Optimizing Industrial Applications of Cement for Street Construction

1GURIJALA AKHIL, 2PITTALA SAMBARAJU, 3SHETTY RADHIKA,4 N.SATHVIKA
123Assistant professor,4Student
Dep of Civil Engineering
Vaagdevi College of Engineering, Warangal, India

ABSTRACT: This study explores optimization strategies for the industrial application of cement in street construction, aiming to enhance durability, performance, and sustainability. With the rapid expansion of urban infrastructure, there is a growing need for street pavements that can withstand high traffic loads and environmental stressors. This research investigates the impact of supplementary cementitious materials (SCMs), advanced curing techniques, and the use of recycled aggregates on the mechanical properties and durability of cement streets. The incorporation of materials like fly ash, slag, and recycled concrete aggregate, along with innovative curing methods, aims to improve compressive strength, flexibility, and resistance to cracking.

A series of laboratory tests, including compressive, tensile, and flexural strength assessments, were conducted to evaluate various cement formulations and curing processes. The findings indicate that the use of SCMs and recycled aggregates significantly enhances durability while reducing the overall carbon footprint associated with cement production. Furthermore, advanced curing techniques, such as polymer-modified curing compounds, were shown to improve moisture retention and reduce shrinkage, contributing to longer-lasting street infrastructure.

This study demonstrates that integrating sustainable materials and efficient construction practices in cement applications can lead to more resilient and eco-friendly street pavements. By providing a framework for optimizing cement use in street construction, this research supports the development of infrastructure that meets modern demands for durability, cost-effectiveness, and environmental stewardship.

INTRODUCTION

1.1 GENERAL

As cities expand and urban mobility demands increase, the need for durable and sustainable street infrastructure has become more critical than ever. Streets are vital for the movement of goods and people, directly impacting urban development and quality of life. However, traditional cement production is associated with high carbon emissions and significant energy consumption, which poses environmental challenges. In response, the construction industry is exploring ways to make the use of cement in street construction more efficient and sustainable while maintaining or improving performance.

Cement is widely favored in street construction for its strength, durability, and adaptability, but optimizing its application requires a shift towards innovative materials and techniques. One of the most promising approaches involves incorporating supplementary cementitious materials (SCMs), such as fly ash, slag, and silica fume, which can partially replace cement, reduce environmental impact, and enhance mechanical properties. Additionally, recycling practices, like the use of recycled concrete aggregate (RCA), offer a sustainable alternative that reduces waste and the need for virgin materials.

Alongside material innovations, advanced curing techniques have shown potential in enhancing the structural integrity and longevity of cement pavements. Traditional water curing methods are now supplemented by more effective approaches, such as polymer-modified curing compounds, which improve moisture retention and reduce shrinkage. By combining these advanced materials and methods, the construction industry can address both the sustainability and performance challenges associated with cement streets.

This study aims to evaluate the impact of SCMs, recycled aggregates, and innovative curing techniques on the durability and strength of cement streets. Through a series of laboratory tests, including assessments of compressive strength, tensile strength, and flexural performance, this research seeks to identify optimal strategies for the efficient application of cement in street construction. By providing insights into sustainable and resilient street construction, this research aims to contribute to the development of infrastructure that meets the demands of modern urban environments while reducing ecological impact.

.2 LITERATURE SURVEY

The optimization of cement use in street construction has been a focus of numerous studies, especially concerning the enhancement of strength, durability, and sustainability. This literature survey reviews findings on supplementary cementitious materials (SCMs), advanced curing techniques, and the integration of recycled aggregates, highlighting their contributions to more durable and environmentally friendly cement applications in infrastructure.

1.1.1 1. Supplementary Cementitious Materials (SCMs)

Recent research has shown that SCMs, such as fly ash, silica fume, and ground granulated blast furnace slag (GGBFS), can significantly improve the properties of cement. **Zhang et al. (2020)** observed that incorporating fly ash at 20–30% replacement levels not only improved the compressive strength of concrete but also enhanced its workability and reduced environmental impact. Similarly, **Li et al. (2019)** found that GGBFS increased resistance to sulfate attack, improving the durability of street pavements exposed to harsh conditions. **Chen et al. (2021)** examined silica fume's effects, noting substantial improvements in early-age strength and resistance to cracking, which are critical for street longevity.

