Composite Thermochemical Energy Storage Materials for building applications

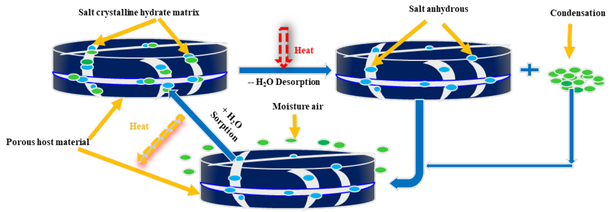
ACTIVE BUILDING CENTRE RESEARCH PROGRAMME

Introduction

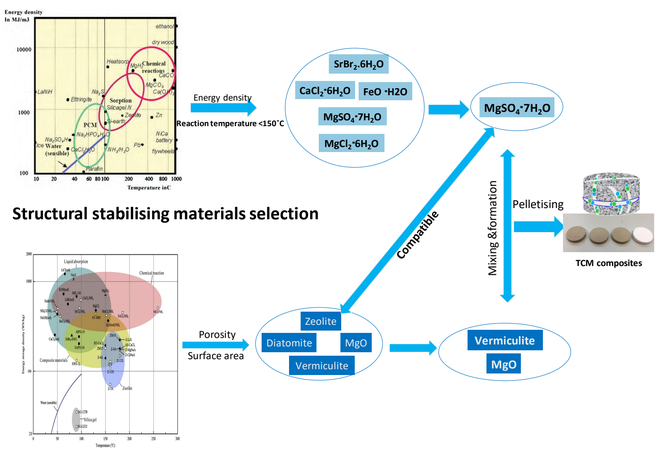
$MgSO_4·7H_2O$ as a potential thermochemical material (TCM) for thermal energy storage has attracted considerable attention in recent decades. Such a material is energy dense with a low cost, particularly suitable for seasonal building applications. A systematic studies were performed to understand of the reaction mechanisms, cyclability and unfavourable dehydration/hydration kinetics of $MgSO_4·7H_2O$ composites, to solve practical issues, and bring it to applications.

Methodology

Working principle of TCM based (desorption/sorption) TES energy storage

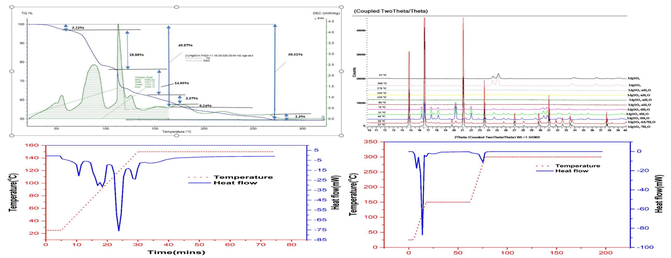


TCM selection



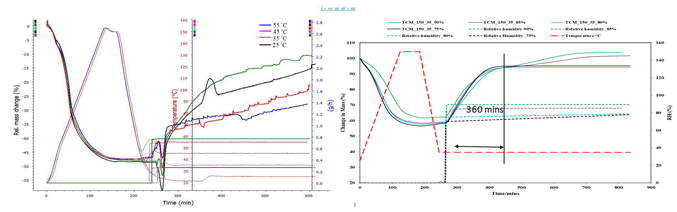
Structural stabilising materials selection

❖ **Pure TCM ($MgSO_4$·$7H_2O$) dehydration stepwise kinetic**



Onset Temperature (˚C)	Enthalpy (J/g)	Enthalpy (%)	ΔTG (%)	Dehydration steps
47.7	168	12	3.23	$MgSO_4·7H_2O(s) \rightarrow MgSO_4·6H_2O(s) + 0.4H_2O(g)$
67.7	378	27	18.88	$MgSO_4·6H_2O(s) \rightarrow MgSO_4·3.5H_2O(s) + 2.5H_2O(g)$
110.6	519	38	14.95	$MgSO_4·3.5H_2O(s) \rightarrow MgSO_4·1.5H_2O(s) + 2H_2O(g)$
140.8	166	12	3.57	$MgSO_4·1.5H_2O(s) \rightarrow MgSO_4·H_2O(s) + 0.5H_2O(g)$
149.7	145	11	0.24	$MgSO_4·H_2O(s) \rightarrow MgSO_4·0.9H_2O(s) + 0.1H_2O(g)$
275	-	-	1.3	$MgSO_4·0.2H_2O(s) \rightarrow MgSO_4(s) + 0.2H_2O(g)$
Total	1376 2.3 GJ/m3	100%	40.9% (T ≤ 150˚C) 50.5% (T ≤ 300˚C)	$MgSO_4·7H_2O(s) \rightarrow MgSO_4(s) + 7H_2O(g)$

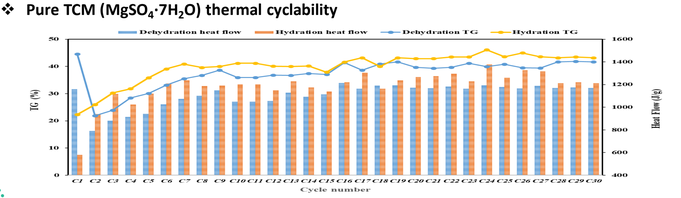
❖ **Pure TCM ($MgSO_4$·$7H_2O$) hydration kinetic_temperature and humidity dependent**



