SCADA - A QUALITY CONTROL TOOL IN ROAD CONSTRUCTION

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Abstract—India has got the second largest road network in the world and hence plays a major role in the economic development of the country. Despite being an area of major concern, road sector is adversely affected by inferior quality and service levels. Quality management and Quality control has an issue of serious concern now. The PWD Maharashtra has used Supervisory Control and Data Acquisition (SCADA) system for quality control of road construction on experimental basis on few sites. The paper investigates the suitability of application of SCADA for quality control during road construction through experience of PWD Maharashtra. The paper describes the SCADA system adopted in this regard and reports the advantages of the system and barriers in implementation of SCADA system in road construction.

Keywords: Quality Control, SCADA, Road construction, Supervisory Control, Data Acquisition

I. INTRODUCTION

Transportation System has always been the lifeline of a nation right from the time when civilizations existed. India's road network carries over 65 percent of its freight and about 85 percent of passenger traffic. There are ample numbers of problems faced by road network in India. The major problem is that the constructions of new roads are not augmenting with the increasing traffic on these roads and have not kept pace with traffic in terms of quality also. Thus the road sector, in spite of its high priority is adversely affected by the poor quality and service levels[1]. 'Vision -2021, IRC Report (2001)' by Ministry of Road Transport & Highways (MORT&H) identified 40% of shortfall for maintenance funds of National Highways and absence of quality check instruments. This has led to the poor quality control during the construction and also poor maintenance of roadways. Thus, in changing scenario, there is a great need to emphasize on proper quality control during construction of road.

A vital aspect of construction management is to plan, directly observe, coordinate, and verify the various activities involved in the project for good quality control. Gleason [2] reported that communication consumes approximately 75% to 90% of a Construction Manager's (CM) time to collect current and available information on demand. Field verification is an important part of a CM's responsibility, but administrative task consume time which would otherwise be spent on site. In order to overcome these shortcomings, there's a necessity to use advanced technologies in road construction which gathers the information efficiently and also helps in proper quality control. SCADA (Supervisory Control and Data Acquisition) is one of the modern day's information technology tool which can be used for quality construction of roads. The SCADA is used successfully in various infrastructure sectors like irrigation, boiler operation, and waste water treatment plants.

Fernández [3] carried out a study on the effect of SCADA system on deficit irrigation of almond trees. Irrigation system was controlled by SCADA application. After evaluating the system for 2 years, they concluded that SCADA improved the working efficiency of irrigation system and allowed for early detection of possible failure of irrigation system. Aburawe [4] conducted a study on water loss control and leakage detection using SCADA system. The field sensors were installed at specific points in the network to record values of pressure and flow rates at the nodes. The data used to detect leakage in water distribution networks. Fifueiredo [5] reported the use of a SCADA system for energy management in intelligent buildings. They found that SCADA controller performance has made a higher utilization of natural light in relation to electric illumination and thus has reduced the energy consumption. Shankar [6] studied on Control of Boiler Operation using PLC –SCADA. The author inferred that there was a better temperature control using PID controller. Morsi [7] scrutinized the use of SCADA system in a desalination plant for a Multi Stage Desalination Plant". The authors concluded that SCADA/HMI interface helped to collect the data from a long distance and can be controlled it by sending and receiving signal from and to this system. Rijo [8] conducted their studies on Supervisory and Control system of MC12 canal of Portugal. It found that SCADA assured the fast convergence to the set point values and stable gate movements of canal.

Similarly, SCADA is used as a quality control system in road construction on experimental basis by PWD Maharashtra on their few sites. This paper aims to investigate the suitability of application of SCADA for quality control during road construction. The paper describes the features of SCADA system established and used by PWD Maharashtra. This paper identifies advantages of SCADA and barriers while implementing SCADA for quality control in road construction.

