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Development of Bricks by Utilizing Waste from Paper Industry

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Abstract: ***Urbanization lead to a vast generation of paper waste and discharge of these waste materials became a major problem. Dumping and landfilling of solid waste leads to environmental degradation i.e ground water contamination through leaching, which results in soil pollution and also impact on human health. In recent years, the utilization of paper waste as become more potential to recycle the valuable material and decrease the volume of waste, other pollutants and dumping cost. This paper is concern to reuse and recycle the available paper waste generated from paper industry. to find a socioeconomic, eco-friendly solution, waste trash can be recycled for the preparation of bricks, which sustain a cleaner environment. The increased quest for sustainable and eco-friendly materials in civil construction works. It is useful to provide sustainable and potential solution in the construction field.***

Index Terms**:** ***eco-friendly products, industrialization, paper waste, recycle.***

I. INTRODUCTION

Environmental conservation is an indisputable industrial responsibility, and market competitiveness has demanded proactive and concrete actions from industry to preserve the environment. This demand promotes the minimisation of environmental impacts through the use of clean technologies that minimise waste generation and maximise reuse. The use of such technologies leads to the utilisation of wastes, energy savings and other gains. Lot of studies have been done for utilisation of this waste specific to the properties of the waste as building materials.To build sustainable environment and to meet the demand of construction material it is very important to find the link between waste generating industries and construction industry.

The generation of large quantities of wastes is a result of rapid industrialization. It creates environmental and ecological problems apart from occupying large tracts of valuable cultivable land.

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It has been observed that some of these wastes have high potential and can be gainfully utilized either as raw mix or as blending component in manufacturing some of the Civil Engineering Components.

The utilization of the industrial wastes will not only help in solving the environmental pollution problems associated with the disposal of these wastes but also help in conservation of natural resources which are fast depleting. The sludge generated from industries like paper manufacturing and toothpaste manufacturing which contains a lot of $CaCO_3$ is prohibited from being discharged due to the contents present in this sludge. These industries hold the generated sludge in open or closed basin in gunny bags. Our study was on the stabilization and solidification of industry sludge and on the engineering behaviour of this sludge.

Our paper industry sector is presently facing the problems of solid waste management for its safe disposal. Paper manufacturing industries generate sludge in large quantity. Despite having 40-50% calcium carbonate, as per present practices, such sludge are being used for filling low lying areas or being burnt in cement kiln along with other toxic sludge. Disposal on open land is possible to some extent only due to non-availability of land and high prices of land. Excess disposal of sludge on land also lead to generation of other pollution problems. Although burning of sludge in cement kiln is environment friendly but it is wastage of such a valuable material which otherwise can be used as construction material leading to reduction in pollution load as generated due to manufacturing of cement. Thus, the development of new technologies has been required. The very feature of paper industry waste is that it contains $CaCo_3$ in abundance; attracts the attentions of Civil Engineers. So, it is appropriate to carry out studies for utilization of sludge from paper manufacturing industries as a replacement of construction material. It also helps in bricks manufacture and it preserves raw materials, decreases energy consumption and volume of waste sent to landfill.

The construction industry is one of the important pillars of any nation. As India is under development, the growth of construction industry in India is very fast. There is a huge demand of good quality construction for which the basic requirement is good quality building materials. Brick is one of the most important and widely used building materials all over the world. It is among the oldest and most sempiternal building materials. It is the simplest of all building materials. The most basic building material for construction of houses is the usual burnt clay brick. A significant quantity of fuel is utilized in making these bricks. Also, continuous removal of topsoil, in producing conventional bricks creates environmental problems.

Brick is made up of clay and water, which is then hardened by drying and burning. Some of the important characteristics of bricks that make it popular building material is its highly economical cost, high compressive strength and good durability. There is an increase in demand of bricks which is resulting in the escalation of cost in India.

There is strong need to adopt cost effective sustainable technologies using local materials and appropriate/intermediate technologies using materials with efficient and effective technology inputs. This problem can be tackled by using some waste material to replace some part of the primary component which in turn can also solves the disposal problem of the waste material. This will also help in economizing the resources. It will help in conservation of resources and reducing pollution. Also, there will be reduction in construction cost. One such material is paper industry sludge. Huge amount of paper sludge is produced on daily basis. Production of burnt clay bricks requires consumption of coal as fuel leading to greenhouse gas emissions. The primary raw material used for bricks is the soil, which is often taken from prime agricultural land, causing land degradation as well as economic loss due to diversion of agricultural land. Use of traditional technologies in firing the bricks results in significant local air pollution. The burnt clay brick industry in India produces over 180 billion clay bricks annually with a strong impact on soil erosion and unprocessed emissions.

