Superimposed reinforcement effect of Microsilica and fibres on fibre cement product

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- Basic formula of fibre cement product.
- Fibre cement strength development mechanism.
- Primary function of Microsilica and fibres in the product.
- Synergistic effect by using Microsilica and PVA fibre
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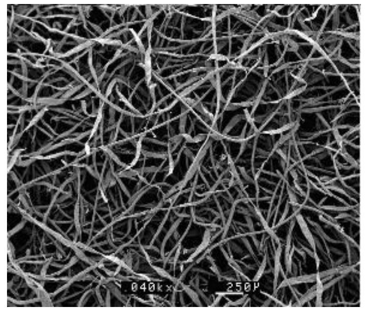
Reference formulation and raw materials of non-asbestos product

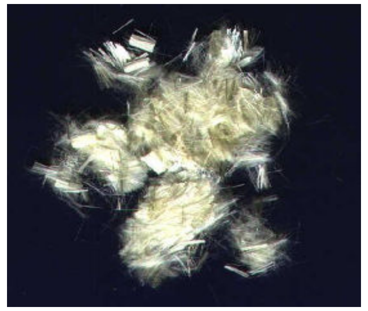
Air-cured recipe

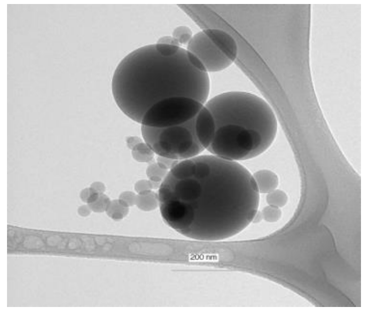
▪ PVA fibre 4-6mm	1-2%,
▪ Cellulose	3~5%
▪ Microsilica®	1~6%
▪ Fillers (Mica, Wollastonite, limestone….)	3-20%
▪ Cement	X

Autoclaved recipe,

▪ Cellulose	~8%
▪ grinding quartz sand	3X~4X%
▪ cement or lime	3X~4X%
▪ Fillers (Mica, Wollastonite, limestone….)	5-15%
▪ (Microsilica®)	3~10%

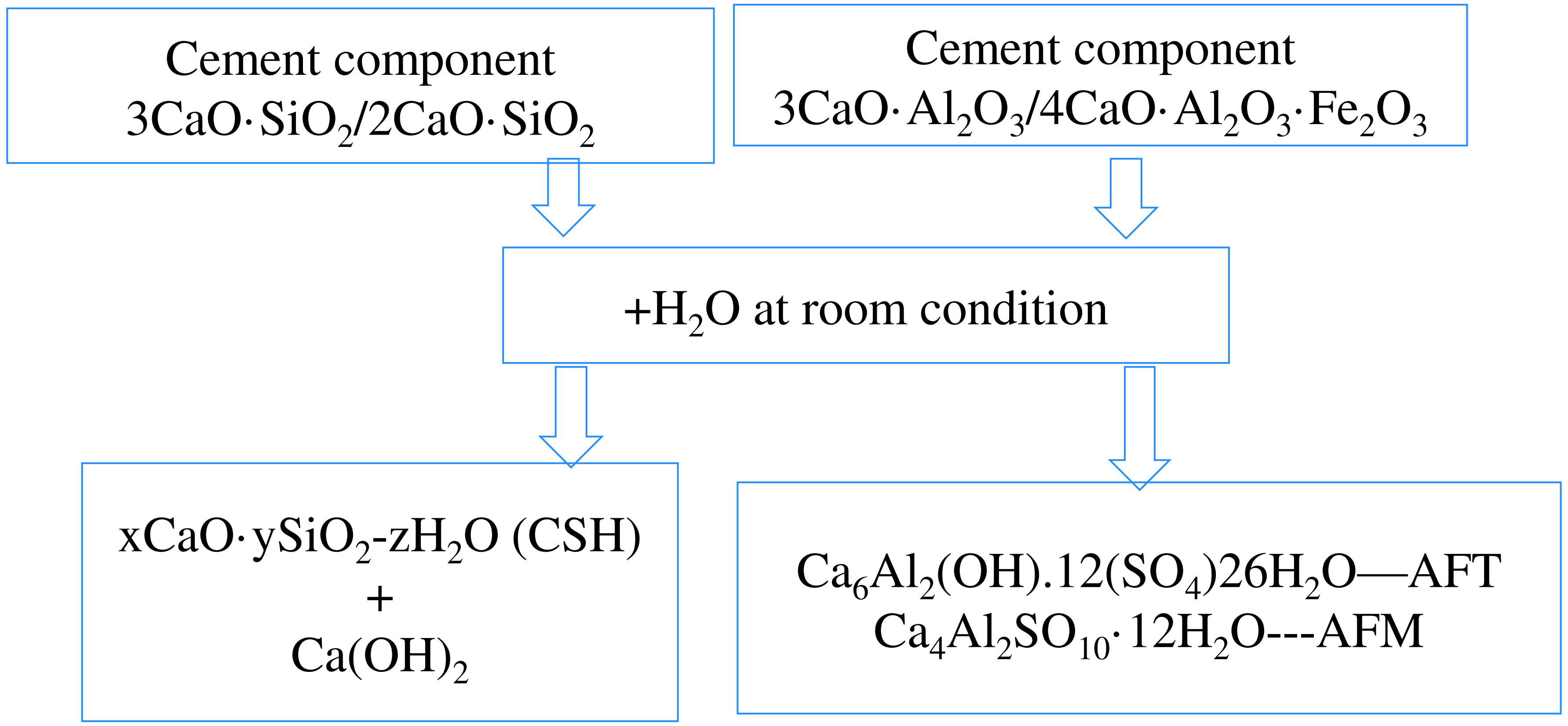






Reaction mechanism of the air-cured recipe.

