International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 8 (2017) pp. 1683-1690

Vibration Impact on Fresh Concrete of Conventional and UHPFRC

Sudarshan N.M.[1*] and Dr. T. Chandrashekar Rao[2]

[1]*Department of Civil Engineering, Satara College of Engineering & Management, Satara, Maharashtra, India.*
(Corresponding author)

[2] *Department of Civil Engineering, BCE Bapatla, Andhra Pradesh, India.*

[1]ORCID: 0000-0001-8618-1241

Abstract

In general vibration is unwanted noise and harmful phenomenon for human beings In some cases vibration is beneficial in construction works in mixing, void filling, cement saving, improve quality of concrete, The vibration technique is applied to concrete industry hardly there is no structure without vibration effect, The present research paper focuses on impact of vibrator during mixing and casting has final appearance on the compressive strength on conventional and UHPFRC concrete, Vibration during mixing and casting stage, The workability of concrete by slump tests conducted for conventional and all types of UHPFRC mixes significantly improves workability and strength of the concrete. By the introduction of vibrator during casting stage, the ultrasonic wave propagation in concrete influences stiffness and elastic properties of Ultra High Performance Fiber Reinforced Concrete (UHPFRC) and the experimental test on Ultrasonic pulse velocity method determines the dynamic modulus of elasticity of UHPFRC has no considerable effect on mixing and casting stage. The mix design developed on the particle packing density theory exhibited 28 day compressive strength is 170.25 N/mm^2

Keywords: UHPFRC, vibration impact, mixing stage, compressive strength, concrete slump, slump flow

INTRODUCTION

The strength and durability of conventional concrete depends on number, shape and size of air voids in a concrete. The vibration is an art of compacting concrete particle to a dense mass,The concrete is a basic building material over the development of human civilization depending on the availability of different construction materials stones, ,Metals, wood, composites, polymers have been used as structural materials. The concrete mix in wet stage, resulting lower strength, durability failures, drying shrinkage, and increased cracking However, the relative importance of these prime construction materials has changed over passing time. Composites are structural materials produced through the combination of different constituents. made of horse hairs, vegetable parts (such as straw) and mud. For achieving higher strength. The compaction is required to air entrapped out, compaction is achieved through vibration generated by means of rotating eccentric having a frequency and amplitude pulse liquefy the mortar portion of concrete and thus reduce the internal friction resulting consolidation by force of gravity, The cohesion is restored and reestablished strength increases. The velocity of compression waves generated is 45m/sec in the beginning of vibration and increases to 240 m/sec of at the end. For 200 Hz these velocities correspond to 0.2 m and 1.2 m in wavelength. Edgington and Hannant [1] investigated effect of steel fiber orientation in concrete by vibration exhibiting anisotropic behavior resulting superior effect beneficial to the stress. The addition of fiber in concrete started in the early 1900's The gradual development in concrete yielded to the modern fiber reinforced technology to make densely compacted cement matrix.

