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# Study on Mixing Equipment Parameters of Cement Stabilized Macadam

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**Abstract:** The mixing uniformity of cement stabilized crushed stone includes two aspects, one is the uniformity of cement coating on aggregate, and the other is the uniformity of coarse and fine aggregate distribution. The uneven cement coating aggregate results in the segregation of base strength distribution. The uneven distribution of coarse and fine aggregates leads to the density segregation of the base layer. Optimization of mixing intensity and mixing time can effectively improve mixing uniformity. The strengthening mechanism of vibration mixing and double mixing tank mixing on cement stabilized gravel mixing was compared and analyzed. Relying on the construction site 800 stable gravel mixing equipment, the key technical parameters affecting the mixing effect were analyzed. The results showed that increasing the number of mixing tanks can effectively solve the problem of short mixing time of continuous mixing equipment. The mixing quality could be improved effectively by increasing the effective mixing time to more than 35s with double mixing tanks; Vibration mixing and forced mixing form energy complementary to solve the inefficient zone of mixing. When vibration mixing is adopted, the vibration frequency should be controlled above 35Hz, increasing the mixing intensity can improve the mixing effect; the selection of filling rate should consider mixture quality and production efficiency. The filling rate of mixing tank is controlled at about 70%, which can ensure the uniform binding of cement binder on aggregate surface.

**Keywords:** Cement-Stabilized Crushed Macadam, Vibration Mixing, Double Mixing Tank, Mixing Time, Vibration Frequency, Filling Rate

## 1. Introduction

Cement stabilized crushed stone mixture is produced by continuous mixing equipment, mixing time cannot be artificially adjusted and controlled [1]. Inadequate mixing will affect the uniformity of the mixture. On the one hand, coarse aggregate is coated with fine aggregate less, leading to macro segregation; on the other hand, the agglomeration of cement particles leads to the failure of cement slurry to uniformly coat coarse aggregate [2, 3]. The uneven mixture reduces the quality of pavement forming, which affects the strength and durability of the base [4]. In order to avoid the low local strength caused by uneven cement binding, the cement guarantee strength index of 0.5%~1% is generally increased in the construction, which has a negative impact on the crack resistance of the base [5].

The mixing quality of the mixture can be improved by increasing the mixing intensity and extending the mixing time. At present, vibration mixing or double mixing tank mixing building is generally used in the construction of high grade pavement [6-8]. The method of mechanical strengthening is to apply vibration on the basis of forced stirring.

## 2. Vibration Mixing Mechanism

Vibration mixing is to apply vibration force on the basis of

traditional mixing, by increasing the mixing strength to destroy fine aggregate agglomeration, so that the cement evenly distributed. The effect of vibration mixing on the mixing uniformity of the mixture mainly has the following aspects:

1) Improve mixing inefficient zone

The vibrator is installed in the central axis of the agitator, and the vibration energy diffuses outward from the stirring axis as the center. The energy decreases gradually with the increase of the propagation distance, resulting in an energy gradient [9]. The static stirring equipment moves faster near the cylinder wall line and slower near the stirring axis. The energy gradient of the vibration source is complementary to the velocity gradient of the stirring blade. There are both macroscopic convection, shear and friction motion and microscopic conversion of vibration energy under the excitation force. Vibration mixing solves the problem of poor mixing quality in low efficiency zone of mixing blade [10].

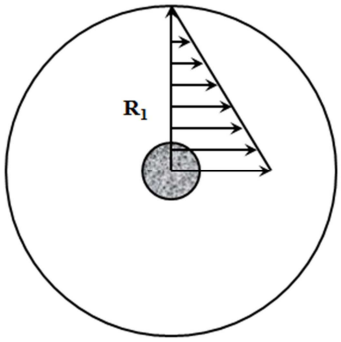


***Figure 1.*** *Vibration Mixing Energy Gradient.*

2) Failure cement agglomeration

In the process of vibration mixing, the high frequency and low amplitude vibration makes the cement particles in a state of flutter and destroys the viscous connection between the cement particles [11]. Under the action of certain amplitude, the hydrate film layer on the surface of cement group is destroyed, and the cement particles change from cement agglomeration state to uniform distribution state. Cement is evenly wrapped by free water, cement particle hydration area will increase, hydration reaction will be more fully.

