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A Brief Study on the Strength Characteristics of Concrete with Utilization of Plastic Waste as Fine Aggregate and Demolished Waste as Coarse Aggregate

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ABSTRACT: Global production of construction and demolition waste has significantly increased over the last few decades, causing environmental problems due to its uncontrolled disposal. The use of recycled materials has been on the rise during the same period, primarily for the purpose of sustainable development and protecting the environment. The aim of this work is to study the use of recycled construction and demolition waste aggregates to create hot asphalt mixtures for urban paved roads, which can be an alternative to mitigate the environmental problems derived from the inadequate administration and disposal of this type of waste. For this purpose, several tests were performed to evaluate the susceptibility of asphalt concrete specimens to moisture damage and plastic deformation. Four different percentages (10–40) of recycled aggregates were used to create asphalt concrete specimens. The volumetric design of the asphalt mixes was based on the Superpave criteria. To accelerate the mix design process, the Ramcodes method, also known as the polygon of voids method, was used. The test results from this study indicate that the use of construction and demolition waste aggregates in percentages of up to 20% for paving urban roads is feasible**.**

I. INTRODUCTION

Now-a-days infrastructure development across the world created demand for construction materials. Concrete is the premier civil engineering construction material, concrete contains ingredients like cement, aggregates, water and admixtures. At present, huge quantities of construction materials are required in developing countries due to continued infrastructural growth and also huge quantities of plastic wastes and demolition wastes are generated every year in developing countries like India. The disposal of this waste is a very serious problem because on one side it requires huge space for its disposal while on the other side it pollutes the environment. It is also necessary to protect and preserve the natural resources like stone, sand etc. Continuous use of natural- resources, like river sand is another major problem and this increases the depth of river bed resulting in drafts and also changing the climatic conditions.

So, the sustainable concept was introduced in construction industry due to growing concern about the future of our planet, because it is a huge consumer of natural resources as well as waste producer. This has created what we call the biggest problem of the world, demolished waste and plastic waste accumulation. Hence there is a need to recycle these waste into something more useful and environment friendly. To achieve this, major emphasis must be laid on the use of waste from various industries. The use of aggregates from construction and demolition waste in pavement beds is the most usual way of reusing this material. Even though considered as a valid reuse technique, it is not the best economic valorization of this resource and it is considered by many researchers to be a down-cycling process that depreciates the capacities of the material. But the production of structural concrete with recycled aggregates, however,

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offers great potential and recycles the materials viably and effectively. Research into new and innovative use of waste materials being undertaken world-wide and innovative ideas that are expressed are worthy of this important subject.

In addition to the environmental benefits in reducing the demand of land for disposing the waste, the recycling of plastic and demolition wastes can also help to conserve natural materials and to reduce the cost of waste treatment prior to disposal. The largest proportions of demolition waste are concrete rubbles and plastic wastes are covers, polythene bags, PVC pipes etc. It has been shown that the crushed concrete rubble, after separated from other construction and demolition wastes and sieved, can be used as a substitute for natural coarse aggregates in concrete. Reuse of bulky wastes is considered the best environmental alternative for solving the problem of disposal.

Today, more than ever before, the civil engineer is required to give thought and time to problems of concrete making and its utilization with economy. The results accomplished in the field by the engineer-in-charge depend upon his knowledge of concrete and of the constituent materials.

ADVANTAGES OF PLASTIC WASTE

Some of advantages of plastics are listed below;

- Generally plastic items like toys, bags can be reused in various ways such as in the manufacturing of fashionable accessories and other plastic goods.
- No doubt the recycling of plastic consume more energy and effort compare to its manufacturing but it is a good alternate to prevent the plastic pollution in environment.
- Plastic materials are light in weight, unbreakable, odourless and can be easily moulded.
- They have excellent finishing; possess good shock absorption capacity, high strength as well as toughness.
- The plastics materials are corrosion resistant and these are inert as far chemical or changes due to atmospheric oxygen goes; besides these have low thermal expansion of co-efficient.
- Therefore, they possess good thermal and electrical insulating property.
- Plastics have water resistant property and possess good adhesiveness. They are strong, durable, good and cheap to produce.
- It is possible to recycle plastic; therefore, no decomposition required which is much more expensive and hazardous than recycling.
- Plastic can be used in building, construction, electronics, packing and transportation industries.
- Plastic can be used to produce other product and reduce soil and wind erosion.
- Because of nonconductive nature of plastic, they can be easily use in electrical installations.