II. RESEARCH METHODOLOGY

The article presents the findings of a qualitative inquiry into implementation of SCADA system for quality control of road construction by PWD Maharashtra on experimental basis. The study utilised three important research methods. First, the literature review was conducted to find the articles explaining the use of SCADA in various infrastructure sectors and to understand the technology of SCADA. To understand the technology of SCADA, information broachers of companies supplying SCADA were very useful. Second, the participant observations by researcher at Batch mixing plant where SCADA system was installed by Contractor of PWD. The researcher spends two days on site. This help to understand the working procedures of each component of SCADA system. Third, the expert interviews were conducted to gain insight of the system, advantages observed by adopting SCADA system and barriers encountered during implementation and working of system. In total 5 interviews were conducted. It includes Engineer who is handling SCADA system at Chief Engineer's office of PWD, PWD Engineer who is using this system in construction of road, Contractor who installed this system first time for experimental basis, Contractor's two Engineers who operates the system, one at batching plant and other at office. All the five people were associated with this experimental project since inception, thus, improves the reliability of data obtained.

III. SCADA SYSTEM

SCADA system is an assemblage of computer and communications equipment designed to work together for the purpose of controlling a commercial process. Data acquisition refers to the procedure used to access and manage information or data from the equipment being controlled and monitored. The information accessed is then forwarded onto a telemetry system prepared for transfer to the various sites. They can be analog and digital information gathered by sensors, like temperature, weight, flow etc. It can also be data to control equipment such as actuators, relays, valves, motors, etc. It is a technique used in transmitting and receiving information or data over a medium [9]. The information can be measurements, such as voltage, speed or flow. These data are transmitted to a different location through a medium such as cable, telephone or radio. Information may come from multiple locations [10]. SCADA system comprises of following components.

A. CMS (Central Monitoring Station or Master station)

The major function of master station is to obtain data from PLC's and RTUs regularly. It also obtains data from other master and sub – master stations. It regulates the field devices through the operator station. Master station consists of either one or more number of personal computers. Master station is the brain of any SCADA system which accomplishes various tasks like gathering information from RTUs, logging, alarm handling, report generation and controlling the process operations based on the data received. Design of master station is not unique and it varies according to the situation. Master station supports various transmission methods like Ethernet, radio, dial-up telephone lines etc. Master station can communicate to number of RTUs networked together, or it can communicate with one RTU which is connected to number of other RTUs.

B. PLC (Programmable Logic Controller)

The actual control of processes is affected in the PLC. It can work with physically connected inputs and outputs or with those provided by RTUs. Two types of control can be achieved: discrete and continuous.

C. RTU (Remote Terminal Units)

It is a vital element of any SCADA system as it peruses the inputs from sensors, switches. It arranges the data into a configuration that SCADA system can read. It also monitors field parameters and transmit the same to Master Station. It also converts output values provided by SCADA system, which will be in the digital format, into the configuration that can be read by field controllable devices.

D. HMI (Human Machine Interface)

The operator interacts with the SCADA system through HMI. HMI is located in the operator room and displays may be animated graphics with colour displays or in the graphical format. It alerts the operator, in case of existence of any problem in the processes.

E. FI (Field Instrumentation)

It consists of sensors which react to the external stimulus such as voltage, temperature, flow etc. and actuators perform mechanical functions such as opening or closing the valve, switching the pump on or off etc.

F. Communication System

Communication system plays a major role in SCADA system as the data collected should be updated in real time to the main station. Usually, the data gathered is to be transmitted with RS485 network, over fiber optic network. Ethernet is preferred over public internet to assuage the security trepidations. PLCs and RTUs deduce the information from sensors and convey it to the Master Station. Master Station sends the commands to the PLCs and RTUs and the same will be transferred to the relevant control devices. Thus the master station can control the processes even in the remote site, from one location through the network.

IV. SCADA SYSTEM IN ROAD CONSTRUCTION

SCADA system with sensors remotely monitors the ample number of parameters in road construction starting from the production of bituminous concrete to the leveling of pavement. This system can give a warning beforehand, of the prevailing or imminent equipment failure or process upset. The application of the SCADA system for road construction is elucidated elaborately below. The figure 1 shows the SCADA hardware architecture for road works.

