

Mechanism of Pavement Compaction Detection Technology to Improve the Quality of Pavement Construction

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ABSTRACT: With the increase in the number of cars in the modern society, the quality of the road has been paid more and more attention. The useful life of the highway is rather short, the phenomenon of the early destruction of the pavement is widespread, the main reason is that its compaction degree is insufficient. Compaction degree is the key to the construction quality control of asphalt concrete pavement, and it is one of the most economical and effective technical measures to ensure the strength and stability of pavement. This paper introduced several compaction degree detection techniques to describe the operation principle and the process of detecting the compaction quality of road surface in highway construction. Which also analyzed the factors affecting the experimental results, and pointed out different test results of different operation, then demonstrated the effect of test method on the quality of pavement construction.

KEYWORDS: Compaction degree; Detection technology; Construction quality.

INTRODUCTION

Along with the scientific and technical development and improvement of living standards, the number of cars are increasing, and the quality of the road has been paid more and more attention. In our country, the useful life of the highway is rather short, the phenomenon of the early destruction of the pavement is widespread, one of the main reason is that compaction degree of the road is insufficient. As is known to all, compaction degree is the key to the construction quality control of asphalt concrete pavement, and it is one of the most economical and effective technical measures to ensure the strength and stability of pavement. It affects the service life of the pavement, therefore, to improve the quality of road construction, we must make full compaction of the structural layer, and through a reasonable testing technique to determine the quality of compaction.

COMPACTION DEGREE

Concept of Compaction Degree

Compactness, also known as the degree of compaction, is refers to the ratio between dry density compacted of the soil or other road materials and standard maximum dry density, expressed as a percentage [1]. Determination of compaction degree mainly includes indoor standard density (maximum dry density) determination and field density test [2].

Compaction degree is one of the key indexes of pavement construction quality inspection. That is the density of the field after compaction, the higher the degree of compaction, the greater the density, the better the overall performance of the material will be. The compaction degree of highway pavement refers to the ratio of dry density of the material after compaction and standard dry density of the material after compaction, the calculation formula is as follows:

$$K = \frac{\rho_d}{\rho_c} \times 100 = \frac{\rho_w}{\rho_c} \times 100 = \frac{\frac{m_w}{m_h} \times \gamma_s}{\rho_c} \times 100$$

In the formula, K is construction compaction (%) of test site; ρ_c is maximum dry density (g/cm³) of the sample was obtained in the experiment;

ρ_d is dry density(g/cm³) of samples; ρ_w is water content (%) of test pit material; ω is water content (%) of test pit material; m_ω is quality (g) of all materials taken out of the test pit; m_b is the quality (g) of sand filled with the test pit; γ_s is unit quality(g/cm³) of sand [3].

Factors affecting the degree of compaction of road surface

(1) Water content

Soil moisture content is one of the key factors that affect the degree of soil compaction. When the water content is smaller, the soil grains remain loose. Moreover, the water is less, gas will be much, the lubrication action of the water film is not obvious and the external function is not enough to overcome the grain gravity. Therefore, it is difficult to move the soil particles, which lead to the compaction effect is not obvious. Similarly, when the water content is larger, the existence of free water in the gap can not be completely discharged, so the compaction effect is greatly reduced. Therefore, we can conclude that: When actual rolling, we must control the water content, make it stable in a certain range, and ultimately achieve the stability standard of the degree of compaction.

(2) Soil physical property.

Aggregate gradation had a remarkable effect on compactness achieved by rolling. Uniformity of sand in the soil will produce incidental impact on roadbed compactness. Therefore, during the construction, only strictly control of gradation, to ensure its uniformity, in order to ensure to achieve the required compaction state.

(3) The factors of technical equipment.

First of all, the effect of compaction machinery on the compaction state of water and pavement materials can not be underestimated. Compaction machinery has two categories of weight and light weight type, we should according to the size of the project, site size, filler type, compaction requirements, climatic conditions, compaction mechanical efficiency and other factors to select the compaction machinery. Secondly, the rate of compaction is also affected the effect of compaction. It is proved that if the rolling speed is uneven, it is easy to cause the surface uneven and roughness, and affected the compaction degree and planeness of the pavement. The influence of the thickness of the rolling layer on the compaction degree can be analyzed as Table 1.

Table 1. The influence of the thickness of the rolling layer on the compaction degree.

Maximum dry density (g/cm ³)	Compaction thickness (cm)	Check depth (cm)	Water content (%)	Dry density (g/cm ³)	Compaction degree g/cm ³
1.93	25	5	7.9	1.97	93
1.93	25	15	7.6	1.91	99
1.85	20	10	13	1.82	98

Through Table 1 we can see, if the rolling layer is too thick, it will have a negative effect on the lower part of the layer and compaction of the upper layer. So during the construction, we should according to the compaction machinery, water content and other factors to select the best compaction thickness.

(4) Temperature

The effect of temperature on the compaction of asphalt and asphalt mixture is very significant. If the temperature of rolling is too low, and the asphalt viscosity is low, then the compaction effect is good. If the temperature of rolling is too high, and the asphalt viscosity is high, then the mixture will move in dislocation, it is easy to crack. Therefore, we should avoid the rolling temperature is too high or too low.