DISADVANTAGES OF PLASTIC WASTE

- Plastic is a soft, non-renewable resources which cannot be used for some crucial applications.
- The poisonous gaseous product produced by the decomposition plastic can causes CANCER
- They are embrittlement at low temperature and deformation at high pressure.
- Plastic materials have low heat resistant and poor ductility. But they are combustibility and release toxic fumes after burning.
- The recycling of plastic is not cost effective process and even more expensive compare to its manufacturing.
- The raw material for manufacturing of plastic bags is petrochemicals which are non-renewable resource.
- Plastic bags are flimsy and not durable like paper or cloth.

The improper disposal of plastic can cause hazard to wildlife as they are not readily biodegradable.

- Plastic materials like plastic bags are mostly end up as harmful waste in landfill which may pollute the environment and threatening our health.
- The biodegradation of plastic takes 500 to 1,000 years but manufacturing takes only seconds.

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RECYCLING OF AGGREGATES

Recycling as part of environmental considerations has become a common feature in the construction industry. Construction and demolition (C&D) debris is the waste material that results from the construction, renovation, or demolition of any structure, including buildings, roads, and bridges.

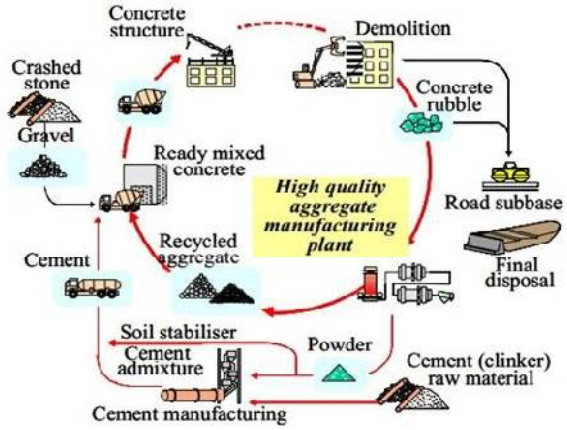

Figure- 1.Showing Recycling of concrete

APPLICATIONS OF CONSTRUCTION AND DEMOLITION WASTE

Construction and Demolition Waste (CDW) is produced during all stages in the life cycle of a building. Many types of CDW can be reused. The option for reuse will be discussed in this article. Unless otherwise started, all percentage quoted refer to percentage by weight.

CONCRETE RUBBLE

Without any processing, concrete rubble can be used for:

1. Hard standing;
2. Bank protection;
3. Fill and raising areas;
4. Road construction;
5. Noise barriers and embankments.

II. REVIEW OF LITERATURE

In this chapter a brief literature survey conducted on utilization of plastic waste and demolished waste in making concrete has been presented.

Tomas U. Ganiron Jr. [1] has reported that Plastic as a substitute to fine aggregate to concrete mixture has shown unusual characteristic upon accumulation of water in the mixture for the material had floated on the surface of the water, nevertheless, upon the completion of mixing the material has suitably bonded to the mixture. In the analysis of its grain particle, in comparison to sand, which is one of the major components of concrete mixture, plastic, implies significant lightness in terms of its mass evaluation. Overall, the effect of the plastic on the properties of the specimen was acceptable.

Franklin, Mmasetlhomo Tommy Gumede, [2] stated that it is obvious that structural compressive strengths may be developed in concretes incorporating up to 100% recycled aggregates based on standard mix design procedures. They also noted that the compressive, split tensile and flexural strengths, as well as the modulus of elasticity of

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recycled aggregate concretes, are generally lower than that of conventional concretes made entirely from natural aggregates.

