Pulp Black Liquor- An Admixture in Concrete

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Abstract

Due to increased construction the use of concrete is also increased. Concrete consists of Ordinary Portland Cement (OPC), aggregates (coarse and fine) and water. To improve the characteristics of concrete, nowadays addition of admixtures to the concrete is widely used. Admixture should be easily available and cost effective. Here in this study, we introduce easily available and cost effective admixture Pulp Black Liquor (PBL), a byproduct from paper industry. The discharge of pulp black liquor to the environment will cause serious environmental issues. So by adding pulp black liquor to concrete as an admixture, can reduce environmental issues and improves the properties of concrete like workability, compressive strength and split tensile strength. In this study the effects of PBL on concrete were studied using two different design mixes.

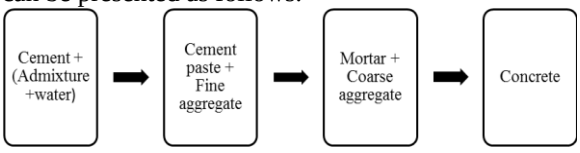
Keywords - *PBL, OPC, Admixture.*

I. INTRODUCTION

Concrete is a composite material composed of coarse aggregates and filler materials embedded in a hard matrix of material (the cement or binder) that fills the voids between the aggregate particles and glues them together. We can also consider concrete as a composite material that consists of a binding medium within which are embedded particles or fragments of aggregates. The simplest form of concrete representation is:

Concrete = Filler + Binder**.**

In concrete construction, the Portland cement concrete is widely utilized. Thus, in our course, the term concrete usually refers to Portland cement concrete. For such kind of concrete, the composition can be presented as follows.



Here we should indicate that admixtures are almost always used in modern construction practice and thus become an essential component of modern concrete. Admixtures are defined as materials other than fine and coarse aggregate, water, fiber and cement, which are added into concrete batch immediately during or before mixing. The widespread use of admixture is mainly due to the many benefits made possible by their application. Chemical admixtures can modify the setting and hardening characteristic of cement paste by influencing the rate of cement hydration.

Ibrahim M Ismail et.al. (2011) studied on "Utilization of Black Liquor as Concrete Admixture and Set Retarder Aid". In this paper characterization of black liquor was performed by determining the relevant parameters using devices available at the Chemical Engineering Laboratory. To achieve the objectives of this research work, two concrete mixes were selected, one with a water cement ratio equal to 0.5 and other with a water cement ratio equal to 0.4. They concluded that black liquor is considered as low cost admixture to increase the workability and retard setting time of concrete. The results of this research show that black liquor noticeably increases the workability of concrete with maximum performance at 15% water replacement by black liquor. It helps to improve compaction and to reduce honeycombing.

Paul Shaji et.al. (2015) studied on "Utilization of Pulp Black Liquor (PBL) as An Admixture in Concrete". In this paper mainly two properties of concrete were studied, compressive strength and setting time of concrete. For the compressive strength analysis, cubes and beams of different design mixes were casted with different percentage of pulp black liquor. Design mixes of M20, M25 and M30 were prepared with a water cement ratio 0.42. As the PBL concentration increases the initial setting time decreases. In this paper they concluded that PBL is considered as a cost effective admixture to increase the workability and retard setting time of concrete. The PBL wastes activates the cement phase and improves the rate of hydration.

H.H.M Darweesh et.al (2013) studied on "Utilization of Pulp Black Liquor Waste as a Cement Admixture". In this he studied the effect of pulp black liquor, a by-product from paper industry, on physical and mechanical properties and micro structure of OPC and PLC cements. In this the result showed that the consistency of cement pastes mixed with PBL was gradually increased with the concentration of PBL while initial setting time and final setting time were decreased.so it can be used as an accelerator. He used black liquor to advantage because of high solubility and low viscosity. In this cement admixtures are used in minor quantities as water-soluble polymers, liquid resins and monomers to confer some beneficial effects as reduction of water requirements, improving workability, regulate setting, accelerating hardening,

improving strength, better durability, desirable appearance and volume change. They concluded that the PBL waste liquor activates the cement phases and improves the rate of hydration. The incorporation of PBL waste with OPC or LPC pastes enhances the water -cement ratio for LPC more than OPC cement paste and decreases the setting times (initial and final).

