

# Application status and problems of machine-made sand in Highway Engineering

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**Abstract.** Based on the investigation of the application of machine-made sand in Shaoxing, Zhejiang Province, this paper analyses the supply and demand of local machine-made sand, combined with the application of machine-made sand in highway engineering projects such as Hangzhou Shaoxing Taizhou expressway. It discusses the problems existing in the current machine-made sand industry, such as slow overall application, uneven quality and low application of high-grade concrete, and puts forward many measures to promote high-quality machine-made sand. In the application of high-grade concrete, it is suggested that the government should develop the machine-made sand market jointly with many departments, increase efforts to crack down on the inferior sand, cultivate the high-quality machine-made sand market, and improve the engineering quality of the machine-made sand concrete.

## 1 Introduction

In recent years, with the Chinese government investing heavily in the construction of transportation infrastructure, the demand for building materials has increased dramatically, especially the introduction of documents such as the outline of building a powerful transportation country issued by the State Council. In the next few years, the traffic construction will be greatly developed. However, as an important material of concrete, the natural river sand, due to the huge consumption, the continuous depletion of resources and environmental protection problems, has become increasingly serious. The machine-made sand is made of the mineral materials that meet the requirements of the parent rock. After treatment, it is mechanically broken, screened and shaped to make the particle size less than 4.75mm. At the same time, its particle shape and grading meet the construction requirements. The replacement of the machine-made sand for the natural river sand is the future development trend [1]. Compared with river sand, machine-made sand has the advantages of high economic benefit, controllable quality and easy to adjust production because of its convenient material and industrial production [2]. Popularizing and applying machine-made sand is not only the main measure to alleviate the dilemma of sand used in highway engineering, but also the direction of green development of highway engineering, which is of great significance for building a powerful transportation country. Based on the investigation of the application of machine-made sand in Shaoxing area of Zhejiang Province, combined with the current situation of the application of local machine-made sand in highway engineering, this paper analyzes the problems existing in

the current promotion and application of machine-made sand, and puts forward the future development direction of machine-made sand industry.

## 2 Current situation of machine-made sand industry

### 2.1. Sand demand

Taking the sand used in Shaoxing as the survey object, the annual investment of the city's comprehensive transportation construction is basically over 22 billion, involving many types of projects, such as expressway, national and provincial highway, rail transit, urban viaduct, etc, involving a wide range of points. The demand for concrete in these projects is basically over 3 million square meters per year, and the proportion of sand in concrete is the largest, accounting for the proportion of concrete about 30% of the concrete structure. According to this calculation, the annual sand consumption in the comprehensive traffic construction field of the city will reach more than 1 million square meters.

### 2.2. Source of sand

At present, there are three main forms of sand used in highway engineering in Shaoxing area.

The first one is high-quality natural river sand. According to the investigation, the source of high-quality natural river sand used in highway engineering in the past is basically the river sand produced in Shengzhou of this city. However, with the continuous depletion of river sand resources, the increasing environmental protection

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requirements, the prohibition of mining and limited mining of river sand and other factors, there is basically no large quantity of high-quality river sand in Shengzhou of this city. The sand for highway engineering is basically purchased to meet the construction needs of the city, mainly from Poyang Lake in Jiangxi, Ganjiang region, Bohai Bay in Liaoning, Guangxi and other regions. However, due to the long transportation distance, the site price is relatively high. Taking Shaoxing city as an example, the price is more than 230 Yuan per ton. Moreover, for highway engineering with large demand, it is difficult for high-quality natural river sand in other areas to fill up quickly meet the construction needs.

The second is inferior sand, including sea sand after simple desalination, natural sand with excessive mud content, weathered rock machine-made sand, stone chips powder, etc. At present, the site price of this kind of sand is less than 150 Yuan per ton. According to the survey, some project construction units use a large number of inferior sand driven by interests, that is, a certain amount of inferior sand is mixed into the natural high-quality sand, and the quality of the sand mixed is difficult to distinguish.

