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Experimental Investigation Properties of Reinforced Cement Concrete with Partial Replacement of Cement by Metakaolin Clay and Structural Health Monitoring Using Sensor

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Abstract: Cement concrete is the most extensively used construction material. Maintenance and repair of concrete structures is a growing problem involving significant expenditure. As a result carried out worldwide, it has been made possible to process the material to satisfy more stringent performance requirements, especially long–term durability. HPC is the latest development in concrete. It has become very popular and is being used in many prestigious projects such as Nuclear power projects, flyovers multi-storeyed buildings. When using HPC, the addition of supplementary materials in cement has dramatically increased along with the development of concrete industry, due to the consideration of cost saving, energy saving, environmental concerns both in terms of damage caused by the extraction of raw materials and carbon dioxide emission during cement manufacture have brought pressures to reduce cement consumption. Metakaolin looks to be a promising supplementary cementations material for high performance concrete. Properties of concrete with metakaolin is mostly preferred additives in high performance concrete. A possible lower cost, due to large availability in our country itself may be advantages to metakaolin usage in HPC. The substitution proportion of metakaolin is to be used was 5%, 10%, 15%, 20% by the weight of cement. To make this cubes and cylinders to determine the strength and durability of concrete of it. A multitude of structural health monitoring options are currently being investigated to address the reliability of concrete infrastructures at different stages of their service life. This review presents the recent achievements in the field of sensors developed for monitoring the health of concrete infrastructures. The focus of this review is on sensors developed for monitoring parameters including temperature, humidity, pH, corrosion rate, and stress/strain and the sensors particularly fabricated based on fiber optic, Bragg grating, piezoelectric, electrochemical, wireless and self-sensing technologies. Several examples of developed concrete monitoring sensors (from laboratory concepts to commercialized products) together with their various benefits and drawbacks as well as open research problems will be discussed in this project.
Keywords: Cement, Metakaolin Clay, Fine Aggregate, Coarse Aggregate, Water, LM35 Temperature Sensors, Piezoelectric Sensors, DHT11 Humidity Sensors

I. INTRODUCTION

Cement plays the role of a binder, a substance that sets and hardens and might bind alternative materials along. The word "cement" comes from Romans, UN agency used the term “opus caementiciumto” describe masonry resembling fashionable concrete that was made up of rock with calcined lime as binder. The volcanic ash and small-grained brick additives (surkhi) that were additional to the calcined lime to get a hydraulic binder were later brought up as cimentum, cäment, and cement. Cement is widely used by human beings and it is second largest material after water used by human beings. Concrete is probably the most extensively used construction material in the world. It is only next to water as the most heavily consumed substance and about six billion tones being produced every year. This is due to the availability of large quantity of raw materials available for cement manufacture. However, environmentalists concern both in terms of damage caused by the extraction of raw material and CO2 emission during cement manufacture have brought pressures on researchers for the reduction of cement consumption by partial replacement of cement by supplementary materials. These materials may be naturally occurring, industrial wastes or by-products that require relatively less energy to manufacture. The other concerns contributing to these pressures are the incidents involving serious deterioration of concrete structures.

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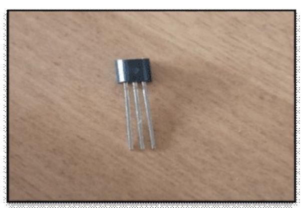
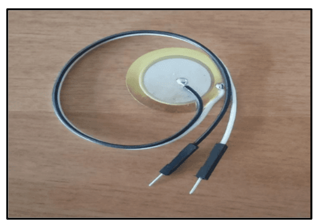
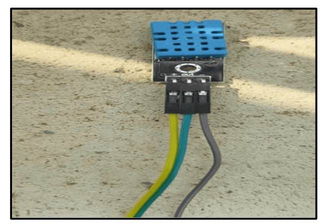
In addressing these concerns and other environmental issues relating to the disposal of waste industrial by products because of economic advantages, mixtures of Portland cement and pozzolans are now very commonly used in concrete production. Structural health monitoring (SHM) of concrete refers to the process of implementing a damage diagnosis and identification strategy. Current methods of the manual evaluation of a structure at fixed time intervals can be costly and labor-intensive. The advances in sensor technologies, wireless communications, data processing techniques, and artificial intelligence, in conjunction with the ever-growing number of aging structures and the pressure to minimize maintenance costs, reducing in-service failures and unforeseen downtimes have led to the development of smarter SHM techniques.

