

Promoting Application of Recycled Aggregate in Public Construction

—— Taoyuan, Taiwan



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Taoyuan and its urbanization process

Taoyuan City is a municipality directly under the jurisdiction of Central Government of Taiwan. It is one of the six municipalities in Taiwan, having been that status in 2014. It is a dual-core city located in the northwestern part of the country. It is a member of the "Capital Life Circle" and "Taoyuan, Hsinchu and Miaoli Life Circle" and has the fifth-largest number of established household registries in Taiwan. It is adjacent to the Taipei Metropolitan Area and boasts a number of major public buildings and investments. Having Taiwan's largest international airport, Taoyuan City has developed rapidly in recent years and the budget has also reached a record high every year, growing beyond NTD110 billion in 2019. Thus, Taoyuan City is experiencing a golden age of construction. In addition to major projects such as the Taoyuan Aerotropolis, Railway Underground and MRT Green Line, Taoyuan City Library, Taoyuan Convention and Exhibition Center, MRT Blue Line A20 and A21 stations, and other large sports events in the southern urban park and more will be granted accelerated development over the next few years.

City Profile



Area: 1,140 km² (440 sq mi)

Population: 2,245,059

Linking SDGs



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Project Duration:

From July 2017 to May 2018

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Engineering organizations and environmental protection agencies often have difficulty in understanding each other as they persist in advocating only for their own ideas. However, in order to support a circular economy as per central government policy, the departments and civil servants in the Taoyuan City Government pay more attention to sustainable development and the original goal of serving the people, so that the Department of Public Works and the Department of Environmental Protection communicate and cooperate efficiently, and find the best pipeline for private enterprises to solve their problems.

In addition, there are two domestic universities and colleges with a long history in Taoyuan City -- National Central University and Chung Yuan Christian University. The history of the civil engineering department of both of these schools spans over 50 years. Each has earned such accolades as being ranked in the top four universities and most preferred private university by corporations. Taoyuan City has the advantage of leading other counties and cities regardless of the academic field or practical application. Due to the above conditions, Taoyuan City implemented a circular economy around public works, which enabled the various central government policies and the Taoyuan City system to be promoted.

Sustainable challenges arising from rapid urbanization in Taoyuan

The following presents sustainable challenges that Taoyuan is facing due to rapid urbanization:

1. There is no place for commercial waste after steel production.

Taiwan's steel industry produces about 21 million metric tons of steel per year, with an output value of about NTD 950 billion. At the same time, 3 million metric tons of slag is predicted to be created, although facilities for dealing with it do not currently exist. Because of the limited storage space for manufacturers, they will be forced to cut production. Industries such as electronics and automotives, among others, indirectly pose serious problems for our country's economy and livelihoods. Difficulties with recycling slag domestically has caused the public to be unable to fully understand the issues regarding slag, making it more difficult to dispose of.

2. Taiwan Asphalt Industry Association reflects the problem of asphalt concrete planning

At present, domestic road repair works will generate at least 3 million tons of asphalt concrete (about 300,000 tons in Taoyuan City specifically). However, according to existing road engineering construction regulations, regenerated asphalt concrete can only be incorporated at a rate of 40% for road repair works; in other words, 60% of the new asphalt concrete material may not be removed. The asphalt plants in all counties

and cities in our country are facing the problem of materials piling up without an easy method for removal, which affects the plants' operations. It is difficult to deal with engineering construction dilemmas, and if it continues to pile up, it may incur sanctions or other punishment from government or industry institutions, putting this industry in a very difficult situation. Thus, the Taiwan Asphalt Industry Association has also invited the Public Works Construction Committee of the Executive Yuan to pay attention to the problem of recycled asphalt concrete planning.

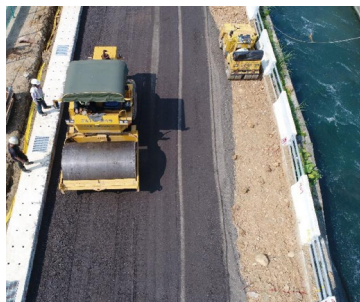
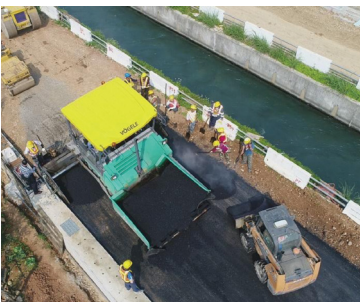
3. A garbage war has occurred among the southern county and city governments

The people's daily waste is reduced in volume after incineration. However, problems with storage space persist as the bottom slag produced after incineration has not generally been removed. People worry about a repeat of issues we faced in 2015, when waste had nowhere to go in Taichung, Changhua and Nantou. Thus, the removal of incinerated waste for recycled aggregate is an urgent issue to be resolved in our country.