Clay being the main component of brick, in this study, an effort has been made to utilize the paper sludge (i.e. waste product of paper industry) in bricks by partially replacing the clay. The objective of this present work is to study the stabilization and solidification of paper industry sludge and then to study engineering behaviour of this stabilized and solidified sludge.

The present research intends for utilizing waste from paper industry as a supplementary clay materials in partial replacement of soil as well as substitute of sand in bricks as alternative to virgin/mineral materials/natural resources.

So, we decided to replace dry paper sludge as soil. Experiments have been performed to study the effect of 10-50% clay replacement with paper sludge.

II. EXPERIMENTAL

This test program includes all the fundamental tests which are completed in the material and the solid. These tests help us to know the properties of the material being utilized for the way toward cementing and in the inference of the blend proportion.

The main aim of this research is to study the utilisation Paper Mill waste in partial replacement of cement/sand and clay in properties of concrete and bricks respectively. The objectives of this work are listed below:

I. To do the characterisation of the lime sludge waste containing $CaCo_3$ from paper industry.
II. To assess the suitability of waste as binder/raw material.
III. Proportioning of waste as binder in concrete and clay bricks.
IV. To assess the various strength (physico-mechanical) and durability studies on above mentioned concrete and bricks.
V. To suggest the optimized mix for M10 bricks (Class-A) and M20 grade of concrete using the sludge from paper industry.

III. LITERATURE REVIEW

Weng et al., (2003) inspected bricks produced from industrial waste water treatment plant sludge and all required properties test were implemented. Results illustration that the quality of the product depends on sludge proportion and the firing temperature. Strength of bricks with up to 20% sludge content at temperature assortments of 960-1000°C met the required Chinese standards. The leaching result on the product illustrations a low metal ooze level.

Kinuthia et al., (2007) investigated the compressive strength and workability of concrete using Waste paper sludge ash and GGBS. This paper concluded that it is possible to combine Waste Sludge Ash (WSA) and GGBS, a waste product and a by-product respectively, to produce a binder without combining Portland cement.

Jayraj et al., (2013) studied hypo sludge (paper sludge) is acquired as waste item from the paper businesses. Examinations were done to investigate the likelihood of utilizing and hypo sludge as a substitution of cement in solid blends. This paper introduces theaftereffects of study embraced to examine the practicality of utilizing hypo sludge as cement in concrete.

Singh et al., (2014) discovered lime use in structures and in different chemical and different enterprises. Lime based cementitious materials can halfway replace customary Portland cement (OPC) in applications like stone work bond, putting over dividers, generous amount of OPC.

Raoa et al. (20016) looked into a global situation diminishing waste produced, and to reuse the loss in cement without decreasing the quality and other physical properties of cement. They found the impact of utilization of reused total on the crisp and solidified concrete and finished up a portion of the downsides in the utilization of RA in reused total cement (RAC), it likewise incorporates absence of mindfulness between the general population, absence of government support, no particular codes for utilizing the RA in new concrete.

IV. MATERIAL AND METHODOLOGY

4.1 MATERIAL

4.1.1 Clay

Materials used in the study were locally procured. The clay soil was taken from a nearby locally based brick kiln. Table-4.1 below presents the tabulation of the chemical composition for clay calculated from XRF tests. It indicates that clay has the silica (67%). The silica in clay is present in a different form as a free form (SiO_2) and in the form of compounds when mixed with other elements such as aluminium oxide (Al_2O_3) to form kaolinite ($Al_2(Si2O_5)(OH)_4$) in the feldspar group.

The element that contributes to the red colour of clay is iron oxide (Fe_2O_3). The colour is not dominant due to the presence of other materials inside raw clay such as organic matters that make raw clay grey, black, or dark brown depending on the amount present. However, the colour changes after the firing process when carbonaceous material and iron compounds start to oxidize.

