Influence of Different Factors of Concrete which are Affecting the Ultrasonic Pulse Velocity of Plain Cement Concrete

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Abstract - *The UPV test of concrete is one of the globally accepted NDT method for evaluation of concrete quality both in laboratory as well as in situ concrete of concrete structures. The ultrasonic pulse velocity of concrete is not an intrinsic characteristics of concrete as it depends on microstructural properties of concrete & many other factors of concrete. Considering the importance of the UPV test & difficulties for evaluation of UPV test results of concrete, it required to work out the influence of all such factors which are directly affecting the UPV test results of concrete. Thus to interpreted the results of UPV of concrete, it is the primary requirement to know the influence of different factors which will affect the test results for actual judgement of concrete quality. As per the available standard guidelines and available literature regarding influence of different factors of concrete which may influence the UPV results of concrete are not very specific and mostly on assumption based. Considering the importance of all such factors of concrete which will influence the UPV test results of concrete an experimental study was conducted for UPV test on different types of plain cement concrete with different w/c ratio, different types of aggregate, concrete with different method of compaction, different types of curing conditions & also heating effect of concrete. Based on the investigational outcome of the research it has been concluded that UPV results of concrete are significantly influenced by all such factors & mostly it depends on the microstructural properties of concrete.*

Key Words: NDT, UPV, w/c ratio, Aggregate, temperature, compaction, direct transmission, indirect transmission

1. INTRODUCTION

The ultrasonic pulse velocity test of concrete is one of the most popular and useful NDT method which are used globally for quality check of concrete. As the concrete being a heterogeneous materials, there are many factors which are affecting the UPV of concrete. The importance of such factors are very high as those factors of concrete plays a vital role on interpretation of UPV test results of concrete. There are very few limited guide lines on available standard and available literature on influence of various factors of concrete which will influence the UPV results of concrete. Thus an experimental investigation was conducted on UPV test of plain cement concrete with varying w/c ratio, different types of coarse aggregate, different method of compaction, different method of curing and heating effect on concrete. The outcome of the experimental investigation has been shown that the UPV test results of concrete are greatly influenced by all such factors. So to interpret the UPV results of concrete influence of such factors are very important to judge the actual quality of concrete by using UPV test of concrete. The research work also concluded that UPV results of concrete is directly de-pends on the microstructure of concrete & also the factors which will influence the microstructural properties of concrete like w/c ratio, type of coarse aggregate, method of curing, level of compaction & heating effect on concrete

2. LITERATURE REVIEW

The investigation of concrete through nondestructive testing methods was in progress in 1930 and lastly recognized in the year of 1970. BS 1881 part 4 and part 5, were the standards on testing method for strength assessment and for others hardened concrete properties were published, and correspondingly BS 1881 part 201, which brought the guidelines for the technique of nondestructive testing of hardened concrete, was printed in 1980. Depending on that report, numerous studies were conceded out on the prerogative of nondestructive testing methods to investigate the quality of concrete structures. In the year of 1992, standards on UPV and rebound hammer test was finally published by Bureau of Indian standard as IS-13311, Part-2 and IS-13311, Part-1. However in the year of 2000 standards on core testing, rebound hammer testing, and ultrasonic pulse velocity testing were publicized by American concrete Institute. ACI 228 Statement on nondestructive testing of concrete in Structures, strength assessment stated with 38 papers were comprised on the standards customarily on the nondestructive evaluation of concrete were printed in 1980. Depending on this statement, numerous past studies were carried out on the massive application of nondestructive testing methods to examine the quality of concrete structure. The explanatory previous educations on nondestructive testing approaches can be summarized beginning with the maximum new improvement. In 2018, Panedpojaman and Tonnayopas (2018) directed an investigation on assessing the left over or residual compressive strength of concrete after a fire disclosure to concrete surface hardness [13]. Hong et al. (2016) and Hong and Cho (2006) directed an investigation on assessing the thickness of concrete as well as the flaw positions inside a slab for concrete structures using the ultrasonic pulse velocity technique and impact echo technique [9,10]. In the year of 2014, Azari, Nazarian and Yuan (2014) directed an investigation on the returns of joining the impact echo technique and the technique of ultrasonic surface waves [3]. In 2013, Bogas et al. (2013) recognized the transformation between lightweight aggregate and normal aggregate using the ultrasonic pulse velocity technique and anticipated assessment equation for envisaging the compressive strength of concrete [14], and Furuich (2013) designates a velocity profile method and an assessment of the projected doubt by an actual flow calibration [15]. In 2011, Roh (2011) conducted research on assessing the corrosion of rebar in concrete walls using a self-potential survey technique and infrared thermographic technique [16]. Baek et al. (2005) conducted research on a method of estimating the rebar corrosion level using infrared thermography data [17]. There are numerous other studies like Nadepour et al. (2017), Sabbag and Uyanik (2017), François Saint-Pierre et al. (2016), Nadepour et al. (2016) and Ghosh et al. (2018) but most of these studies were showed for a concrete at the age of 28 days or even more. However the studies on the factors which may influence the ultrasonic pulse velocity of concrete are still lack of clarity and lots of research are yet required to accentuate the proper assessment of ultrasonic pulse velocity test of concrete.

3. TESTING METHOD

The ultrasonic pulse velocity test of concrete based on the measurement of velocity of ultra sound within the concrete medium. In solid medium there are two types of elastic wave's namely longitudinal wave and Transverse wave.

i) Longitudinal wave: Longitudinal wave is an elastic wave and its particles displacement are in the direction of the propagation of waves, longitudinal waves are also called density or compress wave and it is the fastest in nature.
ii) Transverse wave: It is an elastic wave and its particles displacement are perpendicular to the direction of wave propagation. It is slower than longitudinal wave.

The ultra sound is generated by electro-acoustic transducer having piezo-electric material. The mode of measurement are different based on the placement of transducer. The following are the different method of measurement of UPV in concrete which are as

a) Direct transmission method: Both the transducer are place opposite face of the concrete block.

