Epoxy-Granite Properties using Indian Origin Granite

Kailas V. Gurav, V. M. Kale, Akash Sah

Abstract: Precision machine tools are expected to operate at higher machine speed to produce precise products. Hence, its structures must have high structural stiffness and high damping along with dimensional and geometrical stability. Granite is the material used for metrological and precision machine manufacturing applications. Granite is also used in some of the high accuracy machine tool manufacturing. Considering the natural properties and limitations of granite a new emerging material named Epoxy Granite is evolved. In this paper, Epoxy Granite properties using Indian Black granite are studied. In particular, the maximum load-bearing and density of epoxy granite are focussed. Also, the combination which is best suited for the applications can be easily dragged out. Density is compared with maximum load-bearing and their relation is also put forward to simplify the selection process of epoxy granite.

Keywords: Epoxy Granite, Mechanical properties, Density, Maximum bearing load, Flexural Modulus.

I. INTRODUCTION

Designing process of machine component involves manystages; it starts with defining functionality and performance requirement, to the testing of individual component and finally testing the complete machine. Design considerations also include the time required and cost involved to covert concept design in to a functional machine. Design methodology influences the optimization of material selection which results in an optimized combination of cost, time and functionality. Use of functionally efficient and good performing material, having lower cost can help in reducing the effective cost of the machine.

Fabricated steel structure and Cast iron are some of the conventional materials used for manufacturing structural parts of the machine (1) (2) (3). For precision machines granite is used as the main structural part, e.g. base or bed. Granite is also majorly used in metrological machine manufacturing (4) (5) (6). Good compressive strength, high thermal capacity, high level of hardness, machinability and ability to lap the surface makes it an ideal choice as a machining component. High damping capacity is an added advantage of this material, which damps the external as well machine generated vibrations.It actually helps to achieve great positional accuracy and repeatability that results in the least tolerance parts and accurate measurements. With all these advantage points, come some limitations of granite.

Brittleness, availability of continuous large pieces in the desired shape, and the high skill requirement for processing of the material are the few to be noted. Considering both its good properties aling with its limitations, an entirelynew material named epoxy granite is explored (5) (3) (7).

Epoxy Granite is a composite material having aggregate crushed granite particles mixed with formulated epoxy resin. Once mixed, the mixture is cast in a mould and cured at room temperature. Epoxy granite is a low-density material, owing very good dynamic properties due to which it is the most preferred material in the machine tool industry. The density of granite varies from 2.5×10^3 kg/m^3 to 3×10^3 kg/m^3 whereas the density of epoxy granite varies from 2.45×10^3 kg/m^3 to 2.8×10^3 kg/m^3. Here the variation in the density is caused due to aggregate sizes, shapes and compaction.

A recent study on epoxy granite is about finding the different material properties like its compressive strength, flexural strength, modulus of elasticity, coefficient of thermal expansion, damping capacity, required for machining. (8) (9) (10). Density is a property which decides the total weight of the system, and important from dynamic forces, transport, cost, deformation and self-weight point of views. Generally, lower density with higher stiffness is preferred for designing the structural part of the machine. Young's modulus plays a significant role against the deformation, higher the modulus of elasticity, better is the stiffness. When the loads are in a tensile manner, tensile strength is considered. The structural component of a machine e.g.its base, sustains complete machine loads, here, we use 'compressive strength'for this calculation, whereas, 'flexural strength' is considered in the case of bending loads. Rotatory motion, linear motion and uneven loads generate vibrations in the machine but the damping properties of machine components can damp these vibrations. In porous materials, such as granite, water absorption affects the material properties. Surface Finish, which is the deviation of the surface against the true plane, can be achieved in epoxy-granite composites. And, as a part of the thermal properties, coefficient of thermal expansion is studied.

In the world market, there are nearly 300 varieties of granite, out of which India supplies about 200 varieties (11). Out of these, prime varieties represent a wide spectrum of colour, texture, and structure. The major production of raw as well as processed granite is generally obtained from the southern region of India. Indian black granite, black galaxy, is one of the granites, being used in Metrology Industry. This granite holds certain mechanical, physical and chemical properties suitable for machines (1) (12). A further study and analysis of the properties of epoxy granite using these materials is required.

