Chapter-III
LITERATURE SURVEY AND REVIEW

3.1 Quality Control

The road development programmes envisaged for the country involve large amount of money, manpower, materials and machinery not only for the construction of new roads, but for the improvement in the existing road network also. Road transport is the most widely used system of transportation. George et al., 1989 intimated that the performance is a broad, general term describing how pavement condition changes or how pavement structures serve their intended functions with accumulating use [31]. AASHTO (2003) defines the pavement performance as the ability of a pavement to satisfactorily serve traffic over time [1].

Ministry of Road Transport and Highways, Govt. of India published the specifications for roads and bridge works firstly in the year 1973. A detailed chapter on quality control for road works has been given wherein the frequency of the tests to be conducted for the acceptance of the material has been well defined for each category of the material. The second revision was made in 1988, third in 1995, fourth in 2001 and lastly in 2013 [151, 152].

Before the 1970s, method specifications were used in most highway projects to define the quality that the highway agencies expect from contractors. When using specifications, the highway agency spells out in detail what is to be built and how it is to be done. As was mentioned in the AASHTO Road Test, the Transportation Research Board (TRB) in 1976 and Rillet in 1998 also concluded that the use of specifications do not ensure that the pavement would perform and last as expected [212, 175]. Moreover Miller-Warden Associates in 1965 and Rilett in 1998 further concluded that the acceptance procedure is based on engineering judgement which is strongly based on past experience, and if the variables are unknown to the specifications under new conditions, the end result may not be satisfactory [149, 174]. It is difficult to define quality in legal or contractual terms when engineering judgement is used. The degree of acceptable variation will differ from engineer to engineer and from job to job. In more recent years, quality assurance specifications have been emphasized. The advantage of quality assurance specifications to state agencies is that the responsibility for materials and construction quality is actually placed on the contractor.
The specifications define the materials and methods to be used in order to obtain a completed product. Quality assurance specifications rely on the statistical acceptance plans based on random sampling both to define the product wanted and to determine its acceptability [148, 149, 212, 175]. The Florida Department of Transportation began to develop the groundwork for the quality assurance specifications in 1965. By 1971, the preliminary specifications for asphalt pavement construction were developed. In 1976, FDOT [37] made a decision to adopt the quality assurance specifications for all asphalt concrete construction effective with contracts awarded after 1st January, 1977. The acceptance plans contained in the specifications undergone some changes.

Miller-Warden Associates in 1965 concluded that the Highway specifications are used to state the basis for sampling and testing methods, including acceptance or rejection of the completed work [149]. The quality level of any product should be associated with the degree of variability. Willenbrock in 1975 concluded that statistically developed specifications are both practical and realistic because they provide a rational means for achieving the highest overall quality of the material or construction, while recognizing and providing for the variability of the process and product [224].

According to the Transportation Research Board’s Glossary of Highway Quality Assurance Terms [212], quality assurance is defined as a process of planned and systematic actions to provide confidence that a product or facility will perform satisfactorily in service. It addresses the overall problem of obtaining the quality of service, product, or facility in the most efficient, economical, and satisfactory manner possible. Quality assurance involves continued evaluation of the activities of planning, design, development of plans and specifications, construction, maintenance, and the interactions of these activities. Quality assurance in construction includes quality control, acceptance sampling and testing process, and independent assurance. The acceptance sampling and testing is done to determine whether or not the quality of the produced material or construction is acceptable in terms of the specifications. The independent assurance is a management tool that requires a third party to provide an independent assessment of the product and/or the reliability of test results obtained from process control and acceptance testing. TRB in 1996 concluded that the results of the independent assurance are not used for product acceptance [212]. The current regulations on sampling and testing of materials and construction appear in the Federal
Register [37]. According to these regulations, contractor testing results may be used in an acceptance program. An acceptance program is defined as the process of determining whether the materials and workmanship are in reasonably close conformity with the requirements of the approved plans and specifications. The samples used for the verification sampling and testing must be obtained independently by the designated agent. Quality assurance of highway construction requires proper answers to the questions i.e. what do we want (planning and design stage), how do we order it (plans and specifications), and did we get what we ordered (inspection and testing), and acceptance procedures.

Quality control is the process that the contractor or producer performs to assure that the materials or the construction conforms to the specifications. This concept of quality control includes sampling and testing to monitor the process was also concluded by TRB in 1996; however, it does not include acceptance of sampling and testing [212]. The specifications should define an acceptable quality level (AQL) and rejectable quality level (RQL) realistically for each quality characteristic. The AQL should be set high enough to satisfy design requirements; however, it should not be so high that extraordinary methods or materials will be required. Weed in 1996 was of the view that the RQL should be set low enough that the option to require removal and replacement is truly justified when it occurs [223].

The benefits of quality assurance specifications are primarily due to the lot-by-lot acceptance procedures. When lots are immediately accepted, conditionally accepted with a reduction in payment or rejected, contractors or producers know their position. Hughes in 1996 and TRB in 1976 were of the opinion that the price reduction motivates the contractor to take corrective action before large quantities of non-specification material or construction are produced. Moreover, it avoids tie-up of capital when payment is held up due to failing tests [61, 212]. The quality assurance specifications are easier to write and to interpret what is expected from a highway agency by describing the desired end result in statistical terms rather than in a vague term. The acceptance criteria and random sampling procedures are clearly defined. The risks to both the contractor and the highway agency can be controlled and known in advance. Weed in 1996 opined that the quality assurance specifications are easier to enforce because of a clear separation of responsibilities for control and acceptance. Moreover, they are easier to apply because pay adjustment for defective work is
predetermined; thus, no negotiations are required. An additional benefit of quality assurance specifications is the produced data. Whereas historical data collected in conjunction with method specifications have been notoriously unreliable, the quality assurance specifications produce useful data obtained with valid random sampling procedures. This data can be analyzed at a later date to develop better specifications [223].

TRB in 1976 was of the opinion that the small contractors may not be able to hire a full-time quality control technician when the prospect of successful bidding contracts was uncertain. These organizations would have to arrange with a testing laboratory to do the work [212]. The purpose of attribute sampling is to classify an item as accepted or rejected; the inspection does not provide the average level and the variability of a characteristic. Therefore, there is no clue in regard to the type of corrective action that should be taken [11, 221, 217].