1.1.2 2. Recycled Concrete Aggregates (RCA)

Recycling practices, particularly the use of recycled concrete aggregates (RCA), have gained traction as a sustainable alternative to virgin aggregates. **Duxson et al. (2018)** demonstrated that RCA could replace up to 50% of traditional aggregates in cement without compromising strength or durability, offering substantial environmental benefits by reducing landfill waste. **Meyer (2020)** highlighted the importance of using optimized RCA gradation to maintain concrete quality and observed a slight increase in tensile strength, suggesting RCA's viability in road applications. Additionally, **Shen et al. (2021)** emphasized RCA's role in promoting circular economy practices within the construction sector, aligning with industry sustainability goals.

1.1.3 3. Advanced Curing Techniques

The hydration process and durability of cement are heavily influenced by curing techniques. **Khan et al. (2020)** studied the effects of polymer-based curing compounds, finding that they retained moisture more effectively than traditional water curing, resulting in higher compressive strength and reduced cracking. **Alzubaidi et al. (2021)** examined curing blankets, which provided protection from rapid moisture loss in high-temperature environments, thereby reducing shrinkage-related cracks and enhancing pavement durability. **Bendahou et al. (2019)** explored the impact of internal curing using superabsorbent polymers, concluding that this technique could enhance hydration depth and extend the life of cement-based pavements.

1.1.4 4. Fiber Reinforcement for Enhanced Performance

The use of fibers in cement to improve tensile strength and durability is another area of focus. **Xu et al. (2019)** observed that adding steel fibers increased the tensile strength of cement pavements by up to 25%, making it more resistant to cracking under heavy traffic loads. Meanwhile, **Singh et al. (2022)** studied the use of polypropylene fibers, which improved crack control and provided greater flexibility in high-stress conditions. **Liang and Zhang (2020)** explored the effects of hybrid fiber reinforcement, finding that combining different fiber types (such as steel and polypropylene) led to improved resilience under fluctuating temperatures and moisture levels.

1.1.5 5. Case Studies and Real-World Applications

Real-world applications of optimized cement mixtures have shown promising results in improving street durability and sustainability. **Khan et al. (2020)** documented a street construction project using a high-performance concrete mix with 20% fly ash and polymer-modified curing, resulting in a 30% increase in pavement lifespan and a reduction in maintenance costs. **Meyer (2019)** reported on the use of RCA in urban street construction, showing a marked reduction in the environmental footprint while achieving satisfactory load-bearing capacity.

3 SCOPE AND OBJECTIVE

3.1 SCOPE AND OBJECTIVEOF LOW COST CONCRETE

The advantages of utilizing mineral admixtures in concrete are genuinely settled. They offer advantages as for the cost of assembling of bond since fly slag and silica vapor are results or waste materials supplanting a piece of OPC, thus less essential vitality and crude materials are required underway of minimal effort concrete. This prompts more endeavors towards the utilization of waste materials with bring down natural effect. The point of the present work is to make a near investigation of properties of these two sorts mineral admixtures i.e., fly fiery debris and silica exhaust alongside concrete blended in various extents. Also think about is made to decide the impact on modulus of versatility of cement with expansion of various extents of silica smoke and fly powder to these fastener blends.

1) The extent of the paper is to examine the impact of mineral admixture on the quality attributes of the minimal effort concrete.

2) The target is to think about the mechanical properties of cement i.e., compressive quality, rigidity and effect quality by the fluctuating rate ofFly cinder and silica smolder with 0%,10%, 20%, 25%, 30% each with two water-bond proportion of 0.3 and 0.35 by weight of concrete by M25 review concrete.

3) In this undertaking we additionally contemplate the pressure strain relations bends at various extents of mineral admixture.

4) To examination the test consequences of minimal effort cement and contrasted with the ordinary solid test outcomes.

