infrastructures

MDPI

Review

Demolition Waste Glass Usage in the Construction Industry

Pavels Tihomirovs [1], Patricia Kara De Maeijer [2] and Aleksandrs Korjakins [1,*]

[1] Department of Building Materials and Products, Institute of Materials and Structures, Faculty of Civil Engineering, Riga Technical University, LV-1048 Riga, Latvia; pavels.tihomirovs@edu.rtu.lv

[2] Faculty of Applied Engineering, University of Antwerp, 2020 Antwerp, Belgium; patricija.karademaeijer@uantwerpen.be

[*] Correspondence: aleksandrs.korjakins@rtu.lv

Abstract: Waste glass is an endless issue for the majority of the countries in the world with a linear economy of usage of materials. Demolition waste is counted as part of total construction and demolition waste (CDW). Even today, there are some statistical problems with the quantification of demolition waste and dividing it from total CDW, since most countries do not provide such a division of waste types. The current review shows possible ways of utilizing waste glass in some useful products in the construction industry. It is elaborated using PRISMA@ methodology with bibliometric and qualitative methods to provide a systematical overview of the publications in the period from 2000 to 2023. The bibliometric search was handled with the application RStudio© using sources in the biggest database, Scopus. Most of the published research items are mainly focused on using waste glass in concrete applications. However, there are seven possible areas of waste glass application in the construction industry: concrete products, gypsum–cement composites, asphalt or concrete pavement, geopolymer mortars, foamed glass ceramics, glass ceramics, and soil foundation strengthening/stabilization. In its turn, the circular economy should be applied since it provides a prolonged turnaround of materials throughout their life cycle.

Keywords: demolition waste glass (DWG); waste glass aggregates; glass ceramics; foamed glass-ceramics; circular economy

check for updates

Citation: Tihomirovs, P.; Kara De Maeijer, P.; Korjakins, A. Demolition Waste Glass Usage in the Construction Industry. *Infrastructures* **2023**, *8*, 182. https://doi.org/10.3390/infrastructures8120182

Academic Editor: Hugo Silva

Received: 31 October 2023
Revised: 29 November 2023
Accepted: 14 December 2023
Published: 17 December 2023

1. Introduction

In 2020, according to Eurostat, waste glass generation in the EU-27 was 17.85 million tons [1], and waste glass recycling totaled 15.55 million tons [2]. There is minor waste glass generated during construction (an estimated 4% of total waste glass from construction and demolition waste CDW [3]), and the main waste glass generation is from demolition and renovation projects, i.e., "post-consumer" waste [3]. According to an economic study in 2013, 1.5 million tons was generated from building renovation and demolition [3]. CDW is more than a third of the total waste generated in the EU [4], or more precisely 37.5% in 2020. CDW contains a range of materials such as concrete, bricks, ceramic, wood, glass, metals, and plastic, which is made in the construction, maintenance, and demolishing process of buildings and infrastructures, as well as road planning and maintenance [5]. CDW can be categorized into three categories: construction waste, renovation waste, and demolition waste based on generation stages.

Several products of CDW are of a high value, which can be recycled or reused, but others have lower value, which can still be reprocessed. Some technologies can be used to separate and recover some of the materials. Materials that are not separated at the source can also contain small amounts of hazardous materials such as solvents and asbestos which can pose a risk to the environment.

Commonly, CDW consists of two different categories of waste. Although, according to the available statistical system data of the European Union (EU), a global distinction between the two categories of waste is not handled. These two categories have different characteristics, both in terms of quantities, composition, and recovery potential. Construction waste (originating from new construction) is usually less mixed and contaminated. Its share in CDW is generally low. Demolition waste glass (DWG) is a glass derived from demolition and renovation operations. The definition of treatment operations in Europe is derived from Waste Framework Directive 2008/98/EC (WFD) Annex II categories which is seen as a milestone of modern waste management in the EU. In spite of construction and demolition (CDW) waste being one of the largest waste flows in the world, there is a significant lack of consistent data about the total waste stream and its management [6].

Waste management law [7] defines that there are two types of possible use of waste: reuse and recycling of waste. Reuse means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived. Recycling of waste is any recovery operation by which waste materials are reprocessed into products, materials, or substances, whether for the original or other purposes, including the reprocessing of organic materials but excluding the recovery of energy present in waste and reprocessing into materials that are to be used as fuels or for backfilling operations. EU waste policies set objectives to limit landfilling, as this is the most polluting way to deal with the waste.

CDW grows along with the current world urbanization and development of the construction industry, leading to a certain problem for the environment. According to published data in 2011, the average recycling rate for the EU-27 was 46% [8], with a relatively high level of recycling and material recovery in the Netherlands (98%), Denmark (94%), Estonia (92%), and Germany (86%), and the lowest recycling rates seen in Greece (5%), Portugal (5%), and Cyprus (1%). It is rather difficult to bring cross-country comparisons of CDW due to different definitions of CDW are applied across countries. It should be also noted that the use of recycled material in construction is not sufficient in some countries, which can largely be attributed to various factors like lack of awareness on the part of designers/engineers, lack of awareness campaigns and appreciation of using recycled materials, unorganized markets of recycled construction material, absence of a proper solid waste management system in urban areas, lack of tax incentives, and poor implementation of legislation on the use of recycled materials [9]. Nowadays, the US (recovery rate 76%) and EU-27 (recovery rate 90%) are considered more developed and urbanized CDW generators as they have much less CDW generated compared with other countries like China (recovery rate 10%), for example [10].

DWG recycling is a target of this review. CDW produces less than 5% of waste glass by weight worldwide, while the rest is composed of masonry and inert stones [11]. In Europe, the total waste glass arising from renovation and demolition of buildings in 2013 approached about 1.5 Mt [3]. Glass is one of the most recyclable materials as it can be recycled for multiple uses without loss of quality and purity across a wide spectrum of industries [12]. Waste glass usage in the construction industry has been identified as a replacement for traditional materials [13]. Recovered glass has a high usage priority due to its low cost and wide availability [14]. Although all glass can be remelted and recycled, in comparison with container glass, post-consumer flat glass is not being systematically recycled, for example. Many different steps need to be taken before waste glass can be recycled by the glass industry [3]. Alternative methods of waste glass utilization are still not used at their full potential, and there is a significant opportunity for expansion since DWG has great potential. Although most research items focused on using waste glass as a part of concrete applications, there are several other possible applications, which are to be considered as future areas of applications.

Nevertheless, among 717 reviews about waste management (which can be filtered using the keyword “demolition waste glass”), most of them contain topics about waste management (120 items) with a small number of reviews (15 items) devoted to DWG. Therefore, this review is essential to understand the future perspectives of DWG usage.

2. Methods

In this review, PRISMA@ methodology was used. In the beginning, the list of literature of interest was identified. Then, two methods were used to perform the review: bibliometric and qualitative methods.

2.1. Bibliometric Method

Bibliometrics is a quantitative and objective method of researching and analyzing data obtained from a database. Bibliometric analysis was used to identify the most used keywords. Rstudio© is an integrated development environment (IDE) for R, a programming language for statistical computing and graphics. It is available in two formats: "RStudio Desktop" is a regular desktop application, while RStudio Server runs on a remote server and allows access to RStudio© using a web browser. In this review, RStudio Desktop and the packages Bibliometrix, Bibliometrix.Data, and library ("bibliometrix") for the function "BiblioShiny()" were used, which made some analytical functions available with a web interface.

The data sources for the bibliometric review were obtained through the Scopus database, limiting sources to the years 2000–2023 with the additional criterion of the language set to "English". The results were obtained with these metadata for further research: author (AU), language (LA), publication year (PY), title (TI), total citations (TC), journal (SO), abstract (AB), keyword plus (ID), and keywords (DE). The records obtained from databases were exported in a .bib file, which was used in bibliometric analysis.

The keywords which formed clusters of searches that were used to find sources of the bibliometric analysis were "demolition waste glass", "waste glass cullet", "waste glass usage", "waste glass usage in ceramics", "construction and demolition waste usage", "crushed waste glass", "waste glass alkali-activated materials", "waste glass concrete", "waste glass powder", "waste glass aggregates", "waste glass eco-materials", "waste glass cement", "waste glass cement replacement", "waste glass asphalt", "waste glass pavement", waste glass soil stabilization", and "waste glass in ceramics". The search results received were, respectively, 311, 358, 56, 194, 513, 290, 2390, 413, 2104, 271, and 2491, totaling 9391 search results.

