Effect of Different Percentage Replacement of Weathered Aggregate in Place of Normal Aggregate on Young's Modulus of Concrete to Produce High strength and Flexible/ Ductile Concrete for use in Railway Concrete Sleepers

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Abstract— *High performance concrete (HPC) is generally defined as a concrete with higher structural capacity and/or improved durability as compared to ordinary Portland cement concrete. It is currently being used for pertaining to its mechanical properties and durability characteristics. The associated tests include compressive strength, modulus of elasticity. The objective of this work is to quantify the effects of coarse aggregate on the modulus of elasticity of (HPC) concrete. A series of laboratory tests investigations have been conducted. The laboratory tests pertain to the experimental determination of the elastic modulus of HPC using coarse aggregates from various sources. Results of the tests show that the IS recommended equation is not always appropriate for estimating the modulus of elasticity of concrete. Depending on the source of the aggregates, relationships exist between the modulus of elasticity of the aggregate, its LA abrasion and the resulting modulus of elasticity of the concrete. The main aim of this is to reduce the young's modulus of concrete by considering different percentage of weathered aggregate in place of normal aggregate and also considering the optimum percentage of fly ash can be replaced instead of ordinary Portland cement(53 grade) in M50 concrete mix and also the mechanical properties. Here in this present study we are investigating the effect of different percentage (%) partial replacement of weathered aggregate in place of normal aggregate by considering the replacement percentage (%) of 50%, 75%, and 100% respectively. and also considering the replacement percentage of 20% cement with fly ash.*

Keywords — *High performance concrete, weathered aggregate, High strength reduced modulus concrete, Ductile concrete, Flexible concrete, sleeper concrete, concrete tie*

I. INTRODUCTION

Concrete is widely used construction material for various types of structures due to its structural stability and strength. The objective of this project is to develop and characterize a High-Strength Reduced Modulus High Performance Concrete (HSRM-HPC) and produce, test and qualify a concrete tie made of this material. The proposed concept takes advantage of the high strength of High performance concrete (HPC) while preserving the structural flexibility of the timber or composite ties, as the HSRP-HPC elastic modulus is similar to that of regular strength concrete. A recent pilot study on tie performance indicated that the use of HSRM-HPC reduces the stress amplitudes and, most importantly, regularizes the stress fields in the most critical areas of tie stress failure and improves the load distribution. This concept leads to an inexpensive, technology-based modification of current practices in prestressed concrete tie technology that: (1) improves the safety of the rail service and maintenance operations; and (2) results to significant cost savings by increasing the life span of the tie and further decreasing the maintenance costs.

II. MATERIALS

A. Cement: Ordinary Portland cement, conforming to the requirements of – IS 12269: 1987 was used in this investigation.

B. Water: Potable water available at the laboratory was used throughout the investigation.

C. Coarse Aggregate: 20-mm natural round uncrushed course was used. Both virgin natural unweathered and weathered aggregates from quarry in perecharla (Granite-Gneiss)

D. Fine Aggregate: Locally available sand is used in this investigation.

E. Admixture: CHRYSO Enviro Mix 300 is recommended for all concrete mixes where significant water reduction, improved cementations material performance, (MORE) normal to accelerated set times and enhanced finishing characteristics are desirable. CHRYSO Enviro Mix 300 is especially effective in improving compressive strengths in all ages with good workability. Dosage: 200 to 400 ml for 50 kg bag.

III. LITERATURE REVIEW

High performance concrete (HPC) has been defined in different ways by many authors. In the construction industry, concretes with higher strengths and enhanced performance properties, as compared with normal concrete, are highly desirable. It was not until 1991, however, that quantitative values for performance criteria were given. Researchers of the Strategic Highway Research Program SHRP-C-205 on HPC, in 1991, defined HPC for pavement applications in terms of strength, durability attributes and water-cementation materials ratio as follows (Zia et al., 1991):

1. HPC shall have one of the following strength characteristics:

   a) 4-hour compressive strength ≥ 2500 psi (17.5 MPa) termed as very high early strength concrete (VES),

   b) 24-hour compressive strength ≥ 5000 psi (35 MPa) termed as high early strength concrete(HES),

   c) 28-day compressive strength ≥ 10,000 psi (70 MPa) termed as very high early strength concrete (VHS).