II. TECHNOLOGIES USED FOR DESIGNING SHM SENSORS

1) LM35 Temperature Sensors: LM35 series are precision integrated circuit temperature sensors with an output voltage linearly proportional to the centigrade temperature. It is calibrated in Kelvin. It measures changes in pressure, temperature, acceleration or force by converting them to an electrical charge.
2) Piezoelectric Sensors: Piezo sensors are used within many sensors and devices. They are used to convert a physical parameter, for example acceleration or pressure, into an electrical signal. Piezo sensors are used to measure the change in pressure, acceleration or strain by converting them into electrical charge. Piezoelectric devices are widely used in different industries, environments and applications, allowing to measure dynamic changes in mechanical variables including acceleration, shock and vibration.
3) DHT 11 Humidity Sensors: It measures Humidity of the surroundings. This sensor can be interfaced with any micro controller and it transmits the information to micro controller.


LM35 Temperature Sensors


Piezoelectric Sensors


DHT 11 Humidity Sensors

III. MIX DESIGN

A MIX FOR M25 GRADE OF CONCRETE WAS DESIGNED AS PER IS 10262-2009.

A. Stipulations of Proportioning

- Grade designation = M25
- Type of cement and grade of cement = OPC 43
- Maximum size of aggregate = 20 mm
- Exposure condition = Severe
- Minimum cement content = 300 kg/m3
- Workability in term of slump = 100 mm
- Standard deviation = 5.0 N/mm2
- Type of aggregate = Crushed angular
- Maximum cement content = 450 kg/m3
- Water cement ratio = 0.45

B. Test Data of Material

- Specific gravity of cement = 3.16
- Specific gravity of fine aggregate = 2.46
- Specific gravity of coarse aggregate = 2.73
- Specific gravity of water = 1.00

C. Target Strength

- f' ck = fck + 1.65 s
  = 25 + 1.65 x 5
  = 33.25 N/mm2
- f' ck = Target mean compressive strength at 28 days
- fck = Characteristic compressive strength at 28 days
- s = Standard deviation. (is: 10262-2019, tab -2)

D. Water Cement Ratio

- Exposure = severe
- From IS 456 – 2000, water cement ratio = 0.45
- Adopt water cement ratio = 0.45

E. Water Content

- From IS-10262 Table 2, 20mm aggregate = 186 kg (50mm slump)

For 100mm slump,

- For every 25mm add 3% = 186 + 6% of 186
  = 197 kg
- For super plasticizer reduce 20% = 197-20% of 197
- Water Content = 157.6 kg

F. Calculation of Cement Content

- Water cement content = Water content/Cement content
- Cement content = Water content/Water cement
  = 157.6 / 0.45
  = 394 kg/m3 > 320 kg/m3
- Cement content = 394 kg/m3

G. Aggregate Proportion between Coarse and Fine Aggregate

From IS-10262, Table 5, volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate (zone II),

- For W/C ratio of 0.5 = 0.62
- For every 0.05 decrease, increase 0.01 (W/C – 0.45) = 0.62 + 0.01
  = 0.63

For pump able concrete coarse aggregate can be reduced up to 10%

- Volume of coarse aggregate (0.63-10% of 0.63) = 0.549

H. Mix Calculation & Proportion

Cement	Fine aggregate	Coarse aggregate	Water/cement ratio
394 kg/m^3	791 kg/m^3	1068 kg/m^3	157.6 kg/m^3

IV. CASTING SPECIMEN AND PLACING THE SENSORS

The cubes of size 150 mm X 150 mm X 150 mm were cast to find out the compressive strength of concrete to find out the optimum percentage of metakaolin in concrete. A total of 36 cubes were casted to find out the compressive strength at the age of 7, 14 and 28 days. A three set of specimens were cast for different combinations. The fresh concrete mix was filled in the steel moulds in three equal layers and each layer was well compacted using table vibrator. Finally the concrete are tends to curing.

