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Experimental studies in Ultrasonic Pulse Velocity of roller compacted concrete pavement containing fly ash and M-sand

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Abstract

This paper presents the experimental investigation results of Ultrasonic Pulse Velocity (UPV) tests conducted on roller compacted concrete pavement (RCCP) material containing Class F fly ash of as mineral admixture. River sand, M-sand and combination of M-sand and River sand are used as fine aggregate in this experimental work. Three types of fly ash roller compacted concrete mixes are prepared using above three types of fine aggregates and they are designated as Series A (River sand), Series B (manufactured sand) and Series C (combination of River sand and M-sand). In each series the fly ash content in place of cement is varied from 0% to 60%. In each series and for different ages of curing (i.e 3, 7, 28 and 90 days) forty two cube specimens are cast and tested for compressive strength and UPV. The UPV results of fly ash containing roller compacted concrete pavement (FRCCP) show lower values at all ages from 3 days to 90 days in comparison with control mix concrete (0% fly ash) in all mixes. However, it is also observed that Series B and C mixes containing fly ash show better results in UPV values, compressive strength and Dynamic Elastic Modulus in comparison to Series A mixes with fly ash. Relationships between compressive strength of FRCCP and UPV and Dynamic Elastic Modulus are proposed for all series mixes. A new empirical equation is proposed to determine the Dynamic Elastic Modulus of FRCCP.

Keywords: Compressive strength; Dynamic Elastic Modulus; Fly ash; Roller compacted concrete pavement; Ultrasonic Pulse Velocity

1. Introduction

The River sand obtained from river beds has been used primarily as fine aggregate in concrete production. Since the supply of River sand is inadequate and its incessant supply is not certain, use of manufactured sand (M-Sand) as a substitute to River sand has become inevitable. The International Center of Aggregates Research (ICAR) project work show that concrete can successfully be made using unwashed M-sand without modifying the sand. With the use of manufactured sand in concrete there was increase in flexural strength, improved abrasion resistance, increased unit weight and lowered permeability [44].

In the recent past, there has been enormous increase in the usage of mineral admixtures in concrete such as fly ash and Ground Granulated Blast Furnace Slag (GGBS) and it has become one of the ingredients of concrete [1–12]. The American Concrete Institute (ACI) defines roller compacted concrete (RCC) as the concrete compacted by roller compaction [24]. RCC is a stiff and extremely dry concrete and has a consistency as that of wet granular material or wet moist soil. The use of RCC as paving material was developed from the use of soil cement as base material. The first use of RCC pavement was in the construction of Runway at Yakima, WA in 1942 [25]. The

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Nomenclature

UPV	Ultrasonic Pulse Velocity	t	concrete age [days]
RCCP	roller compacted concrete pavement	V_p	velocity, km/s
FA	fly ash of Class F	V	pulse velocity (m/s)
M-sand	manufactured sand	L	length of travel (m)
FRCCP	fly ash roller compacted concrete pavement	T	effective time (s)
ICAR	International Center of Aggregates Research	g	acceleration due to gravity, m/s^2
ACI	American Concrete Institute	ρ	Density of concrete in KN/m^3
E_d	dynamic modulus of elasticity	f_c	cube compressive strength of RCC in MPa
V_L	longitudinal wave velocity m/s	$(E_d)_t$	dynamic modulus of elasticity at the age of t days in MPa
V_S	shear wave velocity m/s	p_{fa}	% of replacement of cement by fly ash
E	dynamic modulus of elasticity (GPa)		
μ	dynamic Poisson's ratio		

main advantage of RCC over conventional concrete pavement is the speed in construction and cost savings. RCC needs no formwork, dowels and no finishing [26].

In roller compacted concrete pavements addition of active mineral admixtures like fly ash has great scientific significance. Fly ash (FA) consists of SiO_2 and Al_2O_3, and has high potential activity. The main useful and significant effects of FA can be three fold: Morphologic effect, pozzolanic effect, and Micro aggregate effect [49]. Research in India regarding the utilization of fly ash has shown that the quality of fly ash produced at National thermal power Corporation (NTPC) plants is extremely good with respect to fineness, low un-burnt carbon, high pozzolanic activity and conforms to the requirements of IS:3812 – 2003-Pulverized Fuel Ash for use as Pozzolana in cement, cement mortar and concrete. The fly ash generated at NTPC stations is ideal for use in the manufacture of concrete [50].

Assessing the quality of concrete used for paving applications has become essential for control operations during and after construction. Use of fly ash in roller compacted concrete pavement is gaining importance due to numerous advantages. Fly ash has become an essential mineral admixture for producing good pavement quality concrete and the same can be used in the design and construction of low volume rural roads.

Ultrasonic Pulse Velocity (UPV) is a non destructive method of testing of concrete quality, homogeneity and compressive strength of existing structures. This method is also a useful tool in evaluating dynamic modulus of elasticity of concrete [14,15]. The dynamic modulus of elasticity (E_d) is an essential and important factor when assessing the quality and performance of structural concrete [42,43]. The UPV is a useful parameter for estimation of static modulus of elasticity, dynamic modulus of elasticity, static Poisson's ration and dynamic Poisson's ratio [16].

Yıldırım and Sengul [4] conducted experimental investigation on the modulus of elasticity of concrete. A total of 60 mixtures are prepared, in which the effects of water/cement ratio, maximum size of the aggregate, aggregate type, and fly ash content are investigated. Modulus of elasticity of the concretes was obtained besides compressive strength and ultrasound pulse velocities of the concrete. A model is also proposed to predict the dynamic modulus of concrete. The predicted model has close association with experimental test results. Wen and Li [17] conducted experimental study on Young's Modulus of concrete through P-Wave velocity measurements. Two empirical equations for obtaining static Young's Modulus and Dynamic Young' Modulus when dynamic Poisson ratio varies around 0.20. Qasrawi [18] proposed an empirical equation between UPV and Cube Compressive strength of Concrete and its R^2 value was found to be 0.9562. Subramanian Kolluru et al. [19] was proposed a technique for evaluating the elastic material constants of a concrete specimen using longitudinal resonance frequencies using Rayleigh-Ritz method. A simple, accurate and more reliable method is developed for determining dynamic elastic constants of concrete.

Yaman et al. [20] investigated the use of indirect UPVs in Concrete slabs and found similarity between direct and indirect UPVs. A significant conclusion is drawn that the indirect UPV is statistically similar to direct UPV. Choudhari et al. [21] proposed a methodology to determine the elastic modulus of concrete by Ultrasonic method. Conrad et al. [22] investigated stress-strain behavior and modulus of elasticity of young Roller Compacted concrete from the ages of 6 hours to 365 days. The Young's Modulus for the early ages and aged low cementitious RCC can be an exponential type function. Washer et al. [23] conducted extensive research on Ultrasonic testing of Reactive powder concrete. Demirboga et al. [34] found a relationship between ultrasonic velocity and compressive strength of concrete using different mineral admixtures such as fly ash (high volume), Blast Furnace Slag and combination of FA and BFS in replacement of Portland cement. Compressive strength, UPV values are determined at 3, 7, 28 and 120 days curing period. An exponential relationship between compressive strength and UPV was reported.