

ASSESSMENT EQUIPMENT PRODUCTIVITY FOR HIGHWAY PROJECT

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Abstract: Equipments are main assets of a company in today's scenario with increase in infrastructure heavy demand with increase in complexity of construction, plant and equipment has become integral part of every project. In big infrastructure projects like Highway construction projects, equipment's and the plants play a vital role in the construction process. Plant and equipment contribute great deal towards speed, quality, safety and efficiency of a project. With growing use of machinery in construction it has become necessary for Engineers to thoroughly familiar with the working application and upkeep of the wide range of the modern equipment. So, we have to adopt latest technology, modern equipment & modern management techniques to achieve economy, quality and quick results. The largest single controllable expenditure in a project is factors affecting productivity, performance of equipment, management of equipment. Optimizing the return on productivity is now a key strategy for most process projects or plants and equipments being used by construction industry. The aim of this paper is to highlight the productivity assessment of construction equipment's used for highway project based on the factors and is also aimed to identifying the best practices of improving the productivity of equipment for the Indian scenario.

Index Terms - Construction Equipment, Equipment Management, Productivity, Assessment tools.

I. INTRODUCTION

Good project management in construction must strongly pursue the efficient utilization of labour, material and equipment. The use of new equipment and innovative methods has made possible extensive changes in construction technologies in recent periods. The selection of the appropriate type and size of construction equipment often affects the required amount of time and effort and thus the job-site productivity of a project. Construction is a corporate sector that relies primarily on high utilization of construction equipments. Equipment is thus one of the important factors for improving capabilities in performing work more effectively and efficiently. By improving the effectiveness of utilizing equipment, extensive volume of work can be completed within a shorter period of time and, more importantly, within the project schedule. To purpose any project in smooth way it is essential that an engineer should have a detailed knowledge about the equipment available and to direct it on a particular task. The overall growth of the project depends upon how fast the work is carried out. Hence it becomes a necessity to select the equipment by considering all aspects of working on conditions of site. So it is necessary to make the proper planning & management of equipment's available to use it in an effective manner at minimum possible cost and with maximum output productivity.

Equipment engineer (manager) should coordinate with various wings of the organization in discharging his job of equipment planning, balancing, selection of equipment, its deployment and its utilization, personnel selection and training, financial planning, preventive maintenance and general supervision. Thus equipment management and productivity of equipments are integrates and continuously interacts with human, technical, financial and production system in order to achieve top efficiency and cost effectiveness. The role of construction equipment in highway project is continues to grow steadily. Proper emphasis should be on reduce down-time, achieve optimum equipment utilization and increase production at minimum cost. Realization has to be developed and infused into the minds of the users of equipment. Science of cost analysis and the art of adopting proper techniques suited to the situation are basic factors affecting on productivity of equipment to be borne in mind. It is recognized that maximization of the success factors and minimization of failure factors will ensure the construction of highway project understands its well-organized goals. Understanding these aspects, the present study is undertaken to study factors affecting productivity of equipments for highway project.

1.1. Significance of Study:

The productivity assessment of equipment needs experience. The equipment ability to perform an assigned task under a given situation can best be determined from the on-site actual trials or it can be accessed from its past performance records of operation under similar site conditions. The main factors which affect the performance of equipment / plant and for which allowance must be made when estimating output are of two types,

1. Factors affecting hourly output
2. Factors affecting overall output

Equipment management aims at identifying construction equipment for executing project tasks, assessing equipment performance capability, factors affecting productivity, forecasting date-wise requirement of number and type of equipment and finally participating in the selection of equipment to be acquired. To derive full benefits from the equipment, there should be proper selection and good planning and management of its operations.

1.2. Objective of Study:

The objective of this paper is to act as a foundation for future studies and its results will become valuable information in efforts to assess the productivity of equipment for highway project.

1. To study the proper planning & selection of the equipment for construction of a highway project.
2. To identify the factors affecting productivity of construction equipment.
3. To outline the productivity assessment practices for construction of a highway project.