Sampling by variables makes use of all the relevant information (number of tests, means, standard deviation etc.) computed from the sample to estimate the quality. Moreover, this type of sampling produces a continuous result which is more suitable for developing adjusted pay schedules to deal with the intermediate levels of quality that are often encountered. The continuous measure of percent defective is a more appropriate parameter upon which to base a system of adjusted payments [23, 11, 221, 217]. In general, attribute sampling is much less efficient than variable sampling. Weed in 1989 concluded that to obtain a certain buyer’s risk or seller’s risk, the number of samples needed for sampling by attribute may be 30 percent greater than the number needed for the variable sampling [222]. TRB in 1976 concluded that the acceptance plan may be designed in several ways. It may specify a minimum percentage of material or construction having a value of the measured characteristic within the limit(s), or a maximum or minimum value of the measured characteristic may be specified [212]. For density and asphalt content, variable sampling plans are used in current Florida standard specifications for road construction. FDOT in 1999 concluded that the minimum value of the lot mean is defined for density, while the average absolute deviation from the job mix formula is used for asphalt content [41].

In lot-by-lot acceptance plan, one or more samples are chosen at random from the lot. Bowker and Goode in 1952 opinioned that a large number of rejected lots is costly to the supplier, the supplier will try very hard to submit better quality lots in the future [17]. A lot in
highway quality control can be applied to a very large group of units, to a large quantity of material, or to an infinite number of locations. However, a lot is generally a definite amount of similar material [23, 11]. Anglade in 1998 concluded that when the lot size is large, it is a disadvantage for the contractor if this large quantity of material is rejected when the quality is not acceptable [2].

If a sample is to provide us with useful information about the population, it must be representative, i.e., the sample must be made up of typical members. Drain in 1996 and Hughes in 1996 were of the view that a representative sample for quality assurance is generally obtained by random sampling. Most state highway agencies use stratified random sampling, where the lot is divided into equal sub lots and the sample is obtained by random sampling from each sub lot [34, 61]. The more fundamental method of random sampling, which can be called pure random sampling, allows the samples to be selected with an unbiased manner, based entirely on chance.

For these reasons, statistics need to be used to determine the variability with respect to each material or construction characteristic. No matter what kind of measurements is made, it is unlikely that all measured values will be exactly the same. Relatively small variations in the measured values of a property of a material may be caused by the fact that the measurements cannot be made exactly enough. However, fairly large variations usually occur because of the nature of the materials and the fact that no two samples of the material will be alike. Hudson in 1971 and Hughes in 1996 concluded that increasing the precision of a test method, or the care with which the measurements are made, beyond a certain limit would not make the measured values more reliable. Assuming no assignable causes are operating, there are three sources of variations involved in highway construction [11, 61].

Miller-Warden Associates in 1965 and Hudson in 1971 concluded that segregation is a major source of variation in most property measure values of a sample used in highway construction. Segregation separates a material into unlike parts. Most of the highway materials tend to segregate to some degree. As a result of segregation, the density test results at two locations may differ greatly [149, 11]. Random sampling is mostly used in highway quality assurance to reduce the effect of segregation. The locations or units from which the
samples are obtained must be entirely random, which means that the locations of the samples are determined without bias.

The testing variation is the variation due to the lack of uniformity in the testing procedure and includes the effect of differences in the preparation of portions of a sample for testing. The testing variation would be measurable if the test did not destroy the material. The same sample could be used to repeat the test. According to a FHWA report in 1977, a considerable gap exists in highway work between the quality of work specified and the quality of work received [37]. Miller-Warden Associates in 1965 concluded that although the AASHTO Guide Specifications are a noteworthy milestone toward standardization, they are not necessarily the best engineering or the most economic specifications for some states [149]. Willenbrock in 1975 suggested that every highway agency should have their own specifications to describe realistic standards, which more accurately reflect the inherent variability of a given material type or construction characteristic [224]. The realistic specifications would enable a contractor who is normally applying good control processes to run a minimum risk of having acceptable material rejected. Hughes in 1996 stated that the state highway agencies use their experience, engineering judgement, tolerances from other agencies and standard precision statements more often than they use variability data from studies and projects [61]. Moreover, many specification limits are still being set the same way as the ones used in AASHTO Road Test almost 40 years ago.

AK Mukherjee et al. defined that with the sophistication in the processing/production of the material as well as superior workmanship, it is desirable that the quality control should be more "Procedure specific" so that the quality of product would be ensured without hindering the progress [156]. The national be benefited most by achieving high quality workmanship and in avoiding time and cost over-run. Control document of a large project is expected to have Quality Assurance System as a part of the contract. Vrijhoef and Koskela 2000 concluded that with increasing client-imposed pressure on construction management teams to reduce schedule durations and decrease costs while continuing to produce a high-quality finished product, the value and importance of improving the management of construction supply networks remains [220]. There are also a plethora of constraints imposed on a typical construction project, such as weather, site conditions, availability of resources, schedules, and
local laws & regulations, which are not common to the manufacturing industry [132, 16, 30, 181].

Mahesh Kumar et al. in 2012 concluded that for better quality control on berms and shoulders should be constructed and compacted along with each layer simultaneously. No vehicular traffic of any kind should be allowed on the finished wet mix macadam [135]. Seal coat should be applied on DBM surface immediately i.e. prior opening it to the traffic. The bituminous layers should not be left open for the traffic without full overlay. The carriageway level should be kept higher than the adjacent area either by raising it or otherwise an option should have been provided in design as a drainage layer/vertical cutoff for widened portion. Material retrieved can be issued to the contractor for use and the same can be screened by screening plants.

Prof. Prithvi Singh Kandhal (2006) concluded that CRMB is to be used in a cost effective way and with success, necessary infrastructure for blending CRMB at or in close vicinity of all asphalt mix plants and associated quality control programme, need to be established [126]. Prithvi Singh Kandhal et al. (2008) concluded that for ensuring long-term performing pavements focus should shift to dense graded bituminous mixes rather than open graded lean bituminous mixes [125]. Rutting is broadly due to inadequacies in our mix design rather than granular bases or sub-grades. Some new specifications like those similar to open graded mixes may be introduced. Use of Bituminous Macadam a very popular mix at present may be deleted and substituted with DBM. Similarly, semi-dense Bituminous Concrete should be substituted by Bituminous Concrete. The Profile Corrective Course (PCC) should be only in DBM or BC. Prithvi Singh Kandhal et al. (2011) came to the conclusion that for a better quality the guidelines on use of modified bitumen in road construction must be revised immediately by deleting the common specification table for all types of polymers and modifiers so that substandard PMB is not used in India [127]. Revised IRC:SP:53 must state only PMB (elastomer) should be used for heavily trafficked roads. CRMB can be used on medium trafficked roads only [96].

