Utilizationof Hypo Sludge by Eco-Efficient Development of Rigid Pavement in Rural Roads

Prof. Jayeshkumar Pitroda[1], Dr. L.B.Zala[2], Dr.F.S.Umrigar[3]
[1]*Assistant Professor & Research Scholar, Civil Engg Department, B.V.M. Engineering College, Vallabh Vidhyanagar*
[2]*Head & professor, Civil Engineering Department, B.V.M. Engineering College, Vallabh Vidhyanagar.*
[3]*Principal, B.V.M. Engineering College, Vallabh Vidhyanagar – Gujarat – India.*

Abstract— ***The paperproducing industry generates various wastes coming out from the various processes. From the preliminary waste named as hypo sludge, due to its low calcium is taken out to replace the cement in concrete. Major initiatives are needed in India to use these large volumes in construction industry especially in rigid pavement construction and other infrastructure projects. Moreover Use of Hypo Sludge in construction of rigid pavement will improve transportation functionality and ecological sustainability and results in improved traffic safety and reduced life-cycle cost. Use of Hypo Sludge in construction of rigid pavement will benefit urban growth, public health and surrounding communities by encouraging smart growth by integrating and guiding future growth. It is also needed to reduce the cost of concrete pavement for rural development in India. So our study is concerned with eco-efficient utilization of Hypo sludge as partial replacement of cement in concrete for development of low cost rigid pavement of rural road infrastructure.The Hypo sludge was replaced within the range of 10-40% by weight of cement. In the present study, 5 different mixes of Hypo Sludge are tested for parameters like: compressive strength, flexural strength and cost.***

Keywords : Hypo sludge, Eco-efficient, Concrete, Rigid Pavement, Rural Development, Low Cost Roads

I INTRODUCTION

Rural Infrastructure is the key to inclusive growth by connecting the rural hinterlands and enabling the roll out of many additional socio-economic sciences.With a growing rural road network of the country and with ambitious rural road development plans, there is a great need for the roads sector to build a sustainable and environment- friendly road infrastructure for low volume rural roads.

It has been observed that it would be economical to use industrial wastes in the construction of low volume rural roads.

Paper mill sludgeisamajor economicandenvironmental problemfor the paper andboard industry. Thematerial isaby-product of thede-inkingandre-pulpingofpaper.Themilliontonnesquantityof paper mill sludge produced in the world. Themain recyclinganddisposalroutesfor paper sludgeare land-spreadingasagriculturalfertiliser, producingpaper sludge ash,ordisposaltolandfill. Infunctionalterms,papersludgeconsistsofcellulosefibres,calciumcarbonateand chinaclay and residual chemicalsboundupwithwater. Thematerial isviscous,sticky andhardtodry. To produce low cost concrete by blending various ratios of cement with hypo sludge and to reduce disposal and pollution problems due to hypo sludge it is most essential to develop profitable building materials from hypo sludge. To make good quality paper limited number of times recycled Paper fibres can be used which produces a large amount of solid waste. The innovative use of hypo sludge in concrete formulations as a supplementary cementitious material was tested as an alternative to conventional concrete

II EXPERIMENTAL WORK

a) Chemical Properties of Ordinary Portland Cement (OPC) and Hypo sludge:

It is Chemical Properties of Ordinary Portland Cement (OPC) and Hypo sludgeas listed in Table 1:

TABLE 1
CHEMICAL PROPERTIES OF ORDINARY PORTLAND CEMENT (OPC) AND HYPO SLUDGE

Chemical Properties	Ordinary Portland Cement (OPC)	Hypo Sludge
	Percent by mass	
Silicon Dioxide (SiO_2)	21.77%	5.28%
Calcium Oxide (CaO)	57.02%	47.84%
Magnesium Oxide (MgO)	2.71%	6.41%
Sulphur Trioxide (SO_3)	2.41%	0.19%
Aluminium Oxide (Al_2O_3)	2.59%	0.09%
Ferric Oxide (Fe_2O_3)	0.65%	0.73%
Loss on Ignition	2.82%	38.26%

Source: Geo Test House, Vadodara, Gujarat, India

b) Characterization of cement:

The most common cement used is an Ordinary Portland Cement (OPC). The Ordinary Portland Cement of 53 grades is conforming to IS:8112-1989 is being used. Specific gravity, consistency tests, setting time tests, compressive strengths, etc. are conducted on cement. The results are tabulated in table 2.

