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AN IVESTIGATION ON MECHANICAL PROPERTIES AND DAMAGE OF NORMAL CONCRETE AND MORTARS SUBJECTED TO MAGNESIUM SULPHATE ENVIRONMENT

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Abstract

Concrete, is one of the key construction material having good compressive and durable properties among others. Sulphate attack is one of the most important problems affecting concrete structures, especially Magnesium Sulphate (MgSO4) attack. An investigation on the mechanical properties and damage evolution of OPCC exposure to MgSO4 environment. Then I'm collected some information about sulphate and their concentrations in kadapa region, by reference of those concentrations I was prepared MgSO4 solution with different percentages like 1%, 3% and 5% and were casted specimens was exposed for a period of 7, 14, 28, 56 and 90 days. There by parameters compressive strength test, NDT will be investigated at various erosion times of 7, 14, 28, 56 and 90 days. NDT such as UPV and Rebound Hammer strength tests will be performed to evaluate the strength characteristics and also damage characteristics. A relationship between damage and UPV of OPCC was derived according to damage mechanics and a correlation between the damage exposed to sulphate environment by using UPV and Rebound Hammer test. The OPCC performance evaluation under MgSO4 environment exposure conditions will be done by studying relations. Finally correlated an relation between compressive strengths obtained from DT and NDT tests

Keywords:

Magnesium sulphate attack, non-destructive test, destructive test, compressive strength, ultrasonic pulse velocity

I. INTRODUCTION

Concrete, is one of the important construction materials having good compressive strength, flexural strengths and durable properties among others. And this concrete is a versatile building substance made by mixing of cement, water, coarse and fine aggregates. Concrete is mouldable, flexible and relatively fire resistant. Concrete throughout its service life it is subjected to several chemical and physical impact such as act of nature sulphate attack, carbonization and acidic water which may in term guide to wearing. The falling apart offices might be substance-sulphates, chlorides, CO_2, acids and so on or (mechanical) automatic causes like scraped area, affects temperature and so on. Sulphate attack was first observed in 1908 by the "United States Bureau of reclamations(USBR)" and the related researches have been held ever since. The engineering structures are constructed from the underground. In such case, these are affected by the chemicals which are present in the underground water, soils, industrial waste water etc.

SCOPE OF THE WORK

- Before any construction of structures, we should perform water analysis, chemical studies, micro-scopic studies on water bodies at surrounding areas or underground areas.
- If in-case, we observed any chemicals or sulphates are presented, we should prefer for remedial measures i.e.., sulphate resisting cements, high quality concrete etc., must be used.
- As per the study, we are investigated on durability characteristics.
- As per the study, we performed the tests only for 90 days, but the structures life time is prolonged and damage will be affected more by these sulphates.

OBJECTIVE OF THE STUDY

- The main objective of my project is to study the effect of MgSO4 attack on concrete. The study parameter chosen is compressive strength. This compressive strength is measured both by compression testing(CTM) and NDT. The strength from both methods were used to compare.
- The compressive strength of concrete and mortar specimens after exposure to MgSO4 solution with 1%,3%,5% at 7,14,28,56 and 90 days period of time was determined.
- Under non destructive tests, we are going to test the specimens of concrete and mortar i.e., UPV tests and rebound hammer test with different erosions of time up to 90 days..

II. LITERATURE REVIEW

i. M.M. Amin, S.B.Jamaludin, F.C.Pa, K.K.Chuen (2007):

- They Study on "Effects of Magnesium sulphate attack on ordinary Portland cement (OPC) mortars".
- The chemical and minerological compositions in ordinary Portland cement(OPC) were determined and cement which is low of C3A is more easily showing to sulphate environment.
- The relation between physical strength of Mortar sized 150x150x150mm and the effects of different concentrations of sulphate solution(1% 3% and 5%) for 3, 14 and 28 days was establish to be that stronger the sulphate concentrations.

ii. Sheng Cang, Xiaoli Ge, and Yanlin Bao:

- They study on "Assessment of mechanical properties and damage of HPC subjected to magnesium sulphate environment".
- Sulphate attack is most important problem occuring in the concrete Structures, especially magnesium sulphate attack.
- In this paper, they used high performance concrete with addition of fly ash and super-plasticizers.
- In this paper, the effects of magnesium sulphate on ordinary concrete are studied.
- They observed that the addition of flyash to the ordinary concrete is considerably increases the resistance to magnesium sulphate Attack.
- By adding flyash, durability of concrete will be increases but Mechanical properties of concrete will be decreases with significant amount of clay minerals.
- The materials were used cement and mineral admixtures, aggregates, super-plasticizers and they used the mix proportions of about cubic size (100x100x100mm)and Prismatic size (70x70x280mm) specimens of HPC were cast.

iii. Sabit Oymael Leman Sen:

- They study on effects of $MgSO_4$ and Na_2SO_4 Solutions on concrete mortars from cement types PKC 32.5 and PC 42.5.
- Under certain sulphate conditions, this study aims to determine the nature and severity of such difference. The chemical and physical analysis and measurements are observed with XRD and SEM Instruments.
- Water penetrating into concrete cubes after curing in the magnesium sulphate solution the surface of the specimens, where they form a thin whitish layer called "Flowers of Sulphur". In their research on the impact by sulphates from the mixing water on the cement Mortar (paste) features studied about on their yield strength, flexural strength and compressive strength of the mortar(paste).

iv .Wojciech Piasta, Julia Marczewska, Monika Jaworska:

- This paper is about some aspects and mechanisms of sulphate attack. The dissolution of cement Matrix may be considerable because, the destruction of concrete under Sulphate Attack is particularly related to expansion.
- Also discussed about the types of sulphate attacks i.e.,calcium sulphate, magnesium sulphate, Ammonium Sulphate and sodium sulphate.