- For the air-cured recipe, strength of the product mainly originates from cement hydration and additives effect.



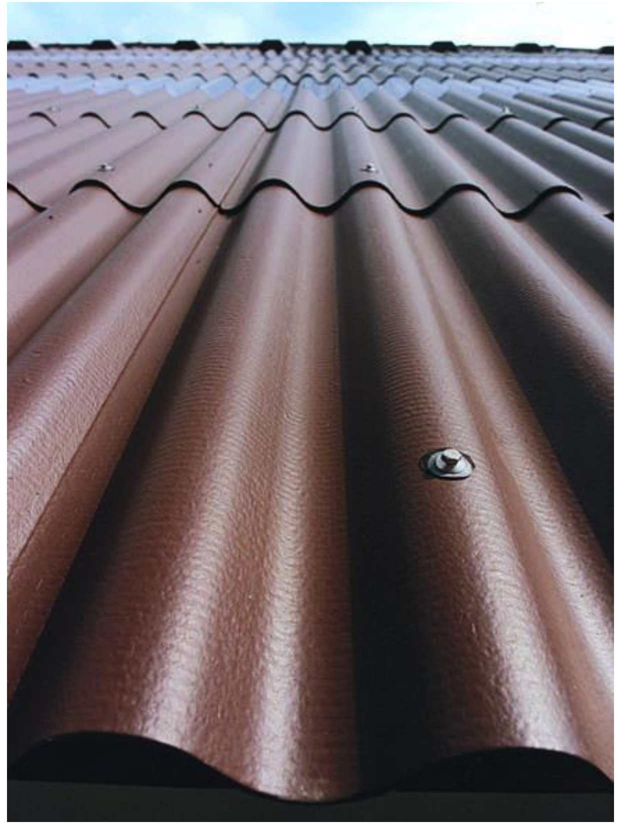


Figure 1. Cement hydration mechanism of the air cured fibre cement product

Reaction mechanism of the autoclaved recipe.

For the autoclaved recipe, hydration process is little different depending on the calcareous raw material.

Cement + SiO_2

CaO (lime) + SiO_2

$+H_2O$

Cement hydration->C-S-H + $Ca(OH)_2$ + SiO_2

Autoclaving, Saturated steam
180~200C, 0.8~1.2MPa

Tobermorite -$Ca5Si6O16(OH)_2 \cdot 4(H_2O)$
Xonotlite- $Ca6Si6O17(OH)_2$
+
C-S-H
+
SiO_2

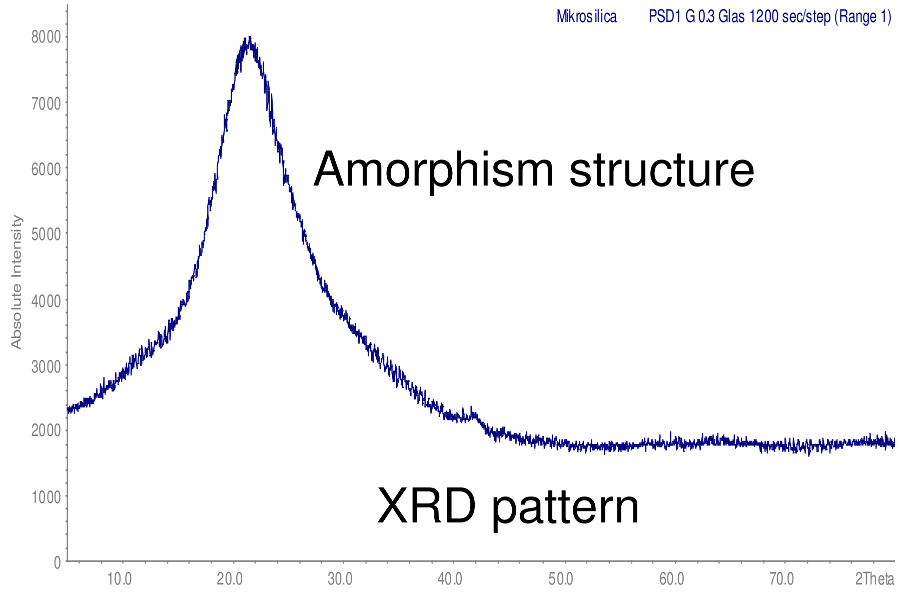
Figure 2. Hydration mechanism of Autoclaved fibre cement product

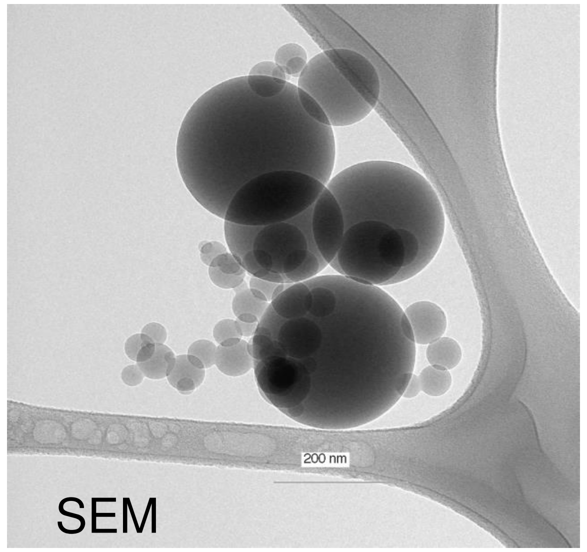
Primary function of Microsilica in the fibre cement.