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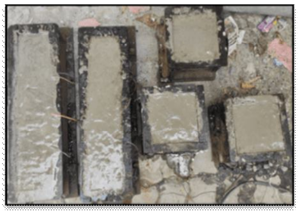
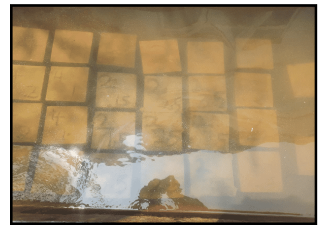

Casting the Specimen


Placing the Sensors


Curing the Specimen

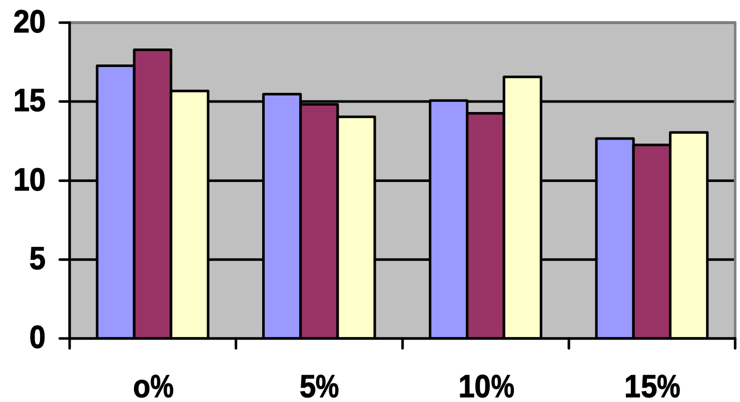
V. TESTS AND RESULTS

A. Compressive Strength Test:

All cubes of concrete were tested in a Compression Testing Machine with the references of IS: 516 – 1959 to determine Compressive Strength of concrete at the age of 7 days. The Values for Compressive Strength of concrete for all the mixes are listed in Table 4.1.

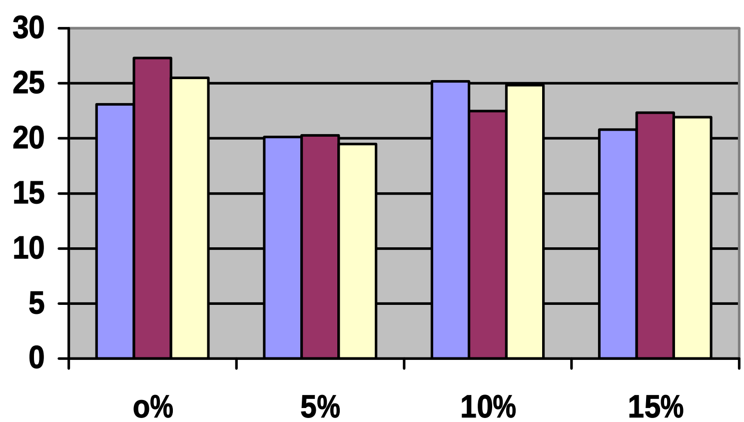
Compressive Strength at 7 days

S.NO	Metakaolin 0% N/mm^2	Metakaolin 5% N/mm^2	Metakaolin 10% N/mm^2	Metakaolin 15% N/mm^2
1	17.269	15.462	15.060	12.651
2	18.273	14.814	14.257	12.249
3	15.663	14.041	16.557	13.052
Avg	17.068	15.529	17.184	14.281



