e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
( Peer-Reviewed, Open Access, Fully Refereed International Journal )
Volume:03/Issue:09/September-2021 Impact Factor- 6.752 www.irjmets.com

# GEOPOLYMER PAVEMENT BLOCK USING M-SAND

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## ABSTRACT

Geopolymer results from the reaction of a source material that's rich in silica and alumina with alkaline liquid. This material is being studied extensively and shows promise as a greener substitute for ordinary Portland cement in pavement block manufacturing. Research is shifting from the chemistry domain to engineering applications and commercial production of geopolymer pavement block. It has been found that geopolymer block has good engineering properties with a reduced global warming potential resulting from the total replacement of ordinary Portland cement (OPC). In this project utilize geopolymer to manufacture the pavement the pavement blocks with different ratio of (Fly ash, fine aggregate, Coarse aggregate) 1:2:4, 1:1.5:3, 1:1:2, and 1:1:1.5 the ratio of alkaline solution to fly ash is taken as 0.4.After casting the pavement block which is left for two days rest period and then hot air oven curing for 24 hrs at 60˚C. After 7 days of casting take the compression test, Flexural test, Water absorption test, Abrasion test as per IS 15658-2006 (code for pavement Blocks).The test results and cost analysis proved that this product is commercially possible. Finally conclude that conclude, this product is Eco friendly because it Emits $CO_2$ up to 78kg/tone of geo polymer production in the other hand OPC Emits 900kg/tone of OPC production, utilized M-sand instead of river sand it reduce product cost and reduce scarcity of river sand. The Fly ash is being utilized and geo polymer has more fire resistance then OPC. It begins new area in Indian roads.

**Keywords:** Coarse Aggregate, Fine Aggregate, Fly Ash, Geopolymer And M-Sand.

## I. INTRODUCTION

Demand for concrete as construction material is on the increase and so is the production of cement. The production of cement is increasing about 3% annually (McCaffrey,2002).The production of one ton of cement liberates about one ton of $CO_2$ to atmosphere (Roy,1999).Among the green house gases, $CO_2$ contributes about 65% of global warming. Furthermore, it has been reported that the durability of ordinary Portland cement concrete is under examination, as many concrete structures especially those built in corrosive environments starts to deteriorate after 20 to 30 years, even though they have been designed for more than 50 years of service life. Although the use of Portland cement is unavoidable in the foreseeable future, many efforts are being made to reduce the use of Portland cement in concrete. On the other hand, the abundant availability of fly ash worldwide creates opportunity to utilize this by-product of burning coal, as a substitute for OPC to manufacture concrete. When used as a partial replacement of OPC, in the presence of water and in ambient temperature, fly ash reacts with the calcium hydroxide during the hydration process of OPC to form the calcium silicate hydrate (C-S-H) gel. The development and application of high volume fly ash concrete, which enabled the replacement of OPC up to 60% by mass (Malhotra 2002; Malhotra and Mehta,2002),is a significant development. Davidovits (1999) proposed that binders could be produced by a polymeric reaction of alkaline liquids with the silicon and the aluminum in source materials of geological origin or by-product materials such as fly ash and rice husk ash. He termed these binders as geopolymers.

### 1.1. GEOPOLYMER

A hardened cementitious paste made from fly ash without Portland cement.It has greater compressive and tensile strengths, high strength gain rate, lower porosity and permeability, and greatly enhanced resistance to chemical attack compared with ordinary Portland cement (OPC) concrete. The structure of geopolymer is given in 'Figure 1'.It combines wastes products into a useful product, conserving landfill space and promoting sustainability, and compared with Portland cement; it features a 90% or greater reduction in carbon di-oxide emission.