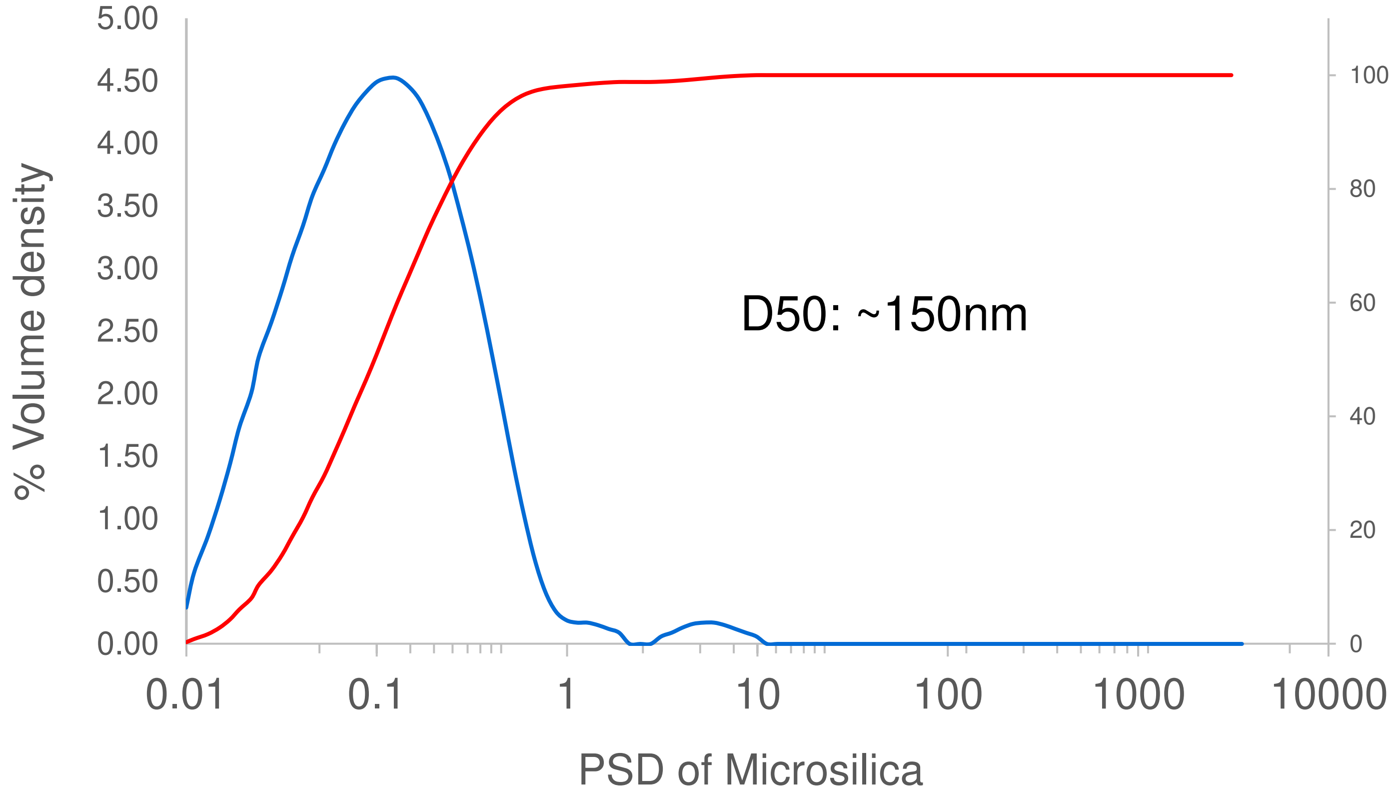
It is a very good process aid and property enhancer in non-asbestos fibre cement sheets, which is due to Microsilica act both as a filler and a pozzolanic function.

1. Filler function
   - Plasticizer - better moulding.
   - Improve interlaminar bonds - less delamination.

2. Strength reinforcement effect due to pozzolanic function (SiO_2+$Ca(OH)_2$->C-S-H)
   - Improved strength.
   - Improve and modify the microstructure.







The reinforcement effect of Microsilica on the bending strength of fibre cement.

