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Analysis of Concrete for Optimum Use of Waste Material in Cement Concrete Precast Products

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***Abstract** – The rapid development in housing and infrastructure from last one decade continuously takes place in India. Along with that naturally the product required to overcome this development produce in mass quantities like Pavement blocks, which are known as industrial products of precast made up by concrete, having various shapes and sizes utilizes in huge quantity in housing and infrastructure construction. The conventional materials in manufacturing these blocks are utilized in large quantity, which may create impact on natural resources. To overcome these impact, we can use different materials such as, Sisal fiber, waste glass, fly ash etc, which helps to save natural resources and achieve economy so that buyers and sellers of these type of materials can also get benefited.*

The present experimental research investigation examines the effect of waste glass, fly ash and sisal fibers at partial replacement of fine aggregate and cement respectively, Experiment is done on M20 mix, with 15%, 30% & 45% partial replacement of both sand and cement. Similarly, sisal fiber is also added in the concrete paving block in 1%, 1.5% and 2% of weight of cement, so as to provide compressive strength to the same. After getting optimum percentage of all these, further experimental work is intended over the use of all these three in a single paving block. The replaced ingredients in this research are artificial waste or partially natural waste. Experimentation is carried out to find the compressive strength, abrasion resistance of the concrete paving blocks. Further these studies compare economical aspect of conventional product and new manufactured product.

***Keywords** – Housing and infrastructure development, natural resources, Sisal fibers, glass, fly ash, Compressive strength of concrete pavement block, economical aspect.*

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1. INTRODUCTION

Due to industrialization, consumption of construction materials is increased which causes the decrease of natural resources day by day. It creates environmental imbalance, so it is necessary to find alternative materials such as industrial waste or agricultural waste which can be replaced with construction materials completely or partially. Pavement blocks, which are industrial products of pre-fabricated unarmed concrete, having various dimensions and special morphology are used for pavement lying of residential project carrying pedestrian and vehicular traffic. Cement concrete paving blocks are precast solid products made out of cement concrete. The product is made in various sizes and shapes viz. rectangular, square and round blocks of different dimensions with designs for interlocking of adjacent tiles blocks. The raw materials required for manufacture of the product are Portland cement and aggregates which are available locally in every part of the country.

A concrete paving block is an accurately dimensioned combination of well-graded aggregates and hydrated Portland cement which fits closely together with other paving blocks to form a pavement surface. The blocks are manufactured in wide variety of shapes, some of which are shown in figure. The blocks are then compacted with a manually operated vibratory plate compacted which seats the blocks in the sand layer, compacts the sand layer, and forces some sand into the joints between the blocks. Additional sand is then applied to the surface and swept into the joints between the blocks. More passes are made with the vibratory plate compactor to compact and wedge the sand into the joints. A base and sub- base course under the leveling course provides structural support similar to that of a conventional flexible pavement. CBP provides low-maintenance, high-strength pavement surface that resists heavy, concentrated or abrasive loads and chemical spills involving fuel, hydraulic fluid, and other materials. Their modular nature and potential for reuse allow easy removal and replacement for access to bury utilities or to correct settlement. A block pavements unique characteristic (strength, abrasion resistance, flexible structure and aesthetics) make it applicable to many pavement uses, including military applications.

Cement concrete paving blocks find applications in pavements, footpaths, gardens, passenger waiting sheds, bus-stops, industry and other public places. The product is commonly used in urban areas for the above applications. Hence, the unit may be set up in urban and semi urban areas, near the market.

A lot of face-lift can be being given to roads, footpaths along the roadside. Concrete paving blocks are ideal materials on the footpaths for easy laying, better look and finish. Whereas the pavement blocks find extensive use outside the large building and houses, lots of these materials are also used in flooring in the open areas of public offices and commercial buildings and residential apartments

2. MATERIAL USED

2.1 Concrete Block –

Concrete block pavements differ from other forms of pavement in that the wearing surface is made from small paving units bedded and jointed in sand rather than continuous paving. Beneath the bedding sand, the substructure is similar to that of a conventional flexible pavement. In concrete block pavement the blocks are a major load-spreading component. The blocks are available in a variety of shapes and are installed in a number of patterns, such as stretcher bond, herringbone bond, etc. A review of existing literature revealed considerable differences in findings regarding the contribution of various block parameters to the structural capacity of pavement. The surface of concrete block paving comprises concrete blocks bedded and jointed in sand. It transfers the traffic loads to the substructure of the pavement.

