BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LVI (LX), Fasc. 1, 2010
Secţia
CONSTRUCŢII. ĂRHITECTURĂ

EXPERIMENTAL INVESTIGATION IN DEVELOPING LOW COST CONCRETE FROM PAPER INDUSTRY WASTE

BY

R. SRINIVASAN, *K. SATHIYA and M. PALANISAMY

Abstract. Over 300 million tones of industrial wastes are being produced *per annum* by chemical and agricultural process in India. These materials pose problems of disposal and health hazards. The wastes like phosphogypsum, fluorogypsum and red mud contain obnoxious impurities which adversely affect the strength and other properties of building materials based on them. Out of several wastes being produced at present, the use of phosphogypsum, fluorogypsum, lime sludge, hypo sludge, red mud, and mine tailing is of paramount significance to protect the environment.

Paper making generally produces a large amount of solid waste. Paper fibers can be recycled only a limited number of times before they become too short or weak to make high quality paper. It means that the broken, low-quality paper fibers are separated out to become waste sludge. All the inks, dyes, coatings, pigments, staples and "stickies" (tape, plastic films, etc.) are also washed off the recycled fibers to join the waste solids. The shiny finish on glossy magazine-type paper is produced using a fine kaolin clay coating, which also becomes solid waste during recycling. This paper mill sludge consumes a large percentage of local landfill space for each and every year. Worse yet, some of the wastes are land spread on cropland as a disposal technique, raising concerns about trace contaminants building up in soil or running off into area lakes and streams. Some companies burn their sludge in incinerators, contributing to our serious air pollution problems. To reduce disposal and pollution problems emanating from these industrial wastes, it is most essential to develop profitable building materials from them. Keeping this in view, investigations were undertaken to produce low cast concrete by blending various ratios of cement with hypo sludge.

This project is concerned with experimental investigation on strength of concrete and optimum percentage of the partial replacement by replacing cement *via* 10%, 20%, 30%, 40%, 50%, 60% and 70% of Hypo Sludge.

Key words: hypo sludge; pozzolanic property; supplementary cementitious materials.

1. Introduction

1.1 General

Energy plays a crucial role in growth of developing countries like India. In the context of low availability of non-renewable energy resources coupled with the requirements of large quantities of energy for Building Materials like cement, the importance of using industrial waste cannot be underestimated.

During manufacturing of 1 tones of Ordinary Portland Cement (OPC) we need about 1…1⅓ t of earth resources like limestone, etc. Further during manufacturing of 1 t of Ordinary Portland Cement an equal amount of carbon-di-oxide are released into the atmosphere. The carbon-di-oxide emissions act as a silent Killer in the environment under various forms. In this Backdrop, the search for cheaper substitute to OPC is a needful one.

1.2. Solid Waste from Paper Industry

a) *Hypo Sludge Properties*

Where, this hypo sludge contains, low calcium and maximum calcium chloride and minimum amount of silica. Hypo sludge behaves like cement because of silica and magnesium properties. This silica and magnesium improve the setting of the concrete.