- Finally they concluded that about the experimental results are;

  The changes in the microstructure of air entrained composites were presented. The air entrained and non entrained Mortars from two various OPC where immersed in 5% sodium sulphate solution.

- The longitudinal strains of mortars samples were measured to determine their expansion. To find out the microstructure of mortars specimens SEM (scanning electron microscope) by using. In Mortars specimens the expansion was compared after formation of a Ettringite Were identified.

V .M Vijaya Sekhar Reddy, I.V. Ramana Reddy, K. Madan Mohan Reddy And C. M. Ravi Kumar:

- This study about curing of concrete plays a major role in developing the concrete microstructure and pore structure and hence improves its durability and performance.
- Due to the high alkalinity of concrete it has always know the behavior of standard concrete of M40 grade specimens curing with acids such as HCL, alkaline such as NAOH and sulphate solution and Mgso4 and Na2So4.
- Another advantage of using SCMS is increases in durability of concrete which consequently results increase in resource use efficiency of ingredients of concrete which are depleting at very fast rate.
- The use of supplementary cementing materials has become an integral part of high strength and high performance concrete mix design.

vi. S. Oymael:

- In this study they watched the effect of sulphate on length change of concrete. Sulphates usually affect calcium aluminates in cement sulphate ions might have negative effects of cement hydration and it would be a reason of decrease in cement strength.
- In this study the effects of Na_2SO_4 solution on the concrete made from OPC with oil shale ash (OSA) addition (0%,15%, 30%) were Investigated. Concretes with 15% OSA gave the lowest value of length change factor (LCF).
- Addition of an optimum amount of super-plasticizer increase positive properties of the concrete with 15%.OSA addition, binds free $Ca(OH)_2$ in OPC, makes its composition more effective, prevents massive alkali aggregate reaction showing that this addition rate is proper.
- In this study, length changes in concrete with OSA addition (0%,15%,30%) OPC burnt at 700°C have been investigated.

III. MATERIALS AND THEIR BASIC PROPERTIES

The materials used in the present project are cement, aggregate, coarse Aggregate, fine Aggregate, mineral Admixture, fly ash, and water.

Cement:

The Cement, which binds, the other material in concrete with a required amount of water it is a key ingredient to concrete. Consequently, cement was invented by Joseph aspdin in the year of 1984. In this project I used OPC 53 grade cement.

Fig 1: Cement Sample

Table 1: Basic tests on cement

S.no	Properties	values
1	Fineness	7.33%
2	Specific gravity test	3.15
3	Soundness	10 mm
4	Consistency	29.15%
5	Initial setting time	30 minutes
6	final setting time	600 minutes

Aggregate:

Aggregates are important ingredients in concrete, aggregates occupy the volume 3quartesof concrete(60% - 80 %) of a volume of concrete. And it gives body for concrete. In previous we had a statement about concrete I.e. concrete was inert material. In the same way, the aggregates are also chemically inert material.

The aggregates are classified into two types based on size of aggregate

- Fine Aggregate
- Coarse Aggregate

Size of aggregate was less than 4.75 mm, that will consider as fine aggregate and size of aggregate was higher than 4.75 mm, that will consider as coarse aggregate.

Fine aggregate

Fine aggregates ordinarily from natural sand or crushed stone with particles passing through 4.75 mm and retains in 0.075 mm sieve. I.e. 50-60% concrete was prepared only fine aggregate and it gives a body to Concrete.

Table 2: Basic tests on fine aggregate

S.no	Properties	Values
1	Sieve analysis	Grading zone II
2	Specific gravity test	2.631
3	Bulking of sand	23.708%
4	water absorption test	0.5%
5	Fineness modulus	Grading zone II

Fig 2: Fine Aggregate Sample

Coarse aggregate

Coarse aggregates are found out by its sieving activity I.e. coarse aggregates ordinarily from crushed stone with particles retained in 4.75 mm sieve. I.e. 40-45% concrete was prepared coarse aggregate and it gives a body to Concrete.

Table 3: Basic tests on coarse aggregate

S.no	Properties	values
1	Flakiness	99.75%
2	Specific gravity test	2.64
3	Elongation test	99.85%
4	Water absorption	0.25%
5	Fineness modulus	7.14%
6	Aggregate impact value test	25.54%

Fig 3: 20 mm aggregate (coarse)

Mix Design

The selection of mix materials and their required proportion is done through a process called mix design. There are number of methods for determining concrete mix design. The method that we have adopted is called the I.S. Method which is in compliance to the Indian Standards. The objective of concrete mix is to find the proportion in which concrete ingredients cement, coater, fine aggregate and coarse aggregate should combined in order to provide the specified strength, workability and durability and possibly meet other requirements as listed in standards such as IS:456 -2000.

Table 4: mix design for conventional concrete of M_{40} grade

S.no	Material	quantity
1	Cement	450 kg/m^3
2	Fine aggregate	732.379 kg/m^3
3	Coarse aggregate	1067.204 kg/m^3
4	water	208 liters
6	**Mix proportion**	**1: 1.634:2.39**

Batching & Mixing

Batching is a process of collecting the materials in one particular place for mixing. in this having two types

- weigh batching
- volume batching

In this project I'm using volume batching

Fig 4: batching of concrete ingredients

Explication of concrete mixing

Mixing of concrete is defined as combine the concrete ingredients with water to required consistency of concrete mix. The mixing of concrete is basically two types they are as follows

- Hand mixing
- Machine mixing

In this study I'm used hand mixing

Fig 5: Hand mixing of concrete

Workability tests on fresh concrete

Workability of concrete as defined as ease to work i.e.mixing, placing and finished. Workability reflects on strength, durability and homogeny. The workability may be determined by the following five methods.

