International Journal of
Science and Engineering Investigations vol. 6, issue 65, June 2017

ISSN: 2251-8843

The Study and Estimation of Accurate Performance of Road Construction Machinery by Construction Management Approach

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Abstract- Analysis of the construction costs is very important to select the proper kind of plan and maintenance by the minimum costs and accurate using of machineries. This analysis is considered as an essential tool for decision making about investment on modern and existed technics. Therefore, perception of the effect of road optimum construction costs is significantly important, and related advantages to regular and periodic repairs are tied to this relationship [1]. Therefore, this research tried to study the effect of repair and maintenance cost and proper usage of these machineries in road construction on road users cost for Iran roads network. In this regard, the effective factors are subordinate of cost of road users for the selected road network. One million Rial increase in the cost of improving the road administration reduces daily performance cost of a vehicle 0.72 Rial per kilometer. The effect of improvement cost on road users' cost is reducing with a reduction rate. In other words, huge investment to reduce users' cost can't be justifiable. Using criterions, regulations, and standards in designing, execution, utilization, and maintenance steps of civil projects are significantly important for technical and economic justification of designs, designing quality, execution (useful life), utilization, and maintenance costs. State executive and technical system has seriously emphasized on applications of technical criterions, standards, and regulations in publications in design preparation and execution, and also necessary attention to maintenance costs of designs.

Keywords- *Load Determination, Soil Operations, Mean Capacity, Road Ramp, Regulations of Application*

I. PROBLEM STATEMENT

Notwithstanding, road is the final product of the collection of dependent related processes including all human activities, the manner of preparing materials, application of all machineries etc., that is under the leadership and supervision of an accurate and organized managerial system, having a specific and plan based on scientific principles and technics, having been formed to obtain macro objectives of development and significant part of state national resources, and credits have been attributed to them. Therefore, accomplishment of purposes such as optimum usage of resources and machineries, achievement of the proper and acceptable quality and performance with the minimum cost and adaptation with the present conditions need application of evaluation systems based on a specific criterions and indexers and all types of executive and technical consideration in each study steps of designing and implementation of all road construction operations; as though, one of the most efficient technics to achieve the mentioned objectives is application of quality control and quality guarantee plans for all types of pavements. The main objective of this research is comparison and evaluation of the technical, executive, and economic aspects of application of various road construction machineries by construction management view [2].

II. RESEARCH BACKGROUND

Chen and Brown believe that using modern road construction machineries as the basis of the road reduces road construction costs while the present resources remained intact. Based on a project report from Kansas City, roller concrete with a compressor truck was taken to the location instead of a drum mixer. The used concrete in this project with density of 85% was arrived to the density of 95-98% and its roller to the density of 98% by a finisher, and the remained water in a mixture is one of the success key in this project [3].

Romanoschi and Metcalf (2014) introduced a qualitative technic to indicate levels between asphalt layers. The obtained curves from this experiment can be defined by 3 parameters: maximum shear stress (shear stress curve vs shear displacement), interlayer reaction modulus (slope of the same curve), and friction coefficient after fracture. They found that all parameters were dependent on temperature after shear stress experiment for various axial loads in various temperatures with or without single jacket. This new model improves the precision of the finite element model as Yoo et al. (2006) showed. It's important role can be an analytical statement including all effective variables in a problem [4].

III. MECHANISM PERFORMANCE OF ROAD CONSTRUCTION MACHINERIES

A tractor with chain wheels was the first motorized machineries that have been used in soil operations. Today, application of tire wheel of a tractor has been still used in construction operations extensively.

An equipped tractor with a blade in front part is known as bulldozer. All various types of blades are usable in tractors. This type of tractor is active in various types of lands for low imposing pressure on land and a proper tensile strength. There are specific models with 3-4 pounds per square inch (equivalent to 0.22 to 0.20 kg/cm2) pressure on land that were effective on loose lands. These machineries are also able of working up to 100% slopes (45%). Trailer was used to carry them to the workshop for their relatively low speed. A tractor is able to act in water in higher than wheels surface level, because chain rollers were lubricated and are protected against water and rust-corruption materials. If no considerations are for rust-proving of machineries, a tractor will be able to act in deeper waters for a short time [5].