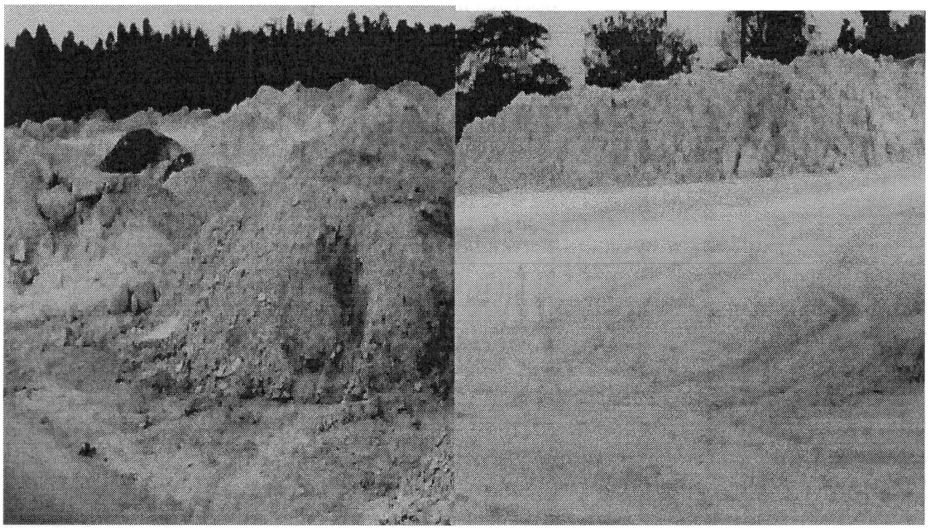

Fig.1 – Raw Hypo sludge disposal from TNPL

b) *Need for Hypo Sludge Utilization*

While producing paper the various wastes are comes out from the various processes in paper industries. From the preliminary waste named as hypo sludge, due to its low calcium is taken out for our project to replace the cement utilization in concrete. Due to the cement production green house gases are emitted in the atmosphere. For producing 4 million t of cement, 1 million t green house gases are emitted. Also, to reduce the environmental degradation, this sludge has been avoided in mass level disposal in land. To eliminate the ozone layer depletion, production of cement becomes reduced. For this, the hypo sludge is used as partial replacement in the concrete as high performance concrete. By utilizing this waste the strength will be increased and also cost reduction in the concrete is achieved.

1.3. Objectives

To investigate the utilization of Hypo Sludge as Supplementary Cementitious Materials (SCM) and influence of these hypo sludge on the Strength on concretes made with different Cement replacement levels.

1.4. Scope

a) To provide a most economical concrete.
b) It should be easily adopted in field.
c) Using the wastes in useful manner.
d) To reduce the cost of the construction.
e) To promote the low cost housing to the E.W.S. group people.
f) To find the optimum strength of the partial replacement of concrete.
g) Minimize the maximum demand for cement.
h) Minimize the maximum degradation in environment due to cement and safeguard the ozone layer from green house gases.
i) To study the crack development in hardened concrete.

1.5. Methodology

a) Tested the material properties as per Indian standards code (IS 383 – 1996) procedures.
b) Mix design for concrete proportion has been developed as per IS 10262 – 1982.
c) Casted and cured the concrete specimens as per Indian standards procedures.
d) The characteristic strength of hardened concrete specimen was tested as per IS 456 – 2000.
e) Finding the optimum strength of optimum replacement of hypo sludge as cement.

f) Compare the results of conventional concrete and partial replacement concrete.

2. Literature Review

Felix F.U d o e y o, Hilary I n y a n g, David T.Y o u n g and Edmund E. O p a r a d u are the authors of a recent paper in this field of articles [1]. The enormous amount of wastes produced during wood processing operations in many countries provides challenging opportunities for the use of wood waste as a construction material. In this research, wood waste (saw dust and wood shaving) ash (WWA) of pretreated timber of 0, 5, 10, 15, 20, 25and 30% by weight of cement was added as a supplement to a concrete of a mix proportion 1:2:4:0.56 (cement: sand: coarse aggregate: water cement ratio), and the strengths and the water absorption of the matrix were evaluated. Also, the metal leachability of WWA was analysed. The compressive and the flexural strengths of WWA concrete for the ages investigated ranged from 12.83 to 28.66 N/mm^2, and 3.652 to 5.57 N/mm^2, respectively, with the lowest values obtained at 30% additive level of ash. When compared with strength of plain concrete (control), the compressive and the flexural strengths of WWA concrete were between 62 and 91% and 65 and 95%, respectively, of the former. The trend of the water absorption of WWA concrete was a reversal of those of the strengths, that is, the highest water absorption values were recorded for the concrete specimens with the highest additive level of ash. A batch leaching test also performed at an ash-leachant volumetric ratio of 20 produced leachate containing chromium, arsenic, iron, copper and zinc with the following concentrations:410; 6,720; 150; 280 and 1,690 μg/L, respectively, when leached at a pH = 4, and 400; 10; 670; 0; 100; 1,470 μg/L, respectively, when leached at a pH = 5. These concentration levels exceed the EPA fresh water acute criteria limits.