Ultrasonic Pulse Velocity (V) = L / T

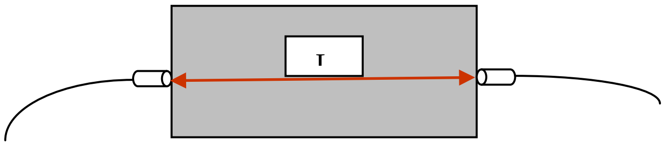

Fig-1: Direct transmission method

b) Indirect transmission method: Both the transducer are place on the same face of the concrete block.

Ultrasonic Pulse Velocity (V) = L / T

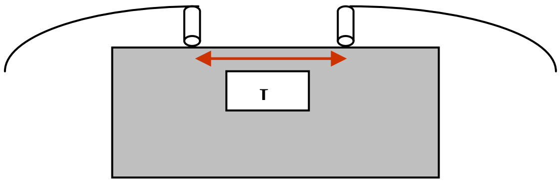

Fig-2: Indirect transmission method

c) Semi direct transmission method: The both the transducer are place corner face of the concrete block.

Ultrasonic Pulse Velocity (V) = L / T

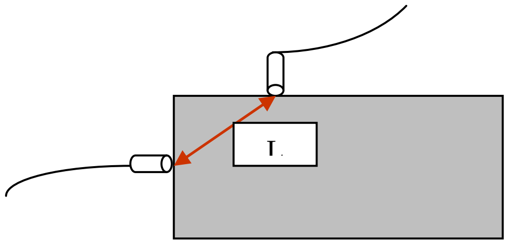

Fig-2: Indirect transmission method

4. MATERIAL AND SAMPLE CONDITIONING.

The grade of reference concrete used for the research work was C-30/37 grade concrete with Portland cement CEM-I, 52.5N class cement as per BSEN-197, Part-1 with w/c ratio 0.4 and coarse aggregate used for the experiment is crushed basalt rock. However the experiment was conducted by changing the different ingredient of reference mix C-30/37 like w/c ratio, type of coarse aggregate, type of compaction, the reference mix proportion of the concrete grade C-30/37 grade used for the experiment is shown in Table-1.

Table-1
Mix proportion of reference mix (M0) C-30/37

Name of the ingredient	UOM	Quantity	Remarks
Cement	Kg/m3	438	Portland cement CEM-I,52.5N class cement is used

Mixing water	Kg/m3	175	The water content is after SSD condition of aggregate
Fine Aggregate	Kg/m3	885	The type of fine aggregate is river sand & the weight is SSD condition
Coarse Aggregate	Kg/m3	1142	The type of aggregate is crushed basalt & the weight is SSD condition
Superplasticizer	Kg/m3	3.5	Superplasticiser [Master polyheed 8650] @ 0.8% weight of cement

Table-2
Mix Details and conditions sampling used for the experiment.

Sl No	Sample details for experiment	Mix ID
1	Reference Mix of C-30/37 grade concrete with CEM-I, 52.5N cement	$\mathbf{M_0}$
2	Reference Mix with water cured samples	$\mathbf{M_C}$
3	Reference Mix with air dried condition but without water cured	$\mathbf{M_{AD}}$
4	Reference Mix with normal tamping for compaction	$\mathbf{M_{TC}}$
5	Reference Mix with vibro compaction for compaction	$\mathbf{M_{VC}}$
6	Reference concrete mix with crushed Lime stone type coarse aggregate all other ingredient remain same	$\mathbf{M_{LS}}$
7	Reference concrete mix with crushed baslt type coarse aggregate all other ingredient remain same	$\mathbf{M_{BS}}$
8	Samples for Effect of moisture content in the concrete	$\mathbf{M_{MC}}$
9	Samples for Effect of w/c ratio in the concrete	$\mathbf{M_{W/C}}$
10	Reference concrete mix with normal temperature of 25^0C	$\mathbf{M_{T25}}$
11	Reference concrete mix with normal temperature of 30^0C	$\mathbf{M_{T30}}$
12	Reference concrete mix with normal temperature of 60^0C	$\mathbf{M_{T60}}$
13	Reference concrete mix with normal temperature of 80^0C	$\mathbf{M_{T80}}$
14	Reference concrete mix with normal temperature of 105^0C	$\mathbf{M_{T105}}$

5. EXPERIMENT AND METHOD

The experiment was conducted by using specimen's size of 150 mm size concrete cubes for different testing condition of the specimens as per the Table-2 for evaluation of the influence of different factors which may affect the results of UPV test of concrete. The UPV testing was performed with transducer frequency of 54 KHz and direct transmission method. The experiment was conducted for following different condition of the specimens.

5.1. Effect of curing of concrete

There are two different type of specimens were used from same mix. 3 no's specimen were kept under water at 27^0C & other 3 no's specimen were kept exposed to ambient temperature and without doing any curing for 28 days & UPV of both the specimens recorded at different ages at 3-days, 7-days and 28-days respectively of all 6 specimens.

Fig-1: Sample in water tank for curing & sample in exposed sunlight & ambient air condition.

Fig-2: UPV test of samples of different conditioning of curing.

5.2. Effect of type of compaction of concrete.

There were total 6 no's specimen were used from same mix for evaluating the effect of compaction of concrete. 3 no's specimen were compacted by using normal tamping of 16 mm MS bar & the other 3 no's specimen was compacted by using vibration table.

Fig-3: Sample in vibration table for vibro compaction & sample compaction by normal tamping with 16 mm MS bar.

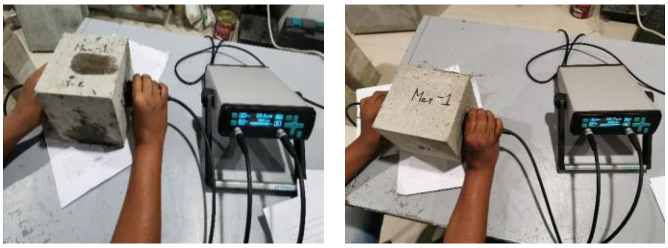

Fig-4: UPV test of samples of different conditioning of compaction.

5.3. Effect of type of different types of coarse aggregate in concrete.

There are two different type of specimens were used from same mix for evaluating the effect of the type of coarse aggregate in concrete. 3 no's specimen were prepared with crushed lime stone aggregate & other 3 no's specimen were prepared with crushed Basalt aggregate.