- Slump cone test
- Compaction factor test
- Vee-bee consistometer test
- Flow table test
- Kelly ball test

We usually perform slump test in site and lab due its ease and results. It gives quick result about the workability of concrete. According to the above statement 99% of workability of concrete is knows only by the slump cone test. But for betterment of results I was done slump& compaction factor test

Fig 6: slump cone with concrete Casting

Fig 7: casting of concrete cubes Curing

Curing is the process of maintaining the moisture content and temperature of concrete cube at starting stages. That is in two ways

- Normal curing
- Accelerated curing

Fig 8: Accelerated curing tank

Preparation of magnesium solution

Magnesium sulphate is a chemical & it contains magnesium Sulphur & oxygen with the formula $MgSO_4$. According to the reference of table no 2 & 3 we had a basic statement on Kadapa region sulphate content and their severity. Based on above statement I'm selected some percentages like from according to my reference authors whatever percentages are taken into their considerations I.e. 1%, 3% and 5%.

As we know 1 PPM = 1 Mg/L
Like that 1 Gram = 1000 Milligrams
In Kadapa region the sulfates are nearer are equal to 1000 Mg/L. So the percentages are like this

For 1% ➔ 1 X 1000 mg of $MgSO_4$ powder/1000 ml of water

3% ➔ 3 X 1000 mg of $MgSO_4$ powder/1000 ml of water

5% ➔ 5 X 1000 mg of $MgSO_4$ powder/1000 ml of water

Table5 : Preparation different percentages of Mgso4 solution

S.no	Percentage	Magnesium sulphate (G or Mg)	Distilled water (L or ML)
1	1	1000	1000
2	3	3000	1000
3	5	5000	1000

IV. Experimental Study

Testing of cubes

In this study the cubes were tested in 3 types

- Compressive testing machine test
- Ultrasonic pulse velocity test
- Rebound Hammer Test

Compressive Testing Test

compressive strength was done on cube with sizes of 150 mm x 150 mm x 150 mm. compressive strength was depends on some elements that are w/c ratio, cement content, aggregate sizes, shape and finally replaced (or) introduced mineral admixtures & their content. In this study I'm tested cubes from 3days, 7 days, 14 days, 28 days, 56 days and 90 days.

Fig 9: Compression testing machine apparatus with cubes

Fig 10: after testing in CTM the cubes were like this

Ultrasonic pulse velocity test

The ultrasonic pulse is one type of non-destructive test. Non-destructive testing is a process of testing the Concrete without damage to cube. It is for quality assessment for Concrete.

In any type of structure we assess the quality by their properties like internal flaws, density, uniformity,homogeneity, inadequate compaction, segregation etc.

If in case is any cracks available in structure the path length growing more and time also more to reach the transducer to receiver it was directly reflected by pulse velocity.

Where the pulse velocity is less in that case the quality of concrete structures also less (poor) in other way transit time increases & reduces the pulse velocity. The magnitude pulse velocity depends on workmanship.

By using this formula we calculate the velocity of concrete cube

$V = \frac{L}{T}$

Where

V = Pulse velocity in km/sec

L = Path length m or km or mm

T = time taken to reach pulse between transducer to receiver in sec

A minimum path length for direct transmission method is 150 mm recommended. In this I'm also using direct transmission and 150 mm cube length.

It was three possible ways to find pulse velocity

- Direct transmission (cross probing)
- Semi-direct transmission
- Indirect transmission (surface probing)

In this study I'm using direct (cross probing) transmission. In this direct transmission method the transducers placed in opposite direction of cube and this method gives maximum sensitivity and defined path length.

Fig 11: Ultrasonic pulse velocity by cross probing

Applications:

- To know the uniformity of concrete
- Strength estimation without damaging of structure
- Find out deterioration in structure i.e. cracks, honeycombing, sapling etc.
- To get the thickness of layer
- To know the elastic modulus by using relations between velocity to young's modulus
- To assess the concrete deterioration due climatic conditions or in case physical errors

Rebound Hammer Test

- For testing, smooth, clean and dry surface is to be selected. If loosely adhering scale is present, this should be rubbed of with a grinding wheel or stone. Rough surfaces resulting from incomplete compaction, loss of grout, spelled or tooled surfaces do not give reliable results and should be avoided.
- The point of impact should be at least 20 mm away from any edge are shape discontinuity.
- For taking a measurement, the rebound hammer should be held at right angles to them surface of the concrete member. The test can thus be conducted horizontally and vertical surfaces or vertically upwards or downwards on horizontal surfaces. If the situation demands, the rebound hammer can be held at intermediate angles also, but in each case, the Rebound hammer will be different for the same concrete.
- Around each point of observation, 6 readings of rebound indices are taken 2nd average of these Readings after deleting outliers as per IS 8900:1978 becomes the rebound index for the point of observation.
- The rebound numbers are influenced by a number of factors like types of cement and aggregate, surface condition and moisture content, age of concrete and extent of carbonation of concrete.

