

# A review paper on Mechanical and Thermal Properties of Granite and its Industrial Applications.

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**Abstract :** In Stone Age, stone were used for making weapon and tools. Granite is a stone with specific chemical composition and with certain impressive properties. Due to some of the better properties, instead of conventional machine tool materials, an attempt is made to use the granite for various industrial applications. In this paper literature survey for impressive property of granite is made. Granite is being used for surface plate, Co-ordinate Measuring Machine parts, and precision machine tool bed and in precision industry.

**Keywords :** Granite, Thermo-Mechanical Properties, CMM, Precision Machine Tools, Epoxy granite.

Abbreviations :HV : Vickers Hardness, IT1 : International Tolerance Grade 1, BC : Before Christ.

## I. INTRODUCTION :

The variety of materials available for industrial applications, basically are metal, reinforced composite materials, stone, ceramic, polymer concrete, and porous. Metals are invented in Bronze Age [46]. In metals Ferrous and nonferrous are main materials used for machine tools and components. Though ferrous materials have good tensile strength, but limitations like achievement of high geometrical accuracies up to micron/sub-micron level, corrosion, high thermal coefficient of thermal expansion etc. are seen. Granite can be used to overcome the limitations. Granite is a crystalline hard stone consisting of quartz, mica and feldspar [30]. The mechanical and thermal behavior of a machine frame depends on the elementary material properties (Young's modulus, shear modulus, bending and tensile strength, material damping, density, heat conductivity and capacity, thermal expansion coefficient), the dimensions and cross sections of the structural components [46]. From literature study the typical physical and mechanical properties like good compressive strength (15 to 30 x 10<sup>6</sup> kg/m<sup>2</sup>) is observed. Granite follows Hook's law and has Young's modulus of 65–113 x 10<sup>6</sup> N/m<sup>2</sup>. Hardness of granite varies in the range of 5 to 7 Moh's scale, which is quite good against scratches. Properties like low density, good damping property and low coefficient of thermal expansion are useful for machine parts. Some of the Indian granite are having magnetic properties. For designing of granite based machines, knowledge about stone processing is essential. All these properties can be marked to use granite in different industrial applications. Granite is used for different applications like surface

plate, coordinate measuring machine parts, precision machine tool beds, road construction, building construction, food storage etc. are discussed in this paper.

Granite:

Granite technically refers to a light-colored granulose plutonic rock composed of feldspars, plagioclase, quartz (35% approx.) and minor amounts (45% approx.) of mafic minerals, such as, biotite, hornblende, pyroxene, iron oxides, etc. Granites are generally medium to coarse-grained igneous crystalline rocks that form by crystallization of certain slow-cooling magma [31, 34]. Granite is defined as the rock having percentage more than 67% silica. It is found in different color shades from light colored to dark grey shade [American Heritage Dictionary of the English Language (2009)] its properties vary region wise all over the world. With smaller grain size, the mechanical properties increase. Processing of granite predominantly includes sawing, drilling and grinding. By grinding, a straightness and planarity of 5 µm/m can be achieved. Granite is nonconductive, stainless and they do not generate burrs [46].

Indian Granite and Other Granite Indian Granite (IG):

The IG is hypidiomorphic in texture and homogeneous in structure. On the basis of mineralogical composition, the IG is also known as biotite–amphibolite granite. The mineralogical composition and mean grain size of IG are given [30]. In the world market, there are nearly 300 varieties of granite of which India supplies about 200 varieties. Out of these, prime varieties represent a wide spectrum of color, texture and structure. Major production of granite in raw as well as processed form is generally from Andhra Pradesh, Rajasthan, Karnataka, Tamil Nadu and Gujarat. State wise breakup of total resources reveals that Karnataka & Rajasthan share about 20% each of the resources which are followed by Jharkhand (19%), Gujarat (18%), Andhra Pradesh (5%) and Madhya Pradesh (4%) these states together account for 86% of the total resources. Grade wise classification reveals that about 7% of the total resources fall under black granite while 92% under coloured granite. About 1% resources are of unclassified grade [Indian Minerals Year book 2013].