Jignesh Patel et.al (2015) discussed on "Investigating effect of Black Pulp Liquor on the Properties of Concrete". This research studies the possibility of utilization of black pulp liquor, received from local paper industry, as concrete admixture and also the steel slag as partial replacement of coarse aggregate in the concrete to create positive environmental impact. The influence of steel slag and black pulp liquor in concrete were evaluated in this study and the following findings are concluded:
- By addition of admixture (Black pulp liquor) results shows prompt increase in workability.
- Addition of admixture (Black pulp liquor) in concrete mix fairly affects the split tensile strength of concrete.

Ephrahim et.al (2014) discussed on "Concrete Admixture and Set Retarder Potential of Palm Liquor". Although there are little or no reports of use of palm liquor as a workability aid for concrete and mortar, the use of black liquor show that alkali black liquor does not have any negative effect on concrete durability. As a low cost product the properties of palm liquor and its performance on concrete at two different water cement ratios were investigated. The results show that palm liquor increases concrete workability, improves compaction, reduces honeycombing and retards the initial and final setting time of concrete.

II. EXPERIMENTAL DETAILS

A. Materials Used

1. Ordinary Portland Cement (OPC-53)

Cement is the individual unit of fine and coarse aggregate into a solid mass by virtue of its essential properties of setting or hardening in combination with water. It helps to fill the voids and gives density to the concrete. In this study Ordinary Portland Cement-Grade 53, having been certified with IS: 12269 – 1987, Grade 53 which is known for its rich quality and high durability is used.

2. Coarse Aggregate (Crushed Rubble)

In this project, coarse aggregate of 20 mm size is used confirming to the code IS: 383 – 1970. Well graded angular aggregates are desirable. Aggregates should be uniform quality with respect to shape and grading.

3. Fine Aggregate (Sand)

Fine aggregates can be natural or manufactured. The grading must be uniform throughout the work and must pass through 4.75 mm sieve size which confirms to the code IS: 383 – 1970.

4. Water

Water is the key ingredient, which when mixed with the cement, forms a paste that binds the aggregate together. Potable water available in laboratory was used for casting all the specimens. The quality of water was found to satisfy the requirements of IS: 456-2000.

5. Pulp Black Liquor (PBL)

The pulp black liquor a waste material from paper industry which has low viscosity and high solubility and it is easily available; due to these factors we are trying to use Pulp Black Liquor as an admixture in concrete. Black liquor can be used as important liquid fuel in the pulp and paper industry. It is the product obtained after the digestive process where the cellulose fibers have been removed from the wood. One of the main component in the pulp black liquor is lignin, which is the main material in trees that hold wood fibers together and make them strong and rigid, and which must be removed from wood fibers to create paper.

Table I Chemical Composition of PBL

Composition	Percentage (%)
NaOH	7
Na_2S	19
Na_2CO_3	36
Na_2SO_4	13
Na_2SO_3	9
$Na_2S_2O_3$	16

III. TESTS AND RESULTS

Mainly two properties of concrete were studied, compressive and spilt tensile strength. One set of cube and cylinders were casted for M25 and M30 concrete with different percentages of PBL such as 0, 1, 1.5, 2 percentages. Compressive strength test and split tensile test are conducted.

The experiment was carried out in two stages.

- First Stage
- Second Stage

In first stage preliminary tests were conducted. It includes

- Specific gravity of cement
  It is obtained as 3.14.
- Bulk density and specific gravity of fine and coarse aggregate.
- Particle size distribution of fine and coarse aggregate.

In second stage, Mix design of M25 and M30 were prepared. Tests conducted are,

- Slump test
- Flow table
- Compressive strength test
- Split tensile test

B. Mix design for M25 and M30 concrete mixes

Table II Mix design for Normal M25 and M30

Particulars	M25	M30
Cement (kg/m^3)	394	437.78
Fine aggregate (kg/m^3)	650.496	614.759
Coarse aggregate (kg/m^3)	1138.368	1140.86
Water cement ratio	0.5	0.45