Fig 12: Rebound Hammer Instrument

V. Experimental Results

Workability of M40 concrete mix:

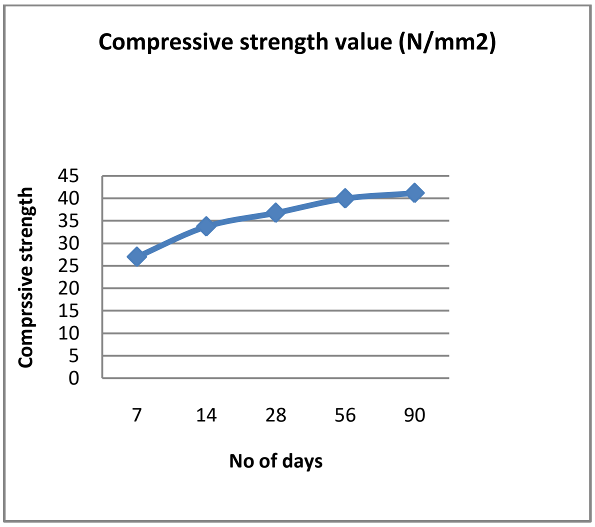
- ✓ In the present experimental investigation M40 grade concrete mix is considered. The mix is designed by the I.S method and for the basic reference mix the concrete content 450 kg/m^3.
- ✓ The water to cement ratio is 0.4. When mixed a stiff and a relatively dry mix was obtained.
- ✓ The compacting factor was found to be which indicates a lower workability. Throughout the whole project, workability is maintain constant.

Compressive strength results

- ✓ The compressive strength results (tables) are given for 3 different concentrations of MgSo4 exposure of mortars and concrete samples considered.
- ✓ In general it is found that compressive strength is getting reduced when the samples are subjected to MgSo4 environment. It is also observed that there is marginal decrease in the compressive strength.

Table 6: Mortar specimens before exposure to $MgSO_4$ environment, the average compressive strength in N/mm^2:

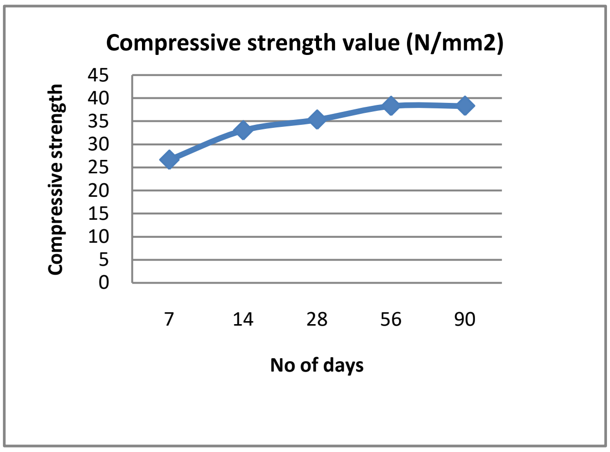
S.NO	Name of the specimen	No. of days	Compressive strength value (N/mm^2)
1.	M1	7	27
2.	M2	14	33.75
3.	M3	28	36.78
4.	M4	56	39.98
5.	M5	90	41.18



Graph 1: Represents compressive strength of mortar specimens before immersion of $MgSO_4$ Environment:

Table 7: Mortar specimens after exposure to 1% Mgso4 environment, the average compressive strength in N/mm^2:

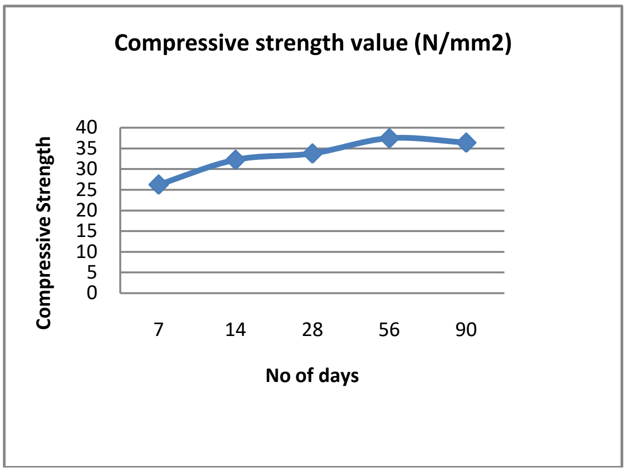
S.NO	Name of the specimen	No. of days	Compressive strength value (N/mm2)
1.	M1,1	7	26.64
2.	M2,1	14	33.03
3.	M3,1	28	35.35
4.	M4,1	56	38.32
5.	M5,1	90	38.35



Graph 2: Represents compressive strength of mortar specimens after 1% immersion of $MgSO_4$:

Table 8: Mortar specimens after exposure to 3% Mgso4 environment, the average compressive strength in N/mm^2:

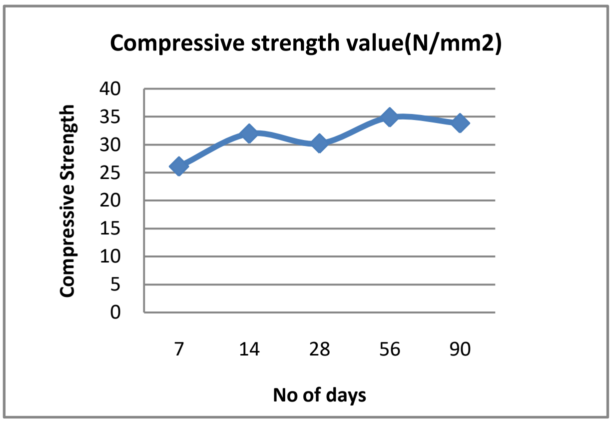
S.NO	Name of the specimen	No. of days	Compressive strength value (N/mm2)
1.	M1,3	7	26.24
2.	M2,3	14	32.23
3.	M3,3	28	33.75
4.	M4,3	56	37.43
5.	M5,3	90	36.38