Ganesh Tapkire1, Satishparihar, et al.,[3] reported that by using the plastic in concrete mix to reduces the weight of cube up 15% and it is possible to use the plastic in concrete and bonding admixture in concrete and also increase the % of plastic in concrete.

Shiva Kumar. M, Nithin K, B.M Gangadharappa, [4] reported that aggregate ratio of 1:8 with 50 % of CA and 50% of BDW is recommended for low traffic volume. Similarly mix design with w/c ratio of 0.40 and 0.45 with 50% of CA and 50% of BDW is suitable for intended use.

Youcef Ghernouti, Bahia Rabehi, et al.,[5] stated that the bulk density has decreased considerably for all concrete's with the content of replacement of sand by plastic waste that also becomes lighter than conventional concrete with 40% of plastic waste. Being given that the concrete must have good workability, fluidity is significantly improved by the presence of this waste.

III. THE MIX DESIGN FOR CONCRETE OF M_{20} GRADE

DESIGN PROCEDURE:

1. Characteristic compressive strength required in the field at 28 days = 20MP_a
2. Maximum size of aggregate= 20mm
3. Degree of workability
   (As per IS456-2000)= 0.90
4. Degree of quality control= Medium
5. Type of exposure= Mild

TEST DATA FOR MATERIALS:

1. Cement Ordinary Portland Cement 53 grade satisfying the requirements of (IS:269-1976)
2. Specific gravity of cement = 3.15
3. Specific gravity
   a) Coarse aggregate = 2.64
   b) Fine aggregate =2.60
   c) Waste plastic = 0.87
4. Free (surface) moisture
   a) Coarse aggregate = Nil
   b) Fine aggregate = 2%
5. Fineness modulus(sieve analysis)
   a) 1) Coarse aggregate = 4.01
   b) 2) Fine aggregate = 4.98

1.) TARGET MEAN STRENGTH OF CONCRETE:

$f_t = f_{ck} + (k \times s)$

Where

f_t= Target mean compressive strength at 28 days

f_{ck} =Characteristic compressive strength at 28 days

S = Standard deviation

K =Assumed value of tolerance factor (Risk factor) = 1.65

$f_t = f_{ck} + (k \times s)$

$20 + (1.65 \times 4) = 26.6$ MP_a

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2.) SELECTION OF WATER AND SAND CONTENT:

For 20 mm nominal maximum size aggregates and sand conforming to grading zone-III, water content per cubic meter of concrete= 186 kg and sand content as percentage of total aggregate by absolute volume= 35%

Minimum cement content as per table IS 456-2000 = 220 kg/m^3

TABLE 1: SELECTION OF WATER AND SAND CONTENT

CHANGE IN CONDITION	PERCENTAGE ADJUSTMENT REQUIRED	
	WATER CONTENT	SAND IN TOTAL AGGREGATE
For decrease in water-cement ratio by (0.6-0.5) that is 0.1	0	-2.0
For increase in compaction factor (0.9-0.8) that is 0.1	+3.0	0
For sand conforming to zone-III of Table 4, IS:383-1970	0	+1.5
Total	+3%	-0.5%

Therefore, required sand as percentage of total aggregate by absolute volume = 35-0.5 = 34.5%

Required water content = 186+ $\frac{186\ X\ 3}{100}$ = 191.58 Kg/cum

3.) DETERMINATION OF CEMENT CONTENT:

Water- cement ratio= 0.5

Water= 191.58 Kg/m^3

Cement= 383.16 Kg/m^3

This cement content is adequate for mild exposure condition, according to IS:456-2000.