3) Clean aggregate surface

In the process of vibration mixing, the dust particles on the aggregate surface are constantly destroyed and the surface is detached, and the aggregate surface tends to be clean and more easily soaked by water. Cement particles are better able to adhere to the wet aggregate surface, providing more room for hydration reaction. With the separation of dust and the destruction of water film, C-S-H gel can be fully formed on the surface of aggregate and produce sufficient adsorption with aggregate.

# 3. Action Mechanism of Double Mixing Tank

On the basis of the original single cylinder, a mixing cylinder is added to prolong the mixing time, which is the optimization of the traditional construction technology [12]. Double mixing cylinder equipment adopts two mixing cylinders to work continuously in series, which does not affect the production efficiency of mixing materials while increasing the mixing time [13]. The specification "Technical Instructions for the Construction of Road Pavement Base" (JTG/T F20-2015) suggests that the two-stage mixing production process should be adopted for the mixing of pavement base material. The technical characteristics of the double mixing tank mixing technology are as follows:

1) On the premise of not affecting the production efficiency, increase the mixing time of the mixture, improve the mixing effect, and ensure the uniformity and stability of the base strength.
2) Reduce the dosage of cement. In order to solve the mixed strength dispersion caused by uneven cement binding, the dosage of 0.5%~1% cement is usually increased in the construction to ensure that the strength index can be reached, which has an adverse effect on the shrinkage crack of the base.
3) Reduce the optimal water content.

In order to ensure the uniform distribution of water in the mixture in the laboratory test is usually carried out in the actual construction. In order to ensure the compaction effect, the production water consumption is usually increased, which has a negative effect on the dry shrinkage of the mixture. Increasing the mixing time can improve the mixing uniformity of water to some extent and reduce the production water consumption.

# 4. Research on Technical Parameters of Mixing Equipment

The improvement of vibration mixing and double mixing tank mixing on cement stabilized gravel mixing has been recognized in the industry. According to the application experience, under the same strength standard conditions, the vibration mixing can reduce the dosage of cement by about 10%, reduce the dry shrinkage strain and the average dry shrinkage coefficient obviously, and improve the crack resistance of cement stabilized gravel [14]. However, the operators on the construction site know little about the reasonable technical parameters of mixing equipment, which leads to the different quality of mixed materials produced by different mixing equipment. Based on mixing time, vibration frequency, mixing speed, filling rate and other key mixing parameters, the uniformity of the mixture was tested and analyzed in this section, and the reasonable parameters for controlling the mixing quality of water-stabilized gravel were proposed.

### *4.1. Vibration Frequency*

The test adopted the 800-type stabilized soil mixing building on the construction site. During mixing, single cylinder and double horizontal shaft were used for forced

vibration mixing. The dosage of cement was 4.5%. The optimal water content of 4.7% and the maximum dry density of 2.483 were determined by vibration compaction method. According to daily mixing experience, the filling rate of mixing tank is selected as 50%, mixing time as 30s. Mixing is performed at multiple frequencies of 20Hz, 25Hz, 30Hz, 35Hz, 40Hz and 45Hz respectively. After mixing, evenly take the material on the belt, pass the mixture through the 9.5mm sieve, and divide it into two parts: mixture A above 9.5mm and mixture B below 9.5mm. The cement dosage of the two groups of materials was tested respectively. Due to the difference of specific surface area of coarse and fine aggregate, the dosage of cement after titration is different. The more evenly mixed the mixture, the smaller the difference of cement dosage, and eventually tends to be stable. The cement dose-titration results of coarse and fine mixtures at different vibration frequencies are shown in Table 1.

***Table 1.*** *Dosage Test Results of Coarse and Fine Cement at Different Vibration Frequencies.*

| Vibration frequency (Hz) | 0 | 20 | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|---|
| A-Cement dosage (%) | 3.7 | 3.8 | 3.9 | 3.9 | 4.0 | 4.0 | 3.9 |
| B-Cement dosage (%) | 5.4 | 5.4 | 5.5 | 5.2 | 5.1 | 4.9 | 5.0 |
| Cement dose difference (%) | 1.7 | 1.6 | 1.6 | 1.3 | 1.1 | 0.9 | 1.1 |

As can be seen from Table 1, vibration frequency has significant influence on mixing uniformity under the same mixing time. When the vibration frequency is less than 25Hz, the effect of vibration on the binding uniformity of cement is very small. When the frequency reaches above 35Hz, the difference of cement dosage of coarse and fine mixtures is small, and the uniformity of mixtures tends to be stable. Therefore, the vibration mixing cement is used to stabilize the gravel, and the vibration frequency should be controlled above 35Hz.