Graph 3: Represents compressive strength of mortar specimens after 3% immersion of $MgSO_4$:

Table 9: Mortar specimens after exposure to 5% Mgso4 environment, the average compressive strength in N/mm^2:

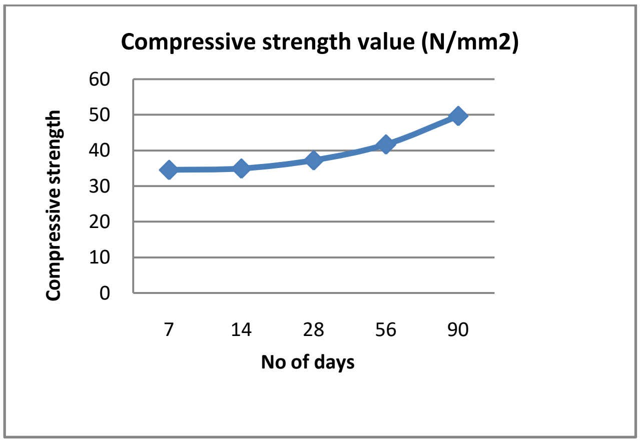
S.NO	Name of the specimen	No. of days	Compressive strength value(N/mm^2)
1.	M1,5	7	26.12
2.	M2,5	14	31.99
3.	M3,5	28	30.24
4.	M4,5	56	34.92
5.	M5,5	90	33.86



Graph 4: Represents compressive strength of mortar specimens after 5% immersion of $MgSO_4$:

Table 10: Concrete specimens before exposure to $MgSO_4$ environment, the average compressive strength in N/mm^2:

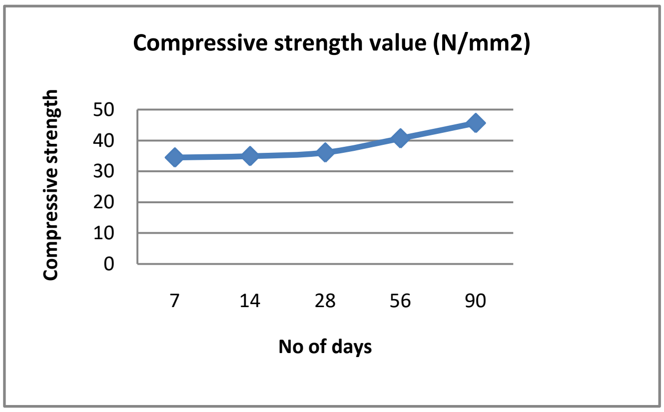
S.NO	Name of the specimens	No. of days	Compressive strength value (N/mm2)
1.	C1	7	34.53
2.	C2	14	34.91
3.	C3	28	37.23
4.	C4	56	41.68
5.	C5	90	49.67



Graph 5: Represents compressive strength of concrete specimens before immersion of $MgSO_4$:

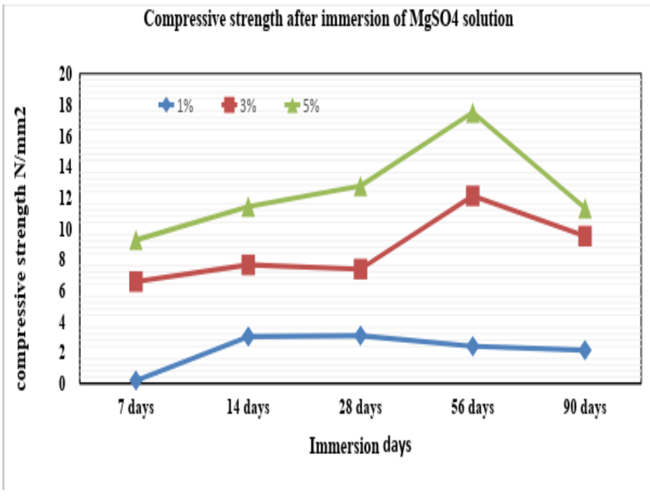
Table 11: Concrete specimens after exposure to 1% Mgso4 environment, the average compressive strength in N/mm^2:

S.NO.	Name of the specimens	No. of days	Compressive strength value (N/mm2)
1.	C1,1	7	34.47
2.	C2,1	14	34.91
3.	C3,1	28	36.08
4.	C4,1	56	40.68
5.	C5,1	90	45.67



Graph 6: Represents compressive strength of mortar specimens after 1% immersion of $MgSO_4$:

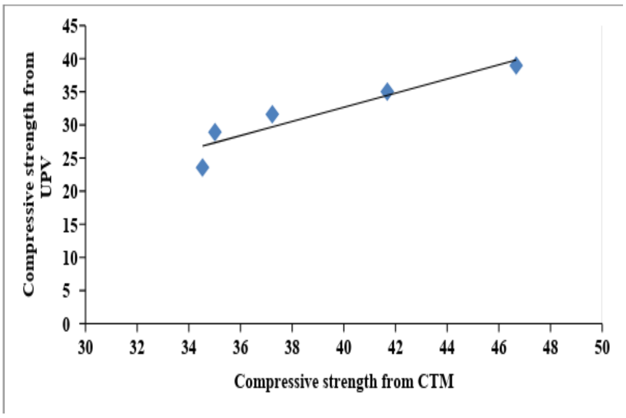
Graph 7: Graphical representation, deterioration of concrete specimens based on solution % with exposure days:



