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STUDY OF CONCRETE BY PARTIAL REPLACEMENT OF CEMENT WITH PAPER MILL SLUDGE AND WASTE WATER SLUDGE

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ABSTRACT

Cement manufacturing industry is one of the carbon dioxide emitting sources besides deformation and burning of fossil fuels and concrete industry is one of the largest consumers of natural virgin materials. Concrete is strength and tough material but it is porous material also which interacts with the surrounding environment. In order to address environmental effects associated with cement manufacturing and constantly depleting natural resources, there is a need to develop alternative binders to make concrete industry sustainable.

To produce low-cost concrete by blending various ratios of cement with paper sludge & waste water sludge to reduce disposal and pollution problems due to paper sludge is most essential to develop profitable building materials from paper waste sludge and waste water sludge. The use of paper-mill pulp in concrete formulations was investigated as an alternative to landfill disposal. About 300 kg of sludge is produced for each tone of recycle paper. The cement has been replaced by paper mill sludge accordingly in the range of 5%, 10% and 15% in place of cement in concrete for M-30 and M-40 mix and to determine the compressive strength, split tensile strength & flexural strength of concrete at 7 days and 28 days compared with conventional concrete.

It is estimated that about 38,254 million liters per day (mld) of wastewater is generated in urban centers. High organic sludge with organic content more than 50% of sludge weight was used as an additive to concrete mixes. The cement has been replaced by waste water sludge accordingly in the range of 5%, 10% and 15% in place of cement in concrete for M-30 and M-40 mix and to determine the compressive strength, split tensile strength & flexural strength of concrete at 7 days and 28 days compared with conventional concrete.

I INTRODUCTION

In order to make concrete industry sustainable, the use of waste materials in place of natural resources is one of the best approaches. It is well known fact that cement manufacturing industries releases large amount of carbon dioxide (CO_2) for their processes which affects the atmosphere and this will lead to global warming. Concrete has attained the status of a major building material in all the branches of modern construction and its rapid increase in construction activities leads to active shortage of conventional construction materials such as cement, fine aggregate, coarse aggregate. It is very difficult to point out another material of construction which is a variable as concrete and which is the best material choice is for strength and durability. Since researches were searching for cheaper material that can be used as substitute for the materials.

Paper mill sludge is a major economic and environmental problem for the paper and board industry. An enormous quantity of waste paper sludge is generated all around the world. In India, 0.7% of total urban waste generated comprises of paper sludge. Waste water sludge also known as sewage sludge. Sewage sludge as an end-product of biological waste water treatment processes. It is estimated that about 38,254 million liters per day (mld) of wastewater is generated in urban centers comprising Class I cities and Class II towns having population of 50,000 and also 70% population of the total urban cities. The municipal wastewater treatment was developed so far is about 11,787 mld which is about 31 per cent of wastewater generation in these two classes of urban centres and high organic sludge with organic content more than 50% of sludge weight was used as an additive to concrete mixes.

This research is aimed at studying the effects of addition of paper mill sludge and waste water sludge on the original properties of the concrete mixes by considering the performance of concrete containing different percentages of paper mill sludge and waste water sludge and by developing a concrete mix which will produces the highest compressive strength, flexural strength and split tensile tensile strength for M30 and M40 grade when compared with the conventional one.

II MATERIALS AND PROPERTIES

The ingredients which had used for this research is cement, fine aggregate, coarse aggregate, water, paper mill sludge and waste water sludge.

2.1 CEMENT

In this research the cement which we had used was ordinary Portland cement of 53 grade conforming to IS: 12269-1987.

Table 2.1: Properties of OPC (53 grade) cement

Physical properties of grade of cement	Results	Requirements as per IS:8112-1989
Specific gravity	3.15	3.10-3.15
Consistency	31.22%	30-35
Initial setting time	98min	30 minimum

Final setting time	260 min	600 maximum
Compressive strength N/mm2 at 28 days	53.14 N/mm^2	53 N/mm^2

2.2 AGGREGATES

Aggregates are of two types i.e

1.Fine aggregates

2.Coarse aggregates

- **Fine Aggregates :**

In this investigation locally available river sand is used as fine aggregate conforming to zone-II according to IS: 383-1970 and their physical properties had shown in the given below table.

Table 2.2.1: Physical properties of fine aggregate

Physical properties		Test results
Specific gravity		2.6
Fineness modulus		2.60
Bulk density (ϒ)	Loosely packed	1493.3
	Compacted	1602.6

- **Coarse Aggregates :**

Coarse aggregate includes natural aggregates. Locally available crushed stone of 20 mm down sizes confirming to IS: 383 have been used as coarse aggregate and their properties had shown below.

Table 2.2.2: Physical properties of coarse aggregate

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Physical properties		Test results
Specific gravity		2.8
Fineness modulus		7.11
Bulk density (ϒ) (kg/m^3)	Loosely packed	1524.02 Kg/m^3
	Compacted	1700 Kg/m^3

2.3 WATER

The water which is used for mixing concrete should be portable drinking water having P^H and its values lies between 6 to 8 and the water should be free from organic matter.

2.4 PAPER MILL SLUDGE

In this research the paper mill sludge which we had taken is from the paper mill in Bhimavaram. The sludge was collected from the sludge drying beds and land filling areas by random sampling method. The sludge had a roughly 30% moisture content.

2.5 WASTE PAPER SLUDGE

The waste water sludge is collected from the waste water treatment plant in Auto Nagar, Vijayawada.

Table 2.5: Properties of paper mill sludge and waste water sludge

Physical properties of replacement materials	Paper Mill Sludge	Waste Water Sludge
Specific gravity	2.6	2.4
Initial setting time	110min	115min
Final setting time	275min	285min

III CONCRETE MIX PROPORTION

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In this, two mix design i.e. M30 and M40 had carried out by following the specifications and limitations of Indian Standard Code (IS 10262-2009) and their mix proportions had shown below in the tables 3.1, 3.2 and 3.3.

Table 3.1: Mix Proportion for M30

Cement Kg/m^3	Fine aggregate Kg/m^3	Coarse aggregate Kg/m^3	Water l/m^3
380	645.19	1290.38	186
1	**1.697**	**3.395**	**0.45**

Table 3.2: Mix Proportion for M40

Cement Kg/m^3	Fine aggregate Kg/m^3	Coarse aggregate Kg/m^3	Water l/m^3
400	694.564	1273.608	186
1	**1.736**	**3.18**	**0.38**

Table 3.3: Mix proportion ratios

Grade	Mix ratio	W/C Ratio
M30	1:1.794:3.29	0.45
M40	1:1.736:3.18	0.38

3.1 MIX COOMBINATIONS

The following mix combination has been carried out for this experimental investigation.

Table 3.4: Mix combination of cement with paper mill sludge for M30 and M40 grades

Mix composition	Cement (%)	Paper mill sludge (%)

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Control mix (CM)	100	0
PST1	95	5
PST2	90	10
PST3	85	15

Table 3.5 : Mix combination of cement with sewage sludge for M30 and M40 grades

Mix combination	Cement (%)	Sewage sludge (%)
Control mix (CM)	100	0
SST1	95	5
SST2	90	10
SST3	85	15

IV RESULTS AND DISCUSSIONS

The specimen of standard cubes of (150mm*150mm*150mm) and standard cylinders of (150mm*300mm) and beams of (100mm*100mm*500mm) were used to determine the compressive strength, split tensile strength, flexural strength and durability of concrete. The strength properties are calculating by replacing cement with paper mill sludge and sewage sludge in different percentages are 5%, 10%, 15% in concrete. The detailed tabulations and graphs are presented as follows.

4.1 WORKABILITY OF CONCRETE

The workability of concrete is observed by the Slump Cone method. The range of slump was selected as 25-50mm.

Table 4.1: Slump obtained for M30 and M40 of paper mill sludge and sewage sludge

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Mix	Slump (mm)	
	M30	M40
Control Mix	35	38
PST 1	32	35
PST 2	28	30
PST 3	25	27
SST 1	30	32
SST 2	27	28
SST 3	25	26

4.2 COMPRESSIVE STRENGTH RESULTS:

The test results are presented here for the compressive strength of 7 days and 28 days of testing.

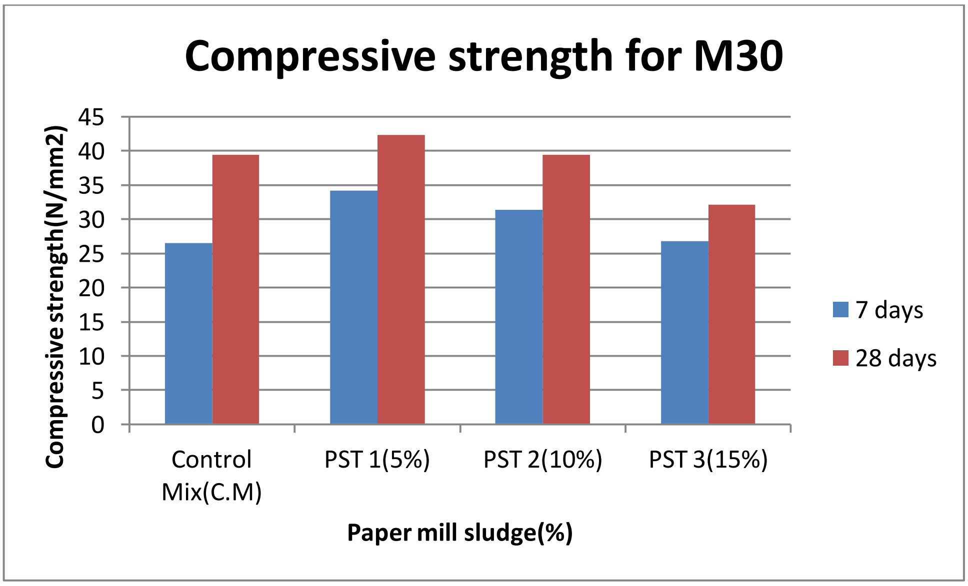

Fig 4.1 Variation of Compressive strength of concrete with paper mill sludge of M30grade for 7&28 days