5) The target is to think about the toughness properties (utilizing corrosive) of ease concrete for 28 days and contrasted with the customary cement.

4 MATERIALS AND THE PROPERTIES

4.1 ORDINARY PORTLAND CEMENT

Portland bond is the most widely recognized sort of concrete when all is said in done utilize all around the globe. It is utilized as a sic element of solid, engine, stucco, and most not-uncommonly grout. It was produced from sorts of pressure driven lime in England in the nineteenth century and is taken from lime stone birthplace. It is a fine powder created by warming the material in a turning furnace to frame what is called clinker granulating .The clinker and expansion of different materials. Such a significant number of sorts customary Portland bond the accessible in advertise. The most well-known OPC is in dim shading. A few kinds are additionally accessible in white shading. Portland concrete is in acidic nature, so it causes concoction consumes, the powder can causes tingling or aggravation. On the off chance that very presented to this powder may causes lung ailments, additionally contains some dangerous fixings, for example, silica and chromium. Natural concerns those are required high vitality to fabricate and transporting. It discharges hurtful gases like ozone depleting substances (e.g., carbon dioxide), dioxide,NOx, SO2, and particulates because of this air contamination happens.

4.1.1 Properties of Portland cement

These properties are taken from the various standard books, journals and some code as reference. Here our aim is to determine actual chemical composition of the sample provided by the company. The chemical properties of Portland cement is listed in Table No 4.1

Table4.1.Chemical Properties ofPortland cement

S NO	CONSTITUENT	PERCENTAGE(%)
1	CaO	64.00
2	SiO_2	22.00
3	Al_2O_3	4.10
4	Fe_2O_3	3.60
5	MgO	1.53
6	SO_3	1.90

4.2 SAND

Sand is common material happening from finely isolated shake and mineral molecule. The most well-known constituent of sand in inland mainland settings and non-tropical waterfront settings is silica (silicon dioxide or SiO2) more often than not as quartz. In light of its concoction latency and impressive hardness it exceedingly opposes the weathering condition. It is utilized as fine total in concrete.

In this stream we are utilizing the locally accessible waterway sand which is adjusting to Zone II of IS: 383-19707 was utilized as fine total with particular gravity.

4.2.1 Sieve analysis of sand

To classify the sand according to zone sieve analysis is to be carried out, the fineness of sand give good compaction of mix. The results are sieve analysis are given in Table No 4.2

Table4.2 Sieve Analysis of Sand

SIEVE SIZE	WEIGHT RETAINED (gms)	PERCENTAGE PASSING (%)
4.75 mm	20	97.8
2.36 mm	13	96.4
1.18 mm	74	91.2
600µ	391	50.7
300µ	416	8.9
150µ	86	1.6
Total	1000	-

From the sieve analysis sand under goes Zone II

4.2.2 Physical Properties of sand

The physical properties of sand are given below in Table No 4.3

Table4.3 Physical Properties of Sand

Fine aggregate	Specific gravity	Water absorption (%)
Sand	2.71	0.7

4.3 COARSE AGGREGATE

The coarse total are normally happening material from partitioned shake material and pounded rock stone. The state of the total likewise impacts the quality attributes of the solid. Among various sorts of shape rakish molded totals are best as it gives better compaction of the blend by diminishing the voids. In this task we are thinking about rakish formed total of most extreme size , 20 mm are tried according to Seems to be: 383-1970. It is squashed rock stone acquired from the neighborhood quarry having particular gravity of 2.76.

Fig 4.1 coarse aggregate

4.4 FLY ASH

Fly fiery debris is a result of the ignition of pummeled coal in warm power plants. A residue collectionsystem evacuates the fly cinder, as a fine particulate buildup, from ignition gases before they are released into the environment. The sorts and relative measures of incombustible issue in the coalused decide the synthetic organization of fly fiery debris. Over 85% of most fly fiery remains is included ofchemical mixes and glasses framed from the components silicon, aluminum, iron, calcium, and magnesium.