Detwiler et al. [2] investigation reports on the effective of use of supplementary cementing materials perform better than the Portland cement concretes. In the early 1950's The first polymer-based composites consisted of glass fibers and then steel fiber concrete tests begin the results showed improvement in overall impact of concrete toughness and fatigue strength achieved by modifying microstructure on the concrete matrix leads to increase in brittleness, strain hardening of the material Graybeal BA [3-4] conducted research program on the Ultra High Performance Fiber Reinforced Concrete (UHPFRC) is a super plasticized, densely compacted worldwide accepted construction material gaining more importance for high strength and durability achieving in construction industry. with suprub properties when compared to conventional concrete Le T, et.al. [5]developed composition of UHPFRC has a high cement and fine aggregate content but no coarse aggregate, a low water cement ratio, high silica fume content and the addition of steel fibers. From the strength and durability point of view, The UHPFRC proven to be new innovative material and ideal solution for long span structures, multi storey buildings industrial structures di Prisco M, et.al. [6] reported the use of the steel fibers are being increasingly employed in floors, road pavements, airport runways, channels linings, and foot over bridges among other applications. One of the main reasons for this increasing use is the possibility of replacing entirely or partially the conventional reinforcement in structural applications the mixing and casting method is over taken to present day with appearance of water on the surface due to use of modern mechanical vibrators and compactors for uniform plastic forming around the specimen. is a sign of higher durability and strength. N.Ochuchi[7] findings in high performance achievement is not a easy task vibration is the alternative method. The production of high strength and durable concrete is possible only with the addition of additives The additives can be broadly divided into two categories based on the nature of availability admixtures and filers. Liquids and solids the most available chemical admixtures are the super plasticizers to increase the workability of the concrete and to reduce water requirement to the mix with high flow ability and packing density achieving Cement, micro silica fine particles size 1-0.1μm and that of cement 35μm the spherical shaped fine particles of micro silica insures a good cohesion between particles and improved resistance to bleeding an efficient filler material in reducing sensitivity and water amount the ratio of chemical admixture to filler material to produce a quality UHPFRC, The vibration requirement is slow in type of material since all materials are very fine particles, The speed vibration may lose properties of material with good form work to support vibration effect and segregation For achieving high design strength material mixing and casting is prime important with vibration. During 1920's Methods other than tamping were tried to consolidate the stiffer concrete. Compressed air was introduced into the fresh concrete through long jets. The introduction of vibration machines begin in 1930's The researchers E.Feyssinet's (1917)[8] improved vibration technique in concrete a symbol of better strength and quality concrete and casting achievement of high strength and durability. L'Hermite (1948) [9] tested several vibration effects on behavior of fresh concrete based on theory and mechanism of concrete i.e. the source of oscillations and behavior of fresh concrete Walz (1960)[10] described the various types of vibrators,i) internal, ii)surface form, iii) table and their applications. showed the reduction in internal friction is primarily the result of acceleration produced during vibration.

Ultrahigh frequency vibration has been investigated in the Soviet Union by Shtaerman (1970)[11] He reported that ultrahigh frequency vibration increases the hydration of the cement and improves the properties of concrete. However, high energy input and heat generation, and the small depth of penetration of the vibration, Allen Hulshize (1970) [12] investigated the vibration effect on fresh and matured concrete affect its properties. In, his investigation broadly focused on the vibration of concrete at required time period. Bastion, et.al. studied the effects of vibratory concrete during the setting period and the floor vibrations on floor mass and longer span lengths, become an area of concern. Krsulovic P [13]studied in a formwork the left over space is not filled with concrete produces poor mechanical physical properties yielding to segregation, insufficient compaction yields to the failure of concrete. Forssblad (1987) [14] reported consolidation needs of flowing concrete mixtures and stress response to internal, surface and vibration. Allen and Rainer, Allen: 1990 b, Murray, 1991[15] Designed a criteria to help designs minimize routine vibrations in floor concrete. In general, hours that comply the criteria useful in their original purpose are observed be acceptable. Safawai M I et. al [16] tested by measuring the workability by slump flow method of SCC and V- flow and suggested four possible categories for improving the concrete. The addition of fibers control cracks bridging a strong interface in concrete matrix with the increase in percentage of steel fibers it transforms strain softening to strain hardening behavior lowering workability efficiency. Laskar AI [17] indicated that difficult to develop globally useful mix design method based on variation in material properties the Ve-Be test could be useful for Fiber reinforced concrete (FRC).

In Modern era the compaction methods of concrete has completely revolutionized by vibration technology, making possible the use of low slump stiff mixes for production of superior quality concrete with required strength and impermeability improved compactness mass. The use of vibration may be essential for the production of good concrete where the congestion of reinforcement or the inaccessibility of concrete in the formwork is such that hand compaction methods are not practicable. Vibration may also be necessary if the available. Concrete is of such poor workability unless large amount of water and cement is used alternatively, vibration produce better quality concrete than by hand compaction. Low cement content and lower water cement ratio can produce equally strong concrete more than by hand compaction. Although vibration properly is a great step forward in the production of quality concrete, it is more often employed as a method of mixing, placing of ordinary concrete easily than a method adopted in high grade concrete at an economical cost. In realiasition potentional advantages of vibration can be done by proper control exercised in the design and manufacture of concrete and certain rules are observed regarding the proper use of different types of vibration.

