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EMERGING TECHNOLOGIES AND THE FUTURE OF GEOTECHNICAL INSTRUMENTATION

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ABSTRACT

The main aim of this paper is to discuss the developing technologies and where geotechnical instrumentation is headed in the future. Geotechnical devices are essential in the fields of building, civil engineering, and mining [1]. Engineers utilize them a lot throughout building and expansion projects, as well as for continuing monitoring. A geotechnical engineer uses geology in a practical way. Building sites are analyzed by engineers using concepts from soil and rock mechanics, and the results of these analyses are used to ascertain whether or not the site is suitable for a particular construction endeavor. Designing structures and their foundations is a primary function of this branch within geological engineering [1]. The mining and petroleum sectors, as well as the government and military, may employ this form of engineering. Geotechnical engineering concepts must be addressed, regardless of whether the event takes place above or below ground.

Keywords: Emerging Technologies, Geotechnical Instrumentation, Soil Analysis, Geotechnical Design Process, geotechnical data.

INTRODUCTION

Instrumentation used in geotechnical engineering is primarily concerned with measuring structural and soil deformations, stresses acting on engineering structures, ground water pressures, and groundwater levels inflows. When it comes to geotechnical instruments, it's important to think about things like range, precision, reliability, sensitivity, compatibility, durability, and dependability. As demand for non-essential infrastructure projects including tunnels, gradients, and excavations increases, the demand for geotechnical instrumentation and monitoring is anticipated to develop considerably. This growth is projected to be driven by technological advancements. Since it allows for high quality, construction control, monitoring of in-service functionality and design verification, the instrumentation is being employed. Geotechnical instruments and monitoring are expected to expand as a result of major technological breakthroughs in the area of sensor technology. Geotechnical instruments and monitoring (GTIM) is being propelled by a number of factors, including an increase in infrastructure spending around the world, strict government regulations aimed at improving the long-term sustainability and safety of constructions, and growing public awareness of GTIM's advantages [2]. Monitoring and instrumentation of geotechnical systems are not only essential to the accomplishment of a project throughout the course of its lifetime, but they are also necessary for the preservation of its good name. There are many immediate threats and issues that need to be addressed in order to maintain the long-term viability and sustainability of the construction as well as the nearby buildings and infrastructure. Geotechnical instrumentation is gaining in popularity due to causes such as rising infrastructure spending, more use of geotechnical instruments to avoid deformations, government legislation requiring more environmentally friendly construction, and a greater public understanding of the advantages of such instruments. On the other hand, the high expenses of installation and monitoring are anticipated to stifle industry expansion.

RESEARCH PROBLEM

The main problem that will be solved by this paper is to explore the Automation of the Digital Information Workflow in the Geotechnical Design Process. This will be accomplished so that the issue may be resolved. Standardized design techniques may cut down on the amount of time it takes to design repeated structures like box culverts; nevertheless, the increased amount of time and effort needed to revise construction drawings can have a detrimental influence on the performance of a project [3]. That the geotechnical engineer must deal with several sources of uncertainty, including inherent geological variabilities, is not a controversy. As a result of these uncertainties and the attendant hazards, there has been a long-running debate over whether they may be dealt more explicitly. Many mathematical approaches are used to simulate the complicated real-world for engineering purposes, and reliability analysis is only one of them. Finite element analysis is prone to misuse in the same way that this method is. The development of theory and computational tools [4,5] has had little effect on the significance of engineering judgment [4,5]. However, its attention has shifted to those design characteristics that are beyond the reach of theoretical analysis." Human judgment is not replaced by data-driven decision making.

LITERATURE REVIEW

A. Analysis of Geotechnical Conditions

A geotechnical analysis may be carried out by either geotechnical engineers or geologists, and its primary purpose is to gather data about the physical qualities of rock and soil. To design foundations for future projects and to make repairs owing to subsurface conditions, these details are employed [6]. A site's subsurface and surface will be examined as part of these examinations. Soil samples and laboratory testing are often used in subsurface investigations [6]. Subsurface investigation may be required in order to learn more about the soil under the surface. Test pits, digging, and in situ experiments are some of the methods used in subsurface investigation. When doing surface exploration, geological mapping might be used, or it can just be a physical examination of the place.