Fig-5: Sample with crushed Basalt stone aggregate (Left) & samples with crushed Lime stone aggregate (Right)

Fig-6: UPV test of samples with different types of coarse aggregate in concrete.

5.4. Effect of temperature or heating effect on UPV test results of concrete.

The samples after 28 days of curing it was allowed to keep in air dry condition for 7-days till the weight of the specimen get constant or unchanged. Once the sample get constant weight it was allowed to kept the specimen at $25^{0}C$ for 24hrs and then UPV of the specimen were recorded. Once the reading were taken at normal 250C immediately the specimens were kept in oven for taking UPV of the same specimens at different temperature. The specimen were heated at $30^{0}C$, $60^{0}C$, $80^{0}C$ and $105^{0}C$ for 1hr at each temperature & record the UPV value of the specimen & subsequently increase the temperature for next higher temperature for 1hr & record the reading . The process of heating & subsequent testing for UPV of the concrete specimens were continued till the maximum temperature of $105^{0}C$ has reached.

Fig-7: Sample oven for heating (Left) & samples before testing temperature check by thermal scanner (Right)

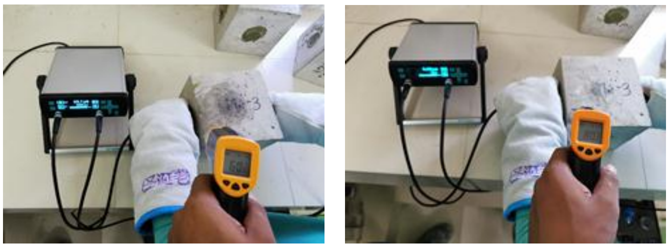

Fig-8: UPV testing & temperature checking.

5.5. Effect of w/c ratio of concrete on UPV test results of concrete.

To evaluate the influence of w/c ratio of concrete on UPV results of concrete, the samples were prepared with different w/c ratio of 0.40 , 0.45, 0.50, 0.55 and 0.60 keeping the other ingredient were remain constant or unchanged as per the mix proportion of reference mix of C-30/37. All the specimens of different w/c ratio were allowed to moist cured for 28-days & after 28-days the same was removed from curing tank & allowed for ambient exposure to specimens till the mass of the same specimen get constant or unchanged at least for 2 to 3 days continuously, the mass changes record of the specimens were monitoring to avoid the moisture effect in UPV test.

Fig-9: Samples preparation with different w/c ratio.

Fig-10: Samples preparation and curing of the specimens.

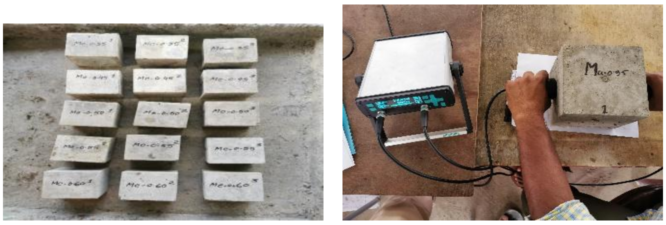

Fig-11: Samples UPV testing of different w/c ratio of concrete.

5.6. Effect moisture content on UPV test results of concrete.

To evaluate the influence of moisture content in concrete on UPV results of concrete, the samples were prepared as per the reference design mix (M_0) of C-30/37 as per Table-1. Total 3 specimens of 150 mm size cubes were prepared and allowed for 28 days curing in curing tank. The specimens after completion of 28-days curing removed from the curing tank and weep off the surface moisture by using cotton cloth & subsequently taken the mass of the specimen and also recorded the UPV readings of all the three cubes specimens. The same specimens immediately after completion of the UPV test were kept in oven at 105^0C for 24 hrs and then remove the specimen from the oven & record the mass of the specimens to find out the moisture content of all the specimens. Once the mass changes were recorded then UPV of the same specimens were also recorded & find out the changes of UPV value with respect to moisture content in the concrete specimens.

Fig-12: Samples for evaluation of moisture effect in concrete.

Fig-13: Samples after oven drying at 105^0C & UPV test of the specimens after drying at 105^0C.

Fig-14: UPV test of the moist specimens immediately after removal from curing tank at 28-days.

Fig-14: UPV test of the specimens immediately after drying of the specimens for 24 hrs at 105^0C.

6. RESULTS AND DISCUSSIONS.

Table-3
Effect of curing on UPV results of concrete

Curing Conditions	Sample ID	UPV results of concrete specimens at different age in Km/sec									
		At 3-days		At 7-days		At 14-days		At 21-days		At 28-days	
		Indiviual	Average	Indiviual	Average	Indiviual	Average	Indiviual	Average	Indiviual	Average
Samples were submerge in curing tank up to 28-days	M_{C-1}	4.664	4.683	4.804	4.818	5.15	5.145	5.239	5.236	5.245	5.265
	M_{C-2}	4.692		4.846		5.164		5.254		5.302	
	M_{C-3}	4.694		4.803		5.12		5.216		5.247	
Samples were exposed to ambient air without any curing up to 28-days	M_{AD-1}	4.565	4.575	4.753	4.682	5.023	4.962	4.992	4.981	5.052	5.042
	M_{AD-2}	4.615		4.684		5.012		4.953		5.043	
	M_{AD-3}	4.544		4.609		4.851		4.997		5.031	

