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STRENGTH CHARACTERISTIC OF GEOPOLYMERCONCRETE CONTAINING FIBERS AND RUBBER FOR PAVEMENTS

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I. ABSTRACT

India's economy is basically depends on road transportation, Most of the pavements are laid by bitumen's or concrete toping where sub-base and base course remains same. It is well know that bitumen pavement requires repair at regular interval to keep the pavement in good operational condition, And at the same time, the cost of bitumen is also going high, In case of cement concrete pavement, initial cost is high and it is well accepted that the cement concrete is week in flexural strength and it is difficult to go in for cement pavement in thick traffic because of concrete requires minimum of 7 days of curing, and traffic cannot be let with in that stipulated time. It is widely known that the production of Portland cement consumes considerable energy and at the same time contributes a large volume of CO_2 to the atmosphere

In this regards, the development of Geopolymer concrete is major technologies breakthrough promoting the use of industrial byproducts such as Flyash and GGBS in replacement of Portland cement concrete, also rubber and fibers used to increase the Mechanical properties of GPC

The two most important factors that govern pavement design are soil sub-grade strength and traffic loading. Depending on the strength of sub-grade soil, the layer thicknesses of flexible as well as rigid pavements are affected. IRC: 37 - 20015 uses soil sub-grade strength in terms of CBR; whereas IRC: 58 - 20026 uses the same in terms of modulus of sub-grade reaction (k). The traffic load is generally estimated from 3-day axle load survey. In the design of flexible pavements, traffic load is expressed in terms of million standard axles (msa); whereas it is expressed in terms of axle load distribution (ALD) in design of rigid pavements.

II. INTRODUCTION

Geopolymer results from the reaction of a source material that is rich in silica and alumina with alkaline liquid. It is essentially cement free concrete. This material is being studied extensively and shows promise as a greener substitute for ordinary Portland cement concrete in some applications. Research is shifting from the chemistry domain to engineering applications and commercial production of geopolymer concrete. It has been found that geopolymer concrete has good engineering properties with a reduced global warming potential resulting from the total replacement of ordinary Portland cement.

This study presents the results of an experimental investigation on the mechanical properties of Geopolymer Concrete. The study analyses of Crumb rubber and polypropylene fiber on the mechanical properties such as Compressive Strength, Split Tensile Strength and Flexural Strength of hardened GPC. Mixtures were prepared with alkaline liquid to binder ratio is 1: 2.5. Crumb rubber added was 3.5%, 5% and 7.5% by weight of fine aggregates.

Polypropylene fibers were added to the mix by 0.5%, 1%, 1.5% weight of binder. The mechanical properties of the specimens were studied up to 28-days of ambient temperature. Use of Flyash along with the GGBS as a base material it is able to produce the GPC of Compressive strength up to 45 Mpa at ambient curing, By adding fiber and rubber in normal GPC, Flexural strength achieved is 80% more than that of normal GPC. The results obtained from abrasion, Permeability, Water absorption test prove that, the GPC performs well as compared to that of cement concrete pavements.

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III. EXPERMENTAL PROGRAM

As far as possible, the current practice used in the manufacture and testing of ordinary Portland cement (OPC) concrete was followed. The aim of this action was to ease the promotion of this 'new' material to the concrete construction industry. In order to simplify the development process, the compressive and flexural strength was selected as the benchmark parameter.

This is not unusual because compressive strength has an intrinsic importance in the structural design of rigid pavements. Although geopolymer concrete can be made using various source materials, the present study used low-calcium (ASTM) fly ash and GGBS have been used as base materials. [2] proposed a system, this fully automatic vehicle is equipped by micro controller, motor driving mechanism and battery. The power stored in the battery is used to drive the DC motor that causes the movement to AGV. The speed of rotation of DC motor i.e., velocity of AGV is controlled by the microprocessor controller.This is an era of automation where it is broadly defined as replacement of manual effort by mechanical power in all degrees of automation. The operation remains an essential part of the system although with changing demands on physical input as the degree of mechanization is increased.

