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Microstructural attributes and physiochemical behaviours of concrete incorporating various synthetic textile and cardboard fibres: A comparative review

Robert Haigh, Malindu Sandanayake [*], Soorya Sasi, Ehsan Yaghoubi, Paul Joseph, Zora Vrcelj

Institute for Sustainable Industries and Liveable Cities, Victoria University, Melbourne, VIC 3011, Australia

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ABSTRACT

The excessive use of virgin materials for manufacturing cementitious materials in the building and construction industry creates detrimental environmental effects. The integration of waste materials in composites promote sustainable opportunities within the industry. This paper presents a systematic review of the use of synthetic textile and cardboard waste fibres in concrete in conjunction with infrequently used additives such as gypsum, metakaolin, alumina and zinc oxide. The synthetic nature of polyester and nylon fibres facilitates their integration into high alkaline environments. Kraft fibres, derived from cardboard, exhibit high tensile strength but also absorb water, limiting their use in construction. However, by employing coating applications, these limitations can be mitigated. Gypsum prolongs setting times, improves workability, and enhances the sulphate resistance of concrete. Metakaolin's reactivity with calcium hydroxide results in improved strength, density, and durability. Alumina oxide can enhance the mechanical and thermal characteristics. Whereas zinc oxide, known for its UV protection and antimicrobial properties has a retarder effect and can improve the materials longevity in extreme environments. Scanning electron microscope images of the synthetic textile fibres demonstrate sustained durability features in the composite materials whereas, kraft fibres exhibited deterioration properties. Fibre bonding and deterioration aspects of the material varied within each matrix environment. This corresponded to a varied microstructural response with the fibrous materials. The findings from this review demonstrate the sustainability opportunities when integrating additive and waste materials in composite designs.

1. Introduction

Concrete is widely used in the construction industry as a major construction material due to its advantageous properties such as workability, durability, and mechanical strength [1]. Despite having high compressive strength characteristics, concrete has a low tensile strength and strain limit [2]. In reinforced concrete, the bond between the cementitious matrix and the reinforcing bars is critical to ensure the serviceability and longevity of the application. However, traditional steel reinforcement cannot always be employed in novel designs with irregular shapes and relatively thin composite materials. Therefore, fibre reinforced composites are emerging as an alternative method owing to their corrosion resistance and economic feasibility [3]. Fibre reinforced composites have also gained

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[*] Corresponding author.

E-mail addresses: Robert.haigh@vu.edu.au (R. Haigh), malindu.sandanayake@vu.edu.au (M. Sandanayake), Soorya.sasi@vu.edu.au (S. Sasi), Ehsan.yaghoubi@vu.edu.au (E. Yaghoubi), paul.joseph@vu.edu.au (P. Joseph), zora.vrcelj@vu.edu.au (Z. Vrcelj).

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significant attention due to their inherent beneficial properties, including lightweight, toughness, and ease of processing [4]. Integrating fibres in composite designs can reduce crack propagation caused by drying and plastic shrinkage while enhancing impact and abrasion resistance [5]. Various types of fibres including steel, glass, plastics, and cellulose fibres have been commonly incorporated in concrete as a reinforcing agent [6]. Most of the synthetic fibres can be utilised more frequently within cementitious composite materials due to their ability to withstand degradation from the high alkaline environment [7]. Lower resistance in high alkaline environment has restricted the use of natural fibres as a reinforcement in concrete. However, there is an emerging trend for utilisation of fibres derived from waste materials in order to enhance sustainability targets within the building and construction industry. Moreover, reducing virgin steel reinforcement can make a significant carbon saving and lead to sustainability targets within the construction industry [8]. The utilisation of alternative additives can also pose a method to enhance composite designs and sustain the longevity of vulnerable waste fibres in concrete materials [9].

Significant research has shown promising outcomes by using additive waste materials such as fly ash (FA), ground blast furnace slag (GBFS) and silica fume (SF) [10–12]. These materials are derived from industrial waste systems and integrated within concrete as a supplementary cementitious material (SCM) [13], yielding beneficial mechanical results and improving the durability of concrete materials [13]. Due to the known effect of these materials, the integration of other additive materials can often be overlooked. Moreover, the use of alternative additives could yield unknown benefits when used with fibres in concrete materials. The utilisation of common SCMs with fibre integration has been comprehensively reviewed [14]. Therefore, this review has systematically focused on infrequently used additive materials that can be used with alternative waste fibres. Waste materials can also provide a sustainable option when reinforcing concrete materials. This has been shown by Bertelsen et al., that by utilising recycled polyethylene (PET) fibres to strengthen cementitious composites [15]. Their research determined the integration of fibres mitigated larger crack formation when under applied stress. It was also shown with 5% fibre integration that increased flexural strength significantly, i.e. by 75%. Moreover, the inclusion of the recycled fibres influenced the drying shrinkage rate of the composite, thus stabilising the curing phases of the material. Recycled plastics have been also heavily researched due to their non-degradability and harmful effect on the environment [16]. Other transitioned fibrous materials such as glass and steel have also yielded mechanical benefits when integrated in fibre composites [16–18]. This can be attributed to the fibres' ability to withstand degradation caused by the high alkaline matrix within cementitious materials. This durability factor demonstrates the potential for other waste material integration, such as textile and cardboard fibrous materials.

Recycling textile products requires extensive energy and economic inputs. Due to these repurposing issues, generally an excessive landfill dumping is undertaken. Therefore, bespoke applications of recycling textiles is highly essential. According to the US Environmental Protection Agency (EPA), approximately 26 billion pounds of textiles are landfilled annually in the United States [19]. Moreover, in Australia, approximately 500 million kilograms of textiles are disposed of annually [20]. As the population is set to increase to 8.5 billion by 2030, the accumulation of these waste materials will continue to grow [21]. Textile fibres such as polyester and nylon are becoming increasingly used in the construction industry, however recycled fibres are not yet commonly adopted. This is primarily due to the uncertainty of the materials strength and durability attributes [22]. However, promising applications using the material have been shown within geotextile-geogrids. Rahman et al., observed a 170% strength increase when applying the fabric reinforcement to weakened soil areas [23]. Similarly, blended waste textiles have the potential to improve both thermal and acoustic insulation properties in soil mass [24]. These applications are critical in the development of various civil construction activities.

Population growth exacerbates all waste streams, especially cardboard materials. Cardboard materials are used across all economic sectors and the demand of cardboard packaging for households has risen 40% since the Covid-19 pandemic [25]. Therefore, to sustain future development of composite designs, it is critical to consider bespoke methods to enhance the use of these materials. Current applications of cardboard waste used in the construction industry include packaging applications, insulation, and acoustic panelling systems [26,27]. The commercial application of cardboard fibres in composite systems has not been adopted due to the uncertainty of the mechanical and durability properties. Moreover, it is also critical to understand the microstructural behaviour of these waste materials in concrete to enhance the promotion of using of textile and cardboard waste as an alternative reinforcement method in composite designs. The primary objective of this review paper is to address the existing gap in literature concerning alternative fibre types, additives, and their associated microstructural behaviour. The findings of the paper will be useful for industries and researchers who are keen to utilise novel waste materials to enhance the sustainability of concrete materials. Furthermore, the discernible outcomes from \ this review will also enhance understanding of current trends, and priorities associated with utilising alternative fibre and additive materials in concrete. Additionally, stakeholders will gain insights into the factors to consider when selecting suitable waste fibrous materials for the development of sustainable building materials.

