MINISTRY OF FOREIGN AFFAIRS
OF DENMARK
Innovation Centre Denmark

REPORT BY
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CONSTRUCTION WASTE

IN CHINA

Introduction

The concept of Circular Economy has been more and more applied in the construction waste and China has drawn more and more attention on the recycling and reuse on construction material.

Up to date, more than 80% of the total solid waste in China's industrial sector is from building material sector every year. The annual increment of bulk industrial solid waste is estimated to be 1.5 billion tons, then the building materials industry has at least 1.2 billion tons of consumption and disposal capacity. According to the current utilization rate of 70% of China's general bulk industrial solid waste, building materials industry consumes about 1.1 billion tons of bulk industrial solid waste including partial domestic solid waste every year.

However, due to the technical boundary of building and construction industry, the industry is facing the challenge of increasing the efficiency in not only reusing and recycling process, but also in turning raw materials into ready-to-use construction material. Furthermore, high energy consumption, niche market application and high cost of production are also the reason circular economy is not commercial benefit in construction waste industry.

The following content will illustrate the current circular economy ecosystem in construction waste in four main parts: regulation and law, 3R treatment, leading companies and opportunities.

1 Regulations and Laws

In general, the regulations and laws are settled for enforcing the power in:

- Classification of construction waste
- Management and responsibility party identification
- Potential financial support from government for treatment
- Technical specification

The regulations and laws are distributed as 2 levels: national and regional, where national laws applies to all provinces and regional ones are tailored for specific regions. More details are addressed underneath.

1.1 National Level

1.1.1 The New Solid Waste Law

On April 29, 2020, the 17th meeting of the standing committee of the 13th National People's Congress deliberated and adopted the revised Law on the Prevention and Control of Environmental Pollution by Solid Waste (hereinafter referred to as the New Solid Waste law), which will come into force on September 1, 2020.

1.1.2 Construction and Demolition Waste Law

The Construction and Demolition Law are first drafted as early as May 1995. (Construction and Demolition Waste Management in China through the 3R Principle). The major department taking charge is Ministry of Housing and Urban Rural Development.

Since Construction and Demolition Management is very comprehensive, the following departments are involved:

- Ministry of Housing and Urban-Rural Development (MOHURD)
- National Development and Reform Commission (NDRC)
- Ministry of Industry and Information Technology (MIIT)
- Ministry of Environmental Protection (MEP)
- Ministry of Science and Technology (MOST)
- Ministry of Finance (MOF)
- the State Administration of Taxation (SAT)

Among all departments and bureaus, MOHURD is the leading authority in CDW management and recycling. (People's Republic of China: Construction and Demolition Waste Management and Recycling)

1.2 Regional Level

Some regions where are more advanced in circular economy and sustainability have their own state-level in order to fit the scenario.

Up to date, 14 provinces and 25 cities in China has established their own regulations and laws, which is 41% and 11% of the total provinces and cities correspondingly. (Research of Chinese construction waste resource utilization and recommendation) the following diagrams will illustrate the process of treating CDW both in Beijing and Shanghai due to different local regulations.