IV. NEED FOR THE STUDY

This study is pointing to developing an geopolymer concrete for a pavement, many experimental reports have shown alkaline activated Flyash and GGBS will achieve an compressive strength up to 60mpa at 28 days of strength. And as percentage of GGBS increase the strength gain at early age of concrete also increase. By considering this, an attempt is made to develop a GPC for pavements. The flexural strength of normal geopolymer concrete less as similar to that of Portland cement concrete as documented in many research papers. So there is a requirement of increasing flexural strength of normal GPC by adding other material like fiber, rubber.

The experimental work involved development of an alkali activated concrete. Fly ash (class F) from Bellary thermal plant & GGBS from Jindal steel plant from Bellary was considered as the source materials. Sodium hydroxide and Sodium silicate were procured commercially from a local vendor. Polypropylene fiber obtained from reliance company distributor and crumb rubber is procured from Tinna rubber and infrastructure Limited, Haryana

V. MATERIALS USED IN THE PREPARATION OF GPC

A. CRUMB RUBBER

Scrap used tires of various automobile vehicles are continuously added to the waste materials in the landfills all over the world and their disposal needs a viable and environmental friendly solution. Different methods have been adopted for the disposal of scrap tires including use of tires as fuel, ground rubber applications for playground or sports surfacing or use in new rubber products and use in asphalt rubber modified concrete.

Property	**Values**		
	Crumb	**Ash**	**Chips**
Fines modules	6.2	2.01	7.65
Minimum size in mm	0.4	0.07	2
Avg bulk volume (kg/m^3)	1.12	1.09	1.3
Water absorption (%)	0.4 to 0.5	0.6 to 0.8	0.2 to 0.3

Table 1: Properties of crumb rubber

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Fig 1: Classification of crumb rubber

B. POLYPROPYLENE FIBER

Polypropylene is one of the fastest growing classes of thermoplastics. This growth is attributed to its attractive combination of low cost, low density, and high heat distortion temperature (HDT). Currently, automotive and appliance applications employ glass or mineral-filled systems with loading levels ranging from 15 to 50 %. This approach improves most mechanical properties, but polypropylene's ease of processing is somewhat compromised. Furthermore, the need for higher filler loading leads to greater molded part weight .The main attraction of polypropylene (PP) is its high performance-to cost ratio.

Property	**Values**
Bulk density	481 – 513 kg/m^3
Water Absorption @ 24 h Immersion	0.3%
Coefficient of frication	0.3
Modulus of Elasticity (Young's Modulus)	1,300 MPa
Poisson's Ratio	0.45
Self-ignition point	>300^0

Table 2: Physical properties polypropylene

The normal mix, N, the mix was prepared with 16M alkali solution with 130 liters of water. This mix is considered to be the base for comparison with the other mixes prepared with fibers and rubber crumbs. All the samples prepared are cured by sun-drying

The second types of mix with the crumb rubber, all the mix constituents have been kept unaltered as in the normal. The percentage of rubber crumbs added varies from 3.5% to 7% of the combined weight of fine aggregates and binder content. The mix has been designated as R1, R2 and R3

Similarly in the third mix, polypropylene fibers have been added to the mix is varying from 0.5% to 1.5%. The mix with the optimum quantity of materials as obtained from the second type of mix is used in the preparation of third mix. From the tests conducted, the optimum combination of base materials was found to be that of mix R-2, and hence the same proportion was used in the preparation of the third mix. The mixes have been designated as RF1, RF2 and RF3.

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Sl.no	Test	Specimen size in mm	Total number of sample
1	Compressive Strength	100 x 100x 100	84
2	Flexure strength	400 x 70 x 70	84
3	Split tensile strength	100 dia 200 height	72
4	Water absorption	100 x 100x 100	18
5	Water Permeability	100 dia 100 height	9
6	Young's modules	100 dia 200 height	9
7	Abrasion	65 x 65 x 35	9

Table 3: Number of specimens cast for experimental work

VI. RESULTS

A. WORKABILITY OF FRESH CONCRETE

The workability of concrete is a measure of the consistency of the concrete in the specific mix and the slump test is an empirical test conducted to measure the workability of freshly prepared concrete mix.