TABLE 2
PROPERTIES OF ORDINARY PORTLAND CEMENT (OPC)

Sr.No.	Physical properties of cement	Result	Requirements as per IS:8112-1989
1	Specific gravity	3.15	3.10-3.15
2	Standard consistency (%)	28%	30-35
3	Initial setting time (hours, min)	35 min	30 minimum
4	Final setting time (hours, min)	178 min	600 maximum
5	Compressive strength- 7 days	38.49 N/mm^2	43 N/mm^2
6	Compressive strength- 28 days	52.31 N/mm^2	53 N/mm^2

c) Cement Hypo Sludge Mix Proportions:

A mix M25 grade was designed as per IS 10262:2009 and the same was used to prepare the test samples. The design mix proportion is shown in Table 3.

TABLE 3
CONCRETE DESIGN MIX PROPORTIONS

Sr. No	Types of Concrete	Concrete Design Mix Proportion (By Weight) in kg				Cement Replacement By Hypo Sludge
		W/C Ratio	C	F. A.	C. A.	
1	A1	0.50	372.00	558.60	1251.90	-
2	C1	0.50	334.80	558.60	1251.90	37.20
3	C2	0.50	297.60	558.60	1251.90	74.40
4	C3	0.50	260.40	558.60	1251.90	111.60
5	C4	0.50	223.20	558.60	1251.90	148.80

W/C = Water/Cement, C= Cement, F. A. = Fine Aggregate, C. A. = Coarse Aggregate

III EXPERIMENTAL RESULTS

Above 5 different concrete samples were used to find the important properties like compressive strength, flexural strength and modulus of elasticity.To make the study from an economic point of view cost of each mix was also worked out from the present market rates. The results for these properties are given in Table 4, 5&6. Figure 1, 3 & 5 shows setup for testing of hardened concrete.

Figure 1: Setup of Compressive Strength Test

TABLE 4
AVERAGECOMPRESSIVE STRENGTHFOR CUBES (150X150X150) (N/mm^2)AT 7, 14, 28 DAYS FOR M25

Types of Concrete	Average Compressive Strength (N/mm^2)		
	7 Days	14 Days	28 Days
A1	28.76	32.00	38.52
C1	29.24	33.63	39.70
C2	22.96	23.35	25.78
C3	20.92	22.96	23.26

C4	19.47	21.04	22.96

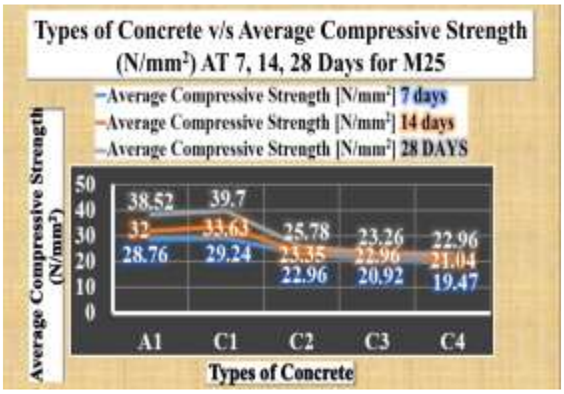

Figure: 2Types of Concrete v/s Average Compressive Strength (N/mm²)At 7, 14, 28 Days for M25