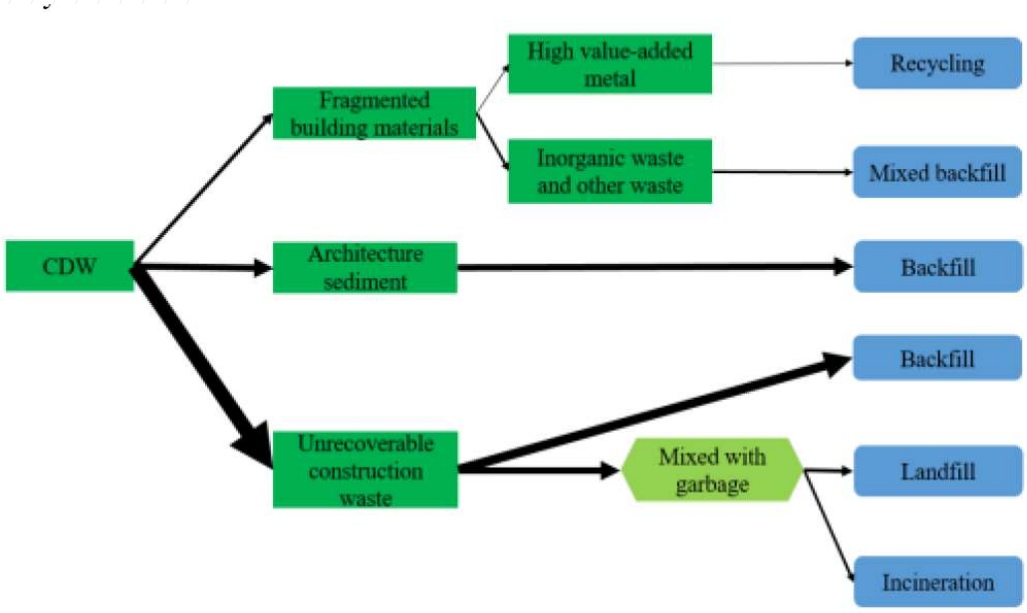


Diagram 1: Beijing Layout of CDW process

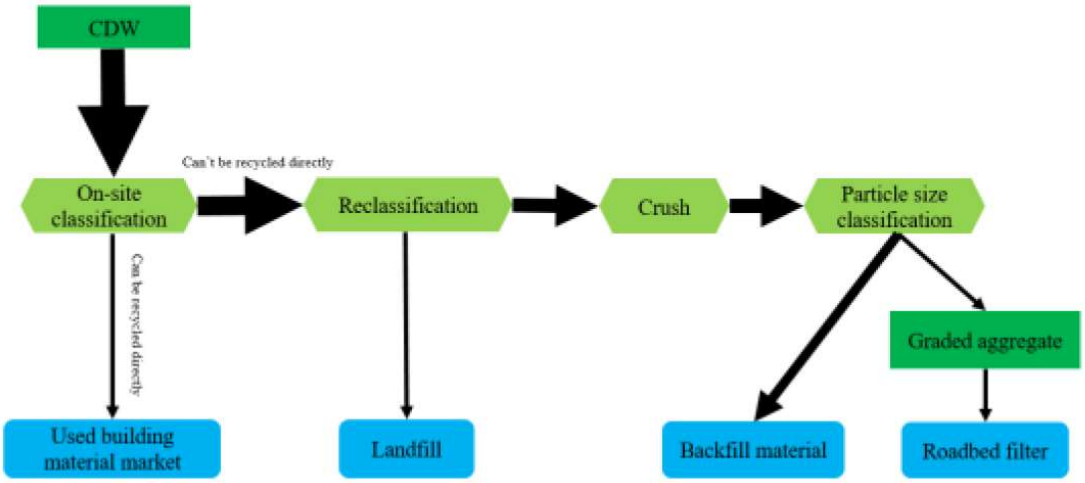


Diagram 2: Shanghai Layout of CDW process

1.3 Industry standard

The following table presents the standards has set up the guidance for what needs to be focused on for construction waste recycling ecosystem.

Table 1. The discharging standard of wastewater from infectious diseases hospitals.

Standard_English	Standard_Chinese	Classified No.
Construction Waste Treatment Technical Standard	《建筑垃圾处理技术标准》	CJJ/T134
Civil Engineering Onsite Green Execution Specification	《建筑工程绿色施工规范》	GB/T 50905
Civil Engineering Onsite Green Execution Evaluation Standard	《建筑工程绿色施工评价标准》	GB/T 50640
Green Building Evaluation Standard	《绿色建筑评价标准》	GB/T 50378
Onsite Execution Recycling and Reuse Technical Standard	《工程施工废弃物再生利用技术规范》	GB/T 50743
Concrete and Mortar-use Regenerated Fine Aggregate	《混凝土和砂浆用再生细骨料》	GB/T 25176

Concrete-use Recycled Coarse Aggregate	《混凝土用再生粗骨料》	GB/T 25177
Recycled Aggregate Technical Application Standard	《再生骨料应用技术规程》	JGJ/T 240
Reused Concrete Technical Standard	《再生混凝土结构技术规程》	JGJ/T 443
Recycled Concrete Combined Construction Standard	《再生混合混凝土组合结构技术规程》	JGJ/T 468
Recycled Aggregate-made Floor Tile and Water Permeable Brick	《再生骨料地面砖和透水砖》	CJ/T 400
Construction Waste-made Aggregate Solid Brick	《建筑垃圾再生骨料实心砖》	JG/T 505

2 Current Existing Challenges

Although China currently is putting more and more attention on construction and demolition waste management and investing heavily in corresponding technologies both financially and resource based, it still needs a long way to go until the ecosystem has been fully established.

