Research on the Recycle of Different Materials from Demolition Waste

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Abstract: Nowadays, with the reduction of energy sources and deterioration of the natural environment, people pay more and more attention to infrastructure sustainability. It is because a large part of the pollution comes from the construction industry. There are lots of construction and demolition (C&D) waste produced every year. This paper analyzes the recycle of aggregates, asphalt, plastic, glass, ferrous metal, and wood and discusses and compares the future of recycling these materials.

1. Introduction
The construction industry always has a huge influence on the environment. In developed countries, energy consumption of buildings accounts for 20-40% of total energy[1]. It is even more than industry and transport figures in the USA and EU. Therefore, infrastructure sustainability has become a more and more serious problem. People notice that it is important to save resources and protect the environment. The United Nation Millennium Ecosystem Assessment announced that the current rate of consumption of natural resources does not support renewal to meet the needs of future generations[2].

Since building infrastructure produces much less waste then dismantling infrastructure, developing reuse and recycling materials is a very important part of reducing the waste. In particular, a traditional way to demolish all building material together will make a waste stream. It is difficult to recycle. Thus, it is significant to research the construction waste recycling technology. This paper analyzes the recycle of different materials.

2. Demolition Waste Materials
Construction and demolition waste materials are collectively called “C&D waste”. Though they share the same term, they are two different parts. One reason is that construction usually uses the new and available materials, but demolition usually demolishes old materials. Demolishing old constructions may have both materials people use today and materials people have not used for a long time. As discussed in the introduction, demolition of these kinds of constructions will make a waste stream. For example, asbestos is a material people used forty years ago, but now it is regarded as hazardous waste[3].

Table 1 shows in 2001, ferrous metals accounted for 45.5% of the total amount of recyclable materials, 803,190 tonnes, and 37.7% of wood and paper production, 665,539 tonnes. Non-ferrous metals have a high value recoverable amount, the value is 1 billion[7].
Table 1. Quantities of solid waste disposed of at landfills in 2001 (EPD, 2002)[7]

| Category of recyclable materials       | Quantity (tonnes) | Value (HK$ thousand) | Value per unit weight (HK$/tonnes) |
|----------------------------------------|-------------------|----------------------|-----------------------------------|
| **Ferrous metals**                     |                   |                      |                                   |
| Alloy steel scrap                       | 16471             | 72171                | 4382                              |
| Pig or cast iron                       | 42970             | 46667                | 1086                              |
| Tinplate                               | 572               | 1134                 | 1983                              |
| Other scraps                           | 743177            | 606669               | 816                               |
| Sub-total                              | 803190 (45.5%)    | 726641 (27.9%)       | 905                               |
| **Non-ferrous metals**                 |                   |                      |                                   |
| Aluminum                               | 17044             | 69285                | 4065                              |
| Copper and alloys                      | 47580             | 296645               | 6235                              |
| Lead                                   | 2785              | 4424                 | 1589                              |
| Metal ash and residues                 | 226               | 13144                | 58159                             |
| Nickel                                 | 63                | 1273                 | 20206                             |
| Precious metal                         | 117               | 656386               | 5561037                           |
| Tin                                     | 2                 | 39                   | 19500                             |
| Zinc                                    | 1270              | 11251                | 8859                              |
| Sub-total                               | 69087 (3.9%)      | 1052447 (40.4%)      | 15234                             |
| **Plastics**                           |                   |                      |                                   |
| Polyethylene                           | 115653            | 124594               | 1077                              |
| Polystyrene and copolymers             | 18445             | 48076                | 2606                              |
| Polyvinyl chloride                     | 2234              | 5065                 | 2267                              |
| Others                                 | 71401             | 120381               | 1686                              |
| Sub-total                               | 207733 (11.8%)    | 298116 (11.4%)       | 1435                              |
| **Textiles**                           |                   |                      |                                   |
| Cotton                                 | 16539             | 25746                | 1557                              |
| Man-made fibres                        | 57                | 295                  | 5175                              |
| Old clothing and other textile articles, rags, etc. | 3434 | 11700 | 3407 |
| Sub-total                              | 20030 (1.1%)      | 37741 (1.4%)         | 1884                              |
| **Wood and paper**                     |                   |                      |                                   |
| Paper                                  | 657336            | 487785               | 742                               |
| Wood (include sawdust)                 | 8203              | 4274                 | 521                               |
| Sub-total                              | 665539 (37.7%)    | 492059 (18.9%)       | 739                               |