4.) DETERMINATION OF COARSE AGGREGATE AND FINE AGGREGATE CEMENT:

For specified maximum size of aggregate of 20mm, the amount of entrapped air in the wet concrete is

$V= [W + \frac{C}{Sc} + \frac{1}{P}\frac{fa}{Sfa}] \times \frac{1}{1000}$

$0.98=\left(191.58 + \frac{383.16}{3.15} + \frac{1}{0.345} * \frac{fa}{2.60}\right) * \frac{1}{1000}$

Fine aggregate (fa) = 598.10 kg/m3

$c_a = \frac{1-P}{P} \times f_a \times \frac{Sca}{Sfa}$

$c_a = \frac{1-0.345}{0.345} \times 598.10 \times \frac{2.64}{2.60}$

Coarse aggregate (ca) =1153 kg/m3

Where,

V= volume of aggregates

f_a = volume of coarse aggregates

c_a = volume of coarse aggregates

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TABLE 2: DETERMINATION OF COARSE AGGREGATE AND FINE AGGREGATE CEMENT

WATER (kg/m^3)	CEMENT (kg/m^3)	FineAggregate (kg/m^3)	Coarse Aggregate (kg/m^3)
191.58	383.16	598.10	1153
0.5	1	1.56	3.01

5.) ACTUAL MIX QUANTITY REQUIRED FOR THE MIX PER BAG OF CEMENT:

The mix is 0.5 : 1 : 1.56 : 3.01. For 50 kg of cement, the quantities of materials are worked out as below

Cement = 50 kg
Fine aggregate = 78 kg
Coarse aggregate =150.5 kg
Water content = 25 kg

For water – cement ratio of 0.5, quantity of water required per bag of cement = 25 litres
Extra quantity of water considering free moisture above SSD (Saturated Surface Dry) condition.
For coarse aggregate, extra quantity of water to be added for absorptions = 0.8% of 150.5 = 1.204 liters
For fine aggregate, quantity of water to be deducted for free moisture present = -2% of 78 kg = - 1.56 litres
Actual quantity of water required to be added = 25+1.204-1.56= 24.64 litres
Actual quantity of sand required after allowing for mass of free moisture = 78+1.56 = 79.56 kg
Actual quantity of coarse aggregate = 149.30 kg
Therefore, the actual quantities of different constituents required for the mix are:
Water = 24.64 kg
Cement = 50.00 kg
Sand = 79.56 kg
Coarse Aggregate = 149.30 kg

The mix proportions of M_{20} grade concrete mix obtained with a constant water-cement ratio as 0.5 in the present investigation is **1:1.56:3.01.**

IV. EXPERIMENTAL RESULTS

TABLE 3: COMPACTION FACTOR TEST VALUES

S. No	Mix Name	% of Plastic Waste	% of Demolished Waste	Slump in mm	Compaction Factor in %
1	N	0	0	80	85.00
2	A	10	0	100	89.00
3	B	10	10	90	89.20
4	C	10	20	75	82.50
5	D	10	30	50	83.40
6	E	10	40	30	82.10
7	F	10	50	20	84.30

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TABLE 4: DENSITIES OF PLASTIC WASTE & DEMOLISHED AGGREGATE CONCRETE

S.No.	Mix Name	% of Plastic Waste	% of Demolished Waste	Wt. of Cube in Kg.	Density in Kg / m^3	% of Increased / Decreased in Density
1	N	0	0	7.66	2270	----
2	A	10	0	7.68	2276	0.26
3	B	10	10	7.72	2287	0.74
4	C	10	20	7.64	2263	-0.31
5	D	10	30	7.60	2252	-0.79
6	E	10	40	7.45	2207	-2.77
7	F	10	50	7.38	2187	-3.65

TABLE 5: CUBE COMPRESSIVE STRENGTH TEST RESULTS

S. No.	Mix Name	Percentage of plastic waste	Percentage of recycled aggregate	Load in KN	Compressive Strength (f_{ck}) in N/mm^2	Load in KN	Compressive Strength (f_{ck}) in N/mm^2
				7 Days		28 Days	
1	N	0	0	517.50	23.00	821.25	36.50
2	A	10	0	547.87	24.35	839.25	37.30
3	B	10	10	589.50	26.20	876.60	38.96
4	C	10	20	517.50	23.00	781.87	37.60
5	D	10	30	506.47	22.51	774.00	34.40
6	E	10	40	436.72	19.41	704.25	31.30
7	F	10	50	453.37	20.15	621.00	27.60