The following two tables illustrates the current issue of CDW management in china in different perspecitive: process focused and method classification.

		current issue
upstream	Sources of CDW	Gaps of legal system and lack of supervision of the market
		Lack of appropriate provisions, randomly dumping hard to stop
		Unsorted CDW affects resource treatment costs and product quality
		Stakeholder Analysis
middlestream	Recycled CDW products	Management of construction waste transportation industry
		Difficulties in land use approval for CDW recycling
		Environmental assessment approval for CDW recycling project is difficult
		High costs and investment of CDW recycling
downstream	Utilization of Recycled CDW Products	Lack of mandatory regulations for recycled CDW products
		Lack of completed standards for recycled CDW products
		Lack of price competitiveness for recycled CDW products
		Traditional conception hinders the use of recycled CDW products

Table 2: Current issue statement by classifying in industry process

Reduce	Lack of Desgin Standards
	Finanical push to reduce CDW: low cost for CDW disposal
	Inappropriate Urban Planning
Reuse	Lack of guidance for collection and sorting
	lack of knowledge and standards for reused CDW
	Under-developed market for reused CDW
Recycle	Inefficient management system
	Immature recycling technology
	no financial benefit from Recycled CDW products

Table 2: Current issue statement by classifying waste treatment methods

To sum up, no matter how to classify, the major issues are:

- Lack of optimization of management in the CDW process
- Lack of efficient technology
- Not enough financial benefit to initiate the CDW process

3 Case Studies and Leading Companies

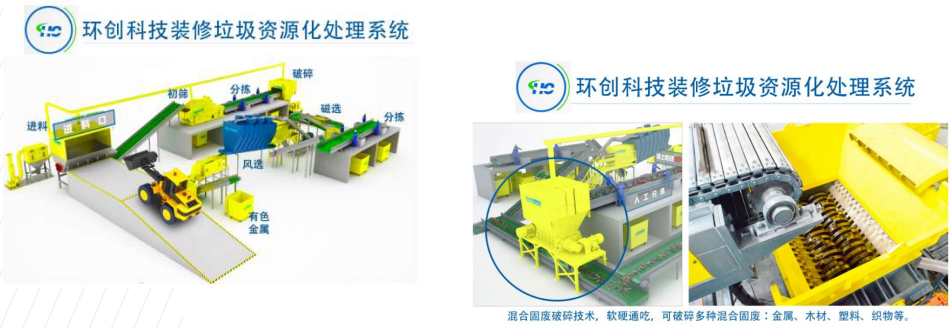
3.1 Zhejiang Hongxiang Environmental Industry co. LTD

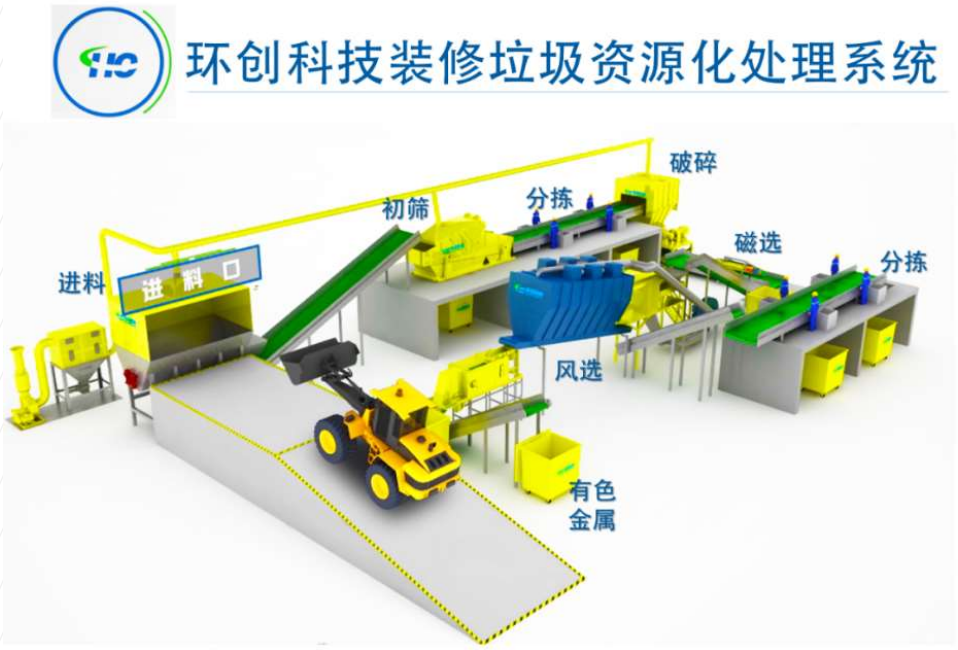
Zhejiang haining hongxiang group is one of the top 500 private enterprises in China. Its industries include construction, real estate, environmental technology and service industries.