2. HPC shall have a durability factor ≥ 80% after 300 cycles of freezing and thawing

3. HPC shall have a water-cementation materials ratio≤ 0.35. Later, in 1996, the Federal Highway Administration (FHWA) developed criteria for four different performance grades of HPC expressed in terms of its durability characteristics and strength parameters. HPC is currently being used for bridge construction to protect reinforcement from corrosion, resist chemical and physical attack and to improve the structural performance of bridges. HPC is intended to reduce the life-cycle cost of bridges, extending the service life of bridges, though usually initial cost is high.

In a report, by Petrou and Harries (1999), on HPC used in South Carolina for Bridge decks, significant shrinkage cracks were observed in many of the bridge decks. This led to the development of a program to determine if the Class E concrete used in South Carolina is considered a HPC according to the FHWA HPC Performance Grade Criteria (Walters, 2002).The durability and strength properties are discussed briefly in the next two sections with respect to HPC currently being used in South Carolina. The HPC used in South Carolina is referred to as Class 6500. When this study was initiated, this concrete was referred to as Class E; the Class E name is used throughout this work.

Wu et al. (2001) performed compressive strength, fracture energy and elastic modulus tests on high performance concrete having a w/c ratio of 0.26 with limestone from Hunan, granite from Fujian, quartzite from Shanghai and marble from Anhui as coarse aggregates. They also determined the mechanical properties of the aggregates by performing tests on cores drilled from the rock at the production sites of the aggregates. The order of increasing modulus of elasticity of the aggregate and of the concrete with respect to the mineralogical characteristics of the aggregate is: limestone, marble, granite and quartzite. They suggest that the reason for this trend may be that the modulus of quartzite is higher than the other aggregates by 30-50%.

Significant similarities in the hysteresis loops between some selected rocks aggregates, located in Canada, and their respective aggregate concretes were observed by Baalbaki et al. (1992c). The water-cementitious ratio of their high performance concrete was 0.27 and the three different aggregates used were dolomitic limestone, quartzite and sandstone. The shape of the loading-unloading stress-strain curve of the respective aggregate-concretes was the same as that of the rocks from which the aggregates were obtained. The sandstone they used produced the highest uniaxial compressive strength but the lowest modulus of elasticity at 28 and 91 days. They concluded that the elastic modulus of concrete is strongly influenced by the elastic properties of the coarse aggregate and that the present formulae relating the elastic modulus of concrete and compressive strength are not valid for HPC. They also suggest that in HPC, the uniaxial compressive strength may be controlled by the weakest component of the concrete.

Alexander and Milne (1995) investigated the influence of four coarse aggregate types available in South Africa: dolomite, andesite, quartzite and granite on the stress-strain behavior and elastic modulus of concrete. Their test results showed clearly that the modulus was obviously dependent on aggregate. Andesite and dolomite yielded considerably stiffer concretes than granite and quartz with granite yielding the least value. They also studied the hysteresis loops of the various aggregate concretes from which they observed that granite showed the greatest non-linear behavior. The stress-strain behavior of dolomite was more linear elastic than granite and the quartzite concretes behavior was intermediate between granite and dolomite concretes. They concluded that stiffer concretes are likely to be produced using dolomite or andesite aggregates. Additionally, 90-180 day old concrete of all aggregate types experience significant increases in modulus of elasticity that are not solely strength related. In their hypothesis they state that different aggregates and cement blends affect the nature of the transition zone, which influences the concrete properties measured.

Aitcin and Mehta (1990) investigated the influence of four coarse aggregate types available in Northern California: diabase, limestone, gravel and granite on the compressive strength and elastic behavior of a very high strength concrete mixture (0.275 w/c ratio). Their test results showed the following order of increasing modulus of elasticity of concrete with respect to the mineralogical characteristics of the aggregate: granite, gravel, limestone and diabase. The granite aggregate they used gave the worst result because of its mineralogy. It was found to contain laumonite, which is known to be an unstable mineral. The gravel was not as weak as the granite but formed a weak aggregate-cement paste bond. They generated hysteresis loops for the different aggregate concretes from which significant differences in the elastic modulus and hysteresis loops were observed. They conceded that concretes made from smooth river gravel and from crushed granite that contained inclusions of a soft mineral exhibited an unrecoverable plastic strain as compared to crushed aggregate from fine-grained diabase and limestone where there was no plastic strain within the elastic limit.