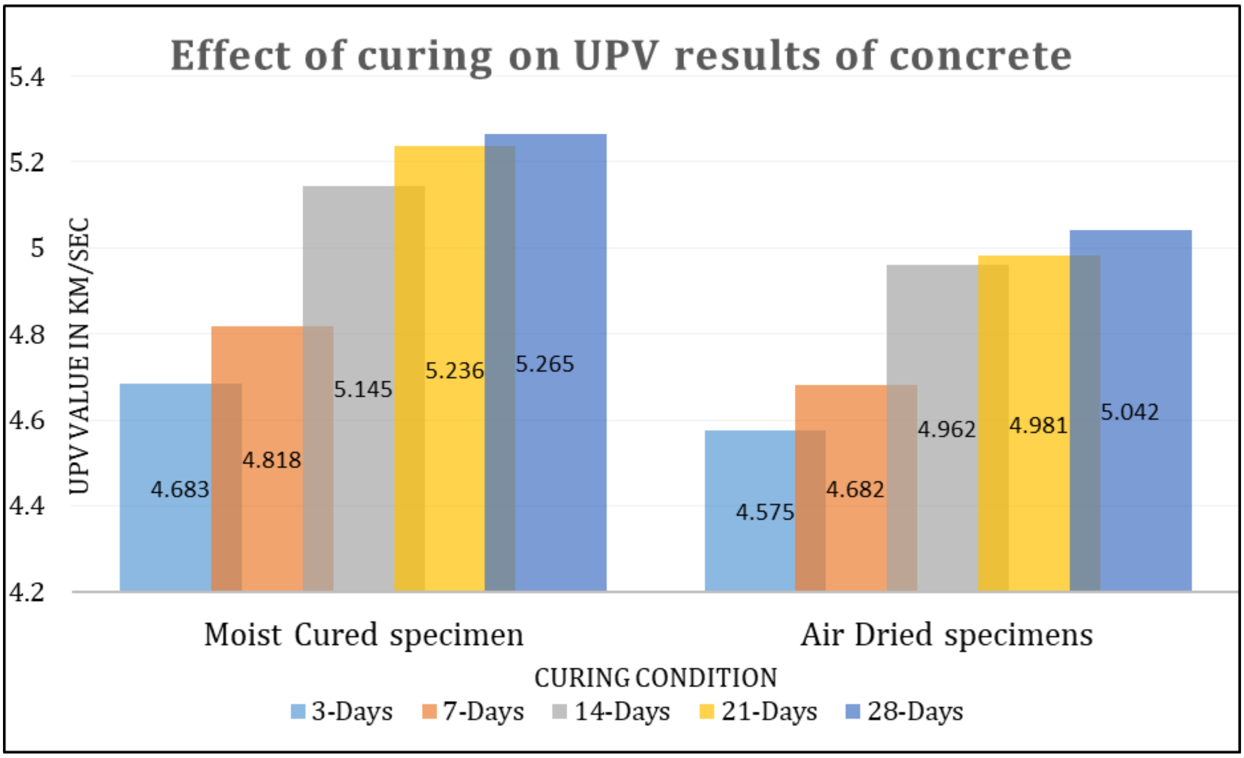

Fig-15: Effect of curing on UPV test results of concrete at different ages of samples.

The above experimental results shows that concrete specimens with curing shows more UPV results of concrete as compared to specimen with no curing. It is also observed that concrete with increasing the age of hydration the UPV is also increasing. The increase in UPV with increase in age of hydration is due to the better filling of pore spaces of concrete microstructure through solid product of hydration C-S-H gel. The experimental results also shows that cured specimens UPV is more than non- cured specimen due poor hydration process in non -cured specimen and resulting less filling of pore spaces by solid hydration product of C-S-H gel.

Thus the effect of curing of concrete is almost 4.5% higher UPV results than concrete having no curing.

Table-4
Effect of type of compaction on UPV results of concrete

Type of Compaction	Sample ID	UPV results of concrete specimens at different age in Km/sec									
		At 3-days		At 7-days		At 14-days		At 21-days		At 28-days	
		Indiviual	Average	Indiviual	Average	Indiviual	Average	Indiviual	Average	Indiviual	Average
Samples were compacted by tamping rod.	M_{TC-1}	4.688	4.718	4.717	4.768	4.934	5.029	5	5.151	5.137	5.197
	M_{TC-2}	4.792		4.702		5.017		5.172		5.172	
	M_{TC-3}	4.673		4.886		5.137		5.282		5.282	
Samples were compacted by vibration table.	M_{VC-1}	4.808	4.798	4.87	4.829	5.172	5.205	5.208	5.222	5.263	5.264
	M_{VC-2}	4.87		4.87		5.357		5.338		5.338	
	M_{VC-3}	4.717		4.747		5.085		5.119		5.19	

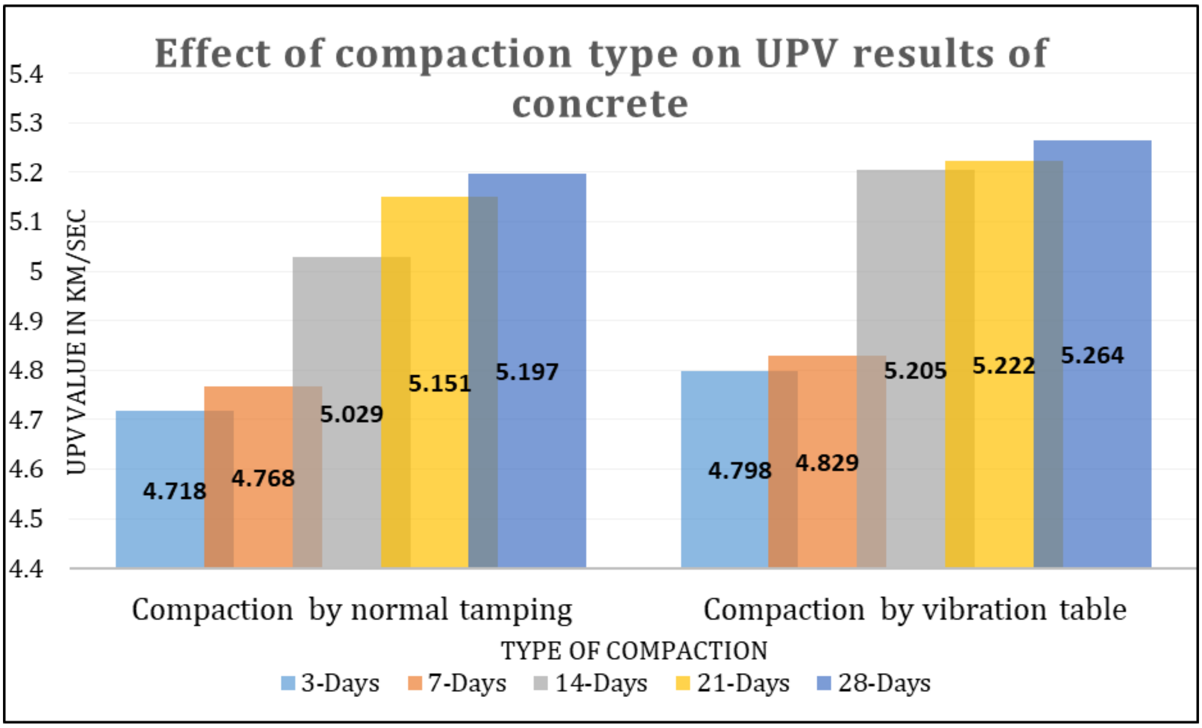

Fig-16: Effect of compaction type on UPV test results of concrete at different ages of samples.