The major technology is introduced from the United States. However, due to the complexity of decoration waste components, the traditional sorting and crushing effect of construction waste treatment equipment is not good, it is difficult to achieve the goal of resource utilization, so hongxiang environment integrated domestic and foreign well-known manufacturers, multi-comparison, chose the "decoration waste recycling treatment program" of environmental science and technology.

Currently, the zhejiang haining decoration waste recycling project designed and built by huanchuang technology has been put into operation successfully since 2018, and has been in stable operation for nearly two years. The processing capacity is up to 50 tons per hour. This project is the first project of private capital participating in the disposal of decoration waste under the PPP mode in haining, zhejiang province, and also the first project of deep

processing and utilization of decoration waste resources in China. Its comprehensive recycling resource utilization can reach 95%, dealing with building garbage capacity of 2 million cubic meters, 520 million a year to produce green brick block, recycled bituminous concrete 150000 square, reclaimed water and slurry 200000, obtained the good economic benefit and social benefit.





Picture: Illustration of the CDW treatment system

3.2 Rizhao Shuangzhu Building Materials Co. LTD

Rizhao Shuangzhu Building Materials Co., LTD was originally a cement factory in Liuguanzhuang town, which is currently mainly used to grind slag powder as the main production material, mainly added in the cement plant and mixing plant, cement than the surface fineness is less than 400 ㎡ / kg, we slag powder grinding to about 450 ㎡ / kg, add into the cement can increase the activity and strength of cement.

According to the introduction, the raw material that the enterprise produces needs is the scrap that the steel plant produces in the steelmaking process, basically take calcium silicate and calcium chlorate as the main component smelting material, the enterprise turns it into treasure, realized waste resources reuse.

3.3 Qingdao Beiyuan Environmental Protection Building Materials Co. LTD

Beiyuan is one of the model building material company advanced in construction waste recycling and reuse model and process.These solid waste will be crushed and processed into three types of ground material aggregate:high quality aggregate for concrete, general aggregate for roadbed cushion, stone slag for a variety of new environmental protection bricks. Company can deal with construction waste and tail are 5 million tons, the annual output of 3.5 million tons of recycled aggregates, 600000 tons of ready-mixed mortar, 1 million cubic meters of ready-mixed concrete and produce 250 tons of fully enclosed construction At present, the company has handled a total of 11.03 million tons of construction waste and tailings gravel.

4 ICDK Assessment

Since circular economy in construction waste is under development, which opens up a lot of opportunities.

- *Sophisticated working model*

Up to date, although a lot of governmental department are getting involved, it is not effective when it comes to executing level. In another word, the regulation is out, not many people are following it due to little attention and little punishment financial and political wise. It would be ideal if the experienced model for how to govern the construction waste from Denmark to adapt to the Chinese ecosystem.

- *Mature and adaptable technology*

Although Chinese government is putting a lot of effort on research in construction waste recyling, reusing and reducing, not many successful techniques are applied into Chinese scenario. It would be positive if Danish and Chinese corresponding governmental departments to cooperate in merging and adapting current market-proven technologies into foreign application by providing some pilot study areas.

- *Efficient financial output*

Also being sustainable is good for the environment, but no business will be sustainable financially if the business does not make profits. The current situation of recycled construction material is lacking of profit push. Although local government currently offers great financial support, it cannot be relied as the financial income. Great consulting service on circular construction would be good business area in the upcoming future.

