International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 11 | Nov - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Utilization of Industrial Sludge and Fly Ash in Highway Construction: A Feasibility and Performance Study

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Abstract -The growing demand for sustainable and cost-effective construction materials has intensified interest in utilizing industrial by-products as partial replacements for cement in pavement-quality concrete. Among these, Fly Ash (Class-F) from thermal power plants and Hypo Sludge from the paper recycling industry offer significant potential due to their pozzolanic and cementitious characteristics. This study investigates the performance of concrete incorporating Fly Ash and Hypo Sludge as Supplementary Cementitious Materials (SCMs) for rigid pavement applications, with a focus on M25 and M40 grade concrete mixes. Replacement levels of 10%, 20%, 30%, and 40% were explored individually and in hybrid combinations to evaluate their effects on mechanical properties, particularly compressive strength. Comprehensive laboratory testing was conducted on cube, cylinder, and beam specimens to determine compressive strength, split-tensile strength, and flexural strength at different curing ages. Results indicate that both Fly Ash and Hypo Sludge contribute to strength gain, especially beyond 28 days due to their slow pozzolanic reaction. Optimum performance was observed at 20% hybrid replacement (Fly Ash + Hypo Sludge) for M25 grade and 10% hybrid replacement for M40 grade concrete. At these levels, the mixes achieved targeted 28-day strength while exhibiting progressive strength gain up to 90 days. Higher replacement percentages resulted in significant reductions in early and ultimate strength. The study further extends its findings to pavement design for rural roads and national highways in Gujarat, considering CBR values of 2%, 4%, and 6%, and wheel loads of 30 kN and 51 kN. Analysis reveals that optimized SCM-based concrete mixes can reduce pavement thickness and construction cost, particularly for rural roads under lower wheel loads. The 20% hybrid mix demonstrated cost savings of up to 14% without compromising structural adequacy. Overall, the research establishes Fly Ash and Hypo Sludge as viable materials for producing eco-efficient, economical concrete suitable for rigid pavements. Their use promotes sustainable waste management, conserves natural resources, and contributes to the development of durable, long-lasting road infrastructure.

Key Words: Fly ash, Industrial waste, Hypo sludge, Concrete, Compressive strength

1.INTRODUCTION

Rural Road connectivity is a key component of rural development, since it promotes access to economic and social services, thereby generating increased agricultural productivity, employment in industry and service sectors as well as productivity, which in turn expands rural growth opportunities and ideal income through which poverty can be reduced. Village roads in general have low volume of traffic, consisting mostly of rural transport vehicles. Due to shifting of industries; towards the villages there is an increase in volume of traffic on village roads. It necessitates providing the cost effective solution of connectivity to the villages. As per IRC: SP: 62-2004 Rigid pavement comes out to be a better alternative to flexible pavement where the soil strength is poor, aggregate are costly and the drainage conditions are bad but they demand a high degree of professional expertise at the design stage, construction and maintenance besides high initial cost.

The low-cost concrete with good strength is used in rigid pavement up to3000 commercial vehicles per day (CVPD) and Dry Lean Concrete (DLC) of 100mm and350mm thick to improve modulus of subgrade reaction (k). The National Highways are the backbone; of the road infrastructure and the major roads in India. They carry most of India's freight and passenger traffic. State highways and major district roads constitute the secondary and interconnecting roads in India. The main roads in India are under huge pressure and in great need of modernization in order to handle the increased requirements of the Indian economy with low-cost eco-friendly materials. In addition to maintenance, the expansion of the network and widening of existing roads is becoming increasingly important. This would then enable the roads to handle increased traffic, and also allow for a corresponding increase in the average travel speed on India's roads. Cement concrete roads! enjoy a clear advantage over bituminous roads and are extremely longer lasting, often going for 40 to 50 years, said Shri.G.Sharan, Director General (Roads), Ministry of Shipping, Road Transport and Highways, Government of India (2008), and added that for sustainable development, the modern society cannot do without using high performance construction material, concrete in roads and highways.

Fly ash, a residue of burning of pulverized coal and lignite in thermal power stations, is now being accepted as a resource material. The concerted efforts in Mission Mode that began in India about a decade back, have developed confidence in fly ash utilization technologies and its large-scale utilization. Even in earlier years, a number of attempts were made through various Committees/ Groups to develop fly ash utilization technologies. Indian coals, though low in sulphur, contain higher amount of ash (about 35-45%),hence the generation of huge quantities of fly |ash in India. The annual generation of fly ash has increased from about 1 million tonnes in 1947 to about 40 million tonnes during1994 and to about 112 million tonnes at present. As per an estimate of FAUP (Fly Ash Utilization Program), TIFAC (Technology Information, Forecasting and Assessment Council, Department of Science & Technology, govt of India) (158), the annual ash generation figures are expected to reach about (70 million tonnes by 2012 and 225 million tonnes by 2017.

In construction of rural roads in low lying or flood prone areas, fly ash should have to be considered as a normal choice in near future. In case of rigid pavements, usage of flyash leads to considerable savings even if fly ash is to be transported over large distances. For rigid pavement construction in a large scales part replacement of cement by dry fly ash is found acceptable. A disposal of huge quantity of fly ash generated from the power plants is a severe environmental hazard. This is detrimental to animal and plant life, since it pollutes the environment as well as it requires large area for its disposal, when the availability of land is getting scarce day by day. This necessitates the effective utilization of this accumulated fly ash is being felt by the engineers and scientists.