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In the following paper, the study of Epoxy Granite properties using Indian black granite is carried out. Waste granite material from one of the metrological industries is used to prepare Epoxy-Granite specimens. Here, the attempt is to find out the maximum density of the dry mixture of different granular sizes of granite in different weight combinations. It also aims to simplify the selection of granite granular weight combinations to maximize the density and subsequent material properties. The study focuses on investigating some of the prime properties like density, compressive strength, flexural strength, damping factor in this context.

II. EXPERIMENTATION

2.1 Specimen preparation

Indian Black Granite with compressive strength of 2700 kg/cm^2 to 3000 kg/cm^2 is selected to prepare granular. Granular particles are segregated into 4 different aggregate sizes of granite i.e., 0.1-0.3 mm, 1-3 mm, 4-8 mm, 8-11mm. A theoretical study has been conducted using 3D cad modelling with spherical shapes to decide the different size and weight percentage in combination as 40-30-20-10%, 30-25-25-20%, 20-20-30-30%, 10-15-35-40% respectively. Four different epoxy percentages by weight - 8%, 12%, 16%, 20% and two different vibrating frequencies - 45 Hz and 60 Hz are taken for experimentation purpose. Hence, variables under consideration are different aggregate sizes of granular granite and their percent aggregate combination by weight, different epoxy percentages by weight and different vibrating frequencies. Total 32 specimens were prepared by considering different combinations, 12 of which are shown in fig. 2.

According to ASTM – C35, a test specimen size of 300x50x50 mm is decided. The vibration table [fig. 1] is specially manufactured to conduct the compaction test of granular weight percentage vs density and to obtain the epoxy granite specimens [fig. 2] by providing different vibration frequency.

Initially, several iterative attempts were made to gain the maximum density and selective combinations were taken. As the outcome of compaction test, it was observed that maximum density is not achieved with individual granule, even though the granular size is 0.1 to 0.3 mm, granular combination of 0.1-0.2+12-14 mm grain size gives maximum density, and combination of 12-14 mm, 8-11 mm, 4-8 mm and 0.1-0.3 mm gives a secondary maximum weight of mixture. Compaction test outcomes were used to decide weight percentage as 40-30-20-10%, 30-25-25-20%, 20-20-30-30%, 10-15-35-40% respectively.
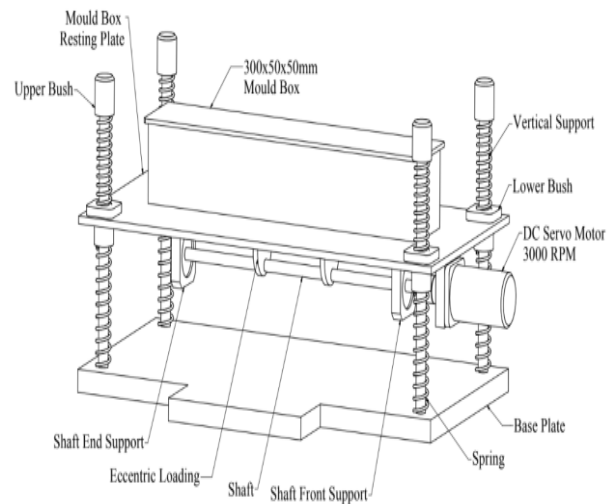

Figure 1: Mould box with vibration table

2.2 Epoxy-granite specimen moulding/casting

Granular granite, resin and hardener were taken by weight percentage and mixed thoroughly for 10-12 minutes, on the other side, mould box was clamped on a vibration table and separating agent was applied on inside walls of mould box for easy removal of cast afterwards. The mixture of epoxy and granular granite is poured in a mould box, and is kept under constant vibrations for about 10-15 minutes at a pre-decided vibration frequency. Mould box with mould is kept at normal room temp for 24 hrs and after 24 hrs the mould box was disassembled and the specimen was taken out for further inspection.

