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Recycling and Reuse Technology for Construction Waste and Evaluation Methods

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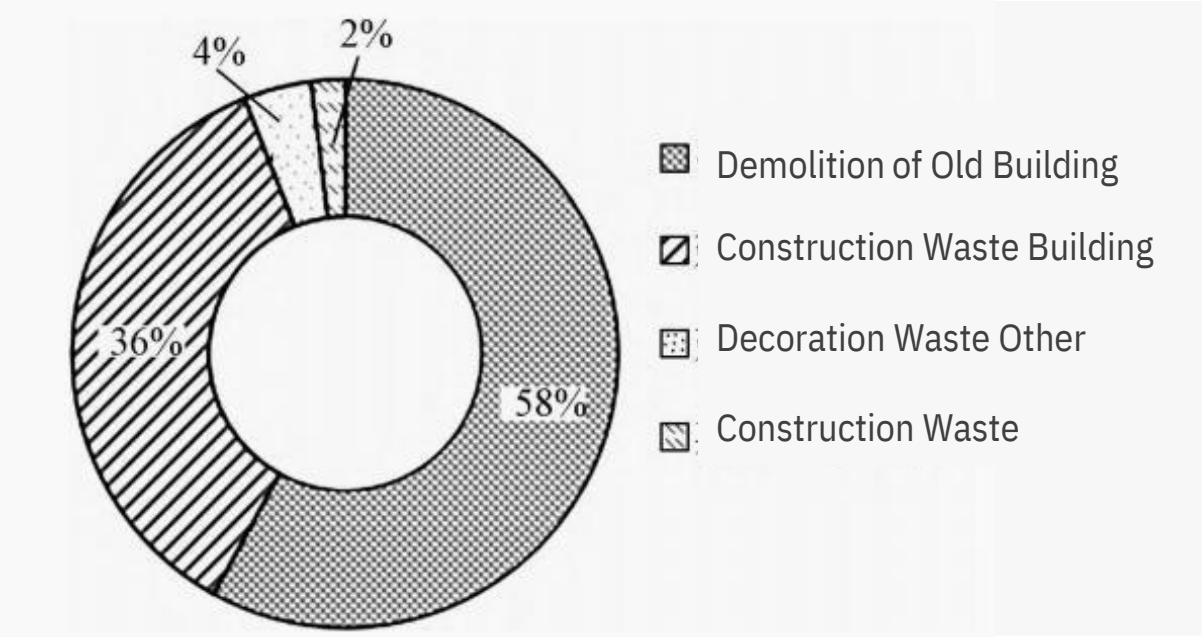
Research background

- The output of construction waste in 2023 is 3 billion tonnes, with an annual growthof about 3-5 %. The stockpile of CDW exceeds20 billion tonnes, and the recycling rate ofCDW is less than20%. The amount of CDW has accounted for 40%~50% of the total urban waste. Due to the natural wear and tear during the design life and maintenance phase of buildings, a large number of obsolete

  buildings in China have entered theC&D waste disposal stage.



Resource characteristics of construction debris

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Classification of construction waste

Table1Classification of construction waste according to the Ministry of Housing and Urban-Rural Development standards

Cla ss if ic at ion Road	**C o mpo s it**
Excavation Waste	Sand, gravel, metal, concrete debris, asphalt, etc. **ion**
Construction Site Waste	Broken bricks, concrete, mortar, pile heads, packaging materials, roofing materials, etc.
Demolition waste from old buildings	Waste bricks and tiles, concrete debris, metal, glass, ceramics, woodenelements, etc.
Excavation waste	Topsoil, subsoil, etc.
Construction material production was te	Waste materials, slag, debris, fragments, waste concrete, excess concrete, etc.