1.3. Highway Construction Equipments:

Construction Equipment is not only the subject of mechanical engineers but also Civil engineers need to be acquainted with the subject. Civil engineers always see at the rate of production. He needs production at minimum cost so that he can control the rates of contractors. Every task or highway layer requires different equipments compared to other task or layers of the highway. Now a Day, the highway work has become an equipment driven job rather than labour driven job. Below are the equipment's required listed according to the job;

1.3.1 Excavation: Excavation work includes shifting the earthwork from one place to other place; it can be done by digging, cutting of earth by teeth of equipment's etc. The extensively used equipment's are listed below;

- i. Bulldozers are utilized to cut, haul and clear the soil or earthwork from one place to other. It can be used only for short distances.
- ii. Scraper is utilized to excavate, shift, and deliver the soil, boulder and earth.
- iii. Power shovel is a basic earthmoving machine which can be used for different works with different types of front & back attachments. A basic shovel has the means of propulsion of the machine, of revolving the superstructure around and of operating the head attached to it.
- iv. Hoe is utilized for excavation of harder materials. It can excavate below the surface of the chain base.

1.3.2 Compaction: Compaction of the pavement is the most important criteria in deciding the quality of a road. Efficient and rigorous compaction ensures greater working life of the road. Some of the compaction equipment's are listed below.

- i. **Smooth wheeled roller** {static, vibratory} is used for compaction of highway layers. Smooth wheeled rollers are used for vast range of soils, namely granular soils, black cotton soil etc. Sometimes, they're also used in laying asphalt in highway construction.
- ii. **Pneumatic rollers** are used when less granular soil is present as it provides kneading action. These kinds of rollers are best used on soft materials and loosely compacted soils.
- iii. **Tamping Roller** also called Sheep foot rollers normally used in projects that have to work with heavy soils such as clay. This is because the overall surface area of the drum that's in contact with the soil at any one point in time is projected to be around 8 to 12%.
- iv. **Rammers** are utilized for compacting small areas.

1.3.3 Batching and Mixing Plant: For the long life of the highway pavement it is important that the Mix i.e. batch mixing is of best quality. A hot mix plant & concrete batching plant of best working and design is required to accomplish above requirement for the production of bitumen & concrete of good quality. These plants can be fully automatic or semi-automatic.

1.3.4 Bitumen Paver: For superior finish, Paver of efficient design is needed. An asphalt paver (paver finisher, asphalt finisher, paving machine) is a piece of construction equipment used to distribute, shape, and partially compact a layer of asphalt on the surface of a roadway, bridges, parking lot, or other area. It is sometimes called an asphalt-paving machine. It lays the asphalt flat and provides minor compaction before it is compacted by a roller. As it is going to lay a wearing course which comes in direct contact with the users of the road. It lays the mix as per the set thickness and is operator driven at speed of 1 to 10 meter per minute.

1.3.5 Hauling of Materials: It involves moving of the materials form one place to other place. It supports the excavator, hoe, hot mix plant, concrete batching plat etc. to perform effectively & efficiently. It is important to use tippers or dumpers, transit mixer & bitumen sprayer of best quality for best results and efficiency.

1.4 Productivity in Highway Construction:

Productivity means the ability to produce. The term 'productivity', as commonly understood, implies the ratio of output to input. The input and output can be measured in physical quantities, economic terms or a combination of both. Productivity is also defined as monetary value of output per man-hour of input. Some consider productivity as performance output in rupees for every rupees of input. In the narrower sense of controlling project resources, the productivity concept is used to measure the performance of resources. Once the equipment needs for an activity have been identified, the next step is to conduct an equipment productivity analysis to select the optimum size. The objective is to determine the number of units and the size of equipment that would permit the constructor to accomplish the activity with a duration resulting in the lowest cost. Because most civil engineering construction projects are awarded based on lowest cost, it is of utmost importance to the constructor to select the proper equipment spread providing the lowest construction cost for the project. The project is segmented into various activities; therefore, the lowest cost must be determined for each activity.