TABLE - 6: CYLINDER SPLIT TENSILE STRENGTH

S. No.	Mix Name	Percentage of plastic waste	Percentage of recycled aggregate	Load in KN	Split Tensile Strength (f_t) in N/mm^2	Load in KN	Split Tensile Strength (f_t) in N/mm^2
				7 Days		28 Days	
1	N	0	0	162.57	2.30	168.93	2.39
2	A	10	0	91.89	1.30	130.06	1.84
3	B	10	10	144.19	2.04	190.84	2.70
4	C	10	20	123.61	1.75	163.98	2.32
5	D	10	30	120.16	1.70	137.12	1.94

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6	E	10	40	118.75	1.68	131.47	1.86
7	F	10	50	118.04	1.67	121.57	1.72

TABLE - 7 SPLIT TENSILE STRENGTH FOR 7 DAYS

S.No.	Mix Name	% of Plastic Waste	% of Demolished Waste	Load in KN	Comparison of Values of Split Tensile Strength in MPa		% of Increase / Decrease in Split Tensile Strength
					Theoretical Values ($0.35\sqrt{f_{ck}}$)	Experimental Values ($2P/\pi DL$)	
1	N	0	0	144.19	1.67	2.04	--
2	A	10	0	130.62	1.73	1.85	-9.31
3	B	10	10	162.57	1.79	2.30	12.75
4	C	10	20	123.61	1.67	1.75	-14.22
5	D	10	30	120.16	1.66	1.70	-16.67
6	E	10	40	118.75	1.54	1.68	-17.65
7	F	10	50	118.04	1.57	1.67	-18.14

TABLE - 8 SPLIT TENSILE STRENGTH FOR 28 DAYS

S.No.	Mix Name	% of Plastic Waste	% of Demolished Waste	Load in KN	Comparison of Values of Split Tensile Strength in MPa		% of Increase / Decrease in Split Tensile Strength
					Theoretical Values ($0.35\sqrt{fck}$)	Experimental Values ($2P/\pi DL$)	
1	N	0	0	168.93	2.11	2.39	--
2	A	10	0	130.06	2.13	1.84	-23.01
3	B	10	10	190.84	2.18	2.70	12.97
4	C	10	20	163.98	1.83	2.32	-2.92
5	D	10	30	137.12	2.05	1.94	-18.83
6	E	10	40	131.47	1.95	1.86	-22.18
7	F	10	50	121.57	1.83	1.72	-28.03

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TABLE - 9 IMPACT RESISTANCE TEST RESULTS FOR 7 DAYS

S.No.	Mix Name	% of Plastic Waste	% of Demolished Waste	No. of Blows	Impact Energy in N-m	% of Increase / Decrease in Impact Energy
1	N	0	0	375	7632.59	--
2	A	10	0	320	6513.14	-14.66
3	B	10	10	400	8141.43	6.66
4	C	10	20	314	6391.16	-16.26
5	D	10	30	292	5943.37	-22.13
6	E	10	40	249	5068.15	-33.59
7	F	10	50	202	4111.51	-46.13

TABLE - 10 IMPACT RESISTANCE TEST RESULTS FOR 28 DAYS

S.No.	Mix Name	% of Plastic Waste	% of Demolished Waste	No. of Blows	Impact Energy in Nm	% of Increase / Decrease in Impact Energy
1	N	0	0	425	8650.27	--
2	A	10	0	319	6492.93	-25.00
3	B	10	10	475	9668.00	10.52
4	C	10	20	364	7408.85	-14.35
5	D	10	30	342	6961.06	-19.53
6	E	10	40	299	6085.84	-29.66
7	F	10	50	251	5108.85	-41.00