**Figure 1:** Geopolymer

A solution of sodium hydroxide and potassium hydroxide (waste products from the chemical and petrochemical industries) must be prepared separately, and then added to the liquid commercial sodium silicate; this solution may then be added to the powdered fly ash (waste product from coal and bio fuel combustion) in the same way as water is added for Portland cement. The polymerization process involves a substantially fast chemical reaction under alkaline condition on Si-Al minerals that results in a three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds. The chemical reaction comprises the following steps:

- ✓ Dissolution of Si and Al atoms from the source materials through the action of hydroxide ions. Orientation or condensation of precursor ions into monomers.
- ✓ Setting or poly-condensation or polymerization of monomers into polymeric structures.

**1.2. METHODOLOGY AND MATERIALS**

- ❖ Collection of materials like Geopolymer, Flyash, Coarse aggregate, Fine aggregate and M-Sand.
- ❖ To study the properties of materials.
- ❖ Mix design using IS 10262-1982 for various design mix.
- ❖ The mix design process for the manufacture of alkaline solution preparation, geopolymer production, mixing with fine and coarse aggregate.
- ❖ Study on physical and mechanical characteristics of concrete like fresh and hardened concrete tests.
- ❖ To analysis and discussion of test results.
- ❖ To calculate the materials and rates for pavement blocks.
- ❖ Summary and conclusion.

## II. MATERIALS

**2.1. FLYASH**

Fly ash is a industrial by-product from Thermal Power Plant (TPP), With current annual generation of approximately 108 million tones and its proven suitability for variety (bricks/blocks) etc., is such an ideal material which attracts the attention of everybody. Cement and Concrete Industry accounts for 50%fly ash utilization, the total utilization of which at present stands at 30MT (The other areas of applications are low lying area fill (17%), Roads &Embankments (15%), Dyke Raising (4%), Brick manufacturing (2%) etc., The life cycle cost of fly ash based building materials/constructions is much lower taking into account the environmental benefits and durability aspects.

**2.2. SODIUM HYDROXIDE**

Sodium hydroxide also known as lye or caustic soda, has the molecular formula NaOH and is a highly caustic metallic base. It is a white solid available in pellets, flakes, granules and as a 50% saturated solution. 'Figure 2' shows the sodium hydroxide. Sodium hydroxide is soluble in water, ethanol and methanol. This alkali is deliquescent and readily absorbs moisture and carbon dioxide in air.


**Figure 2:** Sodium hydroxide

### 2.3. SODIUM SILICATE

Sodium silicate is the common name for a compound sodium metasilicate.$Na_2SiO_3$,also known as water glass or liquid glass. It is available in aqueous solution and in solid form and is used in cement, passive fire protection, refractories, textile and lumber processing, and automobiles. Sodium carbonate and silicon dioxide react when molten to form sodium silicate and carbon dioxide. The appearance of Sodium Silicate is given in 'Figure 3'.


**Figure 3:** Sodium silicate

### 2.4. WATER

Water is a chemical substance with the chemical formula $H_2O$.Its molecule contains one oxygen and two hydrogen atoms connected by covalent bonds. Water is a liquid at ambient conditions, but it often co-exists on Earth with its solid state, ice, and gaseous state (water vapour or stream).Water also exists in a liquid crystal state near hydrophilic surfaces. Water covers 70.9% of the earth's surface, and is vital for all known forms of life.

### 2.5. M-SAND

Natural or River sand are weathered and worn out particles of rocks and are of various grades or sizes depending upon the amount of wearing. Now-a-days good sand is not readily available; it is transported from a long distance. Those resources are also exhausting very rapidly. So it is a need of the time to find some substitute to natural river sand.

### 2.6. COARSE AGGREGATE

Aggregates are inert granular materials such as sand, gravel, or crushed stone that, along with water and Portland cement, are an essential ingredient in concrete. For a good concrete mix, aggregates need to be clean, hard, strong particles free of absorbed chemicals or coatings of clay and other fine materials that could cause the deterioration of concrete. Aggregates, which account for 60 to 75% of the total volume of concrete, are divided into two distinct categories-fine and coarse. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 3/8 inch (9.5mm) sieve. Coarse aggregates are any particles greater than 0.19 inch (4.75mm),but generally range between 3/8 and 1.5 inches (9.5mm to 3.75mm) in diameter. Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder.

