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ASSESSMENT OF FIRE AFFECTED CONCRETE STRUCTURE BY NDT- A CASE STUDY

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ABSTRACT
This paper is an attempt to perform various Non-Destructive Tests on concrete structures. Various tests that are performed under NDT not only enable us to determine the strength of concrete structure, but also provide us information regarding the durability, in-situ properties of the concrete structure. Keeping these points in our mind, we have focused our views on performing a case study to show the comparison between the NDT test results performed on a particular concrete structure and another structure at the same site which is subjected to a continuous fire of say 48-72 hours. The mix design and concrete grade of both the structures were same before the one was affected by fire. The variations in the compressive strength, concrete quality and in-situ properties of the two structures have been discussed in this paper. NDT tests namely Ultrasonic Pulse Velocity Test, Rebound Hammer Test, Core-Cutter Test was performed at both the sites. The main objective of this research is to analyze the variations in the strength and quality of the concrete structure which is subjected to a high temperature fire and the one which isn't exposed to it..

KEYWORDS: Ultrasonic Pulse Velocity Test, Rebound Hammer Test, Core-Cutter Test.

INTRODUCTION
This paper deals with the change in properties of a fire affected concrete structure. A site named as Hardoli Paper mill, near Nagpur, Maharashtra, India was affected by a continuous fire for 48-72 hours. Ultimately, there may be variations in its strength and concrete quality. Hence, by performing the NDT tests on that structure, we can determine these variations. Within the mill area, there are two sites:
1. Country Storage shed (Fire affected)
2. Water storage backside (Fire unaffected)

The mix design and concrete grade properties of both the sites are totally same before the one was affected by fire. NDT tests on both the sites were performed and readings were noted. So the properties such as strength, concrete quality, visual features like cracks and crevices, etc of the fire unaffected structure i.e. water storage backside has been considered as reference base level for our readings and calculations. Accordingly, variations in the readings for the fire affected structure i.e. storage shed can be compared easily.

Thereby, in a very practical point of view, one can study the effect of fire on a concrete structure.

ABOUT THE CONCRETE
Concrete is a very basic material which is used in almost all the civil engineering projects in our daily life. It is a composition of cement, water, fine aggregate, coarse aggregate and any admixture if necessary. All these components are mixed in a definite proportion according to the mix design ratios. The quality of concrete depends upon the grade of cement used, size and properties of aggregates used, type of admixture used, quantity of water, etc. Now due to some human error in mixed-proportion techniques or due to any defects in its constituents, various defects may be produced such as honey-combing, inappropriate slump value, etc.

NON-DESTRUCTIVE TESTING

In general, the term NDT defines the Non-Destructive Testing of concrete structures, i.e. testing the strength and properties of a concrete structure without actually destroying. This is a worldwide used technique and is growing more and more importance day by day due to the results and the information it fetches about the structure. The test fetches us information such as strength of the concrete, grade of cement used, concrete quality, elastic properties, etc of the structure.

The NDT test helps us to test the objects, specimen or a system without affecting its usefulness or integrity. Many more NDT techniques and tools to be used for it have been evolved in the recent times. By using these tools, one can check the surface cracks, discontinuities and other characteristics of a material.

There are several factors that affect the quality and strength of a concrete structure. If a structure is subjected to a high temperature fire, then due to the elevated temperature the strength and concrete quality decreases. In some cases, when the structure is subjected to various loads like the seismic loads, a deflection in that structure is observed. Hence it becomes less stable and again there will be a tendency for its strength getting reduced. And in such cases, NDT plays a very important role as they give us a precise estimate about the properties of a concrete structure. Ultimately, appropriate retrofitting techniques can be suggested so as to increase the life of that affected structure.

Mainly, the properties of concrete are determined by the properties of coarse aggregate present in it. Aggregates used can be classified as follows:

1. Siliceous
2. Carbonaceous
3. Lightweight

There are various tests that come under NDT. These are as follows: Ultrasonic Pulse Velocity Test, Rebound Hammer Test, pH test, Carbonation test, Core-Cutter test, Half-cell potentiometer test, Magnetic particle tests, etc. Among all these tests, the most efficient and widely used tests are USPV test and Rebound hammer test. These tests can be performed in both direct as well as indirect method. A pitch distance usually of 200 to 250mm is taken into consideration.

Among several NDT testing methods, we are going to put into use the Ultrasonic Pulse Velocity Test, Rebound Hammer Test and the Core-Cutter Test. The reason behind selecting these tests is that the compressive strength and the concrete quality which we want to determine can be done quite accurately.