C. Flow chart for mix proportioning of admixture added concrete

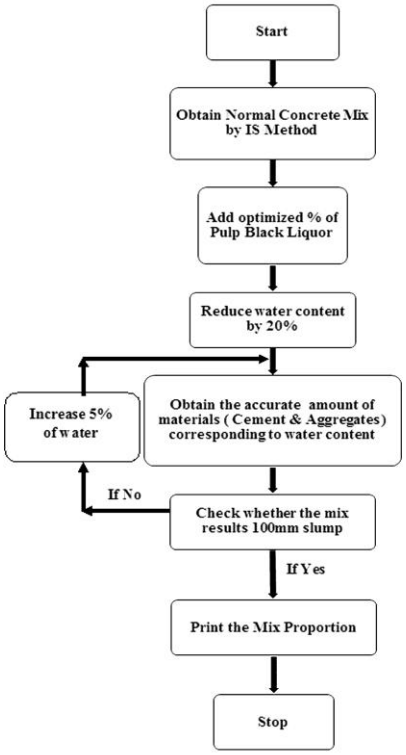


Fig: 1 Flow chart for mix proportioning of admixture added concrete

D. Mix design for admixture added concrete mixes (M25 and M30)

Table III Mix design for M25 and M30 with 1% PBL

Particulars	**M25**	**M30**
Cement (kg/m^3)	374.3	415.89
Fine aggregate (kg/m^3)	662.208	626.709
Coarse aggregate (kg/m^3)	1158.86	1163.038
Water cement ratio	0.5	0.45

Table IV Mix design for M25 and M30 with 1.5% PBL

Particulars	**M25**	**M30**
Cement (kg/m^3)	354.6	394
Fine aggregate (kg/m^3)	676.608	640.883
Coarse aggregate (kg/m^3)	1184.064	1189.342
Water cement ratio	0.5	0.45

Table V Mix design for M25 and M30 with 2% PBL

Particulars	**M25**	**M30**
Cement (kg/m^3)	354.6	394
Fine aggregate (kg/m^3)	674.976	639.123
Coarse aggregate (kg/m^3)	1181.208	1186.07
Water cement ratio	0.5	0.45

E. Slump test

Table VI Slump value for M25 and M30

Sl No	Mix	Slump values for each % of PBL			
		0	1	1.5	2
1	M25	101	105	106	104
2	M30	99	104	105	101

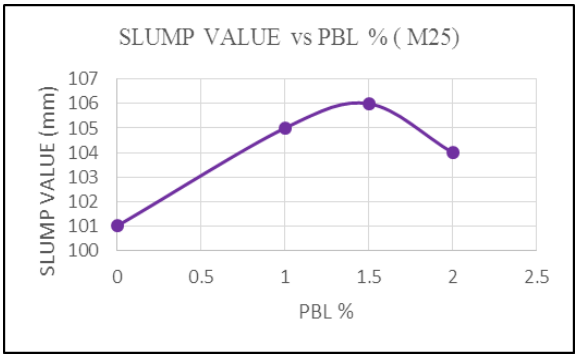


Fig. 2 Slump value vs PBL% (M25)

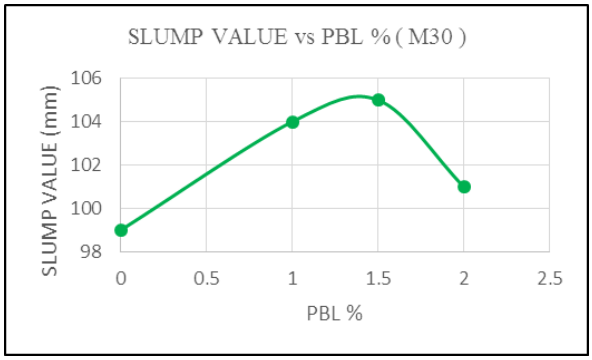


Fig. 3 Slump value vs PBL% (M30)

F. Flow table test

Table VII Flow for M25 and M30 concrete mixes

Sl No	% of PBL	Flow (M25)	Flow (M30)
1	0	85.33	85.60
2	1	112.80	108.00
3	1.5	124.80	120.33
4	2	123.33	118.67

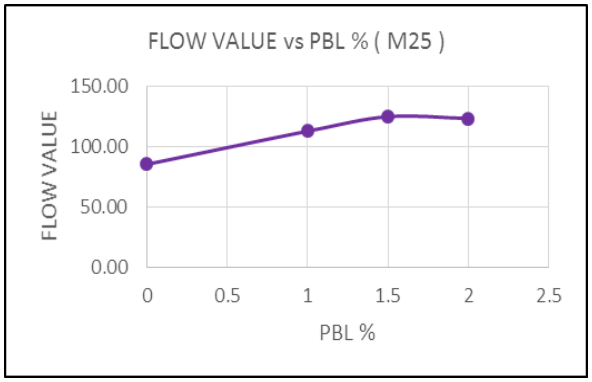


Fig. 4 Flow value vs PBL% (M25)