Resource characteristics of construction debris

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Composition of Construction & Demolition Waste

Table2Composition of demolition waste

Structure Concrete	**Rebar**	**Concrete**	**Brick**	**Glass**	**Wood**	**Total**
Structures Steel	1.81	83.8%	9.94%	0.11	4.13%	100
Structures Brick	%	64.89	18.01	%	9.24%	%
Structures	6.47	%	%	0.28	29.37	100
Brick-Concrete Structures	% 0.26 0.00 %	0.00% 30.66 %	70.49 38.32 % %	% 0.08 0.11 %	% 30.66 %	% 100 100 %

- Waste concrete is the main component in building demolition, and there are many ways to utilize it. The
- proportion of bricks is relatively high, which is another key waste stream typical for this stage.

High-value utilization of construction debris

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Stages of development of the recycled product iIndustry:

- In the first stage, the primary mode is simple small productionplants, with small scale, poor environmental protection, simple disposal technology, and low added value of recycled products. In the second stage, the primary mode is turned to large-scale fixed facilities,fulfilling basic compliance with environmental standards, extensive development stage,but poor profitability.
- In the third stage,integrating franchise licenses, a certain degree of deep resource utilization is carried out, simple separation and sorting are performed, mainly relying on government subsidies,whereas market competitiveness is average. In the fourth stage, multi-level separation and classification processes and equipment are used, the variety of products increases, such as recycled cement, mortar, wall panels, blocks, etc., with high comprehensive utilization rate, large scale, and products beginning to have market competitiveness.

Resource characteristics of construction debris

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Construction waste resources and recycling methods

- The road base is the most common use case, with a large volume but low utilization value, it is just a by-product of the resource utilization of construction waste.
- Recycled aggregate, is the primary recycled product of construction waste, costs are usually higher than natural sand and gravel, with little profit.
- Paving bricks, lattice bricks, and other municipal uses have low added value and an unpredictable market.

Table3 Construction Waste Composition

Primary Category	Secondary Category	Feasible Uses
Inorganic Non-metal	Earth, Ash, Sand	Backfill for foundations, etc.
	Concrete Blocks	Recycled aggregates, etc.
	Waste Mortar	Recycled bricks, rubble, etc.
	Waste Brick Blocks	Recycled bricks, rubble, etc.
	Cer am ics	Recycled aggregates, etc.
	Gla ss	Recycling, reuse, etc.
	Gyp su m Steel and	Gypsum fiberboard
Metal	Iron	Recycling, reuse, etc.
	A luminu m Copper	Recycling, reuse, etc.
	Other Metals Wood and Bamboo	Recycling, reuse, etc.
	Plastics, Textiles	Recycling, reuse, etc.
	Paper Products A sp	Boards, incineration
Other Categories	ha lt	Recycling, incineration
		In cine ra tio n
		Recycling, incineration

High-value utilization of construction debris

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Recycled aggregate is a primary use with low value.

Table4Economic Analysis of Recycled Aggregate

Item	Name	Amo unt (Yuan/tonn e)
1	Raw Materials (Construction Wa ste)	
2 3 4	Power Costs Wages and Benefits	1.5
5 6	Major Repair and Maintenance Costs	15 1.5
7 8	Demolition and Disposal Costs	3 2
9	Management Costs Sales Costs Taxes and	2 2
10	Additional Fees Financial Costs Production	2
11	Costs Sales Price	29
		35

- Fromone tonne of construction waste processed, 0.8 tonnes of aggregate can be obtained, valued at28 yuan, with a production cost of29 yuan. Without considering the value of raw materials and transportation costs, the profit of recycled aggregate is negative, and the enterprise recycling in this way waste cannot survive.