There are several options that can be used to analyze data from sources. The first part of options applied to a narrow search quantity is connected to the analysis of sources. The options used were "Most relevant sources" and "Bradford's Law". The second part of the options used was an analysis of keywords. One of the options of Biblioshiny used to analyze keywords is the Wordcloud function based on the "Keywords plus" function, which represents the occurrence of words in different sources and was used to generate a bibliometric file.

According to Figure 1, the core sources used were 18 sources from a total of 1408 different sources. The 18 journals with the most published articles are "Construction & Building Materials" (456 articles), "Ceramics International" (301 articles), "Journal of Cleaner production" (255 articles), "Materials Science Forum" (220 articles), "IOP Conference Series: Materials Science and Engineering" (214 articles), "Key Engineering Materials" (209 articles), "Materials" (185 articles), "Materials Today: Proceedings" (171 articles), "Waste Management" (169 articles), "Advanced Materials Research" (133 articles), "Journal of Nuclear Materials" (125 articles), "Journal of Building Engineering" (117 articles), "Lecture Notes in Civil Engineering" (117 articles), "Journal of the American ceramic society" (116 articles), "Journal of Non-Crystalline Solids" (105 articles), "Resources, Conservation and Recycling" (91 articles), "Journal of the European Ceramic Society" (89 articles), and "Journal of Hazardous Materials" (84 articles). Also, these 18 journals were applied in further phases of the analysis.

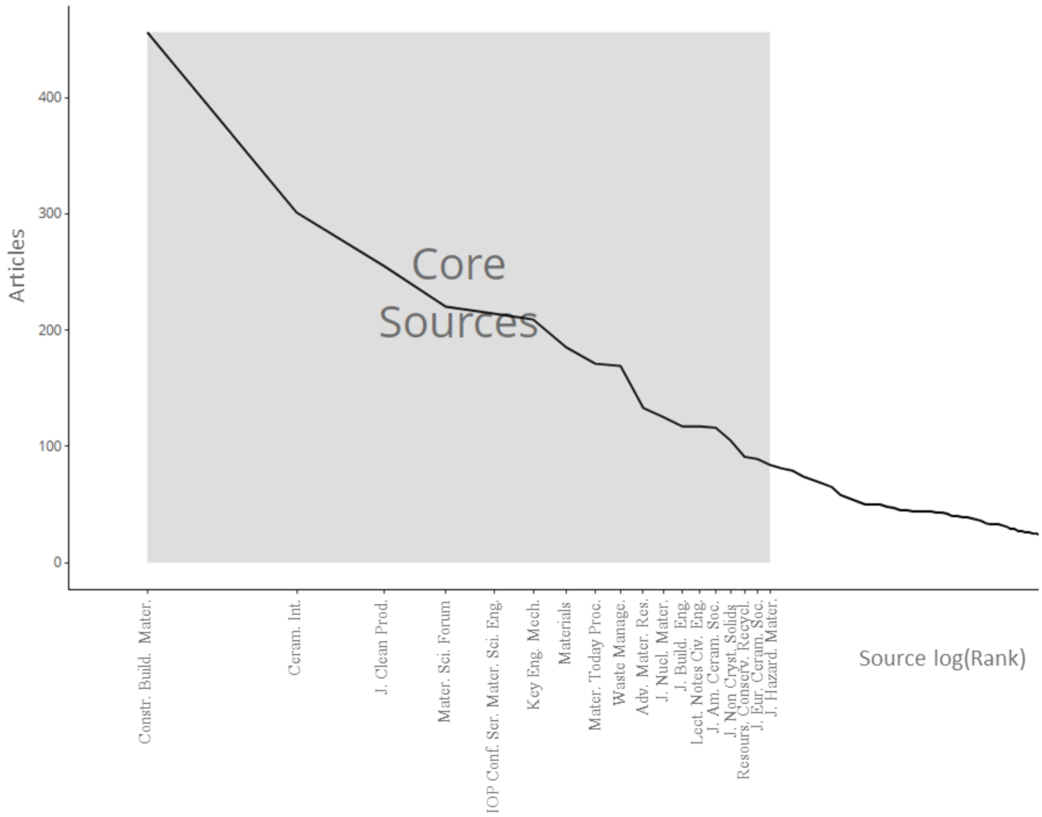

Figure 1. Core sources by Bradford's Law.

It can be seen from Figure 2 that the most frequently used keywords for all search patterns are glass (3882), recycling (2385), glass ceramics (2218), compressive strength (1654), fly ash (1156), ceramic materials (997), concrete aggregates (834), and cements (597).

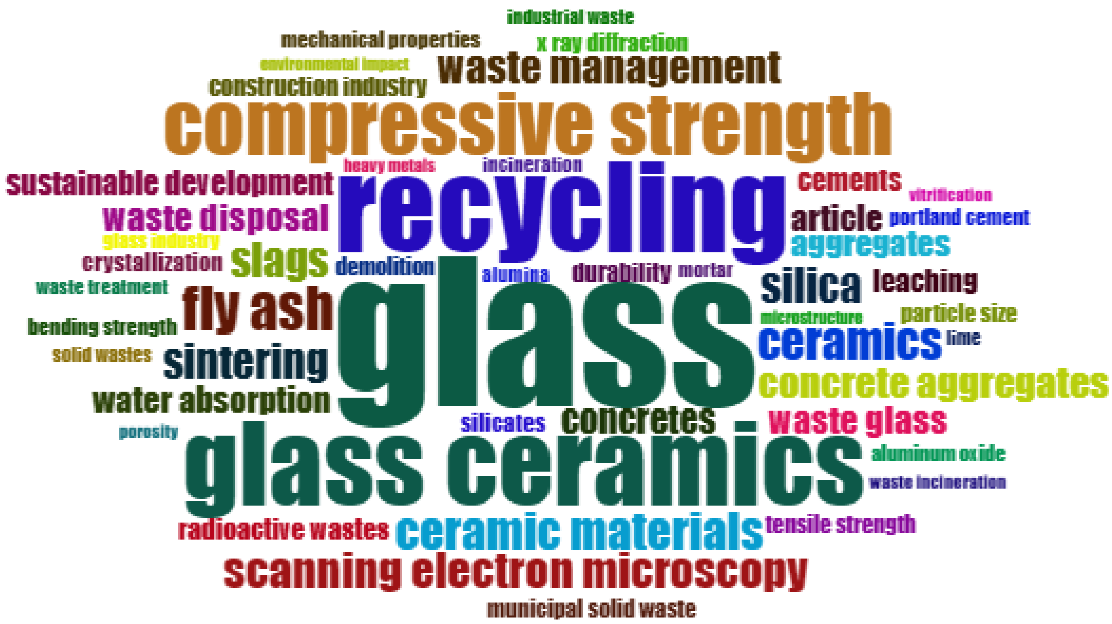

Figure 2. Wordcloud function result representation made by Shiny application in RStudio©.

According to bibliometric research, in the chosen period from 2000 to 2023, the journal "Construction & Building Materials" had the most relevant items to the research of DWG. It has 456 articles, and based on the bibliometric option of the Shiny application 'Author's local impact' with total search results of 9391, it can be seen in Table 1 that ten authors are listed with the best h, g, and m indexes and the highest number of citations. Bernardo E. had the highest h index from the 10 highest values and Ling T. had the lowest. Arulrajah A. had the biggest values of the cited publications (6110) with a g index of 78. Horpibulsuk S. had the highest m index of 3.100, followed by Arulrajah A. with 2.923 and Poon C. with 2.353. The publications of Arulrajah A. and Bernardo E. are included in the results discussion in this review.

Table 1. Bibliometric option result of Shiny application "Author's local impact".