UPV STRENGTH RESULTS:

Table 12: UPV strength results on Concrete specimens before exposure to $MgSO_4$ environment:

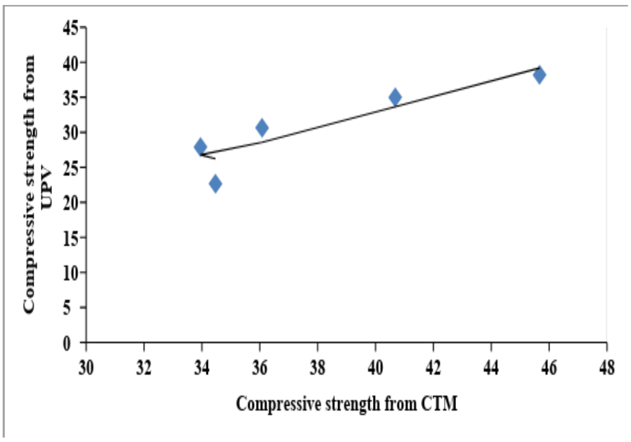
S.NO.	Curing days	Time in micro sec	Velocity (km/sec)	Young's Modulus (N/mm^2)	F_{ck} (N/mm^2)
1.	7	48.47	4.95	30.6x103	23.56
2.	14	48.83	4.92	30.4x103	28.90
3.	28	49.60	4.88	30.2x103	31.60
4.	56	50.26	4.81	30.0x103	35.02
5.	90	50.82	4.76	29.0x103	38.96



Graph 8: shows compressive strength of concrete before exposure to $MgSO_4$, CTM vs UPV:

Table 13: UPV strength results on Concrete specimens after exposure to 1% $MgSO_4$ environment:

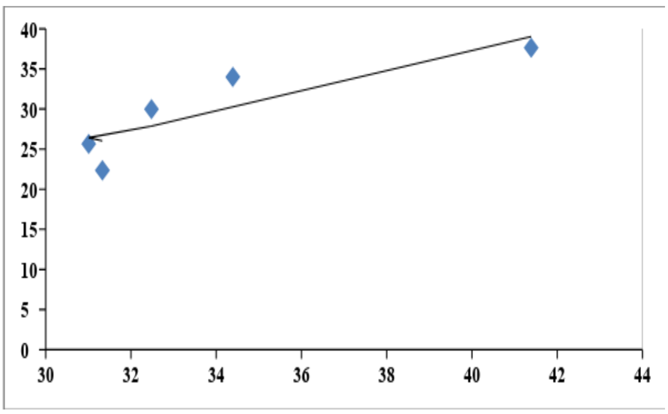
s. no	Curing days	Time in micro sec	Velocity (km/sec)	Young's modulus (N/mm^2)	Characteristic strength of concrete Fck (N/mm^2)
1.	7	48.52	4.91	$30.5x10^3$	22.65
2.	14	48.97	4.84	$30.3x10^3$	27.89
3.	28	49.83	4.80	$30.1x10^3$	30.65
4.	56	50.73	4.72	$30.0x10^3$	35.00
5.	90	50.98	4.68	$29.8x10^3$	38.20



Graph 9: shows compressive strength of concrete after exposure to 1% $MgSO_4$, CTM vs UPV:

Table 14: UPV strength results on Concrete specimens after exposure to 3% $MgSO_4$ environment:

S. N O.	Curing days	Timein micro sec	Velocity (km/sec)	Young's modulus (N/mm^2)	Characteristc strength of concrete F_{ck} (N/mm^2)
1.	7	49.12	4.81	$30.5x10^3$	22.56
2.	14	49.82	4.74	$30.3x10^3$	26.98
3.	28	50.23	4.72	$30.1x10^3$	30.06
4.	56	50.91	4.64	$30.0x10^3$	34.68
5.	90	51.01	4.51	$29.8x10^3$	38.03

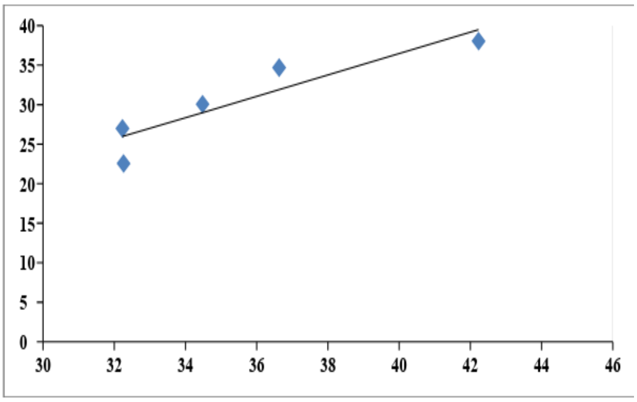


Graph 10: shows compressive strength of concrete after exposure to 3% $MgSO_4$, CTM vs UPV:

