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EXPERIMENTAL INVESTIGATION ON EFFECT OF FLY ASH AND STEEL SLAG IN CONCRETE PAVEMENTS

N. SUMI & R. MALATHY

Department of Civil Engineering, Sona College of Technology, Salem, Tamil Nadu, India

ABSTRACT

This paper describes the optimum level of replacement for strength and workability of concrete for pavement by replacing different percentage of fly ash and steel slag by weight of cement and fine aggregate for a mix of M40 grade concrete. Hence the study is made on effect of fly ash and steel slag on the performance of various parameters of concrete so as to produce an economical concrete for rigid pavements. An experimental investigation has been made to utilize the achieved flexural strength of concrete in the rigid pavement design which is greater than the required flexural strength as per IRC: 58-2002. Pavement design results are verified with Analysis software. The main objective of the project is to find out alternative materials for road pavements to meet the demands of bitumen for the upcoming years, to provide adequate serviceability at minimum cost, to make the eco friendly roads with safety, and speed for the flow of traffic. In this investigation, an attempt has to be made to determine the feasibility of industrial waste products such as steel slag and fly ash use in base layer of concrete road pavements.

KEYWORDS: Concrete Road Pavements, Fly Ash, Steel Slag, Cost Effective

INTRODUCTION

Concrete is a mixture of cement, fine aggregate, coarse aggregate and water. Globally concrete is the backbone for the development of infrastructure Viz., buildings, industrial structures, bridges and highways etc. leading to utilization of large quantity of concrete. In today's situation concrete needs special combinations of performance and uniformity requirements that cannot be always achieved by using conventional constituents and normal mixing. This leads to search for admixtures to improve the performance of the concrete. With the experimental investigations and proven results the mineral admixtures are used in the concrete successively. Concrete may be used as a sub-base / base course material in the rigid pavements. If the locally available materials, including marginal and industrial waste are utilized, it could be possible to reduce the cost of road construction.

The price of the bitumen has gone up hence in the upcoming years the availability also will be a matter of serious concern. For new flexible pavements the design life for major roads is taken as 15 years is recommended for national highways and state highways and a design life of 10 to 15 years is recommended for other roads. India imports about 70 % of its oil needs and this over dependence on imports is likely to increase further during the coming years, causing serious drain on the foreign exchange reserves. Advantages of concrete pavements over bitumen pavement are long life over 30 – 40 years, free maintenance, good riding quality, hard surface, avoiding penetration of water, good reflective characteristics. In concrete pavements we can use the waste materials such as fly ash, slag as a partial replacement gives cost effective and high strength.

CONCRETE ROAD PAVEMENTS

The increasing price of bitumen worldwide has lead to the adoption of concrete pavements and overlays on top of bituminous surface in several developed countries abroad. In France, nearly two-third of the national highway network showed inadequate pavement thickness at the end of the 1060's. the country, therefore took up a co-ordinate programme of concrete overlays. Nearly 18000 kms out of 28000 kms of national highways received concrete overlays during the period 1969 to 1982. Belgium introduced concrete overlays in 1960. The main reason for the choice in Belgium is continuously reinforced concrete overlays for major roads gives excellent performance of this type of pavement in the long term, the virtual lack of maintenance cost and the reduced user cost. In USA, plain concrete has been used extensively for resurfacing in California. Since 1960,in has been reported in 1981 that: " plain concrete resurfacings without dowels are reinforcd cement have given excellent service in California.In UK,the first application of concrete overlays on a flexible pavement in UK in 1981 was reported by Gregory. Considering the damages caused by heavy rains to bituminous surfacing every year, Mumbai city has adopted concreting of its roads in a phased manner over the past twenty years. As a result, out of the 1941 kms of roads maintained by the municipal corporation of greater Mumbai, there are 507 kms of concrete roads.

To achieve high strength, admixtures and low water cement ratio have been used. A technology demonstration project on whitetopping was recently constructed in Bengaluru city. The stretch selected was 30m wide and 350m long stretch of the hosur road. On an experimental basis Delhi government had started a 7 kms stretch of road in the heart of city from devil village to moolchand junction as a BRT corridor which gives priority to the buses. A conventional whitetopping was provided on this road with 25cm. Pune Municipal Corporation has constructed a small demonstration project in whitetopping in front of Pune Municipal Corporation building in may 2003. Ultra thin white topping has been laid on a road patch in thane city on one of the busiest routes near the ghantalimandir in thane in 2007 and Mahagiri road at wholesale market in 2008.

