International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 3, pp: 352-362 www.ijaem.net ISSN: 2395-5252

Comparative study on durability properties of concrete with partial replacement of fine aggregate by pvc waste

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Date of Submission: 25-07-2020 Date of Acceptance: 05-08-2020

ABSTRACT: This paper presents the,pvc waste was used as a partial replacement to the concrete ingredient i.e. fine aggregate and the durabilty properties like compressive strength loss, weight loss with acid and marine attack with curing ages of 56 & 84 days were measured . For checking strength effect of partial replacement of fine aggregate by pvc waste, the fine aggregate is replaced at 2.5%, 5%, 7.5%, 10%,12.5 and15%. For this study, concrete mixtures were prepared, for structural grade M25 and M30. Durability studies like compressive strength loss and weight loss with acid and marine attack with curing ages of 56 & 84 days were conducted and comparisons have to be made with the conventional concrete**.**

Key words: PVC waste, Durability, Acid attack, Marine attack, Compressive strength loss,Weight loss.

I. INTRODUCTION

Concrete is the most widely used construction material in the world. There is a concern to more understanding and to improve its properties. Using waste and recycled materials in concrete mixes becoming increasingly important to manage and treat both the solid waste generated by industry and municipal waste.The advancement of concrete technology can reduce the consumption of natural resources and reduce the burden of pollutants on the environment. The cost of natural resources is increased day by day. They have forced to focus on recovery, reuse of natural resources and find other alternatives. Presently large amounts of PVC waste are generated in pipe industries with an important impact on environment and humans. The use of the replacement materials offer cost reduction, energy savings, arguably superior products, and fewer hazards in the environment. Concrete volume contains from 65–80% aggregate and it plays a substantial role in concrete properties such as workability, strength, dimensional stability, and durability, so the use of waste materials in concrete as aggregates can effect in the amount of waste materials deeply. Lightweight aggregate is an important material in reducing the unit weight ofconcrete.

Plastic is one of the most significant innovations of 20th century material. The amount of plastic consumed annually has been growing steadily and becomes a serious environmental problem. For solving the disposal of large amount of recycled plastic material, use of plastic in concrete industry is considered as feasible application. Plastics are polymers, a very large molecule made up of smaller units called monomers which are joined together in a chain by a process called polymerization. The polymers generally contain carbon and hydrogen with, sometimes, other elements such as oxygen, nitrogen, chlorine or fluorine (UNEP, 2009). Plastics have become an integral part of our lives. The amount of plastics consumed annually has been growing steadily. Its low density, strength, user-friendly designs, fabrication capabilities, long life, lightweight, and low cost are the factors behind such phenomenal growth. Plastics have been used in packaging, automotive and industrial applications, medical delivery systems, artificial implants, other healthcare applications, water desalination, land/soil conservation, flood prevention, preservation and distribution of food, housing, communication materials, security systems, and other uses. With such large and varying applications, plastics contribute to an ever increasing volume in the solid waste stream. The world's annual consumption of plastic materials has increased from around 5 million tons in the 1950s to nearly100 million tons in 2001 (Siddique et al., 2008).

II. LITERATUREREVIEW

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(1)Youcef Ghernouti et al.(1997) The study present the partial replacement of fine aggregate in concrete by using plastic fine aggregate obtained from the crushing of waste plastic bags. Plastic bags waste was heated followed by cooling of liquid waste which was then cooled and crushed to obtained plastic sand having finesse modulus of 4.7. Fine aggregate in the mix proportion of concrete was replaced with plastic bag waste sand at 10%, 20%, 30% and 40% whereas other concrete materials remain same for all four mixes. In fresh properties of concrete it was observed from the results of slump test that with increase of waste content workability of concrete increases which is favorable for concrete because plastic cannot absorb water therefore excessive water is available

(2)Pramod S.Patil.et al(1999) This study presents the use of plastic recycled aggregate as replacement of coarse aggregate for production of concrete. They used forty eight specimen and six beams/cylinders casted from variable plastic percentages (0, 10, 20, 30, 40 and 50%) used as replacement of coarse aggregate in concrete mixes. They have conducted various tests and observed decrease in density of concrete with increase percentage of replacement of aggregate with recycle plastic concrete. They also reported decrease in compressive strength for 7 and 28 days with increase in percentage of replacement of coarse aggregate with recycle plastic aggregate. They have recommended feasibility of replacing 20 % will satisfy the permissible limits of strength.

(3)R L Ramesh et al.(2000) They have used waste plastic of low density poly ethylene as replacement to coarse aggregate to determine its viable application in construction industry and to study the behavior of fresh and harden concrete properties. Different concrete mix were prepared with varying proportions (0%, 20%, 30% & 40%) of recycle plastic aggregate obtained by heat treatment of plastic waste (160-200 centigrade) in plastic granular recycling machine. A concrete mix design with 1: 1.5: 3 proportions was used having 0.5 water/cement ratio having varying proportion of plastic aggregate as replacement of crushed stone. Proper mixing was ensured and homogeneous mixture was prepared. A clear reduction in compressive strength was reported with increase in percentage of replacing plastic aggregate with crushed aggregate at 7, 14 and 28 days of casted cubes (80% strength achieved by replacing waste plastic up to 30%). The research highlights the potential application of plastic aggregate in light weight aggregate.