IV. TRACTOR WITH TIRE WHEELS

A tractor with tire wheels was made to accelerate in pulling skrippers and carriages and similar actions. This type of machineries is in two and four wheel forms. Two-wheel ones must be with another involved machinery like skripper to protect its equilibrium. The four-wheel was in one differential and two-differential form. This type of machineries has 25-35 pound pressure on square inch (equaling to 1.8-2.5 kg/cm2) and makes rotational force that is not equal to chained tractor. Therefore, using them as a bulldozer is limited by the mentioned factors. In addition to relatively high speed, this type of tractor practically doesn't damage the pavement by movement on asphalt. This can be used in densification land or road surface for imposing high pressure on land [5].

V. ALL TYPES OF BLADES AND MAIN ACCESSORIES

Four blades are more important than all types of the present blades for tractor, and they have more applications. These four blade types include: direct blade, angledoser blade, universal blade, and cushion blade. All types of these blades except cushion blade can rotate around length axis of a vehicle and so centralize tractor power at the end of blade. This rotation around length axis is used particularly in ditching or hard ground procedure breaking times. Direct blades and universal blades make front or back movement of blade possible. This action doesn't increase or reduce vehicle blade penetration in the ground by changing angle. Angledoser blade just can be changed in a way not to be vertical on vehicle movement direction. Direct blade is used more than the other types. When carrying distance of materials is short, type of the blade becomes so effective. This blade has hp/ft from the shear ends and hp/yd3 more loose materials than universal blade. Therefore, this type of blade has the power of drilling and carrying more materials than universal blade. Angledoser can be used for cutting in sides of hills and heights, filling the back of the building and slowing down the hills. Universal blade is able of carrying drilled materials in relatively high distances for having two walls at two ends of blade. This blade mustn't be used to carry very heavy materials or penetrate in the ground. Cushion blade was designed to push the skripper. There are various other types of blades including ripdozer blade, U blade proper for light materials, and blades for specific cleaning operations [10].

VI. DETERMINATION OF THE TRACTOR SPEED

The maximum speed of a truck, bulldozer with a skripper under the certain load and condition depends on the powers of wheels and traction (friction) problem, slope resistance, and rolling resistance. The determination technics of these factors and the maximum speed of machineries will be as following using the offered tables and curves by manufacturing companies of these machineries.

VII. TOTAL RESISTANCE AGAINST VEHICLE MOVEMENT

Total resistance against vehicle movement on a surface includes the collection of roller resistance and slope resistance.

Total resistance= roller resistance+ slope resistance (1)

Roller resistance includes resistance against vehicle movement on a surface resulted from internal friction, vehicle immerging on the movement surface, and tire pressure. Roller resistance is obtained by the following relation:

Roller resistance (hp/ton) = 40+ (30* penetration (inch))

Roller resistance (pound) = roller resistance (pound/ton) * vehicle weight (ton) (2)

The values of roller resistance based on pound/ton are shown in table (1) for various types of ground forms.

TABLE I. TYPE VALUES FOR DIFFERENT ROLLER

Type of pavement	Roller resistance (pound/ton)
Asphalt or concrete	*(30)40
Restrict, smooth, and relatively flexible under load	*(50-55)65
Wet and muggy surface on restrict basis	80
Mashed snow	50
Loose snow	90
Soil road, 1-2 impenetrable inches	100
Loose soil, 3-4 impenetrable inches	150
Loose sand or gravel	200
Soft muggy ground	300-400

As the chained vehicles actually move in their own roads (inside surface of vehicle chain), it is usually assumed that there isn't roller resistance against their movement.

VIII. THE EFFECT OF SLOPE RESISTANCE PARALLEL TO ROAD RAMP

Slope resistance includes vehicle weight element that influences parallel to road ramp. This force acts positively for vehicles ascending a height, and acts negatively for vehicles descending a height. It means it actually helps vehicle to come down [11]. The accurate value of these forces includes multiplication of vehicle weight in sinus of angle between ramp and horizon surface. Nonetheless, sinus and tangent of small angles are relatively similar. For example, for 15° ramp surface, using tangent instead of sinus makes error just about 3%. Slope is usually stated as percentage that is the same as slope angle tangent. For example, 1% slope ascends or descends in length of per 100m. Therefore, the following relations are acceptable for the slopes that we deal with in soil operations.