II. LITERATURE REVIEW

This chapter researched and sourced literature ranging from academic books and journals that address the factors affecting assessment of productivity of highway construction; therefore it is better to conduct detail study on equipment planning, selection, management difficulties to mitigate the causes and effects of difficulties.

Productivity is a complex phenomenon at all levels be it individual, organized private sector or government the world over and in all spheres of human endeavor particularly in construction project delivery. Low productivity in the construction industry is a result of diverse identifiable reasons such as; high reduction in skill level of construction workers, shift work, shortages of materials and equipment, change orders, labour shortages, weathers, low level of monitoring and control of projects etc. key factors that leads to productivity improvement in construction project delivery were analyzed. These comprise of project planning, productivity measurement, avoidance of construction site congestion, motivation of workforce and good communication among others (David Ngwoke 2019).

Construction equipments usually constitute a major portion 10-35% of the total cost in a building construction project. For having the best result in profit for a construction industry choosing the best alternative for obtaining equipment is one of the most important issues. The identification of the factors that effect on equipment selection has been carried out using different literatures and by interviewing from experts in construction (Siddharth J. Jariwala 2015).

Productivity has often been cited as a key factor in industrial performance, and actions to increase it are said to improve profitability and the wage earning capacity of employees. Improving productivity is seen as a key issue for survival and success in

the long term. This project focuses on examining key factors of productivity enhancement, and investigating the causal relationships among those key factors to better understand and plan for productivity improvement. The results prove five key productivity factors including leadership, strategic quality planning, people, data and information and process management leading to a conceptual model (D. O. Fakorede 2014).

The past decade has witnessed the continuation of the same relentless research interest in productivity studies. The findings revealed that, in the studies: five types of productivity have been examined; five data collection methods have been deployed; research objects can be classified under seven categories. The research objects in a high number of studies are devoted to 'measurement of productivity' and 'examining the casual relationships with productivity' (A. R. Dolage 2013).

Construction equipment planning and selection plays crucial role for the success of construction firms. Inadequate manual processes of equipment planning and selection and the subjective decisions of equipment managers usually result in major losses in construction firms. An indispensable item of resources, it produces output at accelerated speed, enables completion of task in limited time. Equipment saves manpower, which is becoming costly and more demanding day by day. Equipment improves quality, productivity and safety. Construction equipment planning aims at identifying construction equipment for executing project tasks, assessing equipment performance capability, forecasting date wise requirement of number and type of equipment and finally participating in the selection of equipment to be acquired. To derive full benefits from the equipment, there should be proper selection and good planning of its operations (Mr. Nilesh D. Chinchore 2014).

As per the literature reviews & studied by authors in the various papers, productivity assessment for highway project is depends on various factors affecting on planning, selection & management of equipment.

III. RESEARCH METHODOLOGY

The main objective of this paper is to study & assessment of productivity of equipments for a highway project; finding out the factors affecting the productivity of the equipments; establishing interrelations of the factors and finally formulation of a system to estimate the productivity of the equipments in different environmental and site conditions For this study data collected through a field survey & explorative questionnaire to the respondents involved in monthly activities of construction of highway in the region of Jalgaon - Bhusawal cities of Maharashtra region of India. The questionnaire is designed so that respondents can give the rank to their answers based on the Likert scale. The study & analysis of these data was done by a method named relative importance index (RII) method using Microsoft Excel.

IV. FACTORS AFFECTING THE PRODUCTIVITY OF EQUIPMENTS

From the different literature studies the following factors which affect the equipment productivity are detailed as below:

4.1 Job Factors: Job factors refer to those factors, which affect the specific job because of the particularities of that job's physical conditions but not because of the result of some general conditions.