IV. MIX PROPORTIONS

TRAIL MIXES: To fix the dosage of admixture by conducting different trail mixes:

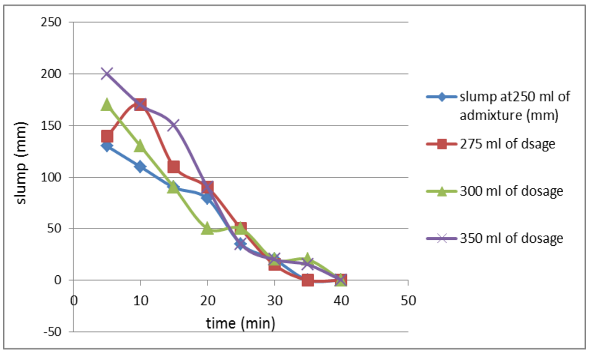

Fig. 1 Slump at Different Dosages of Admixtures

For above trail mixes we can conclude that it was found that the performance of 275 ml of admixture per cement bag (50 kg) is better among the above trail mixes. Cement = 422 kg/m^3

Water: cement: F.A.: C.A. = 0.4: 1: 1.65: 2.92.

V. CONCRETE PROPERTIES EVALUATED

1. Compressive strength
2. Young's Modulus of elasticity

A. Methods of Determination of the Static Modulus of Elasticity: The static modulus of elasticity of concrete in compression is given by the slope of the stress-strain curve for the concrete under concentric uniaxial loading. In reinforced concrete design and analysis, most often than not, empirical expressions are used to estimate the elastic modulus. The laboratory methods and empirical methods are discussed in the following sections.

B. Laboratory/ Experimental: The elastic modulus is generally expressed as a secant, chord or tangent modulus obtained from the stress-strain curve for concrete under uniaxial loading. These three methods are used because of the non-linear behaviour of concrete. The tangent modulus is given as the slope of a line drawn tangent to the stress-strain curve at any point on the curve. The secant modulus is defined as the slope of a line drawn from the origin to a point on the curve corresponding to 40% of the failure load. The chord modulus of elasticity, as determined by IS456, is defined as the ratio of the difference of the stress at 40% of the ultimate strength and the stress at 50 millionths strain to the difference in strain corresponding to the stress at 40% of ultimate strength and 50 millionths strain. Essentially, the slope of the chord defined by these two control points is the chord elastic modulus.

VI. RESULTS AND DISCUSSION

A discussion of the results obtained from the experimental program is presented. A comparison of the results with respect to the source of aggregates and the elastic modulus of concrete and compressive strength respectively. A comparison is also made between the IS 456:2007 formula based elastic modulus and the laboratory concrete modulus.

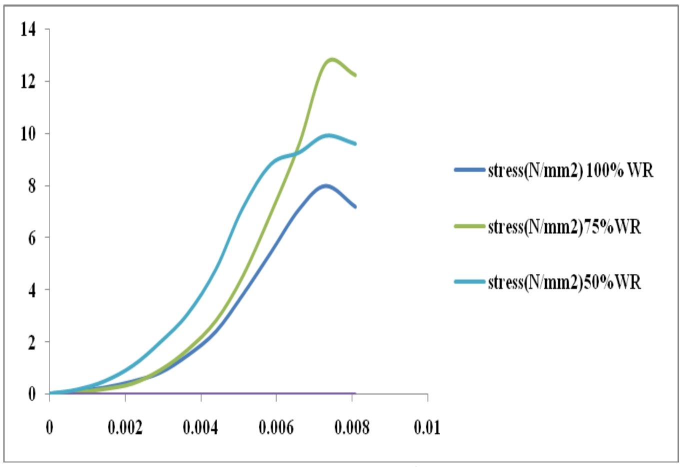

Fig. 2 Stress strain curve in compression for concrete 50% replacement of weathered aggregate @ 7 days