(4)Raghatate Atul M.(2002) The paper is based on experimental results of concrete sample casted with use of plastic bags pieces to study the compressive and split tensile strength. He used concrete mix by using Ordinary Portland Cement, Natural River sand as fine aggregate and crushed granite stones as coarse aggregate, portable water free from impurities and containing varying percentage of waste plastic bags (0%, 0.2%, 0.4%, 0.6% 0.8% and 1.0%). Compressive strength of concrete specimen is affected by the addition of plastic bags and with increasing percentage of plastic bag pieces compressive strength goes on decreasing (20% decrease in compressive strength with 1% of addition of plastic bag pieces). On other hand increase in tensile strength of concrete was observed by adding up to 0.8% of plastic bag pieces in the concrete mix afterward it start decreasing when adding more than 0.8% of plastic bags pieces

III. MATERIALS ANDMETHODOLOGY

1.1 Cement: OrdinaryPortlandCement(OPC)of53gradeofCementconformingtoIS:12269 standards has been procured and various tests have been carried out according IS: 8112-1989 from them it is foundthat

a) Specific Gravity of Cement is3.14
b) Wegetinitialsettingtimeof40minandfinalsetting timeof395min
c) 5% is the fineness ofcement

1.2 FineAggregates: Thenaturalriversandistakenfr omtheusualplaceanditisconfirmedtograding zone-IIfromtheTable4ofIS383-1970.Someofthetestshavebeenvotedforoutasper thetechnique given in IS383(1970)

a) Fine aggregate specific gravity is2.64
b) Fineness Modulus of Fine Aggregate is3.05

1.3 CoarseAggregates: FromIS383-1970consisting20mmmaximumsizeofaggregate shasbeen takenfromthelocalquarryindustry.Afterthatwete stedtheaggregatephysicallyandmechanically mainlysuchasspecificgravityandsieveanalysisre sultsarewrittenasbelow

a) CA Specific Gravity is2.79
b) CA Fineness Modulus of7.408

1.4 Water: Formixingandcuringpurposelocaldrinki ngwaterfreeflowimpuritieshasbeenusedin thisprogram

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3.5 pvc waste: pvc waste can be used in concrete to improve its strength and durability . pvc waste can be used as a partial replacement of fine aggregate, the pvc waste is gathered from nearby SURYA PVC COMPANY PVT LIMITED situated near pattipadu ,West Godavari, A.P.

Table no 3.1 Properties of Pvc waste

S.no	Property	Obtained value
1	Density	1.38g/cm3
2	Specific gravity	0.55
3	Water absorption	0.654%
4.	Finess modulus	4.34

3.6 MIX DESIGN

Table 3.2 Material required for M25 grade concrete per cubic meter quantity of concrete:

Material	Water	Cement	Fineaggregate	Coarse Aggregate
Kg/m^3	197	394	680.16	1172.80
Ratio	0.50	1	1.76	2.97

Table 3.3 Material required for M30 grade concrete per cubic meter quantity of concrete**:**

Material	Water	Cement	Fine aggregate	Coarse Aggregate
Kg/m^3	197	437	649.57	1150.31
Ratio	0.45	1	1.48	2.62

3.7 Durabilitytest:

3.7.1 Acid attack

Sulphuric, nitric, hydrochloric and phosphoric acids these are the mineral acids to attack the concrete.Ordinary Portland Cement (OPC) is highly alkaline in nature with pH values above 12. When the cement paste comes into contact with the acids its components break down, this phenomenon is known as acid attack.If pH decreases to values lower than stability limits of cement hydrates, then the corresponding hydrate loses calcium and decomposes to amorphous hydrogel. The final reaction products of acid attack are the corresponding calcium salts of the acid as well as hydrogels of silicium, aluminum, and ferric oxid.HCL acid have been performed in this study.

In the present experimental investigation, Acid attack test was performed on Concrete cubes of size 100mm×100mm×100mmwerecastandstoredinaplaceatroomtemperaturefor24hoursandthen the specimens were demoulded and kept for curing in water for days. 3 specimens were taken out from water tank and recorded their respective weight and compressive strength. After 28 days, again these specimens have been exposed to 5% concentrated HCl and water. After completion of the exposure period of 56, and 84 days percentage loss of weight of specimens and loss of compressive strength with respect to reference concrete have been calculated. Themasslossduetodeteriorationofconcretewascalculatedafter28daysofimmersionby using the followingformula

$$\text{Mass loss} = \left[\frac{(M_i - M_f)}{M_i}\right] \times 100$$

where,

M_i = Initial mass of concrete specimen before immersion

M_f = Final mass of concrete specimen after immersion

3.7.2 Marine attack

About 80 percent of the surface of the earth are covered by oceans; therefore, a large number of structures are exposed to sea water with high salinity either directly, or indirectly when winds carries sea water spray up to a few miles inland from the coast. As a result, several coastal and offshore sea structures are exposed to the

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continuous action of physical and chemical deterioration processes. This challenge of building and maintaining durable concrete structures in coastal environs have long become a serious issue to the people living in this areas and this provides an excellent opportunity to understand the complexity of concrete durability problems in these areas.