Table 01: Varieties of Granite in Various States of India. [Indian Minerals Year Book 2013]

State	Variety
Andhra Pradesh	Black Galaxy, Srikakulam blue, Steel grey, Paradiso, Anantapur grey, Silver Galaxy, etc.
Bihar	Tiger skin, Mayurakshi blue, Sawan rose, English teak, black-cheeta, etc.
Gujarat	Sonabadi grey, Balaram pink, Ajapur Galaxy, Godhra grey, Maharaja tiger-black, etc.
Haryana	Steel-grey porphyry, Purplish granite porphyry, Deep pink.
Karnataka	Ruby red, Fish Belly, Himalayan blue, Sira grey, Red multi, Tumkur porphyry, Hassan green, Magadi pink, Tiger black, etc.
Kerala	Tropical green, Paradiso, Kerala white, etc.
Maharashtra	Grey silk, Light pink, Jhansi red, etc
Madhya Pradesh	Multicoloured, Black granite, etc.
Odisha	Berhampur blue, Silver grey, Seaweed green, Chilka blue, Red pearl, Jeypur and Keonjhar black, etc.
Rajasthan	Mokalsar green, Nagina green, Rosy pink, Blue Pearl, Chima pink, Bala flower, Platinum-white, etc.
Tamil Nadu	Kashmir white, Rawsilk, Paradiso, Pink multi, Colombo Juparana, Tiger skin, Kunnam black, Turaiyur blue, etc
Uttar Pradesh	Ruby red, Jhansi red, Grey granite, Black granite, etc.
West Bengal	Bero pink porphyry, Streaky gneiss, Purulia black, Birbhum pink, Spotty black, etc.

#### Other granites

Granite rock contains a high percentage of SiO<sub>2</sub> (>70%) and many hard but fairly coarse quartz crystals (>40%). However Gabbro-rocks of which Diabase (Dolorite). Swedish black rock and African Impala are representatives, has less SiO<sub>2</sub>(≈50%) and quartz crystals (≈ 4%), but far more Mg and Fe-oxydes. Due to the low percentage of small quartz crystals this material can easier be finished to a good flatness quality, guaranteeing a surface with good hardness and wear resistance and good bearing capacity [22]. Commonly used natural stone grades are Gabbro Impala, Tarn, Fine Black, Black Galaxy or Ji Nan Black (Table 02). Granite can favorably be used as a base for prototype machines due to its high and fast availability [46].

Table 02: Technical values of natural stone materials [46].

	Impala (South Africa)	Black Galaxy (India)	Ji Nan Black (China)	Tarn (France)
Density x 10 <sup>3</sup> [kg/m <sup>3</sup> ]	2.90	2.90	3.00	2.90
Compressive strength x 10 <sup>6</sup> [N/m <sup>2</sup> ]	30	190	250	180
Bending tensile strength x 10 <sup>6</sup> [N/m <sup>2</sup> ]	20	19	26	24
Young's modulus x 10 <sup>6</sup> [kN/m <sup>2</sup> ]	90	44	70	46
Thermal expansion coefficient [10 <sup>-6</sup> K <sup>-1</sup> ]	6.5	6.0	5.0	6.0

#### Granite Properties under Considerations

##### Density

The density of granite varies from 2.50×10<sup>3</sup> kg/m<sup>3</sup> to 3.0×10<sup>3</sup> kg/m<sup>3</sup>. Indian Granite has a density of 2.59×10<sup>3</sup> kg/m<sup>3</sup>. Variation in density may be because of grain structure (coarse to finer). Density of granite is about one third of steel, hence gives benefit in specific strength. In high precision machine applications, material should be rigid one and do not undergo deformation. Granite gives high damping capacity due to its higher density as compared to Cast Iron. It can withstand against loads without changing its dimension. Granite is often used for high-precision and metrology applications because of its Form(shape) stability.

##### Compressive Strength

Compressive strength is high enough to withstand against environment without changing its structure. Compressive strength varies with change in temperature. Compressive Strength of Indian Granites varies in 100 - 220 x 10<sup>6</sup> N/m<sup>2</sup>. Black Galaxy Granite having a 190 x 10<sup>6</sup> N/m<sup>2</sup> Compressive Strength. Compressive loading is preferred while designing structural element with granite [46].

##### Tensile strength

Tensile strength of the granite is considered while designing structural element. The tensile strength decreases with increase in temperature. So temperature must be maintained to avoid deformation due to changes in tensile strength. Tensile strength is determined by using standard International Society for Rock Mechanics (ISRM). Bending Tensile strength of Black Galaxy Indian granite is around 19 x 10<sup>6</sup> N/m<sup>2</sup> which is compared with other country granites in table 2.

##### Young's modulus (E)

Fine grain granite achieves Young's moduli of 65–113 x 10<sup>6</sup> N/m<sup>2</sup>. [46] Young's Modulus gives elastic nature of material. So for high precision machine applications material should be rigid one and do not go under deformation. Young's modulus (E) values were determined from normal stress vs. axial strain plot. Lateral and axial displacements were recorded with the

help of mechanical dial gauges having least count of 0.01 mm. [30]

#### Hardness

Shore Hardness from 85-100[1] high hardness (850–900 HV) [46]. Due to the high hardness, abrasion resistance and homogeneous surface, granite is suitable for aerostatic and hydrostatic bearings and guides.