Figure 3: Setup of Flexural Strength Test

TABLE 5
AVERAGEFLEXURAL STRENGTH FOR BEAMS(100X100X500) (N/mm²)AT 28AND 90 DAYS FOR M25

Types of Concrete	Average FlexuralStrength (N/mm²)	
	28 Days	90 Days
A1	4.71	5.26
C1	4.49	4.94
C2	2.93	3.31
C3	2.74	3.27
C4	2.62	2.93

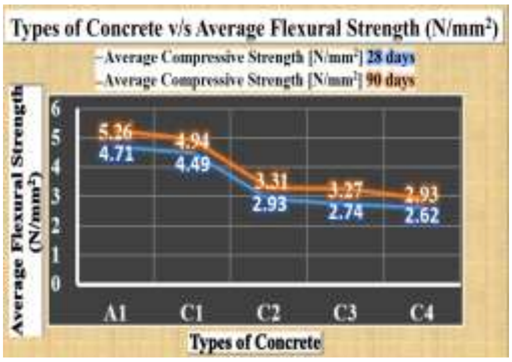

Figure: 4 Types of Concrete v/s AverageFlexural Strength(N/mm²)At 28&90 Daysfor M25

Figure 5: Setup of Modulus of ElasticityTest

TABLE 6
MODULUS OF ELASTICITYFOR CYLINDERS (150X300 DIA) (N/mm²)AT 28 DAYS FOR M25

Types of Concrete	Modulus of Elasticity (N/mm²)
	28 Days
A1	24958
C1	27500
C2	23167
C3	17875
C4	15750

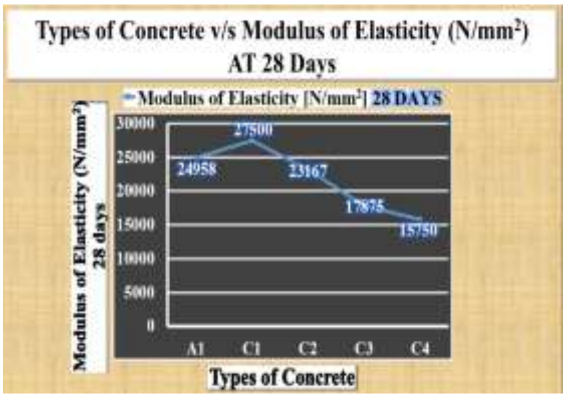

Figure: 6 Types of Concrete v/s AverageModulus of Elasticity (150X300 dia.) (N/mm²) At 28 Days for M25

DESIGN OF A CEMENT CONCRETE PAVEMENT FOR RURAL ROAD (IRC: SP: 20-2002 / IRC: SP: 62-2004)

A cement concrete pavement is to be designed for a Rural Road in Gujarat State having a traffic volume of upto 500 vehicles per day consisting of vehicles like agricultural tractors/trailers, light goods vehicles, heavy trucks, buses, animal drawn vehicles, motorized two-wheelers and cycles. The soil has a soaked CBR value of 2%.

Table 7: Design of CC Pavement For Rural Roads Design Parameters: Sample C1

Traffic Volume (A)	= UP TO 500**(Assume)**
Concrete Grade (f_c)	M25
Characteristic Compressive Cube Strength	= 39.70 N/mm^2 at 28 Days Actual Compressive Strength
Flexural Strength (f_f)	= 4.49 N/mm^2 [44.90 kg/cm^2]
90 days Flexural strength	= 4.94 N/mm^2 [49.4 kg/cm^2]
Soaked CBR Value (%)	= 2%
Modulus of Subgrade Reaction (k)	= 21 (N/mm^2/mm)*10^{-3}
Effective K Value (20% more)	= 25.2 (N/mm^2/mm)*10^{-3}
Elastic modulus of Concrete (E_c) (As per Actual Calculation)	= 27,500 N/mm^2
Poisson's ratio (μ)	= 0.15
Coefficient of thermal coefficient of concrete (α)	= 0.00001/°C
Design Wheel Load (P)	**= 30kN**
Tyre pressure (q)	= 0.5 N/mm^2 [5kg/cm^2]
Spacing of Contraction Joints (L)	= 3.75m [3750mm]
Width of Slab (W)	= 3.75m [3750mm]
Radius of load contact (assumed circular), (a)	=13.82 cm

Trial Thickness for Slab, h= 150mm

- **Check for Temperature Stresses:**

Assuming a contraction joint spacing of 3.75 and 3.75m width.