From the above results it has been observed that the UPV value of concrete having vibro compaction is almost 1.28% higher than concrete compacted by normal tamping method. In general by using vibro compaction of concrete most of the entrapped air is possible to remove as entrapped air is getting accumulated during mixing & placement of concrete. Hence such accumulated entrapped air is occupying some spaces in concrete & later on this air entrapped air void spaces resulting decrease in strength & UPV results of concrete. Thus by doing necessary tamping of concrete it is not possible to remove such accumulated entrapped air during mixing & placement of concrete, however by adopting vibro compaction method it is possible to remove majority of entrained & entrapped air from concrete during plastic stage. The velocity of sound wave in air is 330 m/sec while in sound concrete it is almost 4000 m/sec. So when an Ultrasonic sound wave is travelling through a concrete medium and any interaction with air void or air path it will simply dropped the velocity of Ultrasonic pulse, due to scattering effect of the incident ultrasonic sound wave & acoustic impedance of the air medium.

Table-5
Effect of type of type of coarse aggregate on UPV results of concrete

Type of Coarse Aggregate in the samples	Sample ID	UPV results of concrete specimens at different age in Km/sec									
		At 3-days		At 7-days		At 14-days		At 21-days		At 28-days	
		Indiviual	Average	Indiviual	Average	Indiviual	Average	Indiviual	Average	Indiviual	Average
Samples were prepared with crushed Lime stone aggreagte.	M_{LS-1}	4.021	4.244	4.237	4.448	4.298	4.515	4.298	4.523	4.717	4.689
	M_{LS-2}	4.261		4.478		4.545		4.559		4.573	
	M_{LS-3}	4.451		4.63		4.702		4.711		4.777	
Samples were prepared with crushed Basalt stone aggreagte.	M_{BS-1}	4.854	4.813	5.226	5.163	5.319	5.234	5.326	5.250	5.357	5.278
	M_{BS-2}	4.983		5.263		5.282		5.357		5.357	
	M_{BS-3}	4.601		5		5.102		5.068		5.119	

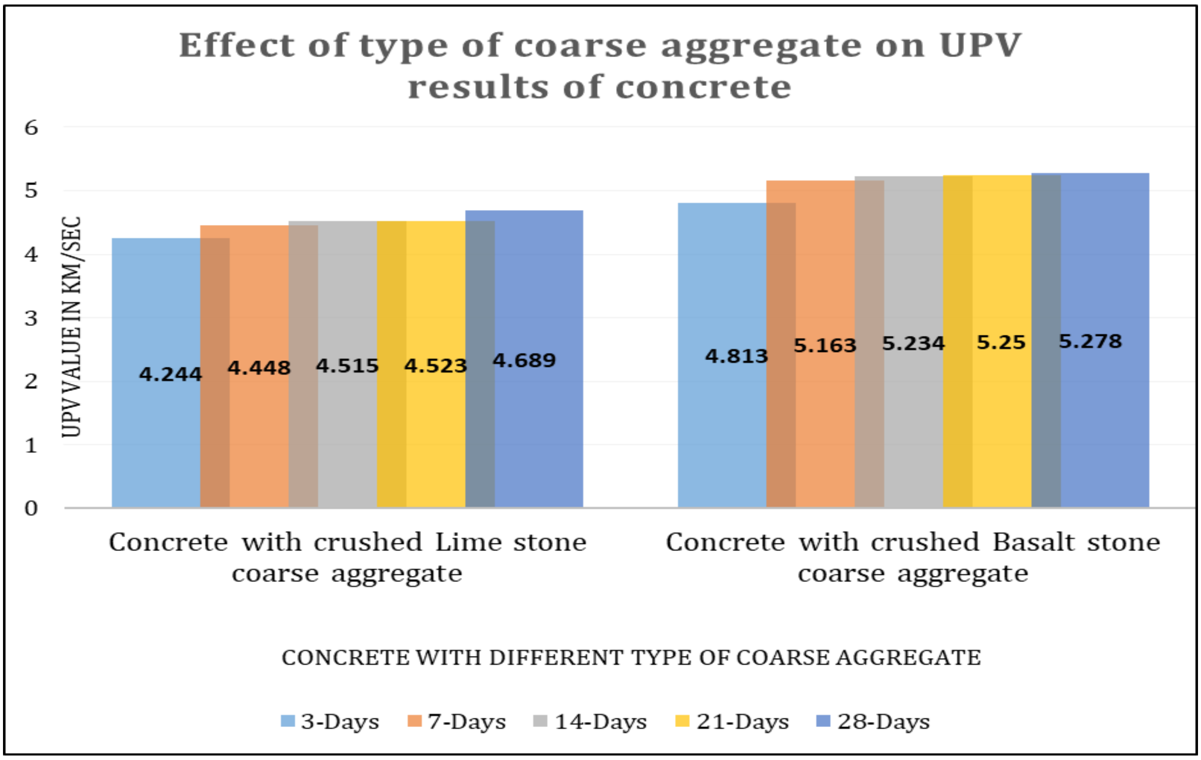

Fig-17: Effect of type of coarse aggregate on UPV test results of concrete at different ages of samples.