Slope resistance (Ib) = slope * vehicle weight (pound)

Slope resistance (Ib/ton) = 20* slope (%) (3)

Total resistance can be stated as a percentage of a slope with slope resistance equal to total resistance. This slope percentage is known as equal slope or total resistance percentage. As a slope is one equal percentage of a 20 pound/ton resistance, we will have:

$$\text{Effective slope (\%)} = \frac{\text{total resistacne } (\frac{\text{pound}}{\text{ton}})}{20}$$

$$\text{Effective slope (\%)} = \frac{\text{total resistacne } (\frac{\text{pound}}{\text{ton}})}{20} + \text{slope (\%)} \quad (4)$$

IX. CASE STUDY OF A RESEARCH

A tractor with tire wheel moves on a soft ground with 5 inch tire penetration. A tractor weight is 20 ton, it is desirable to calculate total resistance and effective slope in the following states:

- A tractor is ascending from a 4% slope.
- A tractor is descending from a 6% slope.

Solution:

$$\text{Roller resistance coefficient } = 40 + (30 \times 5) = 1901b \ / \ ton \quad (5)$$

$$\text{Roller resistance } = 190 \times 20 = 3,8001b \quad (6)$$

A)

$$\text{Slope resistance } = 0.04 \times 20 \times 2,000 = 1,6001b \quad (7)$$

$$\text{Total resistance } = 3,800 + 1,600 = 5,4001b \quad (8)$$

$$\text{Effective slope } = \frac{5,400}{20 \times 20} = 13.5\% \quad (9)$$

Or

$$\text{Effective slope } = 4 + \frac{190}{20} = 4 + 9.5 = 13.5\% \quad (10)$$

B)

$$\text{Slope resistance } = -0.06 \times 20 \times 2,000 = -2,4001b \quad (11)$$

$$\text{Total resistance } = 3,800 - 2,400 = 1,4001b \quad (12)$$

$$\text{Effective slope } = -6.0 + \frac{190}{20} = -6.0 + 9.5 = 3.5\% \quad (13)$$

X. THE EXISTING TENSILE FORCE

The diesel engines that are used in construction machinery lose their power by increasing the height of working surface from sea level, because air pressure reduces. Turbocharge engines are prior on ordinary engines based on this case and can keep their power up to 10000 ft height (about 3000 m). When companies' specific tables are not in access, it is enough to reduce the vehicle performance for 3% for per 1000ft height for more than 3000 ft (about 1000m) height.

$$\text{Tensile force reduction factor (\%)} = 3 \times \frac{\text{height} - 3000}{1000} \quad (14)$$

Therefore, tensile force percentage will include 100 minus reduction factor. When a tractor with tire works in a standard mode, the usable value of tensile force is limited to the made friction between tire and chain. The approximated values for friction coefficients for all types of ground surfaces are shown in table (2):

TABLE II. VALUES OF TYPES FOR FRICTION COEFFICIENT

Type of pavement	Tire wheel	Chain wheel
Dry concrete	0.90	0.45
Wet concrete	0.80	0.45
Dry ordinary ground	0.60	0.90
Wet ordinary ground	0.45	0.70
Loose gravel	0.35	0.50
Mine stone (Quarry)	0.65	0.55
Loose dry sand	0.25	0.30
Wet sand	0.40	0.50
Mashed snow	0.20	0.25
Ice	0.10	0.15

XI. CASE STUDY OF TWO STUDIES

A four-wheel tractor with tire with 41000 pound makes maximum pound of 40000 pound tensile force. This vehicle is in 8000 ft height and on a wet ground. Working condition makes 20000 pound tensile force to move a tractor and related load.

Is a tractor able to work or not?

Solution:

$$\text{Power reduction coefficient } = 3 \times (\frac{8,000 - 3,000}{1.000}) = 15\% \quad (15)$$

$$\text{Present force percentage} = 100 - 15 = 85\%$$

$$\text{Present force value } = 40,000 \times 0.85 = 34,0001b$$

Friction coefficient = 0.45 (from table 2)

The Maximum useful tensile strength $= 0.45 \times 41,000 = 18,450lb$ (16)

Present useful tensile force < necessary force

(18,450)< (20,000)

Therefore, a tractor won't be able to work in this condition.