4. Traditional asphalt industry concepts are deeply rooted

People are afraid to refuse to use the new materials--steel particles (oxidized slag) because the traditional asphalt industry is generally faced with several issues, including a lack of familiarity with the basic properties of new materials, the need to adjust factory storage space, and problems surrounding air pollution, such as the need to obtain a fixed pollution source operation permit, etc. Although incinerating recycled aggregate (ICA) have been used in the basal layer of pavement, the incinerating recycled aggregate are light in weight, more brittle, high in wear rate. This leads to a lack of incentives to use them, and the public is not familiar with the characteristics of these particles. The use of incinerating recycled aggregate in public works is difficult to promote.

Therefore, we should reduce waste generation through prevention, reduction, recycling and reuse, and use the circular economy concept for recycling and reuse to convert waste from the steel industry into mixed-grade materials for the asphalt industry.



The Shimen Canal patrol road was putting asphalt concrete planing particles into the basal layer.(left)

The Shimen Canal patrol road applied asphalt concrete planing particles in the basal layer rolling and pressing operation. (right)

Promoting the application of recycled aggregate in public construction

Solution	Description
<p>Traditional concepts need to change</p>	<p>Before achieving concrete results, the challenge is to persuade the asphalt manufacturers to eradicate doubts regarding the use of steel particles (oxidized slag) and coordinate the environmental protection departments. After a full consultation, at least three asphalt plants in the city have obtained operating licenses for fixed pollution sources and promoted them in a comprehensive way. This has made Taoyuan City the first county and city government in the country to reach a consensus with civil society regarding these issues for decades. The use of incinerating recycled aggregate is based on the concept of creating a suitable material for various applications, and has been applied to soil stabilization. For example, incinerated regenerated particles containing lime elements can improve soil quality, which enhances the willingness of sponsoring agencies and manufacturers to invest in such uses.</p>
<p>New materials require design ratios</p>	<p>(1) Steel particles (oxidized slag)</p> <p>Because the weight of steel particles (oxidized slag) is higher than the weight of ordinary natural particles, in order to obtain a more correct proportion of use, it is necessary to conduct tests through laboratory materials, meet with experts to provide feasible test data and empirical solutions, and then conduct tests for effectiveness. In order to ensure quality control of the steel particles' (oxidized slag) source and to clarify future use strategies, the "Material Plan Provision" is specified in new construction regulations.</p> <p>(2) Asphalt concrete planing particles</p> <p>The original pavement material is asphalt concrete used to remove particles, after which the crushing process will create issues of graded degradation. The particles are coated in oil, which makes reuse difficult. Therefore, natural fractionation and remixing is used to create fractionated particles. Therefore, even if the outer layer is coated with oil, the classification function is not affected. This can be used to replace finer particles after passing basic performance tests such as the Los Angeles Wear Test.</p> <p>(3) Asphalt concrete planing particles</p> <p>The nature of the soil is complicated by various factors. Due to regional ecological differences, the incineration of regenerated particles is slightly different in the chemical composition after sintering. Through experiments, the typical red soil in Taoyuan and the burnt and regenerated particles of the Guanyin ash slag treatment plant in Taoyuan City were mixed. After observing the reaction mechanism and statistical data, the results of stabilizing the soil were significant, and then the optimal application ratio was applied to each application project.</p>
<p>Applied to trial roads</p>	<p>The steel particles (oxidized slag) have been laid on the pavement of Fengde Road in Bade District, and the patrol road of Shimen Canal in Pingzhen District in Taoyuan City. Through the exchange of opinions among industry professionals, official and academic teams, the chances that trials will be successful have been improved. In addition, the results will be promoted through seminars and forums to allow more private enterprises and public agencies to participate in the implementation of the circular economy.</p>

Results

Use of project funds

Since August 9, 2017, the city has entrusted the Chinese Society of Pavement Engineering to carry out the Strategy and Specification Revision Service for the Regenerating and Reusing Materials in Public Works in Taoyuan City with a bid of NTD898,000. The work items included seven meetings of experts and scholars (including normative discussions, feasibility of trial

projects, pavement planning), supporting related experiments, seminars, and promotion of education and training. In order to solve the problem of millions of asphalt concrete remaining in asphalt plants for decades and the difficulty of re-construction of the asphalt plants, they will implement a procurement case of less than NTD1,000,000 over six months.