Compressive Strength at 14 days

S.NO	Metakaolin 0% N/mm^2	Metakaolin 5% N/mm^2	Metakaolin 10% N/mm^2	Metakaolin 15% N/mm^2
1	23.092	20.124	25.187	20.781
2	27.309	20.267	22.474	22.325
3	25.502	19.482	24.842	21.934
Avg	25.354	22.548	25.546	22.054



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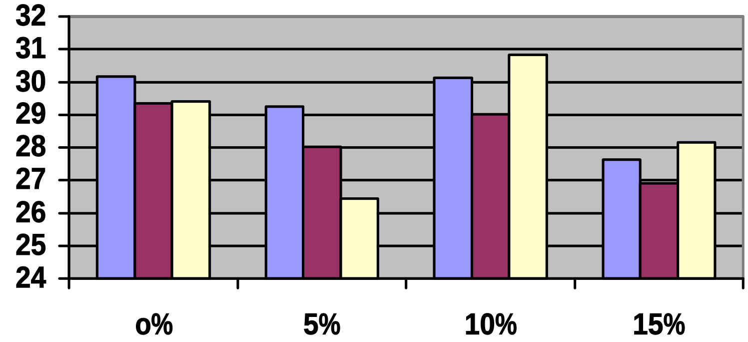
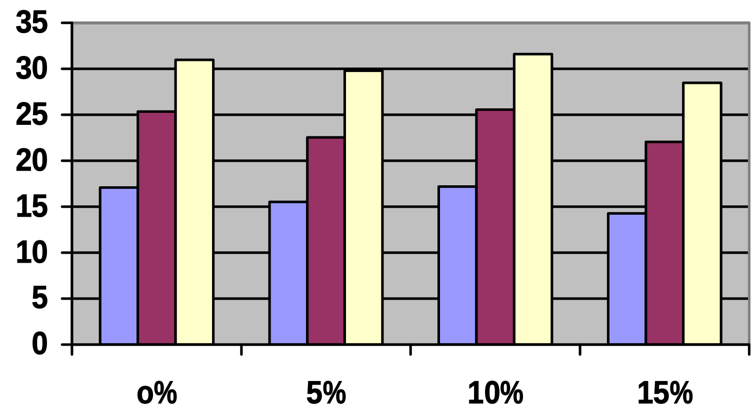
Compressive Strength at 28 days

Days	**Metakaolin 0% N/mm^2**	**Metakaolin 5% N/mm^2**	**Metakaolin 10% N/mm^2**	**Metakaolin 15% N/mm^2**
7	17.068	15.529	17.184	14.281
14	25.354	22.548	25.546	22.054
28	30.980	29.781	31.589	28.485



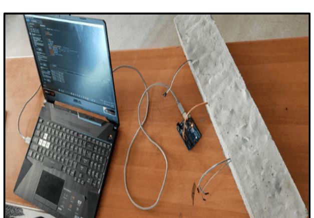
Comparison of Compressive Strength at 7, 14, & 28days

S.NO	**Metakaolin 0% N/mm^2**	**Metakaolin 5% N/mm^2**	**Metakaolin 10% N/mm^2**	**Metakaolin 15% N/mm^2**
1	30.157	29.245	30.127	27.624
2	29.348	28.010	29.021	26.911
3	29.403	26.442	30.820	28.152
Avg	30.980	29.781	31.589	28.485

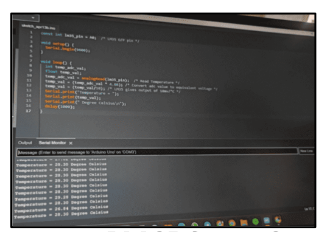


B. Circuit Connection between Concrete Specimen and Arduino Board:

The Arduino platform has become quite popular with people just starting out with electronics, and for good reason. Unlike most previous programmable circuit boards, the Arduino does not need a separate piece of hardware (called a programmer) in order to load new code onto the board -- you can simply use a USB cable.