Some of the job factors that affect the productivity of equipment's in case of highway projects are;

- i. The material characteristics like shrinkage, swelling, plasticity, moisture content of the material etc.
- ii. Rolling resistance and condition of the haul roads, which affect the hauling time of the materials.
- iii. Gradients that can be favorable or unfavorable for loading and travel.
- iv. Tractive efficiency, which will determine how much traction can be applied before slippage will occur.
- v. Reduction of horsepower of engine due to altitude.

4.2 Number and Sizes of Units:

For deciding the number and size of the equipments following factors should be considered;

- a. Quantum of work
- b. Working days available for completion of the project.
- c. Number of shifts planned.

When quantum of work is too much then bigger size equipment are selected. The average rated output of these equipment will help in deciding number of the equipment required keeping in view the number of working days available and number of shifts planning per day.

4.3 Arrangement of Skilled Staff for Operation and Maintenance:

To get optimum output from any equipment, it is essential to handle the equipment by a skilled staff. The skilled staff includes the operator, the mechanic etc. The working hours of any equipment depends upon the maintenance period & the rest period of the engine. If the equipment is working in shifts i.e. first, second, third, the operator shall be separate for each shift. The maintenance staff shall be available round the clock at the construction site with all necessary parts of the equipments, lubricants etc. this will reduce the wastage of time after the breakdown of the machine.

The lubricants shall be change time to time as per the norms given in the manual of the company. This reduces the friction between the parts of the equipment this increases the output of the equipment as it is easy to operate the equipment.

4.4 Management Factors:

Management factors refer those factors, which arise due to arrangement and allocation of plants and equipment's at sites and for managing the same in an effective and efficient manner. The management factors may quantitatively vary from 60% for an average job to 75%-80% for a well-managed job. With respect to a highway project, the key management factors could be Operator efficiency depending on the training and experience of the operator. Proper matching of sizes, numbers, capacity etc. of the equipment's mobilized so that the most important production equipment is not kept waiting or idle. Time required for on-the-job servicing and maintenance. Unavoidable delays in combined operation of all equipment's i.e. delays due to lack of synchronization. Availabilities of well-equipped workshops, maintenance facilities, spare parts, stocks etc. Management-worker relationship. If a manufacturer specifies production of his equipment's as P m³/hr. under ideal condition, then,

Actual Production = P x job factor x management factor.

4.5 Technological & Environmental factors:

- a. Rework
- b. Compatibility and steady among contract records
- c. Condition of haul road
- d. Excess travel/ lifting
- e. Obstacle on site
- f. Temperature and humidity effects
- g. Rain, snow, wind effects and sandstorm

