Surface-functionalization of concrete via nano-modified releasing agent design

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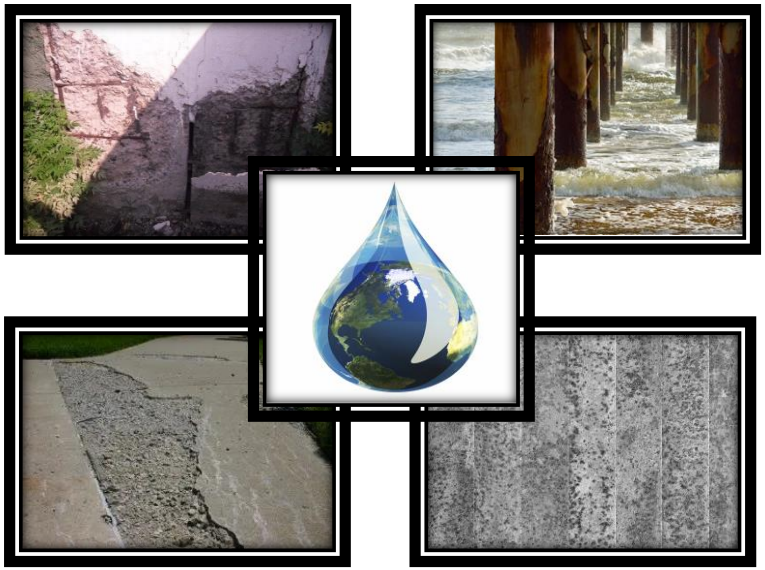
1. Role of concrete surface: Beauty of Nature

- **Decoration**
- **New functions**
  - ✓ **Green buildings**
  - ✓ **Anti-micro organism**
  - ✓ **Self-cleaning**
  - ✓ **Smog-easting**
  - ✓ **Green energy**

1. Role of concrete surface: protection

Deterioration happen from the surface

- ❑ Cracking
- ❑ Acid rain
- ❑ Carbonization
- ❑ Decolorization
- ❑ Sulphate attack
- ❑ Chloride Ingression



Surface treatment are the most using way for enhancing durability. But have also 1) required extra time, 2) extra money required. *(Cheng, 2020)*

How to create a good and durable surface?

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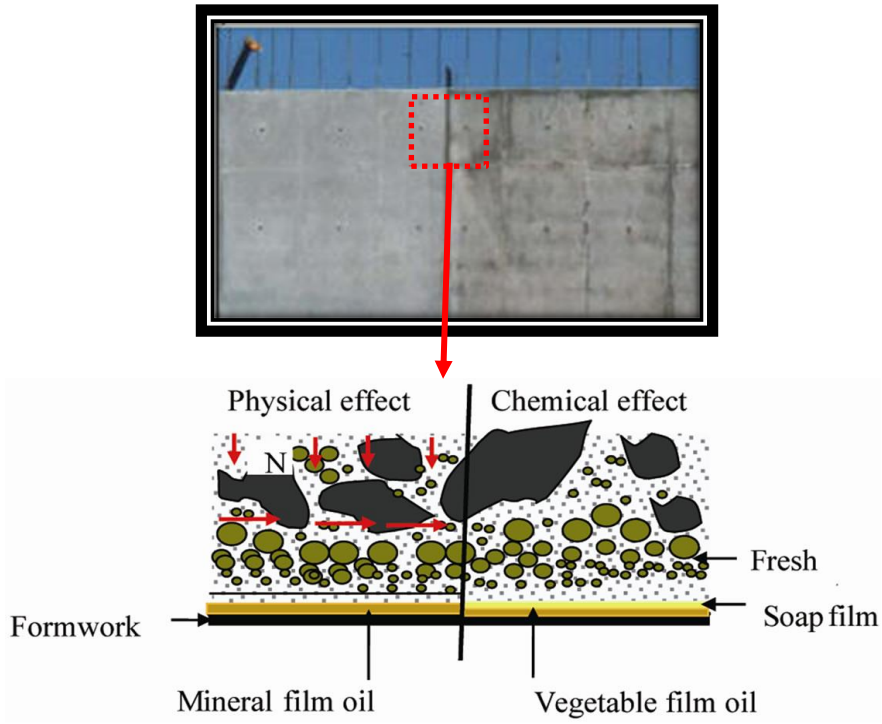
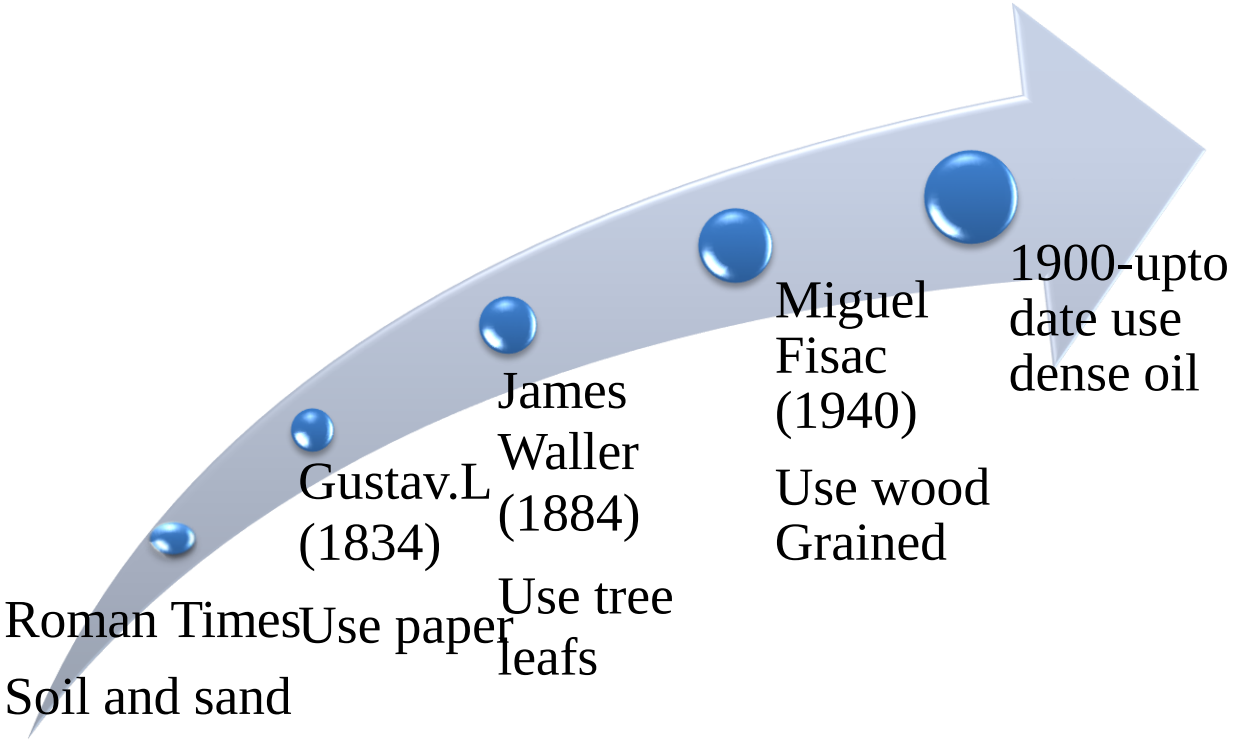
Effects of Releasing agent on concrete surface quality

