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Stability Check Of RCC Chimney Using Health Monitoring.

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Abstract- *Chimney is a tall slender structure and the primary function of the chimney is to discharge pollutants into the atmosphere at such heights with sufficient velocity such that the gases and suspended solids (ash) are dilute due to atmospheric turbulence and concentration of pollutants are deemed harmful to the environment over a defined spread such that their concentration, on reaching the ground is within regulatory limits. Chimney have different associated structural problems and must therefore be treated separately from other forms of tower structures. Damage to the chimneys leads to shut down of the industry and power plants. So, structural health monitoring of RCC chimney is required for find out the stability, service life and condition of RCC chimney. This paper proposes a wireless micro electro mechanical system (MEMS) inclinometer sensor for structural health monitoring (SHM) that can be applied to RCC chimney subjected to various loadings. Inclinometer sensor used in this study for finding out the deflection of chimney and check the deflection data given by the sensor with the deflection value calculate by the classical approach using codal provision standards and STAAD Pro. This type of in-situ, non-destructive structural health monitoring is implemented for stability check of RCC chimney.*

Keywords- *RCC Chimney, Types of chimney, STAAD Pro, Deflection, Inclinometer Sensor, Structural Health Monitoring*

I. INTRODUCTION

Chimneys are very important structures for the emission of poisonous gases in major industries and power plants. After realising the urgent need to restrict the pollution levels, chimney height is being rapidly increased. As large scale industrial developments are taking place all around the world, a large number of tall chimneys would be required to be constructed every year. Chimneys are classified in based on construction material, structural support, lining and number of flues. Chimneys are special structures subjected to many different unconventional loading conditions. Analysis and design of chimney depends on various factors such as wind force, seismic force, temperature effect, types of materials used and cross sectional area of the chimney. The combustion flue gases inside the chimney or stacks are much hotter than the ambient outside air and therefore less dense than ambient air. This causes the bottom of the vertical column of hot flue gases to have a lower pressure than the pressure at the bottom of the corresponding column of outside air. The higher pressure outside the chimney is the driving force that moves the required combustion air into the combustion zone and also moves the flue gas up and out of the chimney. If Damage occurred in chimneys due to some circumstances so it can stop the work of the plants. So, for that health monitoring of structure is require for damage identification, in which certain strategies are implemented for determining the presence, geometric location, estimate severity of damages and evaluate remaining life of structure after the occurrence of damage.

II. MODELLING

2.1. All data is given by USHTA INFINITY

- Height of concrete chimney = 125 m
- External diameter of the shaft at top = 3.6 m
- External diameter of the shaft at bottom = 10.6 m
- Thickness of concrete shaft at top = 0.3 m
- Thickness of concrete shaft at bottom = 0.6 m
- Grade of concrete = M25
- Fy = 415 n/mm^2