Circuit Connection


DHT 11 Sensor Output


LM 35 Sensor Output

VI. CONCLUSIONS

In this review, some recently reported sensors for SHM of concrete and their pros and cons were highlighted. The emphasis was more on the sensors fabricated based on fiber optic, Bragg grating, piezoelectric, electrochemical, wireless, and self-sensing technologies. While fiber optics and Bragg grating based sensors are more popular in monitoring humidity, temperature and pH, electrochemical sensors are commonly employed for corrosion monitoring, and piezoelectric transducers and self-sensing concrete are mainly used for strain/stress detection and monitoring.

The fascinating properties of fiber optics and Bragg grating techniques are likely to continue to generate more activities in the scientific pathway of sensor design. 36 cubes were casted at the replacement ratios of 10%, 20% and 30% which were tested for the compressive strength at the stages of 7, 14 and 28 days. It is found that the addition of Metakaolin in concrete as replacement of OPC increases the compressive strength significantly. The clinker dilution effect occurs due to the replacement of cement by metakaolin and this effect is counter-acted by the pozzolanic reaction of metakaolin. Hence, it is significant to observe the optimum level of metakaolin replacement at which greater strength is achieved. Comparatively, the compressive strength attained the maximum value at the replacement level of 10%. Furthermore, ambient curing of concrete gave better results than water curing.

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REFERENCES

[1] Adams Joe M, Maria Rajesh A, Experimental Investigation on the Effect of M-Sand in High Performance Concrete. American Journal of Engineering Research, 2015, 2, 46-51.

[2] AmritpalKaur, Rajwinder Singh Bansal, Strength and Durability Properties of Concrete with Partial Replacement of Cement with Metakaolin and Marble Dust, International Journal of Engineering Research & Technology., 2015, 4, 1032-1035.

[3] Dinakar P, Pradosh, K. Sahoo, Sriram G, Effect of Metakaolin Content on the Properties of High Strength Concrete. International Journal of Concrete Structures and Materials. 2013, 3, 215–223.

[4] Nova John, Strength Properties of Metakaolin Admixed Concrete. International Journal of Scientific and Research Publications. 2013, 6, 1-7.

[5] Poon C, Kou C, Wong Y.L, Ron Wong, and Rate of pozzolanic reaction of metakaolin in high-performance cement pastes. Cement and Concrete Research. 2001, 31, 1301–1306.

[6] Priyanka A, Dilip K. Kulkarni, Effect of replacement of natural sand by manufactured sand on the properties of cement mortar.International Journal of Civil and Structural Engineering., 2001, 3, 621-628.

[7] Wild S, Khatib M, Relative strength, pozzolanic activity and cement hydration in super plastic is edmetakaolin concrete Cement and Concrete Research., 2001, 10, 1537-1544.

[8] D.Anjali, S.S.Vivek and G.Dhinakaran; Compressive Strength of Metakaolin Based Self-Compacting Concrete; International Journal of ChemTech Research; 2015, Vol.8, No.2, pp 622-625.,