## III. MATERIALS INVESTIGATIONS AND MANUFACTURING

In this investigation deals with the results of tests on fly ash, M-sand, coarse aggregate and water were shown in table 1, 2, 3, and 4 respectively. Also the properties of manufacturing sand and river sand were discussed.

**Table 1:** Tests on Fly ash

| Property | Value |
|---|---|
| Specific Gravity of Fly ash | 2 |
| Fineness Modulus | 1.69 |
| Density of uncompacted flyash | 231.7kg/m$^3$ |

**Table 2:** Tests on M-Sand

| Property | Value |
|---|---|
| Specific Gravity of M-Sand | 2.57 |
| Fineness Modulus | 4.17 |
| Density of uncompacted M sand | 1778.5kg/m$^3$ |

**Table 3:** Tests on Coarse Aggregate

| Property | Value |
|---|---|
| Specific Gravity of M-Sand | 2.74 |
| Fineness Modulus | 1.96 |
| Density ofCoarse Aggregate | 2498.7kg/m$^3$ |
| Water absorption | 4% |

**Table 4:** Tests on Water

| Property | Value |
|---|---|
| Chloride content of water | 372.33ppm |
| Total dissolved water | 1240ppm |

## IV. MANUFACTURING PROCESS

Alkaline solution is the mixing of NaoH solution & Sodium silicate (Na2Sio3).First we have to prepare NaoH solution with -14 mole (mol*NaoH molecular weight) =14*40=560gm NaoH is mixed in litre water then Na2Sio3 is placed in NaoH solution. The Alkaline solution is prepared before 24 hours of pavement Block manufacturing. In the 2$^{nd}$ step the alkaline solution is mixed with Fly ash. It produces Geo polymer. Then the Fine & Coarse aggregate is mixed with Geo polymer by water/Fly ash ratio -0.2.The manufacturing process end with the placing of concrete in the mould& vibrating well.

## V. RESULTS AND DISCUSSION

Specimen size200mm x 100mm x 60mm were initially produced for each trail mix and evaluated for compressive strength for seven days. All of the cubes were evaluated for compressive strength, which increased as the ratio of Na2SiO3 to NaOH increased. Only after good cube strength findings and laboratory testing was the paver block produced. The findings of the tests are mentioned further down.

### 5.1. COMPRESSION TESTS

According to the code procedure IS15658:2006, the compressive strength of geopolymer pavement blocks was measured. Previous research on the compressive strength of geopolymer concrete cubes shown that different factors such as the Na2SiO3/NaOH ratio and the alkaline solution/fly ash ratio had an impact on compressive strength. The compressive values of geopolymer pavement blocks with M-sand are shown in the 'Figure 4'.The compressive strength varies from 25.9N/mm$^2$ to 34.1N/mm$^2$are shown in 'Table 6'.The average compressive strength of geopolymer concrete paver blocks using M-Sand ranges from 34.1N/mm$^2$ to 35.5N/mm$^2$. Compressive strength tests were carried out on geopolymer paver blocks after 7 days using compression testing equipment in accordance with IS 15658 Annexure D. For each concentration of Na2SiO3 /NaOH used in the compressive strength research, the alkaline solutions to fly ash ratios were calculated. The results of the

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trail mixes are shown in Figure, which compares the compressive strength of each GPC/M-sand combination. The compressive strength of the GPC4 trail mix for geopolymer pavement blocks utilizing M-sand was adequate.