ULTRASONIC PULSE VELOCITY TEST

This is a popular method to detect the flaws ad characteristic of the material based on the velocity of the propagation of the waves through the material. This technique is applied on slabs, columns, beams, fire-affected structures, hydroelectric structures, etc. This technique allows the in depth testing of the homogeneity of the material. It determines the quality uniformity, deterioration, internal flaws and voids, etc. This method is used to assess the quality of concrete structure. Finally, regular use of this technique may lead to evaluation of further problems through its data. In this method, the two transducers are connected to the socket and the V meter and it is setup with an internal or an external battery source. Reference bar is provided to check the instrument zero level. Grease is pasted at the faces of two transducers. A path distance of upto 400mm is setup. Now using the direct or indirect methods, the V meter is switched on and the ultrasonic pulse is allowed to flow through the concrete structure. The air or the water voids present in that structure will determine the velocity with which the pulse will travel.

Pulse Velocity = Path Length / Travel Time

The *velocity* of the pulse V can be calculated by:

$V^2 = E (1-\mu) / p (1+\mu) (1-2\mu)$ (*B.S. 1881 Part 203 - 1986*)

Where, E = dynamic elasticity modulus, P = density and μ= Poisson's ratio

Hence we get a particular range of pulse velocity and hence the concrete quality is obtained as follows:

Above 4.5	Excellent
3.5 - 4.5	Good
3.0 - 3.5	Medium
Below 3	Doubtful

REBOUND HAMMER TEST

A *Schmidt hammer* also known as *rebound hammer* is used for this test. This method is a surface hardness testing method which involves an elastic mass being projected against the surface and a Rebound Number is measured. It not only determines the strength or surface hardness but also elastic properties and the penetration resistance of the concrete structure can be determined. Several correlations have been created. This is the simplest and most efficient NDT testing methods. It can be done with a great ease and hence lot of time can be saved. Due to its simplicity, this test is widely performed. One should get to recognize the factors influencing rebound strength. All that is required for this test is a Schmidt hammer which is properly calibrated by using the graph given on it. The rebound value totally depends on the hardness of the surface against which it strikes. This value also depends on the kinetic energy of the hammer before its impact with the shoulder of its plunger and the amount of energy evolved during its impact. It all depends on the stress-strain relationship of the concrete. The rebound value is read from the graduated scale and is termed as the rebound index. On application of a light pressure on the plunger against the concrete wall, it will be released from the lock position and extend it to its ready position after noting the rebound value. Take about 10 to 15 readings and the average reading is taken. This will give us the compressive strength of that particular concrete structure.

Nowadays, this method has also been used to assess the uniformity or the suspicious region in the concrete of low and damaged region.

CORE-CUTTER TEST OF CONCRETE STRUCTURE

While the above mentioned tests will give us an indirect evidence on concrete quality, but the core-cutter test will fetch us a direct assessment on the strength of the concrete structure. For performing this test, a particular core sample is cut out from the concrete slab. This sample maybe cylindrical shape with uneven or parallel square sides. The sample maybe visually having some embedded reinforcement or some aggregate or steel visible. The core sample is then soaked in water and molten Sulphur so as to make its side walls parallel, smooth and at right angles. The moist sample is then tested under compression. From this test, we can determine the strength, density, carbonation depth in concrete, etc.

Once a structure is subjected to a continuous fire of high temperature, depending on the properties of its coarse aggregate, the structure starts burning. In this case, the air and water voids that are present inside the concrete, accelerates the rate of heating. Apart this, these voids also play an important role in determining the strength and quality of concrete. Hence, after a limit is reached, due to the high temperature, the compressive strength and quality of concrete is greatly affected. This may lead the structure to collapse causing loss of property.

Hence, there is a great need of our NDT tests to be performed. These tests are very much put into use since without destroying the structure, they enable us to collect the relevant information about the structure.

LITERATURE REVIEW

K.B. Sanish and Manu Santhanam [1] investigated the development of strength of different concrete mixes using ultrasonic method. The results from this study clearly indicate that pulse velocity need not be the best indicator of strength development. The study shows that the analysis of the entire ultrasonic signal, rather than just the time of flight, can give useful details that can help in characterizing the early age strength development of concrete. In this study, the amplitude of the ultrasonic transmitted pulse, as well as the transmitted energy, were able to present a clearer picture of the rate of change of strength in concrete, as compared to the value of pulse velocity. Andre Monteiro and ArlindoGoncalves [2] suggested two equations for applying the Alternative 1(regression analysis) of EN 13791:2007 for the assessment of characteristic compressive strength in large structures using indirect methods. These equations are based on the assumption that there is no error in the rebound hammer test results(error in x).Experimental field studies, involving a large number of cores and rebound hammer tests, were carried out to evaluate the reliability of the strength predictions using EN 13791:2007 methodologies.