Table 3.4 Chemical Analysis of Fresh water and Sea water

NORMAL WATER	TEST	MARINE WATER
6.30	PH	7.9
0.0060	CONCENTRATION	0.097
250ppm	HARDNESS	4850ppm
20ppm	ACIDITY	100ppm
22ppm	ALKANITY	25ppm

In order to study the durability behavior of PVC waste aggregate concrete, a total of specimens 133 were cast. Mixing of ingredients of specimens has been shown in the fig . For experimentation programme, cube specimens have been cast as per given schedule and kept curing for 28 days. After curing days, 3 specimens were taken out from water tank and recorded their respective weight and compressive strength. After 28 days, again these specimens have been exposed to marine water.After completion of the exposure period of 56 and 84 days percentage loss of weight of specimens and loss of compressive strength with respect to reference concrete have been calculated.

IV. RESULTS ANDDISCUSSIONS:

4.1Acid AttackResults:

The behavior of acids on solidified concrete is the exchange the ferrous compounds into the ferrous salts of the striking acid. It is experienced to additional loss of weight.

Theexperimentresultsofacidattacktestwith5%Hydro chloric acid(HCL)ofM25 &M30 gradeconcrete loss of weight and loss of compressive strength withdifferentproportionsofpvc wasteisdisplayedin Table 4.1,4.2,4.3& 4.4Thelossof weight and loss ofcompressive strength of M25 &M30gradeconcretewithalteredpercentagesof Pvc waste is shown in Figure 4.1,4.2,4.3&4.4

Table 4.1: Acid test results on weight loss of PVC waste with fine aggregate replacement of M25 grade

S.No	Percentage of replacement with PVC waste	Weight of cubes cured in water after 28 days (gms)	Weight of cubes subjected to acid exposure after 56 days (gms)	Weight of cubes subjected to acid exposure after 84 days (gms)	% of weight loss after 56 days	% of weight loss after 84 days
1	0	2529	2508	2487	0.837	1.688
2	2.5	2416	2390	2349	1.087	2.852
3	5.0	2213	2175	2142	1.747	3.314
4	7.5	1987	1946	1909	2.106	4.085
5	10	1847	1804	1771	2.383	4.291
6	12.5	1726	1680	1652	2.738	4.479
7	15.0	1697	1650	1619	2.848	4.817

Table 4.2: Acid test results on weight loss of PVC waste with fine aggregate replacement of M30 grade

S.No	Percentage of replacement with PVC waste	Weight of cubes cured in water after 28 days (gms)	Weight of cubes subjected to acid exposure after 56	Weight of cubes subjected to acid exposure after 84	% of weight loss after 56 days	% of weight loss after 84 days