### *4.2. Mixing Time*

The effective mixing time not only affects the mixing quality, but also affects the production efficiency. In this section, the mixing tank filling rate is 50% and the vibration frequency is 40 Hz. Mixing is performed at different mixing times of 20s, 25s, 30s, 35s, 40s, 45s and 50s. The cement dose titration results of coarse and fine mixtures at different mixing times are shown in Table 2.

***Table 2.*** *Dosage Test Results of Coarse and Fine Cement at Different Mixing Time.*

| Mixing time (s) | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
|---|---|---|---|---|---|---|---|
| A-Cement dosage (%) | 3.5 | 3.7 | 3.9 | 4.1 | 4.2 | 4.2 | 4.1 |
| B-Cement dosage (%) | 5.4 | 5.1 | 4.9 | 4.8 | 4.9 | 4.8 | 4.9 |
| Cement dose difference (%) | 1.9 | 1.4 | 1.0 | 0.7 | 0.7 | 0.6 | 0.8 |

As can be seen from Table 2, with the extension of mixing time, mixing uniformity has been significantly improved. When the mixing time reaches more than 35s, the difference of cement dosage of the mixture gradually becomes stable. Cement stabilized gravel mixing belongs to continuous production, mixing time is less controllable. The effective mixing time can be increased by extending the length of cylinder block or adopting double mixing cylinder to ensure that the effective mixing time of the mixture can reach more than 35s in the continuous production process.

### *4.3. Filling Rate*

Filling rate refers to the ratio of the volume of the mixture entering the mixing tank to the volume of the cylinder. Its value has direct influence on mixing quality and production capacity. When the mixture is stirred at a reasonable filling rate, the interaction between the stirring blade and the dead weight of the material produces boiling effect, which enhances the stirring [15]. With the increase of filling rate, the space above the mixing tank decreases, and the boiling effect will be weakened. When the filling rate is too high, the free fall motion of the mixture in the mixing process is reduced, resulting in the reduction of mixing strength. From the point of mixing quality, the maximum filling rate of mixing should be controlled. Under the condition of ensuring mixing quality, the higher the filling rate, the higher the production efficiency of mixing equipment.

Mixing of the mixture was performed at vibration frequency of 40 Hz and mixing time of 35s. At the filling rate of 40%, 50%, 60%, 70%, 80% and 90%, the mixing was performed to produce the mixture. The cement dose-titration results of coarse and fine mixtures under different filling rates are shown in Table 3.

***Table 3.*** *Dosage Test Results of Coarse and Fine Cement at Different Mixing Time.*

| Filling rate (s) | 40 | 50 | 60 | 70 | 80 | 90 |
|---|---|---|---|---|---|---|
| A-Cement dosage (%) | 3.9 | 4.0 | 4.1 | 4.1 | 3.8 | 3.6 |
| B-Cement dosage (%) | 4.8 | 4.8 | 5.0 | 5.1 | 5.1 | 5.2 |
| Cement dose difference (%) | 0.9 | 0.8 | 0.9 | 1.0 | 1.3 | 1.6 |

As can be seen from Table 3, when the filling rate is below 70%, there is no significant difference in mixing uniformity. When the filling rate of mixing is more than 80%, the dosage difference of mixing cement is obvious. Therefore, in order to ensure the mixing quality of the mixture, the filling rate should be controlled within 70%.

# 5. Conclusion

Mixing time, vibration frequency and filling rate are important parameters of cement stabilized crushed stone mixing. In this paper, the uniformity of cement coated aggregate was used as the index to analyze the production parameters of mixed material. The main conclusions are as follows:

(1) Vibration mixing can effectively increase the intensity of mixing and improve the inefficient zone of mixing, which is complementary to forced mixing. When vibration mixing is adopted, the effect of vibration frequency lower than 25Hz on the uniformity of the mixture is very small. The vibration frequency of mixing equipment should be controlled above 35Hz.

(2) Sufficient mixing time is an important condition for even mixing. Continuous mixing equipment cannot control mixing time, extending the length of mixing tanks or increasing the number of mixing tanks is an effective measure to improve mixing quality. The mixing quality of the mixture can be improved effectively by increasing the effective mixing time to more than 35s with double mixing tanks.

(3) When mixing the mixture, the high filling rate will reduce the mixing strength, and the low filling rate will affect the production efficiency. When the filling rate is more than 80%, the uniformity of the mixture is poor. Mixing effect and production efficiency, the filling rate of mixing tank should be controlled around 70%.

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