Appendix 1

1. Utilization and Application of Construction Waste

At present, there are mainly two ways to reuse building materials: direct reuse and reproducing reuse. Direct reuse is mainly reusing the waste material without changing the material prototype. Reproducing reuse requires steps of treatment and reproducing in order to be elligbile for reuse. Comparing to direct reuse, the biggest disadvantage of reproducing reuse is not only large energy consumption, but also complex processing procedures.

2.1 Effective Utilization of Reclaimed Wood

As a typical traditional building material, the growth process of trees is influenced by the natural environment factors, but also has a very important impact change the natural environment accordingly. The construction industry requires a huge mount of wood resources in the process of development. Therefore, how to effectively increase the recycling and utilization rate of waste wood in the construction industry is the main problem at present. Most of the wood with good quality and integrity can be recycled and used directly. For example, most of the wood removed from buildings can be simply sorted and processed into reusable materials according to market demand. This is also the most direct and effective measure to realize the recycling of waste timber.In addition, by special design, the waste wood can also be used in the interior or exterior decoration of the building, which also illustrate the circular economy concept for people to apply in construction waste industry.

2.2 Effective Utilization of Reclaimed Bricks

As one of the important traditional building materials in China, with the continuous development of China's social economy and the acceleration of the urbanization process, abandoned bricks and tiles can be seen everywhere in cities or rural areas. If the bricks and tiles are piled up for a long time, the environmental pollution problem will become increasingly serious. Therefore, it is necessary to take feasible measures to recycle and utilize the waste bricks and tiles, so as to effectively solve the problem of waste clay bricks and tiles and save the consumption of natural clay and sand resources.

2.3 Efficient Use of Waste Concrete

After crushing and cleaning the disassembled waste concrete from the reconstructed building, the recycled aggregate can be formed according to a certain proportion, which is applied to the construction of the building by adding cement mortar and mixing to form concrete, thus realizing the purpose of replacing the natural aggregate. Will waste clay brick crushing for 5-31.5 mm diameter particles can be used as the coarse aggregate mixed concrete, while the aggregate particle diameter less than 5 mm can be used as fine aggregate to replace sand, through the basic performance of aggregate after testing found that not only waste clay brick aggregate with low density, high strength, bibulous rate is higher remarkable characteristics, and its basic performance straightforward completely meet the requirements of the lightweight aggregate is related indicators. Therefore, the waste clay bricks generated by the building can be used as recycled

lightweight aggregate for benefits. For grain diameter smaller powder, can be used for building mortar, it not only realized the purpose of reducing building mortar production cost, reduced the usage of natural sand resources, maximum limit reduces the waste clay brick also piled up on the environment caused by pollution for a long time, for the sustainable development of construction industry laid a good foundation.

2.3.1 Selection of waste concrete treatment

2.3.1a as recycled cement raw material

Part of the calcareous raw materials and siliceous raw materials contained in the waste concrete and the hardened cement slurry are dehydrated at high temperature to form oxides such as calcium oxide, silicon oxide and iron oxide, which are all necessary for the manufacture of cement. Wan huiwen et al. [9] used some waste concrete as calcareous raw material to replace 60% of limestone in the laboratory, and calcined out cement clinker with strength up to 47.4mpa. However, with the increase of the replacement ratio of waste concrete, the quality of cement clinker becomes worse. This is mainly because the river sand in the unseparated waste concrete contains SiO2 with poor activity (mostly crystallized SiO2), which makes the raw materials difficult to grind and burn, and the f-cao content of clinker increases, resulting in poor quality.Yuan Qitao etc. [10] will give priority to with limestone of waste concrete crushing, isolated from the waste concrete particles as raw material, the calcium to replace natural limestone, calcining of cement clinker and cement clinker market is no obvious difference, but the content of C3S is relatively small, its 3 d low compressive strength, strength of 28 d and commercially available p. O42.5 cement.

2.3.1b as recycled cement mixing material

The mortar in the concrete raw material accounts for about 25% of the total concrete, among which the mortar also includes fine aggregate, cement, auxiliary cementing materials, hydration products and unhydrated cement (auxiliary cementing materials) particles. In low water/cement ratio and high waste concrete strength grade, the amount of hydration of cement to even reach more than 30% of the dosage of cement, this part of the hydration of cement in concrete not only ACTS as a micro aggregate, did not play its hydration activity, if these are not the hydration of cement and auxiliary gelled material contact with water, can continue hydration reaction, give play to the role of gelation.Therefore, the mortar in waste concrete can be used as cement mixture and concrete admixture after treatment and grinding. Tian fang et al. produced grade 42.5 cement by adding 10% waste concrete grinding powder (as mixed material), and grade 32.5 cement by adding 20% waste concrete grinding powder (as mixed material). They pointed out that silicate activators have a good excitation effect on the waste concrete grinding powder, among which the appropriate amount of Na2SiO3 activator is about 1%;The excitation effect of NaOH activator was not obvious.With the increase of the content of grinding powder of waste concrete, the strength of cement mortar decreases.