RESEARCH SIGNIFICANCE

The main objective of the paper is to find out alternative materials for road pavements to meet the demands of bitumen for the upcoming years. Addition of alternate materials which reduces cement content results in the less emission of carbon dioxide. To make the eco friendly roads with high performance and cost effective in this investigation, an attempt has been made to determine the feasibility of industrial waste products such as steel slag and fly ash use in base layer of concrete road pavements.

EXPERIMENTAL INVESTIGATION ON CONCRETE

Materials

The materials involved in this project are cement, fine aggregate, coarse aggregate and admixtures such as fly ash, silica and rice husk ash. The properties of the materials are tested and tabulated.

Table 1: Physical Properties of Material

S. No	Property	Value
1.	Specific gravity of CA	2.79
2.	Water absorption of CA	0.6%
3.	Fineness modulus of CA	6.98
4.	Specific gravity of FA	2.65
5.	Specific gravity of steel slag	3.9
6.	Water absorption of steel slag	2.3%
7.	Fineness modulus of FA	2.48
8.	Fineness modulus of steel slag	2.94
9.	Specific gravity of fly ash	2.45
10.	Specific gravity of cement	3.15

Table 2: Specific Gravity of FA with Steel Slag

% of Replacement of Steel Slag with FA	Specific Gravity of Fine Aggregate
0%	2.65
10%	2.70
20%	2.78
30%	2.86
40%	3.00
50%	3.06

From table 1 The values such as specific gravity, water absorption fineness modulus is within the limits and the adjustments were made in the mix design for its values. From table 2 the property of specific gravity of fine aggregate with the combination of steel slag were tested. The values of specific gravity are getting increased with the increase in percentage of addition of steel slag with natural sand. The increasing effect is due to the greater finer particles in steel slag and the absorption of water is more.

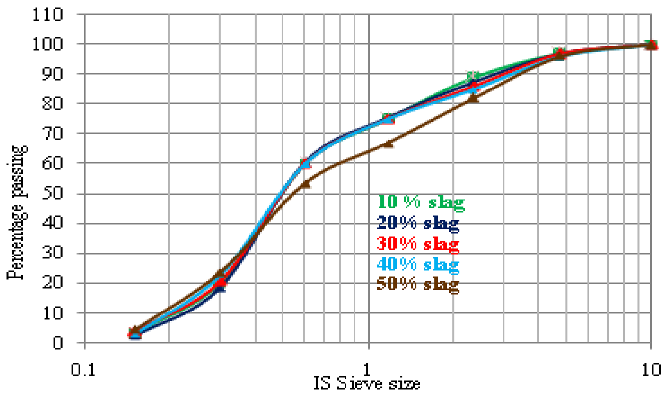
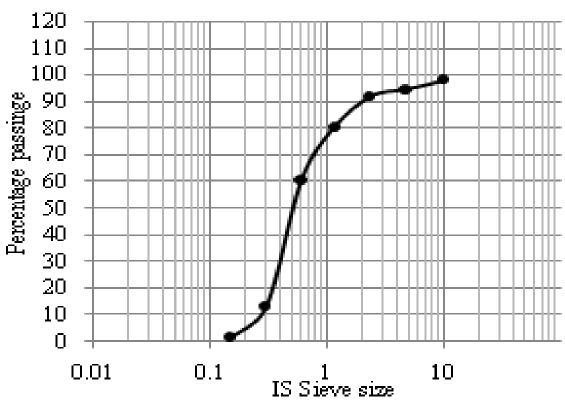
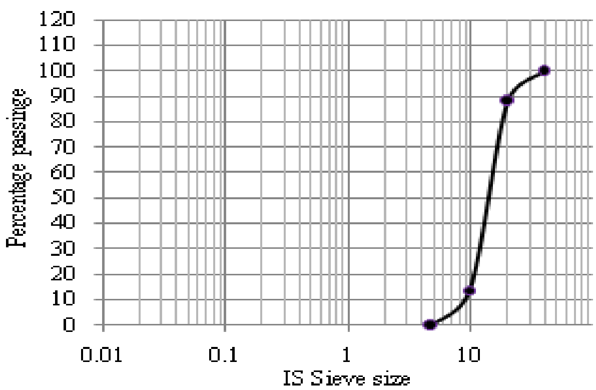


Figure 1: Particle Size Distribution Curve Steel Slag with Fine Aggregate

From figure 1 the sieve analysis has been made with the combination of sand with percentage increase of steel slag as per IS 383 1970 codal provisions. The above graph depicts that the particle size distributionupto 40 % slag it conforms zone III which means finer sand and the adjustments were made in the mix design according to the changes in condition.



a) Fine Aggregate



b) Coarse Aggregate

Figure 2: Particle Size Distribution Curve for

From figure 2a) the particle size distribution curve for natural sand conforming to zone III which was finer sand and figure b) depicts the particle size distribution curve for coarse aggregate satisfies the requirements as per IS 383 1970 of table 5.