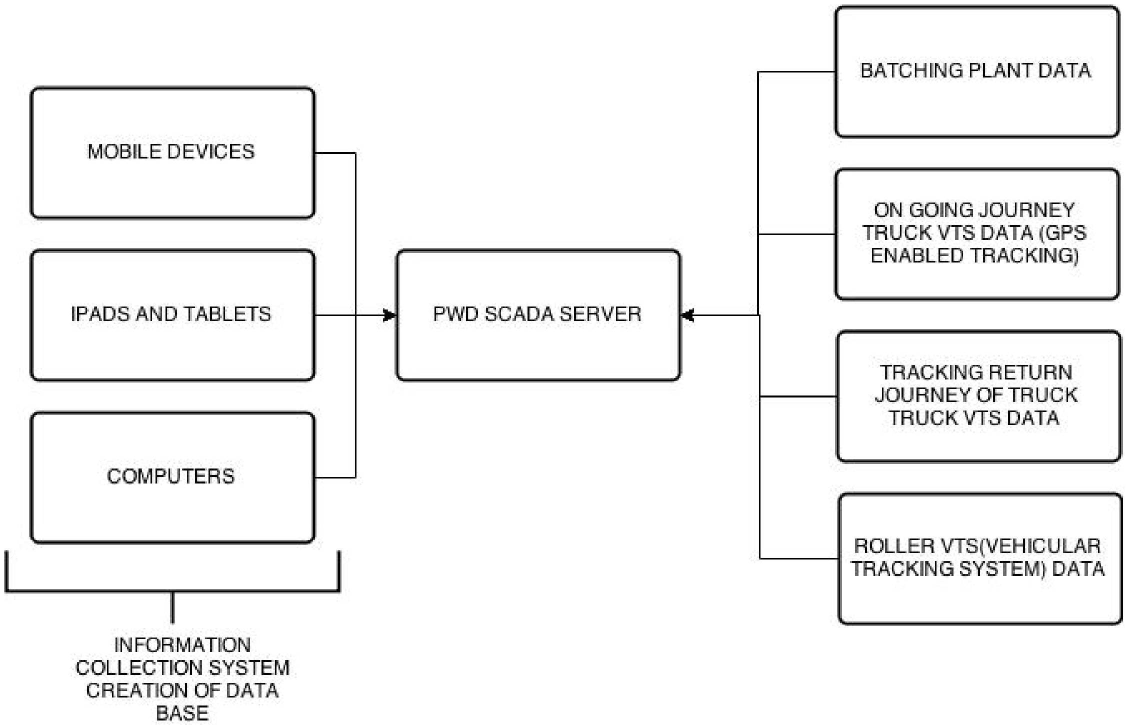

Fig. 1. SCADA hardware architecture for Road work

A. Cold Feed Bins and Vibratory Screens

The proper metering of the aggregates is a vital aspect of the process, as it affects the design mix of the bituminous concrete. For this purpose, transducer is used, which converts physical quantities, weight and temperature of the aggregates, into an analog output. This signal is received by the PLC through a controller, which interprets and compares these values with the coveted values and the corrective actions will be made by the system. Thermistor or temperature sensor controls the temperature automatically and it display on the controller. Aggregates are segregated into different sizes and are loaded into cold feed bins by crushers. The gathering conveyor runs underneath the cold feed bins and aggregates are piled up onto the gathering conveyor. Bins are provided with AC/ DC variable speed drive motors and its operation are regulated by SCADA. The flow of aggregates from the bins are controlled by the SCADA operator and the charging conveyor is furnished with a weigh bridge which measures the weight of the aggregate passing over it, and a sensor to determine the speed of the belt. Using these two values, wet weight of aggregate, in tonnes per hour/tonnes per minute, entering the drum mix plant, can be determined. The moisture content of the aggregate should be pre-determined and should be given as an input value and the plant computer converts the wet weight to dry weight. The proper amount of asphalt content required for the mix is thus determined.

B. Burners and Blower

Blower and burner operations are controlled by control panel. It can be operated both in manual and automatic mode. The required temperature can be pre-set and can be controlled automatically. Usually two/three nozzles type pressure jet burner is used.