2. Research significance and methodologies

Cement manufacturing contributes 5–8% of total CO_2 emissions worldwide annually [28]. Therefore, researchers are integrating waste materials and additives with a view to reducing the amount of cement required in concrete [29,30]. However, further benefits can be associated with the use of waste fibre materials to lower the reinforcement requirements in concrete. Fibre materials can also reduce crack propagation, increase tensile and toughness capacity [31]. Moreover, the use waste fibrous materials in concrete can also enhance sustainable targets within the building and construction industry by reducing the virgin steel consumption. Further advantages of using waste materials include the reduction of waste accumulation in landfill areas. The utilisation of numerous fibres in cementitious composites has been observed worldwide [32]. However, incorporating waste products in concrete materials often has limitations such as availability and cost-related concerns. Therefore, integrating abundantly available textile and cardboard waste materials can be advantageous for these reasons.

Each year, the textile industry consumes approximately 98 million tonnes of non-renewable resources including oil, raw materials for fertilizers and treatment chemicals [33]. At the same time, the final output of CO_2 emissions from the textile industry accounts for 1.2 billion tons, or 8% of the global total [34]. Although the history of textile materials is dominated by cotton and synthetic materials, the industry is searching for sustainable materials such as wood-based cellulosic fibres [35]. The aim to adopt new materials is to reduce the environmental impact the industry is currently causing. Worldwide, there are 100 billion garments produced annually, with 92 million tonnes going to landfill [36]. This is primarily due to economic feasibility for consumers to purchase new clothing. The potential of cardboard waste materials in concrete has often been overlooked due to its inherent challenges associated with using a product derived from natural materials. In 2021, Australia achieved a resource recovery rate of 61.2% for cardboard waste, with 55% being recycled and 6.2% directed toward energy recovery. Despite these efforts, a substantial amount of 2.2 million tons (Mt) of cardboard waste still ended in landfill [37]. This value is particularly significant considering the volumetric size of 1 ton of cardboard waste is equivalent to 1.6 m^3 in size. To promote the use of textile and cardboard waste fibres in concrete, a review of the microstructural behaviour is required when using these materials.

As shown in Fig. 1, a systematic review and experimental methodology of waste textile and cardboard fibre concrete is proposed to understand the current benefits, trends and limitations when used as additive materials. Firstly, synthetic textile and cardboard waste materials that are not commonly adopted in concrete have been reviewed to determine common trends associated with using these materials. Secondly, a review of additive materials used in concrete was undertaken. The output determined four key additive materials that are not commonly used with textile and cardboard materials. Finally, an analysis of the microstructural behaviour when using the infrequently used additives and fibre types in concrete. A scanning electron microscope (SEM) was utilised to determine the microstructure behaviour of the fibres in some of the various concrete materials. These observations were performed using the Phenom XL G2 Desktop SEM. The samples were prepared by crushing the concrete materials to locate the fibres and determine the correlating effects.

3. Synthetic textile and cardboard waste fibres in concrete

3.1. Polyester fibres

Polyester fibres are a class of synthetic material often made from a polymer called polyethylene terephthalate (PET). It is widely used in the textile industry due to its strength and durability. The fibres are moisture resistant and versatile to be blended with other materials. Polyester fibres are not biodegradable and derived from non-renewable sources. In composite materials, polyester resin has been commonly adopted [38–40]. Polyester resin, in the form of a liquid, is a thermosetting binding agent that is shown to enhance versatility, adhesive properties, and chemical resistance of other structural components [40–42]. Although polyester fibres are derived from polyester resin, this review will focus on polyester fibres that can be sourced from recycled textiles. When using recycled textile fibres in composite materials, several challenges arise. For example, contamination and impurities often hinder the commer-

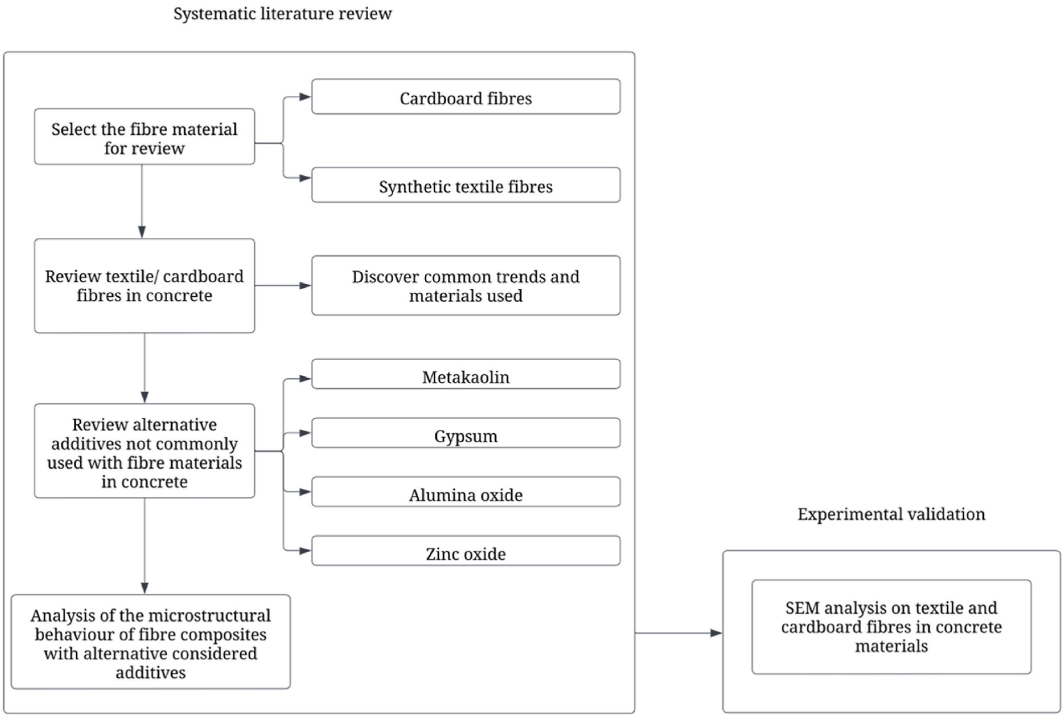

Fig. 1. Proposed review methodology and the experimental validation.

cial adoption of the fibres. Additionally, inconsistent fibre quality can lead to inconsistencies and increase composite variables. These variabilities can create adhesion and bonding issues which can lead to reduced mechanical properties and cause weakened microstructural effects. To mitigate these negative effects, optimisation of processing techniques can aid toward the adoption of recycled materials. This can be created by pre-treatment of recycled fibres and surface modification techniques. Moreover, blended optimisation of various recycled fibres can reduce the variability of one fibre type. This review aims to demonstrate additional resolutions when using waste fibres by the inclusion of additive materials that are not commonly used in composite materials. Table 1 demonstrates different applications of polyester fibres as an additive used in concrete materials. As shown, various additives and activators are often used with polyester fibres to enhance composite behaviour. The synthetic nature of polyester fibres creates an ease of transferability into composite materials compared to their natural counterparts; hence, the integration of both polyester fibres and resin in high alkaline environments.