Figure 5.2 shows the average slump values of different mixtures. Generally concrete mixtures had 'collapse' slump due to its sticky and viscous nature in fresh state. Although no super plasticizer or extra water was added, normal mix showed more than 150 mm of slump. Water content is an important parameter that affects workability. All the mixtures in this study have a Ratio of sodium silicate(Na2 Sio3) to sodium hydroxide (NaOH) of 2.5 and water content of 130 lit/m^3, Slump value may be affected by some other factors such as moisture content of aggregates, variation of ambient temperature, mixing time and degree of condensation reaction between binder and alkaline solution.

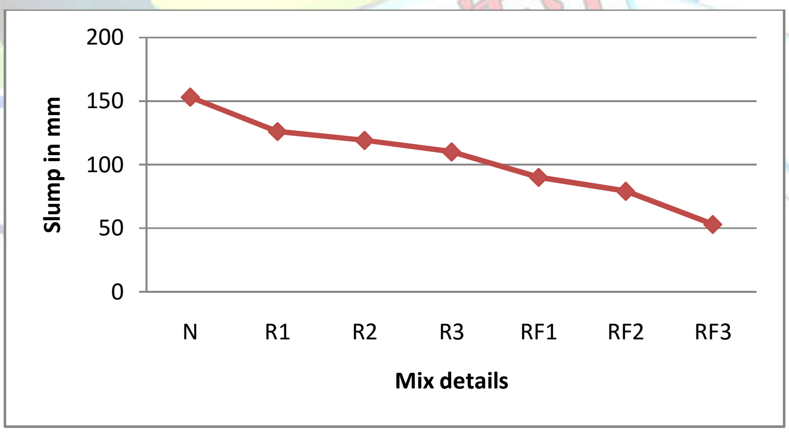

Fig 2: Different mixtures versus slump

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Fig 3: Measuring slump value

B. COMPRESSIVE STRENGTH

Compressive strength development of different geopolymer concrete mixtures was determined up to 28 days of ambient curing. Figure shows the 1, 3, 7 and 28 days compressive strength variation of concretes due to the variation in mix proportion. The results shown in the table 5.4 were the average value of three specimens tested at the test age. From the compressive test results, it could be clearly seen that addition of a crumb rubber and Polypropylene fibers has no significant effect on compressive strength of concrete.

