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5.22 MONITORING SYSTEMS

5.22.1 Introduction

In contrast to using other nondestructive evaluation (NDE) methods where the inspector conducts an inspection over a finite time interval, Monitoring Systems provide continuous data over an indefinite time interval since the monitoring devices are typically mounted to the structure, connected to a data collection device, and left by the inspector to monitor the structure. These systems can be limited to monitor a specific component or section of the structure, or be designed to encompass the entire structure. The scope of monitoring is dependent on the desired data, the identified potential problem areas of the structural components, and/or potential areas of structure movement.

A monitoring system can be comprised of a variety of sensors and a data collection device (computer). In the case of a remote system, a communication device, which transmits the data to the monitoring station for analysis would be used. Refer to Figure 5.22.1-1 for a view of a remote system computer and communication device.

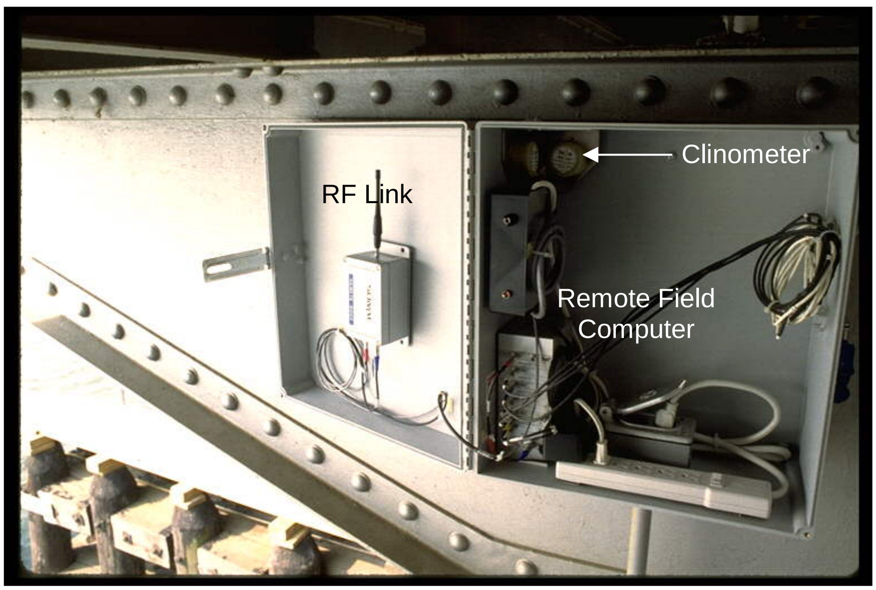

Figure 5.22.1-1: Remote Field Computer, Clinometers, and RF Link Mounted in Protective Enclosure.

Sensor types include strain gauges, clinometers (tilt meters), accelerometers, thermocouples, as well as various other devices.

1. **Strain Gauges:** The term “strain gauge” typically covers a wide range of devices that are used, as their name implies, to measure the strains of structural members under load.

2. **Clinometer:** Measures inclination or tilt of a structure or structural component.

3. **Accelerometer:** Measures structure dynamics under conditions such as high winds, seismic activity, and/or vehicular traffic.

4. **Thermocouple:** Measures the temperature of a structure or its environment.

5. **Transducers:** In Acoustic Emission (AE), these devices detect stress waves emanating from actively growing defects within a bridge structure. Refer to Part 5 Chapter 6 for more information on AE.

Strain gauges are the predominant sensor in use today. A variety of strain gauges are available, and their selection should be made based on the location of their use, as well as the specific data type and amount to be collected. A strain gauge will have an established initial set length, the "gauge length," with a corresponding electrical resistance, which is used as a datum. Strain is a measure of deformation, specifically the change in length of fibers within an object relative to their original length due to an applied stress. Strain gauges measure this change via change in electrical resistance due to the lengthening or shortening of the resistive element within the gauge that is bonded to the component. This change in resistance is proportional to the strain within the member, related through a set of equations. This calculation is typically performed automatically by the data acquisition system. Strain however, is often a very small value, typically measured in microstrain (strain x 10^6) and can be affected by such factors as temperature and lead wire resistance, so it is important to have a good understanding of the technology for proper application and obtaining accurate results. Strain gauges can also be used to measure rotational strain. Strain gauges can be placed either externally, or in certain circumstances, within the object being examined. Groups of gauges are usually installed in patterns determined by the type of data desired. Strain gauges are typically small and flat, and do not interfere with the use of the structure. The strain gauges are connected to a data acquisition system which records the strain data. Under real-time loading situations, the acquisition system can automatically collect data at a user-defined time interval. To obtain a comprehensive strain-time history, data is acquired rapidly, measured in recordings per second or hertz (Hz). This rate of acquisition is required to capture specific loading events (i.e. truck impact). Other applications may only require occasional readings.