Inferior sand brings natural defects to the homogeneity of concrete, directly affects the strength of concrete, and some inferior sand's relevant inspection indexes are unqualified. According to statistics, in the past four years of supervision and sampling inspection, there have been three batches of sand with excessive chloride ion content in the city's highway engineering projects. If the chloride ion content in the sea sand is large, it will have strong corrosiveness to the steel bar and bring great harm to the safety and durability of the engineering structure [3].

The third type is high-quality machine-made sand, which refers to the rock particles with the particle size less than 4.75mm made by de mining, mechanical crushing and screening, excluding the particles of soft rock and weathered rock [4]. At present, the machine-made sand used in the highway projects under construction in the city is mainly in the form of self-processing and outsourcing. In this paper, four representative production lines of machine-made sand are selected for comparison through field investigation of the production of machine-made sand in the city and surrounding areas, as shown in Table 1.

**Table 1.** Comparison of four machine-made sand production lines.

Production line	Base material source	Processing method	Production costs(Yuan)	Particle grading and morphology	Use of structural parts
Dry processing of hangshaotai high speed project	Tunnel slag (tuff)	Combined production of sand and stone	35-45(Production only)	The aggregate has more two ends and less in the middle, and its shape is regular	Bridge substructure C30 and below concrete
Wet processing of Hangzhou Shaoxing Taiwan High Speed project	Tunnel slag (tuff)	Wet sand production with sand and stone	30-40(Production only)	The grading is reasonable, the shape is like gravel, and the content of stone powder is small	Bridge substructure C30 and below concrete
Dry processing of Gangteng building materials	Limestone purchased	Dry process	140(Producer's price)	Similar to high quality natural sand	Up to C55 beam slab concrete
Dry processing of Wencheng Taishun high speed four standard project	Tunnel slag (tuff)	Combined production of sand and stone	80(Production only)	Close to natural sand	C60 main tower concrete

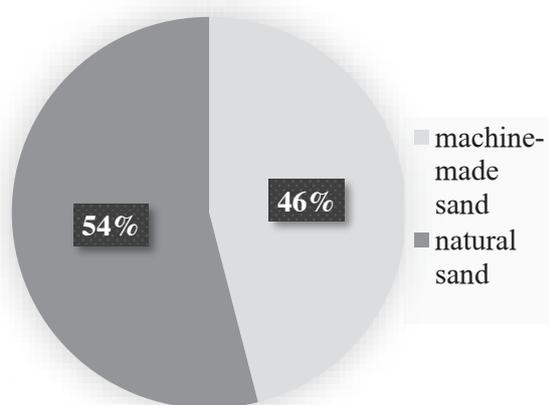
It can be seen from the above table that the processing methods of machine-made sand mainly include dry method and wet method. In the case of the same source of base metal, the comparison of production cost, particle size distribution and morphology shows that the two processing methods are basically similar. From the comparison of self-processing and outsourcing, we can see that the outsourcing cost is much higher than that of self-processing when using the same processing method. From the analysis, we can see that compared with self-processing, the source of base material needs to be purchased increases the cost expenditure. At the same time, the highway engineering has the characteristics of many points, wide distribution in strips, crossing over

large areas, and increasing the transportation cost of the purchased machine-made sand. In the use of structural parts, machine-made sand has been widely used in low-grade concrete and substructure, and part of machine-made sand with good quality has been used in high-grade concrete and beam slab structure.

### 3 Application of machine-made sand in Highway Engineering

At present, the machine-made sand has been gradually applied in the city's highway engineering projects, and has achieved good results, which is not only conducive to

saving the project cost, but also conducive to controlling the project quality. Taking Hangzhou Shaoxing Taizhou expressway as an example, the application of machine-made sand is mainly concentrated in the low grade concrete of substructure. According to statistics, all 5.9 million cubic meters of concrete in Hangzhou Shaoxing Taizhou expressway needs about 1.85 million cubic meters of sand, and the sand use is shown in Figure 1. According to Figure 1, the proportion of machine-made sand used is 46%, about 850000 cubic meters of machine-made sand. According to the current application, first, the cost of using high-quality machine-made sand is lower than that of high-quality natural river sand, and the price is close to that of low-quality sand, which is economically feasible; second, the appearance quality of high-quality machine-made sand is controllable.