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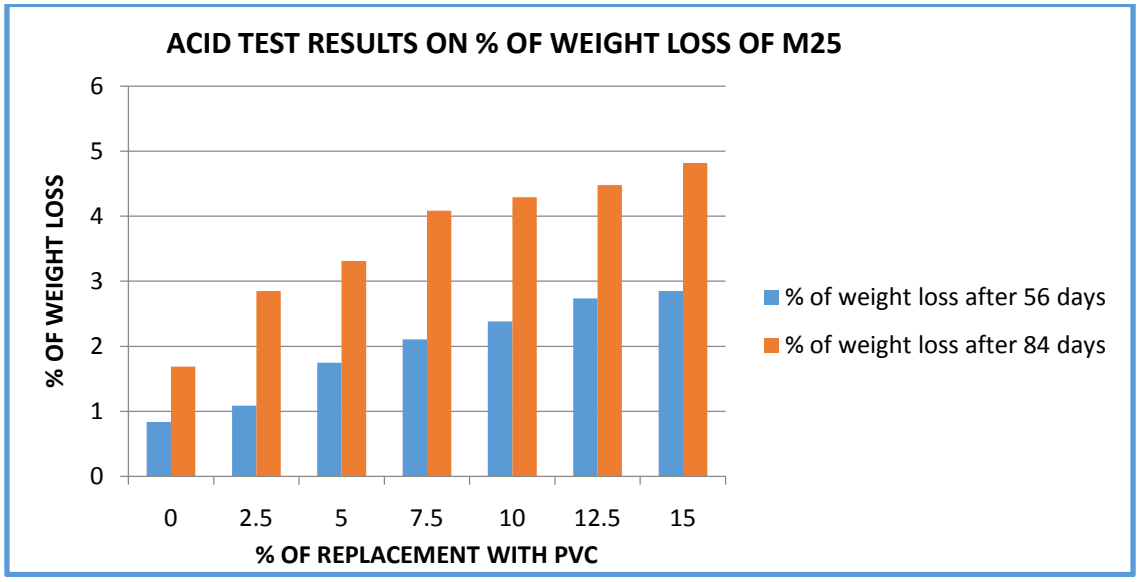
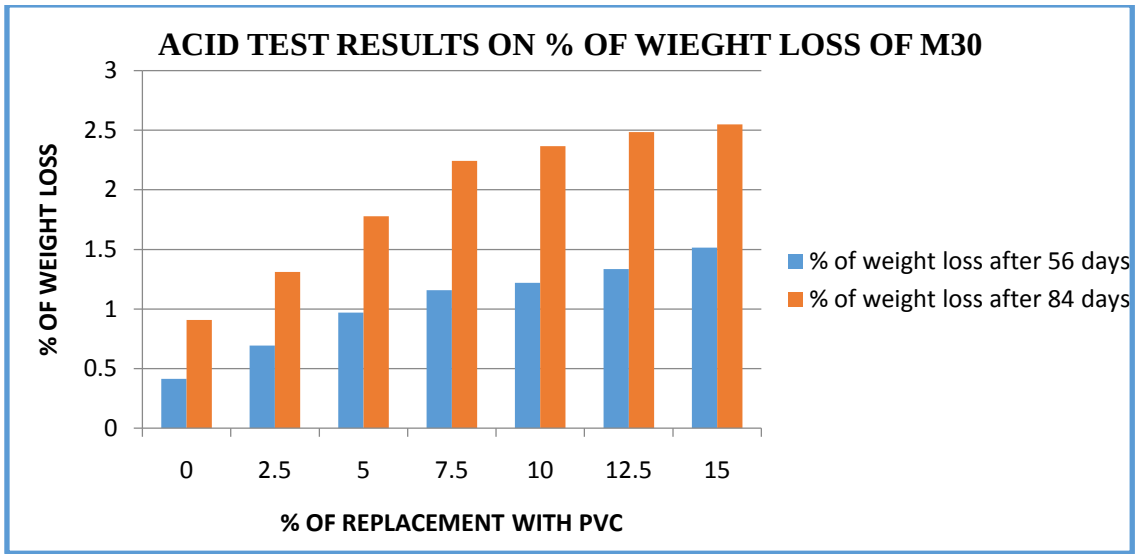
			days (gms)	**days** (gms)		
1	0	2662	2651	2638	0.414	0.909
2	2.5	2473	2456	2441	0.692	1.310
3	5.0	2289	2267	2249	0.970	1.778
4	7.5	2096	2072	2051	1.158	2.243
5	10	1991	1967	1945	1.220	2.365
6	12.5	1897	1872	1851	1.335	2.485
7	15.0	1810	1783	1765	1.514	2.549



GRAPH 4.1: ACID TEST RESULTS ON % OF WEIGHT LOSS OF M25



GRAPH 4.2: ACID TEST RESULTS ON % OF WEIGHT LOSS OF M30

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Table 4.3: Compressive strength loss of pvc waste with fine aggregate replacement with Acid attack of M25 grade

S.No	% of replacement with pvc	Compressive Strength of cubes after 28 days curring(MPa)	Strength of cubes exposure to the 5% concentrated HCl acid after 56 days (MPa)	Strength of cubes exposure to the 5% concentrated HCl acid after 84 days (MPa)	% of strength loss after 56 days exposure the HCL	% of strength loss after 84 days exposure the HCL
1	0	23.83	22.50	21.67	5.58	9.06
2	2.5	25.67	25.00	24.50	2.61	4.55
3	5.0	29.33	28.16	27.83	3.98	5.11
4	7.5	30.83	29.50	28.67	4.31	7.00
5	10.0	18.16	17.33	16.67	5.45	9.05
6	12.5	13.67	12.67	12.00	7.32	12.21
7	15.0	10.00	8.83	7.83	11.70	21.70

Table 4.4: Compressive strength loss of pvc waste with fine aggregate replacement with Acid attack of M30 grade

S.no	% of replacement with pvc	Compressive Strength of cubes after 28 days curing(MPa)	Strength of cubes exposure to the 5% concentrated HCl acid after 56 days (MPa)	Strength of cubes exposure to the 5% concentrated HCl acid after 84 days (MPa)	% of strength loss after 56 days exposure the HCL	% of strength loss after 84 days exposure the HCL
1	0	29.16	27.83	27.00	4.56	7.40
2	2.5	31.33	30.67	30.33	2.11	3.20
3	5.0	33.00	32.00	31.16	3.03	5.57
4	7.5	28.33	27.50	26.83	4.69	6.93
5	10.0	23.16	21.83	21.33	5.74	7.90
6	12.5	17.67	16.50	15.83	6.62	10.41
7	15.0	12.33	11.33	10.67	8.11	13.46

Each and every concrete specimen gets affected by acid attack. From the test results, it was noted that the % of loss of weight for controlled concrete(i.e 0%) of M25 grade for 56 days is 0.837 & 84 days is 1.688%., it was noted that the % of loss of weight for controlled concrete (i.e 0%) of M30 grade for 56 days is 0.414 & 84 days is 0.909%.Hence according to results grade of concrete should be increase weight loss reduced. According to results The%oflossofweightofconcretecubesfound more at15%substituteofpvc waste compare to without replacement.

it was noted that the % of loss of compressive strength for controlled concrete (i.e 0%) of M25 grade for 56 days is 5.58 & 84 days is 9.06%., it was noted that the % of loss of weight for controlled concrete (i.e 0%) of M30 grade for 56 days is 4.56 & 84 days is 7.40%.Hence according to results grade of concrete should be