In this paper the research work is based on introduction of vibrations for conventional concrete and various UHPFRC mixes during mixing, and casting stage effect strength and durability of concrete the difficulties provided by fibers in UHPFRC mixing process generates lack of homogeneity, fluditity and reduction in workability, the vibrations during mixing stage improves workability and in casting stage boosts the robustness, compactness of the concrete, the slump, flow test is conducted.to determine elastic properties, the ultrasonic pulse velocity method is adopted to determine dynamic modulus of elasticity of conventional and UHPFRC concrete the specimens are exposed to 90ºC elevated temperature The 28 day cube compression test conducted for all types of mixes, vibration during casting mix results higher compressive strength.

MATERIAL PROPERTIES

A. Cement

The Aditya Birla brand plant Gulbarga, Ultra tech Portland cement of 53 Grade conforming to IS-12269, 2013, particle size 1-100μ, normal consistency of 28% with specific gravity of 3:15 used.

B.Micro Silica

The R. R. Enterprises Warangal Elkem Micro Silica conforming to Grade 920-D with a grain size 0.2 microns, on combustible irregular shape fine particles and surface area (BET M2-gm < 15) specific gravity 2.25 used as mineral admixture.

B. Sand

The locally available Krishna basin river sand free from impurities with less than 1 mm size sieved through,1000 microns sieve analysis done as per IS 2386-1963 having specific gravity 2.63 conforming to IS 650 specifications.

C. Quartz

The 37 microns India Pvt.Ltd. Hyderabad quartz sand was used from locally available source sized 150-1000 microns contained 99% silicon dioxide; the specific gravity of quartz sand is 2.59

D. Steel Fibers

The R.R. Enterprises Warangal, Dura flex bright, hard non glued ,hook end steel fibers of dia. 0.6mm and length 30mm with modulus of elasticity 210 [GPa] tensile strength more than 1000 MPa having aspect ratio (a / r) =50 are used.

E. Super Plasticizer

United Engineering Corporation Secunderabad supplied polymer based Sulphonated naphthalene Conplast SP430 DIS admixture used to increases the liquid quantity and adequate work ability of concrete to provide excellent acceleration of strength gain reducing water demand in a rheological behavior of concrete mix and its specific gravity is 1.00 confirms to ASTM - C494 type – F.

F. Water

The pure, drinkable, free from chemical, mineral impurities used for mixing & curing to improve the quality and strength of the material clean potable water plays a vital role with super plasticizer to gain higher strengths.

The table No.1 shows the amount of UHPFRC materials variation range the micro silica particle size (1-0.1μm) helps in preventing segregation large particles and allows to transport in all corners of the formwork the level of compaction of concrete mainly depends on the type of vibration effect so as to form evenly spread mix suitable for placing and casting in real conditions

A typical UHPFRC mixture contains various densified materials for achieving higher compressive strength as shown in Table1.Presents range of materials obtained from comprehensive studies of past researchers.

Table 1. UHPFRC Material range in Kg/m^3

Components	Cement	Fine sand	Micro silica	Quartz	Steel fiber	Super plasticizer	Water
Minimum	800	1000	125	180	118	15	120
Maximum	1500	1800	275	350	390	60	220
% by Weight	1.00-2.00	1.25-2.25	0.18-0.37	0.22-0.43	0.09-0.49	0.01-0.07	0.15-0.25