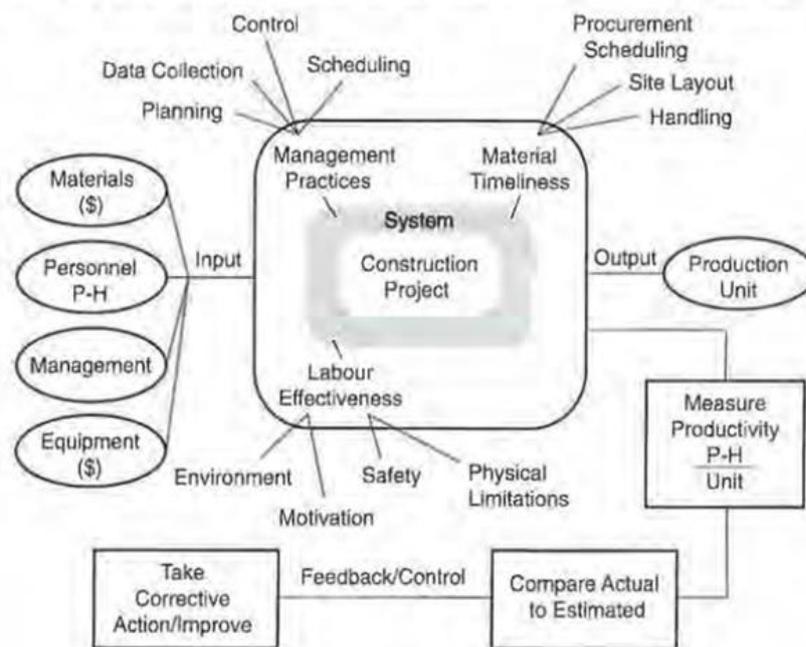


Fig. 1 Framework for Productivity Improvement

V. PLANNING AND SELECTION OF EQUIPMENTS

Modern construction projects are complex in nature and success of a project depends greatly on accurate and systematic planning. The construction activity requires different types of equipments to increase the output at construction site. Before starting every project its planning is done with great care, as the efficiency of the whole project largely depends upon its planning therefore selection of the right equipment is very important. This depends on the type of work, soil condition, magnitude of work, availability of skilled worker etc. Maintenance of equipment plays a very crucial role in the performance of the equipment.

5.1 Planning of Equipment:

Each piece of construction equipment is specially designed by the manufacturer to perform certain mechanical operation. The task of the project planner/estimator or the Engineer on the job is to match the right machine or combination of machine to job at hand. Considering individual tasks, the quality of performance is measured by matching the equipment spreads production against its cost. Production is work done; it can be the volume or weight of the material moved the number of pieces of the material cut the distance travelled, or any similar measurement of progress.

To estimate the equipment component of project cost it is necessary to first determine machine productivity. Productivity is governed by Engineering fundamentals and management ability. Each level of productivity has a corresponding cost related with the effort expended. The expenses that a firm experiences through machine ownership and use and the method of analysing such a cost.

5.2 Selection of Equipment:

Proper selection of equipment for a highway construction project is of importance role for its speedy and economical completion. Selection of equipment has become more complicated and difficult, because large variety of equipments is being manufactured now-a-days. For selection of equipment, a considerable experience in the operation, safety and maintenance in the field is essential. Records kept for operation, provision of PPE for safety, maintenance and actual output obtained under equivalent conditions of previous projects will greatly help in taking decision for equipment selection. While getting the new projects and the retirement of old machinery and equipment, it becomes essential to acquire new construction equipment. In this stage, adequate knowledge base of current brands and products is necessary. It is also important to determine what kind of equipment and capacity is needed.

5.3. Construction Equipment's Under Analysis:

5.3.1 Hydraulic Excavator: Hydraulic Excavator is a basic earthmoving equipment which can be used for different works with different types of front & back attachments. An excavator can be defined as a power driven digging machine. In 1836, William S. Otis developed a machine that duplicated the motion of a worker digging with a hand shovel. The backhoe loader was invented in the UK in 1953 by Joseph Cyril Bamford, founder of JCB, by equipping a farm tractor with both a backhoe and a front-mounted loading bucket. From this machine, evolved a family of cable operated construction machines known as crane shovels. Components of this machine includes the boom, the stick, the bucket, shovel, dragline, hoes and clamshell.. Kerosene, ethanol and gasoline engines were used, but today diesel engines are dominant. Later, with the advent of technology, the cable-operated equipments have mostly been replaced by their hydraulic (hydraulically powered) counterparts. In industry, today, the hydraulic excavators are used as the most versatile equipment in the jobs of excavating and lifting. In the construction of highways, hydraulic excavator is the most widely used equipment at site.

i. Factors Affecting Excavator Production Rate;

The actual production of an excavator is affected mainly by the following factors,

- a. Class of material
- b. Moisture content of materials handled

- c. Bucket capacity
- e. Height / Depth of cut
- g. Operator's skill
- d. Horse power of the engine
- f. Angle of swing
- h. Age of excavator

Apart from the equipment parameters and job conditions there are some more factors which indirectly affect the output as,

- a. Condition of the excavator
- c. Type of disposal
- e. Haul-unit sizing and number
- b. Make of equipment
- d. Haul-unit exchange time
- f. Incentive scheme

ii. Production Estimation: The basic production formula for an excavator is,

$$\text{Excavator production} = \frac{(Q \times F \times (AS:D)) \times E}{t} \times \frac{1}{60} \times \text{Volume correction} \quad (3.1)$$

Where, Q = Heaped bucket capacity in m³
 AS: D = Angle of swing and depth / height of cut correction,
 E = efficiency (in minutes per hour)
 F = Bucket fill factor for shovel buckets
 t = Cycle time in seconds.