B. Analysis of the soil

Size, type, and distribution of mineral components, as well as relative amounts of mineral and air/water in soil medium, determine the soil's engineering properties. A building's foundation is responsible for transferring the weight of the building and its components to the surrounding soil. [7] The load and soil qualities are considered while designing the foundations. The amount and location of the loads to be supported are estimated as part of the soil analysis. Field and laboratory tests are used to investigate the subsurface soil properties. Following that, the foundations are developed with safety and cost in mind. The carrying capacity, ground movement under the foundations, and settlement are the primary considerations for foundation support. Buildings and structures rely on soil bearing capacity [7] for stability. Under the foundations, normal settling occurs in all soil types. The settlements of constructions or rock sites that are not heavily burdened may be small, nonetheless. The overall settlement in nearby buildings and the settlement beneath a particular structure must be analyzed for soft sites or heavy constructions.

C. A Cone Penetration Analysis

The cone penetration test, which aids in geotechnical design preparation, determines on-site geotechnical engineering soil parameters. For soil examination, this is the most often employed method [8]. The instrument probe is inserted into the soil using hydraulic pressure and a constant pace. The cone's penetrating resistance and the friction of the casing's exterior surface are being monitored in real time. This method works well in soil layers that are too thin to be reliably analyzed by standard methods. Electrical characteristics, visible soil pictures, acoustic emissions, wave propagation velocity, and groundwater are all precisely measured in these experiments. Under low strain, the soil's shear modulus and shear wave velocity provide insight into how it responds to vibrations. High-quality, real-time data and little soil disturbance are some of the benefits of doing a cone penetration test. A method like this won't work on rocks[9].

D. Geotechnical Instrumentation: New and Emerging Technologies

As geotechnical instrumentation works with naturally existing heterogenous materials, it is critical in tunnels and subterranean caves. Over time, field instrumentation for safety monitoring has gotten more complex and advanced due to the introduction of disruptive technologies. Modern technology is gaining popularity and becoming more accessible, from cloud-enabled online data monitoring to non-contact ways of monitoring [11]. There is an increase in a dependable sensor network that facilitates rapid and efficient data visualization. This becomes much more critical in high-risk urban tunneling operations. More economical options have been spurred on by the industry's cost competitiveness.

i. Calibrated Catch Container

A calibrated catch container [12] is the easiest way to check the rate of seepage at low flow rates [13]. In order to make use of a catch container, the water from the drain has to be routed either via a pipe that has one end that is open or through a channel that has been built with an overhang and a vertical drop. A stopwatch is then used to record the amount of time it takes for the water to be caught by the calibrated catch container. If possible, the catch container should be composed of corrosion-resistant plastic or stainless steel.

ii. Flow Meter

Seepage water that has been gathered in a toe drain or drain trench of a dam is then transported via open channels or pipelines and released into the water that is located downstream of the dam. The velocity of the water may be used to estimate the volume of this flow[12,13]. Water velocity may be measured in a variety of ways. For this aim, some people use the pivot tube concept. The measuring of velocity is done by other means, such as propeller-type rotating devices, electromagnetic sensors, or acoustic velocity meters. Using a differential pressure transmitter and an orifice plate in a pipe, one may determine the flow of seepage water by measuring the pressure drop across the orifice plate.

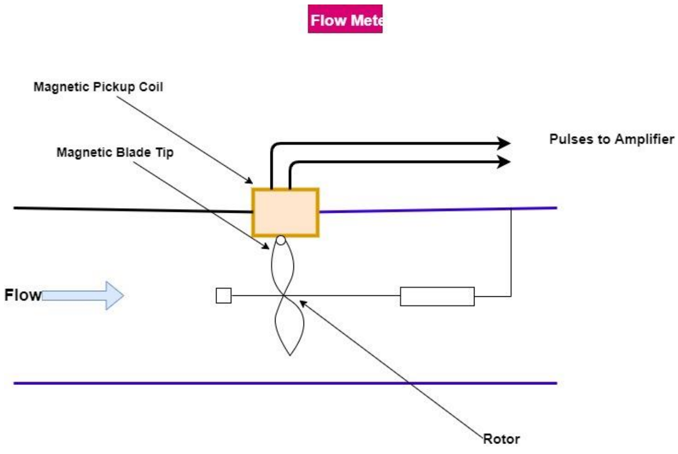

Fig i: An illustration of a Flow meter

iii. Parshall Flumes

A venturi-like open channel flow portion is what a flume is. Over the flume's crest, a converging segment reduces flow. In this way, the discharge may be linked to the differential head.