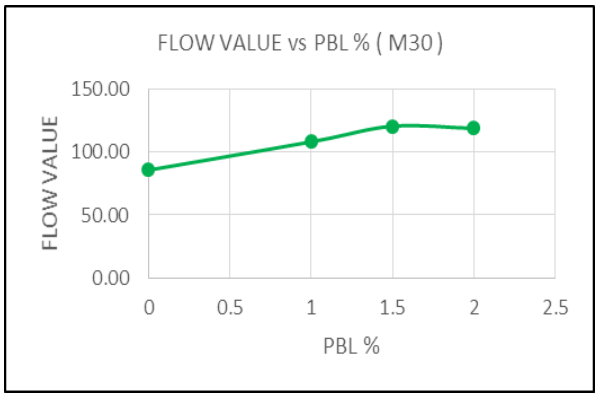


Fig. 5 Flow value vs PBL% (M30)

G. Compressive strength test

Table VIII 7th Day Compressive Strength value for M25

Sample No	% of PBL	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	0	21.19	20.31
2		20.53	
3		19.20	
1	1	20.59	22.09
2		21.98	
3		23.69	
1	1.5	25.85	26.19
2		27.17	
3		25.55	
1	2	19.87	20.00
2		19.76	
3		20.39	

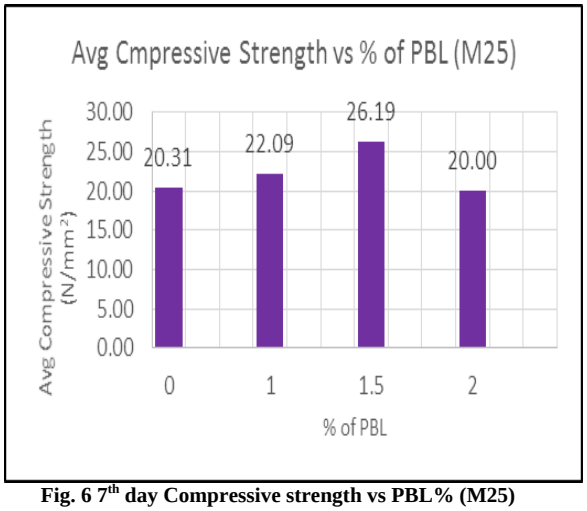


Fig. 6 7th day Compressive strength vs PBL% (M25)

Table IX 7th Day Compressive Strength value for M30

Sample No	% of PBL	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	0	25.31	25.62
2		26.32	
3		25.22	
1	1	29.84	28.73
2		26.38	
3		29.96	
1	1.5	36.49	33.38
2		33.74	
3		29.92	
1	2	34.87	27.75
2		30.27	
3		18.12	

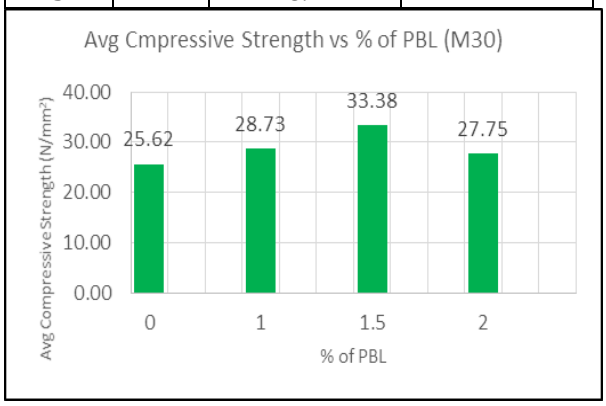


Fig. 7 7th day Compressive strength vs PBL% (M30)

Table X 28th Day Compressive Strength value for M25

Sample No	% of PBL	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	0	24	25.04
2		24.44	
3		26.67	
1	1	26.87	27.88

2		29.78	
3		26.99	
1	1.5	34.67	34.02
2		35.19	
3		32.20	
1	2	32.63	30.31
2		37.24	
3		21.06	