Author	h Index	g Index	m Index	Times Cited
Bernardo, E.	42	56	2.100	3634
Poon, C.	40	67	2.353	4571
Arulrajah, A.	38	78	2.923	6110
Horpibulsuk, S.	31	54	3.100	3437
Lancelotti, I.	31	49	1.292	2581
Barbieri, L.	30	49	1.250	2560
Zhang, Y.	29	46	1.261	2568
Boccaccini, A.	27	63	1.125	4153
Disfani, M.	25	31	1.923	4186
Ling, T.	24	26	1.846	2410

2.2. *Qualitative Method*

After conducting bibliometric research, the received results were grouped by categories of types of sources (article, review), the results were screened for relevance, and a group of results (78 sources) was selected for the final review inclusion (see Figure 3). The criteria of relevancy of whether a scientific publication can be directly included in one of the seven groups are mentioned in Section 3.3.

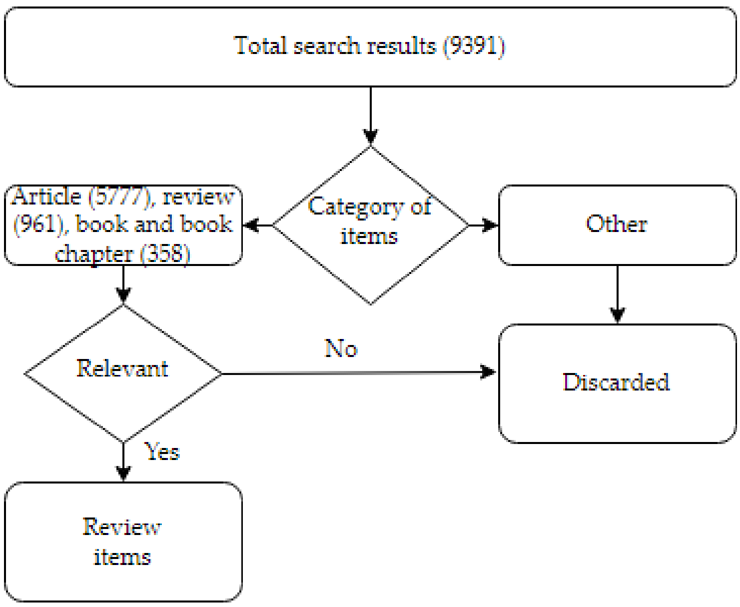

Figure 3. Items selected for review inclusion according to PRISMA@ methodology.

3. Results

Because of the completely different types of waste glass usage, there is no possibility to make a comparative analysis of the mechanical properties of these different applications, although some important values have been introduced.

3.1. Waste Classification

There are plenty of waste classifications that are applied in different research areas. Firstly, let us categorize waste according to the received sources. There are four categories of demolition waste [15,16]:

- Dangerous (asbestos, tar, etc.);
- Inert (concrete, bricks, plaster, asphalt, rock, sand, etc.);
- Non-inert (wood, metal, plastics, glass, paper, etc.);
- Nature-made waste (earthquakes, floods, tsunamis, hurricanes) [15].

This classification shows that this main waste type (waste glass) is a non-inert type of waste. Nature-made waste cannot be a source of waste glass because of no possibility of waste processing for that type of waste.

There is another classification of sectors from which wastes are received [17]:

- New residential construction;
- New non-residential construction;
- Residential demolition;
- Non-residential demolition;
- Residential refurbishment;
- Non-residential refurbishment.

According to this classification, it is possible to receive waste glass in any of the mentioned types of waste generation sectors.

3.2. Glass Classification

Glass chemical composition might be very diverse, although there are three main types of commercial glass which have distinct chemical compositions, which are [18]:

- Soda-lime glass (Container, float, sheet, light bulbs, and temperature ovenware glass. The sheet glass can be found in demolition glass. The sheet glass' chemical composition is SiO_2 71–73%, Al_2O_3 0.5–1.5%, Na_2O 12–15%, MgO 1.5–3.5%, CaO 8–10%);
- Borosilicate glass (Sub-types of this glass are chemical apparatus; pharmaceutical; tungsten sealing. This type of glass contains B_2O_3 in amounts of 13–15%);
- Lead glasses (Sub-types of this glass are color TV funnels, neon tubing, electronic parts, and optical dense flint. This type of glass contains PbO in the amount of 23–65%);
- Barium glasses (Sub-types of this glass are color TV panels and optical dense barium crowns. This type of glass contains BaO in the amount of 2%, PbO in the amount of 2-41%, 10% SrO for color TV panels, and 9% of ZnO for optical dense barium crowns);
- Aluminosilicate glasses (Sub-types of this glass are combustion tubes, fiberglass, and resistor substrates. This type of glass contains Al_2O_3 in the amount of 16–24.5%).

3.3. Waste Reuse Applications

The reuse of waste depends on how the waste has been processed: was there a separation process or not? If the waste separation process was performed, there is a higher possibility of receiving high-value reused material at the end of the reuse process.

There are several applications in which waste glass can be used:

(1) As an aggregate [19–43] or as a cement replacement in concrete [44–72];
(2) As an aggregate in gypsum–cement composite [73,74];
(3) As an aggregate in pavement base/subbase [75,76], asphalt pavements [17,77,78] and concrete pavements [79–81], and as crushed stone dust [82];
(4) In geopolymer mortars [83–89];
(5) To make foamed glass ceramics [90–97];
(6) To make glass ceramic materials [98–103];
(7) As a replacement for the soil underneath the foundation [104] and as a soil stabilization [105,106].

3.3.1. Waste Glass in Aggregate and Cement Replacement in Concrete

Several decades ago, research started on the possibility of using waste glass in concrete production [107–111]. Recycling waste glass in the construction industry not only reduces the burden on landfills but significantly contributes to resource preservation and carbon footprint reduction [112,113]. At the same time, it is well known that glass-reinforced concrete is a highly effective and competitive composite material compared to traditional types of concrete [114]. A lot of research has been carried out for applications of waste glass as aggregates and cement replacements in concrete production.

Aggregates in concrete is one of the primary researched and published themes in waste glass usage in concrete production which is smoothly processed in the cement replacement research domain at the level of ground powder. In the year 2000, it was stated that waste glass causes some of the worst alkali–silica reaction (ASR) expansion if used as an aggregate in concrete [19], and for that reason it was considered unsuitable as an aggregate in concrete [20]. ASR possibility in concrete is high when using quartz glass as an aggregate [38], although lightweight aggregates based on powdered waste glass used in mortar bars did not cause ASR expansion or cracks [21,37]. The addition of steel or polypropylene fibers to the mortar bars with waste glass aggregates proved to be effective in suppressing the ASR expansion [22]. ASR can be suppressed in concrete with waste glass aggregates by additions of fly ash or ground granulated blast-furnace slag [36]. The addition of zeolite was found to reduce ASR expansion too [79].

Replacing natural aggregates with waste glass increases the air content [23,32], flowing, and VeBe values of fresh concrete [23], which is due to the sharper edge and higher aspect ratio of glass and sand to natural sand, which is capable of retaining more air on the surface of the glass particles. There is a certain influence of waste glass on slump: the higher the replacement of aggregates with waste glass aggregates, the higher the slump [25,26]. Waste glass with lower density than natural sand has a tendency to reduce slump while high-density glass increases slump [40]. However, slump decrease was observed with an increase in the waste glass content in the mix, which was attributed to the waste glass grain shapes [28,29,34,41].

The smooth and plane surface of large recycled glass particles can significantly weaken the bond between the cement paste and the glass particles [27,67]. Mechanical properties, in general, decrease in proportion to an increase in waste glass aggregates/powder at earlier ages [23,32,33,38,54,56,59,68]. A reduction in modulus of elasticity with increased waste glass has been observed [54], although finely ground waste glass showed an opposite effect on the mechanical properties [24,58] and reintroduced avenues for the reuse of the ground waste glass aggregate as a fine aggregate for the manufacturing of mortars and concrete, in particular when high performance was required. It was indicated that 10%–30% of waste glass aggregates used in the concrete mixes have no influence on the compressive strength of concrete [29,34,35,43,60,63], and can reach a comparable strength to control or can be even higher at later ages [62,64–66]. The reasonable amount of waste glass powder is considered to be 15% [71].

The presence of waste glass aggregates can improve the carbonation resistance of concrete [30] but can also worsen in cases of blended cement mixes with waste glass powder [55]. The influence of fine glass aggregate content on water absorption clearly seemed more pronounced when finer glass aggregates were used [31]. Replacement of natural sand by waste glass particles led to a higher resistance to chloride ion penetration [32,42,69]. A better behavior of the samples with waste glass aggregates was observed after accelerated decay tests [39].

