Study of Sheet Glass Powder and Metakaolin in Conventional Concrete

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Abstract— Concrete is a widely used construction material. However, the production of Portland cement releases significant amount of CO_2 (carbon dioxide), a greenhouse gas, One ton of Portland cement clinker production releases approximately one ton of CO_2 and other gases, Environmental issues are playing essential role in the substantial development of concrete industry. Today many researches are ongoing for the replacement of Portland cement, using many substitutes like Metakaolin, Fly ash and GGBS. Along with these materials used as substitutes for cement, glass powder is used as a substitute for fine aggregate. Glass is a unique inert material that could be recycled many times without changing its chemical properties. Using glass in concrete is an interesting possibility for economy on wastage disposals. The inclusion of Metakaolin in glass concrete improves the workability and durability properties of concrete. Sheet glass aggregate used in concrete making leads to green environment. Using GP in concrete is an interesting possibility for economy on waste disposal sites and conservation of environment. This project examines the possibility of using GP as fine aggregate replacement in concrete. Natural sand was partially replaced (0%-40%) with GP and cement was partially replaced (0%-30%) with Metakaolin in conventional concrete. Tensile strength and Flexural strength were compared for 28 days, Compressive strength for 7, 28 & 56 days were compared.

Keywords: Concrete, Glass Powder, Metakaolin, Strength.

I. Introduction

Concrete is blending of cement, sand, coarse aggregate and water. Concrete is broadly used and one of the mostly utilized building materials available in the world. It is the next greatest used element in the world next to water. It has very stretchy properties like easy mouldability, high compressive asset and robustness. These properties of concrete have made it most famous construction material for all forms of civil engineering projects. The modern advances in concrete awareness have made it probable to use it in difficult and architecturally compound structures, needing high mark of performance and Artistic look. River sand (fine aggregate) is one of the chief constituents used in the manufacture of conventional concrete has become exceedingly expensive and also limited. During recent years, awareness is increased regarding environmental pollution due to domestic and industrial wastes. Now emission regulator board has been made to check environmental deprivation due to wastes from the manufactures. If once the environment is allowed to degrade, it will take huge amount of public work to clean it. So in view of this, it is better to prevent than searching of solution for concrete. In such endangered atmosphere, there is a huge demand for alternative materials from wastes of industries. Some substitute constituents have previously been cast-off as a partial replacement of regular sand. For instance cut-glass powder, it is used in concrete fusions as a fractional replacement of normal sand. Subsequently the demand in the concrete business process is increasing every day, the consumption of waterway sand as fine aggregate leads to serious exploitation of natural resources and environment, lowering of the water table, descending of conduit piers and abutments, etc. as a common threat to the environment.

Metakaolin is one of the ground-breaking clay products advanced in modern years. It is created by controlled thermal management of kaolin. Metakaolin can be used as a concrete integral, swapping part of the cement content ever since it has pozzolanic assets. The use of metakaolin as a fractional cement replacement material in mortar and concrete has been considered widely in latest years. In spite of the recent revisions, there are still many unknown with the usage of metakaolin. Study is needed to decide the involvement of metakaolin to the performance of hardened concrete. There are boundless concerns on the strength and robustness of metakaolin-concrete when cast-off as building materials in the construction businesses. If it is confirmed that the concrete is long-lasting and strong, this will lead to the usage of metakaolin to swap part of the cement. Metakaolin is not a by-product which means its engineering properties are well organized. Therefore, using metakaolin must promise some gains matched to other cement replacement materials. In this case, studies are required to study the performance of concrete using metakaolin. Efforts have been made in using crushed cut-glass as fine aggregate in the replacement of river sand and Metakaolin as a replacement for cement.

This project study can give some positive information about the usage of glass powder in replacement of sand which leads to eco-friendly concrete.

II. Materials used

A. Cement: Cements used in erection of buildings and civil engineering works comprise complexes of lime, silica and alumina as their chief elements and can be called as complex composites. Portland cement is the most common type of cement in common practice. The cement used in our venture is the ordinary Portland cement (M-43 grade).

B. Fine Aggregates: It is the aggregate most of which passes 4.75 mm IS sieve and holds only so much coarser as is allowable by specification. Here locally obtainable sand confirming to zone II with specific gravity of 2.62 was used.