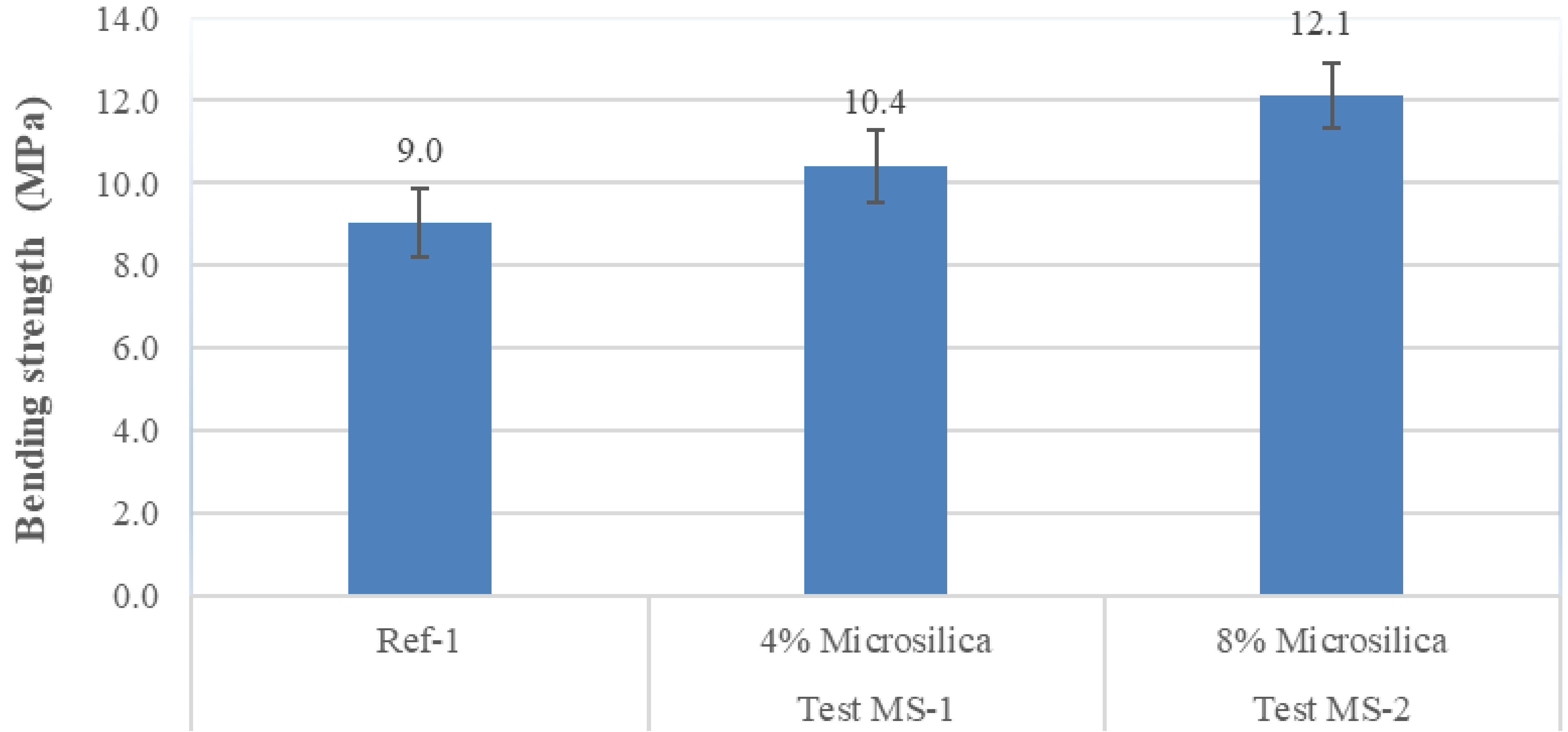
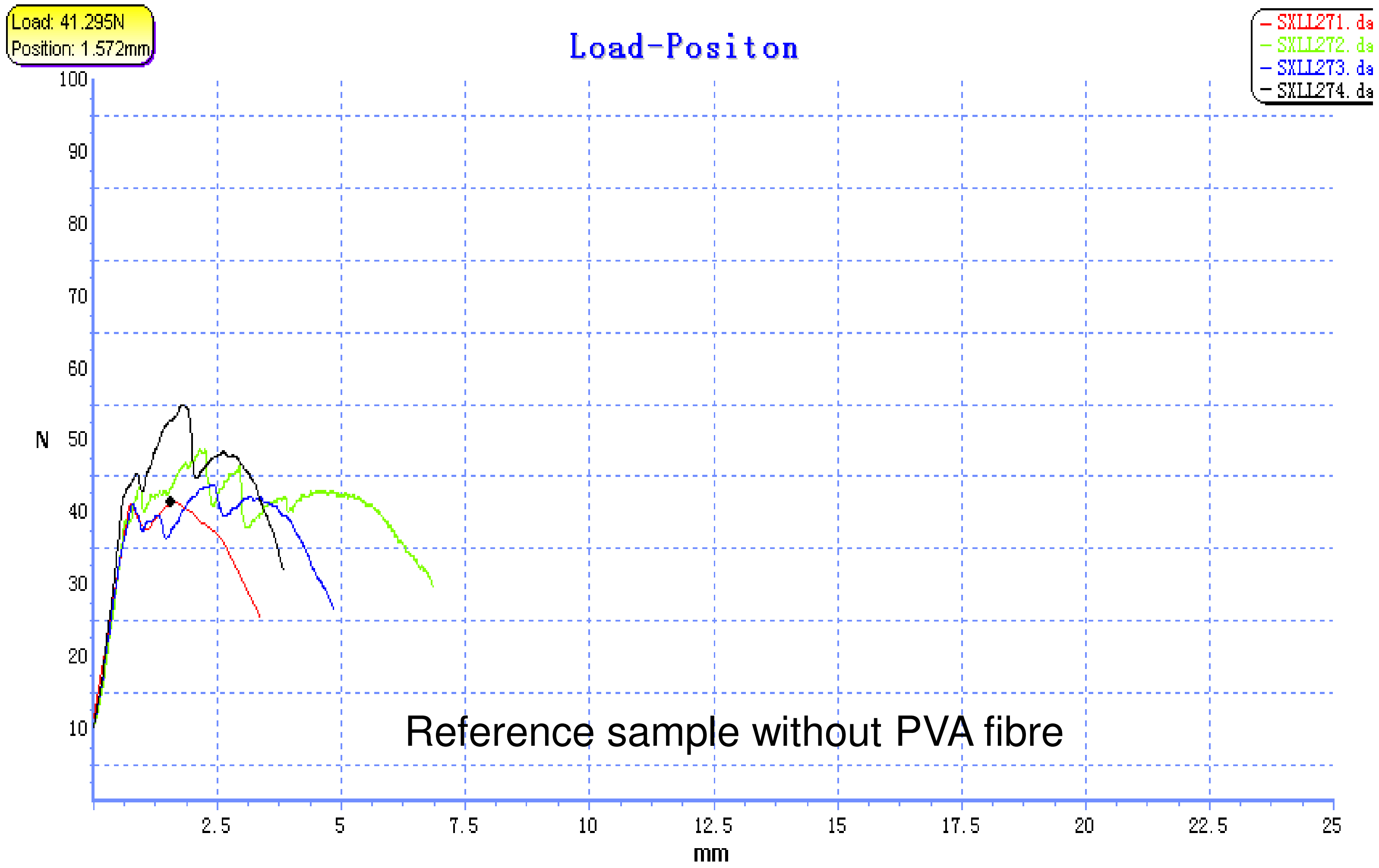