One more thing which needs attention is that not only in urban areas but also in rural area earth is not an easy available material now-a-days. In construction of rural roads in low lying or flood prone areas, fly ash should have to be considered as a normal choice in near future. Fly Ash even though an environmental pollutant, it is an important raw material for various applications. The utilization of Fly Ash in different sectors can help a great emphasis on the development of new technology for efficient utilization of Fly Ash.

Coal fly ash is an abundant industrial waste product that happens to be high in reactive silica, and thus an excellent pozzolanic. The rise of fly ash as a performance-enhancing ingredient in concrete is one of the most outstanding examples of industrial ecology-i.e., making effective use of waste resources, and ultimately eliminating the concept of waste altogether. In fact, given the huge (and growing) volume of concrete production worldwide, the potential for effectively using! fly ash (and other common industrial by products) makes it one of the key components of a global industrial ecology. In coming year (2016-17) it is expected India will produce fly ash 300-400 Million Tons per year, which is approximately double the quantity it has produced now. The consumption should be increased.

The major use of Fly Ash is in the building material as cementing raw material and have many advantages like it reduces Green House gas emission, solve serious waste disposal problem faced by the power generation industry, reduces energy requirements. Due to a high level of acceptance among consultants, architects and engineers, good quality Fly Ash's consumption is growing every year, which resulted increased cost of item the last few years. At the same time low quality fly ash occupies large areas for its stacking and it remains unutilized. To overcome it one needs to find out cost effective solution to it.

The utilization of fly ash has increased to over 73 Million Tonne (MT) in 2010-12. Fly ash was moved from "hazardous industrial waste" to "waste material" category during the year 2000 and during November 2009, it became a saleable commodity. Fly ash utilization has started gaining acceptance, it being 65.75% during 2011-12. The present generation of fly ash from coal based thermal power plants in India is 138.82 MT/year. Fly ash has acquired the status of a "useful commodity" which opens up plenty of opportunities in terms of laying and fine-tuning policies, conducting gainful businesses and Research and Development efforts, and addressing the concerns of environment at the same time. However, it would require a lot of efforts to reach the target of 100% fly ash utilization.

According to National Thermal Power Corporation (NTPC) (99), on average 1MW generation capacity requires 5,000 tonne Indian coal which produces 1,534 tonne fly ash and 384 tonne bottom ash. It will be an enormous environmental and socio economic challenge to handle such amount of ash. According to Gujarat State Electricity i Corporation Limited (GSECL), Report2010-11, Environmental compliance requirements of coal thermal power stations. 5-10%of electricity production cost is for disposing of fly ash. The cost of disposing ash per tonne is approx. Rs.125 (including equipment, labour, utilities and maintenance). Additional cost is purchasing land and established infrastructure which is in the order of Rs. 100-150 Crore per site depending upon the land size and location. World Bank (57) has cautioned India that by 2015 it would require 1,000 sq. km land area to dispose fly ash. Technologies offering high volume ash utilisation will be critical in helping India's future electricity demand and hence nation prosperity. Hence, there is a great scope for development of eco-efficient concrete based rigid pavement made using Fly Ash (Class-F). So, in this study partial replacement of Cement (OPC) by Fly Ash (Class-F) will be carried out.

HYPO SLUDGE

Paper making generally produces a large amount of solid waste. Paper fibres 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 fibres are separated out to become waste sludge which consumes a large percentage of local landfill space. 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; cost concrete by blending various ratios of cement with hypo sludge.

Lime is used in the recycling process of paper. The part of lime becomes waste with paper waste called Hypo Sludge. About 300 kg of Hypo Sludge is produced from each ton of recycled paper. These Hypo Sludge contains, low Calcium (CaO) and maximum Calcium Chloride (CaCL) and minimum amount of Silica (Si02). The shiny finish on glossy magazine-type paper is produced using a fine kaolin clay coating, which also becomes solid waste during recycling. 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 bum their sludge in incinerators, contributing to serious air pollution problems. To reduce disposal and pollution problems emanating from these industrial wastes, which contains ingredients, chemicals similar to the OPC, it is most essential to develop profitable building materials from them. Keeping this in view, investigations are needed tobe undertaken to produce low cost concrete by blending various ratios of cement with Hypo Sludge.

Hypo Sludge Concrete

As Hypo Sludge contains some cementatious properties, there are possibilities to replace the cement up to some percentage. So the concrete, which contains Hypo Sludge as a replacing material is known as Hypo Sludge concrete.

2. LITERATUREREVIEW

This literature review deals with the experimental work carried out by researchers in developing the low cost concrete. The detailed review study for fly ash, hypo sludge and glass fiber is carried out chronologically to arrive at designing experiment to find new outcomes.

