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Use of Strain Gauge in Concrete Structure

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Abstract: The presented study represents the different uses of strain gauge in civil infrastructure. The strain is used to measure load, deformation, resistance and strain at a specific point with strain gauge equipment. This is an experimental procedure used to measure strain by strain gauge equipment. It is more useful in now days to measure loads and deformation. Tremendous techniques and methods are there to measure strain. A gauge is also to prevent for tensile test application. It is most unique technique for beam structure of railway sleepers it carries research at the University of Illinois at Urbana-Champaign (UIUC).It is most innovative to measure cracks at specific point of structural assesment .it is use to measure `invented by Edward.E.Simmons and Arthur c. Ruge IN 1938 .The most common type of strain gauge consists foil pattern. Strain gauge is capable to measure load cantilever load. This gives the determination of the strain and stress state , and the effect of transverse effect on strain along the fibre. Sheath fold strain gauge as used to measure the strain. A novel long-gauge fiber optic sensor has been developed to measure the averaged strain within a long gauge length. A steel frame is designed to measure the existing pre stressing force in the concrete beams and slabs when embedded inside the concrete members. Strain gauge method to identify structural strain flexibility from long-gauge dynamic strain measurement.

Keywords: strain gauge, civil infrastructure, railway sleepers

INTRODUCTION

This section presents the introductory contents related to the subject of Study.

General

Non-cylindrical fold structures, which are characterized by a sharp hinge line bend (hinge angle) of more than 90° are termed sheath folds Three types of folds: analogous-eye, cat's-eye, and bull's-eye, in which the ratio of the outermost closed contour is the same, smaller, and larger from the ratio of the innermost closed contour, respectively [1]. Metal foil strain gauges and slabs made of semiconductors are not suitable because of their inability to accommodate large deformation and conform to surfaces. Printed flexible strain gauges offer advantages over metal foil strain gauges including mechanical flexibility, smaller dimensions and high sensitivity. Throughout the world, the majority of railroad track infrastructure is supported by ballast. [2].

Due to the increased flexural strength, ductility, and resistance to cracking produced by the "pre-tensioned" steel wires ,prestressed concrete sleepers can withstand the high dynamic loading environment imparted by passing trains. The input loading, support configurations, and resulting bending experienced by the sleeper can be quantified through laboratory experimentation, finite element (FE) modeling, and field experimentation, and a broad concrete sleeper research effort funded by the Federa Railroad Administration (FRA) conducted by the Rail Transportation and Engineering Center (RailTEC) [3] Printed circuit boards (PCBs) must be installed with multiple features or be miniaturized without sacrificing functionality. Because of increased awareness on environmental protection, studies have indicated that waste from Pb-containing electronic products can incur pollution to the natural environment[4].

For the measurement of the clamping force, a direct sensing method with piezo-electrical force sensors was used. The aim is to develop a hydraulic clamping system, which is typically used in series production, with sensing capabilities in cooperation with two partners from industry, a clamping technology manufacturer and a fixture construction service provider [5]Strain gauge is an experimental technique to measure the strain at a point. Strain gauges are widely use literature shows that strain gauge technique is most effective and practical technique to measure the strain and stress intensity factor(SIF) at any point on the surface of structure or machine parts the for measurement of strain in static and dynamic systems and thus for both static and dynamic stress intensity factors (SIFs) in the isotropic and composite structures [6]. Structural performance assessment has gained growing attentions from the engineering community to improve the reliability and sustainability of civil infrastructures, and thus minimize the economic or human life loss of unpredicted structural failure[7] .

Residual stresses are inevitable in multi material systems when continuous strain distributions prevail between material components with different thermal expansion coefficients.. Residual strains have been measured successfully in composites using fiber Bragg grating (FBG) sensors embedded between the layers during the lay-up of the composite [8]. The measurement of strain in high temperature environments is of great importance for the development of modern air breathing engines. The electro-mechanical characterization of sputter deposited TiAlN thin films is performed. This material is well-known for high temperature stability and oxidation resistance [9]. This layer usually features a different elastic modulus than the material to be measured, and therefore the strain coupling between the substrate and the sample is another origin of losses [10]. Introduction High-sensitivity strain gauges are extremely essential to pro-vide efficient structural health monitoring and detect the real-time activities of human organs, and promise abundant opportunities for wearable electronics .bio-monitoring, andhuman/machine interface [11].

In the present study a steel frame is designed to be used in the experiments to measure the existing prestressing force in the concrete structures. The steel frame is called as vibrating beam strain gauge (VBSG) since it uses the same principle as the VWSG to measure the existing strain from the measured natural frequencies [12]. The long-gauge fiber optic strain sensor developed recently provides an excellent opportunity of developing the macro strain modal identification theory. It measures the eaveraged strain with in a designed long-gauge length (e.g. 1–2 m), thus it has the feature of measuring both local and global information of the structure [13].