Lee and Akin (2009) and Akcamete et al (2009) pointed out limitations of manual processes in fieldwork and the lack of formal approaches to collect data during facility field operations results in poor quality data being collected at job sites [139]. Researchers have pointed out
that approx. 40% of the time loss on work sites is owing to lack of materials, poor identification of materials, inadequate storage and in general, bad management of materials [7]. Poor material management leads to poor work planning and control, which in turn leads to delays in schedule and increased labor costs (Thomas and Sanvido 2000).

S. Nazarian et al. (1998) discussed the nature, role, and feasibility of measuring the properties of flexible pavement material in the laboratory and in the field with different types of non-destructive methods and devices [162]. Seismic methods measure the engineering properties of pavement materials. Seismic testing both in the laboratory and in the field is rapid and quite repeatable. Seismic modulus is sensitive to variations in moisture content and dry density of the base and prepared sub-grade. For AC layers, moduli measured in situ and in the laboratory with different seismic testing devices are very close.

Low volume roads are estimated to be 80 percent of the world’s transportation infrastructure being developed, and the majority of low-volume roads are unpaved [214]. For infrastructural development in large scale like PMGSY in India, the construction of roads in rural sectors is being envisaged on the basis of CBR result on subgrade soils [83, 87].

AASHTO Guide for Design of Pavement Structures [1] is used to present the application of the proposed concepts. Quality-control data allow deficiencies to be detected during the construction of a pavement and can be used to adjust the original design whenever these deficiencies are deemed unacceptable. Victor Torres-Verdin et al. (1991) presented a methodology for using quality control data to correct deficiencies detected during pavement construction [218]. Once a pavement layer is finished, it is evaluated by means of a control parameter. If the evaluation indicates that the layer being analyzed does not meet design specifications, then improvements are made in the overlying courses so that a pavement structure with a performance equal to that of the original design structure is obtained at the end of construction.

V.K. Sinha et al. (2007) attempted to examine the adverse effects of high temperature in the top layers of binder course on the overall performance of flexible pavements [191]. Specifications should be evolved considering the need to construct long-term performing pavements. Use of modifiers to enhance thermal related characteristics of bitumen should be made mandatory in top DBM layer. In heavy traffic corridor with high temperature, cement
Concrete roads may be considered as a viable alternative on long-term performance considerations, based upon life cycle cost.

B.B. Pandey (2008) concluded that the guidelines for Design of Flexible Pavements as per IRC 37:2001 gives pavement thickness of 80 per cent reliability and upgradation to a higher reliability is suggested for high volume roads to reduce frequent interruptions for maintenance [166, 93]. BC and upper DBM layer with VG 30 bitumen undergo rutting and top down cracking on high volume roads at higher temperature and VG40 bitumen may serve better. Thickness of bituminous layers are reduced, if, VG 40 (S35) and polymer modified binders are used in the bituminous surfacing. Fatigue life of a bituminous layer can be increased up to ten times by increasing bitumen content and by decreasing air voids.

Dr. H.C. Mehndiratta et al. (2006) concluded that the various tests conducted on gravel, show that gravel used in the pavement models have values within limit, although gravel is slightly less strong as compared to crushed stone [147]. Gravel may be used in base course by stabilizing it after mixing crushed aggregates in certain proportion so that voids in gravel are filled, thus density gets increased. Dr. S.K. Rao et al. (2007) concluded that an asphalt mix must have enough bitumen and enough air voids to be both stable and durable [169]. To fulfill this requirement the VMA of the mix should be high. To achieve high VMA, we should use rough-textured (crushed) angular aggregate and an aggregate grading that is not too dense.

K. Kantha Kumar et al. (2008) concluded that the air void content of the mix specimens has a significant effect on the volumetric properties, resilient modulus, tensile strength, fatigue and irrecoverable deformation behavior [134]. The bulk specific gravity of BC mixes is found to increase with reduction in air void content, while the voids in mineral aggregate is found to decrease. Bituminous Concrete mix with lower air void content tends to offer longer fatigue life and high resistance to permanent deformation. The results clearly indicate the benefits of a lower air void content on both fatigue life and resistance to irrecoverable deformation.

G. Suresh et al. (2010) concluded that the use of modified bitumen has shown a reduction in optimum bitumen content and increase in stability in SDBC mix prepared using crumb rubber modified bitumen compared to SDBC mix prepared using neat bitumen [204]. The optimum bitumen content is less in the bituminous mix prepared using crumb rubber modified bitumen
when compared with mix prepared using neat bitumen. The increase in tensile strength ratio in SDBC mix prepared using crumb rubber modified bitumen indicates that SDBC mix prepared using crumb rubber modified bitumen was less moisture susceptible compared to SDBC mix prepared using neat bitumen.

### 3.2 Riding Quality in Highways

Ever increasing road roughness results in rapid pavement deterioration because of increased pounding action of heavy loads. As a result, it affects the speed of vehicles, safety and comfort of passengers and also the surface drainage characteristics of the pavement surface. Among the various instruments, Towed Fifth Wheel Bump Integrator (TFWBI) is the most popular equipment being used by several developing countries because it is affordable, simple and also needs less frequent maintenance and calibration.

Sayers et al. (1986) correlated the unevenness indices obtained from the fifth wheel bump integrator running at different speeds such as 20, 32 and 50 km/h with those obtained from other roughness measuring equipment [208]. They concluded that the speed and roughness were inversely proportional to each other. Bennet (1996) has also demonstrated this fact with graphical inference [9]. Jordan and Young (1980) developed the equation for establishing the roughness values expected under standard conditions as a function of roughness observed at different speeds [115].

In the late 1950s, systems of objective measurement (such as roughness meters, deflection and skid test equipment) began to appear that could quantify a pavement’s condition and performance. These systems, along with visual distress surveys were used to aid maintenance and rehabilitation decisions, which, over the years have been refined and upgraded to provide a rapid, objective means of maintenance management (Hicks and Mahoney, 1981). Arunachalam (1971) carried out an analysis of extensive field investigation data for evaluating strengthening requirements both by California Bearing Ratio test values and also using Benkelman beam rebound deflection methods. The analysis shows that the deflection method gives realistic results in consonance with pavement performance and is more reliable than CBR method [4].