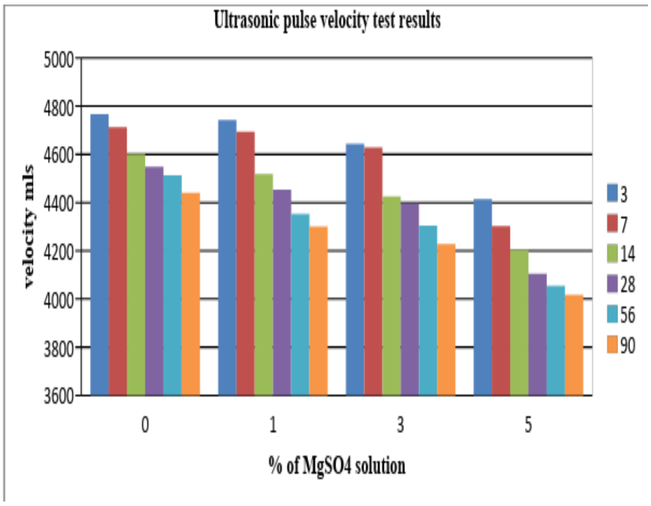
Table 15: UPV strength results on Concrete specimens after exposure to 5% $MgSO_4$ environment:

S.NO.	Curing days	Time in micro sec	Velocity (km/sec)	Young's modulus (N/mm^2)	F ck (N/mm^2)
1.	7	49.41	4.72	$30.3x10^3$	22.35
2.	14	49.93	4.64	$30.1x10^3$	25.66
3.	28	50.43	4.63	$29.6x10^3$	29.99
4.	56	50.99	4.53	$29.7x10^3$	34.00
5.	90	51.51	4.41	$29.3x10^3$	37.63

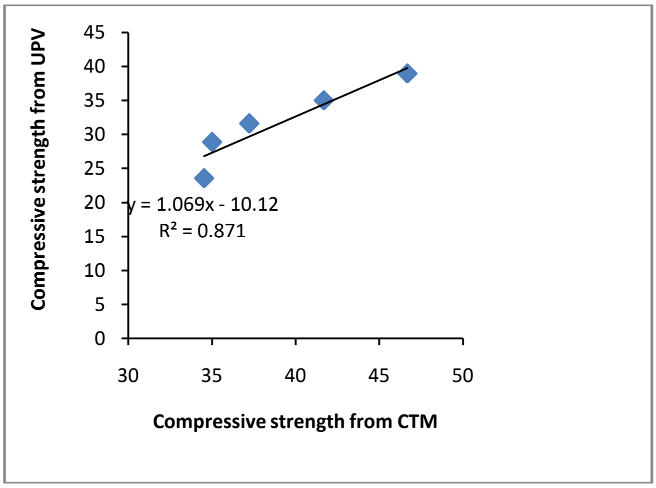
Graph 11: shows compressive strength of concrete after exposure to 5% $MgSO_4$, CTM vs UPV:

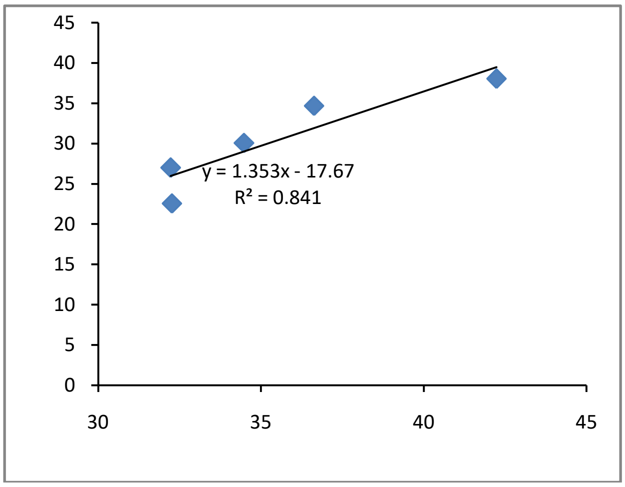


Graph 12: Overall Ultrasonic pulse velocity test results (different % with different days)



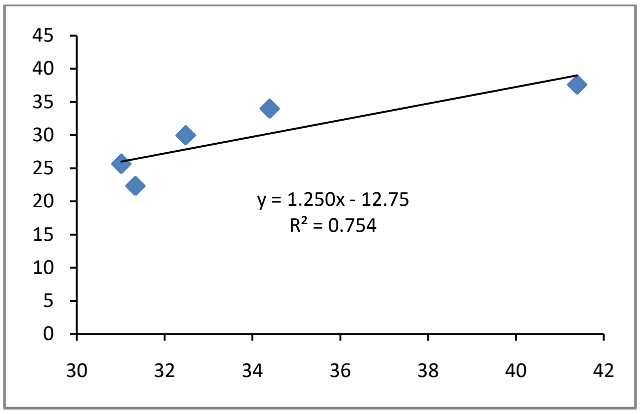
Graph 13: correlated equation between DT & NDT methods for before exposure to $MgSO_4$ solution



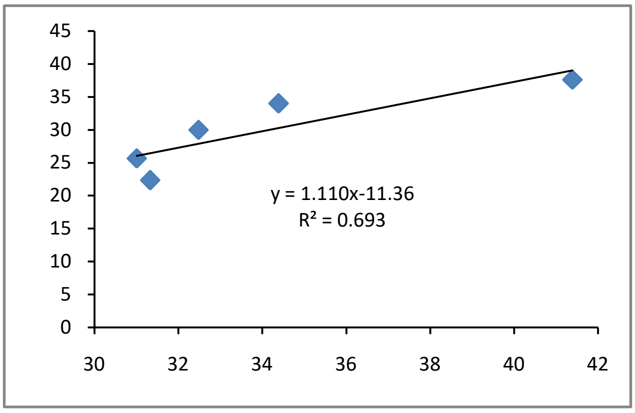


Graph 14: correlated equation between DT & NDT methods for after exposure of 1% MgSO4 solution