3.2. Nylon fibres

Nylon is a synthetic fibre widely used as a textile material. Nylon was first developed in the 1930s and is used across the textile industry since. Nylon is known for its strength and durability factors and is one of the strongest synthetic fibres available [57]. Nylon is also often used in abrasive applications due to its high versatility. However, the material has a low heat resistance is often blended with other fabrics [57]. Nylon is an economically cheap fibre material and is abundantly available. Table 2 depicts research toward the integration of nylon fibres in concrete materials. Additives and activators within the composite designs are a common method to reduce cement consumption, hence increasing sustainable measures. As shown, nylon has been typically used as a reinforcement

Table 1
Previous studies on polyester fibres as an additive in concrete.

Fibre %	Application	Main study focus	Additive	Reference
20.5	Polymer concrete	Mechanical and durability	Silane coupling agent	[43]
0.03–0.05	Concrete	Mechanical and physical	Fly Ash	[44]
0.25	Asphalt concrete	Mechanical and durability	Calcium lignosulfonate	[45]
20	Concrete walls	Mechanical, thermal and acoustic	Gypsum	[46]
0.08–0.16	Concrete road overlay	Mechanical, microstructural and physical	Styrene–Butadiene–Rubber (SBR) latex	[47]
1.1–0.5	Polymer concrete	Mechanical and thermal	Unsaturated resin	[48]
1.1–0.9	Reactive powder concrete	Mechanical, durability, thermal, microstructural	Silica fume	[49]
30	Polymer concrete	Mechanical, durability and microstructural	Polyester resin methyl ethyl ketone peroxide (MEKP)	[50]
0.5–1.4	Concrete	Mechanical, thermal, and microstructure	Methyl ethyl ketone peroxide (MEKP)	[51]
37.1–32.8	Concrete	Mechanical	Methyl Ethyl Ketone Peroxide (MEKP)	[52]
0.1–0.2	Concrete	Mechanical	Micronized silica	[53]
3–5	Concrete	Mechanical	N/A	[54]
0.55	Concrete	Mechanical, microstructure and thermal	Sodium hydroxide	[55]
15	Concrete	Mechanical	Isocyanate, polyol, chain extender and catalyst	[56]

Table 2
Previous studies on nylon fibres as an additive in concrete.

Fibre %	Application	Main study focus	Additive	Reference
0.025–0.05	High strength concrete	Mechanical and thermal (spalling)	Silica fume Fly Ash	[58]
0.9	Geopolymer concrete	Mechanical and physical	Fly Ash	[59]
10–20	Fibre reinforced concrete	Mechanical, thermal, microstructure and optimisation	N/A	[60]
0.5	Concrete	Mechanical, thermal, physical and microstructure	N/A	[61]
0.9–1.8	Fibre reinforced concrete	Mechanical, microstructure	Fly Ash	[62]
0.25–0.75	Concrete	Mechanical	Oil palm shell	[63]
0.25–0.5	Concrete	Mechanical and durability	N/A	[64]
0.05–1	Fibre reinforced concrete	Mechanical, physical and durability	N/A	[65]
2	Nano fibre concrete	Mechanical	Fly Ash Silica fume	[66]
0.2–0.4	Pavement	Mechanical and durability	N/A	[67]
1–10	Concrete	Mechanical and physical	Silica fume	[68]
0.5–1	Fibre reinforced concrete	Mechanical	N/A	[69]
10–20	Fibre reinforced concrete	Mechanical, physical, and thermal	Zeolite	[70]
0.25–0.75	Concrete	Mechanical, physical, and optimisation	Stone dust	[71]
0.75	Concrete	Mechanical, physical, and optimisation	Stone dust	[72]
10–20	Fibre reinforced concrete	Mechanical, thermal, durability, optimisation and microstructural	Zeolite	[73]
0.9–1.8	Fibre reinforced concrete	Mechanical, durability and physical	Fly Ash	[74]
0.125–3	Fibre reinforced concrete	Mechanical	N/A	[75]
0.75–1.25	Fibre reinforced concrete	Mechanical, durability, optimisation, thermal and microstructural	N/A	[76]
5	Fibre reinforced concrete	Mechanical and physical	N/A	[77]
0.485	Concrete	Mechanical, microstructure and thermal	N/A	[78]
0.3–3	Self- compacting concrete	Mechanical and durability	Sodium hydroxide treatment	[79]

agent due to its high strength characteristics. Nylon fibres have less degradation caused on the fibre walls compared to their natural fibre counterpart when integrated within cementitious environments. Therefore, more research is provided on using nylon in research applications.

3.3. *Kraft fibres*

The main constituent of cardboard materials is kraft fibres (KFs). KFs are a natural cellulosic material derived from plant-based materials. The chemical pulping process is known as the kraft process, which enables the fibres to disperse from the plant-based materials [80]. Primarily from soft timbers, KFs have a high tensile strength allowing them to be used in packaging materials. However, repeatedly recycling the material can cause degradation on the fibre walls and reduce the size of the fibres [81]. The natural characteristics of KFs can be challenging to integrate further in construction materials. For example, the fibres have a high-water absorption characteristic, limiting their applications in construction [82]. However, coating applications can reduce the swelling occurring on the fibre walls, minimising water absorption occurring. Additionally, the use of additive materials to overcome reduced strength outcomes could mitigate the negative mechanical effects the fibres have within a composite matrix. Moreover, alternative resolutions are required to enhance the adoptable approach when integrating bespoke materials. This is shown with waste material research provided by Haigh et al., that discuss the trade-offs between multi-objective parameters [83]. When optimising novel materials for further implementation, there is often a compromise between certain limitations. Therefore, this study aims to overcome the limitations presented when using waste fibres in composite materials by highlighting the use of novel additive materials. Table 3 demonstrates the limited research on using waste cardboard materials within construction materials. As shown, KFs can be incorporated as a partial filler, or reinforcement, agent in cementitious composites. There is only limited amount research into the use of these fibres as compared to the synthetic counterparts. Moreover, to enhance the sustainability of the construction industry, utilising waste streams such as cardboard could provide beneficial progress toward target emission goals.

4. Additive materials

4.1. *Gypsum*

Gypsum is a common construction material typically applied in sheeting panels. This is primarily due to the non-combustible elements within gypsum that allow the material to withstand excessive heat and without decomposing [91]. For this reason, gypsum can be beneficial within concrete as an additive material. Gypsum can also prolong the setting time within concrete materials [92]. This is advantageous in excessive environmental heat conditions and transport distances are significant. Other advantages of gypsum in cementitious composites is an improved workability and flowability [93]. Moreover, gypsum has been shown to increase the sulphate resistance of concrete as well as reducing the heat during the hydration process [94]. These properties can also prolong the durability of gypsum-based concrete as there is a reduction in chemical and thermal cracking, respectively [95]. Table 4 demonstrates gypsum within concrete materials. As shown, gypsum is commonly used with other SCM materials to create eco-friendly concrete. However, gypsum has typically been used as an additive, while other SCMs are used to partially replace cement materials.