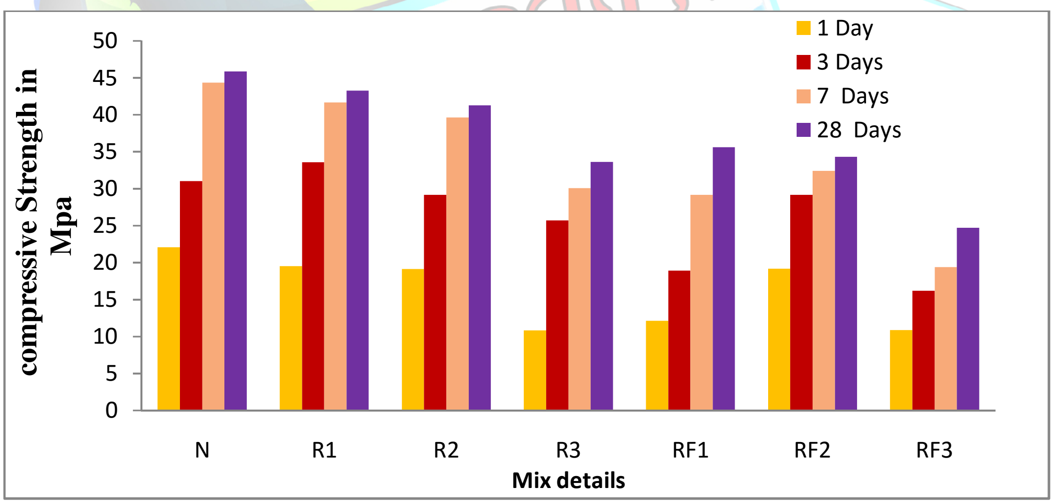

Fig 3: Different mixtures versus compressive strength

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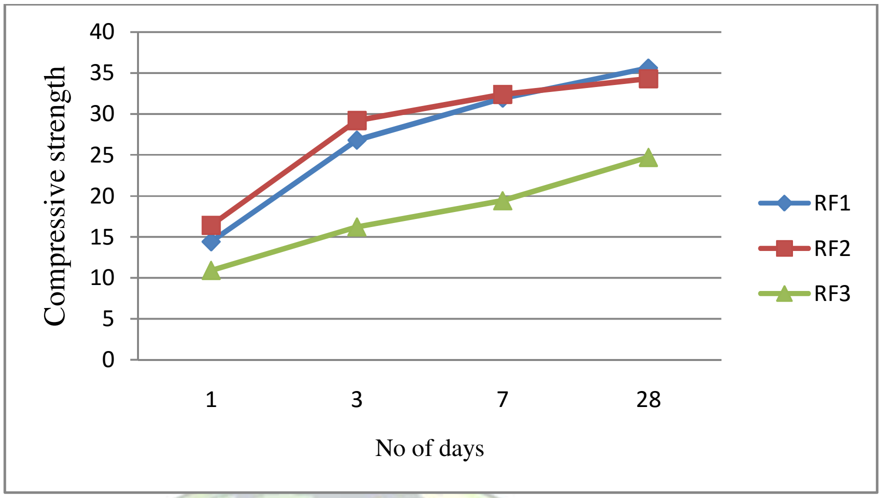

Fig4: Compressive strength of R series

C. FLEXURAL STRENGTH

Flexural test was conducted on beams of size 400x75x75 mm for all the proportions of concrete. Flexural test was done using three point bend load test and were tested at different curing ages

Fig 5 represent flexural strength of various mix proportions, series N shows the lower strength at 28 days as compared to that of other mixtures, when 3.5 % rubber added to that normal mix it shows 40% increase in flexural strength, further addition of rubber in mix will shows only 1 to 2 % of increase in strength of R2 mix. R3 mix indicates the lower strength in R series.

R1 and R2 mix achieved 80% of 28 days strength in 1 to 3 days of curing, and 7 to 28 contributed only 20% of strength, R2 mix is considered as optimum mix in R series and this mix is further studied by adding polypropylene fiber(i.e. mix RF1, RF2, RF3).

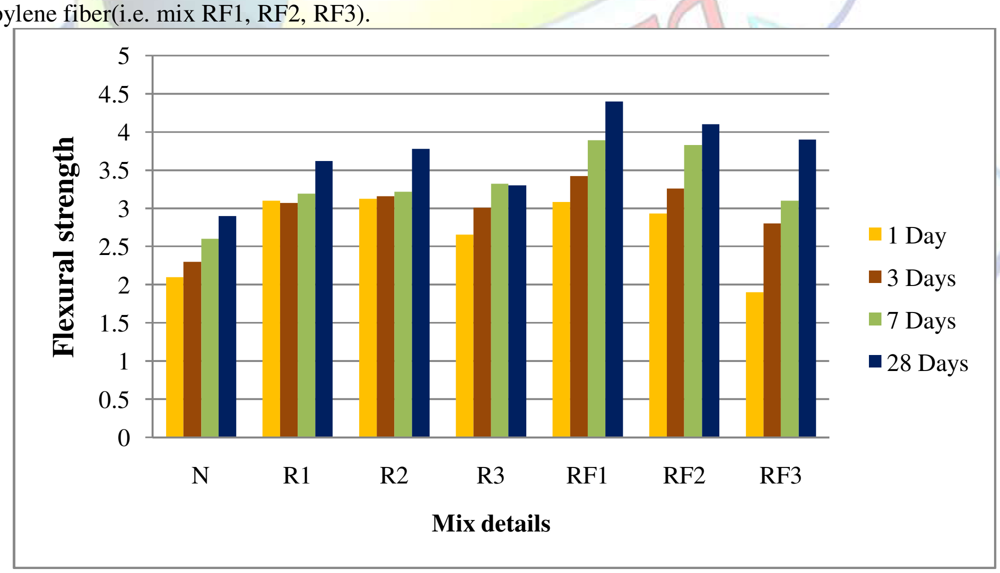

Fig 5: Flexural strength of various mixes

D. PEAK LOAD TEST BY DISPLACEMENT CONTROL MACHINE

Area under load-deflection curve is one of the parameter which is used to find fracture, Area under load -deflection is calculated using ORIGIN 6.1 software.