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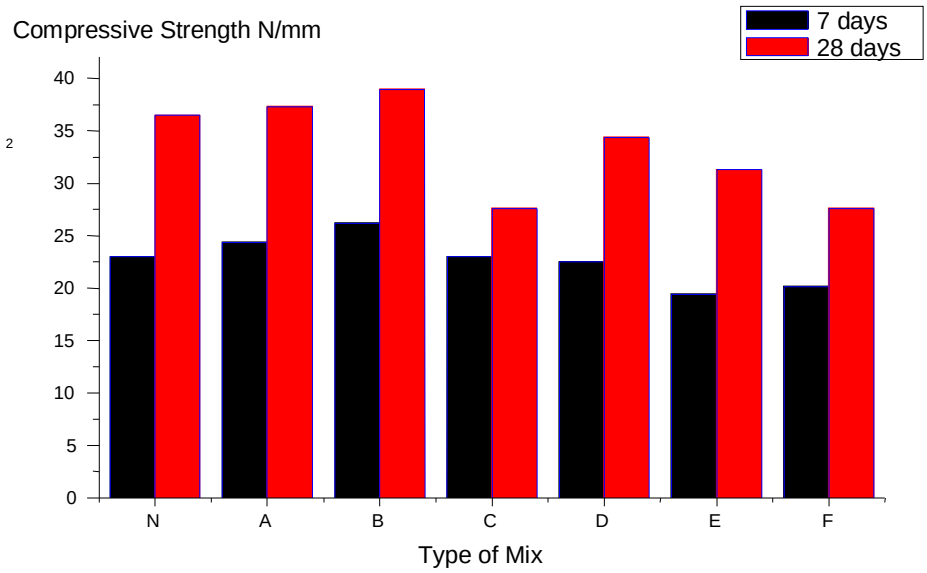
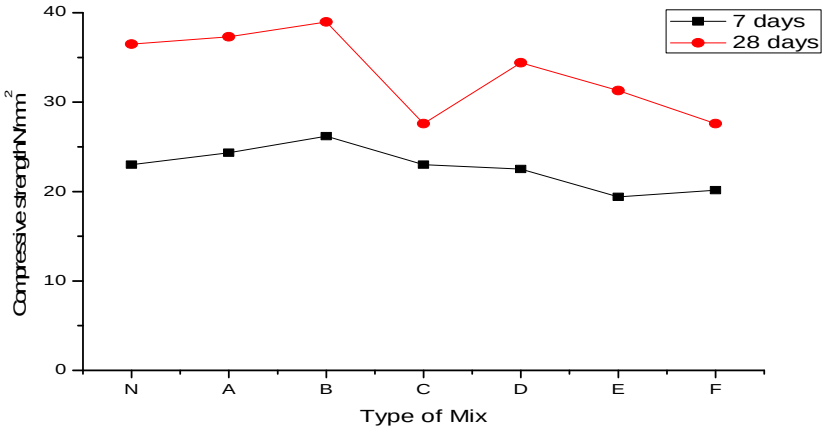