The trial road with oxidizing slag pavement completed on Fengde Road, Bade District. (left)

The improvement project from Wushou Street to Fuling Road has applied asphalt concrete planing particles as basic layers. (right)

Energy saving and carbon reduction

Currently, it is common to use steel particles (oxidized slag) with a 30% substitution of the natural fractionation. Doing so saves about 6.24 Kg CO₂e per ton in terms of carbon footprint. The Taoyuan City Office of Road and Accessory Maintenance conducted an oxidized asphalt concrete pavement trial project on Fengde Road, Bade District, Taoyuan City as a case study, using 1,300 tons of steel particles (oxidized slag). The carbon footprint was reduced by about 8,112 Kg CO₂e, equivalent to one year of carbon dioxide absorption for 740 trees.

Save engineering costs

Steel particles (oxidized slag) is a free material, so 30% of oxidized slag fine particles added to asphalt concrete is calculated to save NTD2,145 per cube compared to new asphalt concrete (about 29% per cubic meter). The market price of natural stone grading is about NTD630. The asphalt concrete planning particles need to be crushed, sifted and mixed before use, and can only be used instead of finer granules. Therefore, after calculating this, about NTD24 (about 4% per cubic meter) can be saved. Incinerated recycled particles are provided freely to the sponsoring agencies by the Department of Environmental Protection of the Taoyuan City government for quality control. Compared to the cost of original replacement of earthwork, and the cost of soil improvement for incineration of recycled particles, NTD530 (about 62%) can be saved per cubic meter.



ICA were used for soil-strength mixing and backfilling in Fuyuan Park for rolling and pressing operations.(left)

ICA were used for soil-strength mixing and blending.(right)

The success of Public-Private Partnerships

1. Government Agencies: Public Works Construction Commission of the Executive Yuan and Taoyuan City Government

The Taoyuan City government took the lead in conducting the trial process of incorporating regenerated particles in public works and used their results and experience to revise construction specifications. Then, the city Government standardized the construction guidelines for the Public Works Construction Commission of the Executive Yuan for reference and use throughout the country. During the trial process, the Taoyuan City Department of Public Works and the Department of Environmental Protection worked together to find solutions to the transaction data change application issue faced by asphalt producers to ensure that the operations were carried out smoothly, and that they were not delayed by cumbersome administrative processes.

2. Academia: Chinese Society of Pavement Engineering

Experts were invited to share their experiences with the trial operations and the analysis of various projects in the laboratory. They recommended conducting pavement trials as part of three different projects. In addition, they also made the design and analysis process into a simple manual, so that the design unit can follow their design methodology.

3. Asphalt Plants, Asphalt Industry Association and Reusing Agencies

In line with the promotion of national recycling economy policies and the need to overcome the necessity of regenerating and reusing particles, private asphalt plants and regeneration facilities have added new equipment and adjusted production processes. This shows that private industries and the government have reached a consensus and endeavor to work together to reach common goals.



The Forum of Regenerated Particles “Tea Party” was held on September 14th, 2018.

4. **Taiwan Steel and Iron Industries Association**

In order to remove the waste generated during the steelmaking process, the Taiwan Steel and Iron Industries Association actively cooperates with the Taoyuan City government to check the quality and assist in water quality testing operations so that the data may persuade the environmental protection groups and the public.

5. **Public Agencies' Visits and Active Promotion**

Many other local government representatives have visited Taoyuan for experience-sharing purposes: The Tainan City government came on December 14, 2018; Taipei City government on May 15, 2019; the Chiayi County government on May 9, 2019; and the Construction and Planning Agency of the Ministry of the Interior on May 10, 2019. The Taoyuan City government will reduce 100,000 tons of recycled industrial materials per year. The program will be extended to various counties and cities, and the amount of oxidized slag and particle removal will be increased by hundreds of tons.

Reflections and the road ahead

1. **There are cross-domain coordination and integration difficulties.**

It is difficult to coordinate across organizations due to waste particle handling issues. Therefore, it is necessary to establish regulations through cross-domain coordination, such as cooperation between administrative agencies. In addition, road excavation management centers, industrial unions, steel plants, asphalt plants and waste incineration plants must work together to form new upstream, midstream and downstream industrial chains to address the problem of waste particles having nowhere to go.