Table4.4.Chemical Properties ofFly Ash

S NO	CONSTITUENT	PERCENTAGE (%)
1	CaO	21.00
2	SiO_2	35.00
3	Al_2O_3	18.10
4	Fe_2O_3	6.0
5	Na_2O	5.8
6	SO_3	4.1

Fig 4.2Fly ash

4.5 SILICA FUMES

Thechemical properties of silica fumes are given in the following Table

Table4.5.Chemical Properties ofsilica fumes

S NO	CONSTITUENT	PERCENTAGE (%)
1	CaO	1.60
2	SiO_2	90.00
3	Al_2O_3	0.4
4	Fe_2O_3	0.4
5	Na_2O	0.5
6	SO_3	0.4

Fig 4.3 silica fumes

4.6 SULFURIC ACID

The sulfuric acid is used for curing to conduct durability test. For l liter of water 10 ml of H_2SO_4 is used.

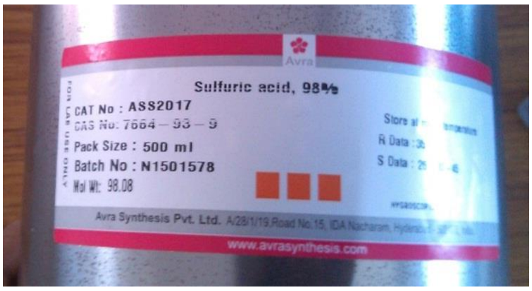

Fig 4.4 sulfuric acid

4.7 WATER

Portable water is used for both mixing and curing of both conventional and low cost concrete.

5 CONCRETE MIX DESIGN

5.2 MIX DESIGN PROCEDURE

1. The quality of the bond as accessible in the nation today has incredibly enhanced since 1982. The 28-day quality of A, B, C, D, E, F. Class of bond is to be explored.
2. The diagram associating, distinctive quality of bonds and W/C is to be restored.
3. The chart interfacing 28-day compressive quality of cement and W/C proportion is to be stretched out up to 80Mpa, if this diagram is to provide food for high quality cement.
4. As for each the correction of 456-2000, the level of functionality is communicated as far as droop as opposed to compacting factor. This outcomes in change of esteems in assessing rough sand and water substance for ordinary cement up to 35Mpa and high quality cement over 35Mpa. The table giving alteration of qualities in water substance and sand % for other than standard conditions, requires suitable changes and adjustments.
5. In the perspective of the above and different changes made in the amendment of IS456-2000, the blend outline technique as suggested in IS 10262-82 is required to be altered to the degree considered essential and cases of blend configuration is worked out.

6 EXPERIMENTAL PROGRAM

6.1 EXPERIMENTAL PROCEDURE

The exploratory program was intended to research the quality of the ease concrete by including fly slag and silica vapor. The trial think about was meant to the compressive quality, split elasticity, affect quality, sturdiness with affect quality and stress strain bends. To think about the above properties M25 blend is considered. The plan of exploratory program given underneath

Stage 1: barrels having size 150mm width and 300 mm stature were threw for the assurance of the compressive quality of the customary cement.

Stage 2: barrels having size 150mm width and 300 mm stature were threw for the assurance of the compressive quality of the ease concrete by including mineral admixtures.

Stage 3: barrels having size 150mm measurement and 75 mm stature were threw for the assurance of the compressive quality of the ordinary cement.

Stage 4: exploratory works were led on regular cement blends by utilizing diverse extents of mineral admixtures i.e., fly fiery remains and silica exhaust this test examination conveyed for two kinds of water-concrete proportion, with five blends at every W/C proportion. The water-concrete proportions considered are 0.3and0.35. the diverse extents of silica exhaust are 0%, 10%,20%, 25%,30% and for fly powder 0%, 10%, 20%, 25%, 30%. At that point the ideal level of mineral admixture was found. Thus comes about are examined and classified.

Stage 5: Here cylinders are prepared with two different types of water-cement ratio.

6.2.2 Mixing

Blending assumes a critical part in solid structures. Legitimate blending gives uniform and top notch concrete and better quality. The solid blend is gotten by mix of Portland bond, fine total and coarse total.