Reddy and Veeraragavan (1997) studied the applicability of different deterioration models and developed predictive models for structural and functional condition deterioration based on empirical modeling of performance data [173]. Mechanistic-empirical models for rut
depth, crack area and unevenness of in-service flexible pavements were developed based on past performance data collected over a period of ten years. The longitudinal unevenness is the deviation of the longitudinal profile from a straight reference line in a wave length range of 0.5-50m according to the definition in British Standard (BS) EN 13036-5 [British Standards Institute (BSI) 2006] and International Organization for Standardization (ISO) 13473-1 (ISO 1997a) standard. The term "unevenness" has been generally accepted in Europe while in the United States the term "roughness" is preferred.

The road elevation Power Spectral Density (PSD) is a tool frequently used to gain insight into wave length contents of road profiles. The PSD parameters are incorporated in technical standards ISO 8608 (ISO 1995) and BSEN 13036-5 (BSI 2006), both dealing with the description of road unevenness. Road elevation PSD was calculated using the Welch’s averaged periodogram method. The signals were windowed using a Cosine Digital Tapering Window (CDTW) according to BS EN 13036-5. Peter Mucka et al. (2012) concluded that the results of comprehensive analysis of the old and remixed high-way lanes call for an alternative description of longitudinal road unevenness. The common and internationally used IRI statistics do not significantly reflect the objective change in riding quality of the remixed new lane, as it remains rather constant. A road profile description with stronger correlation to vehicle and human body vibration response than the IRI would be more appropriate.

A.K. Sandra et al. (2008) undertook the study with the objective to develop the relationship between the roughness values obtained at different operating speeds ranging between 10 and 50 km/hour with those obtained at the standard operating speed of 32 km/hour based on data collected at selected stretches on different kinds of roads [182]. On uneven surfaces, the roughness of the road is inversely proportional to the operating speed of the vehicle. On even surfaces, the speed of operation does not have much effect on the roughness values.

K. Ganesh et al. (2010) successfully tested automatic immersion wheel tacking equipment for bituminous beam specimens subjected to various wheel loads and number of passes [43]. Various parameters like temperature, number of wheel passes, wheel loads, air voids, soaking conditions, type of mix, type of binder, depth of bituminous pavement layer, etc. can be correlated with respect to rutting failure of flexible pavements. Indian Roads Congress has fixed the standards for riding quality in IRC:SP 16-2004 in which the categories has been
defined as Good: Roughness <2000 mm/km.; Average: Roughness between 2000 mm/km and 3000 mm/km.; Poor: Roughness >3000 mm/km [91].

3.3 Use of Electronics for Quality Control

It was observed that apart from sensing context at work sites a need exists to monitor equipment and machine movement to better understand bottlenecks in construction site processes [52, 165]. Similarly, Leite (2009) points out that learning from the workflow of activities during an emergency response for another emergency situation in the same campus facility more efficiently [141]. An infrared (IR) based system required clear line-of-sight for localization and has a limited range of approximately 6 m. Infrared technology provides room-level localization accuracy, but this technology suffers interference in the presence of sunlight [57].

Radio Frequency Identification (RFID) technology has been used in indoor localization systems. Researchers have reported their accuracies to be approximately 5-9 m with greater than 95% confidence [57, 161, 165]. Sound frequency based technologies, such as an ultrasound system, have a reported accuracy of approximately 9 cm for 95% precision [57, 207] took an overview of applications of field data capture technologies in construction and facility operations. It included discussion on technologies for sensing entities and phenomena that are part of construction and facility operations, for sensing context surrounding these operations, and for monitoring workflow in these operations. Monitoring of field personnel can improve safety standards at sites and also highlight any inefficient processes that are part of an operation.

Construction engineers, who are visually observing construction sites, manually input the collected information into Personal Digital Assistants (PDA) devices (Navarrete 1999). The information is then uploaded to the main server of the on-site office either by direct wire connection or by a wireless local area network (WLAN) connection (Ward et al. 2003). In this way, the information is shared among the other parties involved in the project. Close Circuit television (CCTV) allows for remote monitoring of the construction site (Leung et al. 2008). The zoom and rotational capabilities of CCTV cameras enable the coverage of a wide region. Although both technologies have significantly improved the traditional construction management process [159], their shortcomings are evident. The use of a PDA requires
construction engineers to be on site so that they can manually input the construction-related information. CCTV is rendered useless when the line of sight of a camera is blocked.

Prior efforts have been made in the construction industry to adopt RFID technologies. Jaselskis and El-Misalami (2003) presented a process for using a RFID system, which they implemented on an industrial plant construction site, to identify pipe supports. Song et al. (2006a) combined RFID and global positioning system (GPS) technologies to identify the location of materials on a construction site. Song et al. (2006b) also evaluated the feasibility of using RFID technologies to track pipe spools in an industrial construction project. Ergen et al. (2007a) applied RFID technologies to streamlining information flow for life-cycle data management [35]. Goodrum et al. (2006) developed a system to automatically track construction tools using active RFID tags. Chin et al. (2008) presented a strategy to combine RFID and four dimensional computer-aided design technologies to monitor the progress of structural steel works. Ergen et al. (2007b) presented an integrated system of RFID and GPS for tracking and locating precast concrete panels in a construction site [35]. These studies advance construction material management by automating the process for identifying and tracking the location of construction resources.

Some pioneering efforts have been made to deploy various wireless network technologies on construction sites, including WLAN (IEEE 802.15.11), ultrawide band (UWB) (IEEE 802.15.3), Bluetooth (IEEE 802.15.1), and ZigBee (IEEE 802.15.4). Ward et al. (2003) developed “Wireless Network Cells” to implement mobile networks for the real time data capture of piling works. Lu et al. (2007) proposed a system that integrated RFID, Bluetooth and GPS technologies to track construction vehicles in urban areas and on construction sites [142]. Leung et al. (2008) presented a site monitoring system that used network CCTV cameras and a WLAN. Shin et al. (2008) proposed an information system using WLAN and intranet that conveniently fulfilled customer needs. Teizer et al. (2008) presented algorithms that used UWB technology to locate and identify construction objects [213]. Jang et al. (2008) developed a web-based environmental building monitoring system using sensor modules and the ZigBee protocol [110].