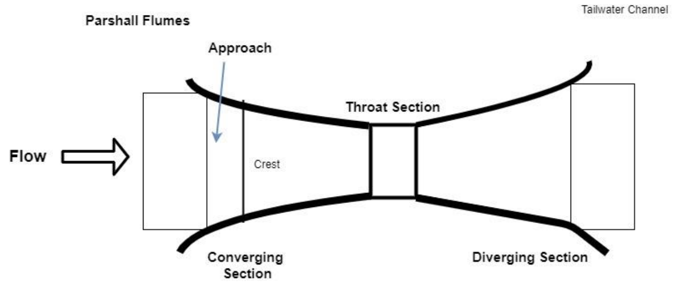

Fig ii: Parshall Flumes Design

iv. Weir

Water flow in a seepage may be measured using the weir, which is an extremely ancient, simple, and reliable method. Most often, a rectangular or 90° V-notch form of weir will be used. It is possible to employ a V-notch weir with an angle less than 90° in the event of a low flow rate A trapezoidal weir is sometimes used. A parabolic or circular weir may be employed in certain circumstances[14]. If we consider the water flow over a thin plate weir as well as the approach channel and the weir's geometry, as well as water's physical qualities and flow characteristics, we may derive a discharge coefficient that accounts for all of these variables[13].

E. Wired & Wireless Sensor Networks

i. SD-12 interface real-time instumentation

instrumentation and monitoring relies heavily on real-time monitoring. GSM/GPRS modems have been incorporated into modern automated data recorders to provide accurate and uninterrupted data capture. A wireless connection to a distant server is provided through an SDI-12 interface on these. There is a daisy chain of sensors linked together using the Serial Digital Interface at 1200 Baud, or SDI-12, which is an asynchronous serial communication protocol [13].

The SDI-12 interface is extensively used since it connects sensors and data loggers on a serial bus using just a single 3-conductor wire. The bidirectional serial data line provides a connection between the SDI-12 sensors and the datalogger when power is provided via the SDI-12 bus from the SDI-12 instruments [14]. The multi-position junction, or switch boxes, connects the wires from various sensors. The multicore wires are then connected to the data acquisition system. There are significant savings in cabling costs when using the SDI-12 monitoring. Using the data recorders' GSM/GPRS capabilities, the recorded data may be instantly uploaded to a remote FTP server. If you want to take a measurement, you may set the timer to go from 5 seconds to 168 hours. With the current date and time and battery voltage, all data is saved. A cable or a Bluetooth modem may be used to communicate between the datalogger and the devices (PC and mobile).

ii. Wireless real-time monitoring using RF

There are a broad range of geotechnical and environmental sensors and RF gateways that are compatible with the wireless monitoring system. Encardio-rite provides a new solution for long-range radio networks that enables real-time monitoring of geotechnical and structural sensors in harsh environments, together with dependable data transmission that is completely free of any lag time [15]. By connecting on to the web-based data management software, any authorized user anywhere in the world may access the data. RF nodes connect our sensors to the long-range, low-power wireless network and reliably transmit recorded data to the Gateway in our end-to-end wireless monitoring system. The sensor data is uploaded to the central/cloud server via the gateway [15]. Large building sites, tunnels, and landslide projects may all be monitored using a long-range radio frequency-based wireless data gathering network. There is no need to run long cords with the wireless technology. When sensors are dispersed over a large region, it makes sense to employ this method to avoid the difficulties of extending lengthy cable lengths over long distances, as well as places where construction may harm the sensor cables in use[15].

Data collecting in tunnels is made easier by the deployment of wireless mesh networks. The information may still be delivered to the gateway through other nodes in the network if the node cannot access it directly at any time during the monitoring process. As a result, it's a solid choice. Each gateway may handle up to 50 nodes, and each node sends data to the gateway. The use of RF nodes for wireless monitoring lowers monitoring costs while also speeding up the process. Furthermore, its remote monitoring techniques[16] allow you to readily access difficult-to-reach sites.