5.3.2 Concrete Batching Plant: Concrete Batching Plant first make known to by Architect Jurgen Heinrich Magens, he get his patented of RMC in Germany in 1903. The first concrete mixed off site and delivered to a construction site was effectively done in Baltimore, United States in 1913 just before the First World War. The first concept of transit mixer was also born in 1926 in the United States. In India RMC was first initially was used in 1950 during the construction sites of Dams like Bhakra-Nangal, Koyna. A concrete batching plant is installed to mix concrete for a large structure such as a dam or for sale to the public. Such a plant includes equipment for handling and storing aggregate and cement batches and concrete mixer. The mixed concrete is discharged into buckets, agitators or dump trucks. A transit mix plant is one where the aggregate, cement and usually water are batched and then discharged into the transit truck/miller for mixing on route to the job site.

i. Factors Affecting Batching Plant Production Rate;

The actual production of a concrete batching plant is affected mainly by the following factors,

- a. Mixer type
- c. Age of plant
- e. Type of control of batching plant
- g. Type and size of aggregate used
- i. Mix design and workability of concrete
- k. Additives used
- b. Mixer capacity
- d. connected power
- f. Skill of operator
- h. make of Batching plant
- j. Storage & handling of material; bin, star type or belt conveyer

ii. Production Estimation: Ready mix concrete that is concrete that is manufactured in a factory or batching plant, according to a set procedure, and then delivered to a work site by truck mounted in- transit mixers. The basic production formula for RMC Plant is;

$$\text{Production (cum / hr)} = (N \times C \times T) / t \quad (3.2)$$

Where,

- N = No. of Transit units,
- C = Capacity of Transit unit m³,
- T = No. of Trips per Transit units
- t = Effective Production Hours

$$\text{Output efficiency} = \frac{\text{Average output per hour} \times 100}{\text{Ideal Production Plant Capacity}}$$

5.3.3 Bitumen Paver: An asphalt paver (paver finisher, asphalt finisher, paving machine) is a piece of construction equipment used to distribute, shape, and partially compact a layer of asphalt on the surface of a roadway, bridges, parking lot, or other area. It is sometimes called an asphalt-paving machine. It laid the asphalt flat and provides minor compaction before it is compacted by a roller. Some pavers are towed by the dump truck delivering the bitumen, but most are self-propelled. Self-propelled pavers consist of two major components: the tractor and the screed. The tractor provides the forward motion and distributes the asphalt. The tractor includes the engine, trolley, hydraulic drives and controls, drive wheels or tracks, receiving hopper, feeder conveyors, and distribution augers. The screed levels & shapes the layer of asphalt. The screed is towed by the tractor and includes the levelling arms, mouldboard, end plates, burners, vibrators, and slope sensors and controls.

i. Factors Affecting Bitumen Paver Production Rate;

Depth of settlement makes a several factors;

Mix Parameters:

- a) Temperature (hotter mixes deform easier)
- b) Grain size (finer mix deform easier)
- c) Gradation curve (well graded mixes deform easier)
- d) Stiffness (stiff mixes deform easier)

Paving Parameter:

- a) Layer thickness (thicker the mat, the deeper the dent)
- b) Paving width (the more extension, the deeper the dent)
- c) Ambient temperature (hotter the day, deeper the dent)
- d) Head of material (lower the head of material, deeper the dent)
- e) Length of stop (longer the stop, deeper the dent)