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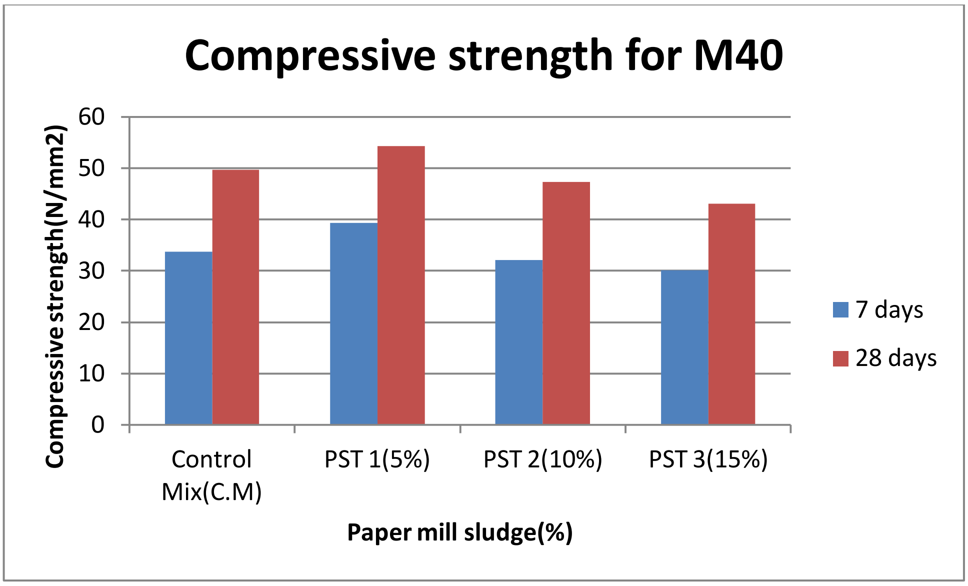

Fig 4.2 Variation of Compressive strength of concrete with paper mill sludge of M40grade for 7&28 days

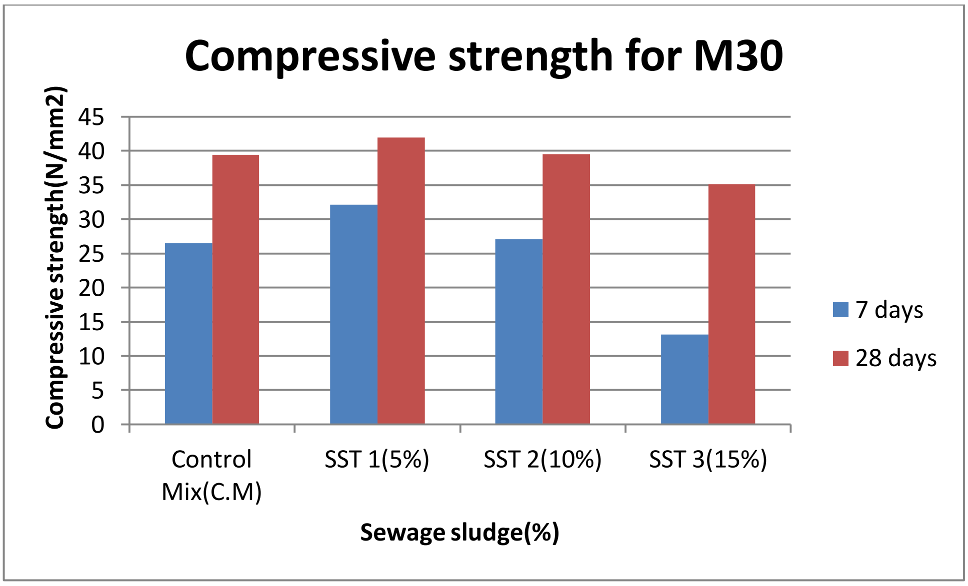

Fig 4.3 Variation of Compressive strength of concrete with Sewage sludge of M30grade for 7&28 days

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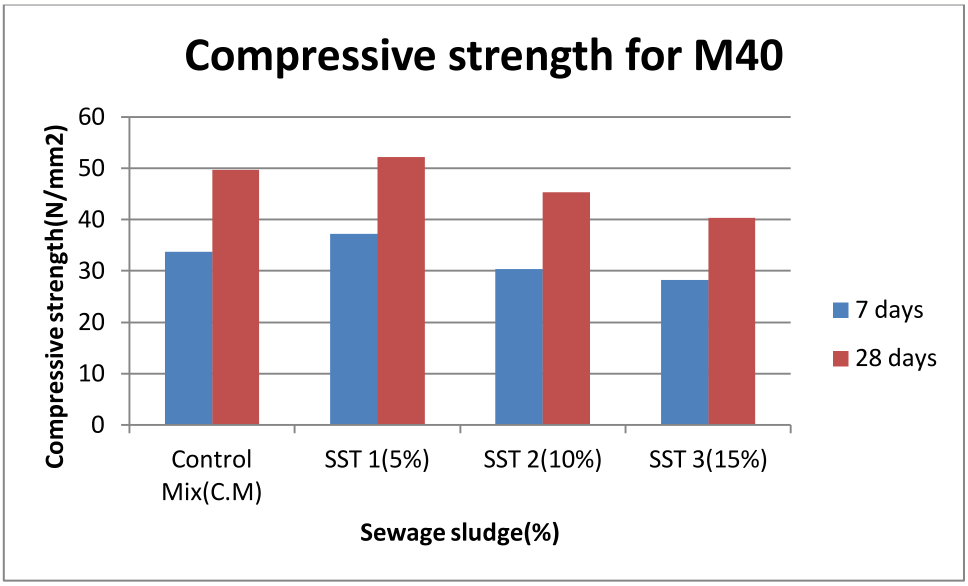

Fig 4.4 Variation of compressive strength of concrete with Sewage sludge of M40grade for 7&28 days

4.3 FLEXURAL STRENGTH RESULTS:

Flexural strength for concrete is determined by casting beam specimens. The beam dimensions are of 500mm x 100mm x 100mm.The variation of flexural strength at days 28 days.

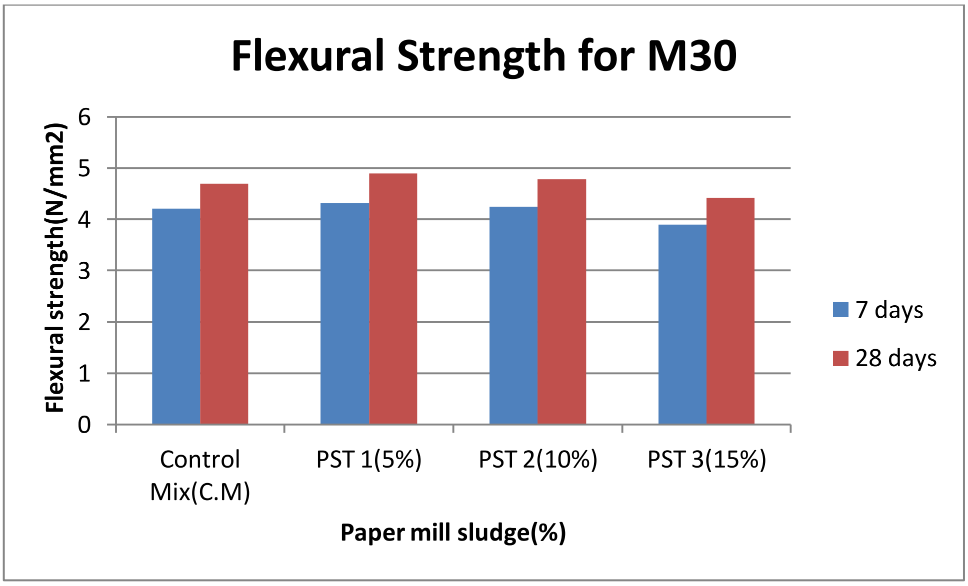

Fig 4.5 Variation of Flexural strength of concrete with Paper mill sludge of M30grade for 7&28 days

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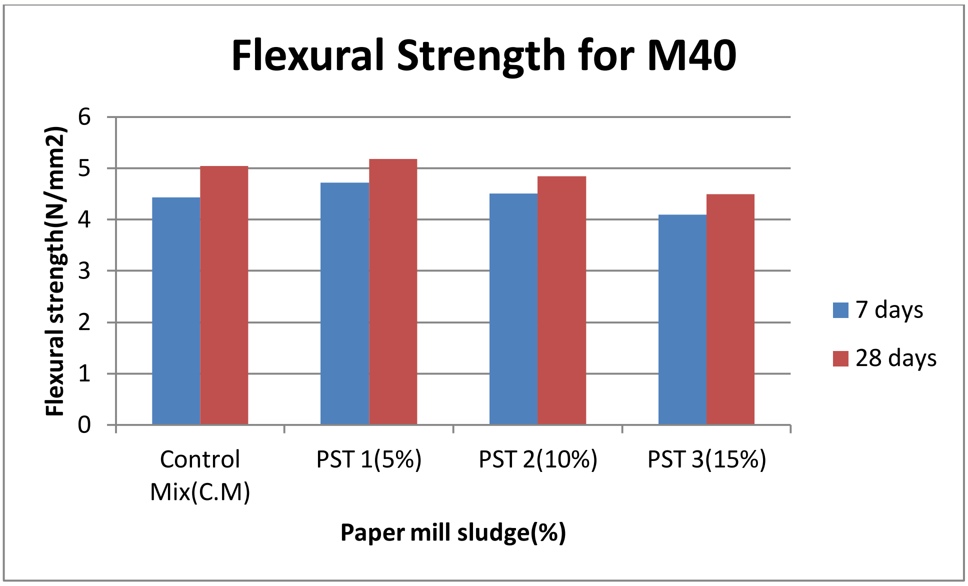

Fig 4.6 Variation of Flexural strength of concrete with Paper mill sludge of M40 grade for 7&28 days