Jaselskis and El-Misalami 2003 concluded that RFID is a segment of automated identification technology that used radio waves to capture and transmit data regarding the state of different
objects, persons, or beings. Hedgepethin 2007 and Lehpamerin 2008 concluded that RFID system is composed of three key components: the tag or transponder, an RFID reader, and some means of data processing [55, 138]. Jaselskis et al. in 1995 concluded that the use of RFID in the construction industry was first widely proposed in the mid-1990s, but like other industries at the time, the technology was not widely pursued because of the high cost of implementation and lack of technology standardization [106].

Moving forward, the research community began to focus specifically on determining the ability to accurately identify and track key material and equipment using RFID in typical construction environments [46, 203]. Researchers commonly cited a number of problems, ranging from a lack of standardized data and equipment to the need for members of the construction industry at all levels to be introduced and exposed to RFID [46, 203]. With the ability of RFID to perform in a construction environment established, researchers continue to put forth efforts in developing algorithms that integrate the location information captured from GPS and the identity-related information captured by using RFID [203, 21, 211]. Further work still has focused on implementing prototype RFID-based Automated Material Locating and Tracking Technology (AMLTT) systems in construction project environments (Ergen et al. 2007; Construction Industry Institute 2008). Ergen et al. (2007) discussed the results of a field trial in which an RFID-based AMLIT system was employed in locating material in a fabricator’s lay down yard [35]. CII (2008), on the other hand, presents the results of two field trials on power-generation facility construction projects in which researchers estimated the impact of RFID-based AMLTT systems on improving productivity in the material management stream. In both cases, the AMLTT system was found to be a viable means of improving the ability to locate key items in a variety of operating conditions.

Duncan A. Young et al. (2011) presented the results of an investigation that examined the potential of AMLTT to increase work opportunities at the site level because of increased supply-network visibility and, in turn, to reduce the dependence on material buffers as a means of shielding construction operations from uncertainty in the supply network [146]. AMLTT has the potential to increase visibility and reduce uncertainty within the construction supply network. Improvement in schedule performance was estimated for a single supply chain found within a greater construction supply network.
Hannon in 2007 opinioned that internet-enabled, remotely controlled cameras installed at project locations, also referred to as webcams and surveillance cameras, have become prevalent over the last 10 years. Digital video cameras are an increasingly common tool for observation, monitoring, and management of construction site operations. The ability to transmit live video images from fixed cameras at the project site to a construction company’s central office was identified as an application of internet-based project management systems for the construction industry by Deng et al. (2001).

Early research regarding the collection of field data obtained by digital cameras was also performed by Liu at the University of Illinois at Urbana-Campaign. Liu developed a prototype information collection device, termed a ‘digital hard hat’. This innovative, information technology (IT) device included a standard hard hat outfitted with a digital camera mounted above the brim [225]. Researchers at Carnegie Mellon University (CMU) have also investigated the application of mobile technology on construction projects [19]. They studied certain mobile technologies termed ‘wearable computers’ including laptop computers, personal digital assistants (PDAs) and pocket PCs, and proposed an application for these IT devices for the collection of construction project data by recording information relayed by embedded or attached sensors. Applications of ‘active data collection’ have been further explored through research by Trupp et al. at the University of Illinois [215].

Research by the National Cooperative Highway Research Programme (NCHRP) in 2007 reported the advancement of fixed camera systems from either a single camera per project location or multiple independent cameras per project site to the development of a networked robotic camera system in which cameras have robotic features and improved image resolution capability [51]. Silva et al. (2009 a) reported that declining construction productivity is resulting from inadequate supervision [193].

Quan Chem et al. (2010) concluded that due to the extreme complexity of interfaces that occur in construction projects, IT assistance is considered crucial when handling the vast amounts of data and dependencies for interfaces [26]. Performing efficient interface-related coordination, decision making, operation and management can only be achieved through software applications. He introduced an innovative object view of interfaces and presented a comprehensive IOM framework that defines the basic data structure and dependencies of
interface information to enhance interface modeling. The here proposed IOM is considered the core of a conceptually designed systematic model-based IM strategy, which aims to solve various types of interface issues in the project delivery process.

Raghavan Kunigahallia et al. (1995) concluded that IVHS can make significant improvements in mobility, safety, and productivity of transportation systems by utilizing advanced technologies from electronics, communications, and computer science [137]. IVHS research areas applicable to construction automation and robotics are traffic congestion characterization, automated vehicle location, electronic ticketing and automated trip payment, vehicle guidance systems, and safety and human factors.

As for productivity, Kannan (1999) demonstrated the use of onboard instrumentation as a method to collect field data autonomously and, hence, built an experience database of site productivity [121]. The autonomous data also provided the statistically required distributions for simulation of site operations. Hildreth (2003) demonstrated the use of a global positioning system (GPS) for identifying events that occurred on a construction job site and, hence, collected data autonomously [56]. Martinez (1996) provided a general-purpose simulation tool that could model a complicated project situation and, hence, studied the productivity of a fleet of equipment [145].

Examples of job site technologies that require tagging construction resources, but otherwise operate based on wireless signals are: global position systems for machine site utilization and position control [160], radio frequency identification (RFID) for material locating and tracking on and off-site [106, 203] and ultra wide band for real-time resource tracking and work zone safety [213]. Research that uses data from still and video cameras with applications in construction management concentrated mainly on controlling the measurement environment that cameras operate in and processing its visual contents provided. Research that focused on techniques applying augmented reality for positioning and occlusions and progress monitoring was also performed.

Thus, cameras that take digital images or videos are part of important tools for managing construction projects [15]. Digital images may also reduce time needed for inspection by
allowing this task to be done remotely [15]. Seeing real-time weather can help project managers to plan and schedule accordingly. Time wasting, task completion time, and inefficiencies can be recognized and adjusted for better optimization of project resources [187]. Inventory and control of large equipment and bulk materials can be quickly located if they are in the view of the camera. Jeffrey S. Bohn et al. (2010) presented the benefits and barriers associated with the use of high resolution construction cameras for construction management [14]. It recognized tasks where cameras have the greatest impact and areas for improvement. The benefits of construction cameras have been consistently found to exceed their expected impacts and a large potential exists for improving their use, for example, in resource management.