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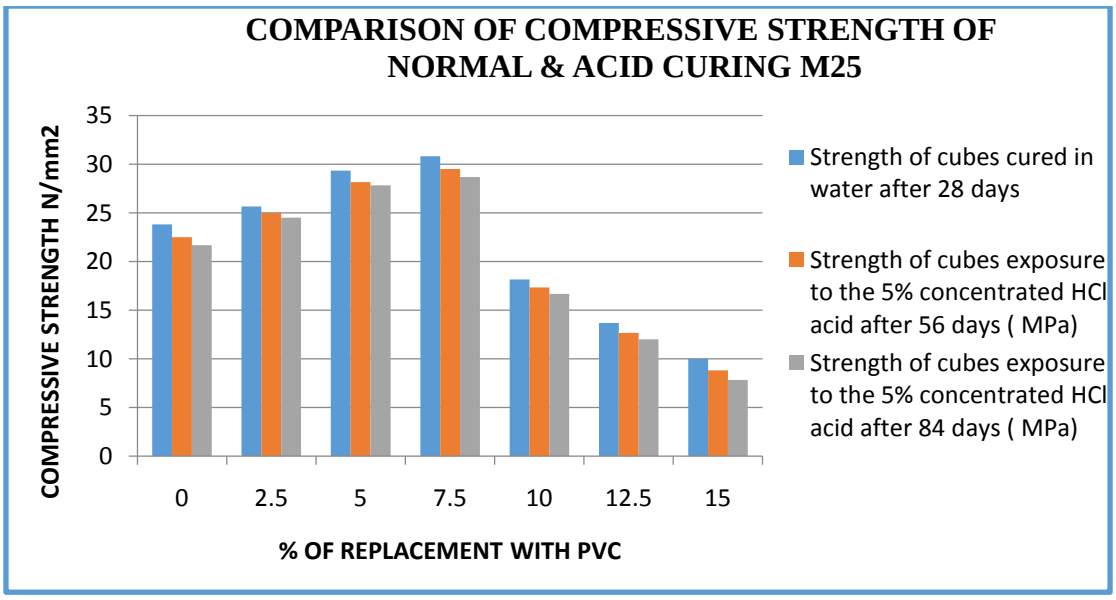
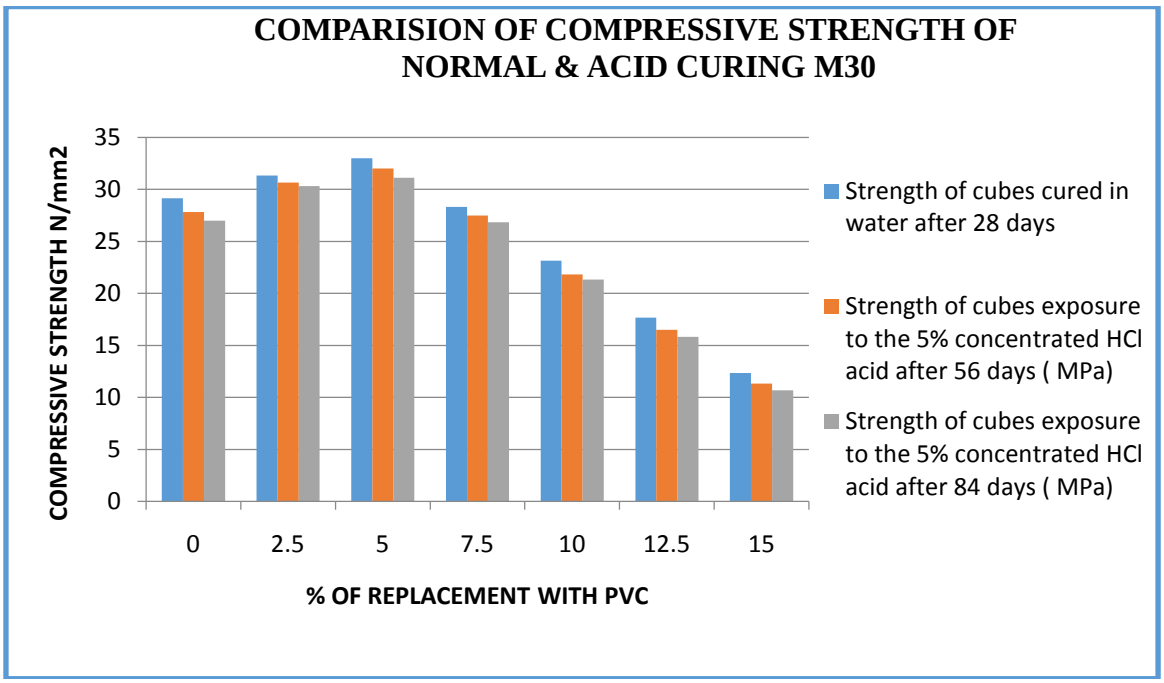
increase loss of compressive strength reduced. According to result the% oflossofcompressivestrengthofconcretecubesfound more at0%substituteofpvc waste upto 7.5% compare to without replacement .
Hence pvc waste resist the acid attack upto 7.5% replacement