1. Temperature Stress (σt_e):

The temperature differential (Δt) for Gujarat for a slab thickness of 150mm is 12.5˚C.

The Radius of Relative Stiffness, l = $\sqrt[4]{\frac{E\ h^3}{12\ (1-\mu^2)\ k}}$

Hence, l = 748.56mm.

L/l = 3750 / 748.56= 5.0

W/l = 3750 / 748.56= 5.0

Both values are same, if not then adopt greater one.

Bradbury's Coefficient**, C = 0.720** (from figure 1, pg. 9, IRC: SP: 62-2004)

[Value of C can be ascertained directly from Bradbury's chart against values of L/l and W/l]

Temperature Stress in edge region, σt_e = $\frac{E\ \alpha\ \Delta t}{2}\ C$

Hence, σt_e= 1.24 N/mm^2.

2. Edge Load Stress (σl_e):

From Page: 12, IRC: SP: 62-2004,

Edge Load Stress:
σle = 0.529 P / h2 (1 + 0.54μ) [4 log10 (l/b) + log10 (b) – 0.4048]

where;
b= Radius of equivalent distribution of pressure,
b = a (if (a/h >= 1.724);
(b) =$\sqrt{1.6\ a^2 + h^2}$ - 0.675 h if (a/h < 1.724),

a/h< 1.724, 0.922< 1.724

For slab thickness of 150mm; **Edge Load Stress, σl_e,** is **3.63 N/mm^2 (3.63MPa).**

Total Stress = Edge Load Stress + Temperature Stress= 3.63 + 1.24= 4.87 N/mm^2, which is less than the allowable flexural strength of 4.94N/mm^2.

Hence, assumed thickness of slab = 150mm, is OK. [As per Temperature Stress Criteria]

- **Check for Corner Stresses (σl_c):**

From Fig. 5 (Page 12), Corner Load Stress for wheel load of 30kN, for k = 25.2 (N/mm^2/mm)*10^{-3} = 0.0252 N/mm^2/mm = 0.03 N/mm^2/mm (Approx.) and slab thickness of 150mm is **3.2N/mm^2 (3.2MPa).**

[Temperature Stress in the corner region is negligible, as the corners are relatively free to warp, hence it can be ignored.]

Hence, σl_c= 3.2 N/mm^2, which is less than the allowable flexural strength of 4.94 N/mm^2.

So, the slab thickness of 150mm is Safe.

The calculations presented above are sample calculations (C1). Similar calculations are done using various values of flexural strengths of concrete.

IV ECONOMIC ANALYSIS

TABLE- 8
COST OF MATERIALS

Sr. No.	Materials	Rate (Rs/Kg)

1	Cement (OPC 53 grade)	6.40
2	Hypo Sludge	0.60
3	Fine aggregate	0.60
4	Coarse aggregate	0.65
5	Grit	0.65

TABLE-9
MATERIALS FOR DESIGNED M25 CONCRETE

Types of Concrete	% Reduction in cement	Materials					Total Cost [Rs./m^3]	% Change in Cost
		Cement [kg/m^3]	Fine aggregate [kg/m^3]	Coarse aggregate [kg/m^3]	Grit [kg/m^3]	Hypo Sludge [kg/m^3]		
A1	0	479.0	485.75	718.22	478.81	0.0	4135.12	0
C1	10	431.1	485.75	718.22	478.81	47.9	3857.30	(-) 6.71
C2	20	383.2	485.75	718.22	478.81	95.8	3579.48	(-) 13.43
C3	30	335.3	485.75	718.22	478.81	143.7	3301.66	(-) 20.15
C4	40	287.4	485.75	718.22	478.81	191.6	3023.84	(-) 26.87

TABLE 10
RELATIVE COST OF SLAB FOR M25

Types of Concrete	Slab Thickness (cm)	Cost of 1m x 1m Slab (Rs.)	Relative Cost (%)
A1	19	785.67	100.00
C1	15	580.12	73.83
C2	19	680.10	86.56
C3	19	627.32	79.84
C4	20	605.17	77.02

Figure: 7 Types of Concrete v/s Cost of 1m x 1m Slab (Rs.)