**1 yuan=0.13 euros*

High-value utilization of construction debris

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Recycled materials are a high-value utilization direction, and recycling enterprises have profits

Table5 Feasibility of replacing building materials byconstruction recycled products

Product Name	Aggregate (For C30 Concrete or Lower)	Dry-Mixed Mortar	Unfired Bricks	Wall Panels
Market Demand	7.5 million tonnes/year	6 million tonnes/year	10 million m^3/year (6 million tonnes/year)	6 million m^2/year (210,000 tonnes/year)
Product Name	Cement Additives	Small Colored Sidewalk Bricks	Lime Ash Crushed Stone	C20 Concrete and Concrete Products
Market Demand	700,000 tonnes/year	/	/	/

Table6Contribution analysis of turning recycled aggregate to recycled products

Product Name	Aggregate (For C30 Concrete or Lower)	Dry-Mixed Mortar	Unfired Bricks	Wall Panels	Cement Additives
Recycled Aggregate Content	100% Sidewalk Bricks 63%	67%	70.40%	74.60%	25% / /
Product Name		Lime Ash Crushed Stone	C20 Concrete and Concrete Products	Sidewalk Cushion Layer	
Recycled Aggregate Content		80%	52.70%	100%	

High-value Utilization of Construction Debris

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High-value utilization benefit analysis

Table7 Analysis of the benefits of treating Construction waste for high-end product utilization

	Name of Recycled Products	Profit Margin
Profit Contribution of Main Recycled Products from Construction Waste	Unfired Bricks	9.40%
	Lime Ash Crushed Stone	12.69%
	Small Crushed Bricks	25.17%
	Wall Panels	
	Cement Additives	24.30%
	Small Colored Sidewalk Bricks	
	Dry-Mixed Mortar	10.30%
	C20 Concrete and Concrete Products	25.17%
		21.80%

Conclusion:

- Recycled dry-mixed mortar and recycled wall panels have high market demand, product profit margins, and recycled aggregate content, which makes them suitableCDW derived recycling products;
- Although non-fired bricks have low overall benefits, they have high market demand and low market risk, making them the leading product of CDW recycling.

High-value Utilization of Construction Debris

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Current status and issues of recycled product enterprises

- There are more than 200 construction waste recycling projects, with a recycling capacity of 55,000 t/a and an actual production capacity of 35,000 t/a. Based on the investigation, unless government subsidies are in place, it is generally difficult for the construction waste recycling industry to operate sustainably and healthy. The main obstaclesfor productionenterprises aresingle type, lack of practicality, and low added value of construction recycled products. The evaluation of high-value utilization should fully consider the demand and form demand-oriented evaluation indicators.

Evaluation of construction recycled materials

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- **High-value recycled construction materials Stakeholders' concerns or interests Key indicators:**
- Service Performance: Having certain utility, meeting the performance required by the market; Whether it meets relevant standards and can be used in construction without obstacles;
- Quality Factors: The quality and performance that can be achieved after recycling(quality stability, uniformity), alleviating the concerns of the application side; Economic Factors: Whether recycled products have a comprehensive cost advantage over new products (whether they have market competitiveness);
- Environmental factors: Provide environmental protection, low carbon, and other labels and performance data for applying for government subsidies;
- Safety factors: The impact of heavy metals and pollutant release when recycled products are used in new construction or construction products.
- Remanufacturing: Recoverability, separability, etc. of materials.

Evaluation of construction recycled materials

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Evaluation of service performance of construction recycled materials

- Service performance: Including mechanical properties, characteristic parameters, etc. depending on the recycled material, there are different parameters. Compared with similar non-recycled products, whether it is close to or has advantages in performance.
- Counter measures:

1)Formulate standards and coordinate with current application standards.

2)Conduct inspection tests to evaluate the performance of various parameters.

Evaluation of construction recycled materials

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Service performance: issuesrelated to standards for recycling

- The standard system is not systematic, with insufficient support and coverage, especially the lack of standards for high value- added recycled products. Lack of standards for high value-added products (blocks, 3D printing materials, ceramsite, etc.).
- Lack of standards for related recycling equipment and evaluation standards for the management behavior of recycling
-

enterprises. Not coordinated with engineering application standards.