GRAPH 4.3 COMPARISON OF COMPRESSIVE STRENGTH OF NORMAL & ACID CURING M25



GRAPH 4.4 COMPARISON OF COMPRESSIVE STRENGTH OF NORMAL & ACID CURING M30

4.2Marine AttackResults:

It is experienced to additional loss of weight.The experiment results of Marine attack test of M25 & M30 grade concrete with different proportions of pvc waste is displayed in Table4.3,4.4,4.5& 4.6.The difference of loss of weight of M25 and M30 grade concrete with altered percentages of Pvc waste is shown in Figure 4.5,4.6, 4.7 &4.8

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Table 4.5: Marine test results on weight loss of PVC waste with fine aggregate replacement of M25 grade

S.No	Percentage of replacement with PVC waste	Weight of cubes cured in water after 28 days (gms)	Weight of cubes subjected to acid exposure after 56 days (gms)	Weight of cubes subjected to acid exposure after 84 days (gms)	% of weight loss after 56 days	% of weight loss after 84 days
1	0	2529	2521	2501	0.716	1.119
2	2.5	2416	2389	2375	1.130	1.726
3	5.0	2213	2180	2160	1.513	2.453
4	7.5	1987	1950	1926	1.897	3.167
5	10	1847	1807	1785	2.213	3.473
6	12.5	1726	1697	1651	2.799	4.542
7	15.0	1697	1649	1612	2.910	5.272

Table 4.6: Marine test results on weight loss of PVC waste with fine aggregate replacement of M30 grade

S.No	Percentage of replacement with PVC waste	Weight of cubes cured in water after 28 days (gms)	Weight of cubes subjected to acid exposure after 56 days (gms)	Weight of cubes subjected to acid exposure after 84 days (gms)	% of weight loss after 56 days	% of weight loss after 84 days
1	0	2662	2655	2649	0.263	0.490
2	2.5	2473	2459	2454	0.569	0.774
3	5.0	2289	2269	2262	0.881	1.193
4	7.5	2096	2073	2065	1.109	1.452
5	10	1991	1967	1953	1.220	1.945
6	12.5	1897	1869	1858	1.498	2.099
7	15.0	1810	1780	1765	1.685	2.549

Each and every concrete specimen gets affected by marine attack. From the test results, it was noted that the % of loss of weight for controlled concrete(i.e 0%) of M25 grade for 56 days is 0.716% & 84 days is 1.199%., it was noted that the % of loss of weight for controlled concrete (i.e 0%) of M30 grade for 56 days is 0.263 & 84 days is 0.909%.Hence according to results grade of concrete should be increase weight loss reduced. According to results The% of loss of weight ofconcretecubesfoundlessfor acid attack compare to marine attack at 15% replacement with pvc waste .

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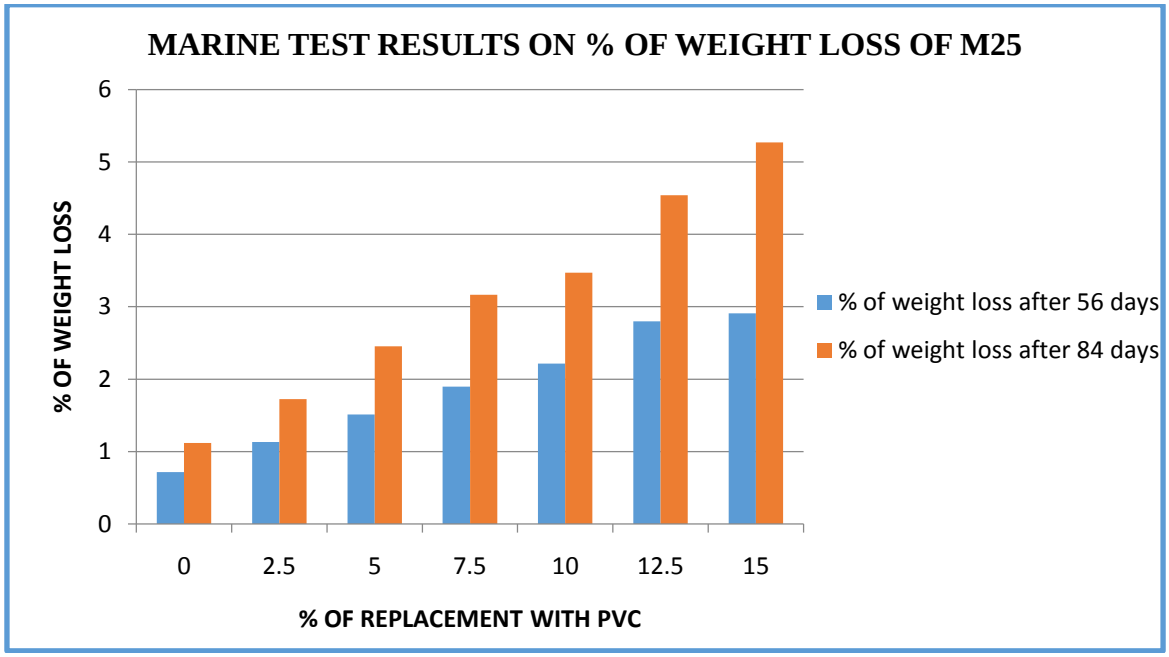
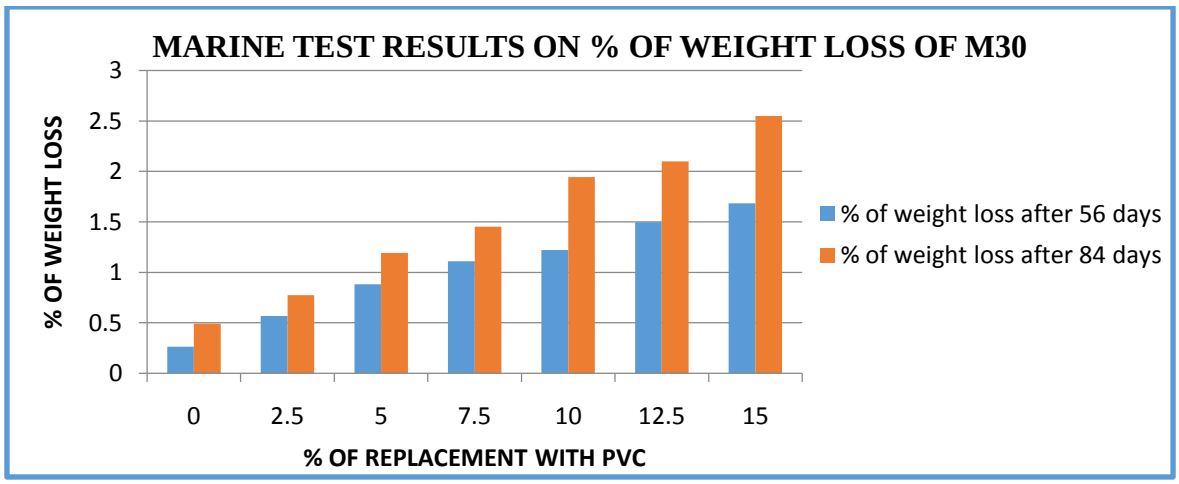