Table-1: Chemical composition of clay

S.No.	Component	Percentage
1	SiO_2	67
2	Al_2O_3	26
3	Fe_2O_3	3
4	Na_2O	1
5	MgO	1
6	P_2O_5	Trace
7	SO_3	0.5
8	K_2O	2
9	CaO	0.1
10	Cr_2O_3	Trace
11	MnO	Trace
12	NiO	Trace
13	CuO	Trace
14	ZnO	Trace
15	Cl	Trace

4.1.2 Paper Sludge

Paper sludge were sourced from a Plant at Kala Amb (District Sirmour, H.P). Wastes from paper industry were obtained in form as powder and sludge. The sludge was kept in containers. In this study the powdered form of sludge was used. Physical properties studied are shown in Table-2

Table-2: Physical Properties of Material Used

MATERIAL	SPECIFIC GRAVITY	FINENESS MODULUS
PAPER SLUDGE	1.89	1.44

The chemical composition was calculated from XRF tests. The composition is described as below in Table 3.

Table-3: Chemical composition of Paper Mill Sludge

Composition	Percentage
O	**44.74%**
Ca	**37.34%**
C	**11.70%**
Si	**4.25%**
Na	**0.86%**
Mg	**0.50%**
K	**0.21%**
P	**0.10%**
S	**0.09%**
Fe	**0.06%**
Cl	**0.06%**
Al	**0.05%**
Sr	**0.01%**
Mn	**38ppm**
Cu	**30ppm**
Ni	**30ppm**
Zn	**27ppm**

4.2 MIXING AND PROPORTIONS

Sludge is mixed properly in the ingredients of brick in desired proportion. Sample prepared from all these mixes were compared and tested for several strength parameters. Figure-1 shows pictures of bricks while mixing and formation.

Figure-1: Figures of bricks while mixing and formation

Table-4: Mix Proportions of trial mixes

S. No.	Die	Soil (kg)	Sludge (kg)	Sludge %	Identity
1	Sk	80	0	0	A1
2	Sk	72	8	10	A2
3	Sk	64	16	20	A3
4	Sk	56	24	30	A4
5	Akm	48	32	40	A5
6	Akm	40	40	50	A6

4.2.1 Weight of the brick after formation

The weight of a few samples of each type was taken and then average weight was found out to get the desired standard weight. The average weight of each type is given below in Table- 5.

Table-5: Weight of Bricks

S. No.	Brick type	Weight(kg)
1	A1	3.104
2	A2	2.555
3	A3	2.431
4	A4	2.228
5	A5	1.956
6	A6	1.769

3.2.2 XRD Analysis:

XRD Analysis was performed at room temperature using powder XRay Diffraction with Cu, K α radiations. The scanning of samples was done from 10˚ to 90˚. The plot between the intensity of the scattered XRay light and the angle difference of Xrays that are deflected. Fig a illustrates the plot for normal brick without any sludge and Fig b illustrates the plot for paper mill sludge brick. In both the samples, diffraction peaks indicate the presence of quartz, calcite and sanidine. XRD analysis indicate large amount of calcite which indicates the brick containing sludge contains in its composition, minerals that are similar to those occurring in normal clay brick.