C. Coarse Aggregates: According to size coarse aggregate is defined as graded aggregate of its nominal size i.e. 40 mm, 20 mm, 16 mm and 12.5 mm etc. for example a graded aggregate of nominal size 20 mm means an aggregate most of which passes 20 mm IS sieve. Coarse aggregate used was 20mm and less size and specific gravity of 2.84.

D. Glass Powder: Glass is an exclusive inert material formed by melting a mix of materials such as silica, soda ash, and Calcium carbonate at high temperature followed by cooling where solidification occurs without crystallization. Glass powder used here is of size 4.75mm passing. Glass was brought from local market and later it was finely grounded with the use of machinery to the desired size.

E. Metakaolin: Metakaolin is a dehydroxylated form of the clay crystal kaolinite. Pebbles that are rich in kaolinite are known as china clay or kaolin, unusually used in the production of porcelain. The element size of metakaolin is lesser than cement particles, but not as tiny as silica fume. The addition of Metakaolin in glass fiber strengthened concrete reduces the ecological pollution and improves the workability and permanency properties of concrete. Cement with Pozzolona related to Metakaolin reduce the penetrability of concrete & compacted calcium silicate hydrate. Metakaolin has pozzolonic assets, denoting that it responds with lime to form cementitious complexes. It is commonly known as a supplemental cementitious material.

Table 1: Chemical composition of Metakaolin

Chemical	Composition
SiO	50% - 55%
Al_2O_3	38% - 42%
CaO	1%-3%
TiO_2	0.8-1.2
Na_2O	<1%
Fe_2O_3	0.2-0.5
K_2O	<1%
MnO	<0.5%
MgO	<0.1%
Loss on Ignition	Max 1.5%
Physical	**Properties**
Bulk Density (g/cc)	0.5461 (When packed)
Color	White
Specific Gravity	2.60

III. Methodology

To study the actions of the concrete when its elementary ingredients are swapped by their respective alternatives, we must perform several trials by increasing the percentage replacement of the component by 5% every time to an allowed limit. Initially the tests on the elementary components of concrete are carried out:

Table 2: Tests on Cement

Test	Result

Table 3: Tests on Fine Aggregates

Standard Consistency	32%
Initial Setting Time	65mins.
Final Setting Time	360mins.
Specific Gravity	3.03
Compressive Strength	18.9 N/mm^2

Test	Result
Specific Gravity	2.62
Fineness Modulus	2.665
Grading units	Zone II
Water Absorption	0.75%

Table 4: Tests on Coarse Aggregates

Test	Result
Specific Gravity	2.84
Aggregate Impact	16.66%
Aggregate Crushing Value	28.76%
Water Absorption	0.56%

Table 4: Tests on Glass Powder & Metakaolin

Test	Glass Powder	Metakaolin
Specific Gravity	2.36	2.60

A. Mix Design: The practice of picking appropriate elements of concrete and determining their relative amounts with the focus of manufacturing a concrete of the requisite, strength, robustness, and workability as economically as feasible, is labeled the concrete mix design. The proportioning of component of concrete is directed by the required performance of concrete in 2 states, namely the plastic and the hard states. If the plastic concrete is not workable, it cannot be appropriately placed and trampled. The assets of workability, therefore, becomes of dynamic importance. Mix design carried out for M40 grade of concrete by IS 10262:2009, resulting to a mix proportion of 1: 1.28: 2.47 with water cement ratio of 0.40. The replacement of cement by Metakaolin was 0% to 30% and replacement of fine aggregate by Glass powder was 0% to 40% both at increment of 10% each.

Table 5: Classification of sets based on % Replacement

Sl. No.	Metakaolin (%)	Glass Powder (%)
M-1	0	0
M-2	0	10
M-3	0	20
M-4	0	30
M-5	0	40
M-6	10	10
M-7	10	20
M-8	10	30
M-9	10	40
M-10	20	10
M-11	20	20
M-12	20	30
M-13	20	40
M-14	30	10
M-15	30	20
M-16	30	30
M-17	30	40

B. Tests on Hardened Concrete: The behavior of hardened concrete can be characterized in terms of its short term properties which include strength in compression, tension and bond. The long term properties include creep, shrinkage, and behavior under fatigue and durability characteristics such as porosity, permeability, freeze-thaw resistance and abrasion. The strength of concrete depends on a number of factors including the properties and proportions of the constituent materials, degree of hydration, rate of loading, method of testing and specimen geometry. The properties of the constituent materials affect the strength are the quality of fine aggregate and coarse aggregate, the cement paste and the bond characteristics.