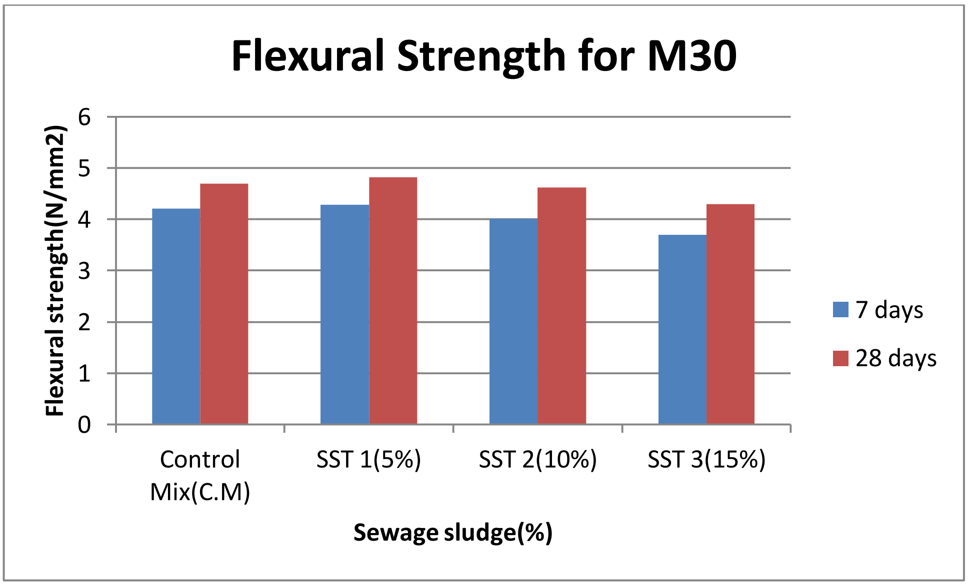

Fig 4.7 Variation of Flexural strength of concrete with Sewage sludge of M30grade for 7&28 days

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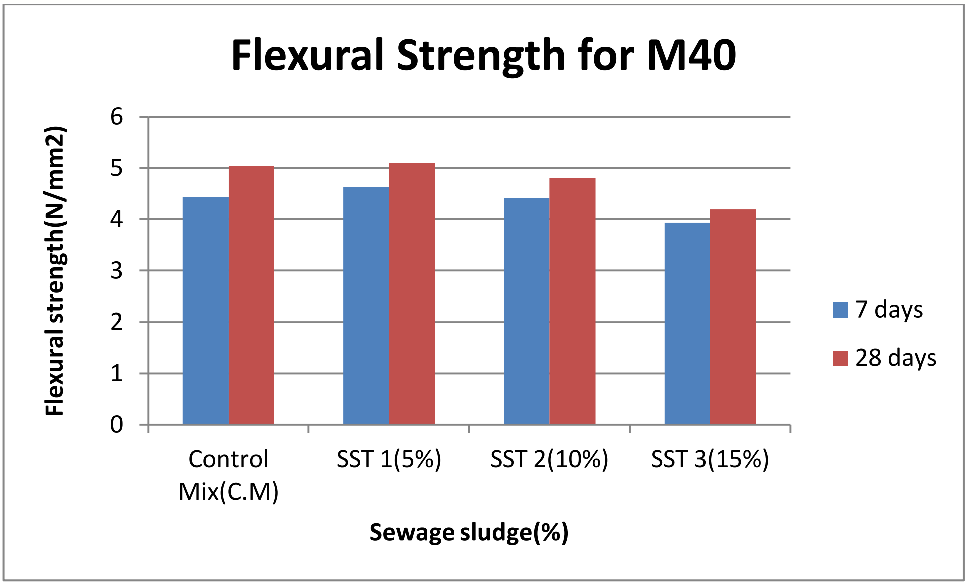

Fig 4.8 Variation of Flexural strength of concrete with Sewage sludge of M40 grade for 7&28 days

4.4 SPLIT TENSILE STRENGTH:

Out of all the properties of concrete, tensile strength is very important one.

The details of test results are summarized below

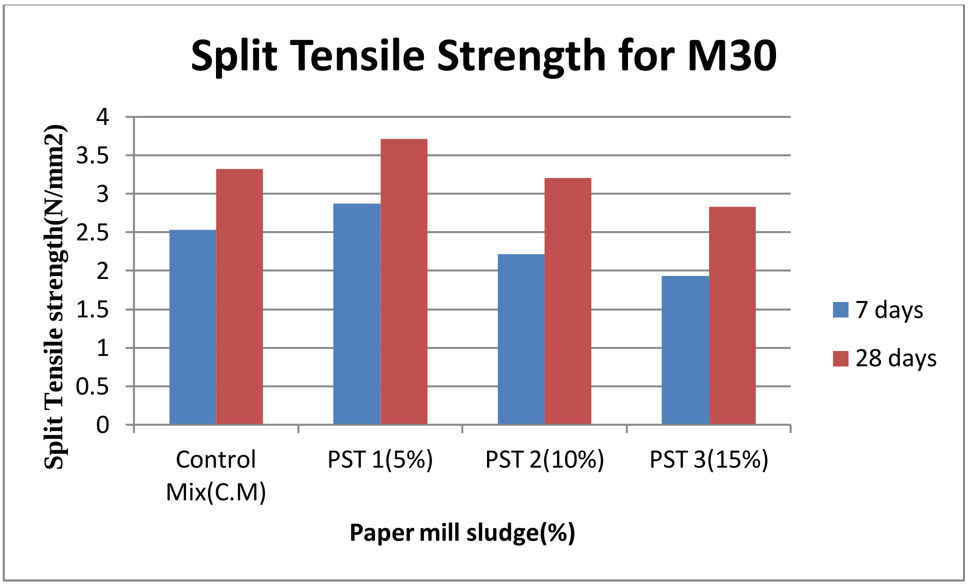

Fig 4.9 Variation of Split Tensile Strength of concrete with Paper mill sludge of M30 grade for 7&28 days

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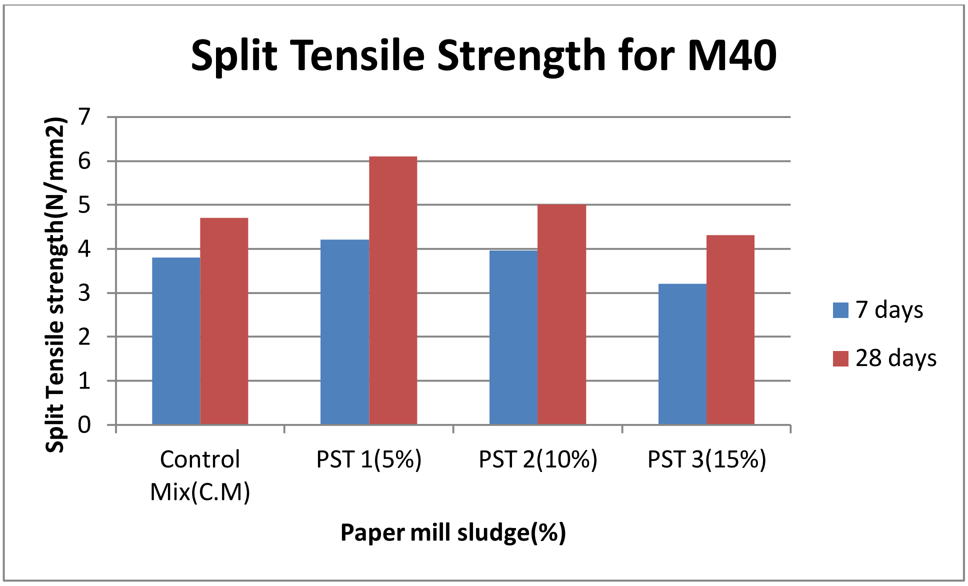

Fig 4.10 Variation of Split Tensile Strength of concrete with Paper mill sludge of M40 grade for 7&28 days

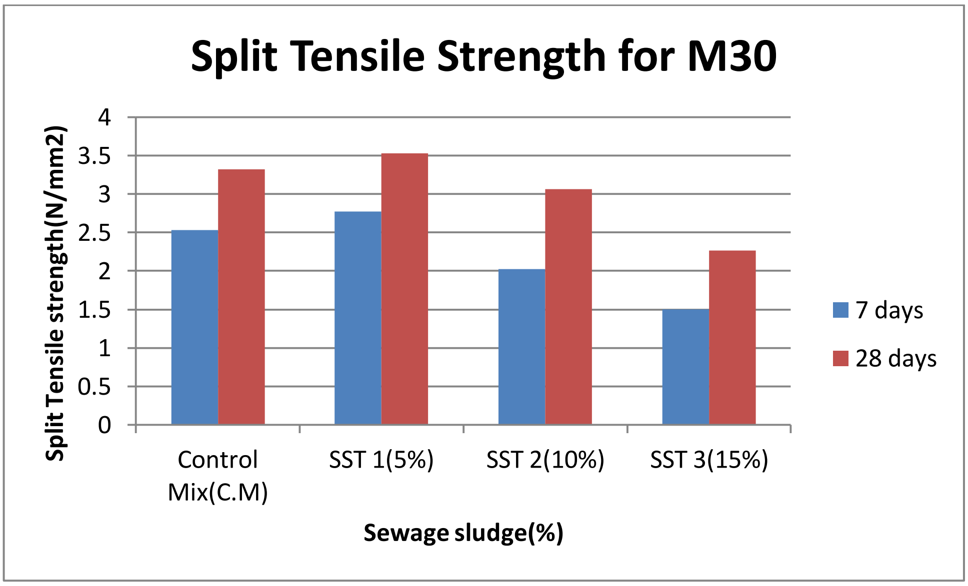

Fig 4.11 Variation of Split Tensile Strength of concrete with Sewage sludge of M30 grade for 7&28 days