Larissa D. Kirchhof, AlexandreLorenzi and Luiz Carlos P. Silva Filho[3] performed a series of tests to evaluate the changes in compressive strength and ultrasonic pulse velocity of concrete subjected to high temperatures as well as to establish a relationship between residual compressive strength and UPV ratios. The results suggested that there is a significant role of the mixture proportion on the residual compressive strength of concrete subjected to elevated temperatures. There was a reduction in compressive strength as well in the UPV results for both NSC and HSC samples due to an increase in porosity/permeability of the fire-damaged concrete and a relationship between the residual compressive strength and UPV ratios was established to estimate the residual strength ratio of fire-damaged concrete with the measured residual UPV ratio.

Lucio Nobile and Mario Bonagura [4] studied the performances of the most used relations between the various NDT parameters in Italy for the estimation of the compressive strength of concrete. The results indicated the good estimation potential of the proposed formulations in the evaluation of the compressive strength of concrete, starting only from the non-destructive parameters. It was observed that the root mean squared error (RMSE) values obtained for all the cases were reasonably low in comparison to those obtained with the other formulas in the literature, thus indicating the accuracy of the proposed estimations.

Jiri Brozovsky and Jiri Zach [5] studied the influence of surface preparation method on the concrete rebound number of the impact hammer test. The results indicated that the rebound number obtained on the specimens that were cleaned using a grinding machine with diamond wheel were 2 units lower. A difference of 3 – 4 MPa was indicated in the compressive strength values which were based on the rebound number.

MohammadrezaMahmoudipour[6]evaluated the results of compression test applied to cores obtained from Behbahan Cement Factory in Iran and then compared those with the models created by using NDTs. It was found that with ultrasonic tests, actual compression strength can predicted more precisely than with Schmidt hammer test. On combining the Schmidt hammer and ultrasonic tests, despite the weak relationship between rebound number and compression strength, it was observed that the model is enhanced.

AmitGoel, Anant Gupta, Rahul Verma and AkshayMihir Das[7]studied the various non-destructive evaluation methods that are used in the field testing of reinforced cement concrete bridge members. They concluded that for determining the in-situ compressive strength the Rebound Hammer method was the appropriate method. This was due to its simplicity in operation and data interpretation. Moreover, the time and resources required for performing rebound hammer tests are less in comparison to other tests. The results of the core cutter method, are based on the crushing of concrete cores that are extracted from the site, in the laboratory environment, using the compression testing machine. Ultrasonic pulse velocity was found to be the best suited method for the quality assessment of concrete due its relative simplicity in operation, requirement of lower resources and higher versatility and accuracy. For visual inspection, based on the field experience, video boroscope was observed to be the best suited method.

H. Wiggenhauser and E. Niederleithinger[8]studied the use of Ultrasonic techniques for the imaging of structures and to monitor the changes inside large concrete structures. There has been a great improvement in these techniques over the last decade and some of the improvements include sensors and sensor arrangements, array techniques, automated data acquisition as well as various data processing techniques. Some of the new methods may require further research and development. They concluded that a set of tools are available for practical application that will help in the assessment of aging large concrete structures.

Francesco Nucera and RaffaelePucinotti[9] investigated the combined use of destructive and non-destructive tests for determining the in-situ compressive strength of reinforced concrete structures. They concluded that the use of the combined methods (SonReb) increases the accuracy of the estimation of the in-situ compressive strength.

Sanjeev Kumar Verma, Sudhir Singh Bhaduria, SaleemAkhtar [10] Rajeev Gandhi Technological University: They have discussed various NDT methods based on different principles along with their merits and limits. It has been recognized that NDT plays and important role in assessing the condition of existing structures and there has been an urgent need to increase its standards and interpretation of results. Major advantage of NDT has been recognized as their capability to test in situ. Great deal of expertise is required to interpret the NDT results.

PREREQUISITE

Within the mill area, there were two sites where the tests were performed, namely:
1. Storage Shed (site subjected to fire for 48-72 hours)
2. Waste Storage Backside (site fire unaffected)
The mix design of both the sites are exactly same, since they come under the same mill location.

Design Criteria:

1.	Characteristic of compressive strength required in 28 days	25N/mm^2
2.	Maximum size of aggregate	20mm Angular
3.	Degree of workability	Slump 65-75mm
4.	Degree of quality control	Good
5.	Type of exposure	Moderate

Test Data of Material used:

1.	Cement	OPC 43 Grade
2.	Specific gravity of cement	3.15
3.	Specific gravity of coarse aggregate 20mm	2.78
4.	Specific gravity of coarse aggregate 12.5mm	2.70
5.	Specific gravity of coarse sand	2.61
6.	Water absorption in 20mm aggregate	0.39%
7.	Water absorption in 12.5mm aggregate	0.54%
8.	Water absorption in coarse sand	0.88%