Giaccio GM et.al (1988) concluded that high-volume fly ash concrete had excellent mechanical properties and satisfactory resistance to repeated cycles of freezing and thawing. The use of ASTM Type III cement appeared to be essential when high strengths at early ages were required. For concretes made with ASTM Type I cement, the use of beneficiated fly ash and condensed silica fume, did little to enhance the properties of concrete compared with “as received” fly ash. For concrete made with ASTM Type III cement, the benefits of using beneficiated Class F fly ash and condensed silica fume were not clear.

Aires Camoes, et al (1988) determined the Compressive strength and diffusion coefficient of concretes replacing 0%, 20%, 40%, and 60% of Portland cement by ‘as received’ fly ash, and 20% and 40% replacement by ‘enhanced’ fly ash. Comparing the results obtained, it was found that High Performance Concrete (HPC) with up to 65 MPa can be made by replacing up to 40% of cement by ‘as received’ and ‘enhanced’ fly ash and using the crushed granite aggregates. It was possible to produce low cost HPC, with 90 day strength in the range of 70 MPa, using low quality fly ash and crushed sand. It was possible to replace up to 40% of cement by low quality fly ash with carbon content up to and slightly higher than 7%.

Ujjwal Bhattacharjee et.al (2000) said that a simple framework for estimation of fly ash utilization potential in India has been developed. Fly ash utilization in cement production, construction of road embankments and manufacture of bricks has been considered. The results obtained for the projected levels of fly ash utilization clearly show that in spite of assuming quite optimistic levels of fly ash use in the three applications, the overall fly ash utilization was less than 25% of the total fly ash produced. Therefore, either a much more aggressive fly ash utilization strategy has to be developed and executed or the extent of the fly ash utilization target (or the year of achieving a specified target) should be reviewed by MOEF.

Ravina D et .al (2000) studied effect of replacing 35 to 50 percent of cement by fly ash on workability, water requirement, bleeding, and setting time of lean concrete mixtures was investigated, using two ASTM Class F and two ASTM Class C fly ashes. Workability of all concrete mixtures containing fly ash was found to be better than that of controlled mixtures (without fly ash). The water required for obtaining the designated slump (2in., 5cm) of all concrete mixtures containing fly ash was reduced by 5 to 10 percent.

According to Bilodeau et.al (2000), the challenge for the civil engineering community in the near future will be to realize projects in harmony with the concept of sustainable development, and this involves the use of high-performance materials produced at reasonable cost with the lowest possible environmental impact. In 1985, Canada Centre for Mineral and Energy Technology (CANMET) developed a concrete incorporating large volume of fly ash that has all the attributes of high-performance concrete, that is, one that has excellent mechanical properties, low permeability, superior durability, and that is environmentally friendly.

Gopala krishna et.al (2001) reported from comparative research that concrete with 25%fly ash performs better than concrete with 50% fly ash. The same observation was made with respect to split tensile strength and flexural strength. Usage of industrial waste such as fly ash as a partial replacement material for cement not only provides a more durable concrete but also finds the way for the safe disposal of otherwise waste material thereby protecting the environment from pollution.

Siddique Rafat et. al (2003) Compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity of fine aggregate (sand) replaced fly ash concrete specimens were higher than the plain concrete (control mix) specimens at all the ages. The strength differential between the fly ash concrete specimens and plain concrete specimens became more distinct after 28 days. Compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity of fine aggregate (sand) replaced fly ash concrete by 50% continued to increase with age for all fly ash percentages.

N. Bhamimathidas et al (2003) studied that the utilization of fly ash in cement and concrete is gaining immense importance today, mainly on account of the ecological benefits and the improvements in the long-term durability of concrete. Very few t technologies can assimilate economy, value addition and eco-service; all in a single go. Fly ash utilization is the unique opportunity to serve these multiple indicators collectively. Goh etal (2003) Compressive strength results indicate that up to 10% by weight of OPC could be replaced by Municipal Fly Ash (MFA), with higher mortar strength being achieved than in the control cubes.

A seven-day strength activity index of 123.6% achieved by the MFA, which is almost 50% higher than the requirement of 75%, suggests its contribution toward the strength development of the blended cements. A. Oner et al (2004) This study showed that strength increases with increasing amount of fly ash up to an optimum value, beyond which strength starts to decrease with further addition of fly ash. The optimum value of fly ash was about 40% of cement. Fly ash/cement ratio was an important factor determining the efficiency of fly ash.

A.K. Jain et al (2004,2011) Large quantity of fly ash and blast furnace slag are generated in India and many other developing countries every year. In absence of proper awareness and technology development, a large portion of these by-products remain unutilized causing severe disposal and environmental problems. The fly ash affects various properties of concrete in its green and hardened state, which are of significant importance to the durability of the concrete structures. The quality of fly ash varies not only from 1 plant to plant, but it may vary within the same plant due to change in the source of coal or inconsistent boiler conditions. Therefore a continuous quality assurance programmed is to be developed to avoid the use of low-grade inconsistent material. The use of good fly ash of a consistent quality with low carbon content, greater fineness and high pozzolanic activity can produce economically a concrete of good quality and higher durability. He also discussed the present status and the future^ prospects of fly ash utilization by Indian Cement Industry. The Indian Cement Industry, which ranks 2nd in the world has whole heartedly taken the dual challenges to utilize the fly ash to resolve the problem of disposal of the waste product and to enhance the performance of cementitious materials.