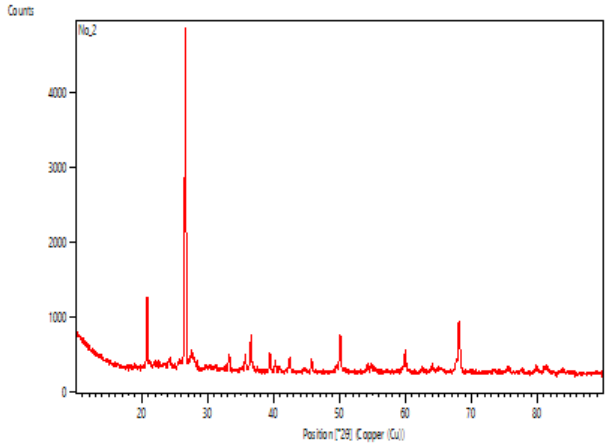


Fig a: XRD for plain brick

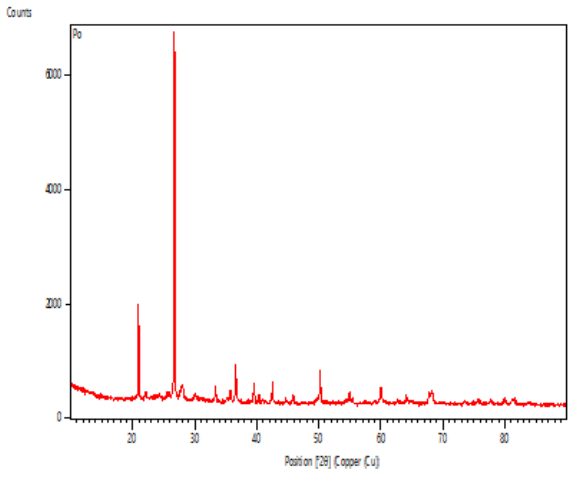
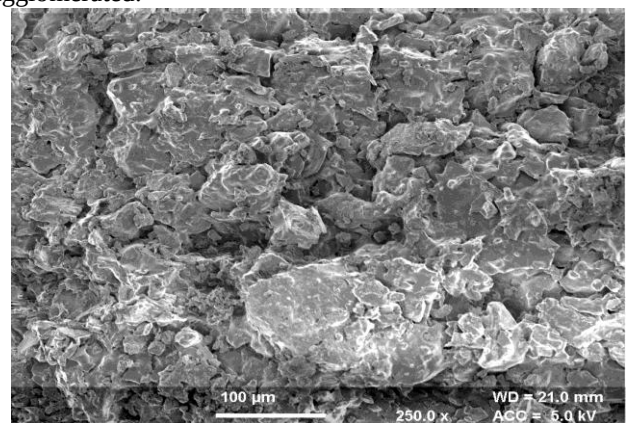


Fig b: XRD for paper mill sludge brick

4.2.3 Scanning Electron Microscope Analysis

The study of microstructure features was done under scanning electron microscope (SEM). There is a difference in pore structure and cracks of both the bricks when analysed through SEM. The texture of the bricks changed considerably with the addition of sludge when we compare it to a normal brick. The bricks with paper mill sludge as seen in fig c is more porous as compared to the normal brick in fig d which has no sludge. Paper sludge brick is porous and agglomerated.



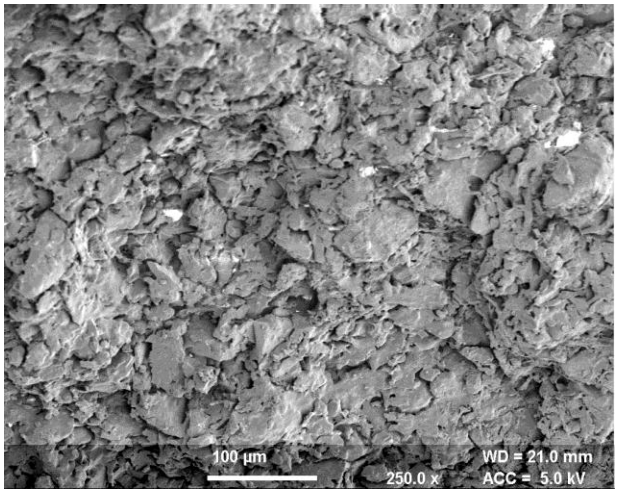


Fig c: SEM for paper mill sludge brick **Fig d: SEM for normal brick**

4.2.4 Water Absorption

The bricks of each type were dipped in water tank and water absorption was found out on a period of 24 hours. The Table-6 below shows the weight of each type and the percentage of water absorption after standard time.

Table-6: %age absorption after 24 hours

Sr. No.	Brick Type	Initial Weight	24 hours weight	% weight after absorption
1	A1	3.111	3.386	8.83
2	A2	2.546	3.128	22.86
3	A3	2.373	3.064	29.11
4	A4	2.239	3.069	37.07
5	A5	1.890	2.796	47.94
6	A6	1.819	2.670	46.80

Figure-2 below shows the pictures of water absorption process in which each brick was dipped in separate container containing water.

Figure-2: Water Absorption of bricks

4.2.5 Compressive Strength

The bricks casted were tested for compressive tests by firstly curing the bricks for a day and then a mixture of cement and aggregate was added to it in ratio 1:3 in the frog section. The bricks were then covered with a damp jute bag for a day and then bricks were cured for 3 days. After drying, the compressive strength was tested in UTM. Following Table 7 shows the amount of compressive strength of bricks.