Properties of Aggregate:

1.	Crushing Value	22.4%
2.	Impact Value	21.6%
3.	Specific Gravity	2.78%
4.	Water absorption	0.39%
5.	Organic impurities	Nil
6.	Deleterious water	Nil

Target Mean Strength of Concrete:

F_{ck}= 25 + (1.65 X 5.3) N/mm^2 = 337.45 Kg/Cm^2

Absolute Value:

1.	Cement	372kg
2.	Water	186 lit
3.	Water Cement Ratio	0.5
4.	Consideration of air trapped	2.0 %

Physical Test of Cement:

Sr. No.	Name of the Test	Values obtained	Specified values in I.S. 8112 &4031
1.	Fineness	269	225 M^2/Kg min.
2.	Soundness Expansion	1	10 Maximum
3.	Setting time: Initial Final	 139 240	 30 Minute minimum 600 Minute maximum
4.	Compressive Strength 3 days average 7 days average	 263 375	 230Kg/cm^2 min. 330Kg/cm^2 min.

Mix details per m^3:

Cement = 400 Kg
Water = 160 Kg
Fine Aggregate = 660 Kg
Coarse Aggregate 20mm = 701Kg
Coarse Aggregate 12.5mm = 467Kg
Admixture = 0.6% by weight of cement = 2.4Kg
Recron 3S = 900 gm

EXPERIMENTAL PROCEDURE

A site namely Hardoli Paper Mill situated near Nagpur has been selected for performing this case study.
Some of the structures in this site was affected by a continuous fire for 48-72 hours.
Now we have selected two structures within the site:

*Country storage shed: **fire affected** structure*
*Waste storage backside: **fire unaffected** structure*

The mix design and concrete grade of both the structures are similar.
Overall physical observation of both the structures was done visually. In this, the presence of cracks and crevices, seepage on the walls, etc. were observed thoroughly.

Now by dividing each concrete slab of the two structures into different grids, NDT tests were performed:

(a) Ultrasonic-Pulse Velocity Test
(b) Rebound Hammer Test
(c) Core-Cutter Test.

Ultimately, the readings for both the structures were noted down separately. Readings of water storage backside has been considered as our reference base level.

On the basis of the test results, graph was plotted so as to show the variation in the determined quality and concrete grade of both the structures.

At last, the conclusions were drawn on the basis of these graphs.

RESULTS

ULTRASONIC PULSE VELOCITY (USPV) TEST RESULTS

SR. NO.	DESCRIPTION	PARTICULARS	TRANSIT TIME in Micro Seconds (T)	PATH LENGTH (L) (mm)	VELOCITY V=(L/T) (in KM/SEC)	AVERAGE VALUE OF U.P.V. Km/Sec
LOCATION: STORAGE SHED						
1.	Grid - 1	Indirect	74	200	2.70	2.64
		Indirect	73	200	2.73	
		Indirect	84	200	2.38	
		Indirect	76	200	2.63	
		Indirect	74	200	2.70	
		Indirect	73	200	2.73	
		Indirect	79	200	2.53	
		Indirect	81	200	2.46	
		Indirect	76	200	2.63	
		Indirect	73	200	2.73	
		Indirect	69	200	2.89	
		Indirect	72	200	2.78	
		Indirect	74	200	2.70	
		Indirect	71	200	2.81	
		Indirect	79	200	2.53	
		Indirect	82	200	2.43	
		Indirect	77	200	2.59	
		Indirect	74	200	2.70	
		Indirect	78	200	2.56	
2.	Grid - 2	Indirect	74	200	2.70	
		Indirect	77	200	2.59	

SR. NO.	DESCRIPTION	PARTICULARS	TRANSIT TIME in Micro Seconds (T)	PATH LENGTH (L) (mm)	VELOCITY V=(L/T) (in KM/SEC)	AVERAGE VALUE OF U.P.V. Km/Sec
LOCATION: STORAGE SHED						
		Indirect	79	200	2.53	
		Indirect	73	200	2.73	
		Indirect	73	200	2.73	
		Indirect	75	200	2.67	
		Indirect	78	200	2.56	
		Indirect	76	200	2.63	2.63
		Indirect	72	200	2.78	
		Indirect	76	200	2.63	
		Indirect	77	200	2.59	
		Indirect	74	200	2.70	
		Indirect	75	200	2.67	
		Indirect	78	200	2.27	
		Indirect	73	200	2.73	
		Indirect	74	200	2.70	
		Indirect	76	200	2.63	
		Indirect	74	200	2.70	
		Indirect	79	200	2.53	
3.	Grid - 3	Indirect	72	200	2.78	
		Indirect	73	200	2.73	
		Indirect	79	200	2.53	
		Indirect	81	200	2.46	
		Indirect	76	200	2.02	

