Fly Ash (F-Class): Oppertiunities For Sustainable Development Of Low Cost Rural Roads

Darsh Belani [1], Prof. Jayeshkumar Pitroda[2]
[1]Student of first year M.E (C.E & M), B.V.M Engineering College, Vallabh Vidyanagar
[2]Assistant Professor and Research Scholar, Civil Engineering Department, B.V.M. Engineering College, Vallabh Vidyanagar-Gujarat-India

Abstract— ***Fly ash, a waste derived from coal burning in thermal power plants is plentiful in India causing severe health, environment and dumping problems. It is estimated that about 150 million tons of fly ash are being produced from various thermal power plants in India. Utilization of fly ash in bulk quantities, ways and means is being explored all over the world to use it for the construction of embankments and roads. This way the fly ash concrete are made a 'greener' building material and the discarded natural wastes can be re-utilized, avoiding otherwise wasteful landfill and harmful open incineration. To make value added concrete for development of sustainable infrastructure there is a great need to study the technical details concerned with various industrial wastes in concrete and to reduce environmental hazards. It is also needed to reduce the cost of concrete for rural development in India. So our study is concerned with eco-efficient utilization of Fly Ash (F-class) as partial replacement of cement in concrete. The aim of the present study is to investigate the low cost rural roads made of fly ash (F-class). The fly ash (F-class) was replaced within the range of 10-40% by weight of cement. In the present study, 5 different mixes of fly ash concretes are tested for parameters like: compressive strength, flexural strength, modulus of elasticity and cost.***

Keywords : Fly Ash, F-Class, Value Added Concrete, Rural Roads, Cost

I INTRODUCTION

The transportation infrastructure system is one of the main investments every modern society must make for their economic and social development. In India, a special drive has been taken at the beginning of the new millennium to improve the road and highway systems in the country. This will require huge quantities of pavement construction materials. It has been observed that it would be economical to use industrial wastes in the construction of low cost roads. The quantities of wastes accumulating throughout the world are causing disposal problems that are both financially and environmentally expensive. One effective method to reduce some portion of the waste disposal problem is by recycling and utilizing these materials in the construction of highways without compromise their quality and performance. India produces a huge amount of waste materials as byproducts from different sectors like industrial, construction, agriculture, etc. These waste materials if not deposited safely it may be hazardous. A large quantity of waste material is dumped on land filling site, which if investigated properly can be utilized in the road construction sector. The utilization of these waste materials can be an economical and eco-friendly alternative in nearby areas for rural road construction.

Fly ash a finally divided mineral residue of burning of coal exhibits excellent Geotechnical as well as pozzolanic properties that make it very suitable for all construction activities including roads, embankments and reclamation of low lying areas. Fly ash based construction materials are becoming favourite of the construction industry, being durable, economical, eco-friendly, easy to use and of consistent quality. Its effective use in concrete as partial replacement of cement will lead to reduce its disposal problems and also to enhance properties of concrete. Fly ash also holds potential to improve the socio-economic status for the development of rural areas in India.

II EXPERIMENTAL WORK

a) *Chemical Properties of Ordinary Portland Cement (OPC) and Fly Ash (F-Class):*

It is Chemical Properties of Ordinary Portland Cement (OPC) and F-Class Fly Ash as listed in Table 1:

TABLE 1
CHEMICAL PROPERTIES OF ORDINARY PORTLAND CEMENT (OPC) AND FLY ASH (F-CLASS)

Chemical Properties	Ordinary Portland Cement (OPC)	Fly Ash (F-Class)
	Percent by mass	
Silicon Dioxide (SiO_2)	21.77%	62.22%
Calcium Oxide (CaO)	57.02%	5.30%
Magnesium Oxide (MgO)	2.71%	6.09%
Sulphur Trioxide (SO_3)	2.41%	3.00%
Aluminium Oxide (Al_2O_3)	2.59%	7.63%
Ferric Oxide (Fe_2O_3)	0.65%	0.13%
Loss on Ignition	2.82%	9.98%

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 fly ash Mix Proportions:

A mix M25 grade was designed as per IS 10262:1982 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)				Cement Replacement By Fly ash
		W/C Ratio	C	F. A.	C. A.	
1	A1-M25	0.40	1.00	1.01	2.50	-
2	B1-M25	0.40	0.90	1.01	2.50	0.10
3	B2-M25	0.40	0.80	1.01	2.50	0.20
4	B3-M25	0.40	0.70	1.01	2.50	0.30
5	B4-M25	0.40	0.60	1.01	2.50	0.40

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, the 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.