Table-7: Compressive strength of bricks

S. No.	Bricks type	Compressive strength (N/mm^2)
1	A1	59
2	A2	23
3	A3	48
4	A4	49
5	A5	3
6	A6	119

Figure-3 below shows compressive strength test on Universal testing machine.

Figure-3: Compression test on UTM

4.2.6 Efflorescence test

The bricks were tested for efflorescence by placing them in tray in vertical position and adding 25cm water twice. Then physical examination was done. Table-8 below shows the results for efflorescence.

Table-8: Efflorescence of Bricks

S. No.	Brick type	Efflorescence
1	A1	Nil
2	A2	Slight
3	A3	Slight
4	A4	Slight
5	A5	Slight
6	A6	Slight

4.2.7 Soundness test

Two bricks of same type were taken and struck against each other. If it does not break and a metallic ringing sound forms then the bricks are sound. Table-9 below shows the details of soundness of samples.

Table-9: Soundness of bricks

S. No	Brick type	Soundness
1	A1	Satisfactory
2	A2	Satisfactory
3	A3	Satisfactory
4	A4	Satisfactory
5	A5	Not Satisfactory
6	A6	Not Satisfactory

The bricks were dipped into separate containers for a period of 28 days and the water in which the bricks were dipped was tested and compared to fresh water before dipping. Comparison was done on certain parameters like pH, conductivity, turbidity, hardness and the amount of chlorides.

4.2.8 pH Test

pH of water in which bricks were dipped was tested for a period of 7 days, 21 days and 28 days and compared with fresh water.

The table-10 below shows the value for pH test.

Table-10: pH Test of Bricks

S. No.	Brick type	Fresh Water	7 day	21 Day	28 Day
1	A1	7.3	7.82	7.55	8.62
2	A2	7.3	7.59	7.56	8.48
3	A3	7.3	8.09	7.58	8.50
4	A4	7.3	7.62	7.75	8.46
5	A5	7.3	7.79	7.85	8.67
6	A6	7.3	7.80	7.85	8.49

Figure-4 below shows the test conducted on pH meter and its calibration.

Figure-4: pH meter

4.2.9 Conductivity Test

Samples prepared were also tested for conductivity for a period of 7 days, 21 days and 28 days and were compared with fresh water used to dip the samples. Below mentioned Table-11 shows conductivity of samples

Table-11 Conductivity Test of Bricks

S. No.	Brick type	7 day	21 Day	28 Day
1	A1	1.112	0.960	0.990
2	A2	1.875	1.785	1.324
3	A3	2.040	1.984	1.481
4	A4	2.600	2.980	2.030
5	A5	2.650	2.100	1.440
6	A6	2.700	1.903	1.304

Figure-5 below shows the conductivity tests performed on water sample dipped with bricks.

Figure- 5: Conductivity test

4.2.10 Hardness Test

Hardness of water in which bricks were dipped was tested for a period of 7 days, 21 days and 28 days and compared with fresh water. The Table-12 below shows the value for pH test.

Table-12 Hardness Test of Bricks

S. No.	Brick type	7 day	21 Day	28 Day
1	A1	400	575	875
2	A2	900	1347	1700
3	A3	800	2175	1900
4	A4	1250	2200	2225
5	A5	1300	1875	1900
6	A6	1400	1670	1775

Figure-6 below shows chemical tests performed on water sample in which bricks were dipped for hardness test.

Figure- 6: Hardness test **Figure- 7: Chloride test**

4.2.11 Chloride Test

Chloride of water in which bricks were dipped was tested for a period of 7 days, 21 days and 28 days and compared with fresh water. Figure-7 shows the chloride test in chemical lab on water in which bricks were dipped. The Table-13 below shows the value for chlorides test.

Table-13 Chlorides Test of Bricks

Sr. No.	Brick type	7 days	21 Days	28 Days
1	A1	34.99	82.98	86.64
2	A2	44.99	84.98	89.97
3	A3	49.98	74.35	89.47
4	A4	54.98	87.97	91.48
5	A5	64.98	84.98	94.98
6	A6	69.98	109.48	116.47

4.2.12 Monitoring of Ambient Air Quality

Two rooms were constructed, one with using paper industry sludge bricks and one with normal bricks without any sludge.

Figure- 8: Ambient air quality of both rooms and outside these rooms was monitored using RDS (Respirable Dust Sampler) for 48 hours.