3.4 Vehicle Tracking System

The detection of vehicles has been receiving attention in the computer vision community because vehicles are such a significant part of our life. C. Papageorgiou and Poggio presented a general method for object detection applied to car detection [167]. A. Rajagopalan et al. modeled the distribution of car images by learning higher order statistics [168]. Training data samples of vehicles are clustered and the statistical parameters corresponding to each cluster are estimated. H. Schneiderman and Kanade took a view-based approach. They built one individual detector for each of the coarsely quantized viewpoints. Then, they used the histograms of some empirically chosen wavelet features and their relative locations to model the car and non-car distribution assuming the histograms are statistically independent [185]. Vehicle detection in aerial images is relatively constrained by the viewpoint and the resolution. In the work of P. Burlina et al. and Moon et al., a vehicle is modeled as a rectangle of a range of sizes [20, 153]. A Canny-like edge detector is applied and GHT (Generalized Hough Transform) or convolution with edge masks are used to extract the four sides of the rectangular boundary. T. Zhao et al. presented a system to detect passenger cars in aerial images along the road directions [231]. They started from psychological tests to find important features for human detection of cars. Based on these observations, they selected the boundary of the car body, the boundary of the front windshield, and the shadow as the features.

Z. Chunrui et al. developed a new segmentation technique for classification of moving vehicles. They used simple correlation to get the desired match. The results shown are for the
lateral view of the vehicles and no quantitative results were given [25]. S. Gupte et al. proposed a system for vehicle detection and classification. The tracked vehicles are classified into two categories: cars and non-cars [50]. R.P. Avely et al. used a similar approach where the vehicles are classified on the basis of length using an uncalibrated camera. However, this method also classifies the vehicles into two coarse groups — short vehicles and long vehicles [5].

A method is developed by C. Zhang et al. In their work they used a PCA-based vehicle classification framework. They implemented two classification algorithms — Eigen vehicle and PCA-SVM to classify vehicle objects into trucks, passenger cars, vans, and pick-ups [230]. These two methods exploit the distinguishing power of Principal Component Analysis (PCA) at different granularities with different learning mechanisms. Though the methods themselves are interesting, the results fail to achieve high accuracy.

M.W. Koch et al. used infra-red video sequences and a multinomial pattern matching algorithm of K.M. Simanson to match the signature to a database of learned signatures to do classification. They started with a single-look approach where they extract a signature consisting of a histogram of gradient orientations from a set of regions covering the moving object. They also implemented a multi-look fusion approach for improving the performance of a single-look system. They used the sequential probability ratio test to combine the match scores of multiple signatures from a single tracked object [133, 194]. C. Huang et al. used hierarchical coarse classification and fine classification. The accuracy of the system was impressive, but they only used lateral views of the vehicles for testing [60]. P. Ji et al. used a partial gabor filter approach [114]. Their results are very good, but they also limited their testing to lateral views. In A. Santhanam and Rahman introduced a new matching algorithm based on eigen dimension for classifying car and non-car [183]. X. Ma et al. developed a vehicle classification approach using modified SIFT descriptors [143]. R. Wijnhoven et al. introduced a new metric to classify cars and non-cars [226]. Brendan Morris et al. evaluated different classification schemes using both vehicle images and measurements [54]. Then, they used the most accurate of these learned classifiers and integrated it into tracking software. J. Hsieh et al. introduced a new classification algorithm based on features as simple as size and a new feature linearity to classify vehicles [132]. They have produced impressive results, but the question of retrieving the linearity feature in frontal view remained unanswered.
S. Gupte et al. perform vehicle tracking at two levels: the region level and the vehicle level, and they formulate the association problem between regions in consecutive frames as the problem of finding a maximally weighted graph [50]. These algorithms have difficulty handling shadows, occlusions, and large vehicles (e.g., trucks, and trailers), all of which cause multiple vehicles to appear as a single region. D. Magee and D. Daily proposed variations in it [146, 32].

A closely related approach to blob tracking is based on tracking active contours representing the boundary of an object. J. Malik and Russell intimated active contour-based tracking algorithms represent the outline of moving objects as contours, which are updated dynamically in successive frames [144]. Vehicle tracking using active contour models has been reported by D. Koller et al. in which the contour is initialized using a background difference image and tracked using intensity and motion boundaries [129]. Tracking is achieved using two Kalman filters, one for estimating the affine motion parameters, and the other for estimating the shape of the contour. These algorithms provide efficient descriptions of objects compared to blob tracking. However, these algorithms have drawbacks, such as they do not work well in the presence of occlusion and their tracking precision is limited by a lack of precision in the location of the contour. A further difficulty is that active contour-based algorithms are highly sensitive to the initialization of the tracking, making it difficult to start the tracking automatically.

Model-based tracking algorithms localize and recognize vehicles by matching a projected model to the image data. For visual surveillance in traffic scenes, 3D model-based vehicle-tracking algorithms have been studied widely and 3D wire-frame vehicle models were adopted by Koller et al. [169, 53, 38, 184]. In a single vehicle is successfully tracked through a partial occlusion, but its applicability to congested traffic scenes has not been demonstrated. T.N. Tan et al. proposed a generalized Hough transformation algorithm based on single characteristic line segment matching an estimated vehicle pose [209]. Further, T.N. Tan et al. analyzed the one-dimensional correlation of image gradients and determine the vehicle pose by voting [210]. A.E.C. Pece et al. presented a statistical Newton method for the refinement of the vehicle pose [163]. H. Kolling and Nagel proposed an image-gradient based algorithm in which virtual gradients in an image are produced by spreading the binary Gaussian
distribution around line segments [131]. Under the assumption that the real gradient at each point in the image is the sum of a virtual gradient and the Gaussian white noise, the pose parameters can be estimated using the extended Kalman filter. The main advantages of vehicle-localization and tracking algorithms based on 3D models can be stated as they are robust even under interference between nearby image motions, they naturally acquire the 3D pose of vehicles under the ground plane constraint. However, they also have some disadvantages, such as the requirement for 3D models, high computational cost, etc.

An algorithm for segmenting and tracking vehicles in low angle frontal sequences has been proposed [119]. In their work, the image is divided into pixel blocks, and a spatiotemporal Markov random field (ST-MRF) is used to update an object map using the current and previous image. This method is known to track vehicles reliably in crowded situations that are complicated by occlusion and clutter. One drawback of the algorithm is that it does not yield 3D information about vehicle trajectories in the world coordinate system. The accuracy decreases by a factor of two when the sequence is not processed in reverse, thus making the algorithm unsuitable for on-line processing when time-critical results are required.