Area under the graph shows the energy required for total failure of the specimen that is total separation of surface along with the notch. More the areas under the graph indicates that more energy required to split the specimen at midpoint

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If the post peak slop is shallower the area under the curve increases and the final fracture property is very high, this is a desired fracture property from the concrete and vaguely it is an indicator of ductility of concrete.

Fig 6: Experimental setup for peak load test

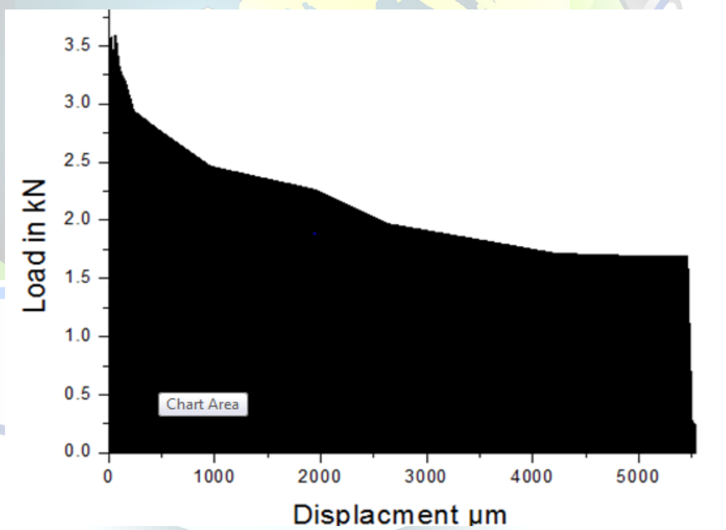

Fig 7: Load versus displacement mix R2

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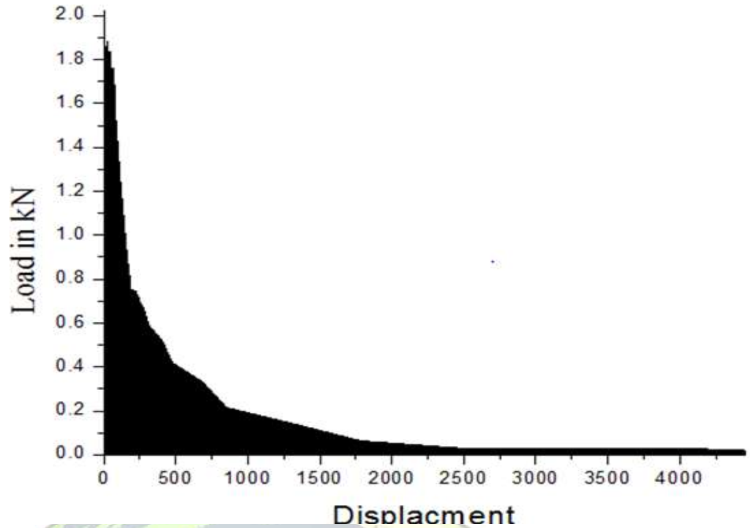