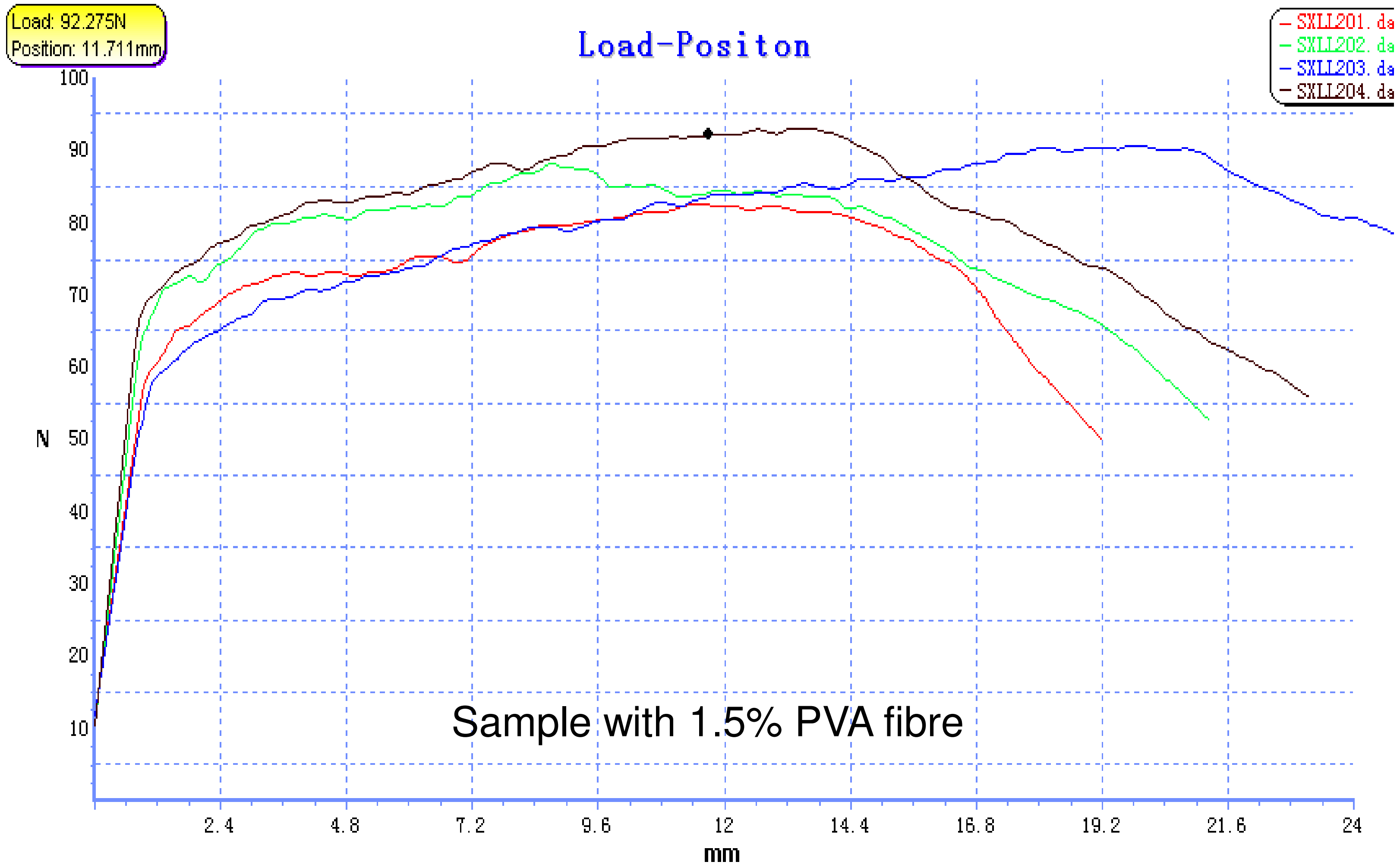


