

Current Status and Countermeasures Research on Resource Utilization of C&D Waste Based on Bibliometric Analysis

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Abstract: In order to understand the current situation of the research on the resource utilization of C&D waste in China, the 1132 literature obtained from the database of CNKI in the past 20 years was used as the research object, and the visual analysis of literature chronology, authors and keywords was borrowed from CiteSpace to give the relevant suggestions for the promotion and industrialization of the resource utilization of C&D waste. This study is intended to provide some reference and basis for the subsequent research on C&D waste resource utilization.

1. Introduction

According to relevant data, the amount of C&D waste generated in China has exceeded 3 billion tonnes in 2021. Previously, the simple disposal of C&D waste in piles or landfills has been contrary to the current policy and economic development. In order to understand the current situation of C&D waste resource utilization research in China and to explore the difficulties and pain points of the development of C&D waste resource utilization, this paper uses CiteSpace software and visual bibliometric methods to analyse and sort out the relevant literature in the field of C&D waste resource utilization in China, with a view to depicting the overall situation of C&D waste resource utilization research in China, identifying the problems in this field in China and proposing the following ^[1,2]. The aim is to depict the overall situation of C&D waste resource utilization research in China, identify the problems in the research process in this field and put forward corresponding suggestions and countermeasures.

2. Bibliometric Analysis of Research on C&D waste Resource Utilization

2.1. Data Sources and Research Methodology

2.1.1. Data Sources

Based on the data of China National Knowledge Internet (CNKI) database, an advanced search was conducted from January 2002 to March 2022 on the theme of “C&D waste recycling”, and a

total of 1373 relevant documents were found.

2.1.2. Research Methodology

After processing the data of the 1132 retrieved articles, CiteSpace software was used to draw and analyse the relevant graphs, which mainly include: drawing the trend of the number of articles to analyse the statistical characteristics of the literature, drawing the cooperation network of authors to analyse the cooperation of authors, drawing the emergence of hot words, the common line knowledge spectrum of keywords and the time line graph of keyword clustering to analyse the keywords and the current status of research [3].

2.2. Chronological Analysis of the Literature

A visual analysis of the posting time of 1132 articles was carried out to obtain a trend chart of the C&D waste research literature, as shown in Figure 1.



Figure 1: Trends in C&D waste research literature

In terms of the temporal characteristics of the distribution of the literature, the development of research on the resourceisation of C&D waste can be divided into three stages.

The preliminary exploration stage (2002-2007): less attention was paid to the resource utilization of C&D waste during this stage, analysing the reason that the C&D waste generated by the previous construction activities could still be disposed of in piles or landfills or the hazards of C&D waste had not yet been revealed. After 2005, the number of publications was 39, and scholars such as Xiao Jianzhuang and Li Qiuyi carried out systematic research on the technological innovation and large -scale application of C&D waste resourceisation in the context of China’s urbanisation construction and current development level, and some scholars began to study the applicable scenarios of C&D waste resourceisation.

Development and gestation stage (2008-2012): 241 publications in the literature. After the Wenchuan earthquake, the destruction of buildings and roads produced a large amount of C&D waste and solid waste, which became a heavy burden in the reconstruction work at that time, and the issue about the disposal of C&D waste attracted the attention of relevant scholars. Xiao Jianzhuang, Lei Bin, Wang Changqing and other scholars published “The Resourceful Use of C&D waste in the Wenchuan Earthquake Area” which made scholars start to focus on the research of C&D waste resourcefulness.

Rapid development stage (2013-present): 1,042 publications in the literature as of the first quarter of 2022. During this phase, with the introduction of new urbanisation and the National New Urbanisation Plan, the rapid growth rate of construction activities, coupled with the development of the idea of building an ecologically civilised city with reuse as the core, research scholars began to explore new paths of C&D waste resourceisation and enrich the research content in the field of

C&D waste resourceisation.

2.3. Analysis of Authors

Using visualization to analyze the authors of publications in the field of C&D waste resource utilization research, the knowledge map of the cooperation common line of highly cited authors shows that the authors of C&D waste resource utilization show an overall small concentration and large dispersion, with a small number of authors forming academic communities among themselves and a large contribution from core authors. Collaborative relationships between authors with a high number of citations are not shown clearly enough, such as Zhao Yucai, Xiao Jianzhuang and Zhong Shiyun. On the whole, the degree of connection between individual researchers is not strong, research is more isolated, and researchers between universities or even within universities have not yet formed an extensive collaborative dynamic.

Looking through the distribution of authors of highly cited literature institutions, the top three are Chongqing University, Xi'an University of Architecture and Technology and Chang'an University, with 6.5%, 5.5% and 5% respectively, for a total of 17%. Xi'an University of Architecture and Technology has a strong connection between researchers in this field, and the research revolves around for the economic benefit analysis model of domestic C&D waste resourceization and the operation model of C&D waste resourceization reduction and industrialization, and, Liu Bingnan established an evaluation model of C&D waste resourceization from the perspective of economics, which is mainly divided into three parts: total investment cost, total investment return and economic benefit; Yan Wenzhou from the perspective of industrialization and Yan Wenzhou from the perspective of industrialization, illustrated the interaction between various subjects in the operation process of resourceization, proposed a model of this field in the operation mechanism of industrialization, and analyzed the considerable economic benefits and feasibility of China's cities in this field through practical engineering, and encouraged more enterprises' investment to make the industrialization of this field develop.