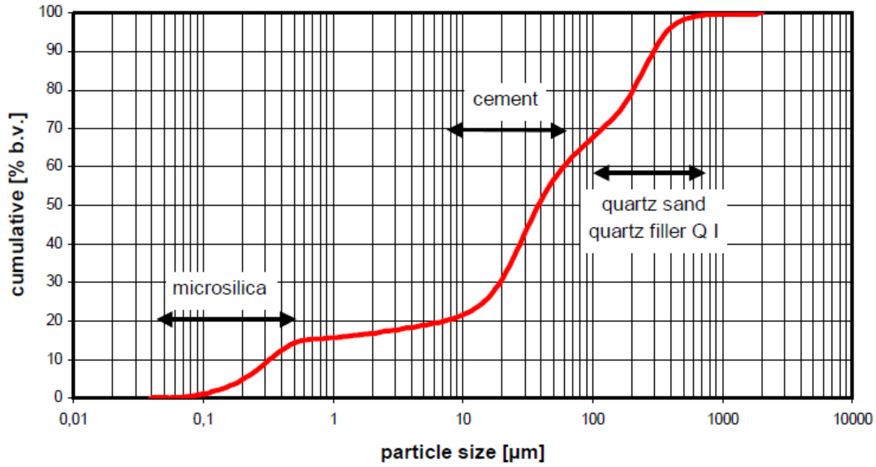

Figure 1: Grain size particle distribution (Schmidt et.al.2003)

The mixture design of UHPFRC material constituents are Cement, Fine sand, Micro silica, quartz, sand, super plasticizer, hooked end steel fiber to resist crack propagation expansion with low water cement ratio. A UHPFRC mix design is based on the crowded particulate suspension with densely compactness of the cementitious material achieving denser concrete matrix. The higher compressive strength of the material linked to the reduced porosity percentage.

$$f_c\ \alpha\left(\frac{1}{1+p_i}\right)$$

$$porosity\ index\ (p_i) = 0.1, 0.2, 0.3$$

Packing Density

A densely particle packing arrangement of materials yields to a higher compressive strength with improved performance to sustain increased load conditions. Mooney[18] developed a new SSM model (solid suspension model) predicting for viscosity of multimodal suspension of non reactive particles in the mix, the liquidity proportion leading to influence viscosity for obtaining optimal mix. The packing density 0.74 component hexagonal arrangement and 0.64 random arrangement the random packing suspension is high but infinite viscosity, relationship between the solid content and mono disperse suspension. In the experimental work focused on the particle packing density by the use micro level fine particles of cement and micro silica as shown in Fig.3 to eliminate air voids in concrete.

The relationship between mono disperse suspension $\emptyset$ and its relative viscosity is given by η_r

$$\eta_r = exp\left(\frac{2.5}{1/\emptyset - 1/\beta}\right) \text{ ----------(1)}$$

$$\eta_r = present\ viscocity,$$

$$\emptyset = relatie\ viscocity,$$

$$\beta = \max.packing\ density$$

$$\eta_r = 1.36\ 10^5 = \eta^{ref},$$

$$\eta^{ref} = new\ viscocity$$

The above equation(1) similar to linear packing density mode(LPMD)

$$\eta_t^{ref} = exp\left(\int_d^D \frac{2.5y(t)}{1/c - 1/c(t)} dt\right)$$

$$\eta_t^{ref} = new\ viscocity\ for\ a\ paricular\ size,$$

$$c = packing\ density, t = paricle\ size,$$

$$d = min.particle\ size, D = max.particle\ size$$

$$y(t) = volume\ size\ distribution\ of\ particle\ mixture\ for\ a\ unit\ integral$$

$$ct = \frac{\beta_t}{1 - \int_d^t y(x) f\left(\frac{x}{t}\right) dx - [1 - \beta(t)] \int_t^D y(x) g\left(\frac{t}{x}\right) dx}$$

$$`\beta_t = virtual\ specific\ density,$$

$$\alpha_t = specific\ packing\ density$$

$$\eta_r = exp\left(\frac{2.5}{1/\alpha(t) - 1/\beta(t)}\right)$$

The β_t virtual specific density is calculated by α_t For $d \le t \le D$

$$\sum_{i=1}^{N} yi(t) = 1$$

The t size particle consists of N different types of particles each characterized for i=1 to N by a own partial volume $yi(t)$. The overall virtual packing density is designed as

$$\frac{1}{\beta(t)} = \sum_{i=1}^{N} \frac{yi(t)}{\beta i(t)}$$

The solid suspension model(SSM) is used to predict solid content of mix by replacing η_r to η_r^{ref} new viscosity . The particle packing density of materials Fig(2) and particle size of cement and silica fume Fig (3)