In this undertaking we required typical ordinary. First we make the blending for M25grade ordinary cement with water/bond proportion of 0.3.similrly another trail of customary cement however with water/concrete proportion 0.35 is blended. Furthermore, second blend is finished by including 80% of concrete, 10% of fly fiery remains and 10% of silica exhaust is set up at both water-bond proportion and other three trails likewise blended with separate relative amount.

Fig 6.1 Mixing Of Concrete Raw Materials

6.2.3 Casting of Cylinder Specimen

Casting of the specimen is done as per IS: 10086-1982, material preparation, requirement of materials and casting of cylinders. The mixing, compacting and curing are done according to IS 516: 1959. After casting the cylinder mould is left for 24 hours for air drying. Then the cylinder is demoulded and the cylinder is placed in the curing tank for 28 days.

Fig 6.2 casting of specimen

7 EXPERIMENTAL INVESTIGATIONS

In this project concrete of mix proportion 1:1.36:1.28 will be prepared by using OPC, is mixed with fly ash and silica fumes and conventional concrete, sand as fine aggregate and kankar as coarse aggregate. According to this mix proportion different samples are done. After testing we compare the results of conventional concrete with low cost concrete. The concrete mix samples will be tested to find properties of concrete as follows

1. Compressive strength after 28 days
2. Split tensile strength after 28 days
3. Durability test after 28 days
4. Impact strength after 28 days
5. Stress strain curves after 28 days

7.1 COMPRESSIVE TSRENGTH TEST OF CONCRETE:

1. After 28 days of curing period the specimens are removed from the curing tank and wipe out the excess water from the surface.
2. Let the specimen dry in atmospheric temperature for 24 hrs before testing.
3. The air dried specimen is placed in the compressive strength testing machine in such way that the load of the machine is applied on the opposite faces of the cylinder.
4. The cylinder is positioned properly on the base plate of the machine.
5. The piston of the machine is adjusted so that it touches the top surface of the specimen.
6. Load is applied gradually without any impacts at a rate of140kg/cm^2 /minute until the specimen fails.
7. At the point of failure note down the maximum load value.

Fig 7.1 Cylinders after Curing Left For Air Drying For 24 hrs.

Fig 7.2 Split tensile test

8 TEST RESULTS

8.1 CEMENT

8.1.1 Normal Consistency of Cement

Normal consistency of cement sample was determined as per IS:269-1976 and IS: 4031-1968.

Table 8.1 Normal Consistencyof Cement

TRAIL NO	WEIGHT OF CEMENT	% OF WATER ADDED	DEPTH OF PENETRATI (mm)
1	400	28	15
2	400	30	10
3	400	32	7

Hence the consistency of cement = 32%

8.4 FRESH CONCRETE PROPERTIES

8.4.1 VEE-BEE Test Results

Table 8.2 Vee -Bee values of concrete

S NO	DESIGNATION	W/C ratio	Vee Bee VALUE In sec	SLUMP VALUE in mm
1	CONVENTIONAL CONCRETE	0.3	9	45
		0.35	8	50
2	80% CEMENT +10% FLY ASH +10%SILICA FUMES	0.3	10	40
		0.35	9	45
3	60% CEMENT +20% FLY ASH +20%SILICA FUMES	0.3	10	40
		0.35	9	45
4	50% CEMENT +25% FLY ASH +25%SILICA FUMES	0.3	11	35
		0.35	10	40
5	40% CEMENT +30% FLY ASH +30%SILICA FUMES	0.3	12	30
		0.35	11	35