**Table 5:** Compressive Tests Results

| S.No | Ratio of Mix Proportion | Area of Block($mm^2$) | Load(KN) | Stress($N/mm^2$) | Curing Period |
|---|---|---|---|---|---|
| 1 | 1:2:4-G1 | 26225 | 68000 | 25.9 | After 7 days |
| 2 | 1:1.5:3-G2 | | 800000 | 30.5 | |
| 3 | 1:1:2-G3 | | 932000 | 35.5 | |
| 4 | 1:1:1.5-G4 | | 896000 | 34.1 | |

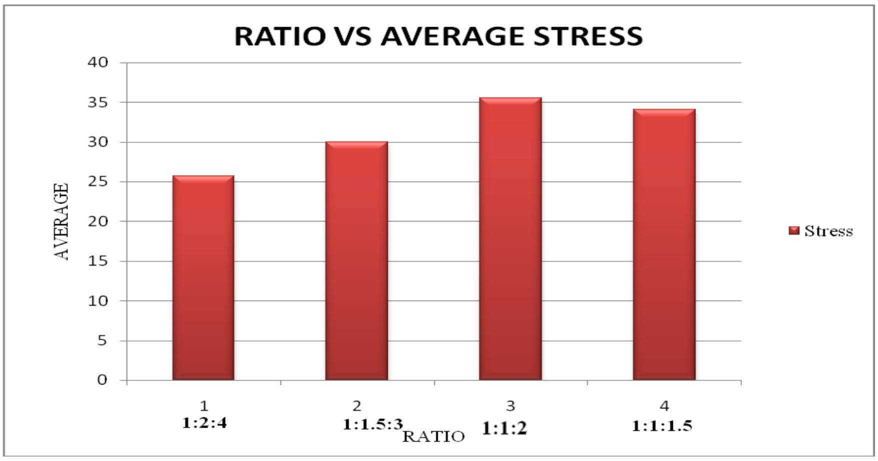


**Figure 4:** Development of Compressive Strength

### 5.2. FLEXURAL STRENGTH

The test was carried out in accordance with IS 15658 Annexure G. According to IS 15658, the minimum breaking load for residential/public pedestrian walkways and heavy duty/industrial roads is 2833 N. The specimen size was determined as 200x50mm (0.74Mpa)based on the flexure test calculation for geopolymer paver blocks. All geopolymer paver blocks met IS15658's minimum flexure strength requirements. The value of flexural strength shown in 'Table 7' and the comparative results are represented in 'Figure 5'.

**Table 6:** Flexural Strength Results

| S.No | Ratio of Mix Proportion | Area of Block($mm^2$) | Load(N) | Flexural strength | Curing Period |
|---|---|---|---|---|---|
| 1 | 1:2:4-G1 | 200x50 | 1650 | 1483 | After 7 days |
| 2 | 1:1.5:3-G2 | | 2900 | 2833 | |
| 3 | 1:1:2-G3 | | 3400 | 3217 | |
| 4 | 1:1:1.5-G4 | | 3400 | 3300 | |