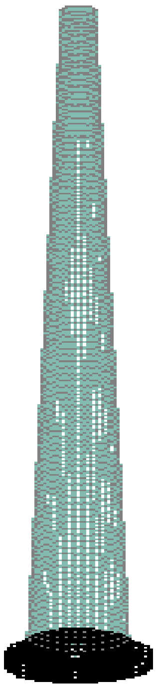


Figure 1. Chimney model

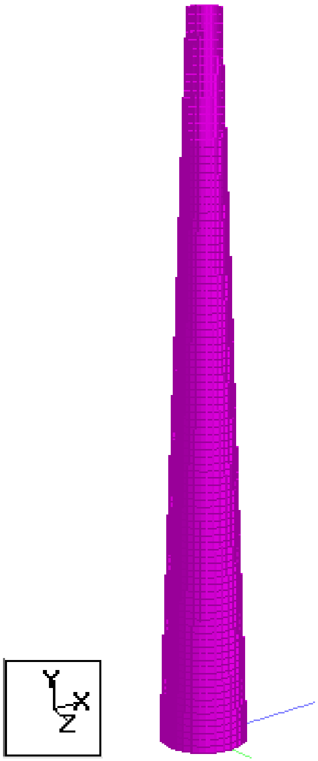


Figure 2. Rendered view

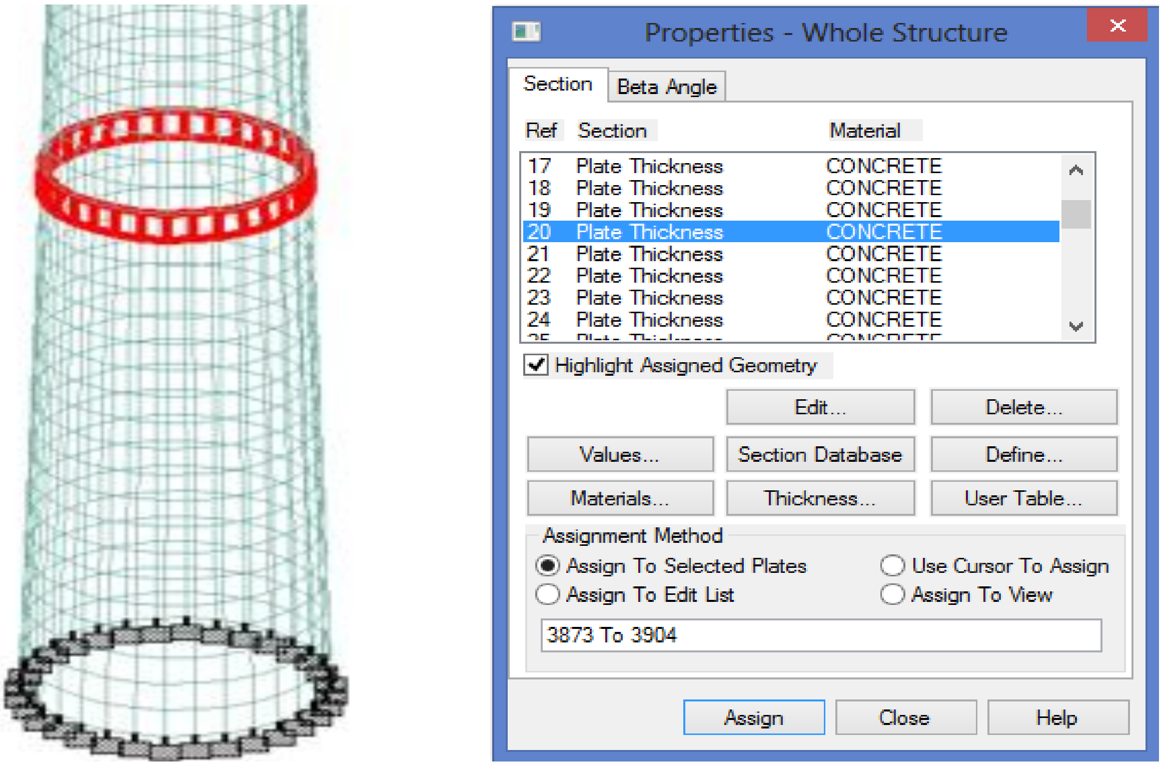


Figure 3. Plate properties of chimney

2.2. Codes and standards

To help ensure safety and better quality chimney structures, several countries have already adopted codes and standards for design and construction of chimney. Few of them are as below:

IS 4998 (Part-1):1992- Criteria for design of reinforced concrete chimneys

IS 1893 (Part-4): 2015- Criteria for earthquake resistant design of structures

IS 875-1987: Part-1(Dead loads-Unit weights of building materials and stored materials)-"Code of practice for design loads (other than earthquake) for buildings and structures"

IS 875-1987: Part-2(Imposed loads)-"Code of practice for design loads (other than earthquake) for buildings and structures"
IS 875-2015: Part-3(Wind loads)-"Code of practice for design loads (other than earthquake) for buildings and structures"
IS 875-1987: Part-5(Special loads and load combinations)-"Code of practice for design loads (other than earthquake) for buildings and structures"

2.3. Load consideration

The various governing loads to be taken into account for analysis of chimney shall be as follows:
Dead load
Live load
Wind load (IS 875:2015, Part-3)
Earthquake load (IS 1893:2016, Part-1)
Temperature effect

2.4. Deflection calculation

Deflection at any section in terms of "x" in cantilever chimney due to uniformly varying load is,
$(W_0\, x^2(10l^3-10l^2x+5lx^2-x^3))/120lEI$
Here, W_0= Maximum intensity (N/m)
E= modulus of elasticity
I= moment of inertia
l= length of structure
x= length of any section of structure

III. INCLINOMETER SENSOR SYSTEM

A sensor is an electronic component, module whose purpose is to detect events, changes in its environment or changes in quantities and send the information to other electronics, frequently a computer processor.