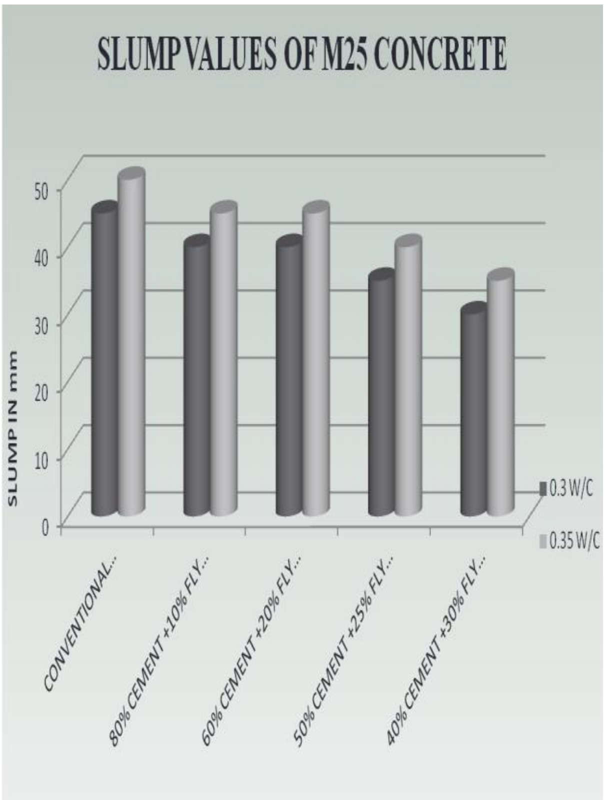

Fig 8.1 Graph representing Slump values of M25 concrete

8.5 FINAL TEST RESULTS

8.5.1 Compressive Strength Results

The results obtained by testing the total 10 specimens of 28 days by considering the average of the test results for conventional concrete and for each mix of concrete. The results are tabulated below:

Table 8.3 Compressive Strength of M 25 concrete at 28 days

S NO	DESIGNATION	W/C ratio	AVERAGE COMPRESSIVE STRENGTH(N/mm^2)
1	CONVENTIONAL CONCRETE	0.3	35.03
		0.35	39.611
2	80% CEMENT +10% FLY ASH +10%SILICA FUMES	0.3	25.745
		0.35	34.2
3	60% CEMENT +20% FLY ASH +20%SILICA FUMES	0.3	24.9
		0.35	31.672
4	50% CEMENT +25% FLY ASH +25%SILICA FUMES	0.3	12.449
		0.35	23.201
5	40% CEMENT +30% FLY ASH +30%SILICA FUMES	0.3	11.883
		0.35	23.766