It is known that if waste glass can be ground even finer to be applied as a powder or filler in concrete, its pozzolanic activity can be remarkably improved [44,50]. In this regard, it is possible to receive an even higher value of compressive strength if a fine waste glass powder particle is used in mixes (less than 45 μm) [38]. Finely divided waste glass particles favor a rapid and beneficial pozzolanic reaction over a slower ASR [45,46,48,51,53,61], although they are not as effective as coal fly ash [47]. Waste glass particles finer than

36 μm show no presence of ASR with cement replacement level at 25% [52]. However, it is well known that waste glass chemical composition plays a fundamental role in creating the conditions for developing pozzolanic and/or alkali–silica reactions [57]. It was also reported that alkali–aggregate reaction (AAR) expansion decreases as glass replacement increases up to 50% [49].

Glass powder added to concrete mixes significantly influences the total, macro, and capillary porosity of the mix (for example, in the particular ultra-weight concrete mixture [72] porosity diminished by 5.84% from 58.50% to 52.66% with a maximum compressive strength of 5.7 MPa with liquid glass as an add-on). The same fact of lower porosity has been concluded by other researchers [67]. A mixture of zeolite and waste glass sufficiently compensates for the cement "dilution" effect and makes it possible to reach compressive strength and porosity values similar to those of unmodified concrete [70].

3.3.2. Waste Glass in Gypsum Composite

One of the applications of waste glass is adding it to gypsum composite [73,74], with a possible end product maximum strength of 37.7 MPa, average bulk density of 1963 kg/m^3, and water absorption 3.1%. In this particular application, waste glass increases the bulk density of gypsum–cement composite (from about 1630 to 1963 kg/m^3) and compressive strength (from about 30 MPa to 37.7 MPa), and decreases water absorption (from 10% to 3.1%). Reduced drying shrinkage may be attributed to the pozzolanic reaction between waste glass aggregate and matrix which contributed to a more compact structure and lowered water absorption [73].

3.3.3. Waste Glass in Pavement Solutions

Recycled waste glass can be used in pavement applications as fine aggregate [17,81,82]. In this particular case, recycled waste glass as a filler was used in percentages of 10%, 20%, or 40% by weight of the binder. Using recycled glass improved temperature susceptibility and softening point, increased fatigue resistance by 35% (compared to the control mixture without recycled waste glass), and provided greater rutting resistance [82]. Waste glass usage to date has been limited to unbound pavement layers. The cement-stabilized blends with fine waste glass as a supplementary material with up to 30% content and 3% of cement were found to have physical and strength properties which would comply with road authority requirements and are suitable for applications such as cement-stabilized pavement bases/subbases [75,76]. It was noted that fine recycled glass (<4.75 mm) and medium recycled glass (<9.5 mm) aggregates have to be blended with high-quality aggregates in order to improve their Los Angeles abrasion (LA) and California bearing ratio (CBR) values before being applied in unbound base/subbase pavement applications [77]. Hot mix asphalt mixture containing 100% glass aggregates (HMAG) can mitigate urban heat island effects since it releases 47% less heat than an HMA mixture containing 100% limestone aggregates (HMAL) [78]. The utilization of waste glass and zeolite in concrete pavement construction leads to cool concrete pavements with reduced ASR expansion [79]. The application of reclaimed asphalt pavement (RAP) together with recycled waste glass enhances mechanical concrete pavement properties and offsets the environmental impact of road construction by reducing the demand for virgin aggregates and pavement thickness [80].

3.3.4. Waste Glass in Geopolymer Mortars

Waste glass powder together with calcium aluminate cement as an additive is feasible for reuse to produce high-strength geopolymer binders [83]. Waste glass sand is a suitable alternative to fine sand for geopolymer concrete applications to increase the alkalinity of the matrix. This higher alkalinity is fully consumed during the gel formation stage and does not lead to carbonation in the later stage of matrix development [84]. Waste glass sand and lead smelter slag [88] have been used to make geopolymer mortars, incorporating different types of natural fibers, such as coir, ramie, sisal, hemp, jute, and bamboo fibers. Mortars with waste glass sand show greater compressive strength than lead smelter slag, which is achieved due to the slightly finer particle size of waste glass sand than for lead smelter slag and natural river sand. The introduction of waste glass can mitigate the strength loss after exposure to the high temperature which can be considered as a superior quality to ordinary Portland cement mortars or concrete [85,87]. The results show that the improvement of the percentage of sulphate attack resistance replaced by waste glass/sand is superior [86]. The use of waste glass powder has the potential to control efflorescence in alkali-activated ground granulated blast furnace slag /waste glass powder samples by providing additional silica in the gel matrix, which inhibits the alkali's release. At a 75% replacement level of ground granulated blast furnace slag by waste glass powder, the resulting binder had the least efflorescence and showed no strength loss after the efflorescence test [89].

3.3.5. Waste Glass in Foam Glass

This option includes waste glass formation from CDW and its expansion with the use of foaming agents, with properties easily controlled by the agent's quantity and composition [91]. In a particular case with municipal waste incineration fly ash (30%) and waste glass, values of apparent porosity of 70.3%, compressive strength of 7.94 MPa, bulk density of 0.79 g/cm^3, and thermal conductivity at room temperature of 0.071 W/(m·K) [93] were achieved. Another example of foamed glass made from ferrochrome slag and waste glass is described in the research of Kurtulus et al. [95], who received samples with porosity values from 59.4% to 89.5%, and compressive strength from 0.54 MPa to 2.23 MPa, respectively. The experimental results of Long et al. [97]'s case study demonstrated that good foam glass ceramics with a bulk density of 0.50 g/cm^3, compressive strength of 1.93 MPa, apparent porosity of 74.10%, and water absorption ratio of 0.30% can be obtained by roasting hazardous waste vitrification slag with 4 wt. % Na_2CO_3 and 2 wt. % trisodium phosphate at 950 °C for 1 h. There is another application of foamed waste glass as a filtration media for industrial water [94] with total porosity from 65% to 80% and compressive strength from around 14 MPa to 2 MPa. Zhang et al. [92] identified that 20% of nickel slag and 7% of Na_2CO_3 mixture can reduce the foamed ceramic's density to 0.498 g/cm^3 with a corresponding flexural strength of 2.66 MPa and a higher porosity of 80.06%. It is possible to receive end products with a volume density from 226.75 to 475.78 kg/m^3 depending on the clay used, with the compression strength of obtained samples ranging from 4.68 to 4.06 MPa [90].

3.3.6. Waste Glass in Glass Ceramics

Waste glass can be used in different glass–clay compositions. A method of utilizing lead/zinc smelting slag to make glass ceramics achieved the maximal high values of flexural and compression strength of 128 MPa and 890 MPa, respectively [102]. It can also be mentioned that several metallurgical slags can be used to make glass ceramic products utilizing metallurgical slag and waste glass—ground granulated blast furnace slag, SS (by-product of steel production), SSS (by-product of stainless steel production), EFFS (by-product of ferronickel production), FS (high-calcium slag formed by quenching high-temperature furnace slag in the smelting process of ferromanganese), LFS (by-product of lead manufacturing process), and low-carbon ferrochromium slag (FCS) [99,101]. A method of using molten mining tailings, recycled glass, and alumina platelets using 50 wt. % of molten tailings, 25 wt. % of recycled borosilicate glass, and 25 wt. % of alumina platelets achieved an end product with values of bulk density of 239 kg/m^3, bending strength of 84 MPa, and water absorption of 0.22% [100]. The optimal composition of porous ceramics based on bottle and flat glasses with two different clays—Lielauce and Samini—was elaborated [103], and the obtained results indicated volume density in the range of 227 kg/m^3 to 476 kg/m^3 and compression strength in the range of 4.68 MPa to 4.22 MPa depending on the composition.

3.3.7. Waste Glass as Soil Replacement

There is a known method to utilize crushed waste glass mixed with construction and CDW as a covering/replacing layer to improve the bearing pressure settlement of a weak sand bed, resulting in a three-fold gain in load-bearing capacity in comparison with the same thickness of sandy soil layers [104]. Stabilization of black cotton soil and loam soil with varying percentages of RAP and crushed waste glass indicated an increase in strength and CBR values [105]. Bottle glass along with GGBFS and fly ash were used to stabilize swamp soils to increase poor soil capacity with a CBR value of 1%, and a significant improvement was observed [106].