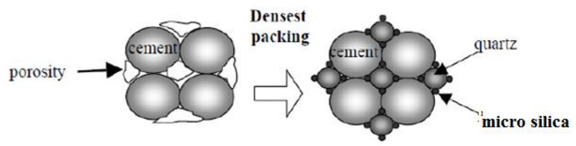

Figure 2: The packing density of particles (coin44)

Figure 3: Particle size of cement and silica fume

The modified Andreasen model acts on a targeted function for optimization of particles the factors responsible for reduction of porosity and obtaining maximum packing density for conventional concrete studied by Fuller and Thomson [19] expressed by cumulative grain size distribution equation

$$y(i) = \frac{D_i^n}{D_{max}^n} 100\%$$

Where (i) – cumulative % of i[th] fraction, D_i- Diameter of the ith fraction in (mm.) D_{max} –Diameter of Max grain size (mm) n- a constant value equal to 0.5

Based on the research work Funk [20] adopted the Fullers curve for composite material similar to UHPFRC

$$y(i) = \left[\frac{D_i^n - D_{min}^n}{D_{max}^n - D_{min}^n}\right] 100\%$$

(i) – cumulative % of i[th] fraction, D_i- Diameter of the i[th] fraction in (mm.) D_{max}- Diameter of Max grain size (μm) n- a constant value equal to 0.37

EXPERIMENTAL PROGRAM AND IMPACT OF VIBRATION DURING MIXING

I] Mixing: The conventional concrete (CNC) mixing involves dry material components followed by water addition for 0.5 minutes and super plasticizer mixing for 2.5 minutes.

The Dry cement, fine sand, micro silica and quartz powder put in a mixer machine of 300kg capacity with drum and blades as per the design proportions and mix is provided with a uniform blending, so as to form a homogeneous material water is added to the homogeneous mix in a until the materials have coagulated, uniformly for few minutes to confirm the water is reacted properly to form a cement paste then the super plasticizer added to the coagulated mixture during the mixing process steel fiber are added the vibration plays important role in the direct impact on the integrity of steel fiber helps in evenly distribution of steel fibers and avoids sinking on the cement paste and mixed thoroughly to get consistent material after 2.0 minutes the mixer stopped to form a blended Ultra High Performance Fiber Reinforced Concrete (UHPFRC) mix as shown in Fig.7 after mixing slump test is performed for conventional fresh concrete and UHPFRC concrete. The properly mixed material is poured in cubes with leveled surface the vibrator 26 mm diameters with the frequency of 18000 turns/minute. is inserted for compaction as shown in Fig.6

The components of material formulation developed to achieve high compressive strength as shown in Table 2.

Table 2. Final Material mix proportions normalized with percentage of cement

Components	Cement	Fine sand	Micro silica	Quartz	Steel fiber	Super plasticizer in %	Water
Current study	1.00	1.32	0.28	0.30	0.21	3.5	0.26

The material composition mixed for conventional concrete (standard mixing) and UHPFRC (Vibrated mixing) and test samples prepared.

Table 3.The Material composition in Kg/m^3

Concrete components	Conventional concrete (Standard Mixing)	UHPFRC concrete (Vibrated Mixing)
Cement	325	945
Coarse Aggregate (>4.75mm)	1100	----
Fine Aggregate(<4.75mm)	550	----
Super Fine Aggregate (0-1mm)	300	1247
Micro silica	----	265
Quartz sand	----	283
Steel fiber	----	198
Super plasticizer	----	3.50
Water	162	242
Total	2439	3185

II] Casting

The specimens of cube shape are casted of sizes 150mmx150mm x 150mm of CNC and UHPFRC were vibrated well during casting specimen top surface were given with smooth finishing, The moulded specimens kept for a day in a room with relative humidity greater than 95% humidity and room temperature 20°±2° for 24 hours after which the specimens were demoulded and kept in Thermostat cabin at 90°C for 24 hours various days tests.