4.2. *Metakaolin*

Metakaolin is a common SCM in concrete. It is produced by thermally activating kaolin clay at temperatures between 600 and 900 °C [109]. This also transforms the kaolin clay into a reactive amorphous material. MK has been viewed as a sustainable alterative to cement because of the reduced energy requirements to create the material. Although MK is not commonly used as other SCMs, the material does produce beneficial results in concrete. MK is highly reactive and can participate in the pozzolanic reaction with calcium hydroxide to form additional calcium silicate hydrates (C-S-H) gels. This leads to improved strength, increased density, and enhanced concrete durability [110]. These benefits lead toward a reduction in permeability, enhanced flowability, and increased workability. MK can also reduce the alkali-silica reaction (ASR) that occurs between different aggregates. MK has been shown to mitigate potential ASR by reducing the alkalis in concrete materials [111]. Table 5 demonstrates previous studies of metakaolin used as an additive in concrete. As shown, MK is often used in conjunction with other additive and activator materials.

4.3. *Alumina oxide*

Alumina oxide is natural mineral compound composed of alumina and oxygen. This material is commonly found in the mineral corundum. When the size of the alumina oxide particles is reduced to nano scale, the material can exhibit unique properties. This material is also referred to as nano-alumina. Nano-alumina can enhance the mechanical properties when used as a filler in composites,

Table 3
Previous studies on cardboard waste in concrete.

Fibre %	Application	Main study focus	Additive	Reference
5	Concrete composites	Mechanical and microstructure	Silica fume coating	[84]
10	Concrete composites	Mechanical, microstructure and thermal	Silica fume coating	[85]
10	Concrete composites	Mechanical, microstructure and durability	Silica fume coating	[86]
15–20	Concrete composites	Mechanical	Silica fume coating	[87]
0.8	Concrete blocks	Mechanical, thermal and durability	N/A	[88]
5–15	Concrete	Mechanical	N/A	[89]
10–40	Concrete	Mechanical, microstructure and durability	N/A	[90]

Table 4
Previous studies on gypsum used as an additive in concrete.

Application	Main study focus	Comments	Reference
Light foamed concrete	Mechanical, physical and microstructure	Increased foaming expansion	[96]
Sustainable concrete	Mechanical, physical, microstructure, economic and sustainability	Reduced carbon emissions and costs	[97]
Shotcrete	Microstructure	Large isotopic heterogeneity	[98]
Concrete	Durability and microstructure	Increased formation of ettringite, decreased pore structure	[99]
Concrete	Mechanical	Orientation of gypsum as a bedding material can alter tensile strength	[100]
Floor slab	Mechanical	Improved flexural strength	[101]
Concrete	Durability	Lowered permeability	[102]
Concrete	Mechanical, thermal and microstructure	Reduced costs and emissions. Improved mechanical properties	[103]
Concrete	Mechanical, thermal and microstructure	Higher porosity and higher drying shrinkage rate	[104]
Concrete	Mechanical, physical and microstructure	Reduced compressive strength	[105]
Ultra-high strength concrete	Mechanical, physical and microstructure	Reduced compressive strength at 11.5% gypsum integration	[106]
Concrete	Mechanical, physical and microstructure	Reduced tensile strength	[107]
Concrete	Mechanical, thermal and microstructure	Improved early age mechanical strength	[108]

Table 5
Previous studies on metakaolin used as an additive in concrete.

Application	Main study focus	Comments	Reference
Concrete	Mechanical and thermal	MK is not as reactive as ultrafine slag and produces less strength in comparison	[109]
Concrete	Mechanical, thermal and microstructure	Increase dosage of MK reduces strength characteristics	[112]
Concrete pavement	Mechanical, thermal, and physical	Less thermal expansion with the presence of MK	[113]
Concrete	Mechanical, thermal, physical and microstructure	MK improves the flexibility of the concrete	[114]
Concrete	Mechanical, physical and microstructure	The amorphous phase of MK is attacked by the alkaline solution	[115]
Concrete	Mechanical, thermal, microstructure and durability	MK reduces the transference of water and chloride ingress	[116]
Concrete	Mechanical and physical	Optimal amount of MK was 15% based on compressive strength characteristics	[117]
Lightweight concrete	Mechanical, thermal and microstructure	Optimal amount of MK was 10%, and 0.8% PP fibres, based on compressive strength characteristics	[118]
Concrete	Mechanical, thermal, physical, microstructure and durability	Mechanical strength is increase with MK and nano alumina integration	[119]
Concrete	Mechanical, thermal and microstructure	12% MK integration and 10% glass powder enhances mechanical characteristics	[120]
Concrete	Mechanical	10% MK, 10% GBFS and 20% copper slag demonstrated the highest mechanical strength properties	[121]
Self-compacting concrete	Mechanical, physical and durability	MK improved the energy absorption of composite materials	[122]
Concrete	Mechanical	1% steel fibre and 15% MK improved mechanical strength	[123]
Concrete	Mechanical and physical	MK lose density during the fusion process. Activators enhance MK properties	[124]
Concrete	Mechanical	15% MK integration increases compressive strength	[125]
High-performance concrete	Mechanical,	5% SF and 5% MK with 1% GF and 0.25% PPF are optimal for strength increase	[126]
Concrete	Mechanical and physical	Cement can be 100% substituted with 50% MK and 50% bottom ash using activator materials	[127]

coatings, and ceramics [128]. Furthermore, nano-alumina has a high thermal stability and has been commonly used within polymer materials to enhance the thermal properties [129]. Generally, alumina oxide does not possess the same pozzolanic properties as other SCMs. Therefore, this material is not commonly used within building and construction materials, specifically concrete. However, alumina oxide can be present within various types of aggregates. Various natural aggregates contain alumina oxide as a constituent material, namely bauxite. Bauxite is a common source of alumina oxide and can be present within concrete materials [130]. Although the material is somewhat chemically inert and does not participate in the hydration reactions of cement, it can influence the colour, thermal properties, and reactivity with other alkali materials. Table 6 demonstrates previous applications of alumina oxide used as an additive in concrete. The studies primarily focus on the mechanical and microstructure elements of the binary blended concretes. Moreover, the research studies highlight that the integration of alumina oxide improves interfacial bonding of the constituent materials, thus improving mechanical strength of the composite materials.

Table 6
Previous studies on alumina oxide used as an additive in concrete.