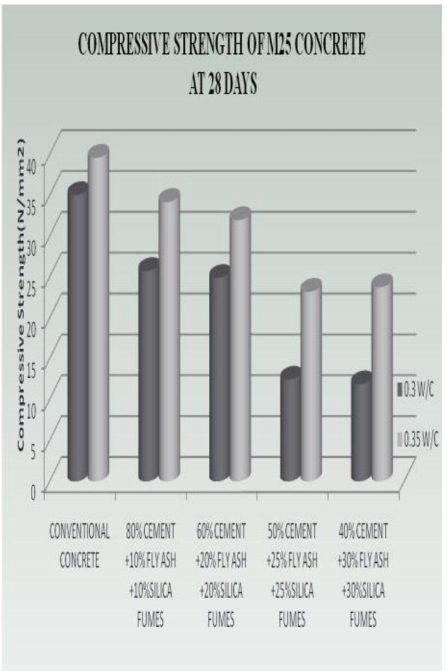

Fig 8.2 graph representing 28 days compressive strength of concrete

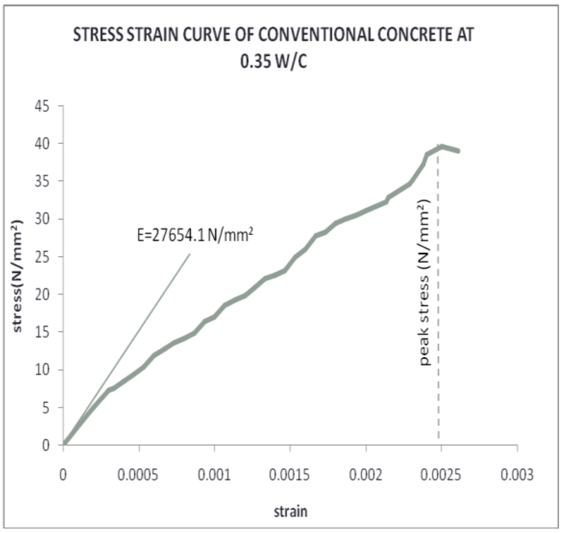

Fig 8.7 Graph Representing Stress Strain Behavior ofMIX 4At 0.35W/C

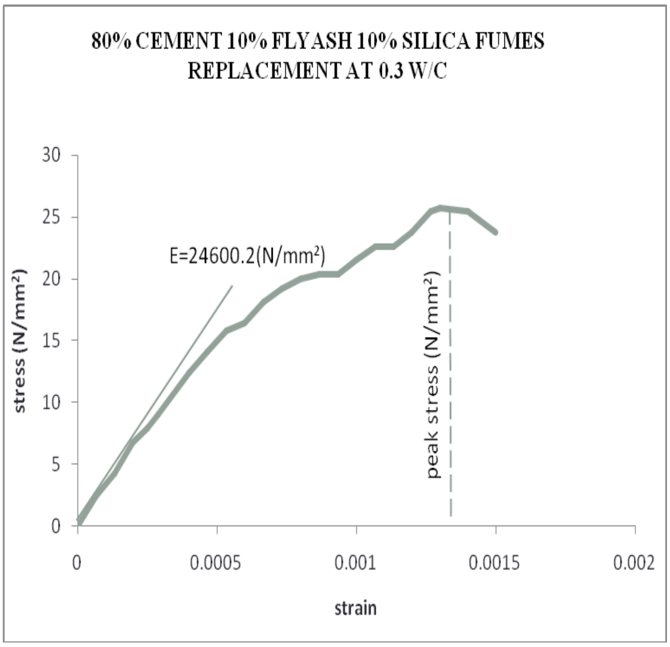

Fig 8.9 Graph Representing Stress Strain Behavior ofMIX 2 At 0.35 W/C

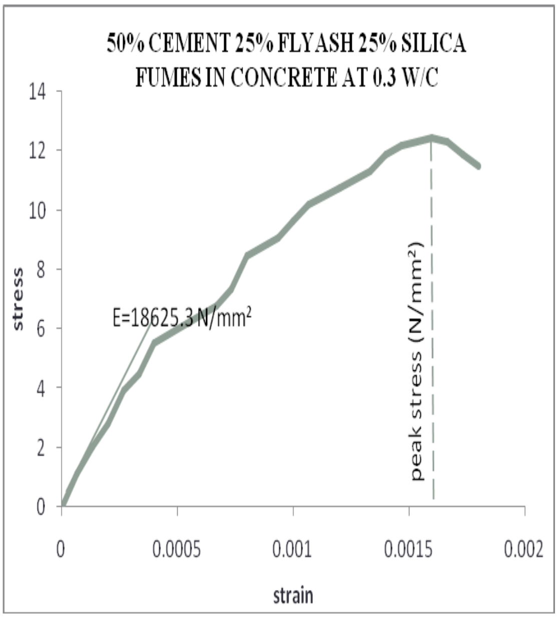

Fig 8.12 Graph Representing Stress Strain Behavior OfMIX 3 At 0.3 W/C

CONCLUSIONS

This study has highlighted the potential for optimizing cement use in street construction through sustainable materials and advanced construction techniques. By incorporating supplementary cementitious materials (SCMs), recycled concrete aggregates (RCA), and innovative curing and reinforcement methods, it is possible to improve the mechanical properties, durability, and environmental sustainability of cement-based pavements.

The research reveals that SCMs like fly ash, slag, and silica fume not only enhance concrete strength and resilience but also reduce the carbon footprint associated with traditional cement production. Similarly, the use of RCA promotes recycling, minimizes waste, and contributes to a circular economy, all while maintaining concrete's structural integrity. Advanced curing techniques and fiber reinforcements have also proven effective in reducing shrinkage, improving crack resistance, and enhancing flexibility under heavy loads.