2.2 Waste Material

2.2.1 Fly Ash

Fly ash is a waste produced in coal-fired thermal power stations. It has pozzolonic properties and can therefore be stabilized with either cement or lime to achieve the strength required for use as base courses in pavements. Agencies such as the Electric Power Research Institute (EPRI) have specified criteria and guidelines for the determination of the stabilizer content. This requires carrying out unconfined compression tests on stabilized fly ash specimens prepared and cured as per standard procedures. The stabilizer content is the minimum amount of the stabilizer for which the unconfined compressive strength of the specimens complies with the specified values. The actual curing conditions of the stabilized fly ash bases in the field, however, will differ from those of the laboratory specimens. This will affect the strength development of the bases, their durability, and their performance.

Most thermal power stations use coal as fuel in the furnaces to produce steam. The fuel gas carries along with it the fine residue of the burnt coal, which is deposited in a field of hoppers called electrostatic precipitators (ESP) This residue, called fly ash, and is generally considered to be an industrial waste. The utilization of fly ash has engaged the attention of experts from various fields for several decades. However, even today, there is a significant gap between the rates of utilization and production of fly ash, as the data in the situation in four major fly ash producing countries. The combined data for both dry type ash disposed of as collected (ESP) and wet type ash disposed of in slurry form in ash ponds and lagoons fly ash disposal systems. Fly ash is a fine-grained material of mostly silt size 0.075– 0.002 mm particles. It is non-plastic and can therefore be handled easily. Further, because of its pozzolanic properties, it can be stabilized with cement or lime to achieve the strength required for use as base and sub base courses in pavements. In Great Britain and France, pavement sections with cement-stabilized fly ash have been constructed for more than 35 years Glogowski et al. 1992. A survey made in 1992 Collins and Ciesielski1994, Coal 2001 indicated that at least 22 states in the United States have made some use of fly ash in stabilized base or sub base applications.

Table 2.1Tests on Fly Ash

Property	Value
Specific Gravity	2.3
Moisture Content	19.75
Fineness	0.001-0.6 mm
Soundness	0.15 %

2.2.2 Waste Glass

As solid waste disposal has received increasing attention, waste glass has been heavily targeted for recycling efforts, with some localities contemplating prohibitions of glass in landfills. Not all waste glass can be recycled into new glass because of impurities, prohibitive shipping costs, or mixed color waste streams that may be difficult to separate into useful raw glass stocks. Use of this waste glass in construction materials is among the most attractive options because of the volume of material involved, the capacity for use of the material in bulk, and the likely ability of construction applications to afford allowances for slight variation in composition or form. Considering waste glass not as waste but as a new resource, we crush, bake and foam it to produce Supersol, an artificial light porous foamed material. It can be used in various areas, such as greening, insulation, horticulture, water purification, architecture and civil engineering, and thus is a highly value-added product indispensible for developing recycling societies.Waste Glass is a transparent material produced by melting a mixture of materials such as silica, soda ash, and CaCO3 at high temperature followed by cooling during which solidification occurs without crystallization. Glass is widely used in our lives through manufactured products such as sheet glass, bottles, glassware, and vacuum tubing. The amount of waste glass is gradually increased over the recent years due to an ever-growing use of glass products. Most waste glasses have been dumped into landfill sites.The Land filling of waste glasses is undesirable because they are not biodegradable, which makes them environmentally less friendly. So we use the waste glass in concrete to become the construction economical as well as eco-friendly. (Source CEA annual report)

Table 2.2 Tests on Glass

Sr. No.	Property	Value
1	Specific Gravity	2.33
2	Bulk Density	2.53
3	Moisture Content	Nil
4	Fine particles less than 0.75mm(%)	13.5
5	Sieve Analysis	Zone II
6	Fineness	3.36
7	Silica (Sio2)	72.5
8	Alumina (Al2O3)	01.06
9	Iron Qxideb	0.36
10	Lime (Ca0)	0.8
11	Magnesio (Mgo)	04.18
12	Sodium Oxide(Na2o)	13.1

2.2.3 Sisal Plant

Sisal fibre is a leaf fibre extracted from the leaves of plant which is scientifically known as Agave sisalana. The Sisal plant is one of the types of perennial shrub which grows in the tropical and subtropical regions of the world.