3.4. Circular Economy

The use of construction and demolition waste and its types of waste glass can be approached systematically in a cycle of use of products. A circular economy is an economic system that uses resources for as long as possible and in that way reduces the generation of waste. A linear economy is an approach that harnesses construction materials for building purposes and trashes them at the end of the life of the building since they are designed and assembled for a single-time use, without the advantage of injecting the used materials back into the system [115]. The linear economy focuses on the limited life span of resources without considering the product's end of life. The cumulative problems of the linear economy have created lots of concerns among governments, construction professionals, and decision makers regarding the need to look for a lasting way to avert the environmental consequences of resource consumption and waste generation. The circular economy has emerged as a veritable initiative to promote a sustainable built environment with increased efficiency for construction resources and waste minimization. Moving to a circular economy not only provides long-term environmental, social, and economic benefits but also preserves natural resources and generates new jobs. The process of decision making to find an optimal method of waste management and transportation can be optimized by using a decision-making visualization environment as shown by [116] in their research. Recycling waste glass in crushed glass aggregate, for example, produces a significant reduction of the environmental impacts compared to sending it to landfills; this was quantified to be approximately (−)10.62 kg CO_2-eq per ton of recycled crushed glass. The Endpoint assessment shows that resource scarcity is a prominent factor over human health and ecosystem damage in measuring the net environmental benefit of waste glass recycling [117].

4. Conclusions

Reusing demolition waste glass as a construction material is a promising way to lessen the amount of glass disposed of in landfills worldwide, reduce the consumption of natural minerals, and minimize the carbon footprint and impact of the construction industry. However, and despite its potential, the percentage of recycling and material recovery of CDW varies greatly worldwide.

The current review indicates enormous efforts dedicated to introducing waste glass as a potential alternative to natural aggregates and cement replacement applications in concrete, and the gaps where this waste can be still applicable and investigated further.

According to the performed bibliometric research in the chosen period from 2000 to 2023, the total search results were 9391 and the journal "Construction and Building Materials" had the most items (456) relevant to the research of demolition waste glass.

There are at least seven areas where demolition waste glass can be used: concrete products, gypsum–cement composites, asphalt or concrete pavement, geopolymer mortars, foamed glass ceramics, glass ceramics, and soil foundation strengthening/stabilization. The most researched subject in waste glass applications is its usage in concrete production. More comprehensive reviews along with life cycle assessment analysis (LCA) on each of the seven areas of application of waste glass can be made in future investigations in each area to provide wider use of waste glass in different approaches, although it is obvious that there is a wide range of items to be researched apart from applications within concrete- and cement-based areas of use.

Author Contributions: Conceptualization, P.T. and A.K.; methodology, P.T. and A.K.; software, P.T.; validation, P.T. and A.K.; formal analysis, P.T.; investigation, P.T. and P.K.D.M.; writing—original draft preparation, P.T.; writing—review and editing, A.K. and P.K.D.M.; visualization, P.T.; supervision, A.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: All data presented in this paper and used for the development of the case study and analysis are publicly available and can be found in the sources cited. If further clarification is needed, the authors are available for further clarifications.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Generation of Waste by Waste Category, Hazardousness and NACE Rev. 2. Activity. Eurostat. Available online: https://ec.europa.eu/eurostat/databrowser/view/env_wasgen/default/table?lang=en (accessed on 29 October 2023).
2. Treatment of Waste by Waste Category, Hazardousness and Waste Management Operation. Eurostat. Available online: https://ec.europa.eu/eurostat/databrowser/view/env_wastrt__custom_8199412/default/table?lang=en (accessed on 29 October 2023).
3. Economic Study on Recycling of Building Glass in Europe. Glass for Europe. Available online: https://www.glassforeurope.com/wp-content/uploads/2018/04/Economic-study-on-recycling-of-building-glass-in-Europe-Deloitte.pdf (accessed on 29 October 2023).
4. Waste and Recycling. European Commission Site. Available online: https://environment.ec.europa.eu/topics/waste-and-recycling_en (accessed on 1 October 2023).
5. Chandru, U.; Bahurudeen, A.; Senthilkumar, R. Systematic comparison of different recycled fine aggregates from construction and demolition wastes in OPC concrete and PPC concrete. *J. Build. Eng.* **2023**, *75*, 106768. [CrossRef]
6. Butler, J.H.; Hooper, P.D. Chapter 15—Glass waste. In *Waste*, 2nd ed.; Letcher, T.M., Vallero, D.A., Eds.; Academic Press: Cambridge, MA, USA, 2019; pp. 307–322. [CrossRef]
7. Waste Management Law. Available online: https://likumi.lv/ta/en/en/id/221378-waste-management-law (accessed on 7 October 2023).
8. Report on the Management of Construction and Demolition Waste in EU. European Commission Site. Available online: https://environment.ec.europa.eu/system/files/2020-12/2011_CDW_Report_0.pdf (accessed on 22 October 2023).
9. Brar, T.S.; Kamal, M.A.; Emerson, P. Recycling of construction and demolition waste material for energy savings in India. *Key Eng. Mater.* **2015**, *632*, 107–117. [CrossRef]
10. Zhang, C.; Hu, M.; Di Maio, F.; Sprecher, B.; Yang, X.; Tukker, A. An overview of the waste hierarchy framework for analyzing the circularity in construction and demolition waste management in Europe. *Sci. Total Environ.* **2022**, *803*, 149892. [CrossRef] [PubMed]
11. Samarakoon, M.H.; Ranjith, P.G.; Hui Duan, W.; Haque, A.; Chen, B.K. Extensive use of waste glass in one-part alkali-activated materials: Towards sustainable construction practices. *Waste Manag.* **2021**, *130*, 1–11. [CrossRef] [PubMed]
12. Robert, D.; Baez, E.; Setunge, S. A new technology of transforming recycled glass waste to construction components. *Constr. Build. Mater.* **2021**, *313*, 125539. [CrossRef]
13. Vigil de la Villa Mencía, R.; Frías, M.; Ramírez, S.M.; Carrasco, L.F.; Giménez, R.G. Concrete/glass construction and demolition waste (CDW) synergies in ternary eco-cement-paste mineralogy. *Materials* **2022**, *15*, 4661. [CrossRef] [PubMed]
14. Bristogianni, T.; Oikonomopoulou, F. Glass up-casting: A review on the current challenges in glass recycling and a novel approach for recycling "as-is" glass waste into volumetric glass components. *Glass Struct. Eng.* **2023**, *8*, 255–302. [CrossRef]
15. Nawaz, A.; Chen, J.; Su, X. Exploring the trends in construction and demolition waste (C&DW) research: A scientometric analysis approach. *Sustain. Energy Technol. Assess.* **2023**, *55*, 102953. [CrossRef]
16. Soto-Paz, J.; Arroyo, O.; Torres-Guevara, L.E.; Parra-Orobio, B.A.; Casallas-Ojeda, M. The circular economy in the construction and demolition waste management: A comparative analysis in emerging and developed countries. *J. Build. Eng.* **2023**, *78*, 107724. [CrossRef]
17. Nandal, M.; Sood, H.; Kumar Gupta, P.; Zia Ul Haq, M. Morphological and physical characterization of construction and demolition waste. *Mater. Today Proc.* **2022**. [CrossRef]
18. McMellan, G.; Shand, E. *Glass Engineering Handbook*, 3rd ed.; McGraw-Hill: New York, NY, USA, 1984; p. 471.
19. Bažant Zdeněk, P.; Zi, G.; Meyer, C. Fracture mechanics of ASR in concretes with waste glass particles of different sizes. *J. Eng. Mech.* **2000**, *126*, 226–232. [CrossRef]
20. Jin, W.; Meyer, C.; Baxter, S. "Glascrete"—Concrete with glass aggregate. *ACI Struct. J.* **2000**, *97*, 208–2013.
21. Ducman, V.; Mladenovič, A.; Šuput, J.S. Lightweight aggregate based on waste glass and its alkali–silica reactivity. *Cem. Concr. Res.* **2002**, *32*, 223–226. [CrossRef]