TABLE 4
AVERAGE COMPRESSIVE STRENGTH FOR CUBES OF (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-M25	28.76	32.00	38.52
B1-M25	21.33	30.90	34.67
B2-M25	16.15	23.78	24.30
B3-M25	13.04	15.11	22.37
B4-M25	9.93	14.81	17.33

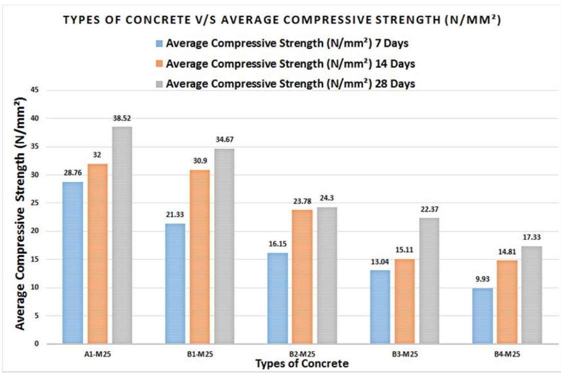

Figure: 1 Types of Concrete v/s Average Compressive Strength (N/mm^2) At 7, 14, 28 Days For M25

TABLE 5
AVERAGE FLEXURAL STRENGTH FOR BEAMS OF (100X100X500) (N/mm^2) AT 28 AND 90 DAYS FOR M25

Types of Concrete	Average Flexural Strength (N/mm^2)	
	28 Days	90 Days
A1-M25	4.71	5.26
B1-M25	3.60	3.90
B2-M25	2.56	2.74
B3-M25	2.21	2.44
B4-M25	1.77	2.05

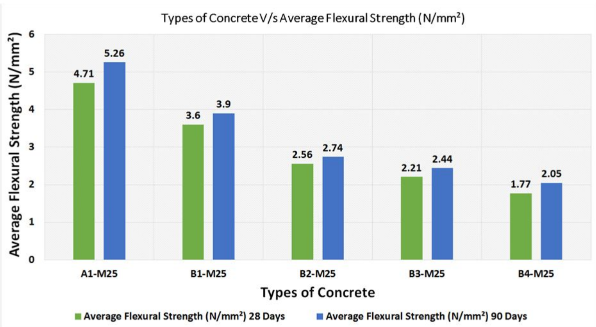

Figure: 2 Types of Concrete v/s Average Flexural Strength (N/mm^2) At 28 & 90 Days For M25

TABLE 6
MODULUS OF ELASTICITY (150X300 DIA.) (N/mm^2) AT 28 DAYS FOR M25

Types of Concrete	Modulus of Elasticity (N/mm^2)
	28 Days
A1-M25	24958
B1-M25	24083
B2-M25	22500
B3-M25	17500
B4-M25	15167

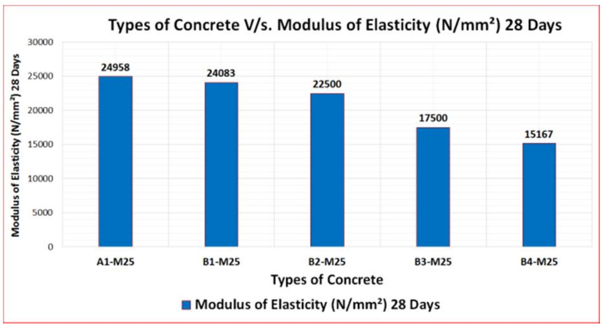

Figure: 3 Types of Concrete v/s Average Modulus of Elasticity (150X300 dia.) (N/mm^2) At 28 Days for M25

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 150 vehicles per day consisting vehicles, like, agricultural tractors/trailers, light goods vehicles, heavy trucks, buses, animal drawn vehicles, motorized two-wheels and cycles. The soil has a soaked CBR value of 2%.

Design Parameters: Sample B1

Traffic Volume (A)	= 150 CVPD **(Assume)**
Concrete Grade (f_c)	= 25 N/mm^2
Characteristic Compressive Cube Strength	= 34.67 N/mm^2 at 28 Days Actual Compressive Strength
Flexural Strength (f_f)	= 3.60 N/mm^2 [36 kg/cm^2]
90 days Flexural strength	= 3.90 N/mm^2 [39 kg/cm^2]
Soaked CBR Value (%)	= 0.02 (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)	= 24,083 N/mm^2
Poisson's ratio (μ)	= 0.15
Coefficient of thermal coefficient of concrete (α)	= 0.00001/°C
Wheel Load (P)	= 51 kN
Tyre pressure (q)	= 0.7 N/mm^2 [7 kg/cm^2]
Spacing of Contraction Joints (L)	= 3.75m [3750 mm]
Width of Slab (W)	= 3.75m [3750 mm]

Trial Thickness for Slab, h = 220mm.

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 220mm is 12.74°C.

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

Hence, l = 965.09 mm.

L/l = 3750 / 965.09 = 3.9

W/l = 3750 / 965.09 = 3.9

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

Bradbury's Coefficient, C = 0.414 (from figure 1, pg. 9)
[Value of C can be ascertained directly from Bradbury's chart against values of L/l and W/l]

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

Hence, σt_e = 0.68 N/mm^2.