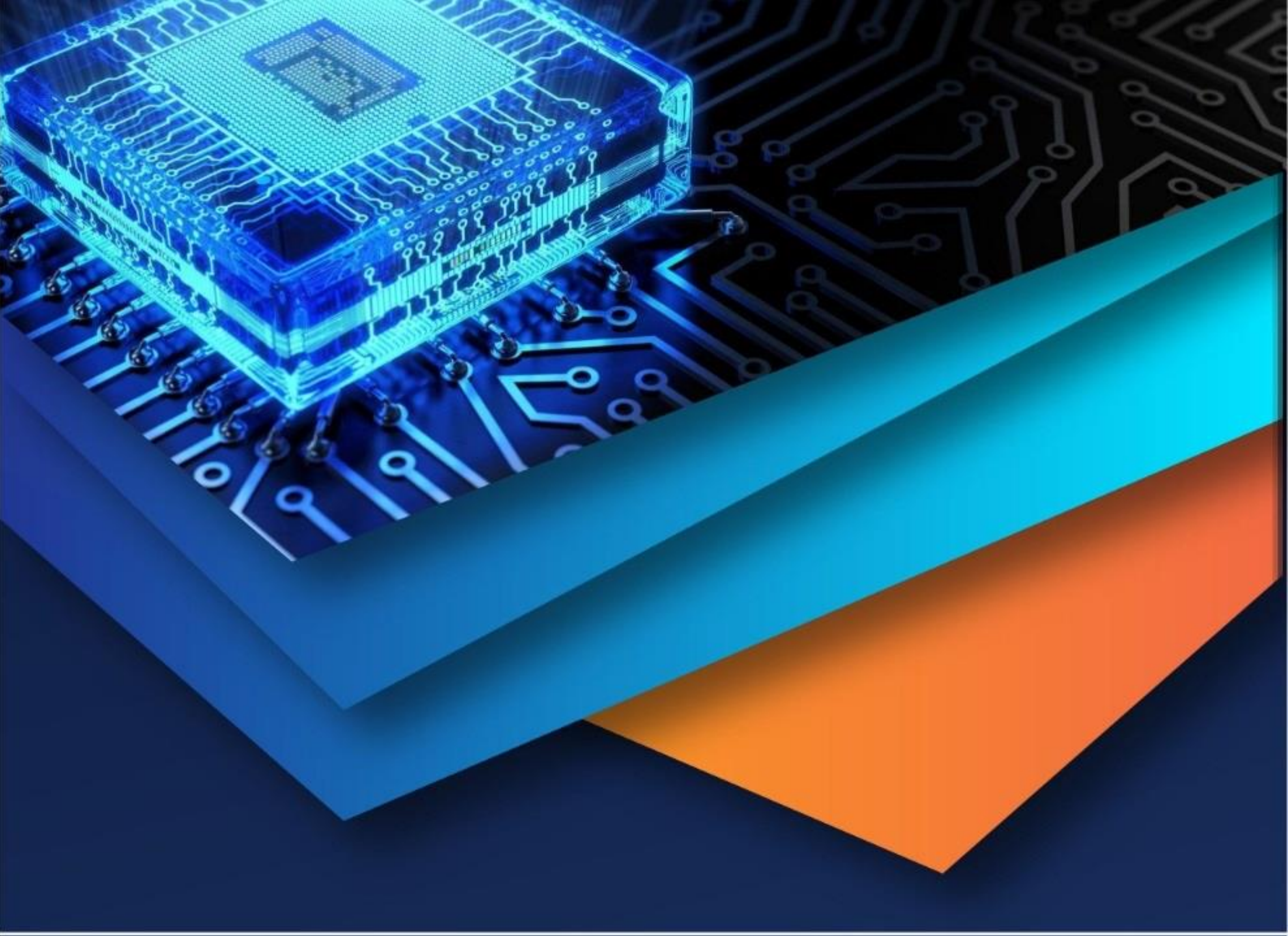
[9] Peter C. Chang, Alison Flatau and S. C. Liu (2003), “Review Paper: Health Monitoring of Civil Infrastructure”, SAGE Publication, Vol 2(3): 0257–267

[10] Charles R Farrar and Keith Worden (2007), “An introduction to structural health monitoring”, Philosophical Transaction of Royal a Society, 365, 303–315 doi:10.1098/rsta.2006.1928.

[11] Claus-Peter Fritzen, (2005 Sep 15), “Vibration-based Structural Health Monitoring – Concepts and Applications”, Trans Tech Publications, Switzerland, Vols. 293-294, pp 3-20

[12] Jina Kim, Benjamin L. Grisso, Dong S. Ha, and Daniel J. Inman (2007), “A System-On-Board Approach for Impedance-Based Structural Health monitoring”, Proc. of SPIE, Vol. 6529

[13] N V Mahure, R P Pathak, Sameer Vyas, Pankaj Sharma, S L Gupta (2013), “Corrosion Monitoring Of Reinforcement in Underground Galleries of Hydro Electric Project” Pankaj Sharma et al Int. Journal of Engineering Research and Applications ISSN : 2248-9622, Vol. 3, Issue 5, Sep-Oct 2013, pp.1087-1090



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