SR. NO.	DESCRIPTION	PARTICULARS	TRANSIT TIME in Micro Seconds (T)	PATH LENGTH (L) (mm)	VELOCITY V=(L/T) (in KM/SEC)	AVERAGE VALUE OF U.P.V. Km/Sec
LOCATION: STORAGE SHED						
	Grid – 3 (Con.)	Indirect	80	200	2.5	
		Indirect	80	200	2.5	2.56
		Indirect	79	200	2.53	
		Indirect	81	200	2.46	
		Indirect	77	200	2.59	
		Indirect	75	200	2.67	
		Indirect	73	200	2.73	
		Indirect	78	200	2.56	
		Indirect	76	200	2.63	
		Indirect	81	200	2.46	
		Indirect	77	200	2.59	
		Indirect	77	200	2.59	
		Indirect	72	200	2.78	
		Indirect	78	200	2.56	
4.	Grid - 4	Indirect	68	200	2.94	
		Indirect	67	200	2.98	
		Indirect	69	200	2.89	
		Indirect	70	200	2.85	
		Indirect	68	200	2.94	

		Indirect	69	200	2.89	

SR. NO .	DESCRIPTION	PARTICULARS	TRANSIT TIME in Micro Seconds (T)	PATH LENGTH (L) (mm)	VELOCITY V=(L/T) (in KM/SEC)	AVERAGE VALUE OF U.P.V. Km/Sec
	Grid – 4 (Con.)	Indirect	70	200	2.85	
		Indirect	73	200	2.73	
		Indirect	71	200	2.81	
		Indirect	69	200	2.89	2.86
		Indirect	69	200	2.89	
		Indirect	69	200	2.89	
		Indirect	69	200	2.89	
		Indirect	72	200	2.78	
		Indirect	71	200	2.81	
		Indirect	71	200	2.81	
		Indirect	68	200	2.94	
		Indirect	69	200	2.89	
		Indirect	71	200	2.81	
5.	Grid - 5	Indirect	81	200	2.46	
		Indirect	78	200	2.56	
		Indirect	76	200	2.63	
		Indirect	77	200	2.59	
		Indirect	79	200	2.53	
		Indirect	80	200	2.5	
		Indirect	79	200	2.53	
		Indirect	77	200	2.59	
		Indirect	81	200	2.46	2.55

	Grid – 5 (Con.)	Indirect	79	200	2.53	
		Indirect	78	200	2.56	
		Indirect	80	200	2.5	
		Indirect	76	200	2.63	
		Indirect	77	200	2.59	
		Indirect	80	200	2.5	
		Indirect	78	200	2.56	
		Indirect	76	200	2.63	
		Indirect	81	200	2.46	
		Indirect	76	200	2.63	
	Grid - 6	Indirect	77	200	2.59	
		Indirect	75	200	2.67	
		Indirect	73	200	2.73	
		Indirect	74	200	2.70	
		Indirect	78	200	2.56	
		Indirect	76	200	2.63	
		Indirect	78	200	2.56	
		Indirect	75	200	2.67	
		Indirect	73	200	2.73	
		Indirect	76	200	2.63	2.50
		Indirect	79	200	2.53	
		Indirect	75	200	2.67	

	Grid – 6 (Con.)	Indirect	78	200	2.56	
		Indirect	72	200	2.78	
		Indirect	74	200	2.70	
		Indirect	75	200	2.67	
		Indirect	78	200	2.56	
		Indirect	79	200	2.53	
		Indirect	75	200	2.67	

IMP: These readings are plotted in Figure 1(a).

BACK SIDE USPV READINGS ARE AS FOLLOWS:

SR. NO.	DESCRIPTION	PARTICULARS	TRANSIT TIME in Micro Seconds (T)	PATH LENGTH (L) (mm)	VELOCITY V=(L/T) (in KM/SEC)	AVERAGE VALUE OF U.P.V. Km/Sec
LOCATION: BACK SIDE						
1.	Grid - 1	Indirect	63	200	3.17	
		Indirect	64	200	3.12	
		Indirect	62	200	3.22	
		Indirect	69	200	2.89	
		Indirect	67	200	2.98	
		Indirect	59	200	3.38	
		Indirect	68	200	2.94	
		Indirect	64	200	3.12	
		Indirect	70	200	2.85	
		Indirect	59	200	3.38	3.38
		Indirect	57	200	3.5	
		Indirect	63	200	3.17	
		Indirect	65	200	3.07	
		Indirect	68	200	2.94	
		Indirect	61	200	3.27	
		Indirect	68	200	2.94	
		Indirect	70	200	2.85	
		Indirect	63	200	3.17	
		Indirect	65	200	3.07	
2.	Grid - 2	Indirect	68	200	2.94	
		Indirect	64	200	3.12	
		Indirect	71	200	2.81	
		Indirect	66	200	3.03	
		Indirect	68	200	2.94	
		Indirect	63	200	3.17	
		Indirect	65	200	3.07	
		Indirect	61	200	3.27	
		Indirect	70	200	2.85	
		Indirect	72	200	2.78	3.07
		Indirect	65	200	3.07	
		Indirect	64	200	3.12	
		Indirect	67	200	2.98	
		Indirect	64	200	3.12	
		Indirect	58	200	3.44	
		Indirect	71	200	2.81	