3.1. Inclinometer sensor specification

- Wireless inclinometer sensor based on MEMS technology
- Bi-axial ±30° measurement range
- Low duty cycle data acquisition mode: 1s to 24 hours
- Storage capacity: Up to 1 million data points
- Operating temperature: -20°C to 65°C

3.2. Methodology

- Select suitable locations on chimney
- Installation of inclinometer sensor at selected locations
- Set up of data collection system for installed sensors
- Collection of data frequently
- Find value of deflection for particular location from the collected data

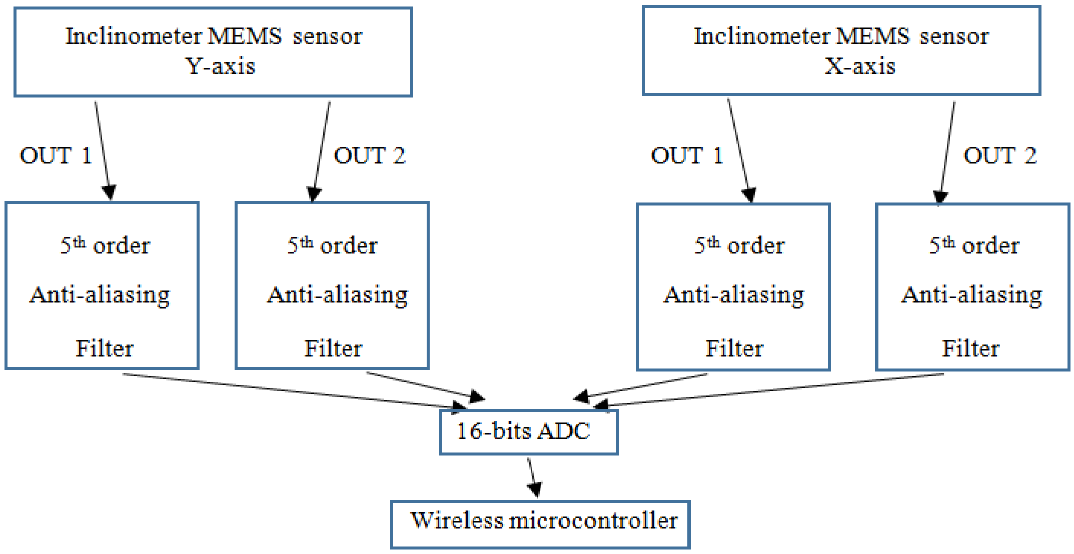


Figure 4. Inclinometer block diagram

At actual site, data collecting using inclinometer sensor.

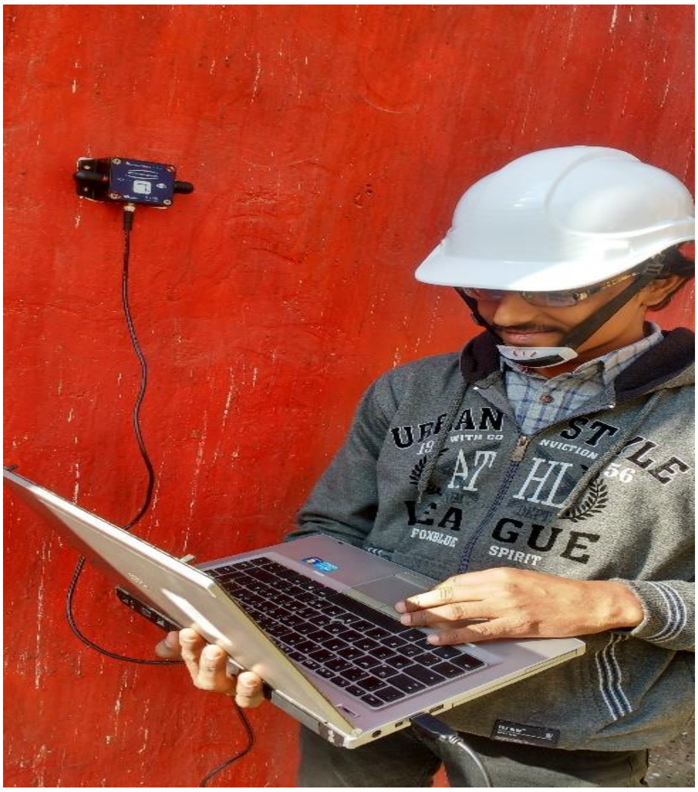
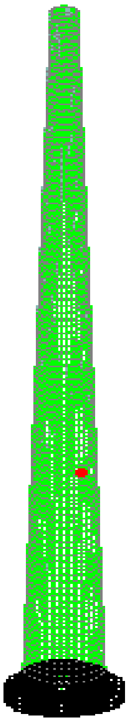