Paver parameter:

- a) Paving speed (higher the speed, greater the settlement)
- b) Tamper the amplitude (higher the amplitude, lower the settlement)
- c) Tamper speed (higher the speed, lower the settlement)
- d) Screed set up (higher the angle of attack, greater the settlement)

ii. Production Estimation: The higher the paving speed, the greater the thickness and more the width, the greater will be the quantity of material passing through the paver during a given time, and vice versa. The following formulas will enable quick calculations to be made of the production required per hour for a given width and thickness of mat.

$$\text{Production (cum / hr)} = (L \times W \times T \times S) \quad (3.3)$$

Where,

L = Length of Road in m,

W = Width of Road in m,

T = Thickness of Asphalt in mm

S = Working Speed in m/hours

5.3.4 Hot Mix Plant: Hot Mix Asphalt (HMA) paving material is a scientifically proportioned mixture of graded aggregates and asphalt cement. The aggregates; which includes stone, sand, and mineral dust, and can include Reclaimed Asphalt Pavement (RAP); make up about 92% to 96% of the total mixture by weight. In addition to use of paving materials for roadways, parking lots, race tracks, etc., HMA can also serve as liners for reservoirs, landfills, and for other containment purposes. It is a unique paving material in that when it is removed from the roadway, parking lot, etc., it can be recycled back into new HMA paving materials, providing a pavement as good as one produced from all virgin materials.

i. Factors Affecting Hot Mix Plant Production Rate;

- Presence of Moisture Content in Aggregates: The existence of moisture content in aggregates plays a important role in preparation, production of hot mix and fuel consumption of hot mix plant. If moisture content is very high say 8-10 percent, the aggregates shall not fall out in a uniform veil, thus there shall not be uniform and adequate heating of aggregates. Thus, increase in moisture content get results in drop of production and increase in fuel consumption also.
- Dust Content in Mix: With increase in dust content in mix, output falls because there is more surface area to be coated by bitumen which requires greater mixing time.
- Altitude: The output of plant is derated approximately @ 3.5 percent every 300 m rise in elevation above sea level. The requirement of plant in specific area should be evaluated based on this factor also.
- Insulation of Drum: The output of plant can be increased by 2.5 percent and fuel consumption decreased by 4 percent by maintaining temperature difference between outer and inner shell of drum approximately 60°C. The drum shell should be shielded with glass wool or aluminium painted to avoid heat losses. Asphalt mixing plant gives maximum production when overall condition are good, quality of aggregate, climatic and weather conditions, state of mixing plant, etc.

ii. Production Estimation: Hot mix asphalt is produced at a central plant and transported to the paving site in trucks. An asphalt plant is a high-tech group of machines capable uniformly blending, heating, and mixing the aggregates and a asphalt cement of asphalt concrete. The production formula for a HMP is;

$$\text{Production (cum / hr)} = (N \times C \times T) / t \quad (3.4)$$

Where,

N = No. of trucks,

T = No. of Trips per trucks units

C = Capacity of trucks unit m³

t = Effective Production Hours

$$\text{Output efficiency} = \frac{\text{Average output per hour} \times 100}{\text{Ideal Production Plant Capacity}}$$

5.5.5 Road Roller: A road roller is engineering type compactor vehicle, which is used to compact soil, gravel, landfills, agriculture, concrete, or asphalt in the construction of roads and foundations. The rolling procedure ensures that foundations are compacted thoroughly so the materials are compact, and do not come loose. Rollers are equipped with basic structures such as diesel engine, canopy to protect the driver, drum(s), which can be a vibratory smooth drum or a static smooth drum, tires, water system and a major role of compaction meter to measure the level of compaction.

i. Factors Affecting Roller Production Rate;