		Indirect	59	200	3.38	

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	Grid – 2 (Con.)	Indirect	64	200	3.12	
		Indirect	59	200	3.38	
3.	Grid - 3	Indirect	59	200	3.38	
		Indirect	63	200	3.17	
		Indirect	71	200	2.81	
		Indirect	68	200	2.94	
		Indirect	64	200	3.12	
		Indirect	71	200	2.81	
		Indirect	59	200	3.38	
		Indirect	66	200	3.03	
		Indirect	64	200	3.12	
		Indirect	63	200	3.17	3.09
		Indirect	68	200	2.94	
		Indirect	59	200	3.38	
		Indirect	62	200	3.22	
		Indirect	66	200	3.03	
		Indirect	67	200	2.98	
		Indirect	63	200	3.17	
		Indirect	71	200	2.81	
		Indirect	59	200	3.38	
		Indirect	64	200	3.12	

SR. NO.	DESCRIPTION	PARTICULARS	TRANSIT TIME in Micro Seconds (T)	PATH LENGTH (L) (mm)	VELOCITY V=(L/T) (in KM/SEC)	AVERAGE VALUE OF U.P.V. Km/Sec
LOCATION: BACK SIDE						
4.	Grid - 4	Indirect	68	200	2.94	
		Indirect	59	200	3.38	
		Indirect	56	200	3.57	
		Indirect	54	200	3.70	
		Indirect	67	200	2.98	
		Indirect	61	200	3.27	
		Indirect	69	200	2.89	
		Indirect	75	200	2.67	
		Indirect	70	200	2.85	
		Indirect	63	200	3.17	3.08
		Indirect	69	200	2.89	
		Indirect	68	200	2.94	
		Indirect	75	200	2.67	
		Indirect	63	200	3.17	
		Indirect	75	200	2.67	
		Indirect	68	200	2.94	
		Indirect	58	200	3.44	
		Indirect	63	200	3.17	
		Indirect	62	200	3.22	

5.		Indirect	69	200	2.89	
		Indirect	71	200	2.81	
		Indirect	75	200	2.67	
		Indirect	62	200	3.22	
		Indirect	64	200	3.12	
		Indirect	75	200	2.67	
		Indirect	62	200	3.22	
		Indirect	69	200	2.89	

	Grid - 5	Indirect	67	200	2.98	
		Indirect	58	200	3.44	2.92
		Indirect	79	200	2.53	
		Indirect	68	200	2.94	
		Indirect	74	200	2.70	
		Indirect	81	200	2.46	
		Indirect	58	200	3.44	
		Indirect	69	200	2.89	
		Indirect	72	200	2.78	
		Indirect	73	200	2.73	
		Indirect	68	200	2.94	

6.	Grid - 6	Indirect	74	200	2.70	
		Indirect	67	200	2.98	
		Indirect	64	200	3.12	
		Indirect	71	200	2.81	
		Indirect	61	200	3.27	
		Indirect	67	200	2.98	
		Indirect	72	200	2.78	
		Indirect	58	200	3.44	
		Indirect	63	200	3.17	
		Indirect	69	200	2.89	
		Indirect	64	200	3.12	
		Indirect	59	200	3.38	
		Indirect	74	200	2.70	3.07
		Indirect	60	200	3.34	
		Indirect	65	200	3.07	
		Indirect	67	200	2.98	
		Indirect	59	200	3.38	
		Indirect	63	200	3.17	
		Indirect	58	200	3.44	

These readings are plotted in Figure 1(b)

The graph of the above readings of USPV methods for both the sites are as follows :