Figure 5. Collecting data using inclinometer sensor

Figure 6. Collecting data using inclinometer sensor

IV. RESULTS

At 40m height of chimney:-



		Horizontal	Vertical	Horizontal	Resultant
Node	L/C	X mm	Y mm	Z mm	mm
132	1 EQ+X	3.857	0.000	0.000	3.857
	2 EQ+Z	0.000	-0.774	3.872	3.949
	3 EQ-X	-3.857	-0.000	-0.000	3.857
	4 EQ-Z	-0.000	0.774	-3.872	3.949
	5 DL	0.000	-2.667	0.039	2.667
	6 LL	-0.000	0.000	0.001	0.001
	7 WL+X	28.765	0.005	0.114	28.765
	8 WL-X	-28.801	0.005	0.114	28.801
	9 WL+Z	0.000	-5.496	28.781	29.302
	10 WL-Z	-0.000	5.493	-29.009	29.525
	11 TMP	-0.000	30.263	2.946	30.406

Figure 7. Node deflection of chimney at 40m height

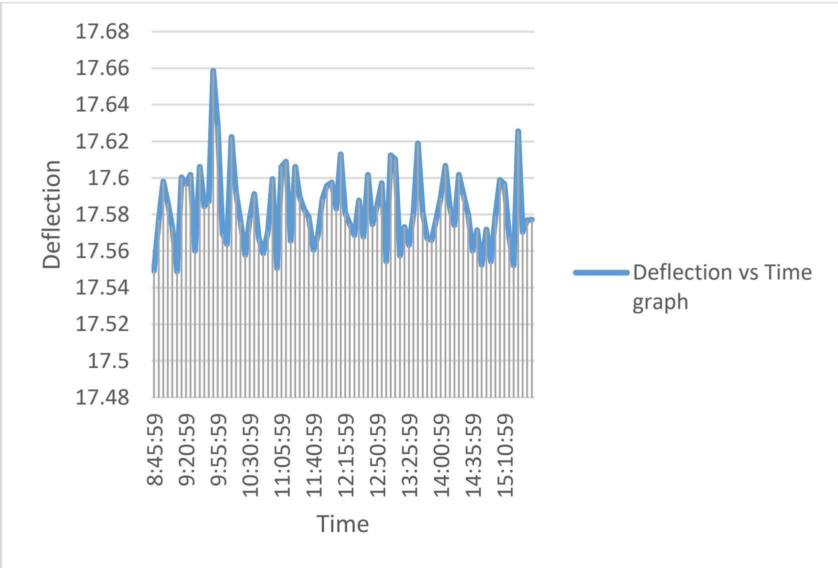


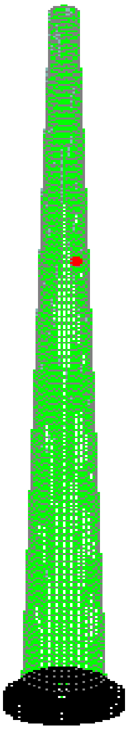
Figure 8. Sensor deflection data of chimney at 40m height

Compare sensor deflection data with STAAD result and manual calculation at 40m height of chimney is as below:

Table 1. Deflection at 40m height of chimney

	Sensor data	STAAD result	Manual calculation
Deflection (in mm)	17.659	28.765	26.280

At 80m height of chimney:-



		Horizontal	Vertical	Horizontal	Resultant
Node	L/C	X mm	Y mm	Z mm	mm
100	1 EQ+X	16.428	-0.000	0.000	16.428
	2 EQ+Z	0.000	-1.209	16.436	16.480
	3 EQ-X	-16.428	0.000	-0.000	16.428
	4 EQ-Z	-0.000	1.209	-16.436	16.480
	5 DL	0.000	-4.550	0.018	4.550
	6 LL	-0.000	-0.000	0.001	0.001
	7 WL+X	112.664	0.005	0.065	112.664
	8 WL-X	-112.736	0.006	0.065	112.736
	9 WL+Z	0.000	-7.718	112.710	112.974
	10 WL-Z	-0.000	7.721	-112.841	113.105
	11 TMP	-0.000	60.263	2.142	60.301