2.3.1c Use of Recycled Concrete Production

Recycled concrete refers to the concrete made by partially or completely replacing the natural aggregate by using recycled aggregate (the waste concrete blocks are sorted, broken, cleaned

and screened and classified, and the aggregate produced by combining them in a certain proportion is divided into two types: recycled coarse aggregate and recycled fine aggregate). According to the types of recycled aggregate used, recycled concrete can be divided into recycled coarse aggregate concrete (only recycled coarse aggregate), recycled fine aggregate concrete (only recycled fine aggregate) and recycled coarse and fine aggregate concrete (both recycled coarse aggregate and recycled fine aggregate).

The performance of concrete depends on the raw material, mixing ratio and preparation process of concrete. Among them, raw materials and mixing ratio are the most important factors. The mix design of recycled concrete is very important to the quality of recycled concrete.M. c. limbachiya et al. studied the mix ratio design of high strength recycled aggregate concrete and determined the appropriate water cement ratio by using the established relationship between the strength of 28 days and the water cement ratio.It is found that the recycled aggregate has no effect on the strength of concrete when the replacement rate is less than 30%.Zhou jinghai et al. prepared recycled aggregate by crushing waste concrete, soaked the recycled aggregate with water slurry, and made recycled concrete by referring to the design method of mixture ratio of ordinary concrete, and conducted experiments on the concrete with different replacement rates of recycled aggregate. The test results show that the compressive strength, splitting tensile strength, bending strength, failure process, failure form and stress-strain curve of recycled concrete are basically the same as those of ordinary concrete.The compressive strength, elastic modulus and splitting tensile strength of recycled concrete are all reduced compared with that of ordinary concrete, but when the replacement rate of recycled aggregate is 50%, the cube's compressive strength is increased by 2% compared with that of 30%, and higher compressive strength can be obtained.They point out that it is not suitable to calculate the tensile strength and elastic modulus of recycled concrete by the formula of "code for design of concrete structure", and put forward the formula for calculating the tensile strength and elastic modulus of recycled concrete.

In addition, many scholars have conducted experimental studies on the durability of recycled concrete such as frost resistance and carbonization resistance. Shang yongkang studied the freeze-thaw durability of recycled concrete and its mechanical properties after freeze-thaw. Through test of gas aggregate (native concrete mechanical crushing, sieving and two types of recycled coarse aggregate air-entraining ARG recycled coarse aggregate and the bleed air of recycled coarse aggregate NRG) is below the air-entraining recycled concrete aggregate and recycled concrete frost resistance, and get the peak stress of concrete after freeze-thaw lower and peak strain increase, the peak strain recycled concrete is greater than that of natural aggregate concrete conclusion.Through experimental research, lei bin et al. concluded that the carbonation depth of recycled concrete increases with the increase of the replacement rate of recycled coarse aggregate. However, when the replacement rate of recycled coarse aggregate is greater than 70%, the carbonation depth of recycled concrete decreases.The carbonation depth of recycled concrete decreases with the increase of the original concrete strength, and the carbonation depth of recycled concrete increases when brick aggregate is added into the recycled coarse aggregate.