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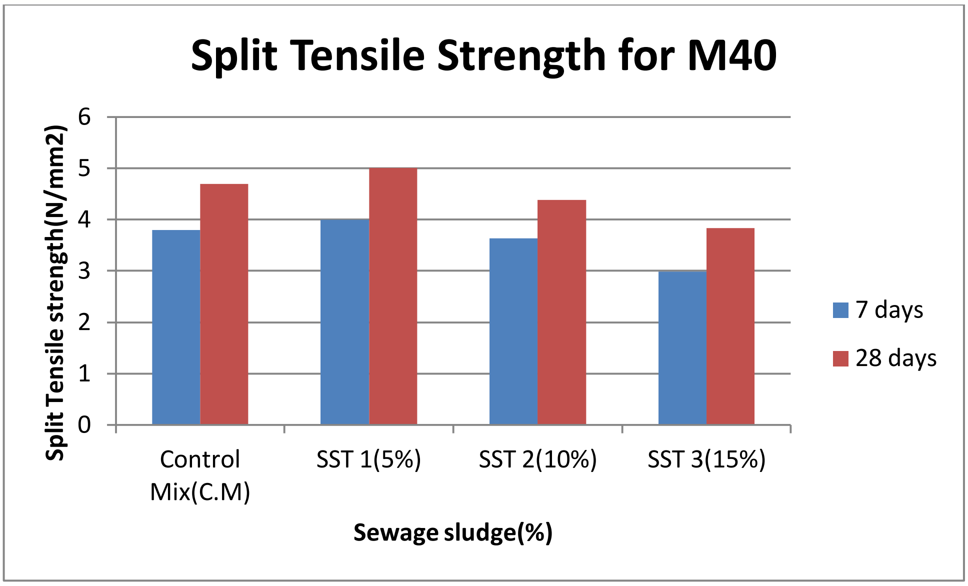

Fig 4.12 Variation of Split Tensile Strength of concrete with Sewage sludge of M40 grade for 7&28 days

V DURABILITY STUDIES

In this experimental work, the properties of acid durability studies such as Acid Attack factor, Acid durability factor and % weight loss are carefully observed and the results are tabulated as follows.

5.1 PERCENTAGE OF WEIGHT LOSS

- **<u>For M30 Grade of concrete</u>**

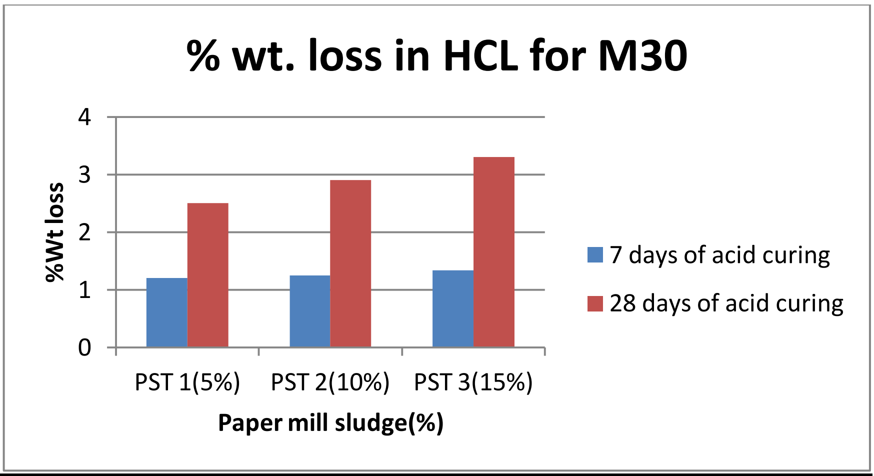

Fig 5.1 Variation of % Wt loss in HCL with Paper Mill Sludge of M30grade for 7&28 days

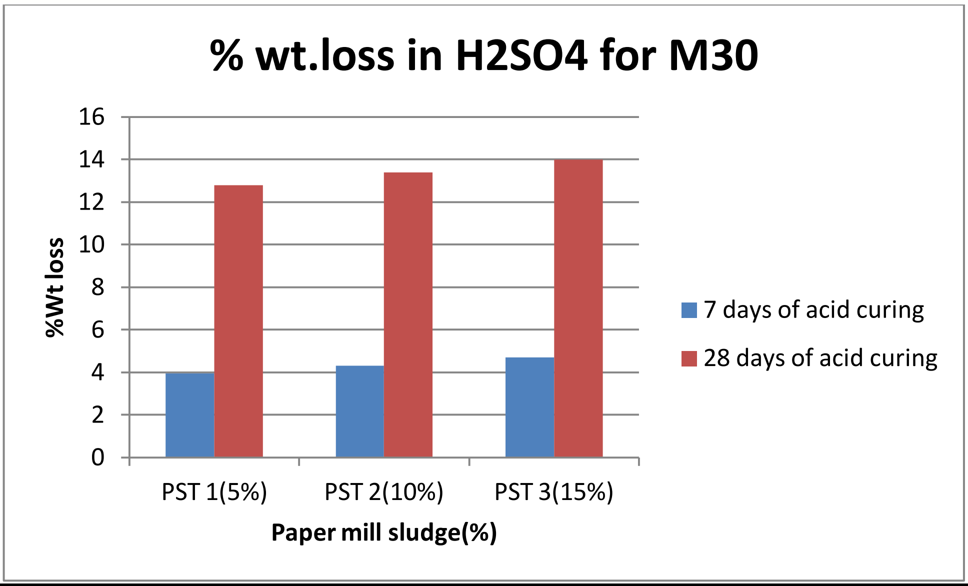

Fig 5.2 Variation of %Wt loss in H_2SO_4 with Paper mill sludge of M30grade for 7&28 days

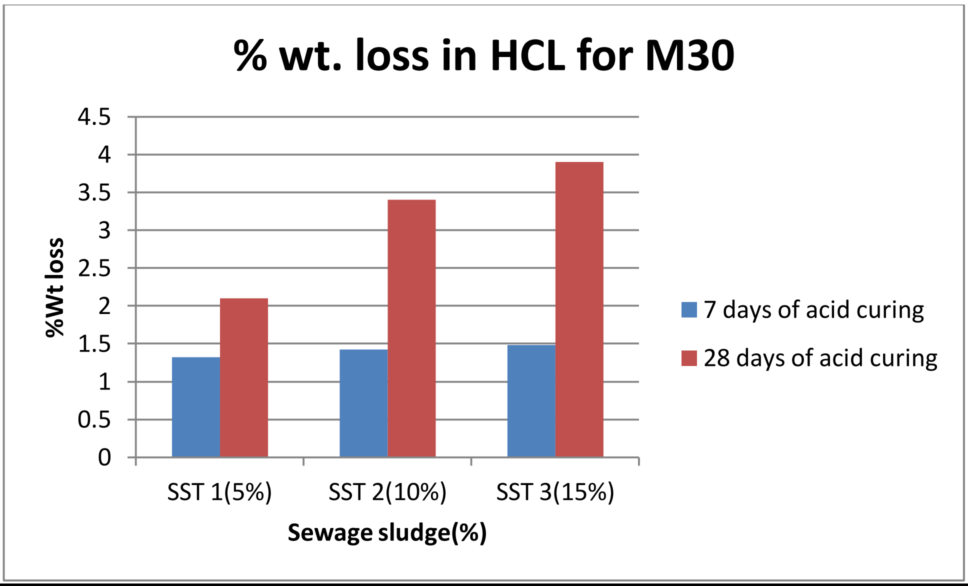

Fig 5.3 Variation **of** % Wt loss in HCL with Sewage Sludge of M30grade for 7&28 days

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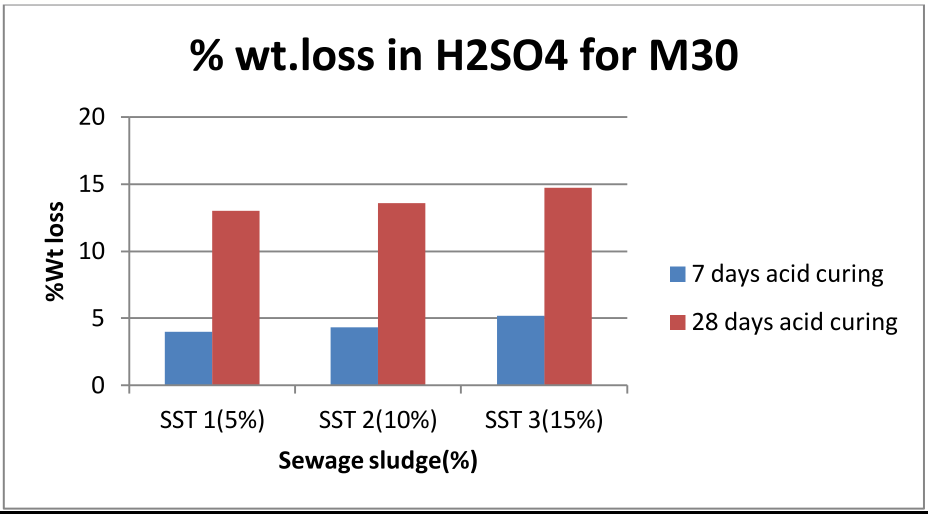

Fig 5.4 Variation of %Wt loss in H_2SO_4 with Sewage sludge of M30grade for 7&28 days