Table -14 below shows the value for ambient air quality monitored.

Table-14 Results of Ambient Air Monitoring

Date of testing	Location	SO_2(□g/m^3) (Limit 80 □g/m^3)	NOx (□g/m^3) (Limit 80 □g/m^3)	RSPM (□g/m^3) (Limit 100 □g/m^3)
31.08.2018	Inside Room (Normal Bricks)	Not Detected	6.69	24
01.09.2018	Inside Room (Normal Bricks)	Not Detected	6.56	22
31.08.2018	Inside Room (Sludge Bricks)	Not Detected	6.71	24
01.09.2018	Inside Room (Sludge Bricks)	Not Detected	6.54	22
31.08.2018	Outside Room	2.0	8.10	46
01.09.2018	Outside Room	2.0	7.90	42

V. RESULTS AND DISCUSSION

The results and properties of various mixes tested are shown below.

5.1 Weight

The weight results show that all the bricks are light in weight as compared to the standard brick A1 which does not contain any quantity of sludge. So, all the bricks are light weight bricks, which is an advantage in construction.

5.2 Water Absorption

According to the Indian standards, water absorption for class I and class II bricks should not be more than 20% after 24 hours immersion. The result of water absorption shows that the samples A1, A2 and A3 have absorption under standard value and hence acceptable. But the rest of the samples have a greater amount of absorption. Figure-9 and 10 shows the comparison of initial and final weight and percentage of water absorption respectively.

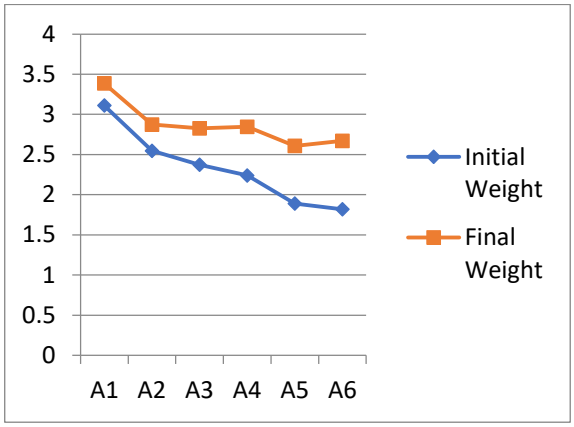


Figure-9: Initial and Final Weight after Absorption

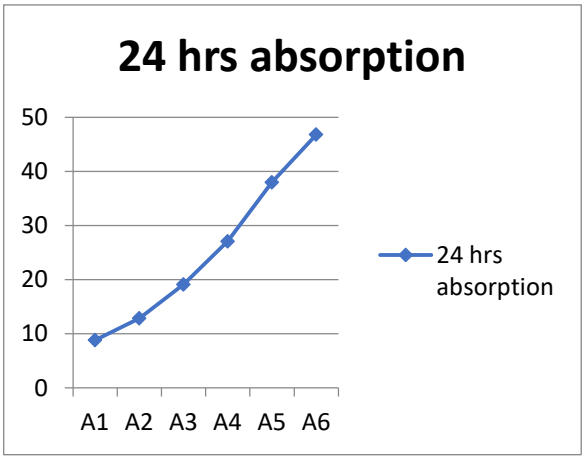


Figure-10: Water Absorption after standard time

5.3 Compressive Strength

The result of compressive strength shows that, the compressive strength of brick can be increased on addition of sludge to a limited quantity of 10% and 20% i.e. A1, A2, A3, but the compressive strength of brick mix will decrease on excess addition of sludge i.e. more than 20%. Figure-11 shows the comparative study of compressive strength test results of various mixes.

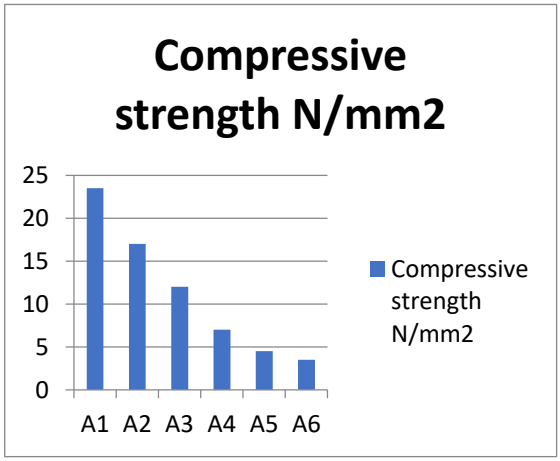


Figure-11: Compressive Strength of Bricks

5.4 Efflorescence Test

According to IS: 3495 part-3 1992, When there is no perceptible deposit, efflorescence is Nil, but there is slight efflorescence when 10% of exposed area has thin deposit of salts. In our specimens, samples with 0% sludge have nil efflorescence but the rest have slight efflorescence.