Figure 2: Specimens prepared by different combinations of epoxy and granite

III. INSPECTION AND TESTING

Dimensional measurement and weight of all 32 specimens were inspected and density of each specimen was calculated. A further study was conducted to find out the relation of a different combination of granular granite and its density.

$$Density = \frac{w}{v} \text{gm/cm}^3$$

w= weight of the specimen, gm
v= volume of the specimen, cm^3
Flexural testing, using the 3-point method is used for measuring maximum load-bearing and flexural modulus.

ASTM C580-02, a widely used UTM was chosen to conduct different tests.

ASTM C580-02 covered the determination of flexural strength and modulus of elasticity in flexure of cured chemical-resistant materials in the form of moulded rectangular beams. These materials include mortars, brick and tile grouts, structural grouts, machinery grouts, and polymer concretes. These materials shall be based on resin, silicate, silica, or sulphur binders. This test is generally applicable to rigid and semi-rigid materials; therefore, this is used as a guide during experimentation.

IV. RESULTS

The results obtained are put into a graphical form and compared with their respective variables to find out the best combination for getting the desired property.
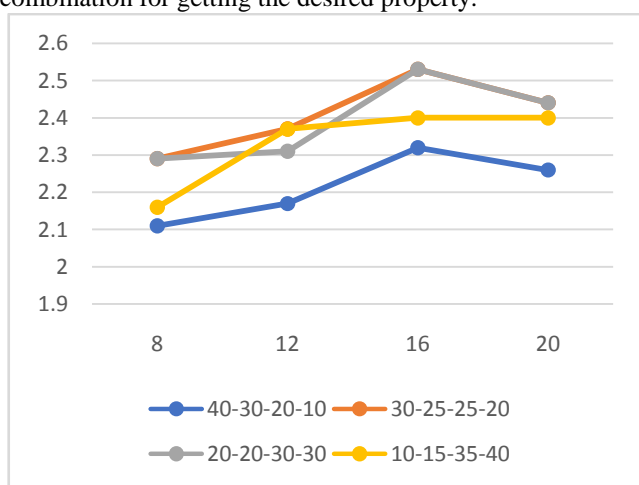
Graph I

A graph for density vs. epoxy percentage [Graph I] is plotted and 4 lines of different colours represent aggregate size combination, the graph clearly indicates that for all the combinations, at 16% epoxy concentration, specimens show greater density. So, it can be concluded that 16% epoxy gives greater density than any other epoxy percentage in the mentioned combinations. Thus, graph I is clearly indicating that density is directly proportional to the Max load.

Graph for density vs aggregate size combination [Graph II] is plotted and 4 lines represent epoxy percentages, graph is showing that 30-25-25-20 and 20-20-30-30 combinations are giving more denser specimen but particularly in case of 12 % epoxy at 20-20-30-30 combination, it is going downward which makes 30-25-25-20 combination superior. So, we can conclude that to get the denser specimen we can select 30-25-25-20 combination.
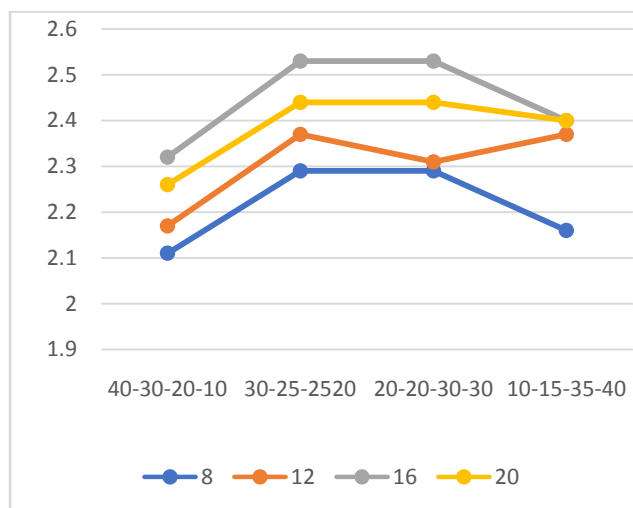
Graph II

Altogether, a specimen of 16% epoxy with 30-25-25-10 combination gives the best density among all the specimens.