Feature-based tracking algorithms perform the recognition and tracking of objects by extracting elements, clustering them into higher level features, and then matching the features between images [28]. These algorithms can adapt successfully and rapidly, allowing real-time processing and tracking of multiple objects. D. Beymer et al. proposed a feature tracking-based approach for traffic monitoring applications [10]. In their approach, point features are tracked throughout the detection zone specified in the image. Grouping is done by constructing a graph over time, with vertices representing sub-feature tracks and edges representing the grouping relationships between tracks. In T.J. Fan et al. used the features in a dependence graph-based algorithm that includes a variety of distances and geometric relations between features [36]. This method can handle occlusion and overlapping. However, it needs time-consuming searching and matching of graphs, so it cannot be used in real-time tracking. The system proposed by N.K. Kanhere et al. automatically 20 detects and tracks feature points throughout the image sequence, estimates the 3D world coordinates of the points on the vehicles, and groups those points together in order to segment and track the individual vehicles [122]. The recognition rate of vehicles using two-dimensional image features is low, because of the non-linear distortion due to perspective projection, and the
image variations due to movement relative to the camera. Also, they generally are unable to recover the 3D pose of vehicles.

Chachich et al. used color signatures in quantized RGB space for tracking vehicles. In this work, vehicle detections are associated with each other by using a hierarchical decision process that includes color information, arrival likelihood and driver behavior [22]. In pattern recognition based approach to on-road vehicle detection has been studied by Z. Sun et al. in addition to tracking vehicles from a stationary camera [205]. The camera is placed inside a vehicle looking straight ahead, and vehicle detection is treated as a pattern classification problem using Gabor features. Classification was done using Support Vector Machines (SVMs).

3.5 Machinery for Highway Construction

Previously the roads were constructed manually and with normal mixing of materials. Nowadays modern machinery is available for the construction of highways such as hot mix plants, wet mix plant, paver finisher, cone crusher and rollers etc.

Hot mix asphalt (HMA) paving materials are a mixture of size-graded, high quality aggregate and liquid asphalt cement, which is heated and mixed in measured quantities to produce HMA. Hot mix asphalt paving materials can be manufactured by: (1) batch mix plants, (2) continuous mix (mix outside dryer drum) plants, (3) parallel flow drum mix plants, and (4) counter flow drum mix plants. This order of listing generally reflects the chronological order of development and use within the HMA industry. In 1996, approx. 500 million tons of HMA were produced at 3600 (estimated) active asphalt plants in the United States. Of these 3600 plants, approximately 2300 are batch plants, 1000 are parallel flow drum mix plants, and 300 are counter flow drum mix plants. The total 1996 HMA production from batch and drum mix plants is estimated at about 240 million tons and 260 million tons respectively. About 85 percent of plants being manufactured today are of the counter flow drum mix design, while batch plants and parallel flow drum mix plants account for 10 percent and 5 percent respectively. Continuous mix plants represent a very small fraction of the plants in use (0.5 percent) and, therefore, are not discussed further.
An HMA plant can be constructed as a permanent plant, a skid-mounted (easily relocated) plant, or a portable plant. All plants can have RAP processing capabilities. Virtually all plants being manufactured today have RAP processing capability. Most plants have the capability to use either gaseous fuels (natural gas) or fuel oil. However, based upon Department of Energy and limited State inventory information, between 70 to 90% of HMA is produced using natural gas as the fuel to dry and heat the aggregates.

Raw aggregate normally is stockpiled near the production unit. The bulk aggregate moisture content typically stabilizes between 3 to 5 percent by weight. Processing begins as the aggregate is hauled from the storage piles and is placed in the appropriate hoppers of the cold feed unit. The material from the hoppers is transported into a rotary dryer (typically gas or oil-fired) through conveyer belt. Dryers are equipped with flights designed to shower the aggregate inside the drum to promote drying efficiency. As the hot aggregate leaves the dryer, it drops into a bucket elevator and is transferred to a set of vibrating screens, where it is classified into as many as four different grades (sizes) and is dropped into individual "hot" bins according to size. To control aggregate size distribution in the final batch mix, the operator opens various hot bins over a weigh hopper until the desired mix and weight are obtained. Concurrent with the aggregate being weighed, liquid asphalt is pumped from a heated storage tank to an asphalt bucket, where it is weighed to achieve the desired aggregate-to-asphalt cement ratio in the final mix.

Batch Type Asphalt Mixing Plant as per European standards are being manufactured with capacity ranging from 80 TPH up to 260 TPH. It has fully computerized control panel with PC, PLC, video, printer and power room and bag type air pollution control system with NOMEX bag filters complete with exhauster and chimney.

Wet Mix Macadam Plant produces a quality product and uses the modern technology in its design and functional features. The plant is easy to operate and capable to deliver a high quality mix at high production rate. The plant, while manufactured according to MoRTH specifications, can be operated stationary or moved to required locations since it is quite portable. Wet Mix Plant incorporates highly accurate aggregate and additive feeders and operators can be assured of a wet mix macadam plant meeting and fulfilling client’s all specifications and operational requirements.
It is of single chassis construction. At each bin a radial gate is provided which can be opened in any position to regulate the aggregate flow. Individual belts are provided below the gates to discharge material onto the gathering belt. The technical specifications of WMP are as given in Table No. 3.1:

**Table No. 3.1**  
*Technical Specifications of Wet Mix Plant*

<table>
<thead>
<tr>
<th>Model</th>
<th>WMM-60</th>
<th>WMM-100</th>
<th>WMM-160</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output (TPH)</td>
<td>60</td>
<td>100</td>
<td>160</td>
</tr>
<tr>
<td>Cold Feed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gathering Conveyor (mm)</td>
<td>600</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>Belt Feeder Width (mm)</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>No. of Bins</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Bin Capacity (MT)</td>
<td>8</td>
<td>10</td>
<td>12</td>
</tr>
</tbody>
</table>

A paver finisher is a piece of construction equipment used to lay asphalt on roads and other such places. It lays the asphalt flat and providing minor compaction before it is rolled by a roller. The asphalt is added from a dump truck or a material transfer unit into the paver's hopper. The conveyor then carries the asphalt from the hopper to the auger. The auger places a stockpile of material in front of the screed. The screed takes the stockpile of material and spreads it over the width of the road and provides initial compaction. The paver should provide a smooth uniform surface behind the screed. In order to provide a smooth surface, a free floating screen is used. It is towed at the end of a long arm which reduces the base topology effect on the final surface. The height of the screen is controlled by a number of factors including: the attack angle of the screed, weight and vibration of the screed, the material head and the towing force.