Figure1 Bending strength

Primary function of PVA fibre in the fibre cement.

PVA fibres significantly impact the toughness of fibre cement products besides to reinforcing the strength.





Synergistic effect by using Microsilica and PVA fibre

Microsilica can effectively increase the amount of hydration products between PVA fibres and the cement matrix, resulting in a denser interfacial region and effectively improving the bond strength between the fibres and the matrix. Thus, the effective contribution rate of the fibres was enhanced, and the toughness of the material was strengthened.

Photo 1 Reference sample without Microsilica

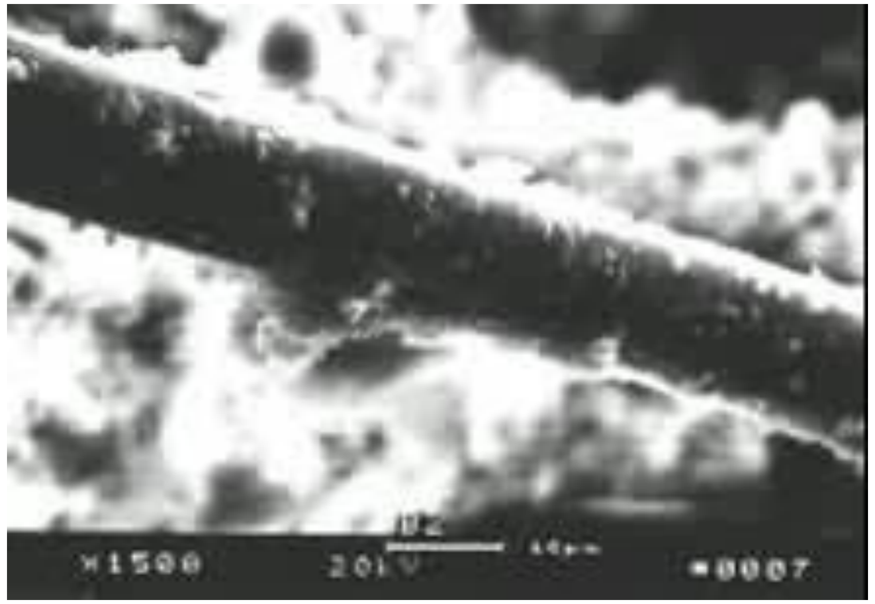


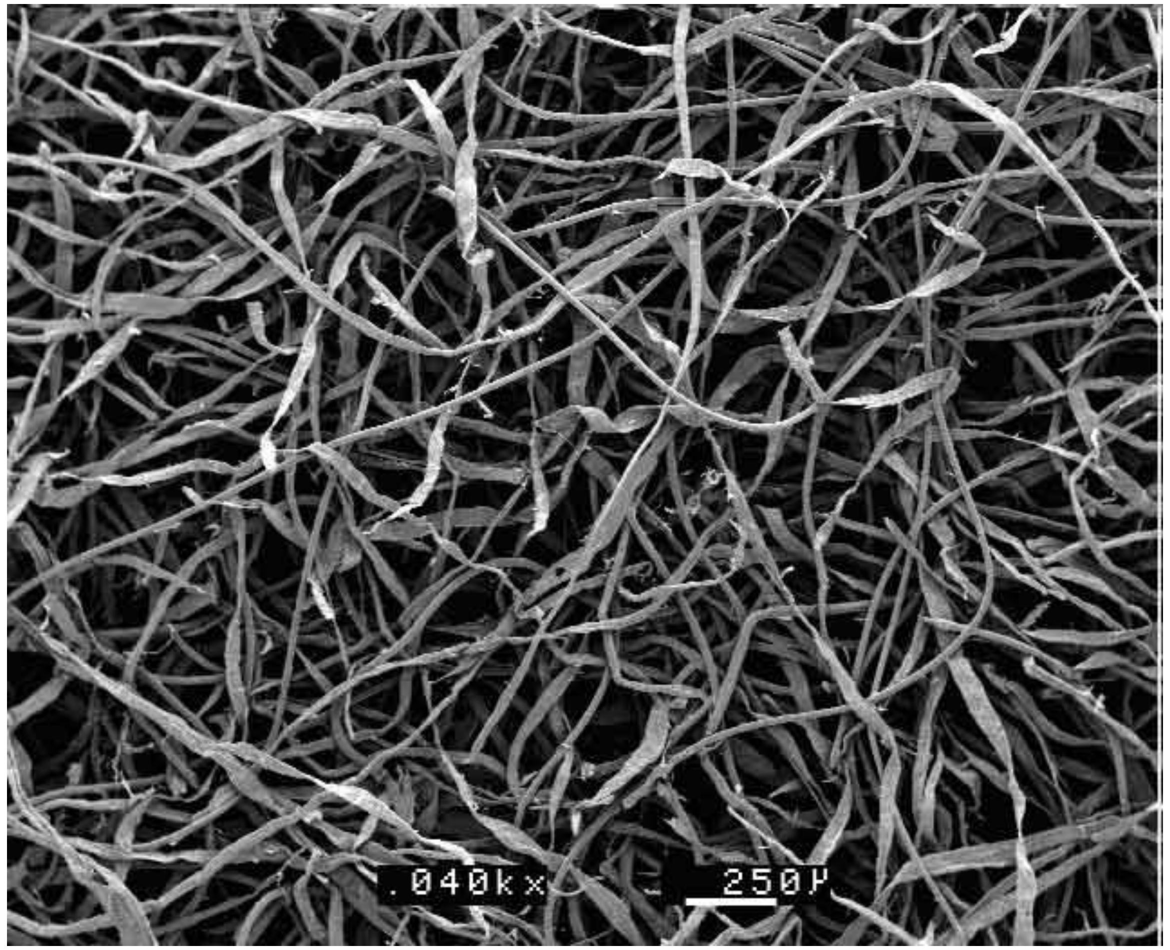
Photo 2 With 4% Microsilica

Photo 3 With 8% Microsilica

Photo 4 With 12% Microsilica