- **Compressive Strength Test:** In the study of strength of materials, the compressive strength is the capacity of a material or structure to withstand load tending to reduce size. It can be measures by plotting applied force against deformation in a testing machine. Compressive strength can also be defined as the load at which the material fails or cracks. In this project we have casted 3 cubes for 7 days and 3 for 28 days, average of 3 values is taken.

- **Tensile Strength Test:** The tensile strength governs the cracking behavior and affects other properties such as stiffness; damping action, bond to embedded steel and durability of concrete. It is also of importance with regard to the behavior of concrete under shear loads. The tensile strength is determined either by direct tensile tests or by indirect tensile tests such as split cylinder tests. We have casted 3 cylinders and cured it for 28 days and average of 3 values is taken.

- **Flexural Strength Test:** Flexural strength is also known as modulus of rupture, bend strength, or fracture strength a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load. The transverse bending test is most frequently employed, in which a specimen having either a circular or rectangular cross-section is bent until fracture or yielding using a single point flexural test or two point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of rupture. We have casted 3 Prisms and cured it for 28 days and average of 3 values is taken.

IV. Results And Discussions

1. **Compressive Strength:** Table 6 and Figure 1 shows the results of test conducted on hardened concrete with 0-30% Metakaolin and 0-40% Glass powder for 7 and 28 days of curing period, the results shows that the compressive strength increases with increasing curing time.

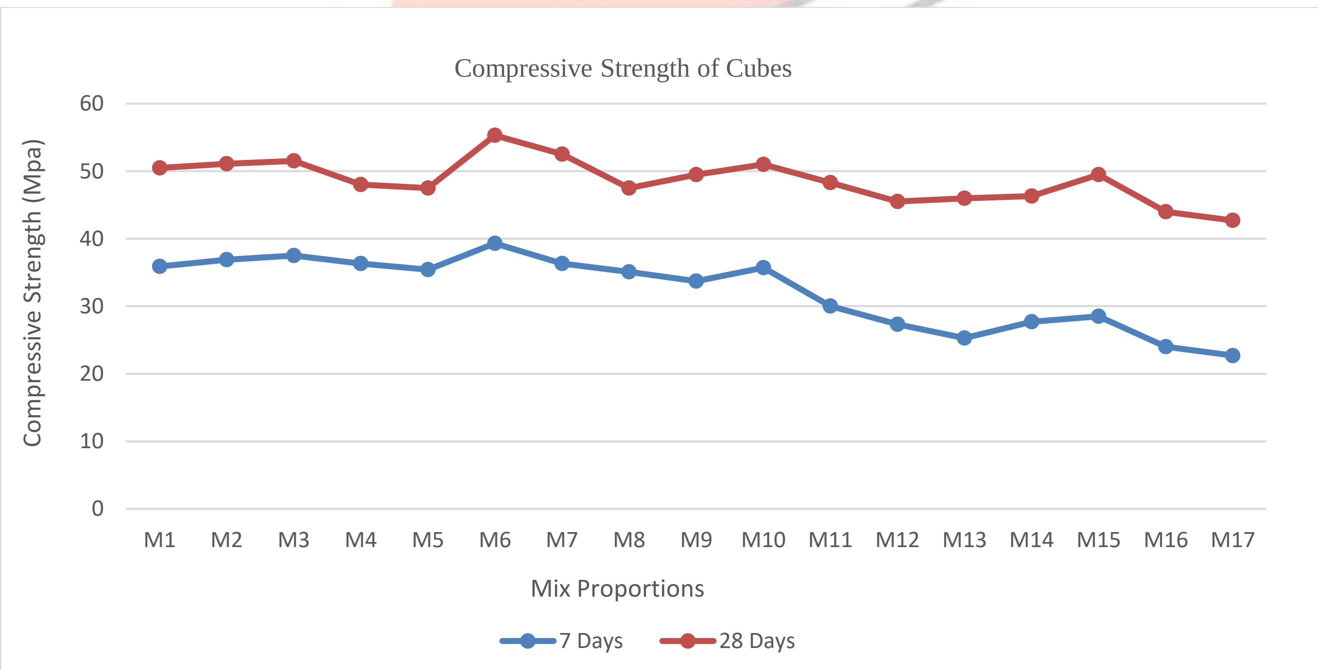

Fig. 1 - Graph showing Compressive Strength of cubes.