Mix Design

Mix has been designed for M40 grade concrete by Indian standard recommended method of concrete mix design as per design code IRC 44 and IS: 10262-1982.

Table 3: Mix Proportion for Concrete

Mix ID	Replacement Level of Steel Slag	Mix Proportion for M40 Concrete
A	0%	1: 0.84: 3.25
B	10%	1: 0.86: 3.25
C	20%	1: 0.80: 3.25
D	30%	1: 0.81: 3.25
E	40%	1: 0.85: 3.25
F	50%	1: 0.86: 3.25

From table 3 the mix ratios for cementitious material which contains 70 % cement and 30 % fly ash, fine aggregate which includes natural sand and steel slag, coarse aggregate were listed.

Experimental Procedure

The experimental investigation carried out in soil to determine their properties and the test procedure for finding out the compressive strength of concrete and flexural strength of concrete as per IS 516-1959. Slump test is used to determine the workability of fresh concrete. Slump test as per IS: 1199 – 1959 is followed. The apparatus used for doing slump test are Slump cone and tamping rod. The cube specimen of the size 150mm X 150mmX150mm is made and tested in compression testing machine to determine the compressive strength of concrete. The beam specimen of the size 500mm X 100mmX100mm is made to determine the flexural strength of concrete. The specimen test is done in Universal Testing Machine (UTM).

RESULTS AND DISCUSSIONS

Slump Test

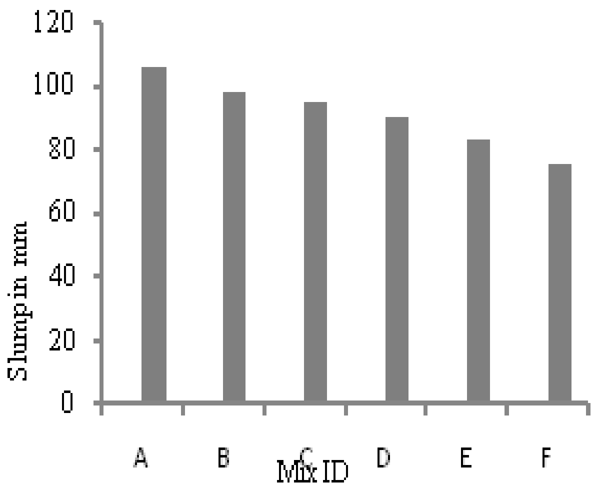


Figure 3: Slump Variation for Different Mixes

"SP-430" of 1.5 % of cement was used to enhance the workability of fresh concrete for selected proportions of ingredients. Figure 3 shows that the slump values for concrete with super plasticizer getting decreased from Mix A to F. The workability of concrete was increasing with the combination of fly ash for cement and steel slag for fine aggregate with addition of super plasticizer in fresh concrete.

Compressive Strength of Concrete

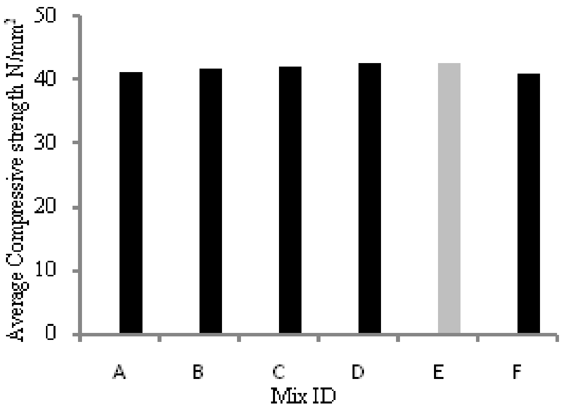


Figure 4: Compressive Strength of Concrete

In this concrete cubes have been made with fly ash as replacement of cement and steel slag as replacement of fine aggregate. From figure 4 the compressive strength of concrete keeps on increasing upto 40% steel slag replacement for fine aggregate and decreased for 50 % replacement. The increasing strength was due to good particle packing of concrete with steel slag. The grain size distribution of steel slag varies after 40% replacement than normal sand.