Literature survey

We show that the fold shapes developing in different interfaces can be characterized by a unique combination of the three parameters depending on strain magnitude. We describe the fold geometry using: 1) interlimb angle (α), 2) hinge angle (β), and 3) aspect ratio of the eye-structures in the section normal to the shearing direction at the fold base. We investigate initiation and evolution of sheath folds developing in multilayer sequences around slip surfaces in simple shear [1]. A strain gauge for tensile test application is also presented in this work Besides formal testing for strain, the strain gauge sensitivity were tested towards humid and warm environment. A high resistive strain gauge is reported that can measure large mechanical deformation with higher sensitivity [2]. A method using concrete surface strain gauges has been developed, deployed, and validated by University of Illinois at Urbana-Champaign (UIUC) for quantification of sleeper bending moments. This method has been successfully deployed in the laboratory and in seven field locations, providing flexural demand data that can be used for the design of concrete sleeper [3]. Printed circuit boards (PCBs) are composite structures consisting of FR-4, solder mask, and Cu materials. Applying this method to soldered PCBs can yield inaccurate warpage data because of differences in component height. By employing a 3-axis strain gauge measurement technique, this study developed a low-cost PCB warpage measurement method that yields accurate PCB warpage data despite considerable differences in component height and flux volatilization during reflow [4]. Clamping errors in work piece positioning decrease the outcome of machine tools Firstly, this gives a general survey of the targeted application and the concept to achieve a sensory clamping system for the industrial use in series production .Firstly, this paper gives a general survey of the targeted application and the concept to achieve a sensory clamping system for the industrial use in series production [5]. An experimental technique based on strain gauge has been proposed to measure the gear mesh stiffness of healthy spur gear as well as of cracked spur gear pair system. Calculation The effect of crack length on mesh stiffness has been investigated by strain gauge technique and results are compared with the established analytical method [6].

Structural performance assessment is essential for maintaining the safety and functionality of in-service civil infrastructures. The field measurements that provide engineers with adequate useful information are required for effectively monitoring and evaluating structural performance. Moreover, strain/stress information generally shows powerful capacity for detecting the local structural property variations. Placing strain gauges is the key step towards a cost-effective monitoring or testing program. The methods are developed and implemented to maximize the strain contributions to the structural performance assessment [7]. The samples were laminated using carbon fiber reinforced plastic (CFRP) and tungsten .Test-specicmen correction functions for thermal output were determined for strain gauge measurement and comparative fiber Bragg grating (FBG) measurement. The strain According to the results, embedded electrical resistance strain gauges can be used to determine thermal expansion of a hybrid laminate at an acceptable accuracy [8]. A custom built measurement setup is used for the evaluation of the gauge factor and the temperature coefficient of resistance of TiAlN thin films up to 350°C. The gauge factor at room temperature is about 2.5, decreasing only moderately at 350°C [9].

Now we present a method for the fabrication of all-printed strain gauges on pre-coated sheet steel substrates. However, has inherent disadvantages in terms of force coupling from the surface strain within the bent substrate to the glued strain gauge sensors. The fact that the glue and the strain gauge substrate have in general different moduli of elasticity affects the maximum achievable gauge factor of the final sensor stack [10]. Strain flexibility, defined as the strain response of a structure's element to a unit input force, is import for structural safety evaluation, but its identification is sold on investigated. Its advantage of measuring both local and global information of the structure offers an excellent opportunity of developing the strain flexibility identification theory. To identify structural strain flexibility from long-gauge dynamics train measurements is proposed. Numerical and experimental examples successfully verify the effectiveness of the proposed method [13]. A steel frame is designed to measure the existing prestressing force in the concrete beams and slabs when embedded inside the concrete members. The steel frame is designed to work on the principles of a vibrating wire strain gauge and in the present study is referred to as a vibrating beam strain gauge. The crack reopening load method is used to compute the existing prestressing force in the concrete members and is then compared with the existing prestressing force obtained from the VBSG at that section [12].

Therotical aspects

Strain measurement

- **For aluminum beam**

For direct measurement strain gauge was employed on Aluminum beam (315 * 25 * 4mm) as shown in figure 3.1. Standard measures using beam were carried out to apply strain gauge to surface. First of all the surface was cleaned using emery paper and ammonia water then residues were removed using phosphoric acid and cotton and the area was finally neutralized with ammonia water. The standard epoxy was then applied to the surface and allowed to dry for some time.