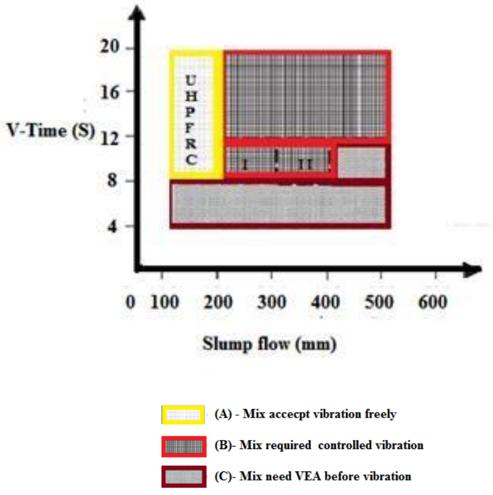

Figure 4: Vibration Susceptibility for UHPFRC fluidity

The internal vibration is done during mixing the needle vibrator 40mm diameter and 60cm in length is used consists of a power unit a flexible shaft and a needle with bearings electrically operated by petrol engine the vibrations are caused by eccentric

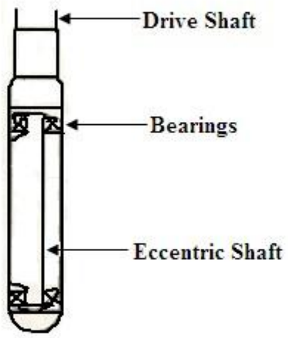

Figure 5: Electrically operated Needle Vibrator

weights attached to the shaft. as shown in fig. 5.the introduction of vibration fills air voids in formwork improved compactness of concrete. The Needle vibrator is pushed slowly, evenly so that material spread all corners of formwork vibrator points spaced equally high-frequency vibrated continuously, When pouring concrete layer the 10 cm thickness of each layer of concrete vibrator is inserted into the lower layer of 5cm, to eliminate the seams between the two layers, while the upper concrete vibrator it is necessary before the lower initial setting of concrete.

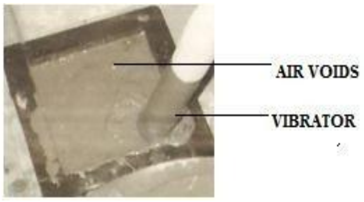

Figure 6: Vibration Mixing during casting

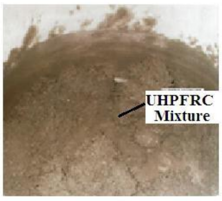

Figure 7: UHPFRC Blended Mix

III] Testing

i) Slump Test

After mixing conventional concrete (CNC) and ultra high performance fiber reinforced concrete (UHPFRC) slump test is performed for fresh concrete, slump is recorded and flow diameter measured for slump flow tests for CNC and UHPFRC concrete.

The workability of UHPFRC tested by slump flow –V funnel in accordance safawi MIet.al [11] to improve quality of concrete divided in to 3 categories namely a).mix that accept vibration freely, b).mix that required controlled vibration c). mix that needed prior treatment of viscosity enhancing agent (VEA) before vibration as shown Fig. 4. Since the density 2585.46kg/m^3 of UHPFRC is high the slump flow is measured 248mm. within the range 200mm-300mm from research studies.The Fig.8 presents slump values of all types of concrete Conventional concrete(CNC),Vibrated conventional concrete(VCNC),StandardUHPFRC(SUHPFRC),Mixed UHPFRC(MUHPFRC),Casting UHPFRC(PUHPFRC) the results show that a slight creased slump in vibrated conventional concrete as compared to conventional concrete and slump in MUHPFRC increase as compared to PUHPFRC