2.4. Keywords Analysis

2.4.1. Burst Terms Analysis

CiteSpace uses an inflated word algorithm to extract mutation words that can identify trends in the field of C&D waste resourceisation. Keywords representing the frontiers of research are bound to receive a large number of citations in a short period of time, and therefore their mediated centrality is bound to be at an extremely high level. The 65 mutation words detected by emergent word mining for research in the field of C&D waste resourceisation research.

Analyzing the emergent words in the past 20 years, combined with the time pattern and word frequency intensity of the development of research on C&D waste resourceization, the keywords with the highest frequency change before 2012 was "earthquake disaster area" (2008-2009), and the treatment of C&D waste after the disaster became apparent within a short period of time, attracting widespread attention of scholars and The research on C&D waste resource utilization began to take a new step forward.

In 2012-2013, the "Green Building Standard" and "Green Building Evaluation Label" began to emerge, and the construction industry has a clear definition of the classification and evaluation of C&D waste.

In 2014-2017, the "Urban C&D waste Management Regulations" began to emerge, and through national policies and related regulations for the construction industry, managers of construction activities have a clearer basis for the disposal of C&D waste, and researchers have focused more on

the “reuse”, “economic efficiency” and “environmental protection” of C&D waste. Researchers are also focusing more on the “reuse”, “economic efficiency” and “environmental protection” of C&D waste, in order to find a good “outlet” for C&D waste [4].

From 2018 onwards, the keyword “resource utilization” burst up, and by 2020 “C&D waste reduction” and “waste-free cities” starts to emerge. This period of research into the resourceutilisation of C&D waste was directed at reducing the problems caused by C&D waste at source, which also coincided with the introduction of the concept of ecological protection in China. Subsequently, “pre-treatment” and “environmental prevention” emerged, indicating that the research on the resource utilisation of C&D waste focused more on the concept of prevention before treatment and treatment at source [5,6].

2.4.2. Keywords Co-occurrence

Keywords are the extraction and condensation of research content and are the essence and core of the research topic. Keyword co-occurrence analysis uses the co-occurrence of keywords within a literature set to determine whether a field is a research hotspot. The keyword co-occurrence mapping shows 226 keyword nodes and 298 keyword concatenations, with a keyword network density of 0.0117. The most frequent words are recycled “aggregates”, “recycled products”, C&D waste and urban C&D waste “waste”, “municipal C&D waste”, “recycling”, “circular economy”, “reduction”. It can be seen that at this stage C&D waste is mainly studied around “resourceutilisation” and a system has been established, with the key words “reuse”, “environmental protection”, “urban waste” and “reduction”, “urban waste” and “circular economy”.

2.4.3. Keyword Clustering Common Line Time Zone

After obtaining the knowledge graph generated by the key nodes, the clustering operation was then performed to derive the keyword clusters for C&D waste resource utilisation. Based on the *Modularity Q* value of 0.8744 and the *Silhouette* value of 0.9749 for this clustering result, which can be considered that this paper is suitable for using cluster analysis.

From the timeline analysis of the C&D waste resourceisation citation clusters, the cluster analysis yielded a total of 9 clusters, from which we know that excluding the data search terms “C&D waste resourceisation”, “C&D waste” and “resourceisation”, the hot topics in the field of C&D waste resourceisation from 2002 to 2022 can be broadly categorised into 6 hot topics, namely” recycling”, “production line” and “production line”. The hot topics of research in the field of C&D waste resourceisation from 2002 to 2022 can be broadly categorised into six hot topics:” recycling, “production line”, “recycled aggregates” and “recycled waste”, “recycled aggregates”, “recycled building materials”, “public welfare industries” and “circular economy”. In the past two decades, the work on C&D waste resourceisation has been centred on “C&D waste resourceisation” and “circular economy” as the core, with a focus on “production lines”, “recycled aggregates”, public welfare industries” and” circular economy”. The focus of research and development has been on “recycled aggregates”, “recycled building materials” and “recycled use”.

As can be seen in the clusters of “resourceisation and C&D waste”, “environmental prevention” and “source reduction” have received more attention in recent years. In recent years, more attention has been paid to “environmental prevention” and “source reduction”. In the future, research that starts from the pre-production and pre-construction stages of construction materials is more likely to be the main battleground and cutting-edge research hotspot for C&D waste resource utilisation research.

2.5. Status of Research on the Resource Utilization of C&D waste

At this stage, there are three main ways of resource utilisation of C&D waste: producing recycled aggregates, producing environmentally friendly building materials and making materials for road construction. There is mature experience in using recycled aggregates as raw materials for bedding and sub-base layers and applying them to urban roads. The technology for the preparation of recycled bricks in China is also quite mature, with all core indicators meeting the requirements of the relevant standards, and this product has more advantages compared to ordinary brick soil. This product not only reduces the consumption and waste of natural resources, but also provides a new approach to the development of a circular economy and realises a virtuous cycle construction materials. The recycled products under the resource utilisation of C&D waste can in fact be applied to many areas, and the potential economic value that can be developed is very large, with a broad prospect of development in combination with industrialisation [7-9].