22. Park, S.-B.; Lee, B.-C. Studies on expansion properties in mortar containing waste glass and fibers. *Cem. Concr. Res.* **2004**, *34*, 1145–1152. [CrossRef]
23. Topçu, İ.B.; Canbaz, M. Properties of concrete containing waste glass. *Cem. Concr. Res.* **2004**, *34*, 267–274. [CrossRef]
24. Corinaldesi, V.; Gnappi, G.; Moriconi, G.; Montenero, A. Reuse of ground waste glass as aggregate for mortars. *Waste Manag.* **2005**, *25*, 197–201. [CrossRef]
25. Terro, M.J. Properties of concrete made with recycled crushed glass at elevated temperatures. *Build. Environ.* **2006**, *41*, 633–639. [CrossRef]
26. Batayneh, M.; Marie, I.; Asi, I. Use of selected waste materials in concrete mixes. *Waste Manag.* **2007**, *27*, 1870–1876. [CrossRef]
27. Taha, B.; Nounu, G. Properties of concrete contains mixed colour waste recycled glass as sand and cement replacement. *Constr. Build. Mater.* **2008**, *22*, 713–720. [CrossRef]
28. Ismail, Z.Z.; Al-Hashmi, E.A. Recycling of waste glass as a partial replacement for fine aggregate in concrete. *Waste Manag.* **2009**, *29*, 655–659. [CrossRef]
29. Limbachiya, M.C. Bulk engineering and durability properties of washed glass sand concrete. *Constr. Build. Mater.* **2009**, *23*, 1078–1083. [CrossRef]
30. de Castro, S.; de Brito, J. Evaluation of the durability of concrete made with crushed glass aggregates. *J. Clean. Prod.* **2013**, *41*, 7–14. [CrossRef]
31. Lee, G.; Poon, C.S.; Wong, Y.L.; Ling, T.C. Effects of recycled fine glass aggregates on the properties of dry–mixed concrete blocks. *Constr. Build. Mater.* **2013**, *38*, 638–643. [CrossRef]
32. Tan, K.H.; Du, H. Use of waste glass as sand in mortar: Part I—Fresh, mechanical and durability properties. *Cem. Concr. Compos.* **2013**, *35*, 109–117. [CrossRef]
33. Zheng, K. 11—Recycled glass concrete. In *Eco-Efficient Concrete*; Pacheco-Torgal, F., Jalali, S., Labrincha, J., John, V.M., Eds.; Woodhead Publishing: Sawston, UK, 2013; pp. 241–270. [CrossRef]
34. Abdallah, S.; Fan, M. Characteristics of concrete with waste glass as fine aggregate replacement. *Int. J. Eng. Tech. Res.* **2014**, *2*, 11–17. Available online: https://www.erpublication.org/published_paper/IJETR021927.pdf (accessed on 23 November 2023).
35. Adaway, M.; Wang, Y. Recycled glass as a partial replacement for fine aggregate in structural concrete—Effects on compressive strength. *Electron. J. Struct. Eng.* **2015**, *14*, 116–122. [CrossRef]
36. Spiesz, P.; Rouvas, S.; Brouwers, H.J.H. Utilization of waste glass in translucent and photocatalytic concrete. *Constr. Build. Mater.* **2016**, *128*, 436–448. [CrossRef]
37. Gorospe, K.; Booya, E.; Ghaednia, H.; Das, S. Effect of various glass aggregates on the shrinkage and expansion of cement mortar. *Constr. Build. Mater.* **2019**, *210*, 301–311. [CrossRef]
38. Khan, M.N.N.; Saha, A.K.; Sarker, P.K. Reuse of waste glass as a supplementary binder and aggregate for sustainable cement-based construction materials: A review. *J. Build. Eng.* **2020**, *28*, 101052. [CrossRef]
39. Alducin-Ochoa, J.M.; Martín-del-Río, J.J.; Torres-González, M.; Flores-Alés, V.; Hernández-Cruz, D. Performance of mortars based on recycled glass as aggregate by accelerated decay tests (ADT). *Constr. Build. Mater.* **2021**, *300*, 124057. [CrossRef]
40. Ferdous, W.; Manalo, A.; Siddique, R.; Mendis, P.; Zhuge, Y.; Wong, H.S.; Lokuge, W.; Aravinthan, T.; Schubel, P. Recycling of landfill wastes (tyres, plastics and glass) in construction—A review on global waste generation, performance, application and future opportunities. *Resour. Conserv. Recycl.* **2021**, *173*, 105745. [CrossRef]
41. Çelik, A.İ.; Özkılıç, Y.O.; Zeybek, Ö.; Karalar, M.; Qaidi, S.; Ahmad, J.; Burduhos-Nergis, D.D.; Bejinariu, C. Mechanical behavior of crushed waste glass as replacement of aggregates. *Materials* **2022**, *15*, 8093. [CrossRef] [PubMed]
42. Junaid, M.F.; Rehman, Z.u.; Kuruc, M.; Medved', I.; Bačinskas, D.; Čurpek, J.; Čekon, M.; Ijaz, N.; Ansari, W.S. Lightweight concrete from a perspective of sustainable reuse of waste byproducts. *Constr. Build. Mater.* **2022**, *319*, 126061. [CrossRef]
43. Ahmad, S.; Upadhyay, S.; Umar, A.; Al-Osta, M.A. Effect of recycled crushed glass and recycled coarse aggregate on the properties of self-compacting concrete. *Case Stud. Constr. Mater.* **2023**, *19*, e02532. [CrossRef]
44. Shao, Y.; Lefort, T.; Moras, S.; Rodriguez, D. Studies on concrete containing ground waste glass. *Cem. Concr. Res.* **2000**, *30*, 91–100. [CrossRef]
45. Dyer Thomas, D.; Dhir Ravindra, K. Chemical reactions of glass cullet used as cement component. *J. Mater. Civ. Eng.* **2001**, *13*, 412–417. [CrossRef]
46. Shayan, A.; Xu, A. Value-added utilisation of waste glass in concrete. *Cem. Concr. Res.* **2004**, *34*, 81–89. [CrossRef]
47. Shi, C.; Wu, Y.; Riefler, C.; Wang, H. Characteristics and pozzolanic reactivity of glass powders. *Cem. Concr. Res.* **2005**, *35*, 987–993. [CrossRef]
48. Shayan, A.; Xu, A. Performance of glass powder as a pozzolanic material in concrete: A field trial on concrete slabs. *Cem. Concr. Res.* **2006**, *36*, 457–468. [CrossRef]
49. Shi, C.; Zheng, K. A review on the use of waste glasses in the production of cement and concrete. *Resour. Conserv. Recycl.* **2007**, *52*, 234–247. [CrossRef]
50. Schwarz, N.; Neithalath, N. Influence of a fine glass powder on cement hydration: Comparison to fly ash and modeling the degree of hydration. *Cem. Concr. Res.* **2008**, *38*, 429–436. [CrossRef]
51. Idir, R.; Cyr, M.; Tagnit-Hamou, A. Use of fine glass as ASR inhibitor in glass aggregate mortars. *Constr. Build. Mater.* **2010**, *24*, 1309–1312. [CrossRef]