GRAPH 4.5: MARINE TEST RESULTS ON % OF WEIGHT LOSS OF M25



GRAPH 4.6: MARINE TEST RESULTS ON % OF WEIGHT LOSS OF M30

Table 4.7: Compressive strength of pvc waste with fine aggregate replacement with Marine attack of M25 grade

s.no	% of replacement with pvc	Compressive Strength of cubes after 28 days curring(MPa)	Strength of cubes exposure to the marine after 56 days (MPa)	Strength of cubes exposure to the marine after 84days (MPa)	% of strength gain after 56 days exposure the marine water	% of strength gain after 84 days exposure the marine water
1	0	23.83	22.67	21.83	-4.86	-8.39
2	2.5	25.67	27.33	28.33	6.46	10.40
3	5.0	29.33	31.67	32.83	7.97	11.93
4	7.5	30.83	33.33	34.67	8.10	12.45

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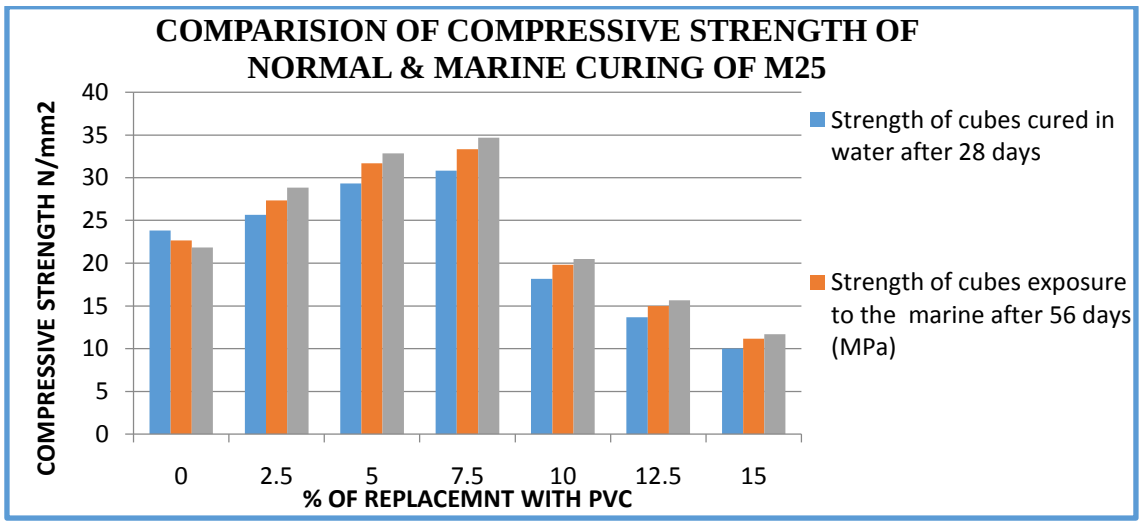
5	10.0	18.16	19.83	20.50	9.19	12.88
6	12.5	13.67	15.00	15.67	9.73	14.63
7	15.0	10.00	11.16	11.67	11.60	16.67