F. Future of geotechnical instrumentation

Most of the revenue will be generated by the geotechnical instrument and monitoring services sector. There are more businesses in the industry selling geotechnical instrumentation and monitoring capabilities than there are firms offering instruments and software [17]. G eological monitoring requires a wide range of devices including in clinometric instruments as well as piezometric ones as well as sensors.

The program analyzes the data collected by these equipment. Because the stakeholders may take preventative and corrective measures to guarantee structural safety as early as possible thanks to these solutions, a higher level of structural safety is enabled. Reusing the hardware and software solutions is an option, but renting them to other businesses is a more common practice for those that acquire them. [18] The existence of a large number of companies that provide geotechnical instrumentation and monitoring services is the primary factor driving market expansion.

Using wireless equipment, including accelerometers,strain gauges, inclinometers,piezometers, linear voltage displacement transducers, and traditional instruments may be connected for data processing and analysis at a single location. Wireless geotechnical instrumentation and monitoring networking technologies are in great demand, which is one of the main reasons for this market's rapid expansion. However, because to the increased deployment of connected instruments for geotechnical monitoring, wired networking technology is likely to have the biggest market share. The Asia-Pacific geotechnical instrumentation and monitoring market is predicted to develop rapidly between 2021 and 2026. During the projection period, Asia Pacific is predicted to have the largest market growth. Growing infrastructure expenditures and the amount of new infrastructure improvements are driving market expansion in this area, as are government instructions for mandatory geotechnical instrumentation and monitoring[18]. Many nations in the Asia-Pacific region are experiencing fast urbanization, which has prompted the start of many infrastructure projects, creating new development prospects for the geotechnical instrumentation and supervising industry.

I. SIGNIFICANCE TO THE U.S

Civil engineering in the United States relies heavily on Geotechnical instrumentation. The necessity for geotechnical instrumentation and monitoring has grown as the globe has developed swiftly and turned into a concrete jungle. Geological instruments, often known as sensors, are devices used to keep tabs on the structural health of huge civil engineering projects[19]. Geotechnical instruments may be used in a wide variety of ways. A new age of architectural wonders is upon us. Emerging Geotechnical instrumentation is required to monitor dams, bridges, tunnels, railroad lines, and other infrastructure on a regular basis. Geotechnical monitoring is essential from the beginning of the construction process until its end. A project's safety and efficiency may be ensured via the use of field instruments. Instrumentation efficiency is largely dependent on the three Ps: planning, installation, and post-installation monitoring. The categorization of geotechnical equipment and the monitoring of already-existing significant structures get particular attention. Structural parameters have been categorised as a source of structural failures [19]. The selection, monitoring, and analysis of instruments have also been studied. A method for making good use of instruments in already-existing, historically significant buildings in order to keep them safe throughout development in the area has been provided.

II. FUTURE IN THE U.S.

Geological instrumentation's future in the United States appears bright, with applications in the construction, energy, oil & gas, and mining sectors all looking potential. Infrastructure investment in many nations, tight government laws to ensure the safety and sustainability of the structures built on them, and a rising knowledge of geotechnical instrumentation and monitoring instruments are the main drivers of this industry Owing to its many advantages, wired networking technology is expected to remain the biggest category [20]. This is due to its fast speed of operation, minimal attenuation of data, and high bandwidth. Geotechnical instrumentation and monitoring techniques will continue to be used in the construction of buildings and infrastructure during the projected period. Key to safety monitoring is the use of instrumentation, which provides critical data and early warning of potential issues.

III. CONCLUSION

This paper focuses on the value of instrumentation monitoring as a means of gaining better control of construction, ensuring the safety of buildings, and authenticating design. It is not only the intricacy of the structure that determines how much and what kind of instrumentation is needed. When a building fails and its owner is held liable, this knowledge is crucial. Geotechnical monitoring and instrumentation is beneficial throughout the whole building process. It may be crucial in the early phases for verifying laboratory findings and evaluating the initial site conditions. In the course of construction, the site team makes use of it to assist manage construction control, improve communication with stakeholders, and aid in value engineering strategies. Millions of dollars are predicted to be generated by the geotechnical instrumentation industry in the United States. Data on revenue, products, expansion, and other aspects of large corporations can be gathered in this way. Market drivers and constraints, as well as opportunities and threats, are all included in the report's analysis.

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