Application	Main study focus	Comments	Reference
Self-compacting concrete	Physical, thermal and microstructure	Passing ability of concrete decreased with the increase of alumina content	[131]
Concrete	Mechanical, thermal and microstructure	Increasing alumina content decreased degradation on mechanical strength	[132]
Concrete	Mechanical	Addition of 2.5% nano-alumina increased compressive strength	[133]
Ultra-high-performance concrete	Mechanical, durability, microstructure and thermal	Reduced crack propagation and enhanced durability	[134]
Self-compacting concrete	Mechanical, thermal, microstructure and physical	Nano-alumina improves compressive strength	[135]
Concrete	Mechanical and microstructure	Nano powder provide nucleation sites for additional formation of C-S-H gels improving mechanical strength	[136]
Concrete	Mechanical and thermal microstructure and physical	Nano-alumina used as a cement additive increased mechanical strength	[137]
Concrete	Mechanical and microstructure	Optimal amount of nano-alumina was 2% to achieve highest mechanical strength	[138]
Foamed concrete	Mechanical, physical and microstructure	Synthetic surfactants reacted well with nano-alumina to create additional adhesion	[139]
Concrete	Mechanical and durability	Compressive strength and frost resistance increased with nano-alumina content	[140]
Concrete	Mechanical and microstructure	1% nano-alumina shows a better dispersion in the matrix and high compressive strength	[141]
Concrete	Mechanical and microstructure	Ultra-sonification technique enhanced dispersion of nano-alumina particles	[142]
Geopolymer concrete	Mechanical and microstructure	2% nano-alumina increased the mechanical properties comparable to GPC	[143]
Concrete	Mechanical and microstructure	1% cement replacement with nano-alumina improved strength and decreased porosity	[144]
Geopolymer concrete	Mechanical, microstructure and thermal	Nano-alumina improves strength and bonding of concrete materials	[145]
Concrete	Mechanical, thermal and microstructure	Nano-alumina improved strength and enhanced ettringite	[146]

4.4. Zinc oxide

Zinc oxide is a transition metal oxide. Zinc is often derived from the mineral zincite, but is primarily produced for industrial applications [147]. Zinc oxide is highly effective as a UV protector and is generally used in sunscreen to scatter the UV radiation away from skin. Other applications include the use of the material within antimicrobial skin creams, electronic applications, and pigment in paints, coatings, plastics, ceramics and rubber [148]. The specific properties of zinc oxide can vary greatly depending on the final application of the product. Zinc oxide is not a common additive within concrete and mortar materials. However, it can be present within various SCMs such as SF, FA or GBFS [149–151]. A key benefit of Zinc oxide is that it can act as a retarder, increasing the setting time in concrete. This is especially critical in high temperature climates where concrete can set prematurely and not bond adequately with other concrete materials [152]. Another benefit of using zinc as a coating mechanism on steel reinforcement within concrete. Using this material as a coating agent can also reduce corrosion and mitigate chemical attacks occurring on steel surfaces [153–155]. Table 7 demonstrates previous studies on zinc oxide used as an additive in concrete. As shown, zinc oxide is typically used to promote the durability of the composite material.

Table 7
Previous studies on zinc oxide used as an additive in concrete.

Application	Main study focus	Comments	Reference
Aerated concrete	Microstructure and physical	The coating applied to steel provided good anti corrosive performance	[156]
Concrete blocks	Microstructure, physical, durability and economic	Compared to titanium, zinc is expensive and more sensitive to UV radiation	[157]
Concrete	Mechanical, microstructure, physical, and durability	Nano-zinc oxide filled voids and promotes C-S-H network	[158]
Concrete	Mechanical	2% zinc oxide improves compressive strength by 20%	[159]
Concrete	Mechanical and durability	Increased protection from radiation and enhanced compressive strength	[160]
Self-cleaning concrete	Mechanical and durability	Increased compressive strength and improved air quality	[161]
Alkali- activated concrete	Mechanical, microstructure and thermal	Zinc prolonged the setting time but slightly decreased compressive strength	[150]
High performance concrete	Microstructure, thermal and durability	Enhanced photocatalytic properties and durability when substituting with cement	[162]
Concrete	Mechanical, physical and durability	Enhanced durability and mechanical strength properties when using both additives as a cement replacement	[163]
Concrete	Mechanical, microstructure, physical and durability	Higher radiation shielding and anti-fungal activity on composite materials	[164]
Concrete	Mechanical and thermal	Delayed setting time of concrete, increased ion leaching in pH solutions	[165]

5. The behaviours of composites incorporating fibres and additives

5.1. Textile fibres with additive materials

The endurance of textile fibres within cementitious composites is dependent on various factors. These factors include the production strategy when repurposing the materials, the matrix of the composite and the fibres agility under applied stress [166]. Research studies have also focused on the mechanical properties of newly sourced fibres pre-application within textile applications [167]. Therefore, there are limited studies that focus on using recycled fibres derived from textile applications. However, for the purpose of this review, available research outcomes can show how various fibres can interact with the alternative additive materials. It is important to note that the methods of fibre integration are critical to understand the materials effect within the composite microstructure. For example, Sadrolodabaee et al. [168] integrated textile waste flax fibre within a silica fume cementitious matrix. The method of application included layering the modified fibre sheets within the matrix. Textile waste was plated together with flax fibres laterally lining the sheets. This enabled the blended sheeting of fibres to undergo significant uniaxial forces due to the woven technique within the application. The application of 30% SF substituting cement within the matrix reduced the attack of calcium hydroxide on the fibres, enhancing fibre durability. Thus, reducing the embrittlement of the fibres within the composite microstructure. Moreover, the integration of additives can not only ensure successful fibre integration but also enhance the application purpose of the composite material for further use within specific industries.

5.2. Gypsum with textile fibre integration

As discussed, gypsum is a common construction material typically used within interior wall and ceiling linings [169]. However, gypsum is yet to be commonly adopted when integrating the material within cementitious composites. Misseri et al. [170] have utilised gypsum with glass fibre reinforcement within a cementitious matrix. Their research demonstrated that gypsum composites provided a higher value of fracture energy and peak shear stress. This can be accredited to the gypsum particles forming a homogenous matrix. The agglomeration of the total matrix creates a tighter bond around the fibres, reducing the rate of fibre pull out. Ensuring the durability when introducing bespoke materials within a composite material is also critical. Another study was conducted on wetting and drying cycles containing gypsum and fibrous materials [171]. Their research demonstrated the use of basalt pumice powder and polypropylene fibres within a cementitious matrix. It was also noted that there was an increase of porosity when integrating these materials together, thus increasing the water absorption. When the porosity of a material is high, the interconnecting pore structure allows fluid mobility, thus increasing the rate of water absorption. The microstructure of the composite is interdependent on the fibrous materials that are integrated. There can be a distinct linear relation between the type of fibre and the agglomeration of the matrix materials. It was shown that samples containing only gypsum had the lowest permeability. Whereas, the integration of fibres, and other additives increased the permeability. Other researchers [172] also utilised gypsum with textile glass fibre nets. Their research focused on the bond behaviour of the composite materials. They have demonstrated that gypsum-based systems provided a higher bond capacity of the fibre walls. Thus, increasing the mechanical strength of the composite. Saidi and Gabor [173] integrated 5% gypsum with textile glass and carbon fibres. Their research focused on the tensile capacity of the composite materials. The authors observed that the textile materials take up the applied load in the post-cracking zone. This allowed further understanding on the fibre pull out strain once mechanical distortion has taken place. Moreover, carbon fibres demonstrated a higher tensile strain due to this phenomenon. Therefore, demonstrating a higher bond rate to textile carbon fibre materials. Romero-Gomez et al. [174] utilised recycled nylon fibres in gypsum composites. Their research focused on the mechanical performance when integrating 1–2% fibrous materials by weight of the gypsum. It is important to note that cement was not used in the composites. It was shown that 2 wt% of nylon fibres enhanced the flexural strength by 7.5%. It was also noted that there was a multi directional arrangement of fibres within the gypsum matrix. Moreover, the multi-directional arrangement can allow for additional strain placed on the composite, enhancing the crack bridging effect within the microstructure. Their research also showed the nylon fibres pulling out of the matrix, rather than breaking under applied load. This demonstrates the interfacial zone of the fibres can be quite weak. However, under compressive loading, there was a 17% strength increase of nylon fibre gypsum composites. It is important to note that longer fibres produced better mechanical results. This was shown by comparison with fibres between 1.5 and 2.5 cm.