In the area of transportation structures, strain gauges may be installed at carefully selected locations on a structure to measure strains under live load conditions. These strains may be due to traffic, wind, temperature, or specifically applied test loads. This strain data is then evaluated directly, or more often converted to stresses that can be compared to calculated design stresses. Thus, strain data allows the real performance of a structure to be compared to the theoretical design, and can provide data for an analytical model to more accurately predict actual performance. Strain gauges are also often employed to study the performance of a local area or detail for which theoretical analysis may be difficult.

In field situations, strain gauges may also be used as monitoring systems at locations of great concern, either of movement, or of changes in stresses. Refer to Figures 5.22.1-2 and 5.22.1-3 for views of strain gauges attached to steel bridge components. This work may be required to verify the safety in areas of uncertain stability or strength. In a system of enough sophistication, movement beyond a certain range may cause alarms to sound at the structure or at an off-site monitoring station. Therefore, strain gauges may be used at locations where it is difficult or prohibitively expensive to replace an existing structure of uncertain strength, while still allowing safe use of the structure.

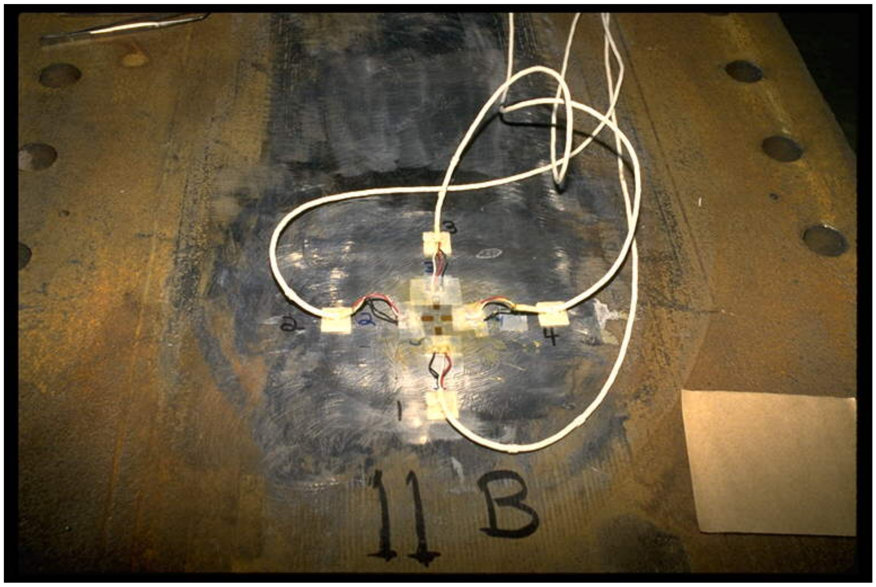

Figure 5.22.1-2: Strain Gauges Attached to the Steel Track Casting of a Movable Bridge.

Figure 5.22.1-3: Strain Gauges Attached to the Tie Girders of a Tied Arch Bridge.

5.22.2 Applications

Monitoring systems have many applications in the inspection of structure components. The sensors are very versatile and can be applied to many materials. They typically are small and can be attached in tight fitting areas. Furthermore, many of the sensors have a high level of accuracy and can be applied in both static and dynamic situations. Once installed, the sensors can provide data for an indefinite period of time.

The ability to continuously monitor structures or specific components, allows the owner to record and clearly observe the performance and detect deterioration. These systems work well from a preventative maintenance stance.

5.22.3 Limitations

Monitoring systems; however, do have some limitations. Sensors take measurements at specific locations, which is useful in many applications, however to obtain a global response of the structure would require a great multitude of gauges which may be cost prohibitive or impractical.

The sensors, although typically inexpensive, are often one-time use devices. Once mounted to a particular structure they cannot be removed and reused for another application. The sensors also typically require a high level of expertise to install.

The data collection and transmission devices, on the other hand, can be expensive and require specialized individuals to maintain and process the data. The gathered data must also be analyzed and manipulated to provide useable information.

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