Shi C o n g K o u, Chi S u n P o o n and Dixon C h a n published the results of a research [2] concerning the use of high percentages of recycled aggregates in concrete which would usually worsen the concrete properties. This paper tries to address the deficiency of the use of recycled aggregates by systematically presenting results on the influence of incorporating Class F fly ash on concrete properties. In this study, two series of concrete mixtures were prepared with water-to-binder (W/B) ratios of 0.45 and 0.55; the recycled aggregate was used as 0, 20, 50, and 100% by weight replacements of natural aggregate. In addition, fly ash was used as 0, 25, and 35% by weight replacement of the cement. The obtained results showed that the compressive strengths, tensile strength and static modulus of elasticity values of concrete at all ages decreased as the recycled aggregate and the fly ash contents increased. Further, an increase in the recycled aggregate content decreased the resistance to chloride ion penetration and increased the drying shrinkage and creep of concrete. Nevertheless, the use of fly ash as a substitute for cement improved the resistance to chloride ion penetration and decreasing the drying shrinkage and creep of the recycled aggregate concrete. The results showed also that one of the practical ways to utilize a high percentage of recycled aggregate in structural concrete is by incorporating 25…35% of fly ash as some of the drawbacks induced by the recycled aggregates in concrete could be minimized.

3. Materials Used

3.1.Cement

The most common cement used is an ordinary Portland cement. The Type 1 is preferred according to IS269-1976, which is used for general concrete structures. Out of the total production, ordinary Portland cement accounts for about 80…90%. Many tests were conducted on cement; some of them are consistency tests, setting tests, soundness tests, etc.

3.2. Aggregate

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. One of the most important factors for producing workable concrete is good gradation of aggregates. Good grading implies that a sample fractions of aggregates in required proportion such that the sample contains minimum voids. Samples of the well graded aggregate containing minimum voids require minimum paste to fill up the voids in the aggregates. Minimum paste will mean less quantity of cement and less water, which will further mean increased economy, higher strength, lower shrinkage and greater durability.

Aggregate comprises about 55% of the volume of mortar and about 85% volume of mass concrete. Mortar contains a size of 4.75 mm and concrete contains aggregate up to a maximum size of 150 mm.

a) *Coarse Aggregate*

The fractions from 80 mm to 4.75 mm are termed as coarse aggregate.

b) *Fine aggregate*

Those fractions from 4.75 mm to 150 micron are termed as fine aggregate.

3.3. Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully.

3.4. Hypo Sludge

The Tables 1,…,4 and Fig. 2 show the hypo sludge chemical properties and comparison between cement and hypo sludge.

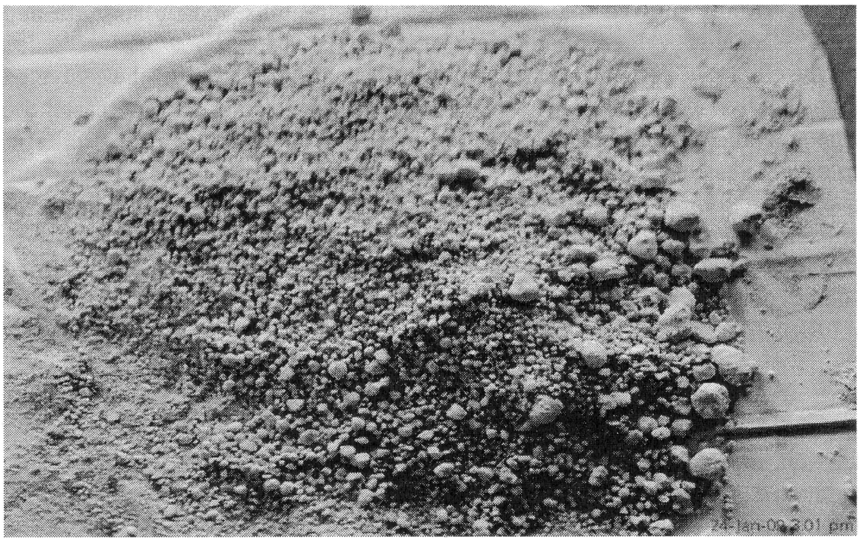

Fig. 2 – Factory outlet hypo sludge.