Fig. 2 illustrates polyester waste fibres within concrete containing 5% gypsum as a partial cement replacement. As shown, the smooth surface of the polyester fibres remains relatively unharmed by the high alkalinity of the cementitious matrix. Petrification has occurred on the fibre walls, demonstrating fibre bonding to the concrete materials. Integrating gypsum has reduced the potential likelihood of calcium hydroxide ($Ca(OH)_2$) attacking the fibres and allowing them to agglomerate in the matrix successfully. Similar to cement, the particle size of gypsum is very small which can create a homogeneous material. This corresponds to the bonding of the fibres losing effectiveness gradually, rather than abruptly. Moreover, this can lead to an increase of the mechanical strength, which can ultimately enhance the durability of the composite material.

5.3. Metakaolin with textile fibre integration

As shown from the results produced from the bibliometric assessment, industrial wastes such as FA and GBFS are common materials integrated within concrete materials. The incorporation of these materials within concrete and mortar is often referred to as geopolymer [175]. Zhang et al. [176], have formed a geopolymer concrete utilising 50% MK and 50% FA with the addition of textile fibre sheets to enhance flexural strength of concrete slabs. Their research focussed on the attachment of carbon fibres via polypropylene strings to form the textile sheets. The concrete slabs had the sandwich effect of utilising 1–3 layers of textile sheeting between 2 and 4 layers of geopolymer mortar. Primarily focusing on the flexural strength, the addition of 1-, 2- and 3-layer textile sheeting proved to enhance the flexural capacity by 26%, 53% and 92%, respectively. Modifying the matrix with MK and FA to form the

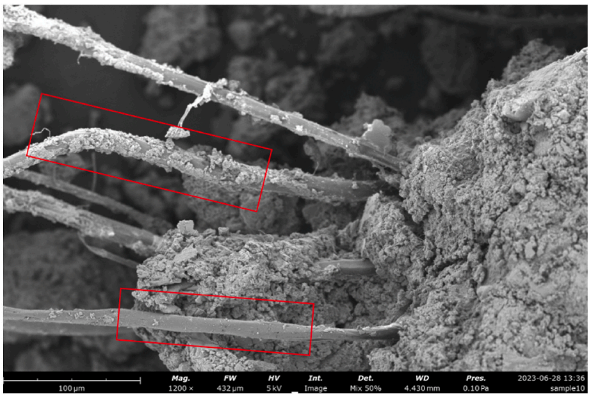

Fig. 2. Polyester fibres in gypsum concrete.

geopolymer mix also enhanced the bonding effects of the composite. It was also note that the microstructures that were formed had enhanced ability to withstand excessive forces when compared to the control. This was further demonstrated with the reduced cracking load of the concrete slabs, as the densified matrix and textile sheeting presumably acted as reinforcement agents. It is also important to note that Zhang et al. [176], reported that the loading on the composite in fact forced the matrix and fibres to act sequentially rather than simultaneously. This was shown with clean fibre pull out from the matrix, and demonstrates the application method of textile fibres is crucial for the functionality of the composite materials. If the fibre materials that are embedded within the matrix have a successful bonding capacity when load is applied, the mechanical results could be improved greatly. Cholostiakow et al. [177] used MK with basalt and glass fibre textile grids. The textile fibre sheeting panels were applied to masonry walls as a retrofitting alternative and tested for diagonal compression loads. Their findings demonstrated that the textile-MK matrix exhibited a 70% increase with comparable stress levels of the control application. This also indicated the MK matrix had a substantially better bond to the textile materials. It is important to note that the basalt fibres had a lower tensile capacity than the glass fibre counterpart. These fibres do not degrade substantially within an alkaline environment and thus demonstrated high mechanical functions. Moreover, Majstorovic et al. [178] integrated high amounts of MK to create a calcium hydroxide free environment when substituting 30% MK with OPC. This enabled the flax textile materials to preserve their strength and flexibility within the cementitious composite. This seems to reduce the degradation significantly on cellulose materials; however, the hemicellulose component was found to be still impacted. Majstorovic et al. [178] demonstrated that integration of MK can have a significant effect of preserving the textile fibres and enabling the application of a reinforcement agent to remain unhindered. As discussed, there are common trends when using MK within cementitious matrices. Firstly, MK densifies the matrix enabling the composite to achieve higher mechanical strength. Secondly, MK protects the fibres from degradation due to reducing the amount of calcium hydroxide.

Fig. 3 illustrates polyester waste fibres within concrete containing 5% metakaolin as a partial cement replacement. The image shown demonstrates a partial damage occurring to the fibre walls. Although the damage is relatively minor, it still demonstrates that how $Ca(OH)_2$ can affect synthetic materials. Typically, synthetic materials are more durable than natural materials; however, this image highlights that even synthetic materials can be affected by the cementitious matrix. MK can reduce the speed of the hydration process by consuming $Ca(OH)_2$ in early stages. This can thus aid the transition of fibres within cementitious composite designs. As shown, there are migrated cement products that have attached to some areas of the fibre walls. This can in turn enhance the bond between the fibre and the concrete materials. As discussed, increasing the bonding of the fibres can increase the mechanical properties.

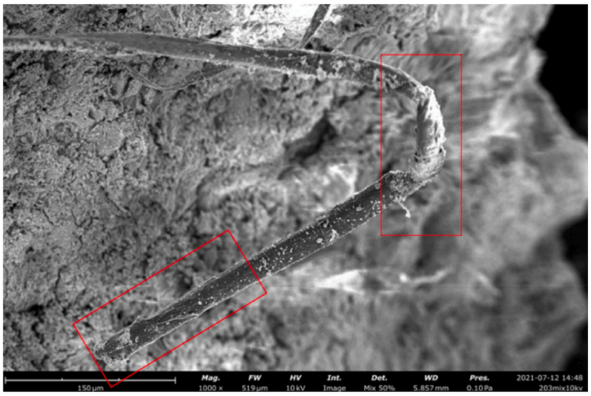

Fig. 3. Polyester fibre in metakaolin concrete.

This can be shown in cementitious composites when calcium silicate hydrate (C-S-H) are present within the inter-transitional zones of the fibre and matrix.