- ✓ Type of soil: Type of soil has a great influence on its compaction Characteristics normally, heavy clays, clays & silts offer higher resistance to compaction whereas sandy soils and coarse grained are amenable for easy compaction. The coarse grained soils yield higher densities in comparison to clays. A well graded soil may be compacted to higher density.
- ✓ Compactive Effort / Compactive Energy: It means type of equipment or Machinery used for compaction. Greater the compactive effort, greater will be the compaction. The equipments used for compaction of soil can be broadly classified into the following categories
 - Kneading type equipment
 - Static type equipment
 - Dynamic or impact type equipment
 - Vibratory type equipment
- ✓ Layer Thickness / Thickness of Lift : Degree of compaction is inversely proportional to the layer thickness, i.e. for a given compactive energy, thicker layer will be less compacted as compared to thin layer. The reason is, for thicker soil layer the energy input per unit weight is less. Therefore it is very important to decide the right thickness of each layer to achieve the desired density. Thickness of layer is reliant on several other factors such as;
 - Type of soil
 - Type of roller
 - Weight of roller
 - Contact pressure of drum
- ✓ Number of Roller Passes: It is obvious that density increases as the no of roller passes increases. But there are two important things we have to remember.
 - After certain number of roller passes, there is no further increase in density.
 - More number of roller passes means more cost of project.

- ✓ Moisture Content: Proper control of moisture content in soil is necessary for achieving desired density. Maximum density with minimum compacting effort can be achieved by compaction of soil near its optimum moisture content.
- ✓ Contact Pressure: Contact pressure depends on the weight of the roller wheel and the contact area. In case of pneumatic roller, the tyre inflation pressure also regulates the contact pressure in addition to wheel load. A higher contact pressure increases the dry density and lowers the optimum moisture content.
- ✓ Speed of Rolling: Speed of rolling has a very important bearing on the roller output. There are two important things we have to consider.
 - a. First, the greater the speed of rolling, the more length of embankment can be compacted in one day.
 - b. Second, at greater speed there is likely to be insufficient time for the desired deformations to take place and more passes may be required to achieve the required compaction.

ii. Production Estimation: The compaction equipment used on a project must have a production capability matched to that of the excavation, hauling and spreading equipment. Usually, excavation or hauling ability will set the expected maximum production for the job. The conventional way of measuring the production of the vibratory roller is based on the roller speed, lift thickness and effective width of compaction. The accuracy of the result obtained would depend on the accuracy of speed and lift thickness. Trial operation is advised to determine the production of a particular type of soil (or metal). The production formula for a compactor is;

$$\text{Production (cum / hr)} = (W \times S \times L \times E) / P \quad (3.5)$$

Where,

- P = Number of roller passes required to achieve the required density,
 W = Width compacted per roller pass (m.), S = Roller speed (kmph),
 L = Compacted lift thickness (mm), E = Job efficiency

VI. CONCLUSION

This research paper provides study and knowledge of construction productivity assessment and focus on factors affecting equipment productivity in highway construction projects and it is concluding that;

1. Proper planning & selection of equipment is very important for timely completion of project, within plant cost and for increasing profit, margin.
2. Incorrect equipment selection may directly affect to its productivity for that particular work.
3. Selection and planning needs to work out very seriously as it is one of the most important factors that affect the progress of work.
4. A databank of Equipment's Productivity for every site must be maintained and studied.
5. Study and use of proper productivity assessment method is of prime importance for successfully completion of project in stipulated time & decided cost.

Thus, it is important role of construction manager to understand and properly utilize such factors for better performance of construction equipments for highway project. Hence, in future, scholarly attention should be drawn to these areas so that new studies can be taken up.

VII. ACKNOWLEDGMENT

I would like to express my gratitude to Dr. P.P. Bhangale who guide me throughout this research work with their support and technical expertise. I would like to express special thanks to my family who has been my friends, who had always support me in all things who had helped me in getting my job done, who had encouraged me to go on when things have gone wrong . I also thankful to a persons who gives me emotional support throughout my study.

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