Graph 15: correlated equation between DT & NDT methods for after exposure of 3% $MgSO_4$ solution



Graph 16: correlated equation between DT & NDT methods for after exposure of 5% $MgSO_4$



REBOUND HAMMER STRENGTH RESULTS:

Table 16: Rebound compressive strength on horizontal direction of concrete specimens:

Exposure to MgSO4	Compressive strength @7 days	Rebound value	Rebound compressive strength	Calibration factor
0%	34.53	36	38	0.90
1%	34.47	32	29	0.84
3%	32.26	34	30	0.92
5%	38.56	34	30	0.77
Exposure to MgSO4	Compressive strength @14 days	Rebound value	Rebound compressive strength	Avg:0.855
0%	34.01	40	36	0.94
1%	33.95	39	35	0.97
3%	39.33	39	35	0.88
5%	36.47	38	34	0.93
Exposure to MgSO4	Compressive strength @28 days	Rebound value	Rebound compressive strength	Avg:0.93
0%	37.23	47	46	0.80
1%	36.08	45	44	0.82
3%	40.31	44	42	0.95
5%	32.24	43	39	0.82
Exposure to MgSO4	Compressive strength @56 days	Rebound value	Rebound compressive strength	Avg:0.84
0%	41.68	48	49	0.85
1%	40.68	47	47	0.86
3%	41.36	46	45	0.91
5%	33.92	46	44	0.73
Exposure to MgSO4	Compressive strength @90 days	Rebound value	Rebound Compressive strength	Avg:0.83
0%	46.67	45	48	0.97
1%	45.67	43	45	0.98
3%	42.69	42	44	0.97
5%	34.86	42	43	0.81

Horizontal calibration factor =H'=0.852

Table 17: Rebound compressive strength of vertical direction of concrete specimen:

Exposure to $MgSO_4$	Compressive strength @7 days	Rebound value	Rebound Compressive strength	Calibration factor
0%	34.53	35	32	0.92
1%	34.47	33	30	0.87
3%	32.26	33	30	0.97
5%	38.56	33	30	0.77
Exposure to $MgSO_4$	Compressive strength @14 days	Rebound value	Rebound Compressive strength	Avg0.88:
0%	34.01	37	37	0.91
1%	33.95	36	35	0.97
3%	39.33	35	34	0.86
5%	36.47	35	34	0.93
Exposure to $MgSO_4$	Compressive strength @28 days	Rebound value	Rebound Compressive strength	Avg:0.91
0%	37.23	43	45	0.82
1%	36.08	43	44	0.82
3%	40.31	42	42	0.95
5%	32.24	41	41	0.78
Exposure to $MgSO_4$	Compressive strength @56 days	Rebound value	Rebound Compressive strength	Avg:0.84
	46.67	50	52	0.89
0%	45.67	48	50	0.91
1%	42.69	47	48	0.88
3%	34.86	45	46	0.75
5%	Compressive strength @90 days	Rebound value	Rebound Compressive strength	Avg:0.85
0%	41.68	48	45	0.86
1%	40.68	47	45	0.90
3%	41.36	45	46	0.89
5%	33.92	44	42	0.80
				Avg:0.86

Vertical calibration factor=V’=0.868

VI. CONCLUSION

- No major damage was observed on specimens exposed to the sulphate solution for a period of 90 days.
- And also observed the formation layer of ettringite on the specimens i.e.., ”Flowers of Sulphate.”
- Loss of weight and loss of density was observed up on exposure with increase no. of exposure days, the strength was observed to decrease.
- Magnesium Sulphate attacks at low temperatures are much faster than high temperatures.
- The attack mechanism of cement hydrates by magnesium sulphates varies from one type of mortars and concrete specimens to another, it depends on the nature of cement as well as on its chemical composition ($Ca(OH)_2$ content and Cao/SiO_2 ratio), type of sand used, PH and temperature of solution.
- The main products are formed that ettringite, thaumasite and gypsum are causing the deterioration of cementitious materials.
- Cements with low C3A content are subject to degradation caused by the thaumasite formed (TSA).
- The test results show that the ultrasonic pulse velocity gives information about the internal micro-cracking for the specimens and provide evidence of damage mortar and concrete specimens.

S.no	Days of curing	Decreased Compressive strength percentage @ 5% $MgSO_4$ solution	
		DT	NDT
2	7	3.2%	1.21%
3	14	4.0%	2.24%
4	28	4.75%	3.56%
5	56	7.29%	3.98%
6	90	9.28%	4.23%

- Rebound Hammer strength within an accuracy of +-20 to +-25% may be possible which the correlation curves are established.
- In earlier there is No correlation among destructive and Non-destructive tests however in this study I'm derived an relation based on my values, the relations are:
- As per the study, we are investigated on durability characteristics. But coming to UPV method useful for both fresh & hardened concrete cubes/structures.

S. no	% of $MgSO_4$	$MgSO_4$ in PPM	Relation among DT & NDT methods	R^2
1	0%	0	Y=1.069x-10.12	0.871
2	1%	1000	Y= 1.353x-17.67	0.841
3	3%	3000	Y=1.250x-12.75	0.754
4	5%	5000	Y= 1.110x-11.36	0.693

- The investigation results shows the maximum deterioration at 5% (or) 5000 Mg/
- According to my study in Kadapa area concrete structures are resisted by sulfates above 3000 Mg/L it should be great change in structure properties compare to ≤ 3000 Mg/L.

VII. REFERENCES

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