DETECTION METHOD OF PAVEMENT COMPACTION DEGREE

(1) Fill sand method

Sand filling method is one detection technology, which is widely used in compaction. Sand filling method, is by spraying sandy particles with the same density, volume to fill the volume of round hole to be measured. That is to get the sample volume of the material, then obtain the wet density of the sample by the relationship between mass volume and density, and then remove the water content, converted into dry density.

Specific steps are as follows [4]:

- a) Get standard dry sand with a uniform particle size (or a single particle size), and mark down its density;
- b) Dig a circular hole which depth equal to the thickness of the roller compacted layer at the location where measuring density. In this process, the wall should be perpendicular to the ground, avoid the hole was a cone cylinder.
- c) Collect all the materials which dug out of the cave, and timely measures its quality, After weighing as much as possible to reduce the evaporation of water content, and take a representative part of the sample to conduct the water content test.

$$\rho_w = \frac{m_w}{m_b} \rho_s$$

$$\rho_d = \frac{\rho_w}{1 + \frac{\omega}{100}}$$

In the formula:

ρ_w - Wet density of soil, g/cm³;

ρ_s - Unit mass of sand, g/cm³;

ρ_d - Dry density of soil, g/cm³;

m_b - The quality of the sand used in the test., g;

ω - Moisture content of soil

But what need to pay attention to is the act does not apply to fill stone embankment, the arched bridge holes and other construction project with large pore filling operations.

(2) Cutting-ring method

The cutting-ring method is rather traditional, and operation is simple, with high efficiency, but its accuracy is not high.

Its specific operation steps are as follows [5]:

- a) Preparation before testing, wipe the dirt on the ring knife, and weigh the quality of m₂, accurate to 0.1g;
- b) Clean up the soil of the surface of the test site, which is loose and not compacted, and scoop out a part of the compacted soil layer to smooth the surface of the site;
- c) Fixed the directional tube at the leveled area by tricouni to be measured, put the ring knife, the ring cover into the directional tube, and keep it perpendicular to the ground;
- d) According to the different situations of site soil properties (density, humidity), using the corresponding simple method (direct pressing method and drop into law or hammer into law), make circular knives into or pressed into the material to be measured;
- e) Take the drop hammer and directional tube and other auxiliary tools, take out of the ring knife and sample from the material;
- f) Gently take down cover of the ring knife, use trimming knife pare off redundant soil samples of both ends of the ring knife, wipe the soil on the etkexine of ring knife, weigh out the gross weight of the ring knife and wet soil m₁(unit: G);

g) Determination of the water content of the sample in the ring knife $w(\%)$

The formula for the degree of compaction:

$$\rho_w = \frac{m_1 - m_2}{v}$$

$$\rho_d = \frac{\rho_w}{1 + 0.01\omega}$$

In the formula:

ρ_w -Wet density of soil, g/cm^3 ;

v -The volume of cutting ring, cm^3 ;

ρ_d -Dry density of soil, g/cm^3 ;

(3) Drilling and sampling method

The commonly used detection method of pavement compaction is the appropriate drilling and sampling method. Quality inspection in the construction process is generally a single-point assessment, which need to meet the requirements. If the compaction degree of a measuring point is not up to the requirement, the frequency should be increased. Drill a few holes in the vicinity to determine, if still not qualified, it is determined to be unqualified. Drill after cooling for pavement. In accordance with the “highway asphalt pavement construction technical specifications” to calculate the degree of compaction:

$$K = D / D0 \times 100$$

In the formula: K is compaction degree of measuring part of asphalt surface.(\%);

D is the actual density of compacted asphalt mixture specimen measured by the test. (g/cm^3)

$D0$ is the standard density for asphalt mixtures (g/cm^3)

Nuclear magnetometer

The working principle of the nuclear method is that the soil molecules have affinity to the radioactive material. During construction, put the radioactive material into the soil layer to absorb the mass nucleon of the molecule to be measured. In order to determine the density and water content of the subgrade or pavement materials, and calculate the compaction degree of construction; The site rapid assessment applied to the quality of the construction should not be used as the basis for arbitration test or evaluation.

The determination methods and steps are as follows [6]:

- a) Determine the test position in accordance with the method of random sampling. Switch on power supply, preheat meter, and check the performance of the instrument whether normal.
- b) When use the scattering method to measure, should put the nuclear instrument smoothly on the test position; When use the direct transmission method, put the radioactive source bar down and insert into the hole which has been drilled in advance.
- c) Open the instrument, testers quit instrument beyond 2m, according to the determination of time to measure, when arrived at the time, read the display of the various values, and quickly shut down.
- d) Tally the results: calculate the dry density of the sample, and then obtain the compaction coefficient K ,

Formula as follows:

$$\rho_d = \frac{\rho_w}{1 + 0.01\omega}$$

In the formula:

ω -Water content, expressed in decimal;

ρ_w -Wet density of the sample(g/cm³);

ρ_d -Dry density of samples(g/cm³);

$$K = \frac{\rho_d}{\rho_{dm}} \times 100\%$$

In the formula:

K -Construction compaction degree of test site(%);

ρ_d -Dry density of samples(g/cm³);

ρ_{dm} -Maximum dry density of the sample obtained by compaction test(g/cm³)

Water bag method

Water bag method is started by the United States, its principle is similar to sand filling method, only change the sand into the water.