The experimental results shows that concrete with crushed Basalt type coarse aggregate shows almost 12.56% higher UPV than concrete with crushed Lime stone type coarse aggregate. This because of the nature & texture of stone aggregate or parent rock. In general Lime stone is basically a sedimentary rock & while crushing for making coarse aggregate for concrete work there is a natural tendency to form more flaky and elongated shape aggregate. Such flaky and elongated aggregate is again have the tendency to occupy position in concrete in flat direction which will accumulate water underneath the aggregate and also it results bleeding in concrete. Thus such accumulated water underneath the aggregate surface once escape because of evaporation will create air voids and thus this air passage will drop the pulse velocity. However with Basalt type of stone aggregate such problem of flakiness and Elongation is nominal phenomenon while making aggregate, hence the UPV is also not affecting much as compared to concrete with Lime stone type coarse aggregate.

Table-6
Heating effect of concrete on UPV results of concrete specimens after 28-days of curing.

Samples with different heating temperature	Sample ID	UPV results of concrete specimens at different heating temperature of concrete in Km/sec		% Reduction of UPV at elevated temperature than sample at 25^{0}C
		Individual Results	Average Results	
Samples at temperature at 25^{0}C	M_{T-25-1}	4.876	4.881	0%
	M_{T-25-2}	4.898		
	M_{T-25-3}	4.87		
Samples at temperature at 30^{0}C	M_{T-30-1}	4.555	4.507	7.67%
	M_{T-30-2}	4.496		
	M_{T-30-3}	4.47		
Samples at temperature at 60^{0}C	M_{T-60-1}	4.533	4.485	8.13%
	M_{T-60-2}	4.474		
	M_{T-60-3}	4.447		
Samples at temperature at 80^{0}C	M_{T-80-1}	4.501	4.475	8.32%
	M_{T-80-2}	4.478		
	M_{T-80-3}	4.447		
Samples at temperature at 105^{0}C	$M_{T-105-1}$	4.5	4.468	8.47%
	$M_{T-105-2}$	4.478		
	$M_{T-105-3}$	4.425		

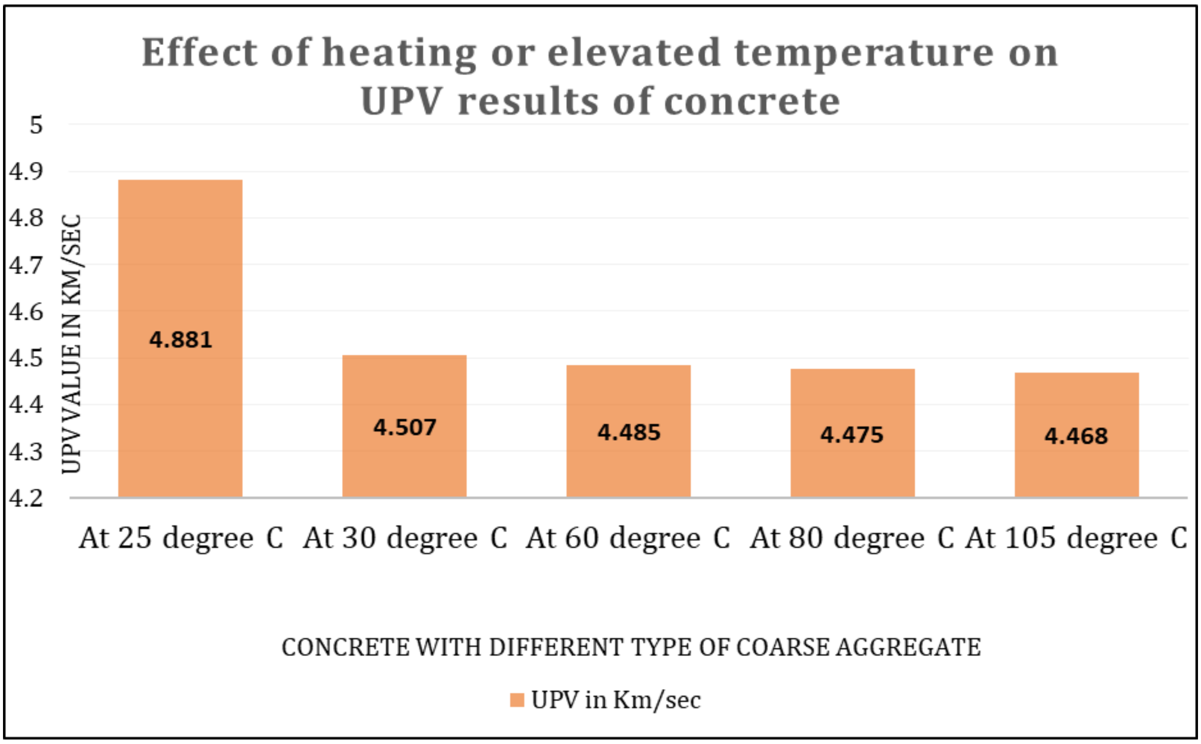

Fig-18: Effect of heating or elevated temperature on UPV test results of concrete.

The experimental results shows that concrete with elevated temperature shows reduced UPV results of concrete. The reduction in ultrasonic pulse velocity is due to changes of material properties like Elastic modulus, density and also increase in temperature leads to increase in dimension of the member & thus increase in time of flight of ultrasonic pulse. It has been observed almost 8.47% reduction in UPV is noticed at 105^{0}C as compared to UPV of same concrete at 25^{0}C.