Pavel Padevet et.al (2005) discussed a use of fly ash in the preparation of the concrete, or the cement paste. He concluded that the fly ash as a waste material is often conveniently applicable material. Fly ash as a waste material in the construction industry has consolidated. A significant effect of energy saying was in use, and therefore the need of only half the amount of cement. The positive trend was reflected in the long term, when the properties cement paste with addition of fly ash was improving. It was the perspective of the use of fly ash in the structures of fire! protection when at elevated temperature reaches the same and better properties than pure cement paste. Richard A. Livingston et.al (2005) The practice of choosing an arbitrary value for the mix proportions did not ensure that, that optimum condition would be achieved. Over a period of the last ten years, the image of fly ash has completely been changed from a "Polluting Waste" to "Resource Material".

3. METHODOLOGY

The present work is undertaken with the primary objectives of evaluating the suitability of Supplementary Cementitious Materials (SCMs) such as Fly Ash (Class-F) and Hypo Sludge in pavement quality concrete, and identifying their optimum replacement levels with cement. Fly Ash, a by-product of coal combustion, and Hypo Sludge, a waste material from the paper industry, are recognized for their potential to partially replace cement in concrete mixes. Their utilization not only contributes to waste minimization and environmental sustainability but also enhances certain properties of concrete when used in appropriate proportions. The study aims to determine how different replacement levels of these materials influence the strength, durability, and overall performance of rigid pavements, thereby identifying the most effective percentage combination of Fly Ash and Hypo Sludge for practical applications in road construction.

This research further emphasizes its significance by focusing on the potential impact of SCM-based concrete on the development of both rural road networks and national highway infrastructure. Since rigid pavements demand materials that can withstand heavy traffic loads and environmental stresses, the integration of Fly Ash and Hypo Sludge presents an economical and sustainable alternative to conventional cement-based mixes. The research plan includes a systematic approach involving the selection and characterization of materials, detailed experimental investigations, mix design formulation, preparation of test samples, and evaluation of mechanical and durability properties. Through this approach, the study seeks to demonstrate that SCMs can provide a safer, simpler, and more cost-effective solution for constructing rural road infrastructure, while simultaneously contributing to sustainable infrastructure growth at the national level.

The experimental investigation begins with the testing of the basic additive materials, namely Fly Ash and Hypo Sludge, to evaluate their physical and chemical properties. This step is essential to ensure their suitability as partial replacements for cement in pavement quality concrete. The characterization includes tests such as fineness, specific gravity, chemical composition, and other relevant properties that influence the behavior of concrete. By establishing the quality and compatibility of these supplementary cementitious materials (SCMs), a solid foundation is laid for their effective use in subsequent stages of the research.

Following the material characterization, Fly Ash and Hypo Sludge are blended with cement in different proportions to prepare pavement quality concrete. A systematic schedule is adopted for concrete mix design, which includes determining suitable mix proportions that meet strength and workability requirements. After the mix design is finalized, specimens in the form of cubes, cylinders, and beams are cast and cured under standard conditions. These specimens are then subjected to various mechanical tests such as compressive strength, split tensile strength, and flexural strength at different curing ages. The data obtained from these tests are carefully analyzed to draw meaningful inferences and establish the influence of SCMs on the properties of concrete.

Finally, the results derived from the laboratory investigations are utilized in the design of rigid pavements for both rural road networks and national highways. By integrating the experimental outcomes with standard pavement design guidelines, the study demonstrates how the optimized use of Fly Ash and Hypo Sludge can contribute to sustainable and cost-effective road construction. This not only validates the engineering applicability of the prepared concrete but also provides a practical framework for adopting such eco-friendly materials in large-scale infrastructure projects. The methodology adopted in this work has been shown in the following figure:

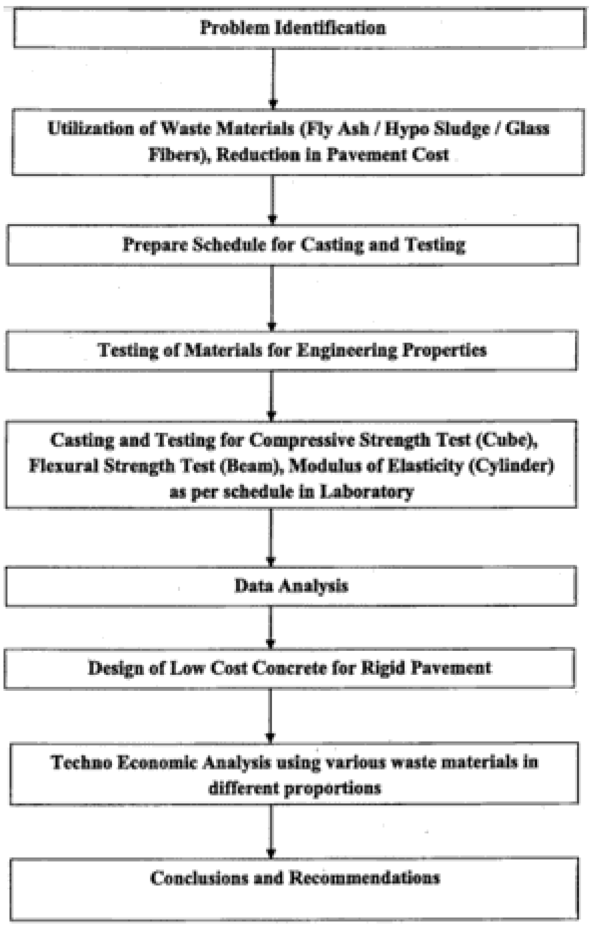

Figure 1. Flow Chart of Methodology

Concrete Mix Design for the study Eight types of concrete (M25 and M40) mix used for casting and testing of cubes, cylinders and beams for making economical and durable concrete. The percent replacement of cement by fly ash, hypo sludge are given in Table 3.1.