5.5 Soundness Test

A brick is sound only if it does not break and ringing sound is produced. The bricks with 10% and 20% sludge are sound and can be used for construction.

5.6 pH Test

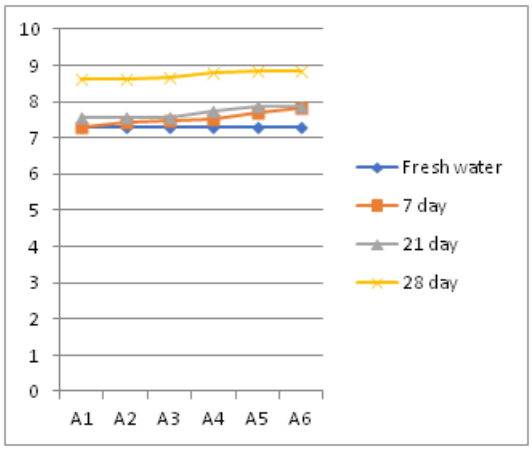


Figure-12: pH Test of Bricks

According to Indian standards, the samples with greater ph have low risk of corrosion. So, all our samples have pH greater than 7 and thus are less prone to corrosion. Figure-12 below shows chart of pH value of different samples at different days.

5.6 Conductivity Test

The tests performed show that our specimen brick A1 without any sludge have conductivity less than 1 and so is shown in brick A2 and A3. Hence these bricks are acceptable to use. Figure-13 and Table-14 shows the comparison of conductivity of different samples.

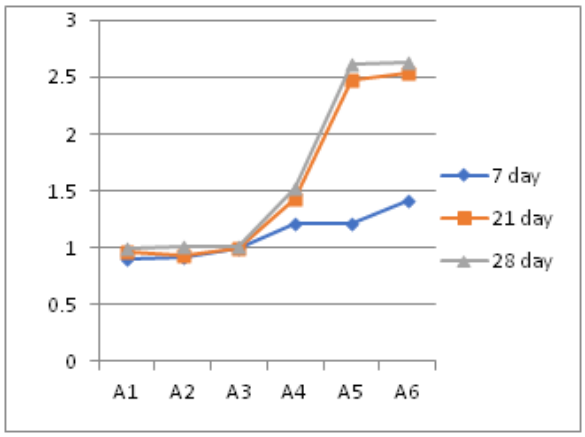


Figure-13: Conductivity Test of Bricks

5.7 Hardness Test

When compared to A1 i.e. 0% sludge, we see that A2 and A3 both have almost same hardness which is near to A1 and thus are acceptable. Figure-14 below shows the hardness test results of water in which bricks were soaked.

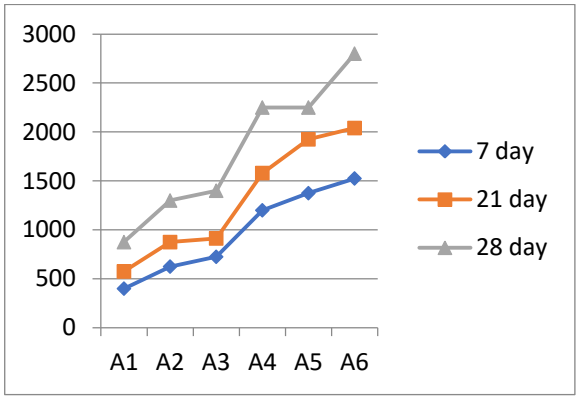


Figure-14: Hardness test of water soaked bricks

5.8 Chloride Test

The chloride tests show the corrosion prone amount of the bricks. Low values usually are less prone to corrosion. We see that A2 and A3 have lower values of corrosion than the sample brick A1 and then the value increases. So A1, A2 and A3 are acceptable. Figure-15 below shows the chloride content of various specimens.