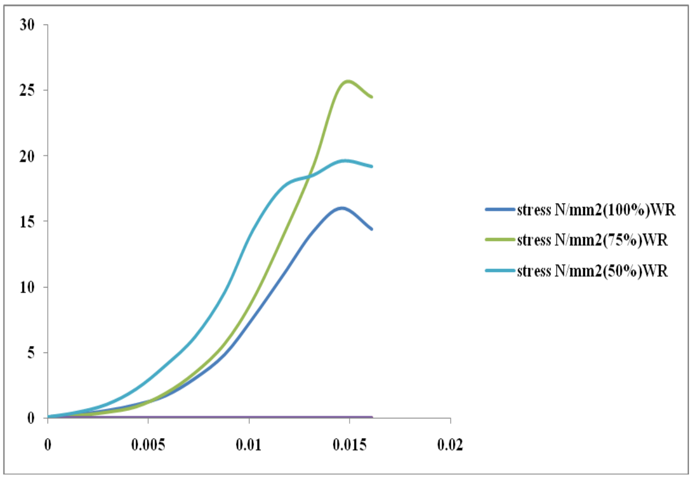

Fig. 3 Stress strain curve in compression for concrete concrete 75% replacement of weathered aggregate @ 7 days

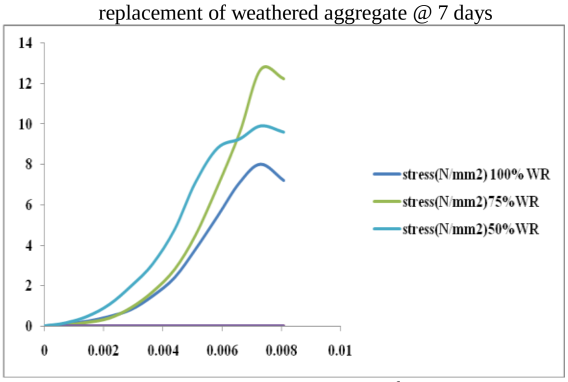

Fig. 4 Stress strain curve in compression for concrete 100% replacement of weathered aggregate @ 7 days

A. Comparison of Traditional and Weathered Aggregate:

Comparison of modulus elasticity of concrete between traditional and weathered aggregate at the age of 7, 14, 28 respectively.

TABLE I

COMPARISON OF MODULUS ELASTICITY OF CONCRETE

Age of concrete in days	**Traditional aggregate (N/mm^2)**	**Weathered Aggregate % replacement (N/mm^2)**		
		50%	**75 %**	**100%**
7	12096.75	194.63	153.73	143.29
14	20107.614	233.32	178.3	152.32
28	30090.05	344.70	265.68	246.04

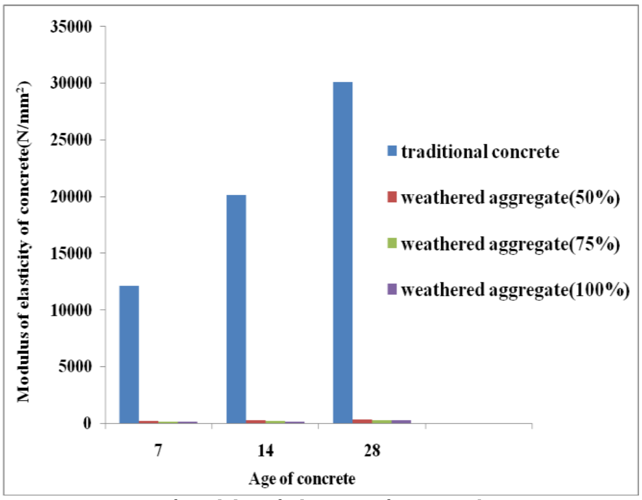

Fig. 5 Comparison of Modulus of Elasticity of Concrete between traditional and weathered aggregate

A graphical representation of the relationship between traditional and weathered aggregate concrete, presented in Table1 is shown in Figure 5. These results show that depending on the type and source of the aggregates used in a high performance concrete mix, the modulus of elasticity increases for un weathered aggregates or remains essentially unchanged for weathered aggregates as the compressive strength increases and modulus elasticity of concrete decreases**.**

B. Compressive Strength for Traditional and Weathered Aggregate:

TABLE II

COMPARISON OF COMPRESSIVE STRENGTH OF CONCRETE

Age of concrete in days	**Traditional concrete (N/mm^2)**	**Weathered Aggregate % replacement (N/mm^2)**		
		50%	**75%**	**100%**
7	25	24.2	23.4	22.2
14	36.93	36.5	36.1	35.2
28	70.815	62.2	60.95	55.27