The specific operation is as follows: first, to dig a circular hole in the position to be measured, put thin rubber bag into the test hole, then added water with the pressure into the thin rubber bag, make the rubber bag expand to the bottom of the test hole touch its wall, according to water volume determine the hole volume.

The deficiency of water bag method is the bag easily to damage. Especially in the structure layer contain the crushed stone particles. When measure in cold winter, due to the water freezes, the accuracy and precision of the measurement is not high. Therefore, although the method is included in the national test procedures, the actual application is not much.

THE IMPACT OF DETECTION TECHNOLOGY ON PAVEMENT QUALITY

The compaction degree test of highway earthwork is the key projects and indicators of construction quality inspection. Compaction degree indicates the compaction condition after compaction of subgrade, the higher the degree of compaction, the greater the corresponding density, the better the overall performance of the roadbed material will be. According to the theory and practice, we can know that: the degree of compaction can affect the quality of highway service from four aspects, such as the strength of the pavement, the stability of the road, the smoothness of the road surface and the durability of the pavement.

(1) Pavement strength. Pavement strength mainly depends on the strength of subgrade, while the strength of subgrade is determined by the compaction degree of subgrade.

(2) Pavement stability. The higher the degree of compaction of subgrade, the higher the probability of deformation under pavement load, the more unstable the road will be.

(3) Pavement evenness. Roadbed compaction degree is lower, under the effect of the surface load, can occur settlement and compression in different degrees, which will cause pavement uneven surface.

(4) Pavement durability. The durability of pavement is the service life of pavement, which is a comprehensive index of pavement strength, pavement stability and pavement smoothness. So it is closely related to the compaction degree of subgrade.

To sum up, the effect of the compaction degree on the use of the quality of the road is quite large, therefore, it is very necessary to use effective detection technology. First, we look at the method of compaction test to determine the maximum dry density: To test compaction degree only include the indoor standard density (the maximum dry density $\rho_{d \max}$ determined by compaction test) and the field density test (ρ_d mainly determined by sand filling method)

$$\text{Compaction degree} = \frac{\rho_d}{\rho_{d \max}} \times 100\%$$

Compaction test principle: under the action of a certain compaction function, the dynamic compaction energy is applied to the soil, which make the gap between the soil particles become smaller, and the soil particles rearrange, so that the density of the soil is increased. The following Figure 1 is a typical compaction curve of fine-grained soil:

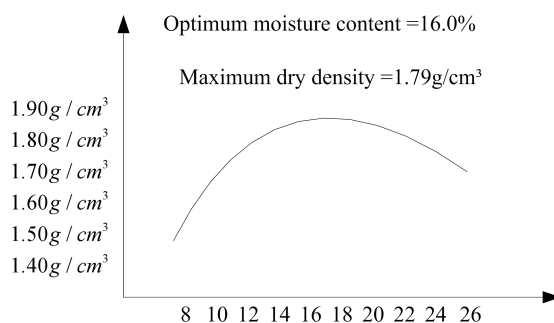


Figure 1. A typical compaction curve of fine-grained soil.

It can be seen from the graph that: ①The real curve has the highest point, which shows that the maximum dry density can be hit by a certain amount of water (under the optimum water content) under certain compaction function; If the water content of the soil is less than or greater than the optimum water content, the dry density will be less than the maximum dry density. ②Subgrade construction specifications, subgrade soil should be in the best water content within the scope of $\pm 2\%$ to carry out construction, which can be seen from the figure, in this range, the subgrade soil is the most easy to reach the compaction standard.

Below, we take the sand filling method as an example, in the detection method of verifying the compaction test, the different operation have different effects on the test results, thus affect the quality of the road.

(1) The test principle: use the uniform sand to measure the size of the hole, and which can measure the quality of the sand. The density of the sand can be calculated by the formula $\rho = m / v$.

The following is the analysis of the test results to the test process:

(2) The quality of sand in the cone under the calibration tube is too large, it will make v the smaller, while it will make v larger.

(3) In the process of digging holes should try to make the test hole avoid vertical, avoid appearing the situation of up big or down small, this will enable detection density too large or too small. The loose particles should be removed in the test hole, otherwise the volume of test pit is easy to measure too small.

(4) When fill the sand, detection thickness should be thickness of the entire roller compacted layer, only take from the upper will make the detection density value too large. Due to backfill soil under the effect of the load stress, which decreased rapidly with the depth, so the compaction degree of the upper part of the backfill soil will be higher.

CONCLUSION

There are so many compaction controls and compaction detection technologies. From the above we can know, compaction detection technologies and compaction techniques play an important role in highway construction, which directly impact on the quality of the highway. Therefore, we should continue to study and discover more and more

effective technologies, while during the construction of compaction, strictly conduct accordance with the specification.

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