Table 2.3 Tests on Sisal Fibers

Waxes	0.5%
Total	100
Density	800-700 Kg/m3
Water absorption	56%
Modulus of Elasticity(E)	15 Gpa
Tensile Strength	268 Mpa

3. EXPERIMENTAL WORK

3.1 Concrete Mix Design of M20 Grade of Concrete

a) Design Stipulation:

i) Characteristic strength 20 N/mm2

ii) Maximum size of aggregate10 mm

iii) Degree of quality control- Good

iv) Type of exposure- Moderate

Chemical	Percentage
Cellulose	71.5%
Hemicelluloses	18.1%
Lignin	5.1%
Pectin	2.3%

b) Materials:

Specific gravity of cement	3.15
Specific gravity of sand	2.62
Specific gravity of coarse aggregate	2.67

Step-1) Standard mean strength for mix design: f´ck = fck +1.65 S

S = Standard deviation.

Now, for M20 concrete, fck = 20 N/mm² & S = 5 N/mm².

f´ck = 20 + 1.65 × 5

f´ck = 26.60 N/mm²

Step-2) Selection of water/cement ratio:

For maximum aggregate size of 10mm, W/C Ratio is 0.45, Adopt ***W/C = 0.45***

Step-3) Selection of water content:

Maximum water content for max agg.size 10mm, is 208 kg/m³. Let us, take it as 189 kg/m³.

W = 188 Kg/m³

Step-4) Selection of cement content:

W/C = 0.45, Water content = 189 kg/m³.

So, cement content = 420 kg/m³

C = 417.78 Kg/m³

Step-5) Estimation of entrapped air:

For maximum aggregate size of 10mm, ***entrapped air is 3% of volume of concrete.***

Step-6) Selection of volume of aggregates in all-in-aggregate: For 10 mm size of aggregate (zone I)

Volume of coarse aggregate = 0.440 Volume of fine aggregate = 0.560

But for every 0.1 increase in C.F. & for zone I, reduce fine aggregate volume by 0.015

Hence, volume of fine aggregates in all-in-aggregate is 0.545.

Step-7) Mix Proportion:

$V = [W + (C/Sc) + (1/P) \times (Fa/Sfa)] \times (1/1000)$

$0.97 = [188 + (417.78/3.15) + (1/0.545) \times (Fa/2.62)] \times (1/1000)$

F.A. = 925.24 Kg/m³

$CA = [((1-P)/P) \times Fa \times (Sca/Sfa)]$

$CA = [((1-0.545)/0.545) \times 925.24 \times (2.67/2.62)]$

CA = 787.19 Kg/m³

Table 3.1: Summary of Mix Design

Sr. No.	Particulars	Quantity
1.	Water-cement ratio	0.45
2.	Cement	417.78 kg/m3
3.	Water	188 kg/m3
4.	Fine aggregate	925.24 kg/m3
5.	Coarse aggregate	787.19 kg/m3

MIX PROPORTION: W : C : FA : CA

0.45 : 1 : 1.5 : 3

3.2 Procedure for Manufacturing of Standard Concrete Block

Step No 1- All the ingredients of Concrete mixed with required quantities on GI sheet and mixing to be done by hand.

Step No 2- The mould for concrete block cleaned and spreading the oil in interior sides Of mould.

Step No 3- Mixed concrete now placed in mould and it get tempered by road the size of specimen will be 15*cm*15cm*15cm

Step No 4-Then the specimen demounted after 24 hours and placed in water tank for required days

3.3 Procedure for Manufacturing of Standard Concrete Paving Block

Step No 1- All the ingredients of Concrete mixed with required quantities on GI sheet and mixing to be done by hand.

Step No 2- The mould for concrete paving block cleaned and spreading the oil in interior sides of mould

Step No 3- Mixed concrete now placed in mould and it get tempered by road the size of specimen will be 15*cm*15cm*15cm

Step No 4-Then the specimen demounted after 24 hours and placed in water tank for required days

4. RESULT AND DISCUSION

Part A) OPTIMIZATION OF RESULTS:

The proportion for replacement of materials as follows

1. Fly ash replacement = (15%, 30%, 45% of weight of cement)
2. Waste glass replacement = (15%, 30%, 45% of weight of fine aggregates)
3. Sisal addition = (1%, 1.5%, 2% of weight of cement)

4.1 Conventional Concrete

Cubes are casted and tested of M 20 grade of concrete for conventional concrete without any replacement result as follows:

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Table No 4.1: Normal Concrete without any Replacement

Block No.	Peak Load (kN)	3 Days Comp. Strength	Avg. (N/mm²)
1.	137	6.1	
2.	132	5.9	6.1
3.	142	6.3	
Block No.	Peak Load (kN)	7 Days Comp. Strength	Avg. (N/mm²)
1.	297	13.2	
2.	288	12.8	12.96
3.	290	12.9	
Block No.	Peak Load(kN)	14 Days Comp. Strength	Avg. (N/mm²)
1	412	18.3	
2	400	17.8	17.91
3	396	17.6	
Block No.	Peak Load (kN)	21 Days Comp. Strength	Avg. (N/mm²)
1.	434	19.3	
2.	420	18.7	18.96
3.	425	18.9	
Block No.	Peak Load (kN)	28 Days Comp. Strength	Avg. (N/mm²)
1.	459	20.4	
2.	470	20.9	20.4
3.	448	19.9	