GRAPH 1: SUPER POSITION OF 7 DAYS AND 28 DAYS CUBE COMPRESSIVE STRENGTH TEST DETAILS FOR VARIOUS MIXES



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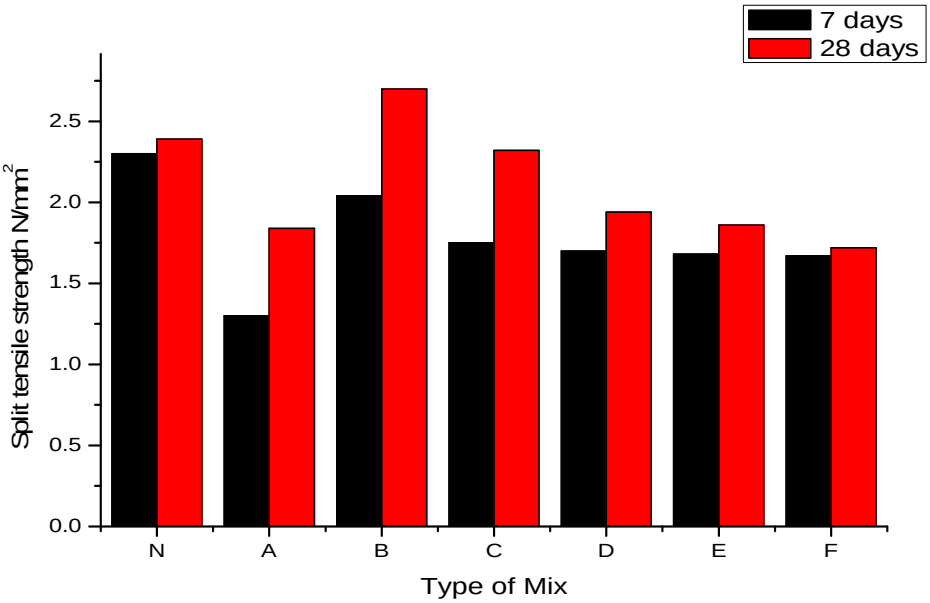
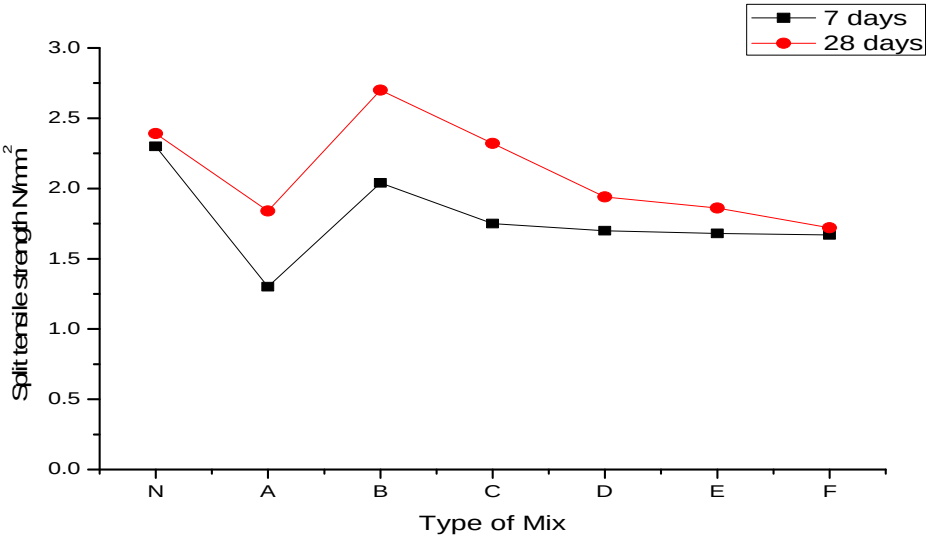