In conclusion, the study demonstrates that adopting these innovative approaches in cement applications can lead to more durable, cost-effective, and environmentally friendly street infrastructure. Moving forward, additional research and industry collaboration will be essential to standardize these practices and promote their widespread use in urban construction. By prioritizing optimized and sustainable cement applications, the construction industry can significantly contribute to resilient and eco-friendly urban environments that meet the demands of modern infrastructure.

REFERENCES

[1] IRC: 44-2008, "Recommended guidelines for mix design of Cement Concrete Pavements"

[2] Nagesh Tatoba, Suryawanshi Samitinjay S Bhansode et al, "Usage of Eco Friendly Material like Fly Ash in Rigid Pavement Construction and Its CostBenefit Analysis" International Journal of Emerging Technology and Advanced Engineering, Vol-4, Issue-12, December 2012, e-ISSN 2250-2459

[3] Vanitha Agarwal, Gupta S.M, Sachdeva S.N, "Investigations on Fly Ash Concrete for Pavements", International Journal of Civil and Structural Engineering, Vol-2, Issue-3, 2012, ISSN-0976-4399.

[4] S. Antony jeteandran, S. Kathirvel, "Durability Study on High Volume Fly Ash Concrete With and Without Fibres for Pavements", International Journal of Advanced Structures and Geotechnical Engineering, Vol- 3, Issue-4, December- 2014, e-ISSN: 2319-5347.

[5] S. Pavan, S. Krishna Rao, "Effect of Fly Ash on Strength Characteristics of Roller Compacted Concrete Pavement", IOSR International Journal of Mechanical and Civil Engineering, Vol-11, Issue-6, Nov-Dec 2014, pp-04-08, e-ISSN: 2278:1614.

[6] Amit Kumar Ahirwar, Rajesh Joshi, Kapil Soni, “Laboratory Analysis of Fly Ash Mix Concrete for Rigid Pavements”, International Journal of Engineering Research and Applications, Vol-5, Issue-2, February-2015, pp-86-91, e-ISSN: 2248-9622.

[7] R. Illangovana, N. Mahendrana, K. Nagamanib, “Strength and Durability Properties of Concrete Containing Quarry Rock Dust as Fine Aggregate”, APRN Journal f Engineering and Applied Sciences, Vol-3, Issue-5, October- 2008, e-ISSN:1819-6608.

[8] VenkataSairam Kumar, Dr.B.Panduranga Rao, Krishna Sai M.L.N, “Experimental study on partial replacement of cement with quarry dust”, International Journal of Advanced Engineering Research and Studies, E-ISSN: 2249–8974. IS: 2720 (Part - 16)-1979, "Laboratory determination of CBR". June 2013.

[9] A.V.S Sai Kumar, Krishna Rao, “A Study on Strength of Concrete with Partial Replacement of Cement with Quarry Dust and Metaoklin”, International Journal of Innovative Research in, Vol-3, Issue-3, and March -2014, e-ISSN: 2319-8753.

[10] Ramarao Chimita, Venkateswara rao .J, “Innovative usage of Quartzite Rock Dust and Effect of Glass Fibres in Rigid Pavements”, International Journal for Research in Applied Science and Engineering, Vol-3, Issue-IX, September 2015, e-ISSN-2321-9653.

[11] A.Suri Babu, U. Ranga Raju, M. Ravindra Krishna, “Behaviour of Concrete on Replacement of Sand with Quarry Stone Dust as Fine Aggregate”. International Journal of Innovative Research in, Vol-4, Issue-1, and January-2015, e-ISSN: 2319-8753.

[12] Anzad Hamid Mir, “Improved Properties of Concrete Using Quarry dust as Replacement for Natural Sand”, International Journal of Engineering Research and Development, Vol-11, Issue-3, March-2015, e-ISSN-2278-067X.

[13] K. Perumal, R. Sundara Rajan, “Effect of Partial Replacement of Cement with Silica Fume on Strength and Durability Characteristics of High Performance Concrete”, 29th Conference of Our World in Concrete and Structures, 25-26 August, Singapore- 2004, Article Online id-100029050.