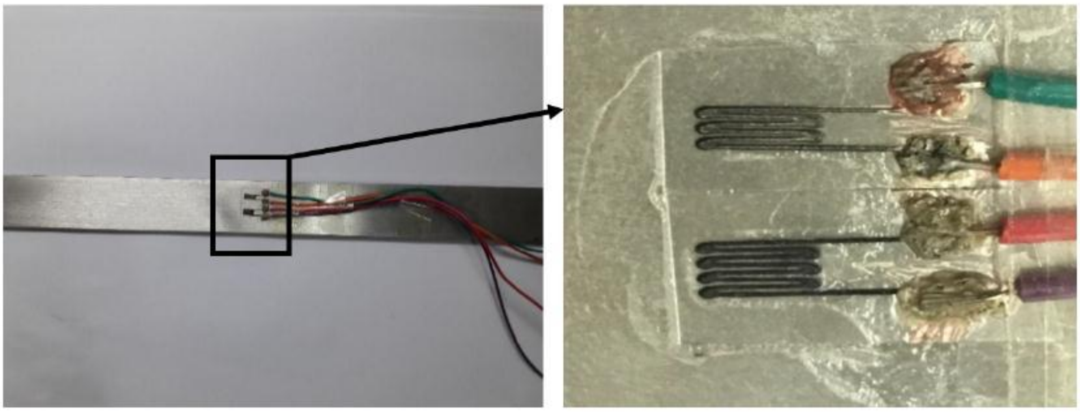

Fig-1: Carbon strain gauge mounted on aluminum beam [2]

- **For railway sleepers**

Measured sleeper strains from field sites and revenue service loading conditions must be correlated to bending moments using factors that are generated using one of three methods; a) using a calibration constant from calculations based on known sleeper sectional geometries and concrete properties, b) generating laboratory calibration curves by applying known moments under controlled experiments (i.e. loading conditions and support configurations), or c)calibrating each sleeper while they are installed in track [3]

Fig-2: Static Tie Tester (STT) at UIUC used for laboratory calibration of concrete sleepers [3]

Strain measurements were carried out using high-temperature resistant, three-wire strain gauges .The gauges were attached to the raw material samples using the epoxy resin defined to form a strong bond with the tungsten foil surface. a thermal-strain compensation sensor (collocating sensor) was located in each ber 20 mm apart from the actual measuring sensor The 3-point bending tests were performed using a testing machine with a 3 kN load cell, 3-point bend test setup and an air-circulating chamber. Force of section data was acquired for making comparisons of flexural strength and stiffness at different test conditions [8].

- **Vibrating beam strain gauge (VBSG) for slab**

The post-tensioned slab used in the validation of VBSG has length of 1400 mm, width of 1000 mm and depth of 500 mm. Three sets of 12.7 mm diameter with seven core strands and twelve numbers in each set are used with an eccentricity of 175 mm from the top surface. The first, second and third sets are placed at 200 mm, at 500 mm and at 800 mm respectively from the left end of the cross-section and along the width. Three VBSGs are used one near each pre stressing duct at a distance of 400 mm from the left end along the length of the slab and at the same level as the center of steel duct containing the strands as shown in fig 3.1 [12].

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Fig-3: VBSG in slab [12].

MATERIAL AND METHODOLOGY

This section presents the material needed for the experiment and process to perform the experiment.

METHODOLOGY

This section gives the detailed of methodology of strain gauge measurement for Experimental example of a cantilever beam.

Multiple-reference impact testing of the cantilever beam as shown in Fig. 4.1 has been performed to verify the effectiveness of the proposed method for strain flexibility identification. The steel beam has a length of 1.6m, and a 0.08

m*0.03 m hollow tube cross section with the thickness of 0.0025m.One end of the beam was oriented on a steel pedestal and another end is free. Fiber optic sensors were placed on each beam element, and the SM130 Optical Sensing Interrogator was used for strain measurements. The NI PXIe-1082 data acquisition system was used for impacting force measurement. The sampling of the measurement data was set to be 0.001 s. Other than the impact test, a static test was also performed by placing the steel block with a mass of 45.8 kg on the beam tip to measure corresponding static strains of all elements. The typical impacting force and macro strain responses are plotted in Fig. 4.1(a) and (b) respectively for illustration [13].