Table 1
Properties of Raw Hypo Sludge

Sl.No	Constituent	Present in Hypo Sludge, [%]
1.	Moisture	56.8
2.	Magnesium oxide (MgO)	3.3
3.	Calcium oxide (CaO)	46.2
4.	Loss on ignescent	27.00
5.	Acid insoluble	11.1
6.	Silica (SiO_2)	9.0
7.	R_2O_3	3.6

Table 2
Properties of Hypo Sludge as Cement Ingredient

Sl.No	Constituent	Present in Hypo Sludge, [%]
1.	Magnesium oxide (MgO)	3.3
2.	Calcium oxide (CaO)	46.2
3.	Loss on ignescent	27.00
4.	Acid insoluble	11.1
5.	Silica (SiO_2)	9.0
6.	R_2O_3	3.6

Table 3
Comparison of Cement and Hypo Sludge

Sl. No	Constituent	Cement, [%]	Hypo Sludge, [%]
1.	Lime(CaO)	62	46.2
2.	Silica(SiO_2)	22	9
3.	Alumina	5	3.6
4.	Magnesium	1	3.33
5.	Calcium sulphate	4	4.05

Table 4
Setting Time for Cement and Hypo Sludge

Sl. No	Ingredients	Initial, [min]	Final, [min]
1.	Cement + 0% hypo sludge	30	600
2.	Cement +10% hypo sludge	31	598
3.	Cement +20% hypo sludge	33	597
4.	Cement +30% hypo sludge	34	595
5.	Cement +40% hypo sludge	36	593
6.	Cement +50% hypo sludge	37	592
7.	Cement +60% hypo sludge	38	591
8.	Cement +70% hypo sludge	40	590

4. Mix Design

A mix M_{25} grade was designed as per Indian Standard method and the same was used to prepare the test samples. The design mix proportion is done in Table 5.

Table 5
Design Mix Proportion

	Water	Cement	Fine aggregate	Coarse aggregate
By weight, [kg]	191.6	547.42	456.96	1255.475
By volume	0.35	1	0.834	2.29

4.1 Mix Proportions

Conventional Concrete	1: 0.834 : 2.29
10% replacement	0.9: 0.834 : 2.29
20% replacement	0.80:0.834:2.29
30% replacement	0.70:0.834:2.29
40% replacement	0.60:0.834:2.29
50% replacement	0.50: 0.834: 2.29

60% replacement	0.40: 0.834: 2.29
70% replacement	0.30: 0.834: 2.29

5. Details of the Experimental Study

5.1 Compressive Strength Test

150 mm × 150 mm × 150 mm concrete cubes were casting using M25 grade concrete. Specimens with ordinary Portland cement (OPC) and OPC replaced with hypo sludge at 10%, 20%, 30%, 40%, 50%, 60% and 70% levels were cast. During casting the cubes were mechanically vibrated by using a table vibrator. After 24 h the specimens were removed from the mould and subjected to water curing for 14 and 28 days. After curing, the specimens were tested for compressive strength using a calibrated compression testing machine of 2,000 kN capacity.

5.2. Split Tensile Strength Test

Split tensile strength of concrete is usually found by testing plain concrete cylinders. Cylinders of size 150 mm × 300 mm were casting using M25 grade concrete. Specimen with OPC and OPC replaced by hypo sludge at 10%, 20%, 30%, 40%, 50%, 60% and 70% replacement levels were cast. During moulding, the cylinders were mechanically vibrated using a table vibrator. After 24 h the specimens were removed from the mould and subjected to water curing for 28 days. After curing, the specimens were tested for compressive strength using a calibrated compression testing machine of 2,000 kN capacity.

6. Results and Discussions

The obtained results are given in Tables 6,…,8 and Figs. 3,…,5.