#### Porosity

Porosity of Indian Granite was determined to be 0.8%. Material should be porous enough so it can't absorb moisture so that it will not undergo deformation to perform its high precision applications [30].

#### Moisture Content

Due to Moisture Content and moisture absorptivity material will undergo deformation. Moisture Content should be as low as possible to avoid dimensional changes along any direction. The average moisture content 0.09%.

#### Coefficient of linear thermal expansion

The coefficient of linear thermal expansion increases with temperature and it will change structure of granite which will give undesirable effect and not perform its function in metrological applications. Coefficient of linear thermal expansion ranges from 4-10 $\mu$ m/m/0C [1]. As coefficient of thermal expansion is low, granite is popular material for precision machine and measuring machine.

#### Thermal conductivity

Thermal conductivity of the Bundelkhand granites are measured by using the Divided bar method. Thermal conductivity of alkali granite varies from 3.5 to 3.6 W/m K whereas thermal conductivity of plagioclase granite is measured as 3.15 W/m K. Alkali granite in which plagioclase content is relatively higher has thermal conductivity value of 3.4 W/m K.[31]. Although change its thermal conductivity is lower in granite takes long time to change its form.

#### Granite and its Industrial Applications

Granite is having very good mechanical and thermal properties. Granites are used for different Engineering and Industrial applications, some the applications are explained here.

#### Surface Plate

Surface plate made up of granite is popular in the world, for measurement of the parts using conventional measurement method. Special characteristics of the Granite Surface are the flatness up to subzero microns, the hardness, wear resistance properties. By lapping, dimensional allowance of IT1 can be achieved. Better thermal stability in comparison with cast iron surface plate. Good compressive strength gives required load carrying capacity. Size of the surface plate for particular load and relative deformation can be calculated using

finite element method. One of the only disadvantages is fragileness/brittleness, because of which rupture may happen. Granite surface plates are fitted with, glued steel inserts, which provides clamping arrangement [22].

#### Coordinate Measuring Machine Parts

Coordinate measuring machine is the machine which is used to get the three coordinates and hence complete geometry of the part to be measured. In the CMM, three scales are attached to each other on the three mutually perpendicular axis. Scale readings are taken through optical read head. Probing system with stylus & ruby sphere is used to touch surface of the part to be measured and pick up the coordinates at that points. These triggered points are given to CMM software for processing & data out is shown on screen of computer.

Accuracy of the CMM is highly depends on the axis accuracy and its thermal stability. Granite axis can be prepared with high straightness accuracy of 1-2 microns per meter, flatness of 0.5 micron per 100 mm square area. Granite is one of the most suitable material to run the aerostatic bearing because of its hardness & super finish. Because of all these properties granite is the most famous material being used as CMM axis material. Granite base is used as first element to build the complete machine and to load the part for measurement. In addition to all above properties Granite base provide high damping, low thermal conductivity (3.2 W/m K) and high long term stability due to the long time natural curing residual stresses are relieved.

#### Precision Machine Tool Bed

Conventional materials used [46] for building machines are wood, cast iron, the improvements and diffusion of machine tools had a major impact on the productivity in industry since the Industrial Revolution 1775–1830. Prior to that time, almost all machinery was made of wood. Precision machine tools are used to produce accurate parts and precision measuring instruments are used to measure the produced part accurately. Structural machine component plays important role in precise and stable performance of machine, both in machine tools and measuring instruments. It is reviewed that, out of the various materials under research, granite is one of the materials used as base to built precision machine.

#### Epoxy Granite

Epoxy Granite is a cold curing mixture of binding agent, reaction resin and hardener, together with selected, graded and mixed aggregates of granite. Epoxy granite is also known as 'Synthetic granite' The compositions of epoxy granite is used in machine structures and precision machine structures. Primarily epoxy granite was used for manufacturing of cylindrical grinding machines structure. Epoxy granite overcomes many of the disadvantages of the conventional materials referred to above, possesses most of the advantages and, in some cases, significantly better them. This material has an internal damping factor 10 times greater than Cast Iron and 3 times greater than granite.

Building Construction

From long period ago stones are used to build the house walls, templewalls. It is proved that stone wall gives long life e.g. first temple built in India is in 500 BC. Concrete is mixture of the sand, stone crush and cement. By using granite dust or granite crush concrete properties are enhanced by 30 %.

CONCLUSION

This paper visualizes different physical and mechanical properties of granite and also its available resources in India. Based on these impressive properties over the other material it can be used for multiple industrial applications like coordinate measuring machine, surface plates, precision machine tool bed, Epoxy Granite, Building Construction and Nuclear Waste Disposal. However, due to thermal and damping characteristics, granite is the dominant material for CMMs and ultra-precision machines. Due to form stability of granite it can be used for surface plates over the cast iron material.

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