gifted by nature. In India, the use of granite is evident in the building architecture of several temples, monuments, forts etc. Most of the important forts, temples, palaces and other buildings in south India, are built of granite stones of various colours whereas similar buildings in northern India are built with marble and sandstone. Ancient forts like the Tanjore Fort in Tamil Nadu, the Golconda Fort near Hyderabad, Chitradurga and Bellary Forts in Karnataka, are few examples of granite architecture. There are thousands of temples spread over Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and Orissa. The tallest monolith statue in the world that of Gommateswara (Bahubali), of the 20th century, at Shravanabelagola in Karnataka is an outstanding example of granite stone statuary. In the Vijayanagara architecture in modern Karnataka, the local hard granite has been used in the Badami Chalukya style. Granite is the most sought-after building stone since long. In the ancient times, the granite pillars and beams were preferred material to support the huge structures of temples and palaces and for making protective walls around them. With the invention of modern tools of greater hardness and polishing ability, the use of granite has rather increased for aesthetic values. Sometimes it is found that the use of granite reduced the density of sculptured works, granite was a more durable material for the temple structure. Because of the flexibility of the cutting tools, many artefacts of granite for decorative purposes were made. The use of granite down the centuries in raising the monuments and memorials is well-known and is evident from the above cited facts. Granite represents one of the oldest building materials and its availability and durability have led to its wide and successful use for building purposes through the centuries.

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