Table 6: Compressive Strength of cubes for 7 & 28 days curing.

Mix Proportion	Compressive Strength For 7 days curing (Mpa)	Compressive Strength For 28 days curing (Mpa)
M-1	35.9	50.5
M-2	36.9	51.1
M-3	37.5	51.5
M-4	36.3	48.0
M-5	35.4	47.5
M-6	39.3	55.3
M-7	36.3	52.5
M-8	35.1	47.5
M-9	33.7	49.5
M-10	35.7	51.0
M-11	30.0	48.3
M-12	27.3	45.5
M-13	25.3	46.0
M-14	27.7	46.3
M-15	28.5	49.5
M-16	24.0	44.0
M-17	22.7	42.7

From the results tabulated in table 6, it is observed that as the percentage replacement of cement and sand increases, the compressive strength increases to a certain level and further more replacement leads to the decrement of strength.

2. **Tensile Strength:** Table 7 and figure 2 shows the variation of results for Tensile strength of concrete with cement replacement by metakaolin and sand replacement by glass powder for 28 days.

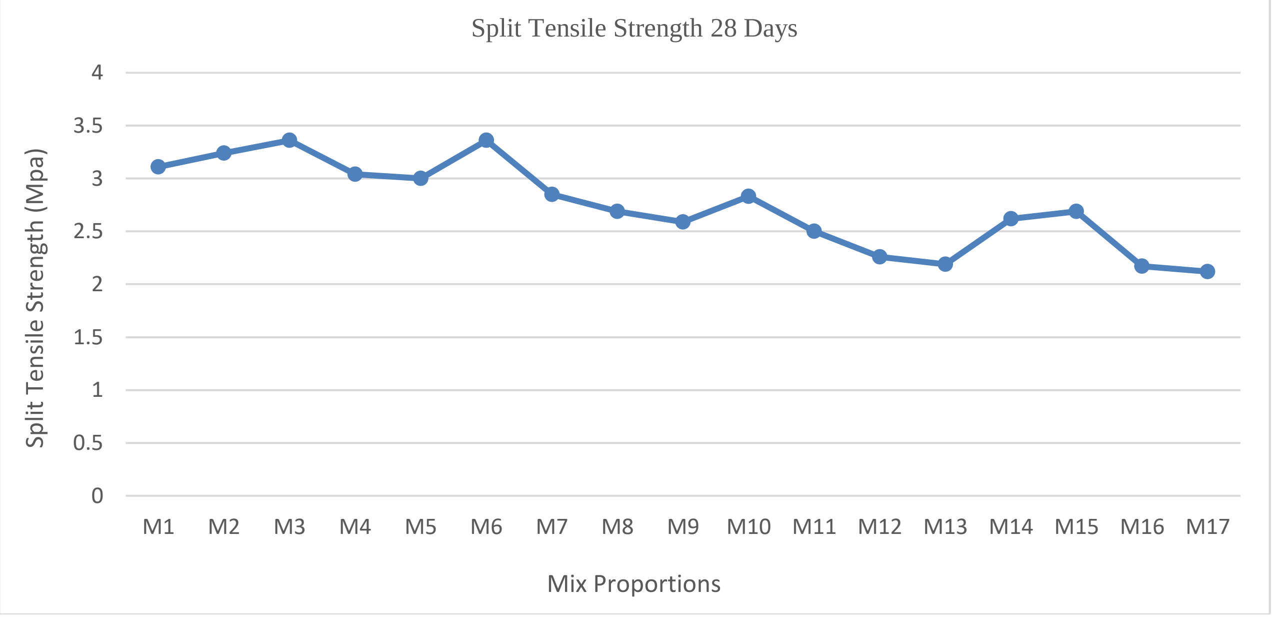

Fig. 2 - Graph showing Tensile Strength of cylinders.

Table 7: Tensile Strength of cylinders for 28 days curing.

Mix Proportion	Split tensile Strength For 28 days curing (Mpa)
M-1	3.11
M-2	3.24
M-3	3.36
M-4	3.04
M-5	3.00
M-6	3.36
M-7	2.85
M-8	2.69
M-9	2.59
M-10	2.83
M-11	2.50
M-12	2.26
M-13	2.19
M-14	2.62
M-15	2.69
M-16	2.17
M-17	2.12

From the results tabulated in table 7, it is observed that as the percentage replacement of cement and sand increases, there is a constant fall in the tensile strength value, except for the value at M-6.