5.4. Alumina oxide with textile fibre integration

Débarre et al. [179] have focused on the use of nano materials within cementitious composites due to their homogenous nature with other materials. There has been also a lot of research interest relating to the use of nano alumina oxide due to its ability to increase mechanical properties. This has been proved to be the case as with integrating 2 and 3% of nano-alumina with basalt fibres has resulted in a n increase of flexural strength by 10 and 15%, respectively [180]. However, the flowability of the mortar material was reduced. Moreover, there was a 15% decrease of initial water absorption with the composite material which correlates to the reduction of flowability. Lomov et al. [181] grafted alumina oxide to woven fabric and yarn materials. Their research stated that the grafted fibres have a higher compression resistance compared to non-grafted carbon nanotubes. Their outcomes signified the durability enhancement due to the integration of alumina oxide materials on the interfacial zone of textile fibres. Khooshechin, M. and J. Tanzadeh [182] also utilised nano alumina within fibre shotcrete materials. Their research demonstrated an increase of 20.6 and 52% for compressive and flexural strength, respectively when integrating 1.5% nano-alumina and 1% glass fibre. Their findings also showed that there was a decrease of penetration depth and water absorption to the composite material highlighting an increased toughness and density. This was also reported by researchers who incorporated alumina oxide fibres with high density polyethylene (HDPE) and polyvinyl alcohol (PVA) fibres [183]. These results proved the effectiveness when using 0.5% alumina oxide with 2% fibre integration. It was also shown that there was a promotion of C-S-H gels when alumina oxide was integrated thus enhancing compressive and flexural strength. This enhanced density of the composites microstructure which can be further attributed to the mechanical strength increase. It is important to note that the HDPE fibres had higher mechanical strength than the PVA fibres. This highlights the importance of fibre selection when determining key strength factors of composite materials.

5.5. Zinc oxide with textile fibre integration

Wanasinghe, D., F. Aslani, and G. Ma [184] have focused on the use of zinc oxide due to the materials durability factors, especially the deterrent of UV radiation. This is especially critical in composite materials when exposed to the weathering conditions and exposed to the natural elements. Researchers have also integrated carbon nano fibres with zinc oxide and GBFS in cementitious composites. Their findings showed that zinc oxide does not overtly affect the compressive strength of the composite materials. However, increasing the amount of zinc oxide from 0.05 to 0.3 % has had a detrimental effect on the flexural strength. This was shown to be primarily due to the increased porosity when zinc oxide is increased. It is important to note here that the compressive strength of the fibre composite increased when mixed zinc oxide, rather than without the additive material. Moreover, it was shown that the reduced flexural strength can be attributed to the retarding effect from zinc oxide. Owing to the delay in hydration, the microstructure formation of the matrix materials is likely to take longer time to fully develop. Thus, conducting mechanical testing before 28-days reduces the mechanical strength target characteristics. Xiao et al. [185] applied a zinc oxide coating on silk textile fabrics to preserve the fibres longevity. Their research demonstrated a zinc fibre have a higher tensile stress compared to original fibres. It was also shown that the application of zinc provides anti-bacterial qualities that can be attributed further in composite specimens. It is important to note that zinc coating on fibres can have a negative effect when in composite designs. This was shown with researchers using zinc coated aramid fibres [186]. Their findings demonstrated that there was a smooth debonding section in the composite indicating a weak adhesion of the fibre. Although the zinc coated fibres had less resistance of fibre pull, it has been shown that zinc coated fibres can withstand higher temperatures and have a slower degradation pattern [187]. Research conducted with polyester and glass fibres showed that 3 wt% zinc oxide can increase composites hardness and thermal stability [188]. This further coincides with previous research detailing the thermal control zinc oxide has within composite designs. Moreover, zinc oxide is a promising filler material for incremental mechanical and thermal behaviour.

5.6. Gypsum with natural fibre integration

At the time of writing this review, there was virtually any literature precedents on the utilisation of KFs and gypsum materials in composite designs. However, there are published research detailing natural cellulose materials with gypsum in cementitious composites. KFs are natural cellulose materials that have been additionally processed. Therefore, utilising current literature, this section will focus on the effect natural fibres have with gypsum cementitious materials. When integrating natural fibres within cementitious materials, the hydrophilic nature of the fibres will inherently absorb more water. This was shown with researchers utilising pine wood fibres with gypsum materials [189]. The workability of the materials becomes effected due to the high moisture absorption ratio of the composite materials. Therefore, increasing the water content or integrating superplasticizers is a common approach when working with these materials [190]. It was shown that the higher amount of fibre integration created a higher shrinkage rate when the composite was curing. This correlates to the water absorption properties of natural fibres. When comparing to KFs, the fibres have undergone thermal and chemical treatments. Therefore, the absorption qualities of KFs are significantly reduced. It is important to note that depending on the strength targets of the composite designs, having a high-water content of 0.60 or above can reduce these negative effects. This was shown with Romero-Gomez et al. [191] that utilised waste cellulose acetate fibres with gypsum in cementitious composites. Their research detailed an improvement of flexural and compressive strength, up to 9% and 1% respectively. Moreover, their research also demonstrated that integrating these materials can reduce the thermal conductivity when 16% gypsum is used with 3.5% fibres.

Fig. 4 illustrates waste KFs within concrete containing 5% gypsum as a partial cement replacement. As demonstrated, cement products have attached themselves to the fibre walls of the natural fibrous material. Moreover, damage can be seen on the fibre

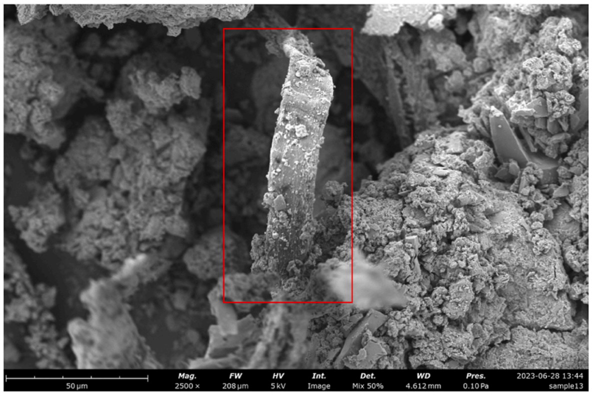

Fig. 4. Kraft fibres in gypsum concrete.

walls, indicating $Ca(OH)_2$ penetrating the outer fibre lumen. The high alkalinity of cementitious matrices can be detrimental to natural fibres. Despite the damage, the fibre is mostly intact and functional within the composite material. The integration of gypsum has created a homogenous material, allowing the fibre to remain mechanically functional. This is integral on the durability of the composite design. As loading gets applied to the composite, the fibres' ability to withstand force is critical on the final application.