Table 6
Compressive Strength of Cubes at 14 Days

Partial replacement %	Number of specimen	Initial crack load, [kN]	Ultimate load, [kN]	Ultimate compressive strength, [N/mm^2]
0	3	193.000	400.725	17.81
10	3	23.850	577.575	25.67
20	3	328.650	764.100	33.96
30	3	360.550	798.750	35.5
40	3	215.950	499.500	22.2
50	3	173.250	348.750	15.5
60	3	128.650	279.000	12.4
70	3	92.550	193.500	8.6

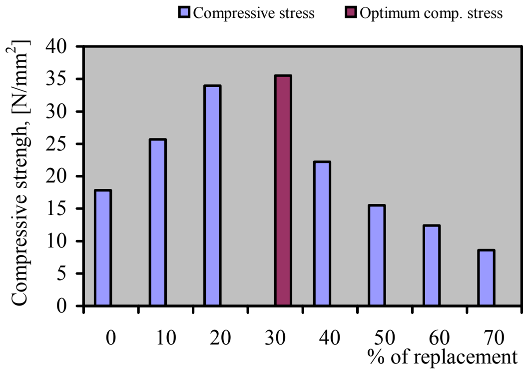

Fig. 3 – Compressive strength of concrete specimen at 14 days.

Table 7
Compressive Strength on Cubes at 28 Days

Partial replacement %	Number of specimen	Initial crack load, [kN]	Ultimate load, [Kn]	Ultimate compressive strength, [N/mm^2]
0	3	697.100	839.925	37.33
10	3	810.300	908.325	40.37
20	3	948.250	1,253.025	55.69
30	3	925.950	1,262.475	56.11
40	3	720.00	898.875	39.95
50	3	308.350	412.537	18.335
60	3	175.650	357.075	15.87
70	3	115.850	291.150	12.94

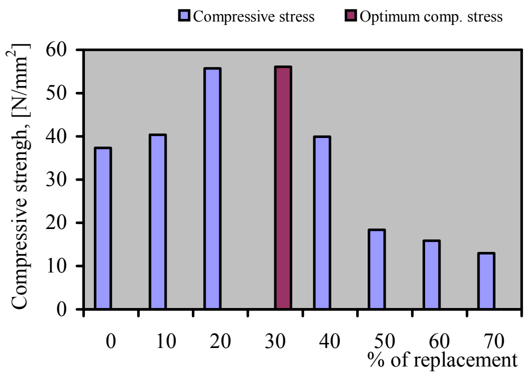

Fig. 4 – Compressive strength of concrete specimen at 28 days.

Table 8
Split Tensile Strength of Cylinder at 28 Days

Partial replacement %	Number of specimen	Ultimate load, kN	Split tensile strength, [N/mm^2]
0	3	130.061	1.84
10	3	110.269	1.56
20	3	104.615	1.48
30	3	100.373	1.42
40	3	98.253	1.39
50	3	97.546	1.38
60	3	101.080	1.43
70	3	102.494	1.45

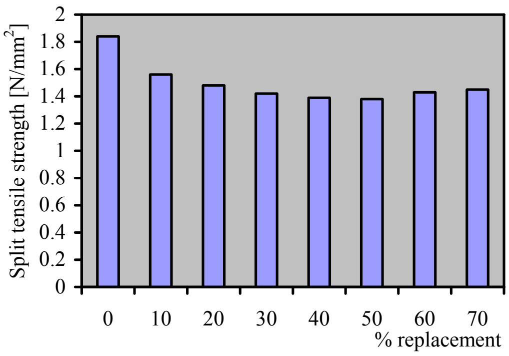

Fig. 5 – Split tensile strength of concrete specimen at 28 days.

6.1. Economic Feasability

Cost analysis is carried out for the optimum proportion of percentage of hypo sludge in concrete. This project was carried out in our college campus. The cost is compared to the conventional concrete.

a) *Cost of Materials*

Cost of cement per bag = 5.37 \$
Cost of sand per m^3 = 18.64 \$
Cost of hypo sludge per kg = 0.01\$
Cost of coarse of aggregate per m^3 = 12.07 \$
(All the rates are included with lead charges).