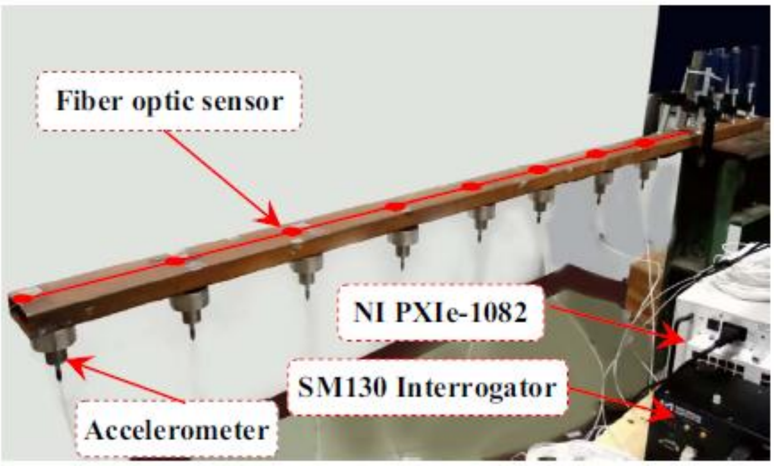

Fig-4: Experiment layout of the cantilever beam test [13]

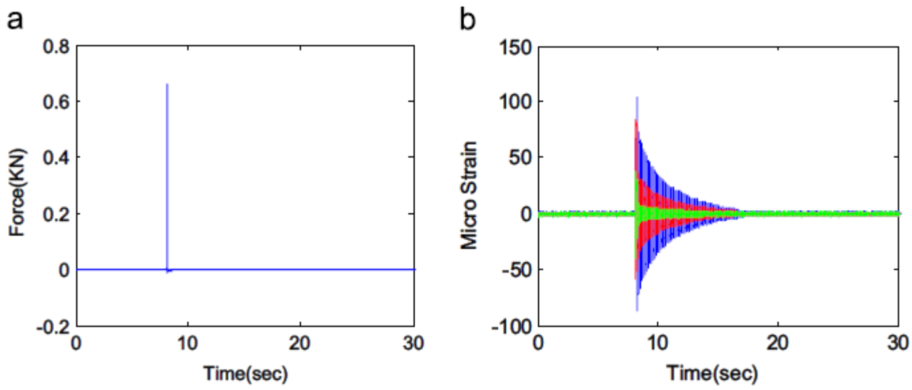

Fig-5: Typical impacting force and macros train response [13]

The following table gives the information about material used of different types which gives the value of give gauge factor and dimension (i.e. gauge length) and different techniques are also used for different material:-

Table-1: Printed strain gauges reported recently

Technique used	Material used	Gauge factor	Dimension
Aerosol jet printing	PEDOT:PSS polyimide substrate	0.53	--
inkjet printing	Silver ink PET substrate	2.7 to 3	Width 200mm Gap 200 mm Gap length 20mm
Aerosol jet printing	Silver ink alumina substrate	3.35	--
Screen printing	Carbon ink glass substrate	0.85 and 2.48	Width 75 &500mm Length 1 & 5.5 mm
Screen printing	Graphite ink polyimide substrate	19.3	Width 500 & 1500mm Length 20-30 mm

RESULT

As only one surface strain gauge at this specific heavy-haul freight railroad site has been damaged over of the two-year time frame in which the field experimentation site has been operational and there have been no fatigue-related challenges with or failures of the strain gauges. Approximately 267 million gross metric tons (295 million gross tons ((MGT)) of heavy-haul freight traffic have accumulated on the sleepers.

It is also important to note that even though the sleeper is cracked, potentially even below the first level of prestress, laboratory experimentation has shown that significant residual capacity remains and Sleeper 4 is likely to function normally for the foreseeable future. This is of specific interest to the railway infrastructure design community, might by overestimate the flexural demand on rail seats and that the design protocol could be better balanced to have similar safety factors for both critical design areas; the rail seat and the sleeper center [3].

DISCUSSION AND CONCLUSION

Discussion on observation

- The steel frame designed on the working principle of a vibrating wire strain gauge is able to estimate the existing prestressing force in the concrete structures. A future study is focused on using the estimated prestress force from the VBSG with uncertainty [12].
- The long-gauge strain sensor has the advantage of measuring not only local but also global information of the structure, thus its output is much more suitable for strain modal analyses than traditional point-type strain measurements [13].
- This concrete surface strain gauge instrumentation methodology and deployment was successful in measuring the bending strains and resulting moments experienced by a variety of rail traffic [3].
- A generic framework of strain gauge placement for structural performance assessment. [7].

Conclusion based on study

- We present three strain gauge diagrams that allow using two out of three parameters 1) the aspect ratio of the outermost closed contour, 2) the hinge angle, and 3) the inter limb angle to estimate the shear strain [1].
- Different types of techniques have been used to fabricate strain sensor. The presented work focuses on printing a strain sensor using a micro dispensing technique using high viscosity conductive paste [2] .
- The effectiveness of surface-mounted concrete strain gauges in measuring sleeper bending behavior has been demonstrated [3] .
- The long-gauge strain sensor has the advantage of measuring not only local but also global information of the structure, thus its output is much more suitable for strain modal analyses than traditional point-type strain measurements [13]. In order to measure different influences on the strain distribution several positions for the sensor placing are discussed [5].

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