- <u>**For M40 Grade of concrete**</u>

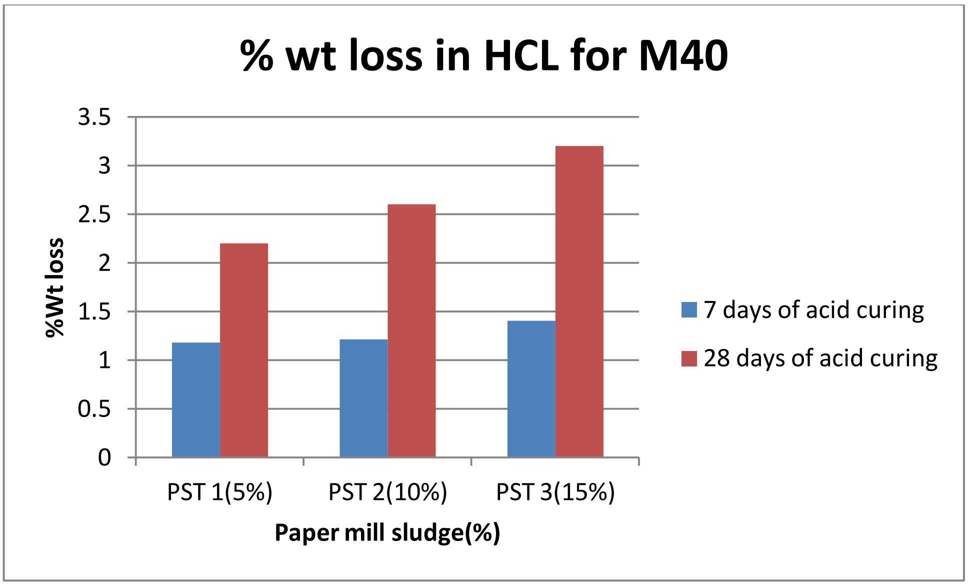

Fig 5.5 Variation of **%**Wt loss in HCL with Paper mill sludge of M40grade for 7&28 days

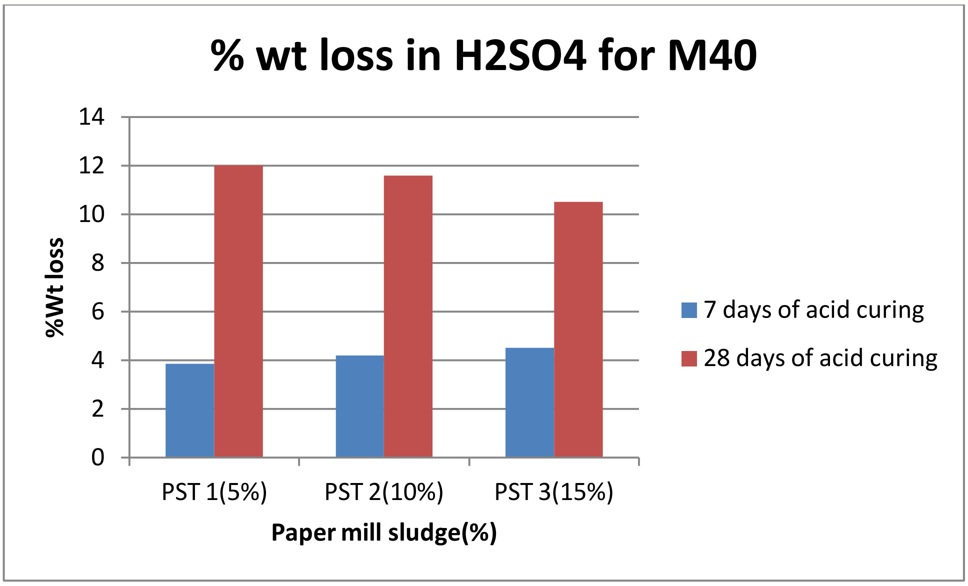

Fig 5.6 Variation of %Wt loss in H_2SO_4 with Paper mill sludge of M40grade for 7&28 days

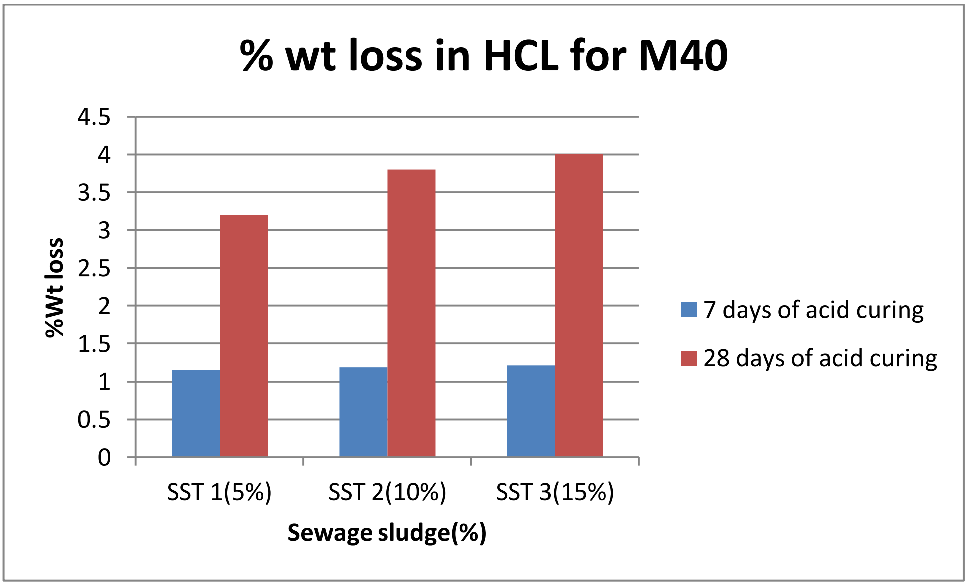

Fig 5.7 Variation of %Wt loss in HCL with Sewage sludge of M40grade for 7&28 days

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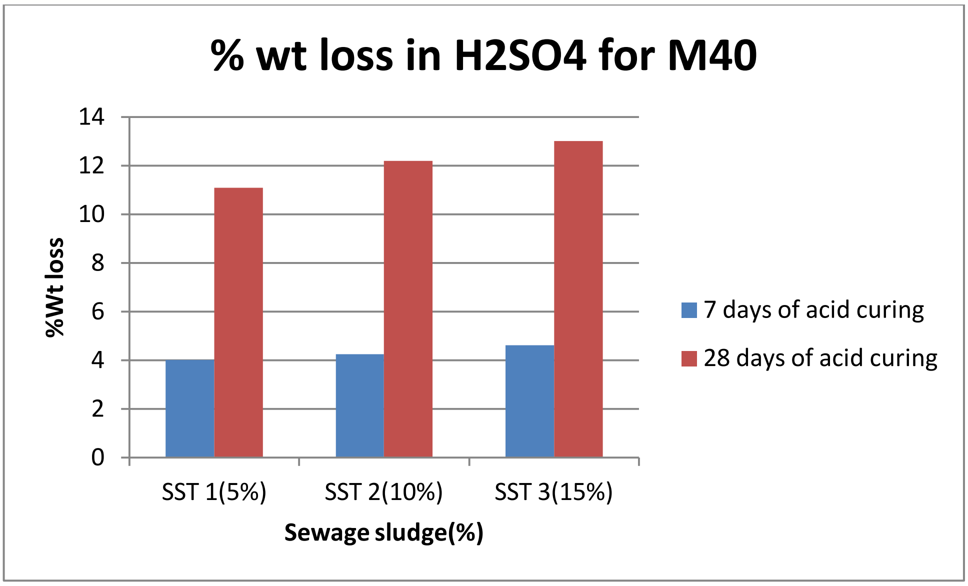

Fig 5.8 Variation of %Wt loss in H_2SO_4 with Paper mill sludge of M40grade for 7&28 days

5.2 ACID ATTACK FACTOR

Acid attack factor is calculated by taking 5% HCL and 5% H_2SO_4 for M30 and M40 grades.

- **For M30 Grade of concrete**

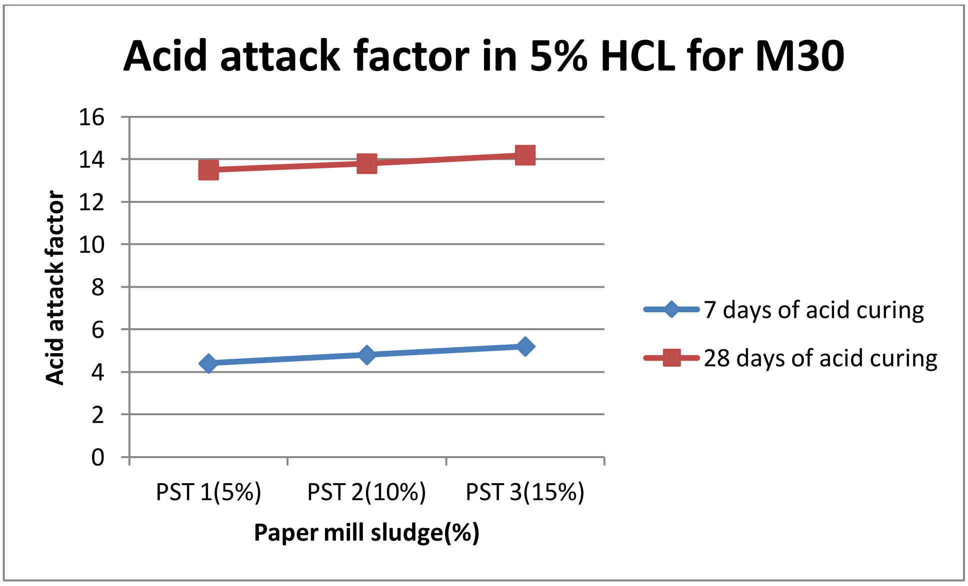

Fig:5.9 Variation of Acid attack factor in 5% HCL with Paper mill sludge of M30grade for 7&28 days