MgSO4·7H2O raw	Dehydration		Hydration	
Hydration temperature (˚C)	Heat flow (J/g)	ΔTG (%)	Heat flow (J/g)	TG (%)
25	1057.6	48.6	670.2	63.4
35	985.8	48.4	765.8	77.8
45	1051	47.5	506.7	48.2
55	920.6	47.4	378.7	41.1

MgSO4·7H2O raw	Dehydration	Hydration	
Relative humidity (%)	ΔTG (%)	TG (%)	
		6h	10h
90	38.3	97	104
85	41.6	95.5	100
80	42.2	94.1	94.1
75	43.3	95.0	95.0

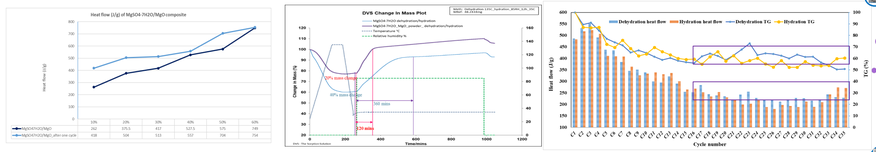
❖ **Pure TCM ($MgSO_4$·$7H_2O$) thermal cyclability**

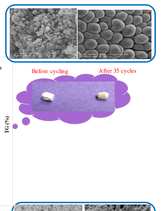


Results and discussion

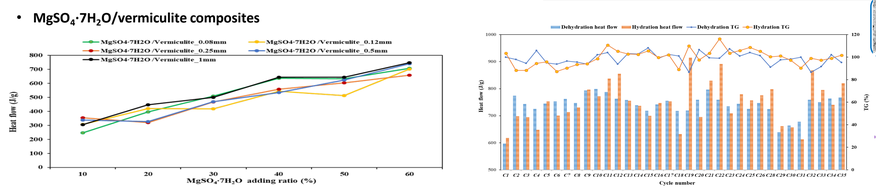
❖ **TCM ($MgSO_4$·$7H_2O$) composites_dehydration/hydration kinetics and thermal cyclability**

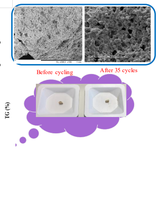
- **$MgSO_4$·$7H_2O$/MgO composites**



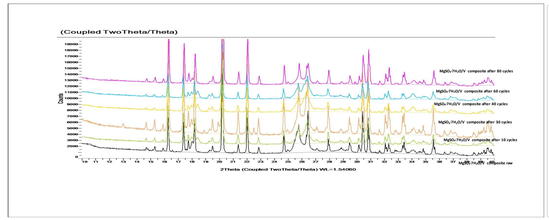


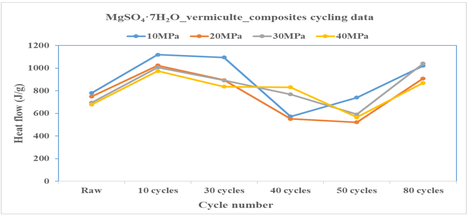
- **$MgSO_4$·$7H_2O$/vermiculite composites**





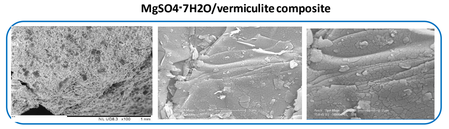
❖ **$MgSO_4$·$7H_2O$/vermiculite composite pellet scale-up chemical and thermal stability**



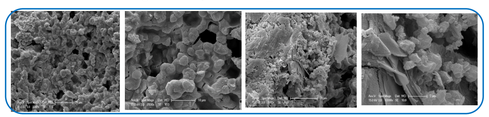


❖ **$MgSO_4$·$7H_2O$/vermiculite composite structure stability morphology study**

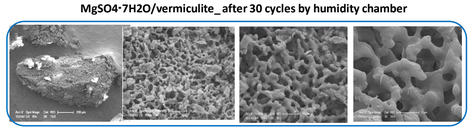
MgSO4·7H2O/vermiculite composite



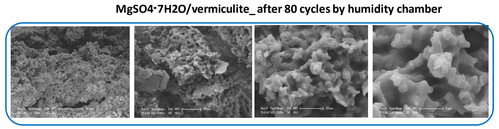
MgSO4·7H2O/vermiculite_ after 35 cycles by STA



MgSO4·7H2O/vermiculite_after 30 cycles by humidity chamber



MgSO4·7H2O/vermiculite_after 80 cycles by humidity chamber



Conclusion

- The host materials, significantly improved the overall sorption performance, leading to faster rehydration process in the composite (3 hours instead of 6-12 hours)
- $MgSO_4·7H_2O$/vermiculite composite has a good cyclability for at least 35 cycles using STA instrument, remains a relatively high heat flow of 750 J/g
- Scaled up $MgSO_4·7H_2O$/vermiculite composite pellet has good stable chemical property and thermal stability in 80 cycles
- $MgSO_4·7H_2O$/vermiculite composite demonstrated good thermal, physical and chemical properties in both mini scale (20mg sample size) and middle scale (1.5g sample size) for long term seasonal energy storage of building applications

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