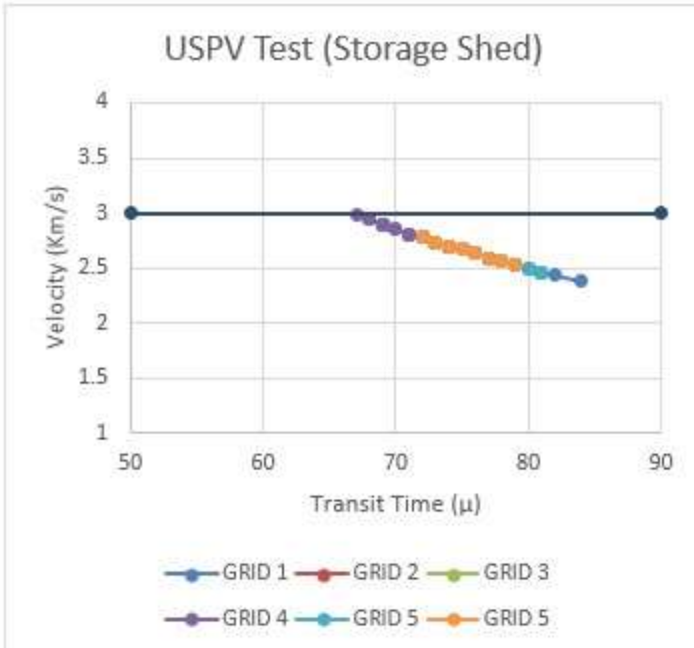

Figure 1(a)

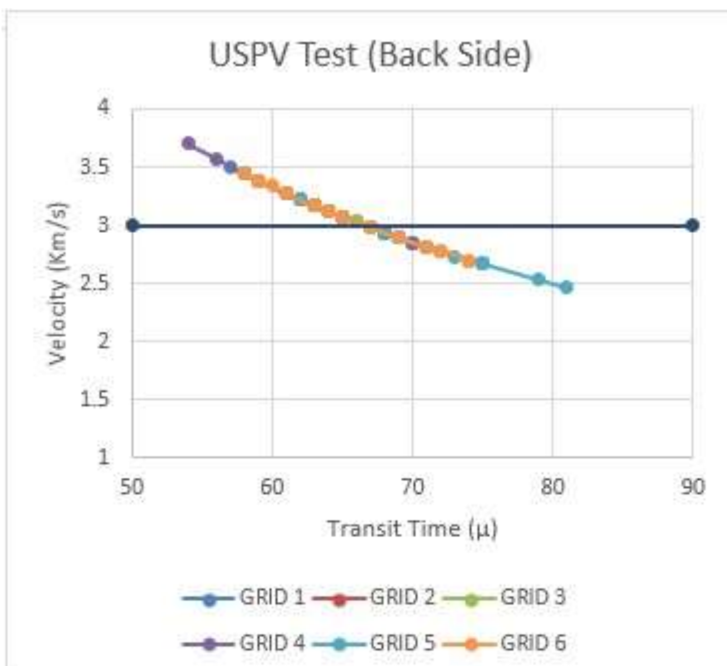

Figure 1(b)

SCHMIDT REBOUND HAMMER TEST RESULTS

SR. NO.	DESCRIPTION	REBOUND NO.	AVERAGE
BASE SLAB GROUND LEVEL			
1.	Grid - 1	24,22,28,22,22,20,26,28,30,32	25.40

2.	Grid - 2	18,24,18,22,14,18,30,24,16,20	20.40
4.	Grid - 3	22,22,24,18,22,20,20,24,28,18	21.80
5.	Grid - 4	20,24,24,20,26,24,28,18,20,22	22.60
6.	Grid - 5	18,20,20,18,22,26,20,26,24,24	21.80
7.	Grid - 6	28,22,16,18,20,16,24,24,26,24	21.80
WASTE STORAGE BACK SIDE			
1.	Grid - 1	36,28,32,34,36,32,28,30,32,28	31.60
2.	Grid - 2	30,28,28,30,28,28,32,,30,30,26	29.00
3.	Grid - 3	24,34,36,26,38,30,26,24,36,30	31.40
4.	Grid - 4	28,34,32,30,22,24,18,22,20,22	25.20
5.	Grid - 5	22,30,28,26,30,32,20,20,30,28	26.60
6.	Grid - 6	20,24,22,24,26,26,24,22,26,24	23.80

These readings are plotted in Figure 2

ULTRASONIC PULSE VELOCITY TEST RESULTS FOR CORE

SR. NO.	SAMPLE IDENTIFICATI ON	PARTICULARS	**TRANSIT TIME** in Micro Seconds (T)	PATH LENGTH (L) (mm)	VELOCITY V=(L/T) (in KM/SEC)	AVERAGE VALUE OF U.P.V. Km/Sec
1.	Core 1 (Storage Shed)	Direct	28	90	3.21	
2.	Core 2 (Storage Shed)	Direct	31	70	2.26	2.93
3.	Core 3 (Storage Shed)	Direct	40	100	2.50	
4.	Core 1 (Back Side)	Direct	29	100	3.45	
5.	Core 1 (Back Side)	Direct	26	100	3.85	3.62
6.	Core 1 (Back Side)	Direct	28	100	3.57	