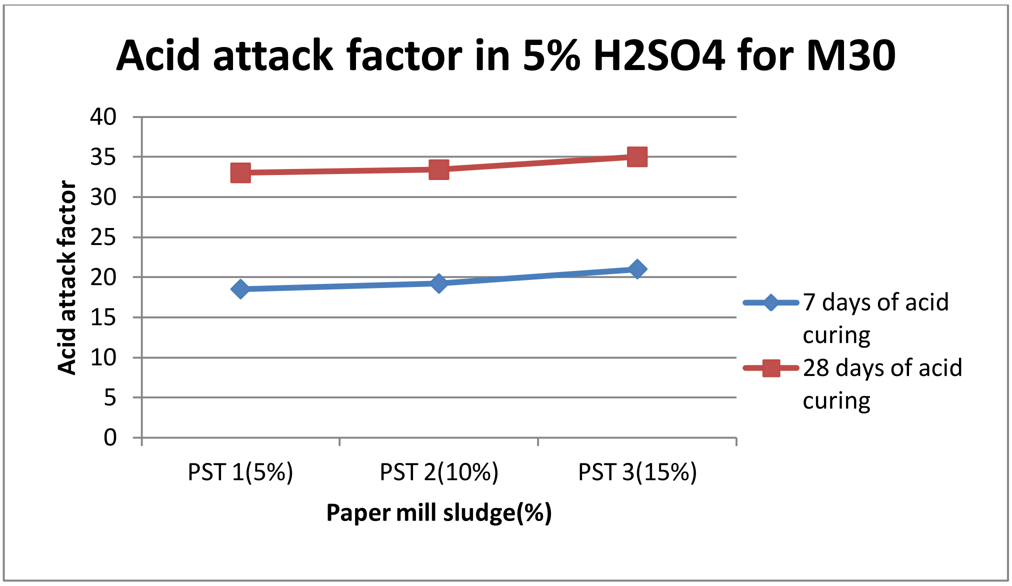

Fig 5.10 Variation of Acid attack factor in 5% $H_2SO_4$with Paper mill sludge of M30grade for 7&28 days

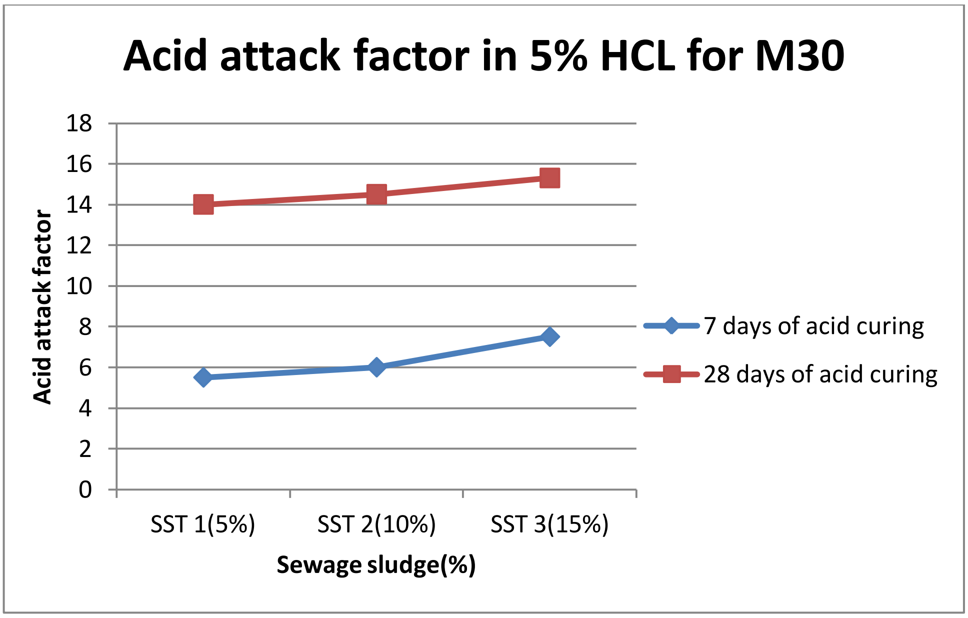

Fig 5.11 Variation of Acid attack factor in 5% HCL with Sewage sludge of M30grade for 7&28 days

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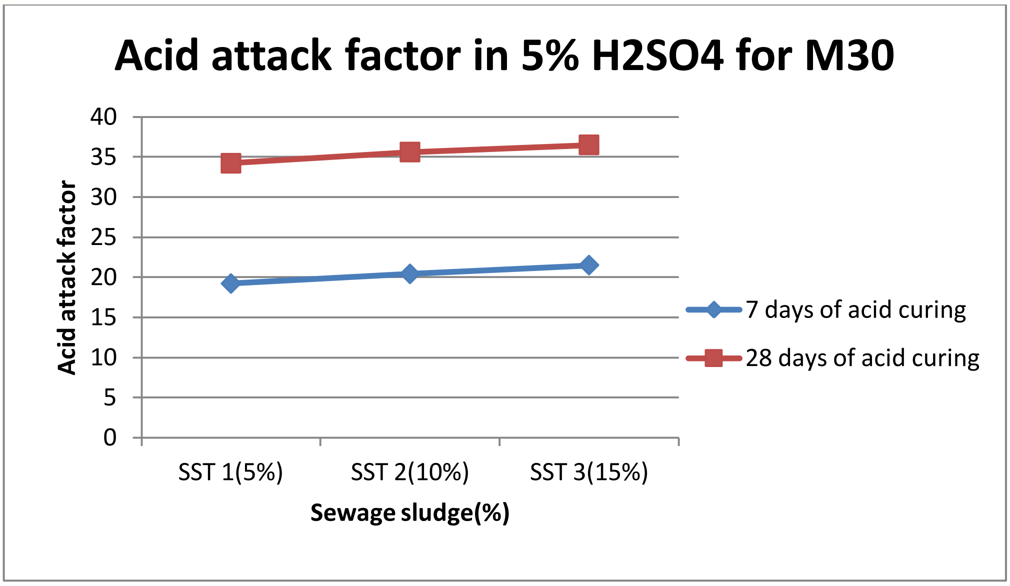

Fig 5.12 Variation of Acid attack factor in 5% H2SO4 with Sewage sludge of M30grade for 7&28 days

- **For M40 Grade of concrete**

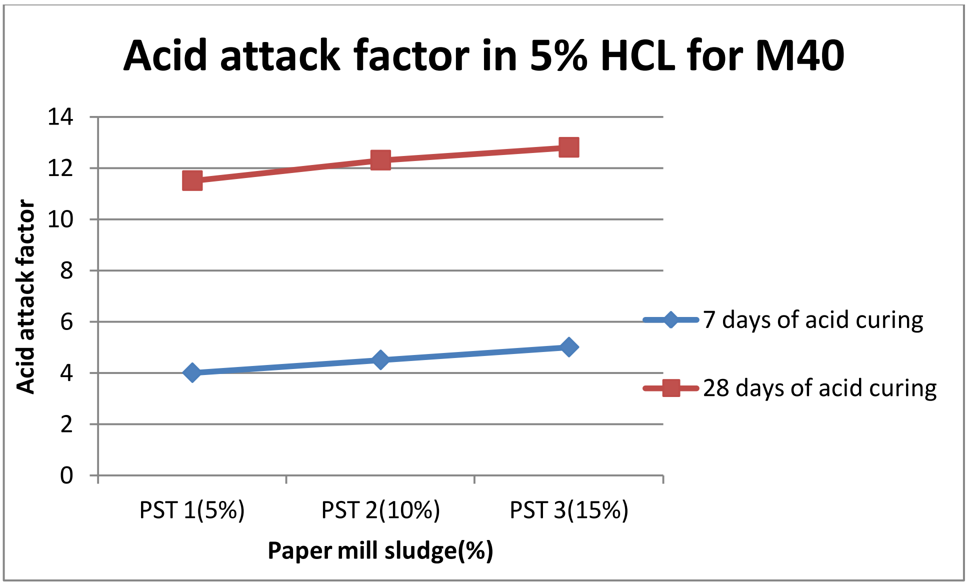

Fig 5.13 Variation of Acid attack factor in 5% HCL with Paper mill sludge of M40grade for 7&28 days

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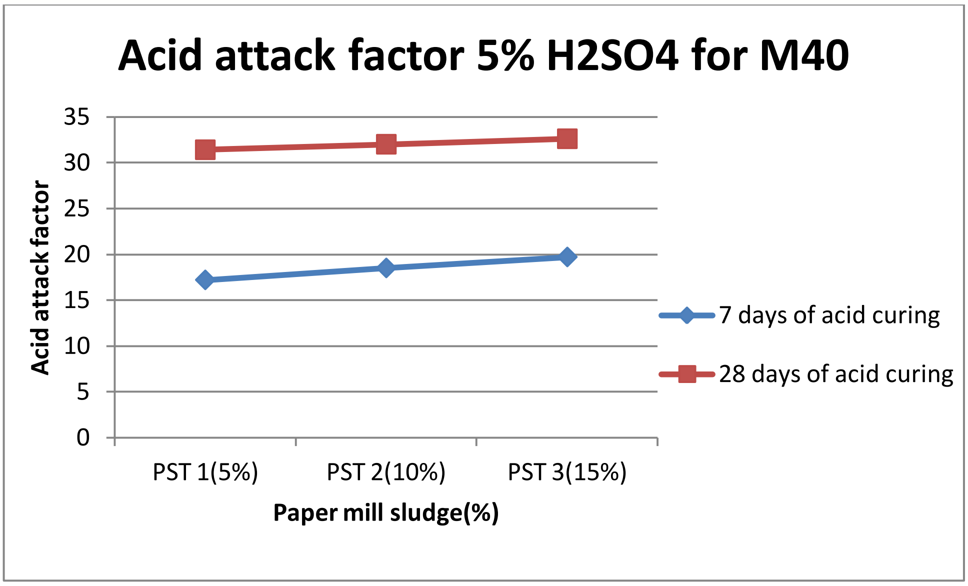

Fig 5.14 Variation of Acid attack factor in 5% H_2SO_4 with Paper mill sludge of M40grade for 7&28 days