2.3.1d Use of Wall Brick Production

In order to promote the development and application of new wall materials, protect land resources and ecological environment, save energy and waste, and build a conservation-oriented society, the state vigorously advocates the research and development, promotion and application of non-clay brick wall materials. At present, there are concrete blocks, aerated concrete blocks, slag concrete blocks and so on. Recycled aggregate made from waste concrete after crushing can be used to produce building materials such as concrete block bricks, paving bricks, and patterned bricks, as well as hollow concrete blocks. Yang jiujun et al. [18] made composition analysis and chemical activity evaluation of the grinding powder of construction waste (waste brick and waste concrete), and took it as the main raw material (more than 80%) to prepare non-steamed building waste wall bricks by pressing and shaping and natural maintenance. The results show that: the pulverized powder of the waste brick and the waste concrete powder have certain reactivity, and the active SiO2, Al2O3 and CaCO3 of the waste brick can form CSH gel and AFt with Ca(OH)2 after calcination at high temperature.The activity of waste concrete powder comes from minerals such as calcium silicate hydrate, which can be used as embryos to promote the continuous hydration of unhydrated cement clinker particles. The fine sand and fine aggregate in the matrix cementing component (MCC) of the waste concrete can also improve the strength of the brick, so it is a good renewable resource. Xu lina et al. [19] put the waste concrete into a heating furnace and heated it to 1000 □ for 5h after cleaning the debris, and then cooled it with the furnace. After being crushed and treated with 100 livm screen, an appropriate amount of fly ash and water are added to mix evenly and then molded on the press (60MPa). Semi-dry pressed brick samples were obtained by steam curing or autoclave curing at different temperatures. The compressive strength of the brick increases with the increase of curing temperature and the time required to reach the maximum strength is shortened. When the curing time reaches a critical value, the strength no longer increases obviously. Alkali excitation can improve the early strength of semi-dry pressed brick, but has no effect on the late strength of semi-dry pressed brick. The compressive strength and freezing resistance of the semi-dry pressed brick are in accordance with the relevant standards.

2.3.1e Use of Foundation and Road Bedding

It is the most common reuse method of waste concrete in China to use the recycled aggregate from the broken waste concrete as the aggregate of building foundation cushion or road base. When recycling, as long as the ordinary jaw mill is used for rolling, the out-of-limit particle size is screened out and re-processed, so that the recycled aggregate can be obtained to meet the requirements, simple operation, convenient material preparation, significant economic effect. In practice, according to the test rules for the stable materials of inorganic binders in highway engineering, the qualified cement is used as the binders, and the compaction experiment and the static compression molding experiment will lead to different degree of crushing of the recycled aggregate, resulting in the internal defects of the recycled aggregate, resulting in the increased dispersion of the test data of the molded specimens. When the raw materials, gradation, cement content and curing conditions are the same, the compressive strength of the specimens varies greatly. It was found that if the method of vibration compaction was adopted and the reasonable

process parameters were selected, the defects could be avoided. The strength and variability of the specimen met the requirements of the highway base standard.

Ways of Construction waste disposal

Mobile processing

Construction site conditions permitting, construction enterprises can according to own actual situation, in the construction engineering construction site configuration mobile construction waste disposal equipment, used in construction waste on the processing and use, this not only effectively reduce the burden of the construction waste sinotrans, but also promote the effective improvement of economic benefits. For example, in the process of building a new factory, a steel enterprise introduced a construction waste recycling enterprise to carry out the recycling of construction waste. According to its actual situation, the company has introduced large crushing and grading production equipment and precast concrete block production equipment to the construction demolition site, which can process about 2,000 tons of construction waste every day. Up to now, the production equipment introduced by the company has processed about 90,000 tons of construction waste accumulatively. With the wide application of these materials in the construction of auxiliary roads in municipal engineering, the goal of zero discharge of construction waste has been achieved and considerable economic benefits have been achieved.

Fixed processing

If the site can't meet the requirements of construction waste comprehensive treatment, so must make the corresponding evaluation, analysis, and then the building waste transport to different construction waste disposal company to carry on the corresponding processing, while the government may, according to the actual situation of regional economic development, building construction waste centralized processing center, a unified centralized processing of construction waste. Fine classification of construction waste is an important means to promote the limited promotion of the application value of construction waste smell. Due to the various types of construction waste, it is impossible to carry out the corresponding pre-classification treatment. For example, in the construction waste for making recycled aggregate, there are not only discarded concrete but also broken brick, ceramics, wood, glass, rubber and other wastes. So, in order to ensure that improving the quality of the recycled building aggregate, and must be in the process of production and processing, renewable building aggregate must be broken equipment, screening equipment, transmission equipment together, do together construction waste such as screening, crushing process, can fundamentally promote improved production quality of recycled aggregates. In addition, electromagnetic sorting equipment and vibration sorting equipment can also be used to promote the steady improvement of the quality and efficiency of the sorting of construction waste.