Table-7

Effect of type of w/c ratio of concrete on UPV results of concrete

Samples with different w/c ratio	Sample ID	UPV results of concrete specimens at different age in Km/sec									
		At 3-days		At 7-days		At 14-days		At 21-days		At 28-days	
		Indiviual	Average	Indiviual	Average	Indiviual	Average	Indiviual	Average	Indiviual	Average
Mix with w/c = 0.40	$M_{W/C-0.4-1}$	4.717	4.840	4.823	4.981	5.085	5.229	5.137	5.303	5.372	5.343
	$M_{W/C-0.4-2}$	4.934		5.102		5.263		5.415		5.363	
	$M_{W/C-0.4-3}$	4.87		5.017		5.338		5.357		5.293	
Mix with w/c = 0.45	$M_{W/C-0.45-1}$	4.82	4.870	4.98	4.928	5.101	5.184	5.186	5.222	5.271	5.273
	$M_{W/C-0.45-2}$	4.815		4.935		5.273		5.21		5.286	
	$M_{W/C-0.45-3}$	4.974		4.869		5.177		5.27		5.262	
Mix with w/c = 0.50	$M_{W/C-0.50-1}$	4.732	4.829	4.732	4.916	4.95	5.162	5.017	5.181	5.19	5.228
	$M_{W/C-0.50-2}$	4.886		5.017		5.282		5.263		5.238	
	$M_{W/C-0.50-3}$	4.87		5		5.253		5.263		5.257	
Mix with w/c = 0.55	$M_{W/C-0.55-1}$	4.658	4.794	4.792	4.906	5.017	5.153	5.267	5.212	5.068	5.216
	$M_{W/C-0.55-2}$	4.87		4.927		5.238		5.213		5.317	
	$M_{W/C-0.55-3}$	4.854		5		5.203		5.157		5.263	
Mix with w/c = 0.60	$M_{W/C-0.60-1}$	4.451	4.604	4.644	4.758	4.95	5.040	5	5.092	5.118	5.150
	$M_{W/C-0.60-2}$	4.644		4.854		5.085		5.19		5.112	
	$M_{W/C-0.60-3}$	4.717		4.777		5.085		5.085		5.219	

The experimental results in Table-7 shows that ultrasonic pulse velocity of concrete is reducing with increase in w/c ratio of concrete and at the same time it is also observed that with increase in hydration age of concrete with different w/c ratio, the Ultrasonic pulse velocity of concrete get increased gradually from 3-days to 28-days. The reduction in ultrasonic pulse velocity with increase in w/c ratio is because of the accumulation of more water in concrete & eventually such water will occupy some spaces in fresh concrete, but when such accumulated water will lost from concrete because of evaporation loss of water at early age of concrete then such spaces of pore will occupy by air. Hence such air spaces will drop the ultrasonic pulse velocity of concrete while travelling the ultrasonic pulse across such air interference. While the experimental results also observed that UPV results is also increasing with hydration age of cement, it's because of the continuous filling of empty pore spaces of concrete microstructure by solid hydration product of C-S-H gel. As the age of hydration will increases the more will be the filling of empty pore spaces by more C-S-H gel and thus increase the UPV of concrete with increase in hydration age of cement. The average increase in UPV results from 3-days to 28-days is almost 9.5%. However concrete with higher w/c ratio of 0.60 shows higher rate of increase in ultrasonic pulse velocity at 28-days than 3-days, while the concrete with lower w/c ratio the increase rate at 28-days is slightly lower side than concrete with higher w/c ratio of 0.6. This is because of the more hydration of cement due to sufficient amount of water availability for hydration process in higher w/c ratio of concrete, while concrete with lower w/c ratio hydration process get suppressed because of water scarcity in pore spaces of concrete and maximum part of cement will remain un-hydrated because water scarcity and thus leaving micro pores in concrete, which will thus further reduce the UPV of concrete.

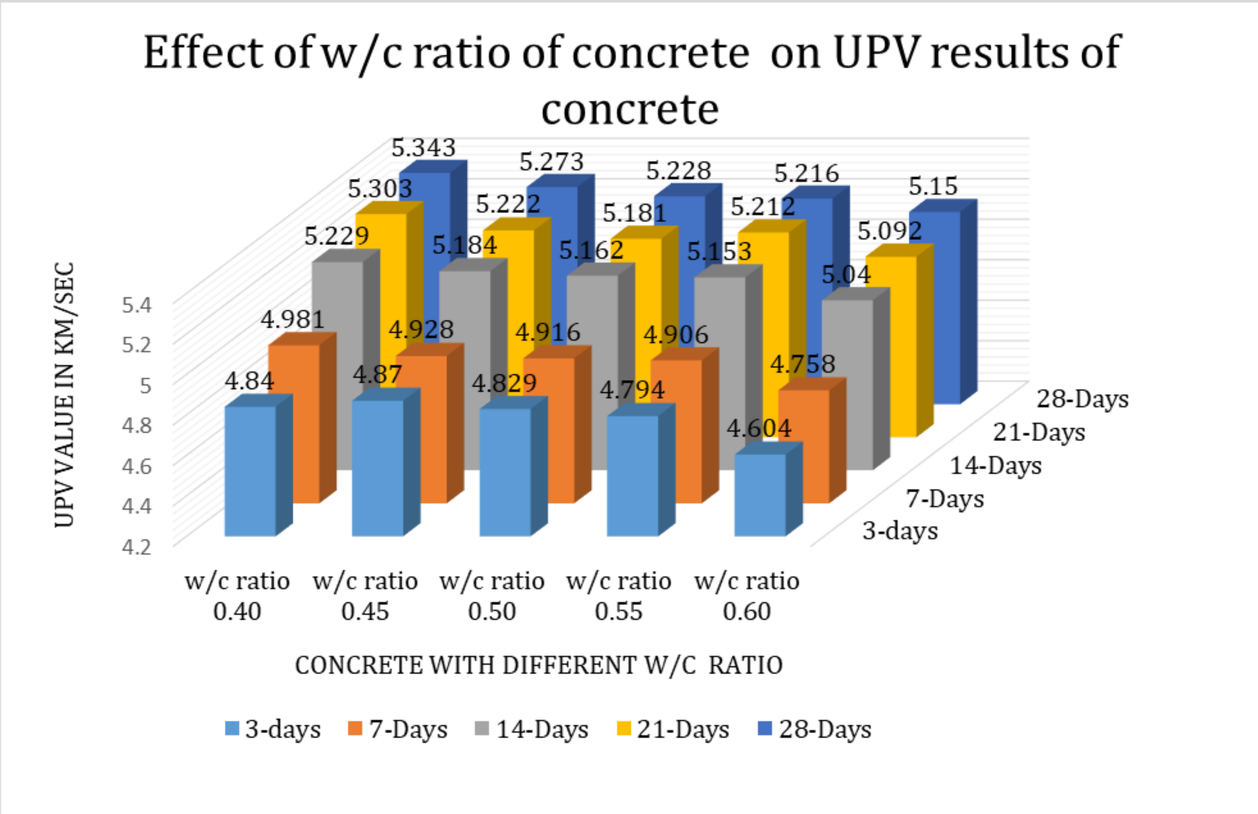

Fig-19: Effect of w/c ratio of concrete on UPV test results of concrete.