C. Bitumen Transfer System

A high capacity pump, fitted with AC variable speed drive feeds the metered amount of bitumen into the mixing section of the rotating drum. The fully automatic control panel ensures a precise metering of bitumen. Bitumen tank is provided with the sensors to measure the temperature of the binder. When the bitumen switch is in forward mode, bitumen will be pumped to the drum mixer for blending the aggregate. Once the sufficient amount of binder is passed on to the drum mixer, the switch is set to reverse mode, in which the bitumen flows back to the bitumen tank. Bitumen flow is controlled by Voltmeter. Higher the voltage more is the flow.

D. Intelligent Compactors

Compaction is a process of densification of various layers of a pavement. The serviceability of roads depends on the level of compaction it undergoes during the construction process. Intelligent Compactors is a technology used to achieve the required compaction using sensors, GPS and other devices. The main features of IC are enlisted below.

1) Integrated measurement system which determines the extent of compaction and surface temperature of the underlying pavement in real-time.
2) A GPS based documentation system for continuous recording of roller position and corresponding compaction level data for the complete road.
3) On board display system to display the real-time operation parameters like compaction level, temperature of pavement, roller pass, direction of roller, GPS location of the roller, and a colour coded mapping of compaction level at each location. Figure 2 shows the display screen of roller.
4) A feedback control system that can change the operational parameters of the roller such as frequency, amplitude, speed, direction to vary the compactive effort on the pavement according to the compaction level. Colour coded display maps are an important feature of Intelligent Compactor. Figure 2 shows a display map of a particular road.

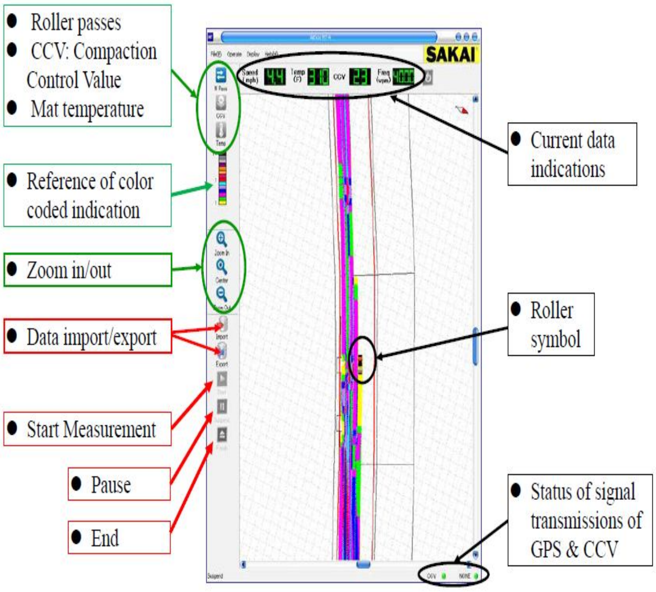

Fig. 2. Color coded display of roller passes [11]

E. Intelligent Sprayer

For applying an asphalt prime, tack or seal coat, a specially designed "Intelligent Asphalt Distributor" is required to produce uniform application. Intelligent Asphalt distributor consists of asphalt tank, asphalt pump and spray system, heating system, power system, combustion system, control system, pneumatic system, hydraulic system. The main features are as follows:
1) The Intelligent Asphalt Distributor are equipped with Global Positioning System (GPS) measurement and a documentation system that continuously records the sprayer location, quantity of bitumen sprayed on surface area.
2) All operations can be performed in cab, equipped with SCADA and is able to send live reports of work/equipment performance to concern engineer in charge.
3) Asphalt application rate is controlled by computer and discharge varies with speed of truck, thus able to deliver always the quantity of bitumen required, irrespective of truck speed.
4) Heating and heat preservation system is fully automatic.

F. Mechanical Paver Finisher

Paver finisher is used to spread the Hot Mix Asphalt in a uniform layer of required thickness or differential layer to a desired cross section and elevation. The automatic screed controls may be set in manual, semiautomatic, or automatic operation mode. The grade sensors detect the changes in elevation by riding on a string line and the information is sent to the control box in real time. By the use of slope sensors, crown and super elevation slopes are controlled. The automatic control system helps to produce the smooth pavement surface irrespective of irregularities in the surface being paved. Once the screed is set for the desired mat thickness and slope, the automatic controls activate the motors or cylinders to change the screed tilt to automatically compensate for road surface irregularities. The position zone sensors also known as trackers, with the help of GPS antennas, know the accurate position every moment. The trackers continuously provide the elevation and horizontal position information of the paver to the control box containing digital site plan.