3. The Environmental Problem
Nowadays, the environmental problem is one of the most important problems in the world. Table 1 shows in 2005, there is 38% of waste generated by construction projects, that is, about 6,408 metric tons of waste are generated by construction projects each year.
### Table 2. Quantities of solid waste disposed of at landfills in 2001 From the statistic of EPD (2005)[7]

| Waste type                                           | Quantity (tpd) |
|------------------------------------------------------|----------------|
|                                                      | Public | Private | Total |
| (a) Domestic waste                                   |        |         |       |
| Waste from household, public cleansing                | 5822   | 1644    | 7466  |
| Bulky waste                                          | 28     | 57      | 85    |
| Sub-total                                            | 5850   | 1701    | 7551  |
| (b) Commercial waste                                 |        |         |       |
| Mixed waste from commercial activities               | –      | 1120    | 1120  |
| Bulky waste                                          | –      | 68      | 68    |
| Sub-total                                            | –      | 1187    | 1187  |
| (c) Industrial waste                                 |        |         |       |
| Mixed waste from industrial activities               | –      | 534     | 534   |
| Bulky waste                                          | –      | 28      | 28    |
| Sub-total                                            | –      | 562     | 562   |
| (d) Municipal solid waste received at disposal facilities (a + b + c) | 5850   | 3450    | 9300 (55%) |
| (e) Construction and demolition waste (landfilled)   | –      | 6408    | 6408 (38%) |
| (f) Special waste (landfilled)                       | 502    | 607     | 1109 (7%) |
| (g) All waste received at landfills (d + e + f)       | 6352   | 10465   | 16817 |

4. Construction waste recycling technology

#### 4.1. Aggregates

Since C&D waste has lots of aggregates, it is always an important material to reuse. Recycled aggregates are usually used for construction of roads and other infrastructure as loose fill[3]. With the development of technology, people begin to be interested in aggregates from recycled construction. Recycled precast elements and cubes and demolished concrete buildings can produce recycled aggregate concrete[4]. What is more, the recycled aggregate concrete is different with conventional natural aggregates. Recycled aggregate concrete is mainly composed of three stages consisting of aggregate phase, mortar phase and the interface transition zones between coarse aggregate and matrix, and a adhered mortar for another matrix[8]. Figure 1 shows the differences between natural aggregate concrete and recycled aggregate concrete.

Recycled aggregates comes from different materials. The type, strength and size of the materials will affect the physical parameters of recycled aggregates. Therefore, it is important to identify the attributes of the materials.
4.2. Asphalt
In England, there are about 95% of roads paved with asphalt mixture. Its maintenance and construction need lots of aggregates. It is estimated that England produces about 26 million tonnes of hot mix asphalt (HMA)[5]. There are some solid waste materials that can be reused, such as waste glass, steel slag, tyres and plastics.

In the Netherlands, 50% of waste was used to produce new asphalt and there were 10-15% recycled asphalt added to new asphalt in 1990[6]. The rest of the broken asphalt can bond to cement and replace the sand or cement base. The old asphalt material is crushed and recycled as asphalt aggregate, then mixed with sand and binder. A binder may be a liquid in the form of cement or asphalt emulsion. A combination of cement and liquid binder can also be used[7].

4.3. Plastic
It is still important to dispose though plastic typically accounts for only 1% of construction and demolition waste[3]. Plastics take centuries to biodegrade, and when plastic waste is incinerated or buried, the chemicals it contains pose a serious threat to air and water quality. Once plastics are disposed, there will be a huge influence on the environment. Here are some applications of reusing plastic:

- Panels: recycled plastic can only be used in lower face due to it has lower quality than new roofing element. After grinding at low temperature, the panel becomes powder. Then mix the powder with plasticizers and other materials to produce new panels[7].
- Generate Electricity: waste plastics has huge potential to generate electricity.
  Recycled plastic can be used in specific produce which is designed for recycled plastic, such as roof and floor, piling, noise barrier, cable ducting and pipe, cladding and insulation foam, street furniture, PVC window, and panel.
- Artificial soil: In Japan, waste plastic is burned at high temperatures and then turned into ultra-fine particles[7].

4.4. Glass
Glass can be reused in the construction industry. In 1997, the British glass industry recycled 425,000 tonnes of glasses. America, Japan and Germany each have recycling rates of 20%, 78% and 85%. Nevertheless, Hong Kong only has a 1% rate of recycling[7]. Here are some applications of reusing glass:

- Windows: glass window unit can be reused if it does not break during the demolition.
Filling material: Recycled glass was used in The UK as a fine material called “ConGlassCrete” as an alternative to cement, to improve the strength of concrete[7].

Ceramic tiles: 100% replacement of recycled glass used in the US. It has an attractive reflection on the surface after polishing its appearance[7].

Shattered glass is used to make decorative surfaces of buildings, reflective materials, arts and crafts, and clothing accessories for great visual effects.

Pavement aggregate: broken glass aggregate for asphalt concrete pavement has been developed. It is called “Glassphalt”, and it has been tested in America[7].

Artificial soil: Japan uses waste glass as ultrafine particles at high temperatures[7].