Figure 9. Node deflection of chimney at 80m height

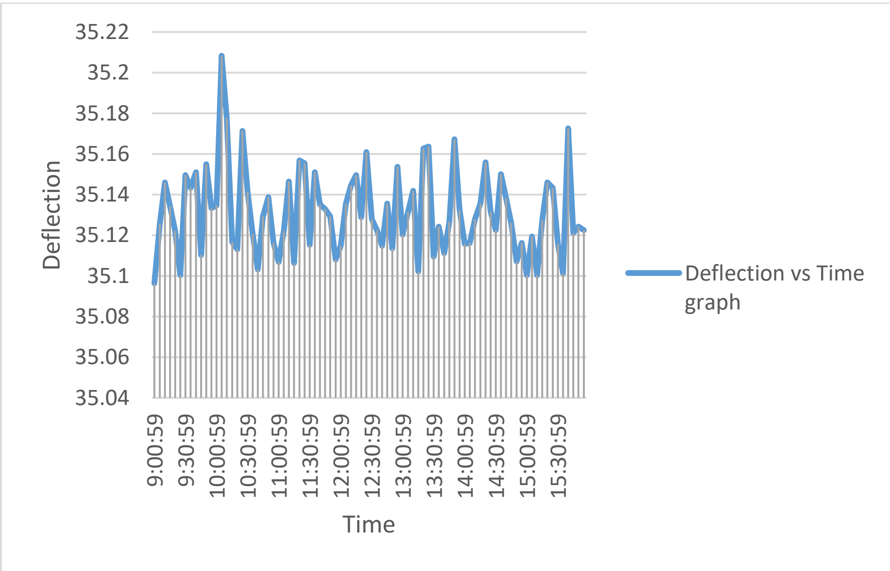


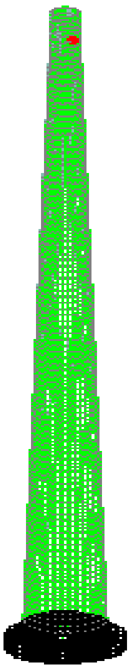
Figure 10. Sensor deflection data of chimney at 80m height

Compare sensor deflection data with STAAD result and manual calculation at 80m height of chimney is as below:

Table 2. Deflection at 80m height of chimney

	Sensor data	STAAD result	Manual calculation
Deflection (in mm)	35.208	112.664	124.42

At 120m height of chimney:-



		Horizontal	Vertical	Horizontal	Resultant
Node	L/C	X mm	Y mm	Z mm	mm
68	1 EQ+X	36.699	0.000	-0.000	36.699
	2 EQ+Z	0.000	-0.981	36.700	36.713
	3 EQ-X	-36.699	-0.000	0.000	36.699
	4 EQ-Z	-0.000	0.981	-36.700	36.713
	5 DL	-0.000	-5.433	0.001	5.433
	6 LL	0.000	-0.000	-0.000	0.000
	7 WL+X	237.624	0.006	0.024	237.624
	8 WL-X	-237.731	0.006	0.024	237.731
	9 WL+Z	0.000	-5.946	237.709	237.783
	10 WL-Z	-0.000	5.954	-237.757	237.831
	11 TMP	0.000	90.263	1.338	90.273

Figure 11. Node deflection of chimney at 120m height

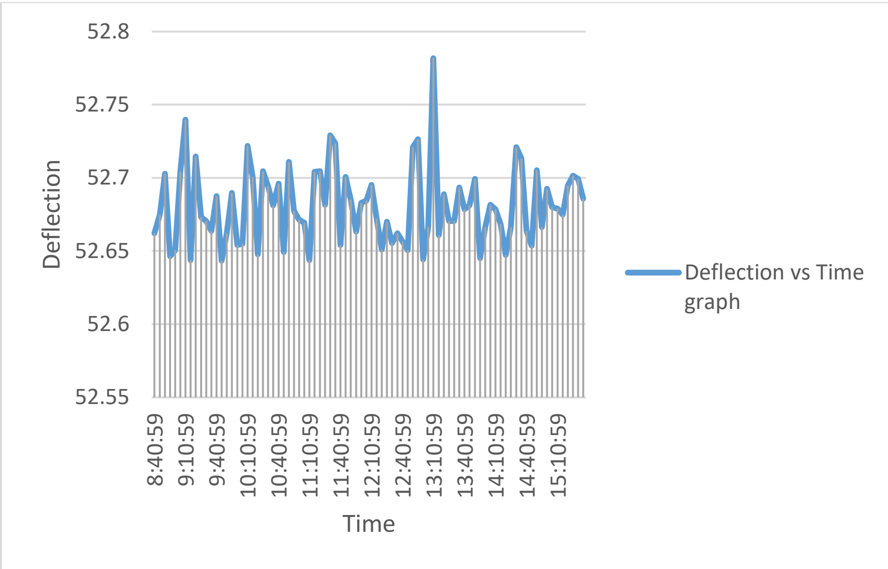


Figure 12. Sensor deflection data of chimney at 120m height

Compare sensor deflection data with STAAD result and manual calculation at 120m height of chimney is as below:

Table 3. Deflection at 120m height of chimney

	Sensor data	STAAD result	Manual calculation
Deflection (in mm)	52.782	237.624	244.66

V. CONCLUSION

- Deflection values at selected locations are found within permissible limits as per Indian standard code, so it is safe.
- Structural health monitoring using wireless inclinometer sensor is in-situ and non-destructive tool for ensuring condition of structure, stability check and serviceability of structure.

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