PULP function in the fibre cement

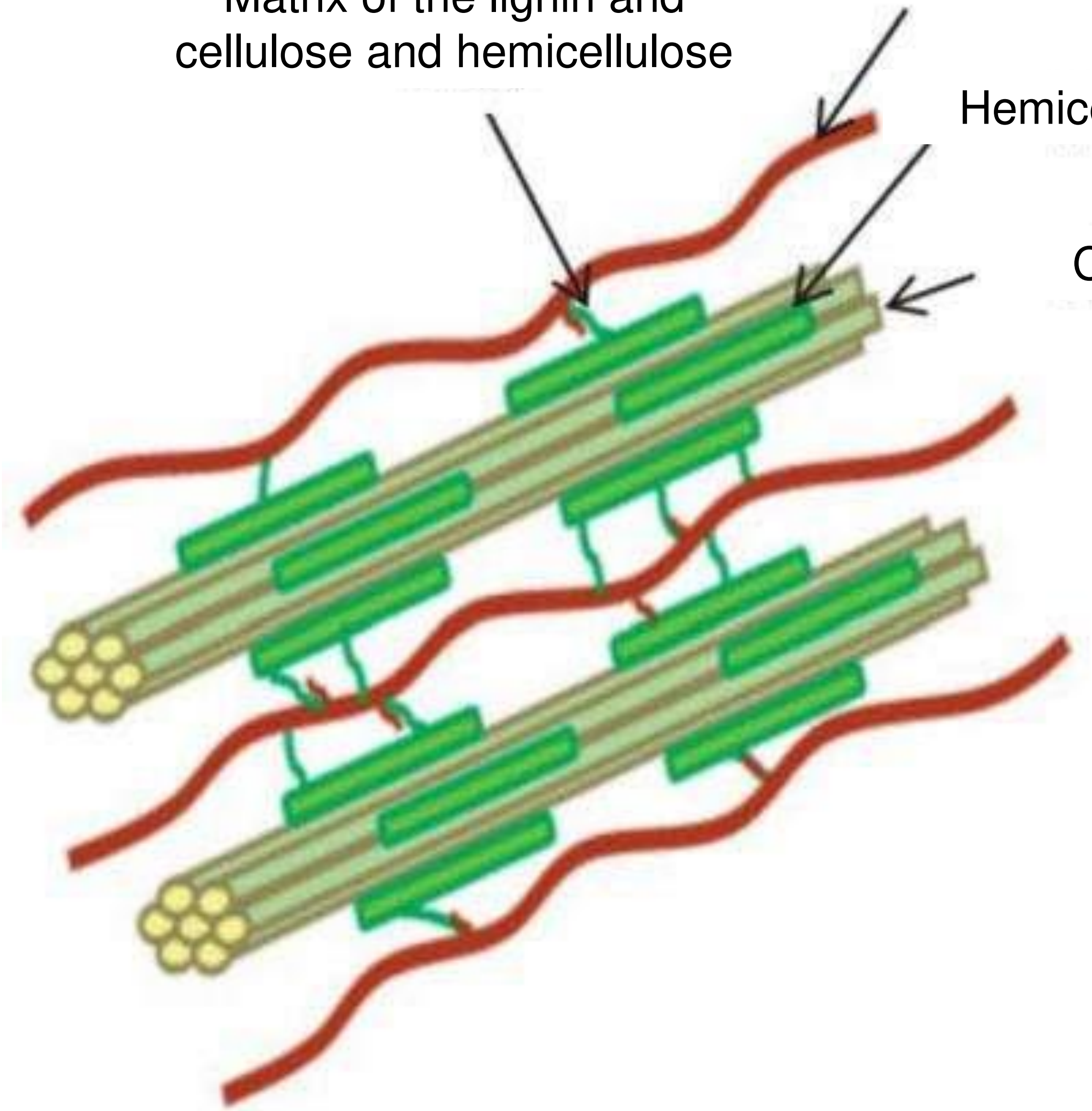
- Wood pulp fibre is the necessary fibre in the production of non-asbestos fibre cement products. For the air-cured non-asbestos fibre cement products, due to the presence of PVA fibres, pulp was mainly functioned as the process fibre to pickup the materials.
- For the autoclaved non-asbestos fibre cement products, since only wood pulp was used in the formulation, it was also used as a reinforcing fibre besides the functioned as process fibre, so its dosage was also higher than that of the air-cured dosage.



PULP property

The properties of the pulps were mainly determined by three main components: lignin, hemicellulose, and cellulose. The main functions of these three components in pulp fibre can be summarized as follows.