2. Edge Load Stress (σl_e):

From Page: 12, Edge Load Stress,
Radius of equivalent distribution of pressure (b),
b = a (if (a/h >= 1.724);
(b) = $\sqrt{1.6\,a^2 + h^2}$ - 0.675 h if (a/h < 1.724),

For slab thickness of 170mm; **Edge Load Stress, σt_e,** is **3.05 N/mm^2 (3.05 MPa).**

Total Stress = Edge Load Stress + Temperature Stress = 3.05 + 0.68 = 3.73 N/mm^2, which is less than the allowable flexural strength of 3.90 N/mm^2.

Hence, assumed thickness of slab = 220mm, 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 51kN,
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 170mm is **2.65 N/mm^2 (2.58 MPa).**

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

Hence, σl_c = 2.65 N/mm^2, which is less than the allowable flexural strength of 3.90 N/mm^2.

So, the slab thickness of 220mm is Safe.

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

IV ECONOMIC ANALYSIS

TABLE- 7
COST OF MATERIALS

Sr. No.	Materials	Rate (Rs/Kg)
1	Cement (OPC 53 grade)	6.40
2	Fly ash (F-class)	0.60
3	Fine aggregate	0.60
4	Coarse aggregate	0.65
5	Grit	0.65

TABLE-8
MATERIALS FOR DESIGNED M25 CONCRETE

Types of Concrete	% Reduction in cement	Materials					Total Cost [m^3]	% Change in Cost
		Cement [kg/m^3]	Fine aggregate [kg/m^3]	Coarse aggregate [kg/m^3]	Grit [kg/m^3]	Fly ash (F-class) [kg/m^3]		
A1-M25	0	479.0	485.75	718.22	478.81	0.0	4135.12	0
B1-M25	10	431.1	485.75	718.22	478.81	47.9	3857.30	(-) 6.71
B2-M25	20	383.2	485.75	718.22	478.81	95.8	3579.48	(-) 13.43
B3-M25	30	335.3	485.75	718.22	478.81	143.7	3301.66	(-) 20.15
B4-M25	40	287.4	485.75	718.22	478.81	191.6	3023.84	(-) 26.87

TABLE 9
RELATIVE COST OF SLAB FOR M25

Types of Concrete	Slab Thickness (cm)	Cost of 1m x 1m Slab (Rs.)	Relative cost (%)
A1-M25	19	785.67	100.00
B1-M25	22	848.60	108.00
B2-M25	26	930.66	118.45
B3-M25	28	924.46	117.66
B4-M25	30	907.15	115.46

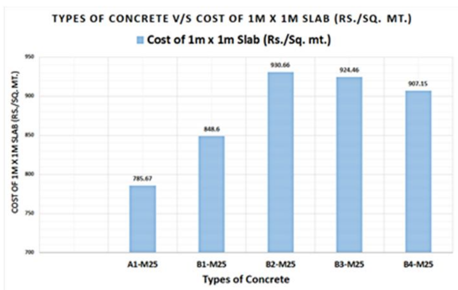

Figure: 4 Types of Concrete v/s Cost of 1m x 1m Slab (Rs./Sq.mt)

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) Use of fly ash in concrete can save the thermal industry disposal costs and produce a 'greener' concrete for low cost rural roads.
(b) This research concludes that fly ash (Class-F) can be an innovative Supplementary Cementitious Material useful for development of low cost rural roads.
(c) India should aggressively identify projects that can use large amounts of fly ash in road construction so that harmonizing environment and ecological sustainability can be developed. Use of fly ash in road construction works will result in the less depletion of naturally available stone metal, gravel, sand and soil; and will save cement, which is the costliest ingredient will lead to reduction in construction cost. With adequate knowledge on performance of fly ash based road pavements, a huge demand can be expected from the road sector to use fly ash for construction purposes, but judicious decisions are to be taken by engineers, for development of low cost rural roads.
(d) This research study concludes that there is a great scope for eco-efficient utilization of Fly Ash (Class-F) for sustainable development of Indian Road Network.

ACKNOWLEDGMENT

The Authors thankfully acknowledge to Dr. C. L. Patel, Chairman, Charutar Vidya Mandal, Er.V.M.Patel, Hon.Jt. Secretary, Charutar Vidya Mandal, Dr. F. S. Umrigar, Principal, , Dr. L. B. Zala, Head of Civil Engineering Department, Prof. J. J. Bhavsar, Associate Professor and PG (Construction Engineering and Management) Coordinator, B.V.M. Engineering College, Mr. Yatinbhai Desai, Jay Maharaj construction, Vallabh Vidyanagar, Gujarat, India for their motivations and infrastructural support to carry out this research.