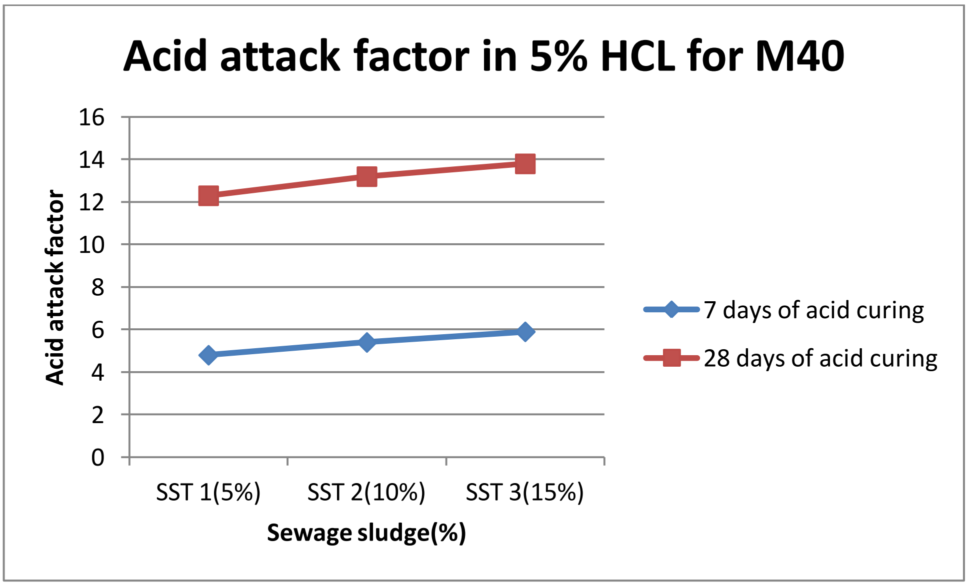

Fig 5.15 Variation of Acid attack factor in 5% HCL with Sewage sludge of M40grade for 7&28 days

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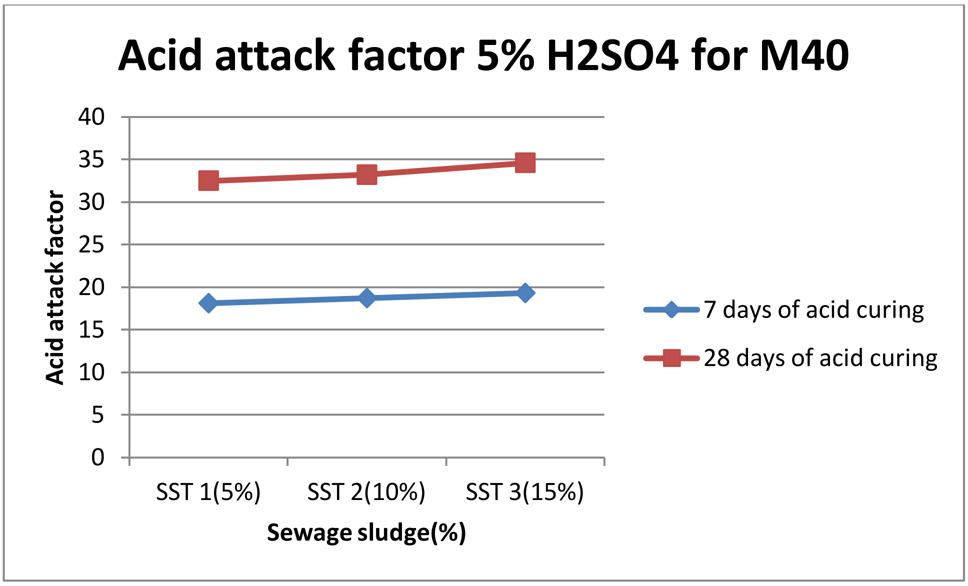

Fig 5.16 Variation of Acid attack factor in 5% H2SO4 with Sewage sludge of M40grade for 7&28 days

5.3 ACID DURABILITY FACTOR

- **For M30 Grade of concrete**

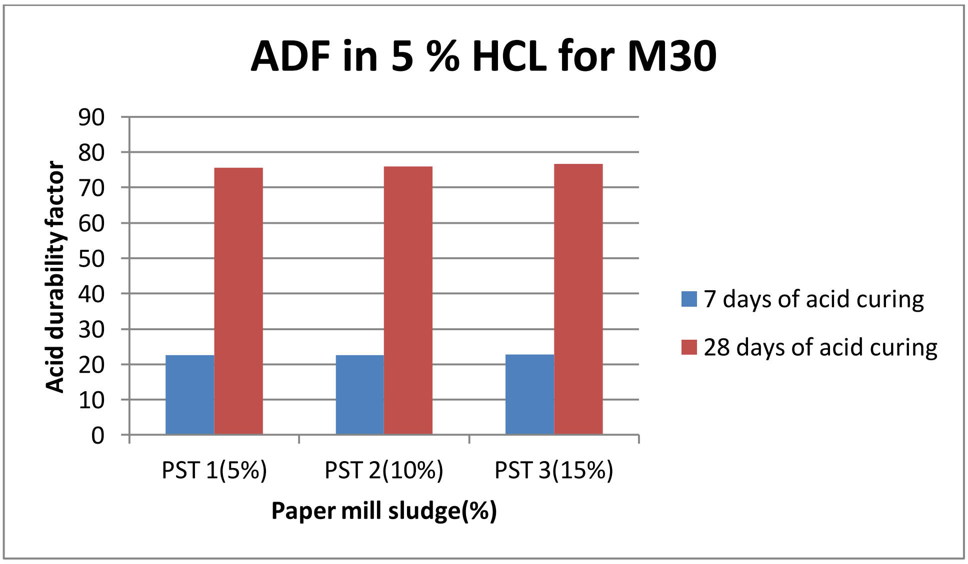

Fig 5.17 Variation of acid durability factor in HCL with Paper mill sludge of M30grade for 7&28 days

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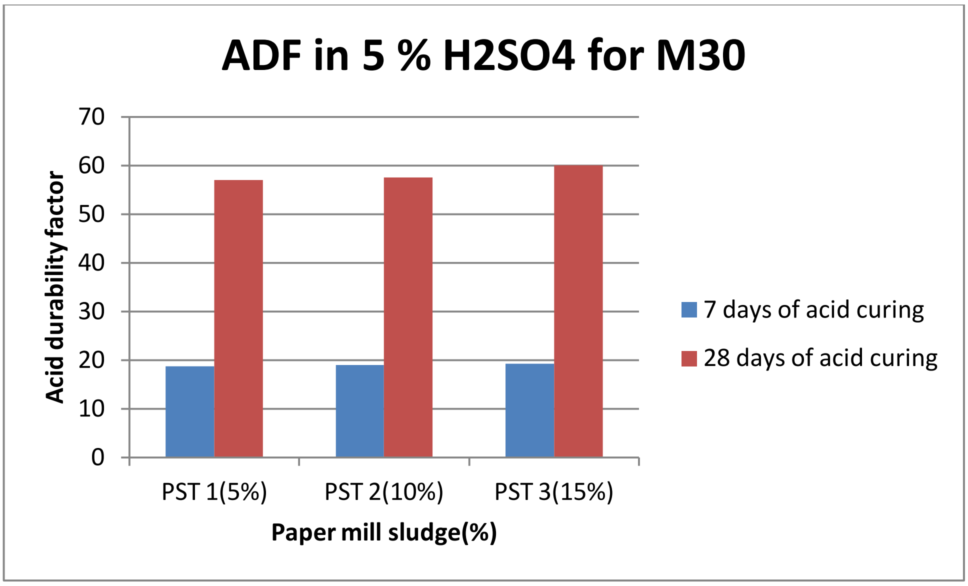

Fig 5.18 Variation of acid durability factor in H_2SO_4 with Paper mill sludge of M30grade for 7&28 days

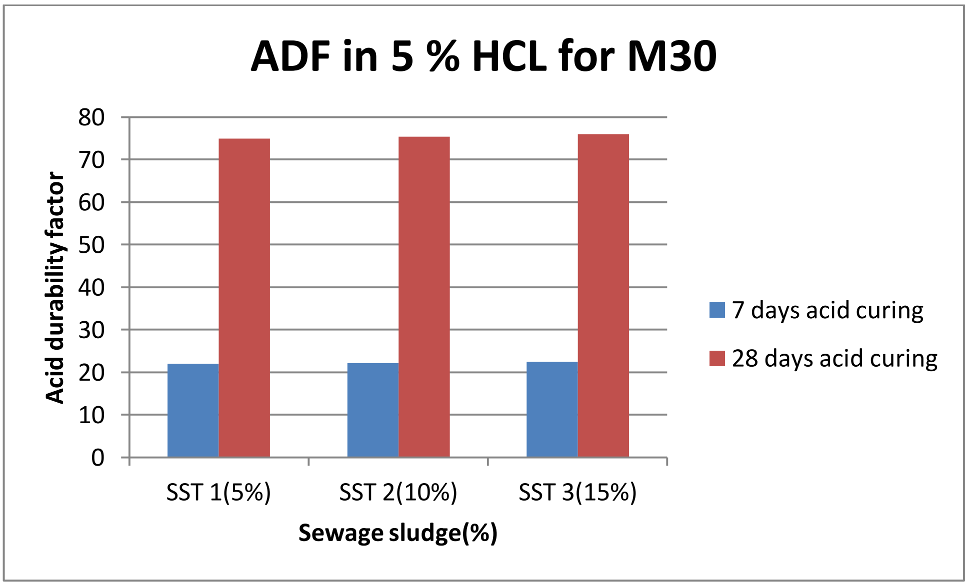

Fig 5.19 Variation of acid durability factor in HCL with Sewage sludge of M30grade for 7&28 days