3. **Flexural Strength:** Table 8 and figure 3 shows the variations of results for Flexural Strength of Concrete Prisms cured for 28 days.

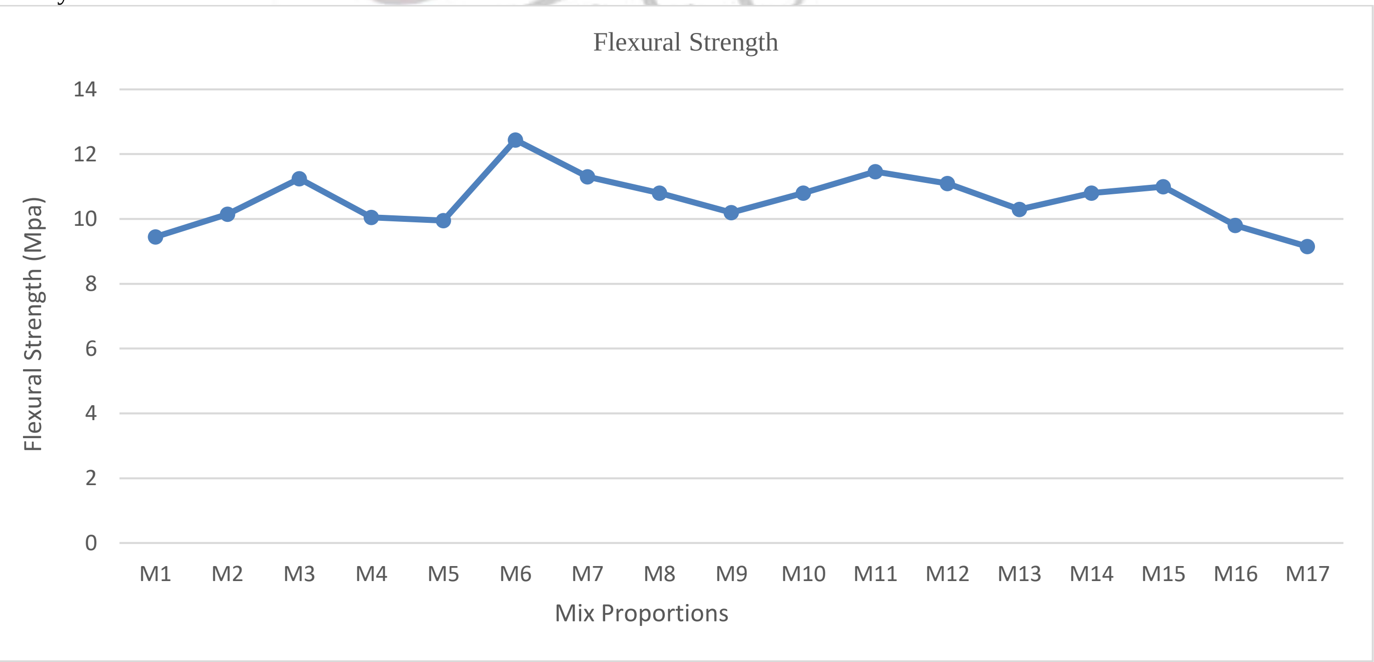

Fig. 3 - Graph showing Flexural Strength of Prisms.

Table 8: Flexural Strength of Prisms for 28 days curing.

Mix Proportion	Flexural Strength For 28 days curing (Mpa)
M-1	9.45
M-2	10.15
M-3	11.24
M-4	10.05
M-5	9.95
M-6	12.44
M-7	11.30
M-8	10.80
M-9	10.20
M-10	10.80
M-11	11.46
M-12	11.10
M-13	10.30
M-14	10.80
M-15	11.00
M-16	9.80
M-17	9.15

From the results tabulated in table 8, it is observed that as the percentage replacement of cement and sand increases, there is a random rise and fall in the Flexural strength value, the highest flexural strength noted is at mix M-6.

4. **Durability:** The Compressive strength values varies in the below table where the cubes are cured for total of 56 days, 28 days in normal water and remaining 28 days in water with acids.