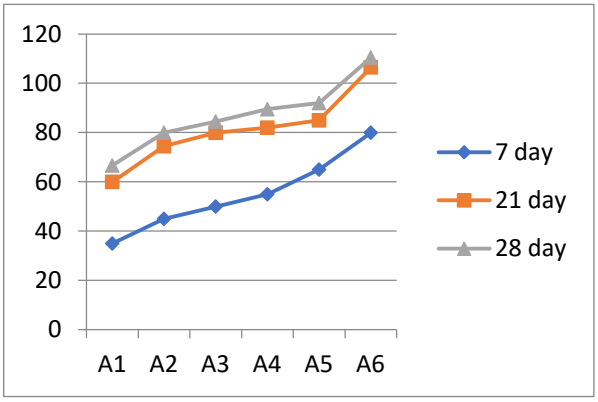


Figure-15: Chlorides Test of Bricks

5.9 Ambient Air Quality

Ambient air quality of rooms constructed using normal bricks and using paper mill sludge was found well within the standards prescribed under Environment Protection Act, 1986. Negligible difference between air quality of both rooms was found in respect of Sulphur dioxide, Oxide of Nitrogen and Respirable Suspended Particulate Matters. Figure-16 and Figure-17 below shows the ambient air quality in respect of Oxide of Nitrogen and Respirable Suspended Particulate Matters.

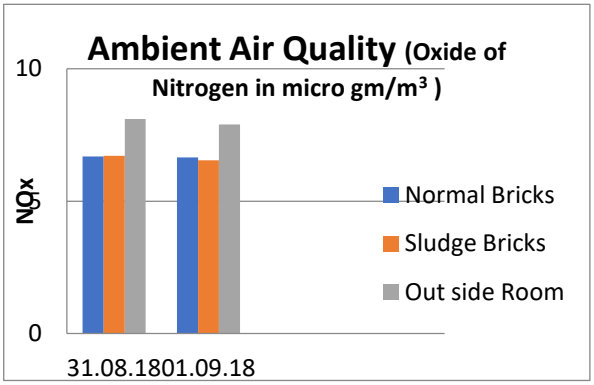


Figure-16: Ambient Air Quality (Oxide of Nitrogen)

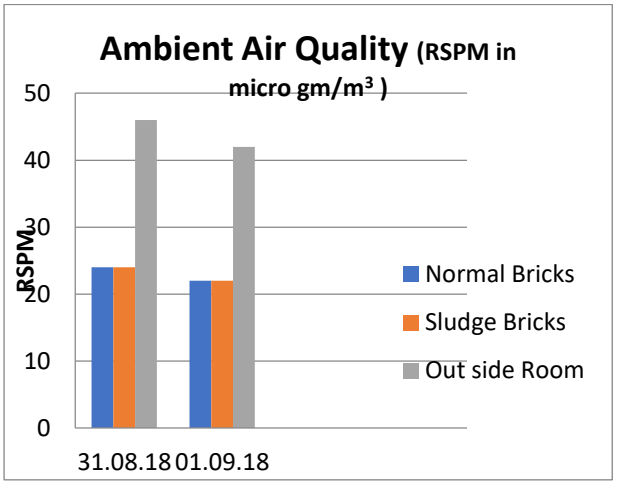


Figure-17: Ambient Air Quality (Respirable Suspended Particulate Matters)

VI. CONCLUSION

After the experimental investigation of use of paper mill sludge in manufacturing of bricks and construction of room using these bricks, following conclusions were made:

- The paper sludge can be utilized as an additive in the form of powder in the production of bricks upto 20% of replacement of soil (clay).
- Light weight materials are formed as we keep increasing the amount the sludge in brick.
- Compressive strength holds well if sludge is added up to 20%, further increasing the percentage of sludge in bricks will lead to decrease in the compressive strength of bricks.
- Addition of sludge in bricks leads to well sounded bricks provided a limited amount of sludge is added.
- Addition of sludge in bricks leads to negligible efflorescence in it provided a limited amount of 10% is added.
- With addition of 20% of sludge there is lower chloride content and higher pH content than the specimen without sludge which means resistance to corrosion.
- There is negligible adverse impact on ambient air quality of structures constructed using paper mill sludge bricks. Hence, proved as environmental friendly.

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