- Example: Although according to GB/T 25176—2010 'Recycled Fine Aggregate for Concrete and Mortar' and GB/T 25177—2010
- 'Recycled Coarse Aggregate for Concrete', recycled aggregates of different grades can be used in concrete of different strength grades, GB 50164—2011 'Standard for Quality Control of Concrete' clearly stipulates that coarse and fine aggregates for ready- mixed concrete should comply with JGJ 52—2006 'Standard for Quality and Inspection Methods of Sand and Stone for Ordinary Concrete'. Due to the limitations of the standard requirements, recycled aggregates cannot be widely used in concrete because their various test indicators do not meet the requirements.

Evaluation of construction recycled materials

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Quality factors of construction recycled materials

- Quality Factors: Product Uniformity, Durability, Stable Quality etc., to alleviate application concerns.
- Counter measure: Establish Quality Assurance Evaluation and Traceability Mechanism.

- **Quality Assurance and Traceability Evaluation Procedure for Construction Recycled Material:**
- Raw material evaluation (impurities content, pollutants);
- Intermediate product quality evaluation (aggregate particle size distribution, aggregate mechanical properties, etc.);
- Recycled product evaluation (mechanical, quality);
- Collect, analyze, and process test data;
- Assessment: make qualitative or quantitative assessment.
- Environmental label or certification.
- Information traceability platform.

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- **Economic factors of construction recycled materials** Economic factors: Do recycled products have a comprehensive cost advantage over new products (do they have market competitiveness).
- Counter measures:

  1) Conduct economic analysis and evaluation of alternative competitiveness;

  2) Provide the content of construction waste.
- Establish rules similar to carbon trading: those who generate construction waste pay, and those who use construction waste can receive tax reductions or subsidies based on the amount used.

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Economic factors of construction recycled materials

Table1 Cost comparison table of different aggregate products

Product Type	Strength Grade (M P a)	Cost of Natural Sand and Stone Products (Yuan/m³)	Cost of Recycled Aggregate Products (Yuan/m³)	Cost Savings (Yuan/m³)
Ru bbl e	MU5.0	13	117	13
Concrete	C30	0	201	44
Pavement Bricks	CC40	24	40.2	4.
Cement Mortar	M10.0	5	312	8
Dry Mortar	M5.0	45	241	53
		36		54
		5		

Evaluation of construction recycled materials

Environmental factors of construction recycled materials

- Environmental factors: Provide environmental footprint, low carbon, and other labels and performance data.
- Countermeasures: Evaluate low carbon performance, environmental footprint, etc., provide environmental and low carbon labels, and convert environmental performance and low carbon performance into added value.
- Reconstruction enterprise incentive rules: The government subsidizes enterprises based on carbon labels, environmental footprint performance, etc., to promote the development of low carbon and low environmental load recycled materials.

- **Environmental load evaluation content of construction recycled materials:**
- Non-renewable resource consumption;
- Greenhouse effect; Environmental
- acidification; Photochemical smog effect;
- Land occupation.
-

Evaluation of construction recycled materials

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Safety factors of construction recycled materials

- Safety Factors: The impact of heavy metals and pollutant release when recycled products are used in construction.

The lack of safety standards poses a safety risk when construction waste is made into recycled products. If harmful substances in the construction waste are not completely eliminated, they may pose certain hazards to the environment and human health, causing concerns about the quality and safety of recycled products.

- Counter measures:

1) Formulate corresponding standards;

2) Conduct tests for heavy metals and pollutant release.

Evaluation of construction recycled materials

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Safety factors of construction recycled materials

- Remanufacturing: Recoverability and separability of recycled materials. Comply with the3R
- principle, and it is best if it can be reused after simple processing. Counter measure:
- Evaluate the above factors when designing recycled products.

Outlook

- The development of an information platform for construction waste would integrate full life-cycle information management, quality assurance traceability, and environmental performance, thereby improving the efficiency of construction waste utilization and promoting industry development.

- The optimization of demolition decision-making, intelligent sorting, refined sorting, and grading classification technologies for construction waste will play a key role in enhancing the quality of recycled products and increasing the added value of recycled materials.

- The evaluation, certification, and labeling of recycled products will promote the development of market-competitive recycled products.

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