Table 3.1: Design of Various Concrete Mixes with various proportions of Fly ash and Hypo sludge

Concrete Mixes	M25	M40
A	0% Cement Replacement	0% Cement Replacement
B	10%, 20%, 30%, 40% Cement Replacement by Fly Ash Class "F"	10%, 20%, 30%, 40% Cement Replacement by Fly Ash Class "F"
C	10%, 20%, 30%, 40% Cement Replacement by Hypo Sludge	10%, 20%, 30%, 40% Cement Replacement by Hypo Sludge
D	5+5%, 10+10%, 15+15%, 20+20% Cement Replacement by Fly Ash Class "F" and Hypo Sludge	5+5%, 10+10%, 15+15%, 20+20% Cement Replacement by Fly Ash Class "F" and Hypo Sludge

4. RESULTS AND DISCUSSION

4.1 INTRODUCTION

The experiments were conducted as per standard procedures and findings were summarized in the form of tables and figures for the critical review and forming the conclusions of the proposed work.

4.2 TABULATIONS OF RESULTS FIGURES RELATED OBSERVATIONS AND COMMENTS

The results are presented in the following tables by observing impact of fly ash, hyposludge, fly ash + hypo sludge, with normal concrete with any replacement on compressive strength, flexural strength and modulus of elasticity (MOE).

4.2.1 COMPRESSIVE STRENGTH OF VARIOUS CONCRETES MIXES FOR M25 GRADE CONCRETE

Experimental results of compressive strength of various concretes mixes (mentioned below as concretes mix A1 to concretes mix D4 are recorded in table: 4.1 and Figure: 4.1 to Figure 4.3.

Table: 4.1 Compressive strength of various concretes mixes in N/mm2 for M25 grade(Cubes)

Concrete	% replacement	Concrete Mixes	Compressive strength (N/mm^2)				
			7 days	14 days	28 days	56 days	90 days
Standard	0%	A1	28.76	32.00	38.52	40.30	42.52
Fly ash	10%	B1	21.33	30.90	34.67	35.41	36.30
	20%	B2	16.15	23.78	24.30	25.63	26.07
	30%	B3	13.04	15.11	22.37	23.26	24.74
	40%	B4	9.93	14.81	17.33	22.22	23.56
Hypo sludge	10%	C1	29.24	33.63	39.70	40.15	42.67
	20%	C2	22.96	23.35	25.78	27.11	29.19
	30%	C3	20.92	22.96	23.26	24.30	25.19
	40%	C4	19.47	21.04	22.96	23.11	23.85
Fly ash + Hypo sludge	5%+5%	D1	31.26	35.27	40.33	42.81	45.30
	10%+10%	D2	30.59	34.85	36.89	40.78	43.56
	15%+15%	D3	15.33	18.67	22.22	23.41	24.89
	20%+20%	D4	12.59	17.19	21.78	22.37	23.85

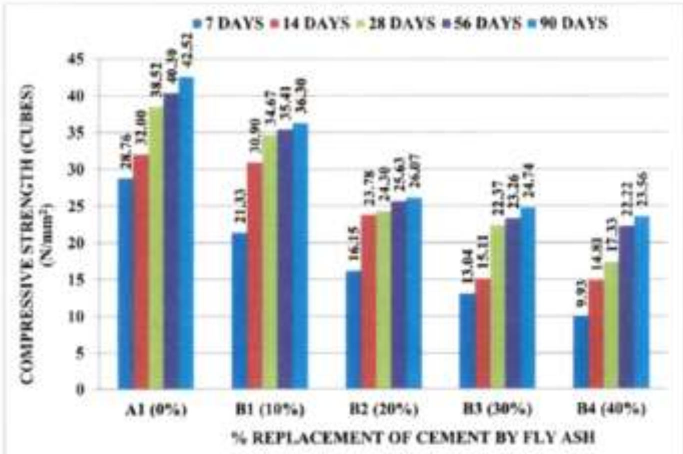

Figure 4.1 Comparison of Compressive Strength (cubes) (N/mm2) of Various Mix ofFly Ash in M25 Grade Concrete