CONCLUSIONS

Based on limited experimental investigations concerning the compressive strength, flexural strength & modulus of elasticity test of concrete (M25 Grade) for rigid pavement, the following observations are made in the ray of the objectives of the study

(a) Effective utilization of Hypo Sludgein concrete can save the Paper industry's disposal costsand storage problems; and also produces a 'greener' concrete for low cost rural roads.
(b) This research study concludes that Hypo Sludgecan be an innovative Supplementary Cementitious Material useful for construction of rigid pavement in development of low cost rural roads.
(c) For a CBR value of 2% and Wheel Load (P) of 30KN; Cost of rigid pavement decreases from Rs. 785.67 to Rs. 580.12. (73.83% Relative Cost)

ACKNOWLEDGMENT

The Authors thankfully acknowledge Dr. C. L. Patel, Chairman, Charutar Vidya Mandal, Er.V.M.Patel, Hon.Jt. Secretary, Charutar Vidya Mandal, Prof. J. J. Bhavsar, Associate Professor and P.G. Coordinator(Construction Engineering and Management), B.V.M. Engineering College, Mr.Yatinbhai Desai, Jay Maharaj construction, Vallabh Vidyanagar, Gujarat, India for their motivations, infrastructural support and cooperationto carry out this research.

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AUTHORS BIOGRAPHY

Prof. Jayeshkumar R. Pitroda was born in 1977 in Vadodara City. He received his Bachelor of Engineering degree in Civil Engineering from the Birla Vishvakarma Mahavidyalaya, Sardar Patel University in 2000. In 2009 he received his Master's Degree in Construction Engineering and Management from Birla Vishvakarma Mahavidyalaya, Sardar Patel University. He joined Birla Vishvakarma Mahavidyalaya Engineering College as a faculty where he is Assistant Professor of Civil Engineering Department with a total experience of 12 years in the field of Research, Designing and education. He is guiding M.E. (Construction Engineering & Management) Thesis work in the field of Civil/ Construction Engineering. He has papers published in National Conferences and International Journals.

Dr.L.B.Zala completed his B.E. (Civil) Engineering from BVM Engineering College, S.P. University in 1984, M.E. (Civil) Transportation Engineering from University of Roorkee (now IIT, Roorkee) in 1994. Dr. Zala joined BVM Engineering College as Assistant Lecturer in August 1986. He completed his Ph.D in Civil Engineering from S.P. University in 2009. He is working as Head Civil Engineering at BVM Engineering College. He is guiding M.E. / M. Tech & Ph.D Dissertation work in field of Civil/Transportation Engineering.

Dr. Farokh Sorabji Umrigar completed his B.E. (Civil) Engineering from SVNIT in 1976, M.Tech. (civil) Transportation System Engineering from IIT, Kanpur in 1982 and Ph.D with specialization in Transportation Engineering from University of Roorkee,(now IIT, Roorkee) Roorkee in 1990. Dr. Umrigar joined Birla Vishvakarma Mahavidyalaya Engineering College (BVM) in 1978 as Assistant Lecturer and reached to the position of Principal of BVM in April, 2002 with a total experience of 35 years in field of Research, Designing, education and administration. Dr. Umrigar is also Dean, Faculty of Engineering & Technology, Sardar Patel University since April, 2002. Dr. Umrigar has published many papers at National and International level. He is an author of two books of civil engineering. He has guided many students at master's and Ph.D level in the field of civil engineering and transportation planning.