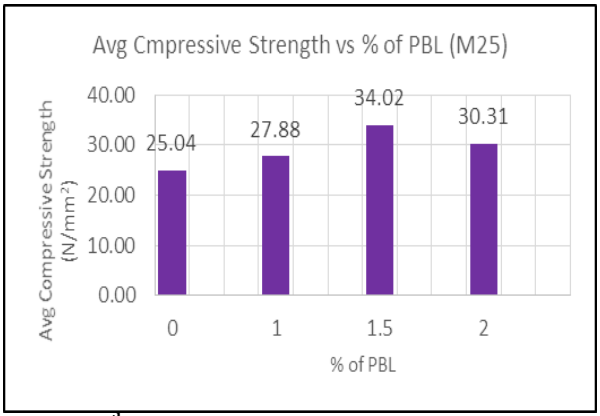


Fig. 8 28th day Compressive strength vs PBL% (M25)

Table XI 28th Day Compressive Strength value for M30

Sample No	% of PBL	Compressive Strength (N/mm²)	Average Compressive Strength (N/mm²)
1	0	31.56	30.46
2		30.67	
3		29.16	
1	1	33.38	32.22
2		33.51	
3		29.78	
1	1.5	37.55	37.83
2		37.56	
3		38.38	
1	2	27.47	30.26
2		34.42	
3		28.88	

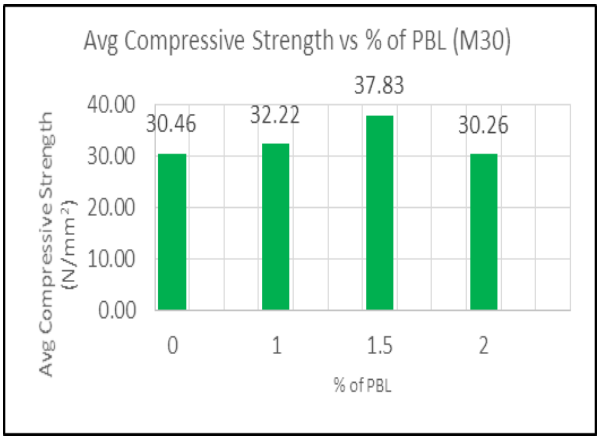


Fig. 9 28th day Compressive strength vs PBL% (M30)

H. Compressive strength comparison of M20 and M30

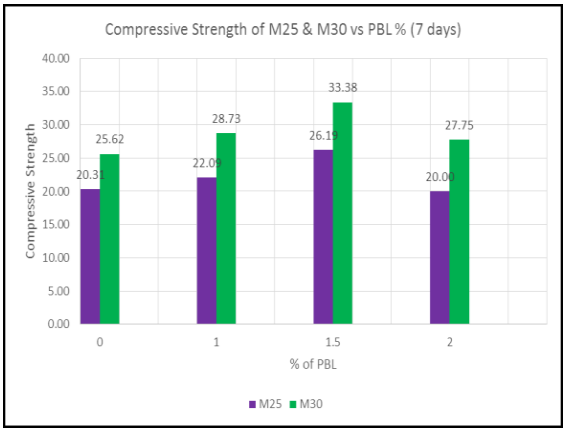


Fig. 10 Compressive strength comparison of M25 and M30 (7 days)

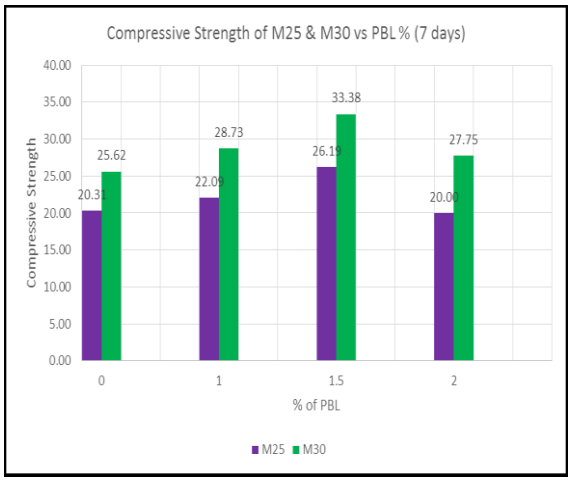


Fig. 11 Compressive strength comparison of M25 and M30 (28 days)

I. Split Tensile test

Table XII Split tensile Strength value for M25

Sample No	% of PBL	Tensile Strength (N/mm²)	Average Tensile Strength (N/mm²)
1	0	3.59	3.67
2		3.73	
3		3.68	
1	1	3.79	4.05
2		3.82	
3		4.53	
1	1.5	4.81	4.75
2		5.21	
3		4.24	
1	2	4.53	4.13
2		3.85	
3		4.02	