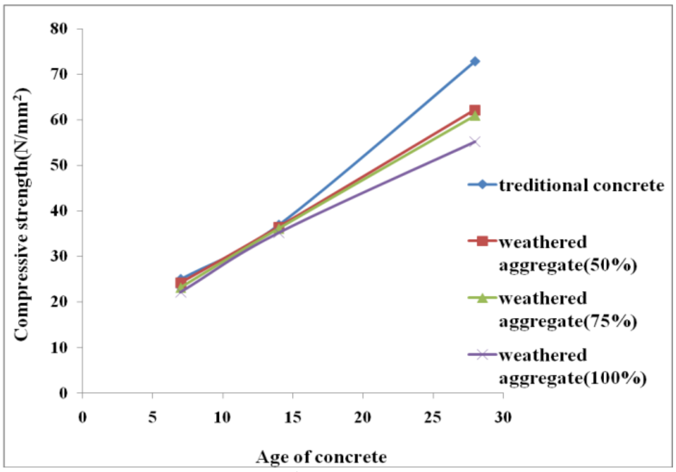

Fig. 6 Compressive Strength for Traditional and Weathered Aggregate

C. Elastic modulus VS compressive strength:

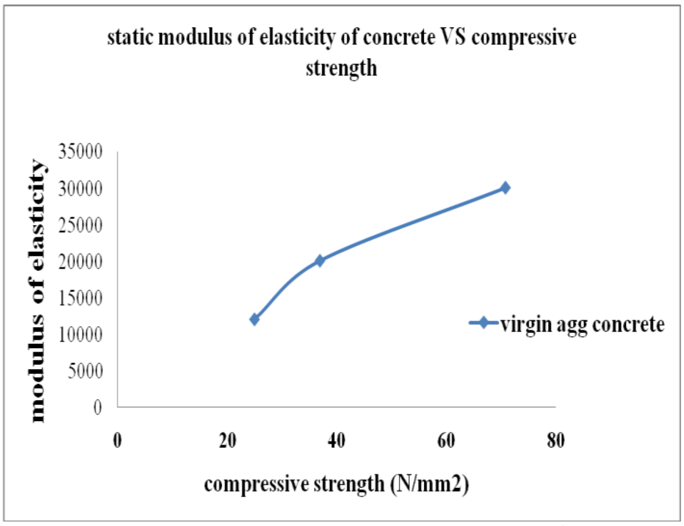

Fig. 7 Elastic modulus VS compressive strength for Virgin Aggregate Concrete

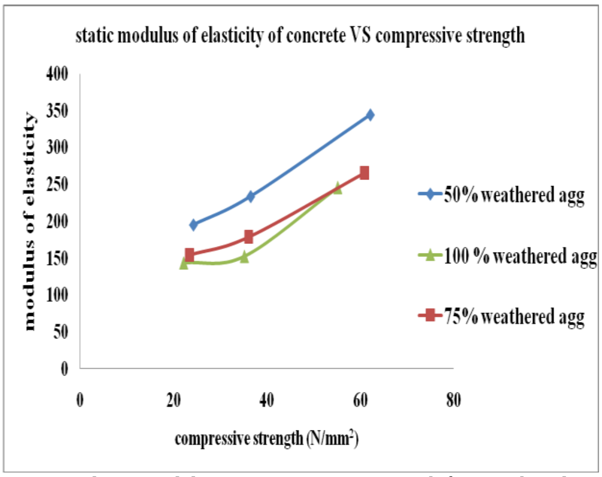

Fig. 8 Elastic modulus VS Compressive strength for Weathered Aggregate Concrete

VII. CONCLUSIONS

The optimum dosage of admixture is 275 ml per 50 kg bag of cement. Two weathered aggregate quarry concretes were investigated and its potential in terms of young's modulus and compressive strength at different ages were investigated and compared to traditional virgin aggregate concrete. For the weathered aggregate concrete modulus of elasticity becomes very less and observed increased ductility indicating the concrete flexible. Moreover the weathered aggregate concrete has got enough strength on par with traditional concrete. As the percentage of virgin aggregate decreases concrete is becoming flexible and we can observe very less young's modulus of concrete. Hence this high strength reduced elastic modulus can be used in concrete sleepers to reduce stresses. The weathered aggregate concretes are characterized by transgranular type of fracture, with the shear plane passing through the aggregates and cement mortar. The un weathered aggregate concretes are characterized by fracture mainly through the cement mortar and not necessarily through the aggregates.

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