4.2 Determination of Optimum percentage of Fly ash/Glass Powder/Sisal Fiber

The fly ash added (15%, 30%, and 45% of weight of cement) and cubes are casted and tested to determine optimum percentages of replacement of cement by fly ash. The result as follows

Table No 4.2: Optimum percentage of Fly ash/Glass Powder/Sisal Fiber

Block No.	% of Replacement	Peak Load	3 Days Comp. Strength	Avg.
1	15	155	6.93	
2	15	158	6.99	7.00
3	15	159	7.1	
4	30	148	6.60	
5	30	155	6.90	
6	30	141	6.30	6.60
7	45	137	6.10	
8	45	142	6.32	
9	45	146	6.50	6.30

Block No.	% of Replacement	Peak Load	7 Days Comp. Strength	Avg.
1	15	293	13.04	
2	15	290	12.90	
3	15	297	13.20	13.04
4	30	291	12.93	
5	30	283	12.60	
6	30	265	11.80	12.44
7	45	205	9.15	
8	45	236	10.50	
9	45	252	11.20	10.28

Block	% of	Peak Load	14 Days Comp.	
1	15	220	9.78	
2	15	232	10.34	10.36
3	15	147	10.98	
4	30	362	16.11	
5	30	371	16.50	16.47
6	30	378	16.80	
7	45	292	12.98	
8	45	306	13.60	13.29
	9	45	299	

Block No.	% of Replacement	Peak Load	21 Days Comp. Strength	Avg.
1	15	406	18.08	
2	15	418	18.60	
3	15	425	18.90	18.76
4	30	407	18.10	
5	30	405	18.03	
6	30	402	17.90	18.01
7	45	402	17.90	
8	45	401	17.86	
9	45	399	17.74	17.83

Block No.	% of Replacement	Peak Load	28 Days Comp. Strength	Avg.
1	15	472	20.98	
2	15	474	21.10	21.12
3	15	479	21.30	
4	30	457	20.35	20.61
5	30	463	20.60	
6	30	470	20.90	
7	45	442	19.68	
8	45	445	19.80	19.83
9	45	450	20.02	

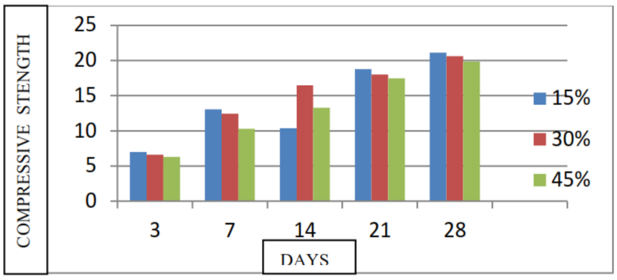

FIG No 4.3: Optimum Result For fly Ash Replacement

5. CONCLUSION

From the Experimental results we can conclude that,

1. The properties of ingredients of concrete which are using for conventional concrete are as per limit of IS code, so it can be used for further process.

2. The properties of fly ash, sisal fibers, and glass powder examined carefully , then we conclude that due to some similar properties

of conventional ingredients this waste materials can be added in concrete.

3. By the comparative study we can conclude that

i) Incorporating 15% Fly ash in place of cement helps to reduce the cost and thereby achieve economy with increase in compressive strength 30% waste glass in place of fine aggregate, gives acceptable mechanical properties with increased compressive strength at an age of 28 days. Additional sisal fiber **(**0.5% by weight of cement) increases compressive strength of concrete pavement block.

ii) Compressive strength increases with increasing the glass percentages from 15% to 30%, replacement of glass to the fine aggregate ,which helps to reduce cost and after 30% waste glass replacement onward, the strength decreases as the internal void of waste glass increases.

4. Fly ash can replace the cement up to 15%, which will help to reduce the cost & thereby bring economy. Cost of paving blocks decreases with increase in glass content. Sisal fiber will develop the strength in the concrete paving blocks which helps to give a long lasting performance by the paving blocks.

5. The value of abrasion resistance for paving block with addition of waste is minimum which is within limit of IS code.

6. Manufacturing cost of paving block can be reduced by using waste material up to 10%.

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