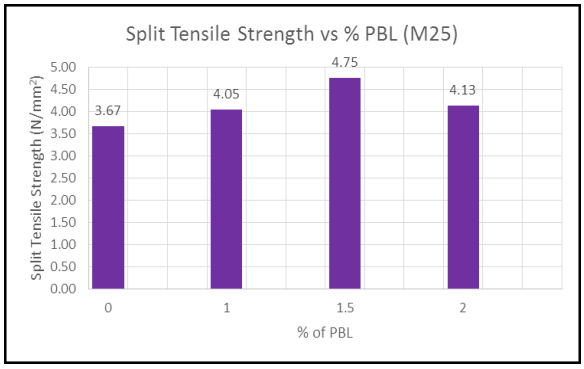


Fig. 12 Split tensile strength comparison of M25

Table XIII Split tensile Strength value for M30

Sample No	% of PBL	Tensile Strength (N/mm^2)	Average Tensile Strength (N/mm^2)
1	0	4.07	3.99
2		3.99	
3		3.90	
1	1	3.96	4.23
2		4.22	
3		4.53	
1	1.5	4.39	5.12
2		5.38	
3		5.60	
1	2	3.78	4.12
2		3.86	
3		4.73	

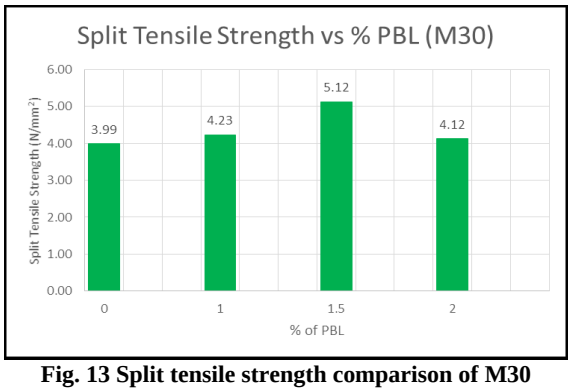


Fig. 13 Split tensile strength comparison of M30

J. Split tensile strength comparison of M20 and M30

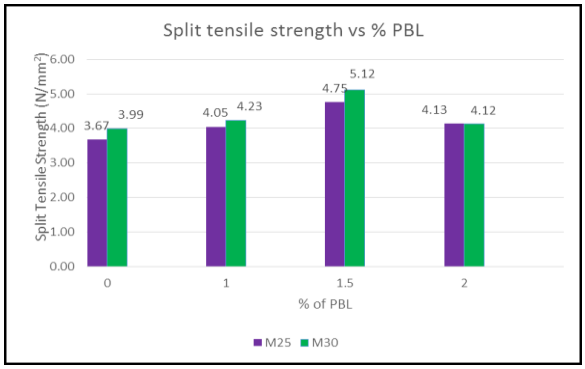


Fig. 14 Split tensile strength comparison of M25 and M30

IV. DISCUSSIONS

The flow value and slump value were obtained and plotted .The results shows that the flow value and slump value gradually increases with Pulp Black Liquor concentration up to 1.5% and then decreases.

The characteristic strength of concrete depends upon the concentration of Pulp Black Liquor, it is found that the compressive strength of concrete increases and then decreases. The maximum pulp black liquor that can be added to the concrete to obtain maximum compressive strength is 1.5%. This is same for M25 and M30 mixes. The value of split tensile strength is also varies with pulp black liquor concentration and maximum value obtained at 1.5% pulp black liquor. Hence from these results we can conclude that pulp black liquor can be used as an admixture in concrete.

V. CONCLUSIONS

The influence of pulp black liquor produced in paper industry (Hindustan News Print Limited, Vellore) on concrete were studied. The obtained results shows that pulp black liquor improves the properties of concrete like workability, split tensile strength and compressive strength. Compressive strength and split tensile strength depends on concentration of pulp black liquor. The values of compressive strength and tensile strength increased up to certain percentage of pulp black liquor. The obtained optimum value of pulp black liquor is 1.5% for both mixes, at this percentage concrete shows maximum improved results. Finally concluded that, utilization of pulp black liquor from Hindustan News Print Limited, can be used as an admixture with increased workability, compressive and split tensile strength.

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