However, there are some problems with the resourceful use of C&D waste. Especially in recent years, in the process of urbanisation in China, the amount of C&D waste generated by demolition and new construction work has been increasing year by year, coupled with the frequent occurrence of natural disasters of different degrees in different areas, the amount of broken C&D waste brought about by repair sand renovations should not be underestimated.

The development of industrialisation is limited. Through the analysis of the above knowledge mapping and the real situation, we can also learn that the maturity of C&D waste resource utilization technology is not only far from enough to support the independent competition of small enterprises in the market, but also not conducive to the formation of a market atmosphere beneficial to the development of C&D waste resource utilization enterprises.

The management system of the resource utilization industry needs to be further improved. The development of the industrialisation of C&D waste resource utilisation in China is relatively short, and the construction of the management framework is not perfect. The management of this industry often appears to be governed by nine dragons, especially in the interface of different management organisations, which needs to be further strengthened. In fact, these problems reflect from the side that we need a detailed management model and the establishment of a sound relevant management system.

The collaboration among researchers is faintly and it is difficult to implement research. On one hand, this may be due to the fact that it takes along transition period for research on the resourceful use of C&D waste to be implemented, and researchers are not able to see the feedback results, resulting in a low research atmosphere. The low level of awareness of resource use, the difficulty for researchers to disseminate results and the lack of technical skills make much of the useful C&D waste go to waste, and the effectiveness of the research on resource use is greatly diminished.

2.5.1. Frontier Research of C&D Waste Resource Utilization

Through the analysis of the knowledge spectrum, I believe that the focus of future research on the resourceful use of C&D waste will be more around recycled products to help promote the industrialisation of C&D waste resourceful use, however, with the establishment of the carbon neutral target or carbon peaks, its development will also focus more on reducing carbon dioxide emissions from the source, and scientific researchers will also actively comply with the development of intelligence and digitalisation, using BIM technology and green development concepts to reduce the formation of C&D waste during the construction process, and strongly support research into the development of assembled buildings to increase the proportion of green buildings in new construction [10].

2.5.2. Suggestions for Promoting the Development of C&D Waste Resourceisation

The disposal of C&D waste requires both administrative supervision and the establishment of detailed statutory disposal standards for its various components. The first is a statutory standard in the pre-construction phase, which should include five specific categories of C&D waste: on-site use, delivery to a resource company, direct landfill, and hazardous disposal. Only legislation on the classification of C&D waste will make it easier for the authorities to manage. The second is the application of the producer's responsibility system to this area, through legislation to clarify: the subject of responsibility, the order of the recycling market, the consequences and other specific content, so that each responsible person in the construction takes responsibility. The third is that the builder is responsible not only for the building, but also for the environmental impact generated by the C&D waste.

By improving the details of C&D waste resource utilization at the legislative level, it is possible to control it more reasonably at the macro level, so that the management department can have the law to follow and the relevant enterprises can be punished for violating the law, which is more convenient for promoting the industrial development of C&D waste resource utilization.

The prospects for the industrialisation of C&D waste resource utilisation are good, but there are still many bottlenecks in the development of the C&D waste resource utilisation industry during the exploration period, and the resource utilisation rate of C&D waste is still less than 5%. As a result of comprehensive research, the industrialisation of C&D waste resource utilisation can be promoted from three aspects: 0 increase the policy support for the industrialisation of this field; 2 grant concessions to some qualified enterprises according to regional divisions; 3 refine the management of the industry, such as incorporating the indicators of C&D waste resource utilisation into the green site assessment system, and at the same time establishing an internet plus C&D waste information platform, so that C&D waste can be transferred from one site to another. C&D waste information platform, the C&D waste from the generation to the treatment of the whole process of information for public display, but also online to carry out related economic activities to attract investment in order to achieve resource sharing.

The main objects of research on recycled products are recycled aggregates, recycled bricks, recycled concrete, water stabilisation materials, recycled mortar, recycled micronized powder, waste steel, waste soil and light materials. The research on recycled products starts with the study of their strength, feasibility, scope of application, etc., to strengthen the quality of buildings built with recycled products. Regarding the application of recycled products, the government and enterprises can prioritise the promotion of recycled products that meet the standards, and give preferential treatment or policies such as tax breaks for the products in relevant procurement.

3. Conclusions

Through a systematic bibliometric study on the current situation and hotspots of C&D waste resource utilization in China, the statistical characteristics of the literature, the authors of the published articles and the specific research contents of the C&D waste resource utilization literature are analyzed, and the three parts are specified using knowledge spectrum diagrams such as author co-linear diagram, cluster diagram, time zone diagram and emergent diagram. The analysis results are also combined with relevant suggestions for the promotion and industrialization of C&D waste resource utilization, with a view to providing certain reference and basis for C&D waste resource utilization-related enterprises, universities and governments.

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