52. Chidiac, S.E.; Mihaljevic, S.N. Performance of dry cast concrete blocks containing waste glass powder or polyethylene aggregates. *Cem. Concr. Compos.* **2011**, *33*, 855–863. [CrossRef]
53. Liu, M. Incorporating ground glass in self-compacting concrete. *Constr. Build. Mater.* **2011**, *25*, 919–925. [CrossRef]
54. Ali, E.E.; Al-Tersawy, S.H. Recycled glass as a partial replacement for fine aggregate in self compacting concrete. *Constr. Build. Mater.* **2012**, *35*, 785–791. [CrossRef]
55. Matos, A.M.; Sousa-Coutinho, J. Durability of mortar using waste glass powder as cement replacement. *Constr. Build. Mater.* **2012**, *36*, 205–215. [CrossRef]
56. Kara, P.; Korjakins, A. High Efficiency Ecological Concrete. *Key Eng. Mater.* **2014**, *604*, 157–160. [CrossRef]
57. Bignozzi, M.C.; Saccani, A.; Barbieri, L.; Lancellotti, I. Glass waste as supplementary cementing materials: The effects of glass chemical composition. *Cem. Concr. Compos.* **2015**, *55*, 45–52. [CrossRef]
58. Kim, J.; Yi, C.; Zi, G. Waste glass sludge as a partial cement replacement in mortar. *Constr. Build. Mater.* **2015**, *75*, 242–246. [CrossRef]
59. Afshinnia, K.; Rangaraju, P.R. Impact of combined use of ground glass powder and crushed glass aggregate on selected properties of Portland cement concrete. *Constr. Build. Mater.* **2016**, *117*, 263–272. [CrossRef]
60. Aliabdo, A.A.; Abd Elmoaty, A.E.M.; Aboshama, A.Y. Utilization of waste glass powder in the production of cement and concrete. *Constr. Build. Mater.* **2016**, *124*, 866–877. [CrossRef]
61. Kara, P.; Csetényi, L.J.; Borosnyói, A. Performance Characteristics of Waste Glass Powder Substituting Portland Cement in Mortar Mixtures. *IOP Conf. Ser. Mater. Sci. Eng.* **2016**, *123*, 012057. [CrossRef]
62. Omran, A.; Tagnit-Hamou, A. Performance of glass-powder concrete in field applications. *Constr. Build. Mater.* **2016**, *109*, 84–95. [CrossRef]
63. Ramakrishnan, K.; Pugazhmani, G.; Sripragadeesh, R.; Muthu, D.; Venkatasubramanian, C. Experimental study on the mechanical and durability properties of concrete with waste glass powder and ground granulated blast furnace slag as supplementary cementitious materials. *Constr. Build. Mater.* **2017**, *156*, 739–749. [CrossRef]
64. Elaqra, H.A.; Haloub, M.A.A.; Rustom, R.N. Effect of new mixing method of glass powder as cement replacement on mechanical behavior of concrete. *Constr. Build. Mater.* **2019**, *203*, 75–82. [CrossRef]
65. Hilton, B.; Bawden, K.; Winnebeck, K.; Chandrasiri, C.; Ariyachandra, E.; Peethamparan, S. The functional and environmental performance of mixed cathode ray tubes and recycled glass as partial replacement for cement in concrete. *Resour. Conserv. Recycl.* **2019**, *151*, 104451. [CrossRef]
66. Bueno, E.T.; Paris, J.M.; Clavier, K.A.; Spreadbury, C.; Ferraro, C.C.; Townsend, T.G. A review of ground waste glass as a supplementary cementitious material: A focus on alkali-silica reaction. *J. Clean. Prod.* **2020**, *257*, 120180. [CrossRef]
67. Esmaeili, J.; Oudah Al-Mwanes, A. A review: Properties of eco-friendly ultra-high-performance concrete incorporated with waste glass as a partial replacement for cement. *Mater. Today Proc.* **2021**, *42*, 1958–1965. [CrossRef]
68. Gimenez-Carbo, E.; Soriano, L.; Roig-Flores, M.; Serna, P. Characterization of glass powder from glass recycling process waste and preliminary testing. *Materials* **2021**, *14*, 2971. [CrossRef]
69. Baikerikar, A.; Mudalgi, S.; Ram, V.V. Utilization of waste glass powder and waste glass sand in the production of eco-friendly concrete. *Constr. Build. Mater.* **2023**, *377*, 131078. [CrossRef]
70. Kriptavičius, D.; Girskas, G.; Ivanauskas, E.; Korjakins, A. Complex effect of Portland cement modified with natural zeolite and ground glass mixture on durability properties of concrete. *Buildings* **2023**, *13*, 2576. [CrossRef]
71. Muhedin, D.A.; Ibrahim, R.K. Effect of waste glass powder as partial replacement of cement & sand in concrete. *Case Stud. Constr. Mater.* **2023**, *19*, e02512. [CrossRef]
72. Serelis, E.; Vaitkevicius, V. Effect of waste glass powder and liquid glass on the physico-chemistry of aluminum-based ultra-lightweight concrete. *Constr. Build. Mater.* **2023**, *390*, 131615. [CrossRef]
73. Zhang, L.; Mo, K.H.; Yap, S.P.; Gencel, O.; Ling, T.-C. Mechanical strength, water resistance and drying shrinkage of lightweight hemihydrate phosphogypsum-cement composite with ground granulated blast furnace slag and recycled waste glass. *Constr. Build. Mater.* **2022**, *345*, 128232. [CrossRef]
74. Zhang, L.; Mo, K.H.; Yap, S.P.; Tan, T.H. Recycled waste glass as fine aggregate in eco-friendly gypsum-cement composite. *Mater. Today Proc.* **2023**. [CrossRef]
75. Arulrajah, A.; Disfani, M.M.; Haghighi, H.; Mohammadinia, A.; Horpibulsuk, S. Modulus of rupture evaluation of cement stabilized recycled glass/recycled concrete aggregate blends. *Constr. Build. Mater.* **2015**, *84*, 146–155. [CrossRef]
76. Saberian, M.; Li, J.; Boroujeni, M.; Law, D.; Li, C.-Q. Application of demolition wastes mixed with crushed glass and crumb rubber in pavement base/subbase. *Resour. Conserv. Recycl.* **2020**, *156*, 104722. [CrossRef]
77. Mohajerani, A.; Vajna, J.; Cheung, T.H.H.; Kurmus, H.; Arulrajah, A.; Horpibulsuk, S. Practical recycling applications of crushed waste glass in construction materials: A review. *Constr. Build. Mater.* **2017**, *156*, 443–467. [CrossRef]
78. Mammeri, A.; Vaillancourt, M.; Shamsaei, M. Experimental and numerical investigation of using waste glass aggregates in asphalt pavement to mitigate urban heat islands. *Clean Technol. Environ. Policy* **2023**, *25*, 1935–1948. [CrossRef]
79. Balan, L.A.; Anupam, B.R.; Sharma, S. Thermal and mechanical performance of cool concrete pavements containing waste glass. *Constr. Build. Mater.* **2021**, *290*, 123238. [CrossRef]