Fig 8: Area under the curve for mix N

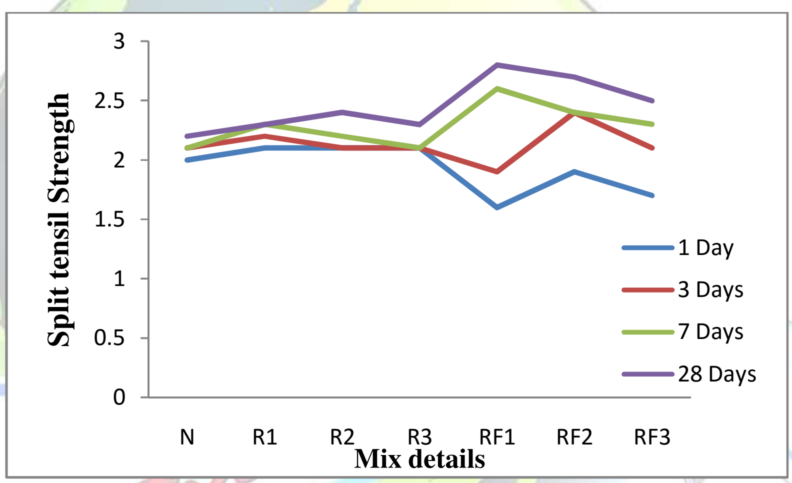

Fig 9: Split tensile strength at various curing age

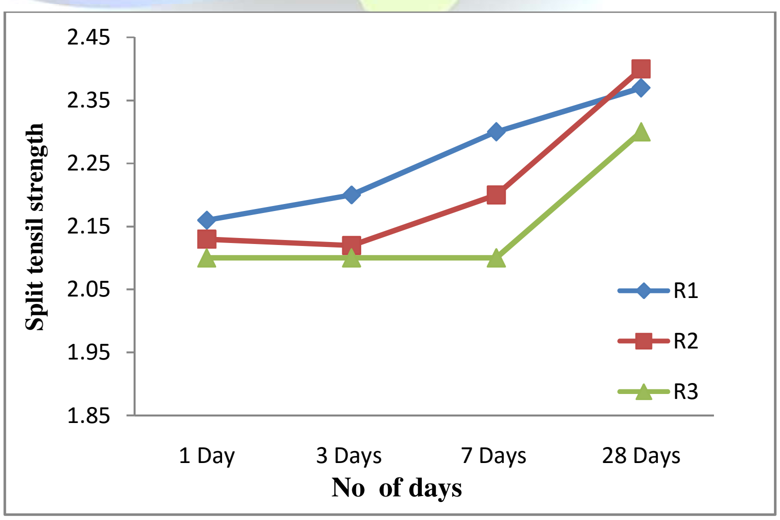

Fig 10: Split tensile strength of R series

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E. SPLIT TENSILE STRENGTH

The tensile strength of GPC was measured by performing the cylinder splitting test on 100x200 mm concrete cylinders in accordance with the IS 5816. The test results are given in Table 5.6 these test results show that the tensile splitting strength of GPC is only a fraction of the compressive strength, as in the case of Portland cement concrete.

Series N shows the normal GPC results, it is found that adding crumb rubber (i.e. R1 R2, R3 mixes) to normal mix will show increase in splitting tensile strength, further adding of fiber (RF1) will show some increase in strength at 28 days of curing as compared to that of mix R1, R2 and R3

This is due to contribution of more fibers in tensile load before fracture of the samples. In addition, the increased fiber availability makes it more efficient in delaying the growth of micro cracks and thereby improving the ultimate tensile stress capacity

MIX	N	R1	R2	R3	RF1	RF2	RF3
1 Day	2	2.1	2.1	2.1	1.6	1.9	1.7
3 Days	2.1	2.2	2.1	2.1	1.9	2.4	2.1
7 Days	2.1	2.3	2.2	2.1	2.6	2.4	2.3
28 Days	2.2	2.3	2.4	2.3	2.8	2.7	2.5

Table 4: Split tensile strength result

VII. CONCLUSION

Based on the experimental work reported in this study, the following conclusions are drawn:

- Use of fly ash and GGBS as binder along with sodium based alkalis in geopolymer concrete results in early setting time and early strength gain, promises to be a good material for pavement concrete.
- The indirect tensile strength of fly ash & GGBS -based geopolymer concrete is a fraction of the compressive strength, as in the case of Portland cement concrete.
- The average density of Geopolymer Concrete is similar to that of Ordinary Portland Cement (OPC) concrete, its value varies between 2370 to 2410 Kn/m^3.
- Flexural strength of crumb rubber and polypropylene fiber concrete is increased by 50% compared to that of normal GPC and 70% of this strength are achieved within 7 days at sun-dry curing. It is evident that additions of crumb rubber enhance toughness and modules of elasticity of GPC.
- Abrasion resistance is more in polypropylene fiber reinforced geopolymer concrete which is essentially required for pavements.

The usage of Polypropylene fiber and crumb rubber in Geopolymer synthesis suggests an approach to further enhancing the environment benefits and solving the problems of large shrinkage and high brittleness

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