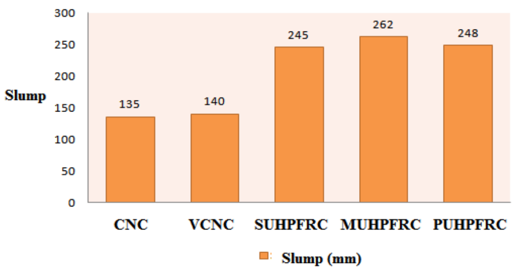

Figure 8: Slump test results of all types of concrete

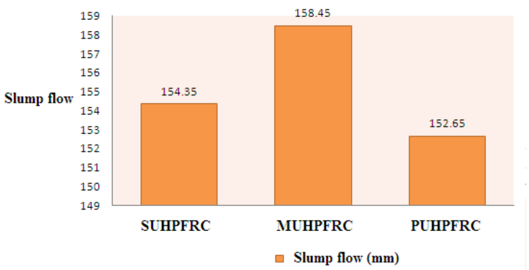

Figure 9: Slump flow test results for UHPFRC

ii) Ultrasonic pulse velocity Test

The Ultrasonic pulse velocity method is a most preferable method globally accepted in research works and construction industry used to determine elastic properties of concrete. Ultrasonic pulse velocity (UPV) testing is a preferred non destructive method Jin X, Li Z.[21], reported a technique has been used successfully to obtain the modulus of elasticity of normal concrete, The basic theory of ultrasonic wave propagation in concrete was described by Jones[22] the velocity of wave influence on stiffness, elastic properties and density of concrete. if the density of concrete and velocity of wave propagation is known the modulus of elasticity can be determined The method involves the measurement of time to travel electronically generator mechanical pluses through concrete The pulses generated by the use transducer. The Electro acoustic transducer is preferred as they provide better control on the type and frequency of pulse generation. The dynamic modulus of elasticity was determined using the equation below

$$V = \sqrt{\frac{E_d(1-\mu)}{\rho(1+\mu)(1-2\mu)}}$$

$$E_d = \frac{v^2\rho(1-\mu)(1-2\mu)}{(1-\mu)} \text{------(2)}$$

$$E_d = Dynamic\ modulus\ of\ elasticity$$

$$\rho = Concrete\ density$$

$$\mu = Poission's\ ratio$$

$$V = Velocity\ of\ wave$$

the concrete density determined using cube 150mm specimens (ρ) 2458 kg/m^3 (v) the measured ultrasonic pulse velocity of in 4781m/s (μ) poissions ratio the density of the test samples within the range 2249.21—2473.23 kg/m^3 and Poisson's ratio 0.20 according to Kumar M, Asce AM, Ma Z and Matovu M [23] for High strength concrete. The UHPFRC density ranges 2550.45-2750.25kg/m^3 and Poisson's ratio 0.2-0.24 to the measured ultrasonic pulse velocity is From the experimental test results the dynamic modulus of elasticity concrete is determined by substituting the values in equation (2)

$$E_d = \frac{4781^2 X 2458 X(1+0.22)(1-0.22)}{(1-0.22)}$$

$$E_d = 49.21GPa$$

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 8 (2017) pp. 1683-1690
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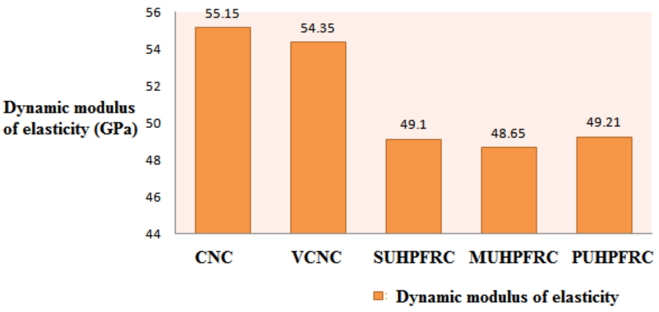