80. Patel, N.; Amin, S.; Iqbal, R. Use of reclaimed asphalt pavement and recycled waste glass as partial aggregate replacements in concrete pavements. In *Role of Circular Economy in Resource Sustainability*; Ghadimi, P., Gilchrist, M.D., Xu, M., Eds.; Springer International Publishing: Cham, Switzerland, 2022; pp. 97–109. [CrossRef]
81. Maurya, N.; Srivastav, Y.; Rawat, S.; Ranjan, Y.; Srivastava, R.; Shukla, B.K.; Varadharajan, S. Reinforcing civil infrastructure with waste glass-enhanced concrete: A comprehensive review of properties, performance and applications. *Mater. Today Proc.* **2023**. [CrossRef]
82. Gedik, A. An exploration into the utilization of recycled waste glass as a surrogate powder to crushed stone dust in asphalt pavement construction. *Constr. Build. Mater.* **2021**, *300*, 123980. [CrossRef]
83. Vafaei, M.; Allahverdi, A. High strength geopolymer binder based on waste-glass powder. *Adv. Powder Technol.* **2017**, *28*, 215–222. [CrossRef]
84. Hajimohammadi, A.; Ngo, T.; Kashani, A. Glass waste versus sand as aggregates: The characteristics of the evolving geopolymer binders. *J. Clean. Prod.* **2018**, *193*, 593–603. [CrossRef]
85. Lu, J.-X.; Poon, C.S. Use of waste glass in alkali activated cement mortar. *Constr. Build. Mater.* **2018**, *160*, 399–407. [CrossRef]
86. Luhar, S.; Cheng, T.-W.; Nicolaides, D.; Luhar, I.; Panias, D.; Sakkas, K. Valorisation of glass wastes for the development of geopolymer composites—Durability, thermal and microstructural properties: A review. *Constr. Build. Mater.* **2019**, *222*, 673–687. [CrossRef]
87. Zhang, B.; He, P.; Poon, C.S. Optimizing the use of recycled glass materials in alkali activated cement (AAC) based mortars. *J. Clean. Prod.* **2020**, *255*, 120228. [CrossRef]
88. Gholampour, A.; Danish, A.; Ozbakkaloglu, T.; Yeon, J.H.; Gencel, O. Mechanical and durability properties of natural fiber-reinforced geopolymers containing lead smelter slag and waste glass sand. *Constr. Build. Mater.* **2022**, *352*, 129043. [CrossRef]
89. Ali, H.A.; Sun, K.; Xuan, D.; Lu, J.-X.; Cyr, M.; Poon, C.S. Recycling of high-volume waste glass powder in alkali-activated materials: An efflorescence mitigation strategy. *J. Build. Eng.* **2023**, *65*, 105756. [CrossRef]
90. Bernardo, E.; Cedro, R.; Florean, M.; Hreglich, S. Reutilization and stabilization of wastes by the production of glass foams. *Ceram. Int.* **2007**, *33*, 963–968. [CrossRef]
91. Domínguez, A.; Domínguez, M.I.; Ivanova, S.; Centeno, M.A.; Odriozola, J.A. Recycling of construction and demolition waste generated by building infrastructure for the production of glassy materials. *Ceram. Int.* **2016**, *42*, 15217–15223. [CrossRef]
92. Zhang, C.; Wang, X.; Zhu, H.; Wu, Q.; Hu, Z.; Feng, Z.; Jia, Z. Preparation and properties of foam ceramic from nickel slag and waste glass powder. *Ceram. Int.* **2020**, *46*, 23623–23628. [CrossRef]
93. Fan, Y.; Li, S.; Li, Y.; Liang, H.; Tang, M.; Huang, K.; Zhu, L. Recycling of municipal solid waste incineration fly ash in foam ceramic materials for exterior building walls. *J. Build. Eng.* **2021**, *44*, 103427. [CrossRef]
94. Shishkin, A.; Aguedal, H.; Goel, G.; Peculevica, J.; Newport, D.; Ozolins, J. Influence of waste glass in the foaming process of open cell porous ceramic as filtration media for industrial wastewater. *J. Clean. Prod.* **2021**, *282*, 124546. [CrossRef]
95. Kurtulus, C.; Kurtulus, R.; Kavas, T. Foam glass derived from ferrochrome slag and waste container glass: Synthesis and extensive characterizations. *Ceram. Int.* **2021**, *47*, 24997–25008. [CrossRef]
96. Nguyen, M.; Sedlačík, M.; Sokolař, R.; Opravil, T. Preparation of inorganic foam glass-ceramic with utilization of waste diatomite as a raw material. *Mater. Sci. Forum* **2022**, *1071*, 222–228. [CrossRef]
97. Long, Y.; Song, Y.; Huang, H.; Yang, Y.; Shen, D.; Geng, H.; Ruan, J.; Gu, F. Preparation of foam glass ceramics from hazardous waste vitrification slag with the addition of Na_2CO_3. *Constr. Build. Mater.* **2023**, *404*, 133225. [CrossRef]
98. Hamidon, A.; Badarulzaman, N.A.; Muhamad Nor, M.A.A. Recycled glass potential as porous ceramic determine by spectroscopy analysis. *Adv. Mater. Res.* **2015**, *1087*, 457–459. [CrossRef]
99. Shang, W.; Peng, Z.; Huang, Y.; Gu, F.; Zhang, J.; Tang, H.; Yang, L.; Tian, W.; Rao, M.; Li, G.; et al. Production of glass-ceramics from metallurgical slags. *J. Clean. Prod.* **2021**, *317*, 128220. [CrossRef]
100. Cetin, S. Production of sintered glass-ceramic composites from low-cost materials. *Ceram. Int.* **2023**, *49*, 22386–22392. [CrossRef]
101. Deng, S.; Li, C.; Guo, H.; Zhao, W.; Yan, B.; Li, P. Crystallization characteristics, microstructural evolution, and Cr migration mechanism of glass-ceramics synthesized entirely from low-carbon ferrochromium slag and waste glass. *J. Hazard. Mater.* **2023**, *445*, 130621. [CrossRef] [PubMed]
102. Liu, X.; Wu, Y.; Pan, D.a.; Li, B.; Wang, W. Study on controllable preparation of high performance andradite based glass-ceramics by harmful iron-rich waste slag. *Sci. Total Environ.* **2023**, *901*, 165754. [CrossRef] [PubMed]
103. Tihomirovs, P.; Korjakins, A. Recycled waste glass usage for construction materials. *J. Phys. Conf. Ser.* **2023**, *2423*, 012002. [CrossRef]
104. Moghaddas Tafreshi, S.N.; Khanjani, A.A.; Dawson, A.R.; Faramarzi, A. Performance of recycled waste aggregate mixed with crushed glass over a weak subgrade. *Constr. Build. Mater.* **2023**, *402*, 133002. [CrossRef]
105. Kumar, C.R.; Gadekari, R.S.; Vani, G.; Mini, K.M. Stabilization of black cotton soil and loam soil using reclaimed asphalt pavement and waste crushed glass. *Mater. Today Proc.* **2020**, *24*, 379–387. [CrossRef]
106. Kusuma, R.I.; Mina, E.; Fathonah, W.; Fatwari, M.H.A. Utilization of waste steel slag, fly ash, glass bottle powder for swamp soil stabilization. *Mater. Sci. Forum* **2023**, *1101*, 109–114. [CrossRef]
107. Chen, G.; Lee, H.; Young, K.L.; Yue, P.L.; Wong, A.; Tao, T.; Choi, K.K. Glass recycling in cement production—An innovative approach. *Waste Manag.* **2002**, *22*, 747–753. [CrossRef]

108. Chandra Paul, S.; Šavija, B.; Babafemi, A.J. A comprehensive review on mechanical and durability properties of cement-based materials containing waste recycled glass. *J. Clean. Prod.* **2018**, *198*, 891–906. [CrossRef]
109. Gołek, Ł. New insights into the use of glass cullet in cement composites—Long term examinations. *Cem. Concr. Compos.* **2022**, *133*, 104673. [CrossRef]
110. Qaidi, S.; Najm, H.M.; Abed, S.M.; Özkılıç, Y.O.; Al Dughaishi, H.; Alosta, M.; Sabri, M.M.; Alkhatib, F.; Milad, A. Concrete containing waste glass as an environmentally friendly aggregate: A review on fresh and mechanical characteristics. *Materials* **2022**, *15*, 6222. [CrossRef]
111. Epure, C.; Munteanu, C.; Istrate, B.; Harja, M.; Buium, F. Applications of recycled and crushed glass (RCG) as a substitute for natural materials in various fields—A review. *Materials* **2023**, *16*, 5957. [CrossRef] [PubMed]
112. Jiang, Y.; Ling, T.-C.; Mo, K.H.; Shi, C. A critical review of waste glass powder—Multiple roles of utilization in cement-based materials and construction products. *J. Environ. Manag.* **2019**, *242*, 440–449. [CrossRef] [PubMed]
113. Ahmad, J.; Zhou, Z.; Usanova, K.I.; Vatin, N.I.; El-Shorbagy, M.A. A step towards concrete with partial substitution of waste glass (WG) in concrete: A review. *Materials* **2022**, *15*, 2525. [CrossRef] [PubMed]
114. Bessmertniy, V.S.; Puchka, O.; Bondarenko, M.; Gorety, V. The glass powders' dispersion effect on the glass-reinforced concrete performance properties. *Mater. Sci. Forum* **2020**, *1011*, 85–91. [CrossRef]
115. Oluleye, B.I.; Chan, D.W.M.; Saka, A.B.; Olawumi, T.O. Circular economy research on building construction and demolition waste: A review of current trends and future research directions. *J. Clean. Prod.* **2022**, *357*, 131927. [CrossRef]
116. Wang, T.-K.; Wu, Z.; Luo, C. Multi-participant construction waste demolition and transportation decision-making system. *Resour. Conserv. Recycl.* **2021**, *170*, 105575. [CrossRef]
117. Tushar, Q.; Salehi, S.; Santos, J.; Zhang, G.; Bhuiyan, M.A.; Arashpour, M.; Giustozzi, F. Application of recycled crushed glass in road pavements and pipeline bedding: An integrated environmental evaluation using LCA. *Sci. Total Environ.* **2023**, *881*, 163488. [CrossRef]