GRAPH 3: SUPER POSITION OF 7 DAYS AND 28 DAYS CYLINDRICAL SPLIT TENSILE STRENGTH TEST DETAILS FOR VARIOUS MIXES



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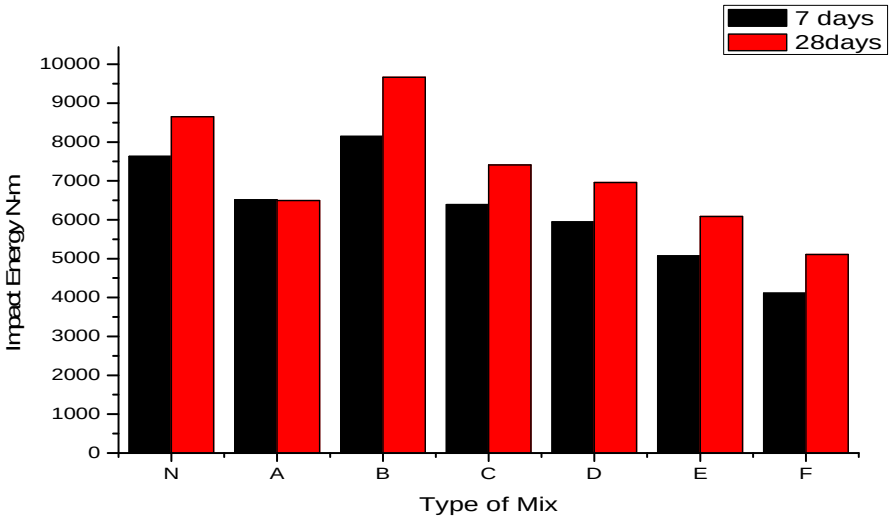
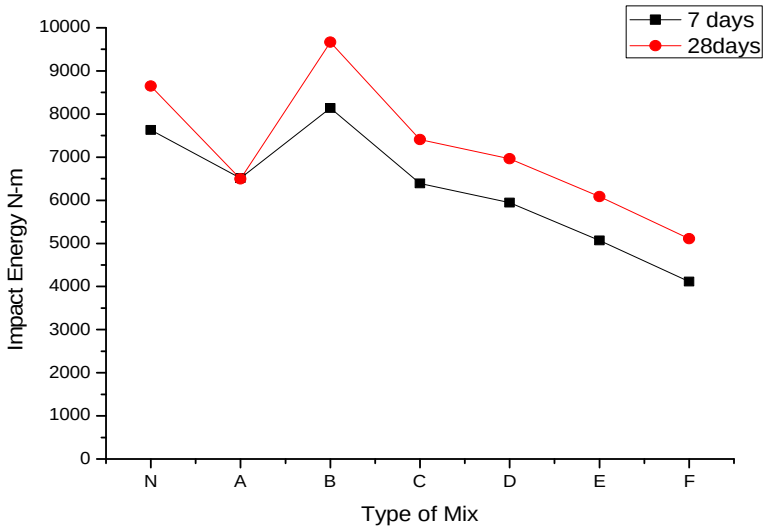


GRAPH 5: SUPER POSITION OF 7 DAYS AND 28 DAYS IMPACT RESISTANCE STRENGTH TEST DETAILS FOR VARIOUS MIXES



GRAPH 6: SUPER POSITION OF 7 DAYS AND 28 DAYS IMPACT RESISTANCE STRENGTH TEST DETAILS FOR VARIOUS MIXERS

V. CONCLUSIONS AND FUTURE RECOMMENDATIONS

From the limited study conducted in the present investigation using plastic waste as fine aggregate and demolished waste as coarse aggregate the following tentative conclusions have been arrived at.

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Conclusions:

There is a great potential for usage of the abundantly available environmental pollutants like Plastic Waste and Demolished waste in the Structural Engineering.

- It is observed that the Cube Compressive strength for 7 days increased to 26.20 N/mm^2 when constant percentage of plastic waste replaced to fine aggregate is 10% and varying percentage of demolished waste used to coarse aggregate is 10%,and for 28 days for the same replacement the cube compressive strength increased to 38.96 N/mm^2 from here the strength started decreasing for rest of the proportions.
- It is observed that the Split Tensile strength for 7 days increased to 2.04 N/mm^2 when constant percentage of plastic waste replaced to fine aggregate is 10% and varying percentage of demolished waste used to coarse aggregate is 10%,and for 28 days for the same replacement the split tensile strength increased to 2.70 N/mm^2 from here the strength started decreasing for rest of the proportions.
- It is observed that the Impact resistance energy for 7 days increased to 8141.43 N-m when constant percentage of plastic waste replaced to fine aggregate is 10% and varying percentage of demolished waste used to coarse aggregate is 10%,and for 28 days for the same replacement the Impact resistance energy increased to 9668 N-m from here the strength started decreasing for rest of the proportions.
- Finally it can be concluded that replacement of fine aggregate with plastic waste at a constant rate of 10% and replacing varying percentage of coarse aggregate with 10% demolished waste, there is a gain in cube compressive strength, split tensile strength, impact resistance of concrete. The use of plastic waste and demolished waste in conventional concrete has proved to be advantageous because of social benefits, cost reduction and usage of waste material into usable product.

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