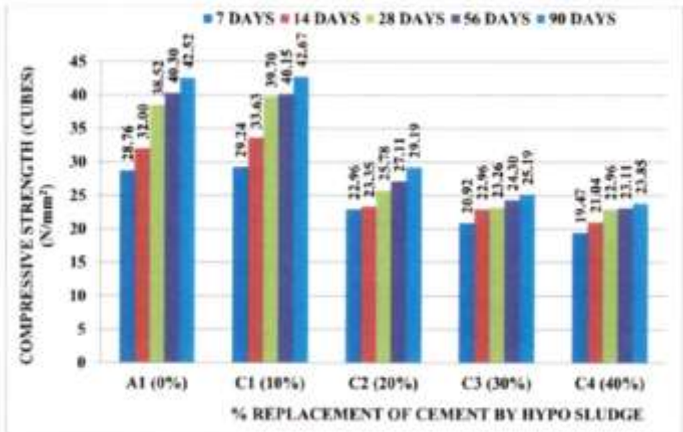

Figure 4.2 Comparison of Compressive Strength (cubes) (N/mm2) of Various Mix of Hypo Sludge in M25 Grade Concrete

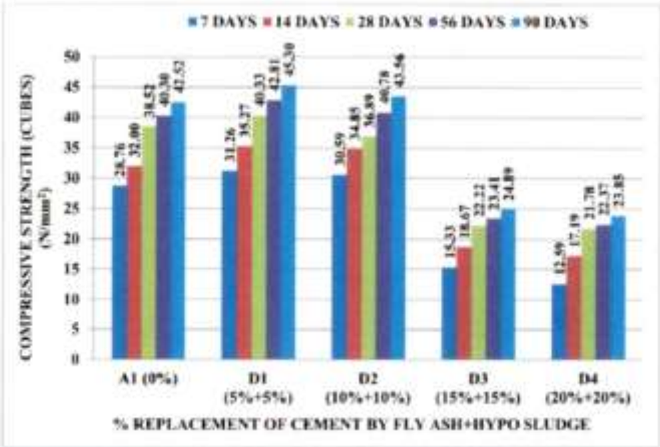

Figure 4.3 Comparison of Compressive Strength (cubes) (N/mm2) of Various Mix ofFly Ash + Hypo Sludge in M25 Grade Concrete

All the mixes with inclusion of different percentages of supplementary cementitious materials shows gain in compressive strength with respect to the age of concrete.

From Figure no 4.1 it is observed that the use of fly ash up to 20% by weight of cementitious materials reflects targeted strength at 28 days and the major part of the strength up to 20% inclusion is gained at 14 days. Beyond 28 days the increase in compressive strength is 9.95% for 56 days and 14.63% for 90 days.

The result indicates considerable reduction in compressive strength to the order of 48.47%, 43.57% and 43.20% on average for 30% and 40% inclusion of fly ash at 28, 56and 90 days age respectively.

Figure no 4.2 shows the optimum replacement of cement by hypo sludge is 20%. Up to 20% replacement the gain in compressive strength during early age at 7 and at 14 days is of the order 100% and 85% which reflects the important characteristics of sludge.

Beyond 28 days all samples shows increase in strength at an average rate of 4% and 10%at 56 days and 90 days respectively.

From table no 4.1 it is observed that hybrid replacement with fly ash and hypo sludge gains the strength as per requirement by 20% and onwards there is decrease in compressive strength. The gain in compressive strength at 28 days is of the order 2% on an average with reference to only fly ash as substitute.

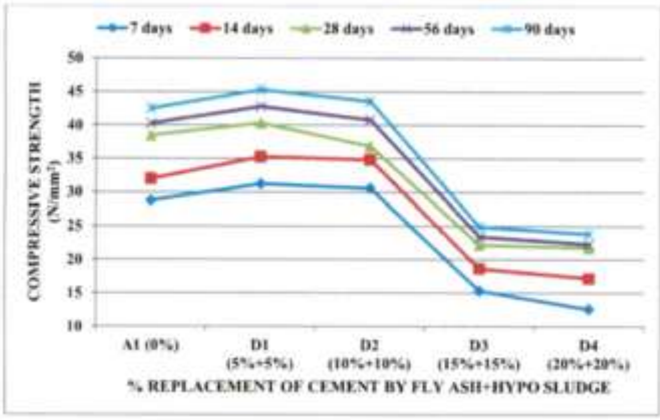

Figure 4.4 Compressive Strength (N/mm2) Development of Hybrid Mix (Fly Ash + Hypo Sludge) Concrete Time in Days for M25 Grade Concrete

The characteristic compressive strength of various mixes of concrete are presented in table no. 4.1. Figure 4.4 shows the graphical representation of hybrid mix (fly ash + hypo sludge) concrete. The curves in figure 4.4 show the rate of compressive strength development of hybrid mix (fly ash + hypo sludge) concrete over a span of 90 days. Majority of compressive strength is gained within 28 days and beyond it is not measurable. With inclusion of fly ash and hypo sludge the ultimate strength and rate of gaining strength decreases in comparisons to the conventional mix.

Percentage increases in hybrid concrete both parameter show reduction. But for hybrid concrete there are significant increases in compressive strength beyond 28 days which reflects the major advantage of using industrial waste as a pozzolanic material.