2. **There is a lack of construction specifications and success stories**

Regenerated particles are used in road engineering due to a lack of construction specifications. There are no relevant successful engineering cases in our country for reference, so it is difficult to promote. It is necessary to start with institutional initiatives. Thus, the Taoyuan City Department of Public Works, the Taiwan Construction Research Institute, and the Public Works Construction Commission of the Executive Yuan will formulate, review and approve design and construction specifications for compliance.

3. **Factionalism of public agencies and public awareness generally do not support**

In the past, the public agencies paid too much attention to factionalism and did not dare to challenge conservative thinking. That's because once any issue arose, it was necessary to bear "responsibility." Furthermore, some people still have doubts about the use of regenerated particles in pavement and road engineering. They are worried that the particles are



Pilot road with oxidized slag was paved on Fengde Road, Bade District

toxic and polluting. There were obvious rust spots and the result was not aesthetically pleasing when one county or city government has used oxidized slag for road paving. People's initial impression was not good, so they generally did not support continuing the project after this initial trial.

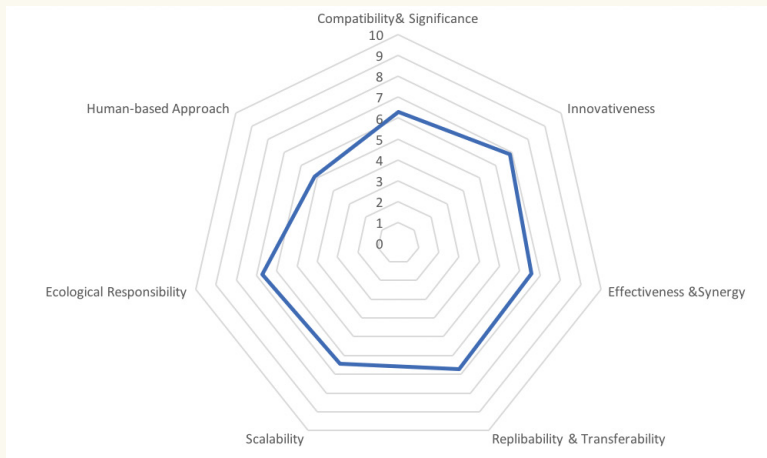
4. Advise other cities or explain any future plans or concepts related to the project

3,283 kilometers of road are under the jurisdiction of the Taoyuan City Government, with an area of about 41,483,000 square meters (20,761,000 in city roads and 20,722,000 in local roads). If waste particles that have been difficult to treat for some time can in fact be treated (oxidized slag, asphalt concrete planing particles, incinerating bottom slag, etc.) to appropriate specifications, they can be used for mixing in asphalt concrete for paving roadbeds, road surface layers, or emergency road pit repairs, which will effectively remove waste particles. In order to re-use resources such as waste, it may be gradually applied to public works. This can help us achieve the policy goal of national development and takes circular economy policy goals into account.

According to the Taiwan Industry Asphalt Association, asphalt concrete planing particles have exceeded 3 million tons and Taoyuan City has replaced 1,600 tons of asphalt concrete. At present, the plan is for it to be used in bottleneck roads and rezoning areas at a replacement rate of 33,500 tons. If it is applied to the Aerotropolis road, it is expected to replace 1.65 million tons of asphalt concrete.

In the future, we plan to establish a regenerative particles and life cycle management platform (a form of traceability management). Through the construction of platform modules, and using the circular economy materials actively promoted by various engineering units in Taoyuan City, the back-end management platform will be tracked, analyzed and managed. The benefits of the circular economy are also used as a comprehensive performance evaluation platform for future integration, and the use rights are granted to the sponsoring agencies and factories to enhance the correctness and application of the platform.

Evaluation



- The initiative of promoting the application of recycled aggregate on public construction is considered a great innovation. The project successfully turned the waste into a usable component of oxidized slag pavement instead of using asphalt pavement or asphalt concrete fine materials.
- Though the scale is not big enough, the plan could reduce many problems of the construction industry, especially on asphalt. The remarkable things from this plan are energy saving, carbon reduction, and engineering cost reduction.
- Standardization is needed for the plan so it could be easily adopted in other places in the world.
- This case showcases a very technical solution to circular development. It would be worth knowing whether the solution can be applied in different cities and easy to replicate.