Table 9
Cost of Material of Normal Cncrete/ m^3

Description	Quantity, [kg/m^3]	Cost, [$]	Cost of material, [$]
Cement	547.42	0.11/kg	58.83
Hypo sludge	–	0.01/kg	–
Sand	456.96	18.64/m^3	5.32
Coarse aggregate	1,255.475	12.07/m^3	6.89
Total cost			71.04

Table 10
Cost of Material of 10% Partially Replaced Concrete/m^3

Description	Quantity, [kg/m^3]	Cost, [$]	Cost of material, [$]
Cement	492.678	0.11/kg	52.95
Hypo sludge	54.742	0.01/kg	0.59
Sand	456.96	18.64/m^3	5.32
Coarse aggregate	1,255.475	12.07/m^3	6.89
Total cost			65.75

Table 11
Cost of Material of 20% Partially Replaced Concrete/m^3

Description	Quantity, [kg/m^3]	Cost, [$]	Cost of material, [$]
Cement	437.936	0.11/kg	47.07
Hypo sludge	109.484	0.01/kg	1.18
Sand	456.96	18.64/m^3	5.32
Coarse aggregate	1,255.475	12.07/m^3	6.89
Total cost			60.45

Table 12
Cost of Material of 30% Partially Replaced Concrete/m^3

Description	Quantity, [kg/m^3]	Cost, [$]	Cost of material, [$]
Cement	383.194	0.11/kg	41.18
Hypo sludge	164.226	0.01/kg	1.76
Sand	456.96	18.64/m^3	5.32
Coarse aggregate	1,255.475	12.07/m^3	6.89
Total cost			55.16

Table 13
Cost of Material of 40% Partially Replaced Concrete/m^3

Description	Quantity, [kg/m^3]	Cost, [$]	Cost of material, [$]
Cement	328.452	0.11/kg	35.30
Hypo sludge	218.968	0.01/kg	2.35
Sand	456.96	18.64/m^3	5.32
Coarse aggregate	1255.475	12.07/m^3	6.89
Total cost			49.86

Table 14
Cost of Material of 50% Partially Replaced Concrete/m³

Description	Quantity, [kg/m^3]	Cost, [$]	Cost of material, [$]
Cement	273.71	0.11/kg	29.42
Hypo sludge	273.71	0.01/kg	2.94
Sand	456.96	18.64/m^3	5.32
Coarse aggregate	1,255.475	12.07/m^3	6.89
Total cost			44.57

Table 15
Cost of Material of 60% Partially Replaced Concrete/m^3

Description	Quantity, [kg/m^3]	Cost, [$]	Cost of material, [$]
Cement	218.968	0.11/kg	23.53
Hypo sludge	328.452	0.01/kg	3.53
Sand	456.96	18.64/m^3	5.32
Coarse aggregate	1,255.475	12.07/m^3	6.89
Total cost			39.27

Table 16
Cost of Material of 70% Partially Replaced Concrete/m^3

Description	Quantity, [kg/m^3]	Cost, [$]	Cost of material, [$]
Cement	164.226	0.11/kg	17.65
Hypo sludge	383.194	0.01/kg	4.12
Sand	456.96	18.64/m^3	5.32
Coarse aggregate	1,255.475	12.07/m^3	6.89
Total cost			33.98

The compared values of cost show gradual decrement in total cost of per cubic meter concrete. The above tables show cost values up to 30% replacement and the *difference in cost* from normal concrete to partially replaced concrete was **15.88 $**.

7. Conclusions

Based on limited experimental investigation concerning the compressive and split tensile strength of concrete, the following observations are made regarding the resistance of partially replaced hypo sludge:

a) Compressive strength of the concrete should be increased when the percentage of replacement is increased up to 40% and replacement increased compressive strength become reduced.

b) The split tensile strength should be decreased when the percentage of the replacement is increased.

c) From this level, replacement of cement with this waste of hypo-sludge material provides maximum compressive strength at 30% replacement.

d) We find the glory to E.W.S. group people by get the 28 days curing test. When government implement the projects for temporary shelters for who those affected by tsunami, E.Q., etc., this material can be used for economical feasibility.

e) Cost of cement should become low from this project.

f) Environment effects from wastes and maximum amount of cement manufacturing is reduced through this project,

g) A better measure by a *New Construction Material* is formed out through this project.