REFERENCE

[1] American coal ash association (2003), "fly ash facts for highway engineers", report no: FHWA-IF-03-019
[2] Binod Kumar, G.K. Tike, P.K. Nanda, "Prospects & New Approaches of Using Industrial wastes in Building Materials", *Journal of Materials in Civil Engineering*, Vol. 19 (10), October 2007: 906-911.
[3] Cindy K. Estakhri, Donald Saylak, "Reducing greenhouse gas emissions in Texas with high-volume fly ash concrete", *Transportation Research Record No. 1941*, 2005: 167-174.
[4] Darsh Belani, Prof. Jayeshkumar Pitroda (2013), *"Harmonising Environment and Ecological Sustainability by Utilization of Fly Ash in Rigid Pavement"* International Journal Global Research Analysis, (GRA), Volume: 2, Issue : 2, Feb 2013, ISSN No 2277 – 8160, pp-97-99
[5] Guru vittal u. k., scientist satander kumar scientist, deepchandra, head sr div. dr. p. k. sikadar, Director Central Road Research Institute New Delhi."Utilization of fly ash in road construction". CE and CR April 99 Pp 60-63. Rigid Pavement Division, Maharashtra Engineer's Research Institute Nashik "Study of fly ash samples from Eklahre Thermal Power Station".
[6] Gambhir, M. L. (2004), "Concrete Technology", Tata Mc-Graw Hills.
[7] J.P. Desai, "Construction of HVFA concrete pavements in India: Four case studies", *Indian Concrete Journal*, Vol. 78 (11), November 2004: 67-71.
[8] Mr.Nagesh Tatoba Suryawanshi, Mr. Samitinjay S. Bansode, Dr. Pravin D. Nemade, "Use of Eco-Friendly Material like Fly Ash in Rigid Pavement Construction & It's Cost Benefit Analysis", International Journal of Emerging Technology and Advanced Engineering Volume 2, Issue 12, December 2012
[9] P. Srinivasan, A.K. Tiwari, Anil Banchhor, "Suitability of HVFA concrete for pavements", *Indian Concrete Journal*, Vol. 78 (11), November 2004: 58-61.
[10] *Pavement Engineering and materials for Rigid Pavements, Central Road Research institute, Annual Report 2009-10)*
[11] Seehra s. s. and Satander kumar," Technoeconomic aspects of rigid pavements" International seminar on Civil Engineering Practices in 21st century Roorkey, India 1996.
[12] Shetty, M.S. "Concrete technology", S.Chand & Company Ltd.
[13] Tarun R. Naik, Bruce W. Ramme, Rudolph N. Kraus, Rafat Siddique, "Long-term performance of high-volume fly ash concrete pavements", *ACI Materials Journal*, Vol. 100 (2), March/April 2003: 150-155.
[14] Ujjwal Bhattacharjee, Tara Chandra Kandpal , "Potential of fly ash utilisation in India" *Centre for Energy Studies, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110 016, India*

[15] U.S. Department of Transportation, Federal Highway Administration, "User Guidelines for Waste and By-product Materials in Pavement Construction, Coal Fly Ash", Publication Number: FHWA-RD-97-148.

[16] V. Mohan Malhotra, "High-performance HVFA concrete: A solution to the infrastructural needs of India", *Indian Concrete Journal*, Vol. 76 (2), February 2002: 103-107.

[17] Vimal Kumar, "Overview of Fly Ash for Use in Rural Development", Workshop on Non-Conventional Materials/ Technologies,Central Road Research Institute, *New Delhi 110 016, India,* February 2012:1-15

[18] Dr Praveen Kumar, Dr G D Ransinchungh R.N., Aditya Kumar Anupam, "Waste Materials- An Alternative to Conventional Materials in Rural Road Construction", Workshop on Non-Conventional Materials/ Technologies,Central Road Research Institute, *New Delhi 110 016, India,* February 2012:16-26

[19] Ashoke K. Sarker, "Use of Non-Conventional Materials for the Construction of Low-Volume Roads", Workshop on Non-Conventional Materials/ Technologies,Central Road Research Institute, *New Delhi 110 016, India,* February 2012:27-38

[20] Prof. B. B. Pandey, "Low Cost Concrete Roads for Villages", Workshop on Non-Conventional Materials/ Technologies, Central Road Research Institute, *New Delhi 110 016, India,* February 2012:39-41

AUTHORS BIOGRAPHY

Darsh Belani was born in 1991 in Ahmedabad, Gujarat. He received his Bachelor of Engineering degree in Civil Engineering from the L. D. College of Engineering, Gujarat Technological University in 2012. At present he is First year student of Master`s Degree in Construction Engineering and Management from Birla Vishwakarma Mahavidyalaya, Gujarat Technological University. He has papers published in international journals.

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.