GUIDELINES FOR STRUCTURAL HEALTH MONITORING

Version 0 (Dated 10 June 2024)
Approved by General Body of ISHMS in the 4th General Body Meeting (GBM) held on 10 June 2024

1. INTRODUCTION

India is witnessing a high surge in construction activities as part of the infrastructure boost accompanying its strong economic growth. Numerous bridges, tall buildings, airports, railway stations and similar structures are currently under various stages of construction all over the country. Unfortunately, not enough seems to be done with regard to the monitoring and maintenance of the ever growing infrastructure repository. There is no code of practice at the present related to structural health monitoring (SHM) in India. The Indian infrastructure industry typically follows the “run to failure (RTF)” model as far maintenance in concerned. This means ignoring any monitoring or maintenance needs till some problem creeps in. No sensor-based data driven scientific approach is often followed. SHM is defined as a continuous sensor based data driven approach aimed to facilitate informed decision about current health condition of the structure. This is the right time Indian infrastructure industry adopts modern SHM sensors and related technologies so that decisions backed by scientific data are arrived at any future instant of time rather than relying on the RTF approach leading to greater downtime as well as higher recovery cost for infrastructure.

This document is prepared by the Governing Council (GC) of the Indian Structural Health Monitoring Society (ISHMS) based on its body of expert members and also after receiving feedback from industry experts as well as relevant government agencies. The second General Body Meeting (GBM) held on 11 Dec 2023 decided to prepare a document serving as basic guideline to various stakeholders. The Governing Council Meeting (GCM) held on 12 January 2024 decided to receive suggestions from industry also. Accordingly, online surveys were conducted from 06 March 2024 to receive inputs from industry and other stakeholders. The document was approved in the Fourth GBM held on 10 June 2024. The document attempts to provide basic guidelines to stakeholders to implement SHM in their structures.

2. STRUCTURES ON WHICH SHOULD SHM BE IMPLEMENTED?

It is recommended that SHM be implemented on following category of structures right from the construction stage. In case of existing structures, it is recommended to implement SHM at the earliest possible:

(a) Buildings

- more than 15 storeys or height 50 m and above: up to zone IV (as per IS1893)
- more than 7 storeys or height 20 m and above: zone V (as per IS1893)

(b) Following types of bridges

(i) RCC bridges with span equal to or exceeding 25 m

(ii) Prestressed girder bridges with span equal to or exceeding
- 30 m for I-type
- 40 m for Box type

(iii) Steel truss bridges with span equal to or exceeding 75 m

(iv) All cable stayed, suspension and extradosed bridges irrespective of span

(v) Skew bridges with span equal to or exceeding
- 20 m: RCC I-shaped girder, 25 m: Pre-stressed I-shaped girders
- 25 m: RCC Box-type girder, 30 m: Prestress Box-type girder

(c) Nuclear power plants

(d) Structures under continuous vibrations, such as critical machine foundations, such as those for turbo generators

(e) Structures with importance factor of more than one as per IS 1893 (I)

(f) Spaces/ domes exceeding 30 m span

3. PARAMETERS TO BE MONITORED AS PART OF SHM

Generally, SHM involves monitoring static and dynamic parameters. Concerned agencies may decide to instrument sensors for measuring following parameters.

(a) **Static:** Deflection, strain, temperature

(b) **Dynamic:** Deflection, strain, at least first natural frequency and mode shape

4. SENSORS

Sensors play crucial role in the process of SHM. Following is the list of commercially available sensors, which the concerned agencies might consider while instrumenting a structure

(a) Vibrating wire strain gauges

(b) Linear Variable Displacement Sensor (LVDT)

(c) Laser based sensor/ techniques

(d) Tilt/ inclinometers (for deflections)

(e) Piezo sensors (for global vibration technique or electro-mechanical impedance technique)

- Lead zirconate titanate (PZT) for surface bonding
- Concrete vibration sensors (CVS) for embedding inside RC structures
- Macro-fiber composite (MFC) for surface bonding

(f) Accelerometers
(g) Vision based techniques/ sensors
(h) Fiber-optic sensors
(i) Any other scientifically established sensors deemed relevant to the structure or the component

5. INSTRUMENTATION CUM MEASUREMENT MODE

Depending upon the expertise and budget available, concerned agencies may decide to adopt either manual or internet of things (IoT) based automatic mode (preferred) for data acquisition from the instrumented sensors. If IoT based instrumentation is adopted, the data should preferably be available to users in online real-time graphical user interface. Suitable sampling interval be adopted for static and dynamic measurement such that it is able to enable appropriate feature extraction, whether static strain/ deflection or dynamic parameters such as natural frequencies, mode shapes or any structural signature representative of the condition of the structure.

Sampling should be accompanied by a report generation, which should be at least monthly for IoT based monitoring and at least six monthly for manual SHM. The measured data should be analysed to enable suitable feature extraction based on the particular measurement and utilizing the currently available SHM literature. In case of IoT mode, the system should be capable of generating alert/ warning in case of threshold exceedance.

6. STRUCTURAL COMPONENTS TO BE INSTRUMENTED

Following components of structures can be instrumented:

(a) Foundations/ piles for measurement of settlement, inclination, tilt etc.

(b) Bridge-deck for strain (static/ dynamic), deflection and acceleration. Static strains are relatively easy to measure as compared to deflection and can be used for compliance to deflection limits imposed by bridge codes such as IRC 112 (2020). Following theoretical expressions (based on Euler-Bernoulli beam theory) can be used to convert measured mid-span strain into mid-span deflection for simply supported bridges

- Under uniformly distributed load: $\delta = \frac{5L^2}{24D}\varepsilon$
- Under point load: $\delta = \frac{L^2}{3D}\varepsilon$

(c) Bridge Piers and abutments
(d) Beams, columns and joints of framed structures
(e) Building floors for acceleration response measurement under wind/ earthquake [refer IS 16700 (2017)].

7. REFERENCES

1. **IRC 112 (2020)** Code of Practice for Concrete Road Bridges.
2. **IS 16700 (2017)** Criteria for Structural Safety of Tall Concrete Buildings
3. **IS 1893 (I)** Criteria for Earthquake Resistant Design of Structures: Part 1 General Provisions And Buildings