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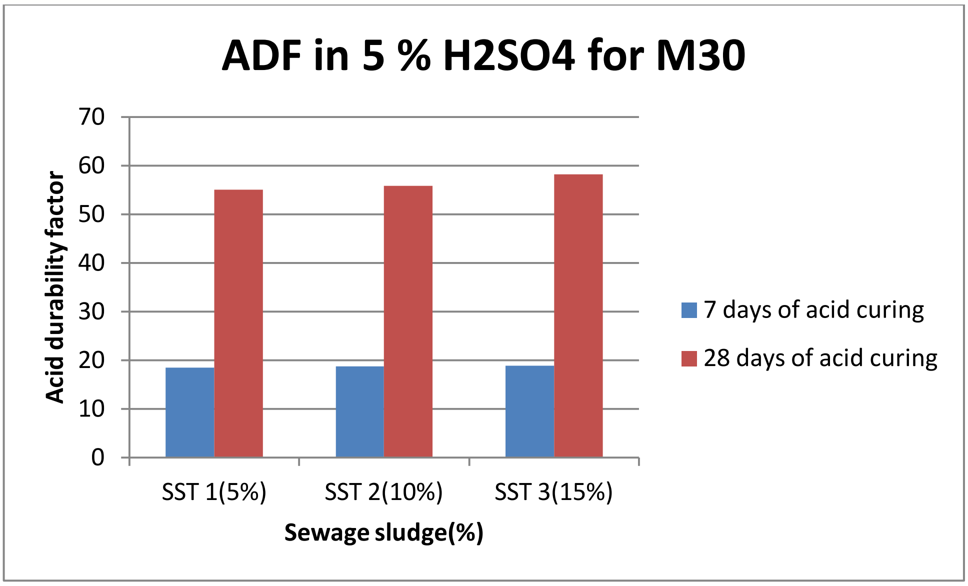

Fig 5.20 Variation of acid durability factor in H_2SO_4 with Sewage sludge of M30grade for 7&28 days

➢ **For M40 Grade of concrete**

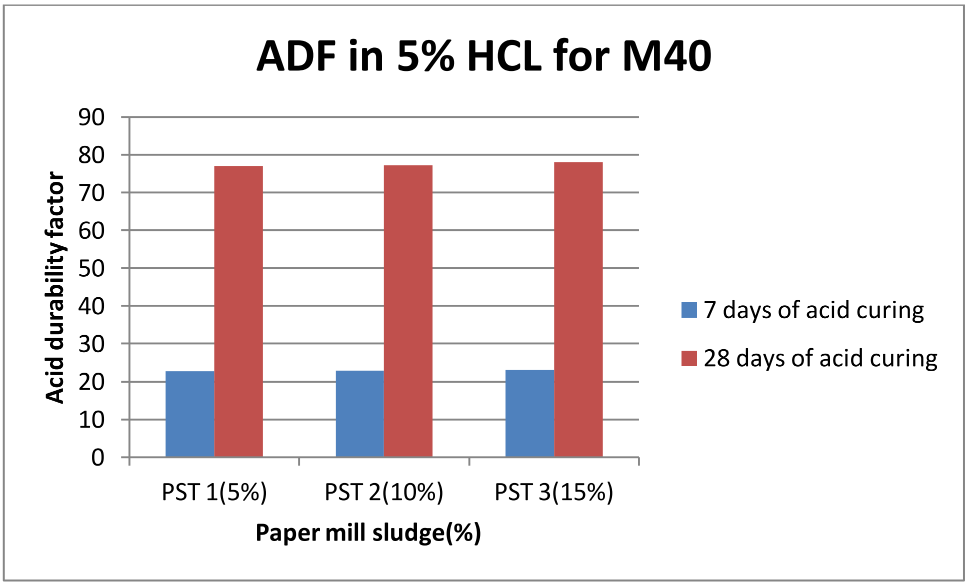

Fig 5.21 Variation of acid durability factor in HCL with Paper mill sludge of M40grade for 7&28 days

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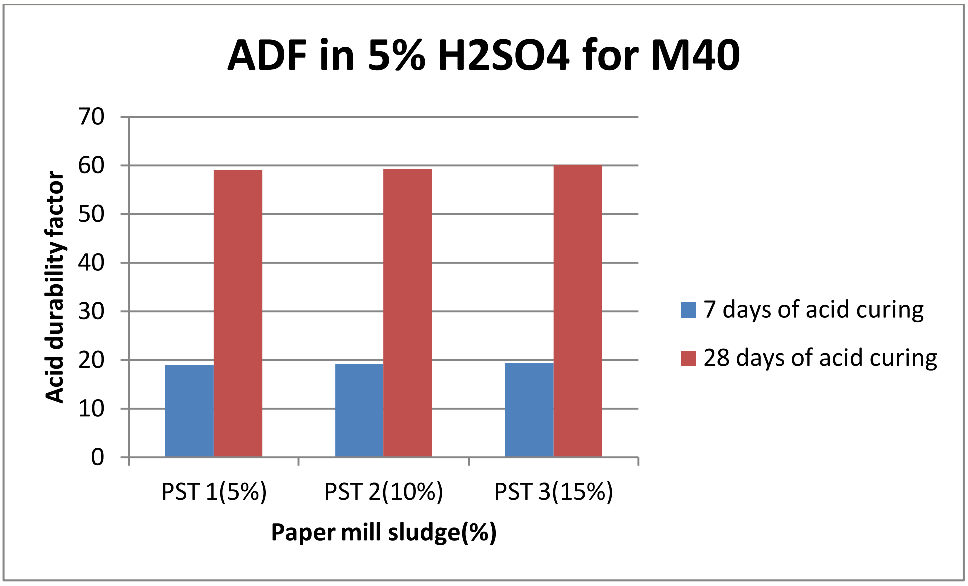

Fig 5.22 Variation of acid durability factor in H $_2SO_4$ with paper mill sludge of M40grade for 7&28 days

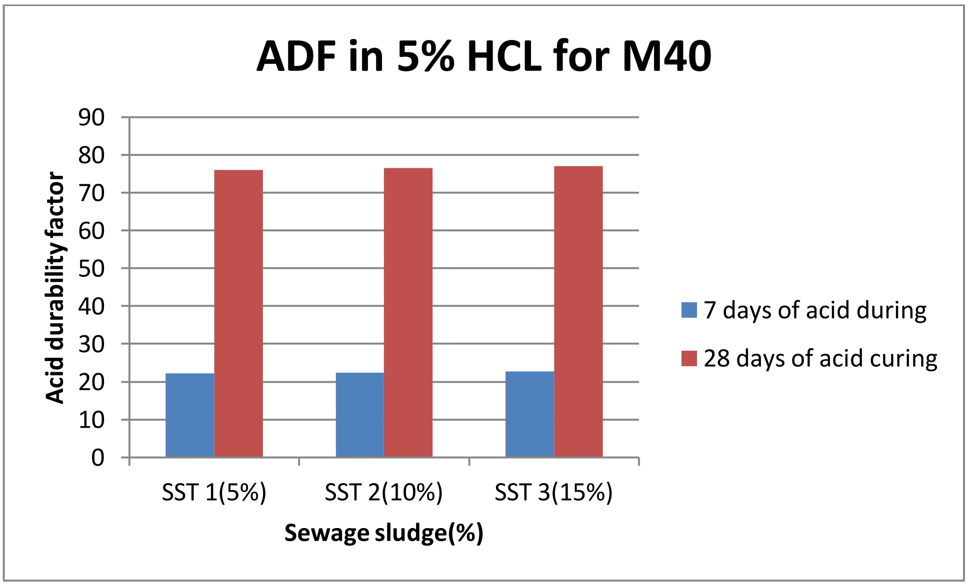

Fig 5.23 Variation of acid durability factor in HCL with Sewage sludge of M40grade for 7&28 days

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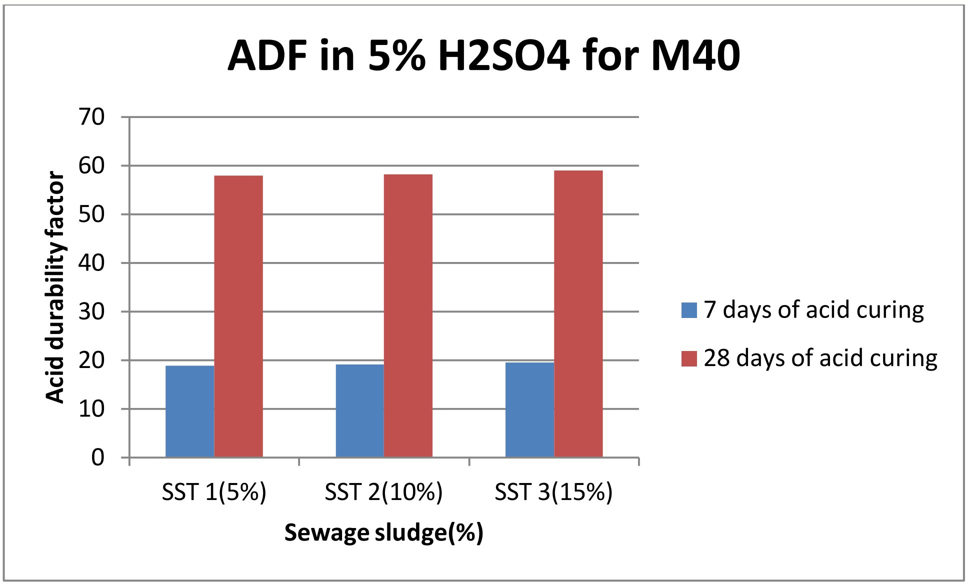

Fig 5.24 Variation of acid durability factor in H_2SO_4 with Paper mill sludge of M40grade for 7&28 days

VI CONCLUSIONS

- Paper mill sludge and waste water sludge wastes is suitable for the use in small number of concrete mixes as a replacement for the cement, but it is not appropriate for large quantities.
- The productive use of a waste material represents a way of solving some problems of the solid waste management.
- The workability is decreased because of increase in paper mill sludge and waste water sludge.
- The paper industry waste can be innovative supplementary cementitious construction material but judicious decisions are to be taken by engineers.
- Compressive strength and split tensile strength and flexural strengths are increased up to 5% replacement of cement with paper mill sludge for M30 and M40 mix.
- Compressive strength and split tensile strength and flexural strengths are increased up to 5% replacement of cement with waste water sludge for M30 and M40 mix.
- The maximum optimum level of the replacement of paper mill

sludge and waste water sludge with cement is 10%.

- Use of a waste paper sludge in the concrete can save the pulp and paper industry disposal costs and produce a ‘greener’ concrete for construction.
- With increases in the waste paper sludge content, percentage water absorption increases.
- Use of waste paper sludge in concrete can prove to be a economical as it is non useful waste and free of cost.

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