From the application point of view, if density is playing a vital role and is responsible for many other parameters, this reference or experimentation is enough, as well as, provides a guideline on how to find the best epoxy granite for loading applications particularly.
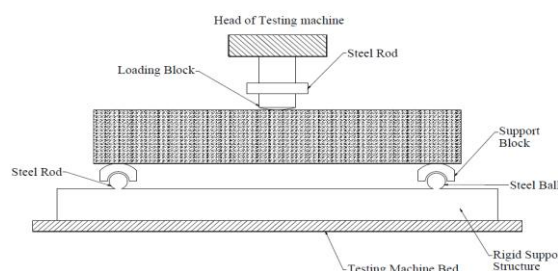

Figure 3: Flexural testing set up

Flexural Strength checking, in total 12 specimens were selected for this experimentation covering all the ranges of granite-epoxy combinations available.

Table 1: Density and max load of selected epoxy granites specimen

Specimen No.	Density (gm/cm³)	Max load (kN)
1	2.33	4.8
2	2.29	2.73
3	2.37	6.1
4	2.54	7.95
5	2.44	8
6	2.29	3.99
7	2.3	4.35
8	2.44	7.14
9	2.16	1.86
10	2.37	4.7
11	2.4	7.1
12	2.4	7.1

By plotting the results into a graphical form, Maximum load vs density, we can observe that, for density value 2.54 gm/mm3, which is maximum among all it shows the maximum load capacity of 7.95 kN.
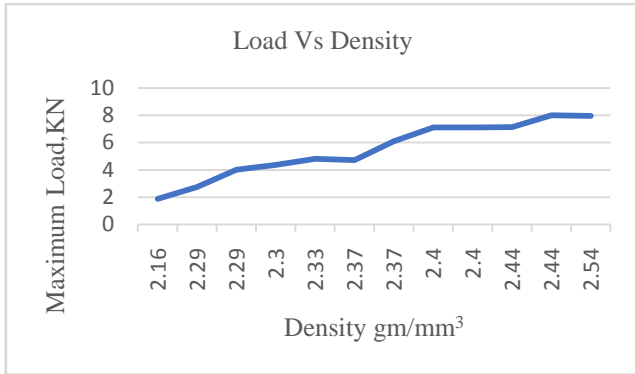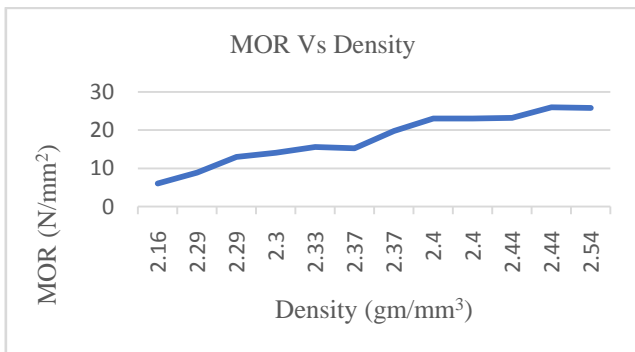

Graph III

Hence, sample no. 4 (Aggregate combination - 30,25,25,20; Epoxy percentage - 16%; Vibrating frequency - 60Hz; Epoxy type - E1) is taking maximum load. Least density which is 2.16 gm/mm^{3}of sample no. 9 (Aggregate combination - 10,15,35,40; Epoxy percentage - 8; Vibrating frequency - 60; Epoxy type - E1) has least max load of 1.86 kN.

Hence, from the results and graph, it can be observed that density has a direct relation with maximum load and density is directly proportional to the maximum load.

Also, modulus of rupture is directly proportional to maximum load. Hence, density is directly proportional to the modulus of rupture, as shown below:

Graph IV

$$MOR = \frac{3 * F * L}{2 * b * d^2}$$

MOR= modulus of rupture, N/mm2
F = load at a given point on the load deflection curve, N
L = Support span, mm
b = Width of test beam, mm
d= Depth or thickness of tested beam, mm

V. CONCLUSION

1. Compaction technique can be used to maximize the density of Epoxy-Granite.
2. Maximum Density results into maximum flexural strength and max load carrying capacity.
3. Competitive Epoxy Granite Properties can be achieved by using Indian Black Granite.

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