Figure 10: Dynamic modulus of elasticity of conventional and UHPFRC

The results of dynamic modulus of elasticity of conventional and UHPFRC Fig.10 show that the vibrations during casting stage (PUHPFRC)have highest dynamic modulus of elasticity compared to (SUHPFRC) the lowest average value of (MUHPFRC) the differences are very small the conclusion states that the mixing and vibrating have very small difference in dynamic modulus of elasticity

iii)Hardened UHPFRC Concrete

The compression test conducted for conventional concrete (CNC) and all types of UHPFRC Mixes in accordance ASTMC-39[24] standards for 28 days as shown in Fig 11.The vibrated and non vibrated specimens of the surface finish needs fully vibration to achieve highest compressive strength The introduction of vibrations of MUHPFRC is worse as compared surface of PUHPFRC concrete even though the concrete mix content is same. Introduction of vibrations during casting stage improves compressive strength test, It wasn't noticeable that were vibrated during the mixing the concrete with lower degree of cement hydration generally with lower gel porosity which explains that this type of concrete has higher compressive strength and better mechanical properties with lower degree of hydration.The SUHPFRC and PUHPFRC have greater compressive strength as compared to PUHPFRC

The compressive strength results are as shown in Fig12. The result show that the conventional concrete compressive strength for standard conventional concrete and vibrated conventional concrete slight increase in strength in the concrete mix is stable introduction of vibrations during mixing stage does not contribute to the quality of concrete. The UHPFRC concrete at casting stage have highest compressive strength the samples vibrated during the mixing stage have lowest compressive strength the difference is very much high as compared to vibrated at casting stage Sudarshan N.M.and T.Chandrashekar [25] studied increase in volume fraction of steel fibers on compressive strength

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Figure11: Automatic Compression Testing Machine 3000KN

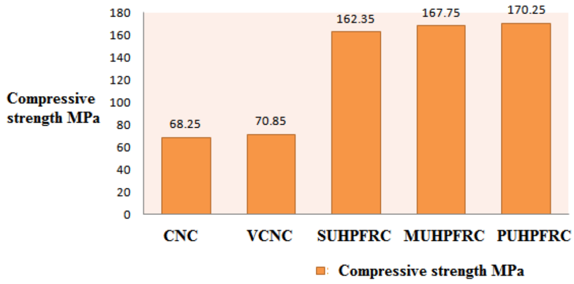

Figure12: Compressive strength of test samples

CONCLUSIONS

The vibration during casting allows uniform Mix to reach all corners of formwork yields arrest air voids blocks cement slurry to segregation In UHPFRC the steel fiber evenly spreads in concrete matrix producing behavior strain hardening properties is prime important to act as high density and ductile material delay in collapse of the structure. The vibration during casting and mixing stage has effect to produces higher compressive strength concrete after 28 days

The experimental test results shows that

*The introduction of vibrations at mixing stage improves the formability of concrete.

*Vibrations during mixing or the casting stage had a little effect of dynamic module of elasticity of conventional concrete and UHPFRC

*Vibrations during mixing stage had no impact on the normal strength but significantly improves the UHPFRC

*The Highest strength is obtained vibration during casting stage filled with voids in formwork the compactness of the concrete improves the strength

*The UPV testing method was found to be the most reliable, suitable non-destructive testing method that can be used in the assessment of the elastic properties of UHPFRC both in the laboratory and on site.

*Further studies are recommended for UHPFRC design mixes containing different volumes of micro silica and steel fibers to confirm the workability, reliability of the test methods.

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AUTHOR'S DETAILS

Prof. Sudarshan N.M. holds a B.E. and M.E. from Gulbarga University and pursuing PhD from ANU University Guntur. His areas of interest are Mix design of High strength concrete, UHPFRC and studies on achieving high concrete strength He is a Life member of ISTE,published research papers in National/International journals,Project Guide for Graduate and Post Graduate students.

Dr. T.Chandrashekar Rao holds B.Tech from ANU University Guntur and M.Tech and PhD from JNTU Hyderabad His areas of in interest in Concrete technology, High strength concrete, UHPFRC and studies on Mix design He published Many research papers in National/International journals and Project Guide for Post Graduate and PhD research scholars.