**Figure 1.** Proportion of two kinds of sand used in concrete of Hangzhou-Taizhou Expressway.

**Table 2.** Application of machine-made sand in Section 4 of Wentai highway project.

Site of use	Sand	Placing concrete	Concrete strength
Bearing platform and tower base of Hongxi super large bridge	Machine-made sand	C45	>55 MPa
T-beam	Machine-made sand	C50	>61.3MPa
Tower column of 1 # pier of Hongxi bridge	Machine-made sand	C60	>69MPa

## 4 Current problems in machine-made sand industry

### 4.1. Source of sand the overall application of machine-made sand is slow

(1). The application of machine-made sand is not enough. In the field of highway construction, Zhejiang Provincial Department of transportation issued *the technical guide for production (dry process) and concrete of machine-made sand of Zhejiang provincial traffic construction project* and *Technical guide for production (wet process) and marine concrete of machine-made sand in traffic construction engineering of Zhejiang Province* in January 2016, specific standards and requirements are put forward to standardize the production and use of machine-made

The mechanism adopted in Section 4 of Wentai highway project is shown in Table 2, C45 concrete prepared by machine-made sand is applied to the cushion cap and tower structure of Hongxi super large bridge, and the construction technology of centralized mixing on site and automobile pumping pouring is used; C50 concrete is prepared by machine-made sand to cast T-beam, the compressive strength of concrete test block in 28 days is greater than 61.3 MPa, and the surface of T-beam is free of sand line, crack and bright and clean; C60 high pumping is used for tower column of 1 # pier of Hongxi bridge machine-made sand concrete, the vertical pumping height is about 126m, the horizontal pumping distance of the bridge deck is about 134m, the concrete slump is 200~220mm, the 28 day compressive strength is greater than 69 MPa, meeting the requirements of concrete performance and mechanical properties.

sand. However, in the past four years, the development of the whole machine-made sand industry in Shaoxing is still relatively slow. At present, only part of the projects in Shaoxing are producing and using machine-made sand. The atmosphere of actively promoting and guiding the application of machine-made sand in the industry is weak, the driving force is not strong, and the resistance is great. It is mainly affected by the traditional use habits. As long as there is natural sand, whether its quality is qualified or not, the construction unit or the habitual use, the participating units are easy to recognize.

(2). The market for machine-made sand has not yet taken shape. At present, there are not many normal sand and stone markets in Shaoxing, and no unified planning has been formed. Most of the sand and stone transactions are in the original state of relying on individual information and relations, resulting in the mismatch between the buyer's and seller's markets. At the same time,

due to price factors, a large number of poor sand flows into the market, hindering the healthy development of mechanism sand market.

(3). Social capital dare not enter mechanism sand market easily. The development of machine-made sand is mainly driven by the infrastructure construction. The main restriction of the current production of machine-made sand is the source of base metal. Taking Shaoxing city as an example, limestone produced in Zhuji, basalt produced in Xinchang and Shengzhou, and tuff produced in other places can be used as the base material of machine-made sand. But at present, there is no market for mining materials. To investigate and visit the machine-made sand field of the construction project, basically, the tunnel slag excavated by the project is used as the base material, and then a temporary production line is established for the use of the project. The visited machine-made sand factory for commercial production has a production equipment investment of about 20 million Yuan. The source of the base material is the purchase of finished gravel from Fuyang, Hangzhou Because the base metal is directly restricted by the upstream enterprises, and at the same time, it also faces the situation of difficult sales, which makes the operation of the machine-made sand factory difficult.