These readings are plotted in Figure 3

The graph of the above mentioned readings of Rebound Hammer Test and Core Test USPV are as follows:

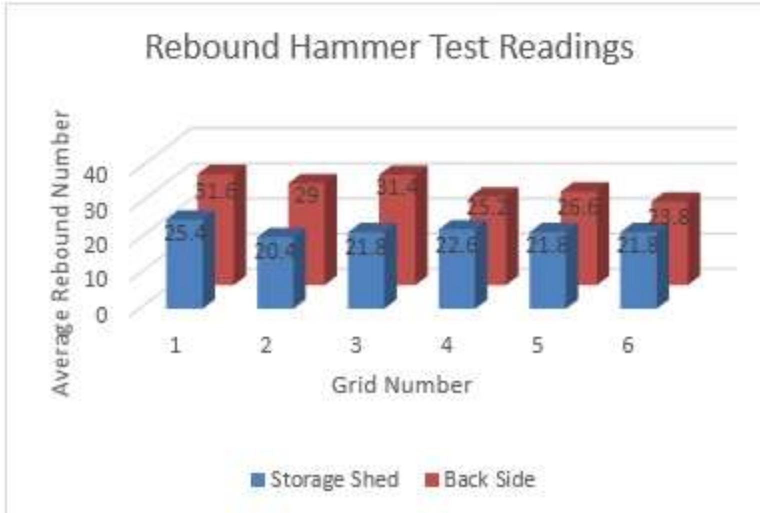

Figure 2

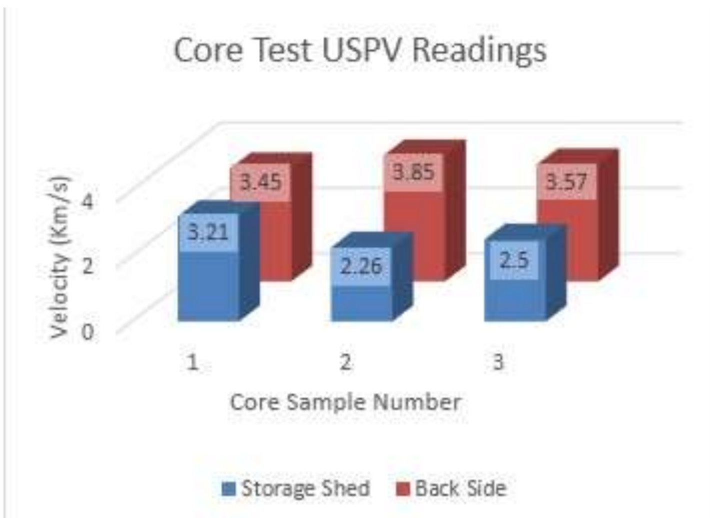

Figure 3

CONCLUSION

Before the structure was affected by fire:

1. On the basis of the readings obtained by performing Ultrasonic Pulse Velocity Test, the quality of concrete comes in the range of 3 to 3.5. Hence, it is of medium quality.
2. Lesser number of air and water voids in the concrete structure since the transit time for the travelling of pulses was quite less.
3. On the basis of the readings obtained by performing Rebound Hammer Test, the compressive strength of the concrete structure comes out to be around 25N/mm2.
4. On the basis of readings obtained by performing Core Cutter Test, the quality of concrete used on the floor slab comes to be in the range of around 3.5. Hence, we can say that the quality of the concrete is medium or even good.
5. Physical observations of the concrete structure says that there can be seen hardly any cracks and crevices. The structure seems to be in a stable and good condition.

After the structure was affected by fire (48-72 hours):

1. The Ultrasonic Pulse Velocity Test determines the quality of that concrete structure to be in the range of 0 to 3. Hence, the quality is doubtful.

2. Number of voids has been increased since the pulses take comparatively more time to travel through the concrete structure.
3. The Rebound Hammer Test results predict the compressive strength of that concrete structure to be around 20N/mm2. Hence, the strength of that structure is drastically deteriorated.
4. The core sample readings indicate that the quality of the floor slab is in the range of 0 to 3. Hence it is of doubtful quality. Again there is deterioration on its quality.
5. Physical observations mark the presence of some cracks and crevices on the edges of floor slab and columns. Some part of the structure seems to be deteriorated and unsafe for use due to the risk of it getting collapsed.

Overall, a concrete structure consisting of the load bearing members such as slabs, beams and columns which when exposed to a very high temperature gets deteriorated drastically, developing cracks and crevices, more number of air and water voids in it ultimately affecting the compressive strength and the quality of the concrete structure.
Hence, a thorough case study has been done on analyzing the variations on the strength and quality of a concrete structure when it is affected by a high temperature continuous fire.

CONFLICT OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this paper.

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