Table: 4.2 Compressive strength of various concretes mixes in N/mm2 for M40 grade(Cubes)

Concrete	% replacement	Concrete Mixes	Compressive strength (N/mm²)				
			7 days	14 days	28 days	56 days	90 days
Standard	0%	A2	34.81	45.04	50.81	52.89	53.93
Fly ash	10%	B5	29.33	34.96	38.22	40.74	42.52
	20%	B6	23.79	25.48	27.70	30.81	33.78
	30%	B7	18.10	18.37	22.52	25.48	26.52
	40%	B8	14.61	16.44	21.63	23.70	25.33
Hypo sludge	10%	C5	36.59	46.52	51.26	53.33	54.52
	20%	C6	34.22	39.11	40.74	42.81	43.26
	30%	C7	24.30	27.85	28.74	30.52	33.19
	40%	C8	20.36	23.26	24.00	25.19	26.52
Fly ash + Hypo sludge	5%+5%	D5	37.78	47.96	52.78	54.59	55.44
	10%+10%	D6	36.80	46.67	51.85	53.50	54.82
	15%+15%	D7	22.37	26.52	27.26	29.33	31.26
	20%+20%	D8	19.70	22.96	23.85	24.15	25.33

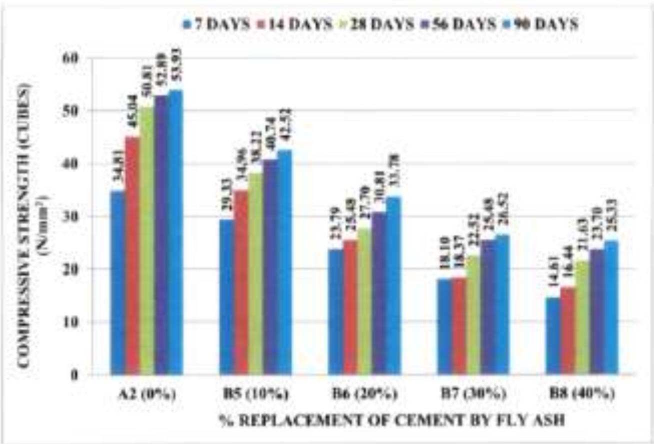

Figure 4.5 Comparison of Compressive Strength (cubes) (N/mm2) of Various Mix of Fly Ash in M40 Grade Concrete

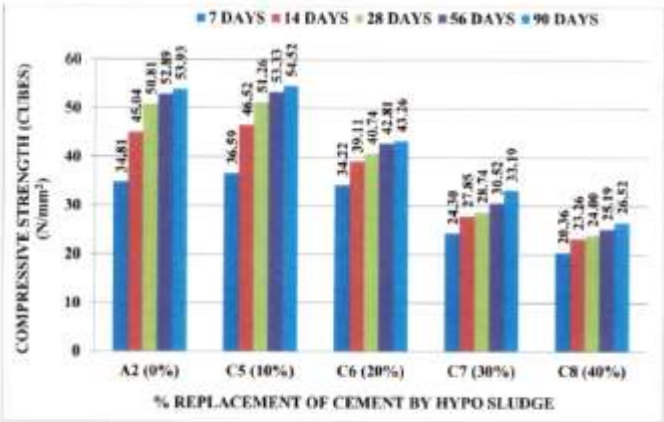

Figure 4.6 Comparison of Compressive Strength (cubes) (N/mm2) of Various Mix of Hypo Sludge in M40 Grade Concrete

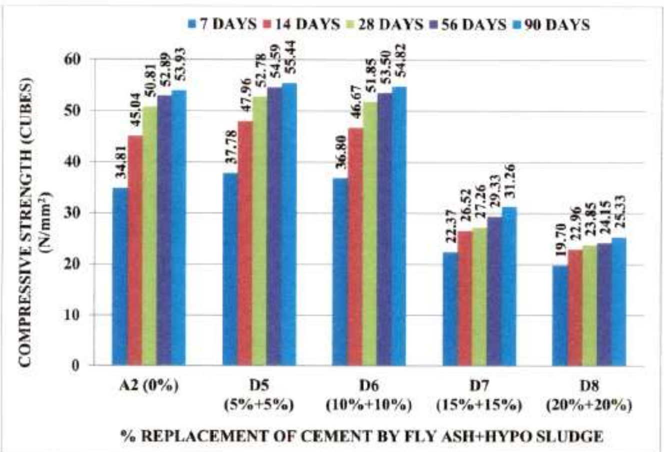

Figure 4.7 Comparison of Compressive Strength (cubes) (N/mm2) of Various Mix of Fly Ash + Hypo Sludge in M40 Grade Concrete

All the mixes with inclusion of different percentages of supplementary cementitious materials shows gain in compressive strength with respect to the age of concrete. From Figure no 4.5 it is observed that the use of fly ash upto 20% by weight of cementitious materials reflects targeted strength at 28 days and the major part of the strength upto 20% inclusion is gained at 14 days. Beyond 28 days the increase in compressive strength is 10.13% for 56 days and 17.02% for 90 days. The result indicates considerable reduction in compressive strength to the order of56.55%, 53.51% and 51.93% on average for 30% and 40% inclusion of fly ash at 28, 56and 90 days age respectively. Figure no 4.6 shows the optimum replacement of cement by hypo sludge is 20%. Up to20% replacement the gain in compressive strength during early age at 7 and at 14 days is of the order 100% and 85% which reflects the important characteristics of sludge.