Table 4.8: Compressive strength of pvc waste with fine aggregate replacement with Marine attack of M30 grade

s.no	% of replacement with pvc	Compressive Strength of cubes after 28 days curing (MPa)	Strength of cubes exposure to the marine after 56days (MPa)	Strength of cubes exposure to the marine after 84days (MPa)	% of strength gain after 56 days exposure the marine water	% of strength gain after 84 days exposure the marine water
1	0	29.16	28.00	27.33	-3.97	-6.27
2	2.5	31.33	32.50	33.33	3.73	6.38
3	5.0	33.00	34.67	35.50	5.06	7.57
4	7.5	28.83	30.67	31.00	6.98	8.12
5	10.0	23.16	25.16	26.00	8.64	11.14
6	12.5	17.67	19.50	20.16	10.35	14.09
7	15.0	12.33	13.83	14.50	12.16	17.59

Each and every concrete specimen gets affected by marine attack. From the test results, it was noted that the % of loss of compressive strength for controlled concrete(i.e 0%) of M25 grade for 56 days is 4.86%& 84 days is 8.39%., it was noted that the % of loss of compressive strength for controlled concrete (i.e 0%) of M30 grade for 56 days is 3.97 & 84 days is 6.27%.Hence according to results grade of concrete should be increase compressive strength loss reduced. According to results in themarine attack%ofcompressivestrength should be increased with replacement of pvc becauseof alkali reactive aggregates are present in concrete .



GRAPH 4.7: COMPARISON OF COMPRESSIVE STRENGTH OF

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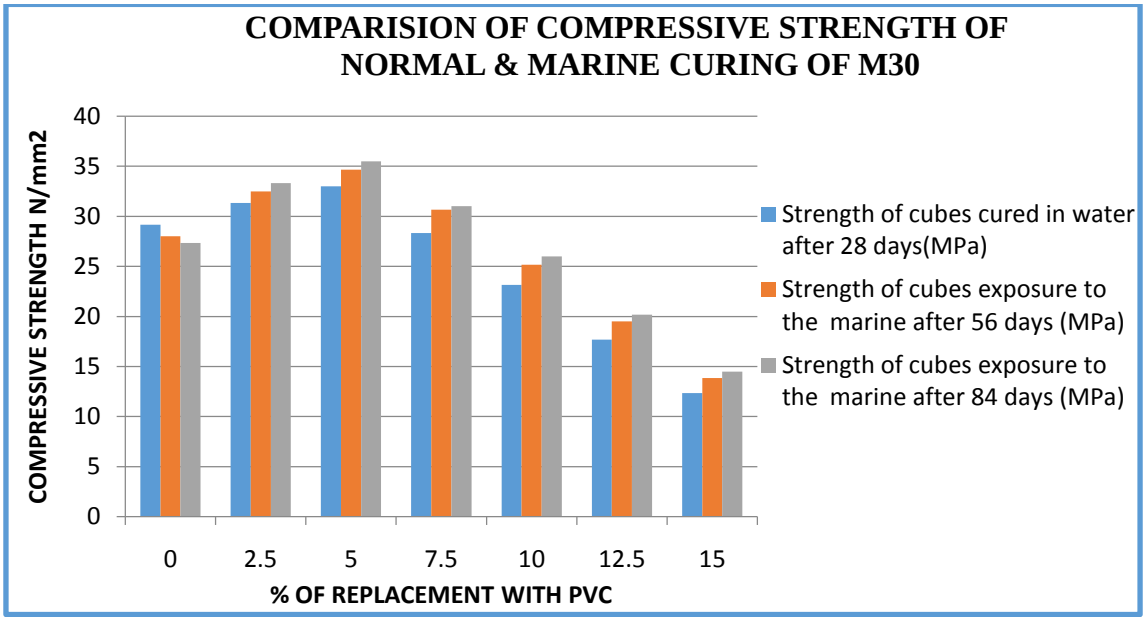
NORMAL & MARINE CURING M25



GRAPH 4.8: COMPARISON OF COMPRESSIVE STRENGTH OF NORMAL & MARINE CURING M30

V. CONCLUSIONS:

The present study of effect is alarmed with the estimation of the performance of pvc waste in concrete. Experimental investigation was carried out to study the durability properties of concrete.

The following conclusions were knows at from the experimental investigation:

1. So, accordance to above result M25& M30 grade got the 7.5 & 5.0% Optimum percentage of replacement of PVC waste in concrete is determined.
2. Compare to M25 & M30 grade in acid attack compressive strength loss results, M30 grade less compressive strength loss obtained.
3. Compare to acid attack & marine attack weight loss results, marine attack less weight loss obtained.
4. When comparison of Compressive strength results for normal &marine curing of M25 &M30 grade the strength was littlie increased when curing period was increased. According to chemical compositionof seawater has a total salinity of about 3.5 percent (78 percent of the dissolved solids being NaCl and 15percent MgCl2 and MgSO4) and produces a slightly higher early strength but a lower long term strength.

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