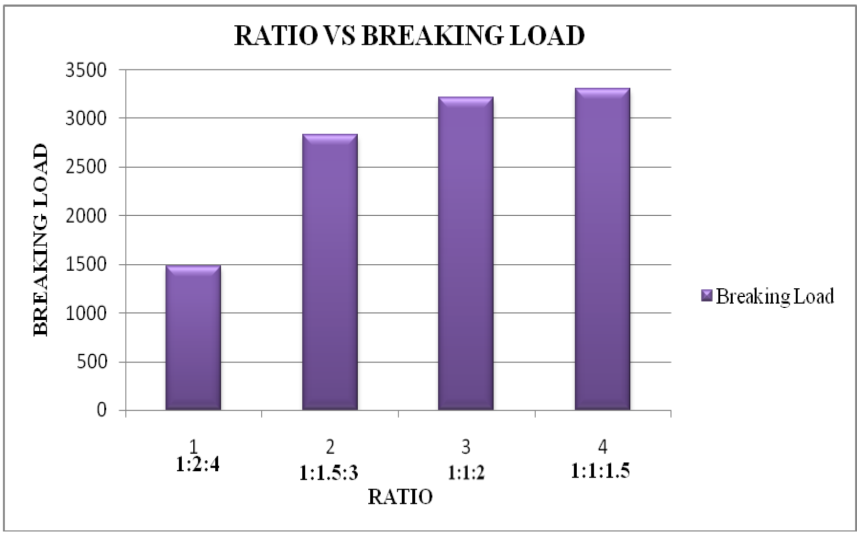


**Figure 5:** Development of Flexural Strength

### 5.3. ABRASION RESISTANCE TEST

Abrasion resistance test carried out as per Annexure E of IS 15656.The standard size of specimen was 70mm x 70mm x 25mm. The abrasion resistance was determined by calculating the volume loss following abrasion, as shown in Table 8. The volume loss varies between 1972.05mm$^2$ and 1373.25mm$^2$.The average abrasive resistance that is loss in volume for GPC paver block with M-sand was 776.45mm$^2$ per 4900mm$^3$.The development of abrasion resistance shown in 'Figure 6'.

**Table 7:** Abrasion Resistance Test Results

| S.No | Ratio of Mix Proportion | Weight of Specimen | Size of Specimen | Abrasion value |
|---|---|---|---|---|
| 1 | 1:2:4-G1 | 210.23 | 70X70X25 | 1972.05mm$^2$ |
| 2 | 1:1.5:3-G2 | 219.22 | | 986.03mm$^2$ |
| 3 | 1:1:2-G3 | 237.32 | | 776.45mm$^2$ |
| 4 | 1:1:1.5-G4 | 234.67 | | 1373.25mm$^2$ |

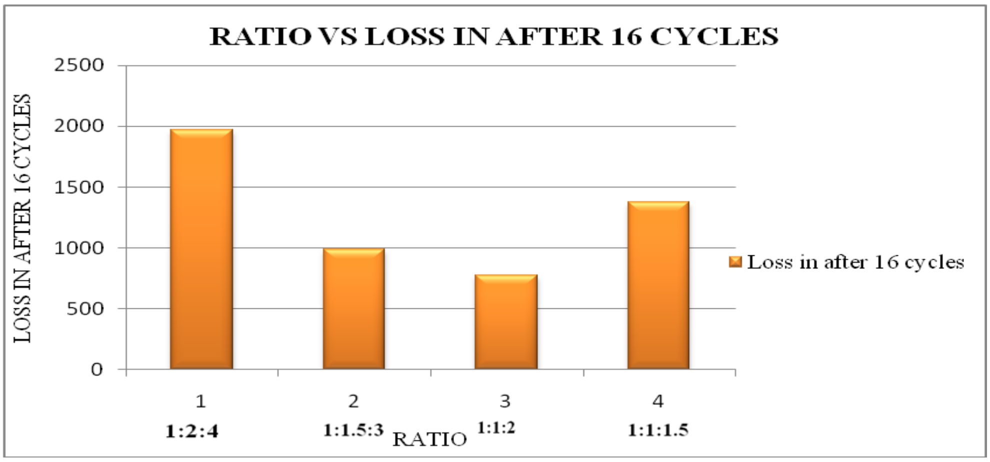


**Figure 6:** Development of Abrasion Resistance Test

## VI. CONCLUSION

The concrete cubes and beams of required sections were casted and the results were tabulated. The various tests that were done in order to assure the quality of concrete are slump test, compaction factor test, flow table test, compressive strength test, abrasion test, flexural strength tests and also we calculated the materials calculation and rates for blocks. They are concluded as follows:

- The fly ash is more economical without any adverse effect.
- This can be also marketed very easily anywhere. The availability of this material is high and the will be no scarcity.
- The geopolymer has less $CO_2$ Emission (78 kg/tonne of geopolymer production). In short these findings we will be of immerse use to the construction community.
- All of the test findings for the geopolymer pavement block made with M-sand and a GPC4 mix percentage were within the IS15658 limits, indicating that it may be used in non-traffic, light-traffic, residential routes, light vehicles/public pedestrian, and light-vehicle paths.
- So the geopolymer pavement block with M-sand will be more economical compared to normal pavement block.

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