Flexural Strength of Concrete

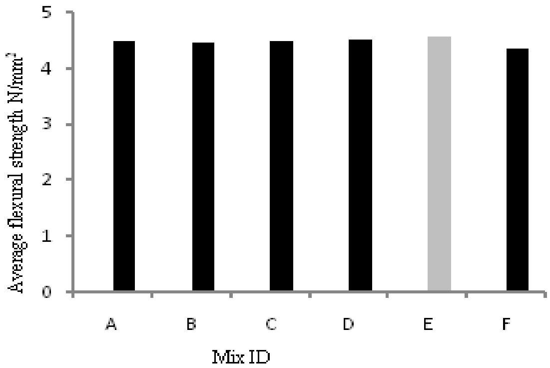


Figure 5: Flexural Strength of Concrete with Fly Ash and Steel Slag

In this concrete beams have been made with fly ash as replacement of cement and steel slag as replacement of fine aggregate. Figure 5 the flexural strength of concrete increases and shows that maximum flexural strength attained during 40% replacement of steel slag with fine aggregate. When the compressive strength increases as well as the flexural strength also increases which is the important criteria for concrete road pavement.

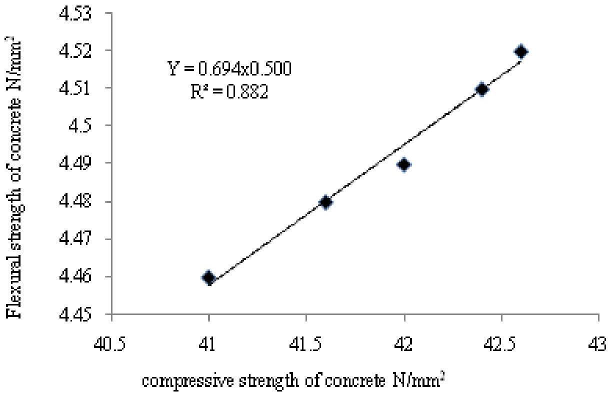


Figure 6: Compressive Strength vs Flexural Strength of Concrete

Figure 6 shows the graph between compressive strength of concrete and flexural strength of concrete. The trend line was drawn for the relation between them and the equation has been developed for the points. The equation displayed is almost similar to $f_b = 0.7 \sqrt{f_{ck}}$ ..the flexural strength of concrete is important criteria for concrete road pavements and it should be more than 4 N/mm^2 as per IRC 44 and IRC 58 which were attained using 40 % replacement of steel slag for fine aggregate in the present research.

Cost Analysis

The cost of concrete pavement was evaluated and analyzed. The comparison of normal concrete pavement has been made with concrete pavement using replacement of fly ash for cement and steel slag for fine aggregate. The result of cost analysis with comparison shows that the concrete pavement with replacement of fly ash and steel slag was reduced. The cost of 15 percentages has been saved for every 1 cubic meter of concrete.

CONCLUSIONS

From the investigations the following conclusions were made

- The physical and chemical properties of fly ash, steel slag were experimented as per codal recommendations and studies have been carried out.
- The optimum replacement level of steel slag for fine aggregate is found to be 40 % combined with 30 % fly ash. Flexural strength of concrete pavement with 40% steel slag and 30% fly ash was determined experimentally for M40 grade concrete, which was found to be greater than the required as per IRC 58.
- The cost analysis of normal concrete pavement and concrete pavement using fly ash for cement and steel slag for fine aggregate has been made with the current price in the market.
- The evaluated cost has been compared for normal concrete pavement with concrete pavement using fly ash and steel slag and discussed. The result of concrete pavement using fly ash and steel slag was found to be economical when compared with normal concrete pavement.
- The cost saving was found to be 15%, hence it shows that the utilization of industrial waste products such as fly ash and steel slag in concrete pavements were cost effective, eco friendly and energy efficient.

Scope for Further Work

The effect of other industrial by products like silica fume, metakaolineetc on road pavement may be incorporated and to reduce the thickness of the road pavement fibers can also be incorporated. The steel slag may also be replaced for Coarse aggregate and its behavior can be studied. Further investigation is needed to reduce the grade of concrete without compromising its flexural strength.

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