Table-8
Effect of moisture content in concrete on UPV results of concrete

Sample ID	Mass of the 28-days cured specimens in kg after weeping of surface moisture	Mass of the 28-days cured specimens after drying at 105^{0}C for 24 hrs	% of moisture of the individual specimens	Average % of moisture of the specimens	UPV results of both moist specimens & dried specimens in Km/sec				
					UPV-results of dried specimen after heating at 105^{0}C	Average UPV-results of dried specimen	UPV-results of moist individual specimen	Average UPV-results of moist specimen	% Increase in UPV results
M_{MC-1}	8.372	7.911	5.51%	5.53%	5.056	5.086	5.212	5.218	2.60%
M_{MC-2}	8.343	7.920	5.07%		5.030		5.165		
M_{MC-3}	8.42	7.915	6.00%		5.172		5.278		

The experimental results shows that moisture content in concrete shows higher ultrasonic velocity of concrete as compared to dry concrete at 105^{0}C. As the velocity of sound wave in water is about 1480 m/sec and that of air is 330 m/sec, thus concrete with moisture eventually shows slightly higher UPV than dry concrete. Actually when the pore structure of concrete is occupied with water then the UPV will be more as because of velocity sound wave in water is 1480 m/sec, while the same concrete when it will dry then such pore water will lost by evaporation and leaving empty air pore structure which will thus reduce the pulse velocity in concrete as the velocity of sound in air is 330 m/sec. As per the experimental outcome it is concluded that about 5.53% moisture in concrete can increase the UPV of concrete by 2.6% than dry concrete.

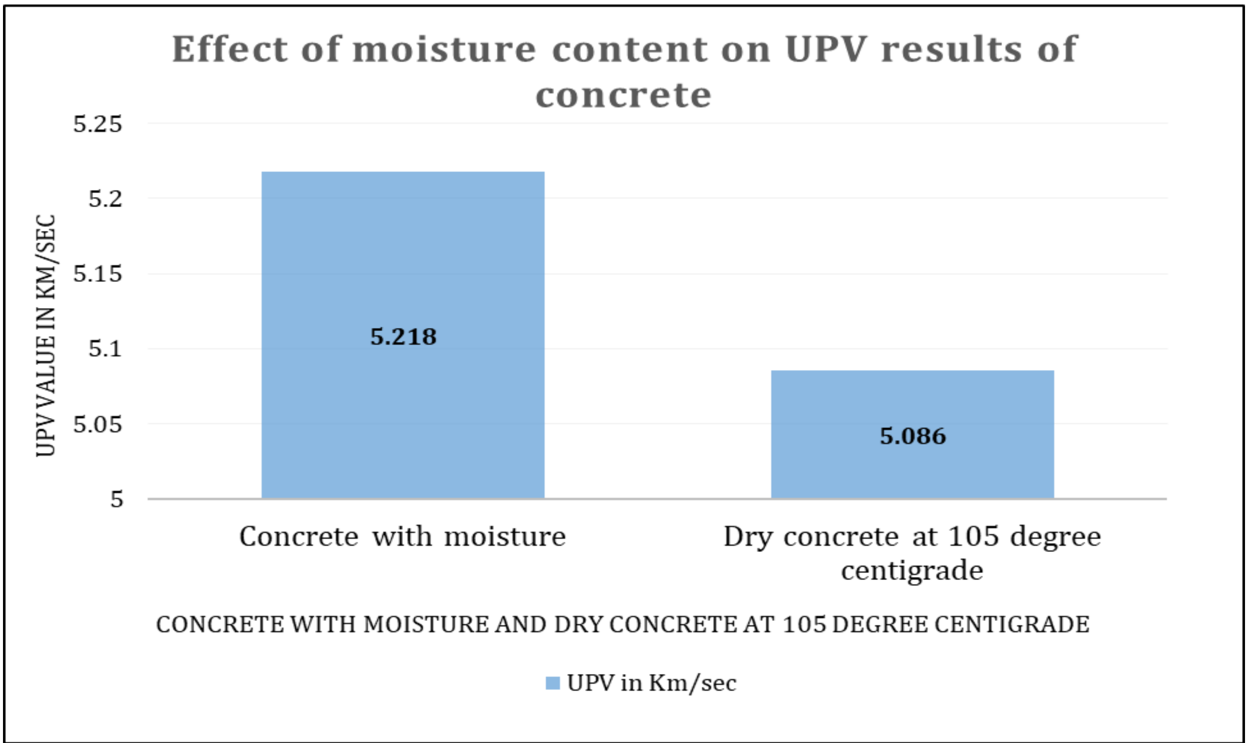

Fig-20: Effect of moisture content of concrete on UPV test results of concrete.

6. CONCLUSIONS

The following are the conclusive outcome of the research work on effect of different factors of concrete on UPV results of concrete are as follows.

i) The cured concrete shows higher UPV of concrete over non cured concrete and approximate difference is about 4.5% higher than non-cured concrete.

ii) The UPV of concrete with vibro compaction is almost 1.28% higher than concrete compacted by normal tamping method.

iii) The type coarse aggregate i.e. the type of rock is also influencing the UPV of concrete. It has been observed that almost 12.56% higher UPV is noticed in concrete made by using coarse aggregate of Basalt type rock than concrete made with Lime stone type coarse aggregate.

iv) The UPV of concrete decreases with increase in temperature of concrete and it is being observed that the % of reduction of pulse velocity is almost 8.47% for maximum temperature of 105^0C as compared to UPV of concrete at 25^0C.

v) The UPV of concrete decreases with increasing the w/c ratio of concrete.

vi) The ultrasonic pulse velocity of saturated concrete is higher than the dry concrete. It has been observed that almost 2.6% increase in pulse velocity with 5.53% moisture content in concrete.

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