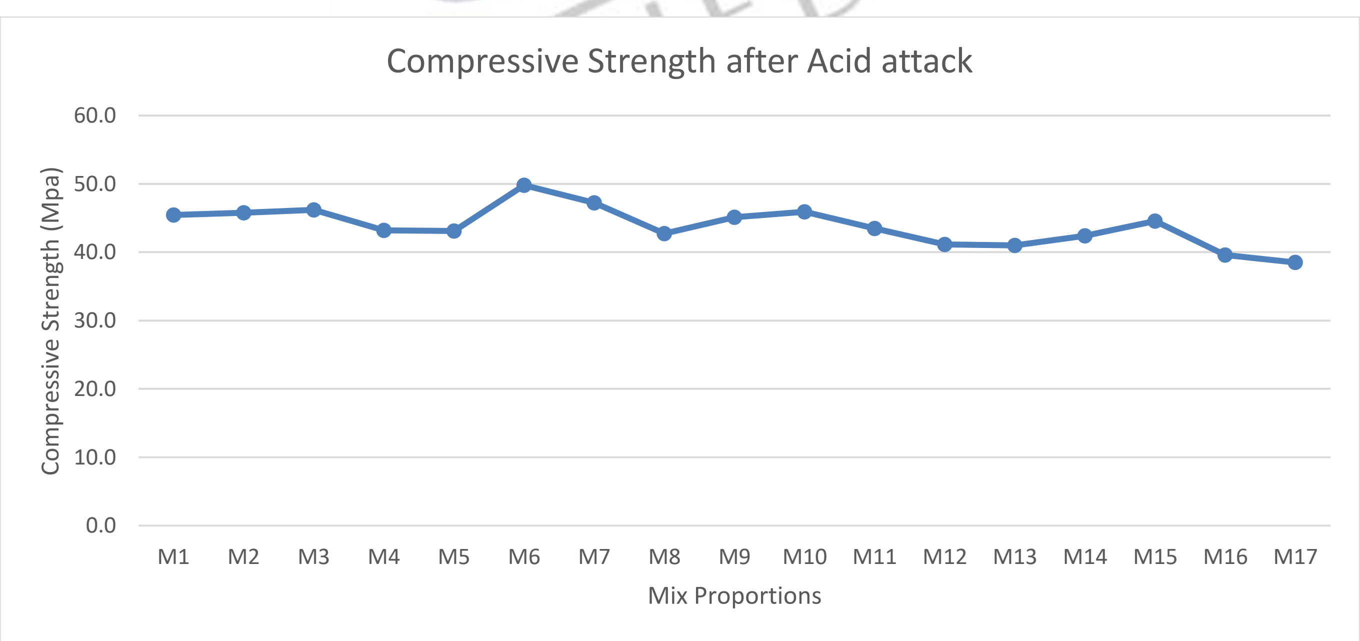

Fig. 4 - Graph showing Compressive Strength of cubes for 56days of curing in acid

Table 9: Compressive Strength of cubes for 56 days of curing in acid

Mix Proportion	Compressive Strength For 56days curing (Mpa)
M-1	**45.5**
M-2	**45.8**
M-3	**46.2**
M-4	**43.2**
M-5	**43.1**
M-6	**49.8**
M-7	**47.3**
M-8	**42.8**
M-9	**45.1**
M-10	**45.9**
M-11	**43.5**
M-12	**41.2**
M-13	**41.0**
M-14	**42.4**
M-15	**44.6**
M-16	**39.6**
M-17	**38.5**

From the above tabulated values, we can see that the compressive strength values of cubes cured for 56 days in acid were lower when compared to the cubes cured for 28 days in normal water. Due to the presence of Metakaolin in the concrete, the effect of acid attack is less as addition of metakaolin reduces the permeability of concrete.

V. Conclusions

Replacement of sand and cement by glass powder and Metakaolin respectively in the conventional concrete enhances various types of strengths of hardened concrete.

1. When 10% Metakaolin and 10% GP is used– Compressive strength of 7 days is increased by around 10% and 28 days strength is increased by 9% when compared to normal concrete.
2. When related to normal concrete, the split tensile asset of Mix Proportion with 10% MK and 10% GP was comparatively increased by 8%.
3. Flexural strength of Mix Proportion with 10% MK and 10% GP was increased by 32% when related to normal concrete.
4. Therefore 10% Metakaolin and 10% glass powder can be successfully cast-off in conventional concrete.
5. Due to the finer particles, the air cavities and micro cracks were almost reduced.
6. Durability of the concrete is increased as the concrete is less permeable.

VI. Acknowledgment

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