5.7. Metakaolin with kraft fibre integration

Metakaolin has been used extensively as a SCM and typically used in conjunction with research on FA and GBFS. However, less research has focused on using the material with KFs. It has been shown that the integration of MK lowers the amount of calcium hydroxide, increases the ionic absorption from the pore solution with the formation of supplementary C-S-H gels [192]. These key factors can enhance the strength characteristic of KF composite materials when utilising MK as an additive material. Moreover, it was shown that only binary SCM materials enhanced the durability of KFs rather than ternary SCM composite mix designs. Up to 25% MK integration was deemed acceptable to mitigate the degradation caused on the KFs. Booya et al. [193] incorporated 0.5–2% OPC supplementation with MK and determined a higher compressive strength. However, when using KFs with MK there was a reduction in compressive strength. This can be primarily attributed to fibre integration rather than the matrix of the composite materials. Nonetheless, KFs are a natural material and thus have a relatively low-density compared to their synthetic counterparts. Therefore, when compressive loading is applied on the composite, the KFs cannot withstand the pressure beyond a service point. This was also shown with research conducted by Haigh et al. [86] that demonstrates the use of waste cardboard KFs in reinforced concrete. Their research details the reduced compressive strength when integrating 10% KFs to supplement OPC. However, when 5% MK partially supplemented OPC, there was a strength increase. It has been observed to be due to the reduced degradation caused on the KF walls because of the consumption of $Ca(OH)_2$.

Fig. 5 illustrates waste KFs within concrete containing 5% MK as a partial cement replacement. As shown, a significant amount of cement products have attached to the outer fibre lumen. This can reduce the mechanical strength of the fibre and enhance fibre snapping occurring when under implied loads. MK can reduce the amount of $Ca(OH)_2$ created in early stages of hydration however, it does not delay the creation at later stages of hydration. This is shown with the additional attachment to the natural fibre material. When MK consumes $Ca(OH)_2$ there is a creation of C-S-H gels, that can lead to a refined and denser microstructure. Increasing the density of the microstructure can be beneficial to fibre materials due to the increased bonding capacity. Moreover, the image

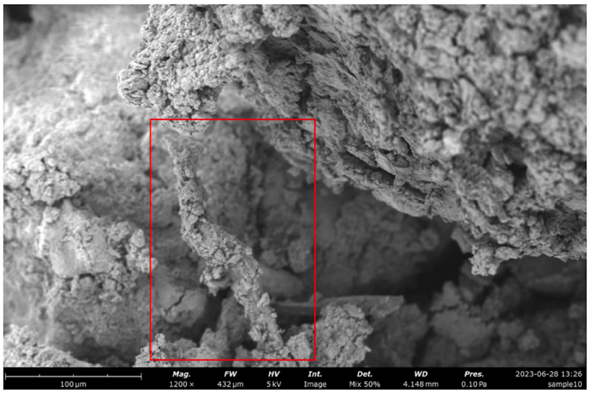

Fig. 5. Kraft fibres in metakaolin concrete.

demonstrates between the cement products on the fibre, there appears to be no or minimal damage to the outer fibre wall. This is significant for the longevity of the fibre and to increase the mechanical strength of the fibre concrete.

5.8. Alumina and zinc oxide with natural fibre integration

At the time of the literature search for this paper, there was hardly any published work(s)using alumina and zinc oxide with KFs in composite materials. However, there is literature that has utilised natural fibres with the use of these materials. Therefore, this section will focus on natural fibres that correlate to the similar properties within KFs. Research has shown that covering natural fibres with metal oxides can enhance the anti-bacterial properties of fibrous materials [194]. As discussed previously, this can further enhance longevity of the fibres by protecting the outer layer on the fibre walls. Cement containing high alumina has been shown to have significantly increased rates of hydration [195]. When fibres are integrated within the matrix, the decomposition of calcium aluminate hydrates can be beneficial for the strength characteristics of the fibre composites. This is shown via lower strain yields on fibre composite materials [195]. It is also important to note that the high content of alumina in the cement paste does not provide sufficient high temperature durability. Therefore, when integrating natural fibres with alumina oxide other pre-treatments may be required to sustain durability factors. Mudra et al. [196] demonstrated that the addition of alumina oxide on micro fibres can provide a higher friction rate with other materials [196]. This can be beneficial in a composite matrix to reduce the rate of fibre pull occurring. Typically, fibre pull out occurs due to low adhesion of the fibre and the matrix environment. Enhancing the adhesion of the fibre can also increase the strain yield on the composite and therefore increase the strength of the material. Zinc oxide has been shown to provide better control to reduce bacterial growth when applied as a pre-treatment to fibrous materials [194,197]. This was further shown when researchers utilised lignin derived from natural fibres in conjunction with zinc oxide [198]. Their findings demonstrated the use of these materials provided antimicrobial resistance and confirmed the lack of microbial growth. However, the presence of lignin also reduced the compressive strength in proportion to the increasing amount. Although the strength was marginally hindered, it did not affect the dispersion of oxide mixtures within the composite material. This was partly due to the increased porosity from zinc oxide integration but enhanced by the additional lignin content. High zinc oxide content can create a porous microstructure, this can prolong setting time as the agglomeration of all materials are not cohesive [199]. However, dependent on the weathering application of the materials, this may reduce the need for superplasticizers when delaying hydration.

6. Conclusion and future perspectives

Concrete and cement-based products are the primary materials used throughout the building and construction industry however, the extraction of virgin resources to produce them has significant environmental impacts and depletes valuable resources. Thus, research has focused on exploring the use of waste materials, but not all waste materials have been fully optimised. Specifically, the potential valorisation of waste textile and cardboard fibres remains largely unexplored. Polyester and nylon fibres, widely used in the textile industry, are moisture-resistant, strong, and durable. Research has shown that they are effective as reinforcement agents in concrete composites, with less fibre degradation compared to their natural counterparts. KFs, derived from plant-based materials, have high tensile strength, and are predominantly used in packaging materials. Their integration in construction materials can be challenging due to their high-water absorption characteristics, but coating applications can mitigate this issue. Limited research has explored their use in construction materials, and their utilisation could contribute to sustainability in the construction industry. The objective of this review was to examine the utilisation of alternative additive materials such as gypsum, metakaolin, alumina and zinc oxide used within fibre concrete-based applications. Gypsum used as an additive in concrete materials can enhance workability, flowability, and sulphate resistance. It can also reduce thermal and chemical cracking, prolonging the durability of gypsum-based concrete. Metakaolin improves concrete strength, density, and durability. It reduces permeability, enhances flowability, and mitigates alkali-silica reactions in concrete materials. Alumina oxide, especially in nano form, can enhance the mechanical properties of composites, coatings, and ceramics. When integrated with fibres, it can improve interfacial bonding and increase mechanical strength. Zinc oxide is used in concrete to act as a UV protector and a retarder, especially in high-temperature conditions. It can also reduce corrosion on steel surfaces within concrete. Both textile and KFs, can be integrated with the mentioned various additive materials to enhance their durability and performance in concrete composites. The current study highlights the need to further explore mechanical and durability properties when using waste textile and cardboard fibres in composite designs. Alternative methods of fibre treatment and the microstructure reactivity within the matrix could aid toward the use of the alternative considered materials being used further. The various combinations and methods of these materials can enhance the sustainability and performance of construction materials.

CRediT authorship contribution statement

Robert Haigh: Writing – original draft, Visualization, Methodology, Conceptualization. **Malindu Sandanayake:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization. **Soorya Sasi:** Writing – original draft, Visualization. **Ehsan Yaghoubi:** Writing – review & editing, Supervision, Funding acquisition. **Paul Joseph:** Writing – review & editing, Supervision, Funding acquisition. **Zora Vrcelj:** Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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