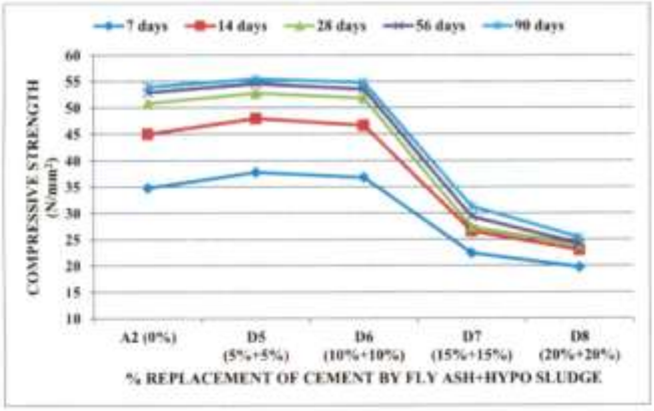

Figure 4.8 Compressive Strength (N/mm2) Development of Hybrid Mix (Fly Ash + Hypo Sludge) Concrete Time in Days for M40 Grade Concrete

The characteristic compressive strength of various mixes of concrete are presented in table no. 4.2. Figure 4.8 shows the graphical representation of hybrid mix (fly ash + hypo sludge) concrete. The curves in figure 4.8 show the rate of compressive strength development of hybrid mix (fly ash + hypo sludge) concrete over a span of 90 days. Majority of compressive strength is gained within 28 days and beyond it is not measurable. With inclusion of fly ash and hypo sludge the ultimate strength and rate of gaining strength decreases in comparisons to the conventional mix. Percentage increases in hybrid concrete both parameter show reduction. But for hybrid concrete there are significant increases in compressive strength beyond 28 days which reflects the major advantage of using industrial waste as a pozzolanic material.

5. CONCLUSION

(A) INGREDIENTS:-

All the ingredients for the conventional concrete and industrial sludge, waste and by-product concrete were tested as per relevant standards and all the properties in terms of physical and chemical composition found satisfactory for the use.

(B) MECHANICAL PROPERTIES:

Compressive Strength

1. For grade of concrete M25 20% hybrid mix (fly ash and hypo sludge) replacement with cement gives the design strength at 28 days.

2. For grade of concrete M40 10% hybrid mix (fly ash and hypo sludge) replacement with cement gives the design strength at 28 days.

3. For design mix M25 grade concrete up to 20% replacements gains early strength at7 days and required strength of 66% at 14 days age. Average increase in strength from 28 to 90 days for grade M25 with an optimum replacement of cement with a hybrid mix (fly ash and hypo sludge) (20%) founds to be 18.09%.

4. For design mix M40 grade concrete up to 10% replacements gains early strength at7 days and required strength of 66% at 14 days age. Average increase in strength from 28 to 90 days for grade M40 with an optimum replacement of cement with a hybrid mix (fly ash and hypo sludge) (10%) founds to be 5.03%.

5. All the mixes reflect progressive gain in strength linearly from the age of 7 days to90 days.

(C) PAVEMENT DESIGN FOR RURAL ROAD

1. The use of only Fly Ash increases slab thickness up to 60% and cost by 20% under 30 kN wheel load, hence it is not beneficial.

2. The use of only Hypo Sludge increases slab thickness up to 33% and cost by 8% under 30 kN wheel load, hence it is not beneficial.

3. An optimum 20% replacement of cement with a Fly Ash–Hypo Sludge blend maintains slab thickness and reduces cost by 14% under 30 kN wheel load.

4. For 51 kN wheel load, all mixes with SCMs increase slab thickness compared to normal concrete at 2%, 4%, and 6% CBR.

5. The use of only Fly Ash increases slab thickness up to 57% and cost by 20% under 51 kN wheel load, hence it is not beneficial.

6. The use of 10% Hypo Sludge alone maintains slab thickness and reduces cost by 6% under 51 kN wheel load, but higher replacement levels increase both slab thickness and cost.

7. An optimum 20% replacement with the Fly Ash–Hypo Sludge hybrid mix reduces the slab thickness and cost by 20% for 2%, 4%, and 6% CBR. With 51kN wheel load.

Research outcome:

1. Potential use of industrial waste and by-products makes green concrete, leading to the preservation of natural resources and a contribution towards the reduction in costs and greenhouse emissions.

2. The concrete with inclusion of hypo sludge and fly ash can be used for the high-value application as it has both improved engineering as well as durability parameters.

3. The experimental investigation recommends 20% and 10% replacements of ordinary Portland cement by hybrid supplementary cementitious material for grade M25 and M40 respectively

Future Scope:-

1. The study of behavior of rural road and national highway can be done using various concrete mix made by using industrial waste like copper slag, foundry sand, metakoline, pond ash, rice hush ash etc.

2. The effect on rural road and national highway slab thickness can be studied using various fibers such as polypropylene, carbon, high-density polyethylene (HDPE), etc.

3. Other durability aspects, such as Carbonation, Rapid Chloride Penetration, and Chloride Iron Penetration of concrete using industrial waste could be studied.

4. The relationship between different days' compressive strength can be derived using different computerized techniques like Artificial Neural Network (ANN).

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