Received, January 4, 2010

Tamilnadu College of Engineering,
Karumathan Patti, India,
e-mail: srinivasan_civil@rediffmail.com
and
* *Avinachilingam University for Women,*
Tamilnadu, India

REFERENCES

1. Udoeyo F.F., Inyang H., Young D.T., Oparadu Ed.E., *Potential of Wood Waste Ash as an Additive in Concrete*. J. of Mater. in Civil Engng., ASCE, 605-612 (2006).
2. Shi Cong Kou, Chi Sun Poon, Dixon Chan, *Influence of Fly Ash as Cement Replacement on the Properties of Recycled Aggregate Concrete*. J. of Mater. in Civil Engng., ASCE, 709 (2007)
3. Ganesan K., Rajagopal K., Thangavelu K., *Effects of the Partial Replacement of Cement with Agro Waste Ashes on Strength and Durability of Concrete*. Proc. of Internat. Conf. on Recent Adv. in Concrete a. Constr. Technol., organised by Dept. of Civil Engng , S.R.M. Engng. College, Chennai, Dec. 7-9, 2005.
4. * * * *Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete*. Bureau of Indian Standards, New Delhi, IS 383 -1970.
5. * * * *IS Method of Mix Design*. Bureau of Indian Standards, New Delhi, IS 10262 –1981.
6. * * * *Methods of Tests for Strength of Concrete*. Bureau of Indian Standards, New Delhi, IS 516 –1959.
7. * * * *Code of Practice for Plain and Reinforced Concrete.* Bureau of Indian Standards, New Delhi, IS 456 -2000.

INVESTIGAŢII EXPERIMENTALE PRIVIND PRODUCEREA DE BETOANE IEFTINE FOLOSIND DEŞEURI DIN INDUSTRIA HÂRTIEI

(Rezumat)

Anual, în India sunt produse peste 300 de milioane de tone de deşeuri şi reziduuri industriale datorate industriei chimice şi chiar agriculturii. Aceste deşeuri

prezintă un adevărat risc la adresa sănătății. Deşeuri precum fosfo-gipsul, fluoro-gipsul şi „noroiul roşu" conțin impurități ce pot avea efecte nedorite asupra rezistenței materialelor de construcții în a căror componență sunt folosite. Folosirea deşeurilor susmenționate, la care se pot adăuga şi deşeurile provenite din industria producătoare de hârtie, ca materiale înlocuitoare în construcții, este de un real interes atunci când este vorba de protejarea mediului.

În urma procesului de producere a hârtiei rezultă numeroase deşeuri solide. Spre exemplu, fibrele de hârtie pot fi reciclate doar de un număr limitat de ori înainte de a deveni improprii (prea scurte sau cu rezistență scăzută) producerii de hârtie de calitate. Acestea sunt date deoparte şi devin astfel deşeuri. La fel şi cerneala, vopseaua, straturile protectoare, capsele precum şi benzile adezive sunt îndepărtate din hârtia reciclată şi devin deşeuri. Hârtia lucioasă provenită din cataloage şi reviste este acoperită cu un strat subțire de caolin. Acestea din urmă, prin îndepărtare, devin deşeuri.

Deşeurile rezultate în urma procesării hârtiei reciclate trebuie depozitate în halde de steril ce ocupă suprafețe importante de teren, fiind expuse intemperiilor. Mai mult, anumite deşeuri sunt împrăştiate în zonele cultivate, sub formă de îngrăşământ, creând motive de îngrijorare în ceea ce priveşte contaminarea solurilor şi a pânzei de apă freatică. Unii producători folosesc incineratoare pentru a scăpa de aceste deşeuri, ceea ce duce la o mai mare poluare a atmosferei.

Pentru a reduce efectul acestor deşeuri asupra mediului, este de dorit folosirea lor în obținerea de materiale de construcții. Astfel, s-au făcut investigații privind producerea de betoane în care s-au folosit deşeuri provenite din industria hârtiei pentru a înlocui o anumită parte din ciment.

În lucrarea de față se prezintă rezultatele investigațiilor experimentale în ceea ce priveşte rezistența la compresiune a betoanelor în care s-a înlocuit cimentul în proporție de 10% până la 70% cu deşeuri provenite din industria hârtiei. Cercetările s-au axat şi pe dozajul optim de ciment înlocuit pentru a crea un beton de cât mai înaltă rezistență.