#### **4.2. The quality of machine-made sand varies greatly**

The quality of base metal directly affects the quality of machine-made sand. On the one hand, weathered mountain sand is used as the base material of machine-made sand by washing or simple processing. This kind of machine-made sand has good apparent particle type, qualified grading and fine modulus in the range of medium coarse sand, but its compressive strength is very low, so it cannot be used as fine aggregate of concrete. On the other hand, if tunnel slag and cobble are used as the base material of machine-made sand, there is no strict screening, and soft rock is directly processed into machine-made sand. In addition, due to the unclean base metal and the presence of soil and harmful substances, the quality of machine-made sand becomes poor or even unavailable. If the mud content exceeds the standard, the concrete strength will be affected [5].

Some backward processing lines seriously affect the quality of machine-made sand. Due to the lack of attention to the sand making equipment and insufficient production investment, there are some problems in the machine-made sand produced by the backward production line, such as poor particle grading (dry method), lack of stone powder content and excessive needle flake (wet method); part of the construction projects of self-mining stones are mainly the production of macadam for concrete, and the way of combined production of sand and stone is basically adopted, and the quality of machine-made sand produced is not high. There are also some production units of machine-made sand to reduce mechanical wear and production cost. The fineness modulus of machine-made sand produced is more than 4, which is not inspected before delivery, and even the necessary test equipment is

not available, resulting in uncontrollable quality of sand.

#### **4.3. The impact of inferior sand on the popularization and application of high-quality machine-made sand is great**

According to the survey visits and some units' reports, there are a certain amount of inferior sand in the current market, such as desalination of non-standard sea sand, natural river sand mixed with sea sand, and natural river sand with quality not meeting the requirements, which will impact the market at a price of 50~60 Yuan lower than the price of high-quality natural river sand. Some sand using units use low-cost low-quality sand under the influence of interest driven, long-term use habits and short-term use of low-quality sand in concrete will not expose quality problems. In addition, some suppliers and construction units may use rules to avoid sampling inspection of raw material quality, or there are fraud, shoddy and other phenomena. At the same time, because there are too many industries involved in sand use, the detection is basically only extended to the mixing site, and the supervision of poor sand in material source, wharf yard and other parts is basically blank.

#### **4.4. Lack of application of machine-made sand in high grade concrete**

In the traffic construction field of the whole city, only the machine-made sand used is mainly concentrated in the substructure, and not used in the high-grade concrete of the superstructure, which is also a factor that causes the promotion of machine-made sand to pay little attention.

#### **4.5. Increasingly strict environmental protection policies**

At present, there are also many environmental protection problems in the production process of machine-made sand, such as destructive mining and no treatment after the production of machine-made sand; the second is the problem of dust, whether mining or tunnel slag production, there are dust pollution and noise pollution. Although the public's awareness of environmental protection is constantly enhanced and environmental protection measures are constantly improved, environmental protection reports and complaints are also constantly emerging.

### **5 Future development direction of machine-made sand industry**

#### **5.1. Multiple measures to promote the application of high quality machine-made sand**

The project owner can strengthen the quality of construction sand in the bidding stage, define the key indicators, and the conditional project owner can carry out dynamic management by establishing the access system and other ways to restrict the production base material,

production process, equipment, finished products and other aspects of machine-made sand, and encourage the projects involving tunnels, large excavation and other bid sections that can provide high-quality base material to process and produce by themselves sand, but the base metal, process, equipment and finished products should also be approved in advance, and if necessary, experts in the industry should be organized to demonstrate and guide.

## **5.2. Exploring the application of machine-made sand in high grade concrete**

On the basis of ensuring that the finished machine-made sand products meet the requirements, the construction unit shall first pilot, encourage the application of high-quality machine-made sand on structures, continuously accumulate experience, promote the application of high-quality machine-made sand on high-grade concrete, lead the research of high-quality machine-made sand to deepen, and expand the proportion of high-quality machine-made sand in construction sand.