4.5. Wood
Clean and contaminated wood usually accounts for a large proportion of the carbon waste produced in North America. Therefore, it is important to distinguish between clean and contaminated wood. Clean wood refers to wood sawn without adding glue, resin, plastic or other materials. Contaminated wood, also known as dirty wood, includes engineered wood products with glue and resin added, as well as wood products coated with paint or dyes.

Wood can be reused in construction. It is because wood is a versatile material. Frame wood is usually the easiest to reuse because the size of the wood has changed little over the past century.

In many countries, like The United State Australia, they also use clean waste wood as a fuel source for electricity and heat. What is more, clean waste wood has other functions. In parts of the United Sates, there is significant demand of wood flour. It is because clean waste wood can also be used as cheap fillers in wood fiber - plastic composite wood[3].

4.6. Ferrous Metal
Ferrous metals have higher values than other materials. It is because there are lots of demands for ferrous metals. Due to its high cost, there is not much waste from construction projects[3].

Steel can be used directly or molten to produce new steel. There is more than 80% waste recycled and about 100% waste was announced can be reused[7].

5. Discussion
Construction and demolition waste make up a large part of all waste. The problem of the environment has become more and more severe. Whether in developed and developing countries, reducing construction and demolition waste has been extremely important.

In the construction and demolition waste, demolition waste is much more than construction waste. With the development of technology, construction and demolition waste can be disposed of the same way. People do not need to distinguish between them. It would be more efficient and better influential.

This paper reviews six materials which are very common in the demolition waste. Some of them still have space for development. As an important raw material, there are lots of aggregates that can be recycled. It is significant to filtrate the aggregates. The production process of recycled aggregate has a low level of automation in China. Compared to the production process in some other countries, China still has much to improve. Such as the recycled aggregates has low quality, which means there are many impurities and the process has low recovery efficiency and economic benefit. For the future, China can improve facilities and form a better recycling system.

Asphalt is widely used in roads, roofs, waterproof of underground structures and so on. There are many useful filtrates that can help to recycle asphalt. Nowadays, especially China, has a mess of demands for asphalt. But it needs a lot of energy from production to storage of asphalt. What is more, the process also emits many poisonous and harmful gases and. Recycled asphalts can only relieve solid pollution. In the future, there will be a new source which is efficient and environmental to gradually replace the asphalt.

Though plastic has a low proportion of the demolition waste, it is one of the most common materials in people's daily life. Recycling plastic is generally known as a common sense of
environmental protection. Current technology cannot degrade plastics well. Recycling plastic has become a practical way to reduce pollution. Most Asian countries cultivated the concept of using less plastic and taking action. European countries also issued many policies to reduce the use of plastic. Furthermore, degradable plastic is researched as well. Countries like the United States have worked on it for a long time. There is no doubt that it will be a tendency in the future. The degradable plastic will replace common plastic in all probability.

Glass is a common material, too. There are so many glasses whatever in demolition or people's daily life. In the above-mentioned six methods of recycled glass, the first four methods are practicable with today’s technology. But method 1 and method 4 are impractical to take action. It is very troublesome to demolish glass without breaking and there is no big demand for shattered glasses used in buildings, reflective materials, arts and crafts, and clothing. Method 5 is the glassphalt, there will be great developments in the future.

Wood is widely used in many fields. It is very easy to get and process wood. In China, there is a large amount of wood waste and there is lack of forest resources. So that wood would be one of the major problems of the Chinese environment. As mentioned above, clean and contaminated wood are different in recycling. Therefore, the primary thing is to improve the way which is used in classifying wood. The country should also encourage people to recycle wood to alleviate environmental pressures. Besides, wood used as a fuel source and the clean wood flour used as cheap fillers in fiber-plastic composite wood are very promising.

Ferrous Metal has great values. It can be recycled over and over again without degrading its performance. As a result, people tried to recycle it as much as possible. There should be a complete recycling system for it. It is predictable, whether in China or other countries, governments will invest more and more in it.

It is great to see that whatever in economic efficiency or environmental protection, recycling material is always essential. But it still has much to improve. People all over the world will also pay more and more attention to development sustainability as time goes on so that recycling material will be more efficient.

6. Conclusion
We are living in a world of rapid changes. As the time goes by, people face more and more difficult problems. On the one hand, people use energy even more than the supply. Therefore, it is significant to reduce the use of energy. On the other hand, the construction industry produces lots of C&D waste. According to statistics, the construction industry has a huge impact on the environment. That means it is also important to reduce C&D waste in order to protect the environment.

This paper introduces the problem people face, the definition and problem of demolition waste material, and recycle of 6 different materials. The materials are aggregates, asphalt, plastic, glass, and wood. They can be reused in different places or produce new material. Furthermore, this paper discusses the ways used in recycling these materials and the future of these ways. It also discusses that finding new alternative sources and new ways to recycle materials are encouraging ways to make less waste and make it more efficient as well.

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