Knowing where the paver is located within the digital site plan, knowing the grade required at the exact position, the control box sends correction signals to the screed to maintain the mat thickness and slope for that position on the site. The grade information is displayed continuously and one control box can operate both the sides.

G. Remote Monitoring

The client station will be entitled with Remote web access. It allows the client or the Engineer in charge to monitor the processes and to collect the production data in real time. They can make the necessary changes in real time if needed, which saves the time and money required for repair of work in the later stages. In order to secure the SCADA data, and to minimize the unauthorized use, system is provided with Virtual Private Network (VPN). VPN provides the users with secure access to their organizational network. The user can logon to the system with his registered username and password.

H. Local Monitoring

A mimic display of the entire plant is exhibited on SCADA control panel for easier monitoring of ongoing processes. All the parameters can be monitored online and necessary changes can be made. The main screen display for batching plant is shown in figure 3 and following are the parameters monitored.

Cold feed bins: Monitors on/off status of cold feeder bins motor, temperature sensors and weight sensors, on/off status of gathering conveyor motor.

Vibratory Screen: Monitors on/off mode of hydraulic motors.

Drum Mixer: Monitors on/off mode of dryer and blower pumps, temperature sensors, controls the temperature of the dryer and blower speed.

Filler Tank: Monitors on/off mode of blower unit or air compressor and proper metering of filler (Electronic belt weighing system).

Bitumen Tank: Monitors On/Off mode of AC speed drive and burner, Temperature sensors and metering system (Electronic belt weighing system).

Hot Oil Tank: Monitors On/Off mode of Hot oil pump and temperature sensor.

Hot Conveyor: Monitors On/Off mode of conveyor motor, temperature sensor.

Fig. 3 Main display screen of SCADA control panel (Actual Photograph on site)

V. Advantages and Barriers of SCADA System in Road Construction

This section reports the advantages of SCADA system in road construction and barriers encountered during execution explained by experts.

A. Advantages

1) SCADA monitors and controls the processes which ensure to achieve the required performance consistently.
2) All the operations can be controlled from a single central location.
3) It reduces the dependency on labour force for operational requirements, as it is automated, improves the quality to high standards.
4) SCADA stores all the data in its database server, thus if required, the data can be accessed in the future to assess the performances.
5) The site engineer or the construction manager has a control over all the processes at centralized location.
6) It is difficult to monitor the temperature variation in bituminous mix during transportation from plant to site; However, SCADA removed this difficulty.

B. Barriers

1) The effort involved in implementation of SCADA in the field and training the personnel requires large investment in time and cost by the contractors. Therefore, contractors are reluctant to adopt this system.
2) The personnel working in the remote construction site may less expertise in using the software and hence the company might have to either train its staff or have to send the experts to the remote site by paying more. This is not vindicated for small projects which will usually have a small profit margin.
3) The new users may find it difficult to deal with the problems posed by the software in the arduous environment of the construction site.
4) Bandwidth is one of the major problems for exchange of documents from the remote sites. GPS system may not be available in all the working sites, which hinders the working of SCADA.
5) Also, the savings from SCADA usage may not be reflected in monetary terms and might be in terms of reduction in wastage and savings in time. Since it is not quantifiable, the contractor might not notice the benefits but might have the mindset that project has incurred loss and might be reluctant to employ SCADA for the future projects.

VI. Conclusion

Road construction involves various parameters to be controlled, so requires constant monitoring. Implementation of SCADA in road construction is a key issue to improve the quality of roads. Thus, this paper has described the SCADA system used by PWD Maharashtra on experimental basis. The various components of the system and its operations are explained in detail. This will help the civil engineers in understanding of the system. The paper has reported the advantages of SCADA system and barriers encountered during its implementation from the experience of PWD Maharashtra. Thus, the paper will be useful to other departments, working in road construction all over the country as an information guide.

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