## **6 Suggestions**

The machine-made sand plays an important role in traffic construction engineering, but through investigation and analysis, it is known that there are many problems in its current development. For the healthy and sustainable development of the machine-made sand industry, this paper proposes as follows:

### **6.1. Government guides multi departments to develop mechanism sand market**

Sand and stone is a kind of material with strong regionalization and consumes a lot of natural resources. In the form of building a resource-saving, environment-friendly society and developing circular economy, we must attach great importance to the production and application of high-quality machine-made sand. In the past, the main body of natural sand production was scattered, involving water conservancy, land, environmental protection and other management departments, resulting in management confusion. Therefore, the government must take the lead to strengthen the top-level design.

(1). The development of machine-made sand should be carried out in a comprehensive and long-term plan from the government level in combination with the long-term urban and rural construction plan. Based on the resources such as mines and tunnels, the high-quality and environmentally friendly high-quality machine-made sand processing plants should be reasonably arranged.

(2). The government should introduce policies to encourage state-owned enterprises such as local investment institutions and urban investment institutions to invest in mechanism sand production plants, so as to control the quality from the source and use it in the corresponding construction projects. It is also necessary to guide private capital to enter and carry out full competition.

(3). In the corresponding areas, with the support of the government departments and in combination with the construction needs, we will speed up the sale and auction of some high-quality mines for the production of building materials. At present, transportation investment companies in Shengzhou, Xinchang, Zhuji and other places are exploring the implementation.

(4). In the planning of new construction and reconstruction of highway, the line position can be reasonably selected, and if the conditions permit, the line for excavation can be excavated through exploration in advance, which is used to produce machine-made sand and crushed stone for concrete, so as to meet the local demand for construction stone and sand. The construction unit should change the concept of excessive pursuit of the balance of filling and excavation in the past route selection, and on the premise of high quality base material, it should reasonably consider the supply and demand relationship of stone materials within its jurisdiction, and provide the market with high-quality materials with conditions, and even purchase the road building materials to fill and replace the high-quality materials excavated from the subgrade. On the other hand, the departments of land and resources should issue corresponding policies to support the marketization of mine resources in highway projects. The current situation that the abandoned stonework is only used for the same project and cannot be transferred or sold out can be avoided through auction, adjustment and other ways.

### **6.2. Strengthen the attack of inferior sand and cultivate the market of high-quality machine-made sand**

The sand using unit shall increase the frequency of random inspection on the quality of engineering sand, prohibit the unqualified sand from entering the construction site, and increase the penalty for breach of contract for the unqualified sand. The government departments shall increase the statistics and supervision of the inflow of construction sand, such as relying on the monitoring and testing of the sand carrier by the port, shipping and water transport departments; the quality inspection department shall intervene in the construction sand market according to the provisions of the product quality law, strengthen the inspection of construction sand products according to the requirements of industrial products, and crack down on the inflow of inferior sand into the market. The industry supervision department should also strengthen the supervision and random inspection of construction sand, increase the frequency and content of random inspection, and increase the punishment for the use of inferior sand, form a comprehensive and multi-level sand supervision network, and make every effort to investigate and deal with inferior sand, so as to create a good market environment for high-quality mechanism sand.

## **7 Conclusion**

To sum up, the application of machine-made sand in

traffic construction engineering is less, and there are some problems in the machine-made sand industry, such as slow overall application, uneven quality, and little application in high-grade concrete. In view of the problems of machine-made sand, this study draws a conclusion through field visit, research and analysis: for the promotion and application of machine-made sand, collaborative efforts are needed in many aspects. Firstly, the government should guide the joint efforts of multiple departments to develop the machine-made sand market, secondly, it should increase the attack on inferior sand, cultivate the high-quality machine-made sand market, and finally, it is necessary to improve the quality of machine-made sand concrete in the solid project.

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