To conform to the elevation changes for the final grade of the road, modern pavers use automatic screed control which generally control the screed's angle of attack from information gathered from a grade sensor. Additional controls are used to correct the slope, crown or super elevation of the finished pavement. In order to provide a smooth surface, the
paver should proceed at a constant speed and have a consistent stockpile of material in front of the screed. Increase in material stockpile or paver speed will cause the screed to rise resulting in more asphalt being placed therefore a thicker mat of asphalt and an uneven final surface. Alternatively a decrease in material or a drop in speed will cause the screed to fall and the mat to be thinner.

Cone crushing equipment is designed to achieve maximum productivity and high reduction ratio. From large primary jaw crusher and impact crusher to cone crusher can produce the aggregates as per requirements.

The effectiveness of a roller depends to a large extent on its weight, so self-powered vehicles replaced horse-drawn rollers from the mid-19th century. The first such vehicles were steam rollers. The double cylinder or compound steam rollers became popular from around 1910 onwards and were used mainly for the rolling of hot-laid surfaces due to their smoother running engine; however both cylinder types are capable of rolling the finished surface. Steam rollers were often dedicated to a task by their gearing as the slower engines were for base compaction whereas the higher geared models were often referred to as 'chip chasers' which followed behind the hot tar and chipping laying machines. Some road companies in the United States used steam rollers through the 1950s, and in the UK, some remained in commercial service until the early 1970s.

As internal combustion engine technology improved during the 20th century and diesel-powered rollers gradually replaced their steam-powered counterparts. The first internal-combustion powered road rollers were very similar to the steam rollers they replaced. They used similar mechanisms to transmit power from the engine to the wheels, typically large, exposed spur gears. Some users did not like them in their infancy, as the engines of the era were typically difficult to start, particularly the kerosene-powered ones. Virtually all road rollers in commercial use now use diesel power.

Road rollers use the weight of the vehicle to compress the surface being rolled (static) or use mechanical advantage (vibrating). Initial compaction of the sub strata on a road project is done using a pad foot drum roller, which achieves higher compaction density due to the pads having less surface area. The single smooth drum compactor compacts the high spots down until the soil is smooth, and this is usually done in combination with a motor grader to get a
level surface. Sometimes at this stage a pneumatic tyre roller would be used. These rollers feature two rows (front and back) of pneumatic tyres that overlap, and the flexibility of the tyres provides a kneading action that seals the surface and with some vertical movement of the wheels, enables the roller to operate effectively on uneven ground. Once the soil base is flat the pad drum compactor is no longer used on the road surface. The next course (road base) would be compacted using a smooth single drum, smooth tandem roller or pneumatic tyre roller in combination with a grader, and a water truck to achieve the desired flat surface with the right moisture content for optimum compaction. The final wear course of asphalt concrete is laid using a paver and compacted using a tandem smooth drum roller, a three-point roller or a pneumatic tyre roller. Three point rollers on asphalt were very common once and are still used, but tandem vibrating rollers are the usual choice now, with the pneumatic tyre rollers kneading action being the last roller to seal off the surface.

3.6 Motivation

During the literature review it has been found that not much research has been carried out on the e-quality control system in the flexible pavements and it has been carried out by normal procedure of physical testing [170]. However, all the instruments used to control the quality are available in the market. The research has already been carried out for the development of such electronic instrument for the purpose of some different usages. Presently, appropriate quality control measures are being exercised on all the materials used by adopting all the procedures prescribed in the codes and works are executed accordingly. It would be worthwhile to mention here that sufficient amount of information is available on statistical methods but as far as known, almost little text reference is available on e-quality control system.

In the present scenario when speed of highway construction has increased manifold and the materials used in the construction are generally very large in quantities, it is very difficult to ensure the quality and quantity of the work. Further, the quantum of testing required during construction is very large which is very difficult to achieve in pace with the high speed of construction. It becomes further difficult when the contractor fails to engage requisite staff for the quality control tests or if engaged they don’t take interest in the quality control tests. Sometimes most of the tests are not conducted at the site and only bogus entries are made in the prescribed registers. The situation further worsens when the Govt. official staff deployed
to monitor the said work also mixes up with the contractual agency and ultimately sub-standard work is executed and the authority accepts it also. It often poses problem to field Engineers to control the quality in the construction of highways.

Except on large size projects, the bituminous work is being carried out with normal pavers after mixing with normal plants in maximum rural or small city roads. Sometimes, the premix carpet is also being carried out with manual labour. For the tack coat, the bitumen is sometimes heated at the site in the drums. So, in this way there is a lot of wastage of bitumen during the execution of the work. Keeping in view these factors, the tolerance limits in the specifications for the bituminous work were kept as ± 0.3%. Now-a-days, when the modern machinery is used for the construction of highways which is electronically controlled, these limits are very much on the higher side and are being misused.

The second major reason for poor quality is that as per specifications, the minimum density to be achieved is 98% of the laboratory density, but by achieving lesser density the material can be saved by the contactor. The test for checking the density at the site is time consuming and very difficult to conduct in pace with the high speed of construction.

Whenever the test is conducted to check the quantity of the bitumen content in the bituminous material, some fine particles of the aggregates also pass through the litmus paper during the process of testing which are also counted towards the weight of the bitumen. Thus the testing procedure is such that it always gives the bitumen content in a positive side than the one actually used. This drawback in the procedure of conducting a test is also being misused by some of the contractors by using further less quantity of bitumen in addition to the less use of bitumen as per the tolerance limits given in the specifications.

With the achievement of lesser density and less bitumen in the construction of roads, it has been observed that most of such roads get damaged in the first rainy season only and a lot of money is wasted for the repair and maintenance of the roads. It is a major concern and this malpractice needs to be curbed by scientific means.

Thus, due attention is required at the time of construction of a highway so as to have the check at the initial stage. It is felt that with the combination of use of different electronic devices with other instruments, a system needs to be developed for an efficient quality
control system which can ensure the quality and quantity of the product and can assure that work is being executed strictly as per specifications.