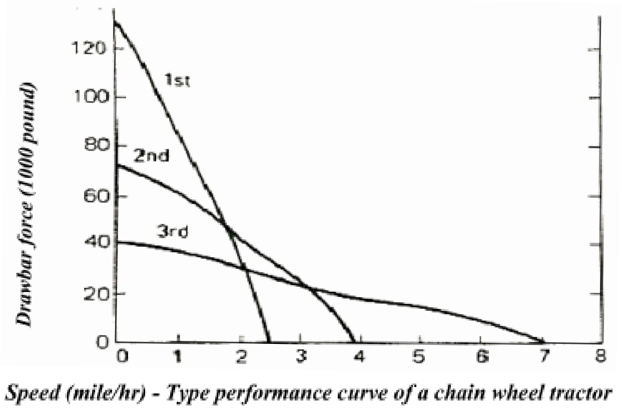

Figure 1. Type performance curve of a chain wheel machine

A. *Case study of 3 studies*

It is desirable to determine the maximum speed of a tractor when necessary tensile force is 60000 pound.

It is observed that drawn horizontal line cut two curves from 60000 pound.

Speed in gear one is 1.5 mile/hr and in gear 2 is 1 mile/hr that is made in gear one.

XII. CONCLUSION

It is necessary to calculate vehicle blade mean capacity to estimate bulldozer work. There are 4 technics for this work.

- The provided statistics by a manufacturing factory can be used to determine the mean capacity of blade. Estimation is done based on the obtained experiences from the previous similar works with similar soil materials and machineries. Blade load is weighted practically using workshop observations, and blade load can be practically measured.

- working mean cycle of the vehicle must be determined after determination blade mean load. Total cycle includes fixed cycler plus varied cycle. Fixed cycle includes the necessary time to aim on soil materials, starting loading, and changing gears that are suggested for bulldozer in table (3-5).

Varied time is the necessary time to collect materials and returning to the loading place after material evacuation. Since bulldozer carries materials to the short distance and the returning path is usually passed by reverse gear, it is suggested to calculate the related times of travels by the provided speed values in standard tables. The necessary times to carry and returning to the loading place is obtained by dividing distance to going round speeds.

- Bulldozer is usually used in soil operations for digging and carrying soil in short distances. Working conditions can include hard and inaccessible land, steep gradients, and poor friction. This short distance of carrying operations is usually called "power zone". Although, the maximum effective working radius of bulldozer is about 300 ft (100m), this distance must be determined by considering working conditions and vehicle in each specific state. Other techniques are also used in addition to choosing the right type of vehicle and blade to increase production. These technics include side by side bulldozers and using bulldozer in downhill. Two or more than two bulldozers are active which are in side by side with contacting blades. This technic increases bulldozers production.

REFERENCES

[1] American Society for Testing and Materials." Standard Specification for Coal Fly Ash and Raw or Calcincd Natural Pozzolan for Use as a Mineral Admixture in Concrete, ASTMC618, 1997.

[2] American Society for Testing and Materials," Standard Test Method for Determining Consistency and Density of Roller Compacted Concrete Using a Vibrating Table, ASTMC1170,1991.

[3] A.S.C.E, "Roller Compacted Concrete ", Technical Engineering Design Guides as Adopted from United States Army Corps of Engineers, No, 5. ASCE1994.

[4] U.S.A.C.E., Roller Compacted Concrete Pavement Desig and Construction, United States Army Corps of Engineers, Technical, Technical Lctter No. ETL 1110-3-475, Oct 1995.

[5] U.S.A.C.E.," Standard Practice for Concrete Pavements. United States Army Corps of Engineers Teehnical Manual TM 5-822-7. AFM88-6, Chapter8, Aug1987.

[6] PIARC, Technical Committee on Concrete Roads, "The Use of Roller Compacted Concrete for Roads", 1995.

[7] American Concrete Institute, "Guide for Selecting Proportios for No-Slump Concrete. AC1211. 3R- 1997.

[8] Concrete Type, American Concrete Pavement Association ,www.pavement.com

[9] Michacl. E. Ayers. Ph.D., Global Pavement Consultants, Inc., "Roller-Compacted Concrete for Roadway. Industrial& Port Applications". Concord, North Carolina. February 28. 2016.

[10] Piggou. R.W, "Roller Compacted Concrete Pavements –A Study of Long Term Performance",RP366, Portland Cement Association, Skokie.11.1999.

[11] RC concrete versus conventional concrete in pavement contemporary Engineering sciences, Vol.2, 2016, no.3, 139-148.