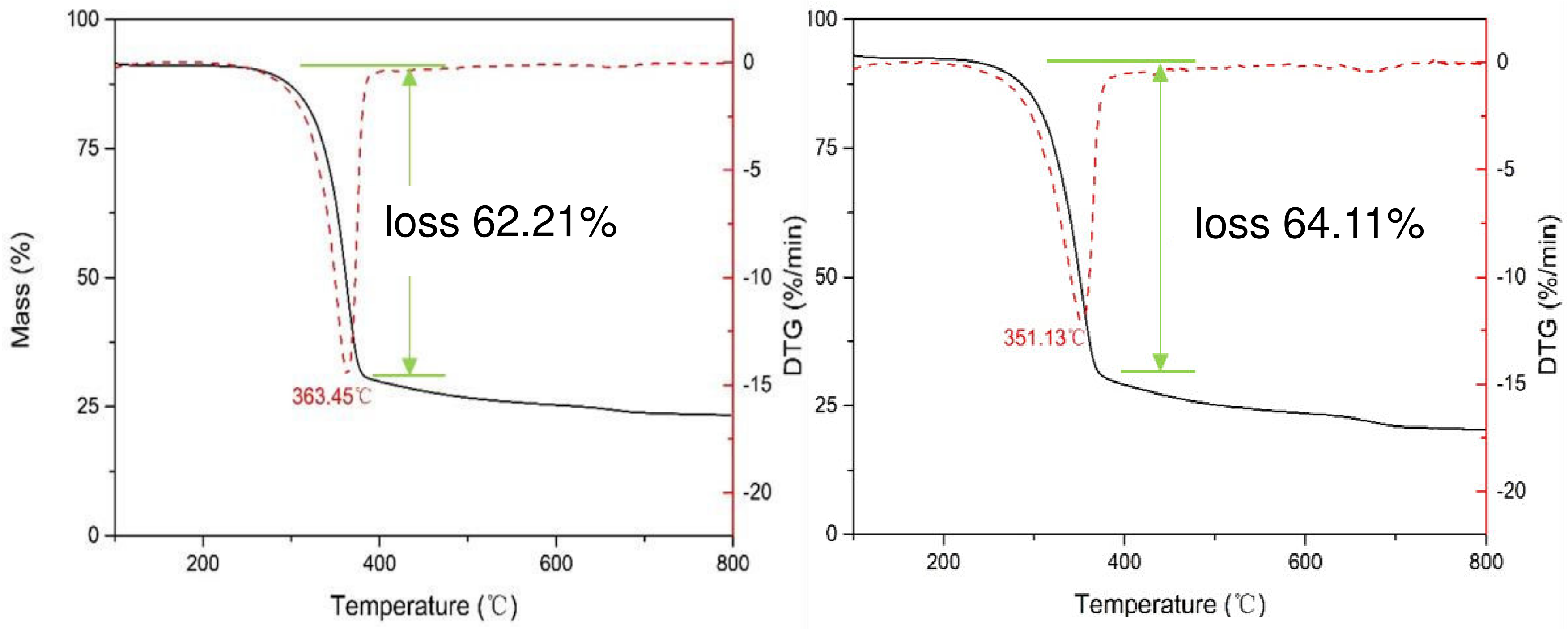
- Lignin in the pulp was similar to the cement materials in concrete structures, playing a role of binding network structure and support function. Generally speaking, the higher the lignin content, the stiffer the fibre.
- Hemicellulose was similar to the aggregate in concrete materials, playing a role of material supplementation and bridging.
- Cellulose was similar to the steel bars in concrete, mainly enhancing toughness.
- The single fibre strength of the pulp was positively correlated with the degree of polymerization (DP) and intrinsic viscosity index.



Durability of PULP in the fibre cement

Wood pulp in fibre cement products exhibits a tendency towards degradation in an alkaline environment, while the damage to pulp properties in an autoclaving environment was more significant.

- Thermal stability of wood pulp fibres decreases in an alkaline environment due to the slow dissolution of effective components such as cellulose, lignin, and hemicellulose within an alkaline environment,
- Significant decrease in fibre polymerization degree under autoclaving conditions, ultimately resulting in the degradation of fibre properties.



1# Ref pulp1 **2# Alkaline pulp 1**

Figure 10. TG/DTG chart of the pulps.

Table 5 Degree of polymerization (DP value) and Intrinsic viscosity index

Sample ID		Intrinsic viscosity index [η]	Degree of polymerization [DP]
3#	Water-Pulp 2	860	1277
4#	Autoclaved water Pulp2	180	235
5#	Autoclaved alkaline PULP 2	190	239

Sustainable development of fibre cement

The role of Microsilica in fibre cement perfect aligns with the goal of sustainable development for fibre cement.

- Microsilica plays a crucial role in enhancing the strength of fibre cement products and improving the interface performance between PVA fibres and substrates; while effectively enhancing the fibre contribution rate, it also opens the possibility of utilizing recycled fibres and a wider range of other fibre varieties.

- The high pozzolanic activity of Microsilica reacted with calcium hydroxide at room temperature was helpful to reduce the Autoclaving temperature and time; additional the consumption of calcium hydroxide also reduces the alkalinity surrounding the pulps, it was benefit to protect the pulp.

CONCLUSION

- Microsilica has a significant reinforcing effect on fibre cement products by create more binders due to pozzolanic effect and improves the interfacial properties between the fibres and the matrix. The role of Microsilica in fibre cement aligns perfectly with the goal of sustainable development.

- Wood pulp fibres and PVA fibres are the main reinforcing fibres in non-asbestos fiber-reinforced cement products. PVA fibres have a crucial impact on the toughness of the products.

- Wood pulp are at risk of degradation in an alkaline environment. Autoclaving conditions will increase the risk of degradation and significantly reduce the performance of wood pulp fibres.

Thank you for your attention!

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