- ✓ **Releasing agents** could prolong the life of formwork. (waterproof, corrosion resistance, easily detachment)
- ✓ **Vegetable oil** based releasing agent with wood formwork,
- ✓ **Mineral oil** based releasing agent with steel formwork can get good surface.
- ✓ **Water based releasing agent** can get more bugs hole as compared to mineral oil.



Releasing agents can prevent materials from sticking to the mold surface.

Development history of Releasing agent



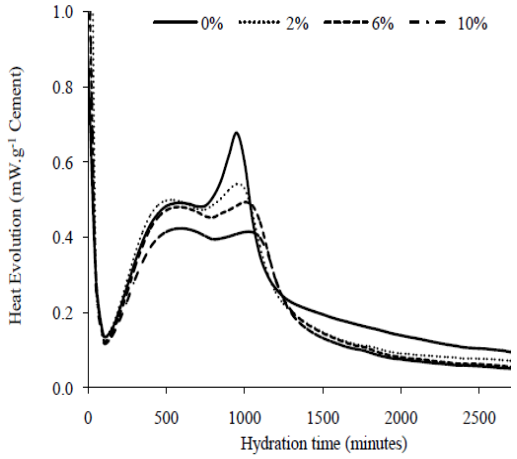
Effects of Releasing agent on concrete surface quality

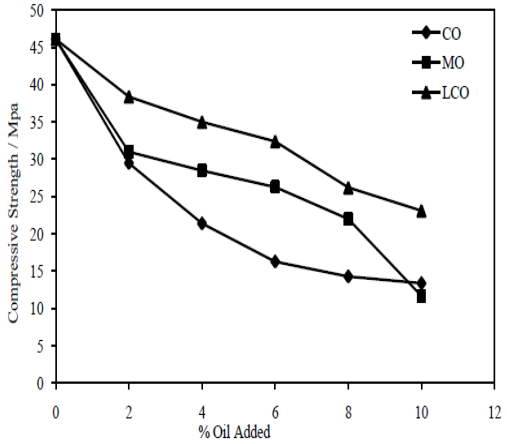
Advantages of releasing agents

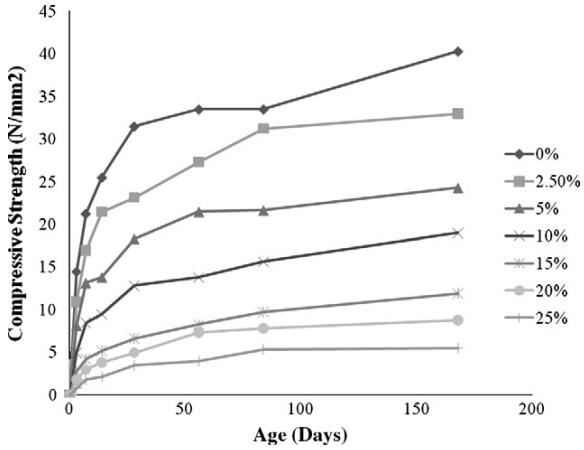
- Good quality of surface
- Smooth surface
- Easily cleaning
- Labour cost
- Decorative surface
- …

Retardation on cement hydration

- **Effect C_3A Hydration, C_3S Hydration**
- **Prevent cement particles from hydration**







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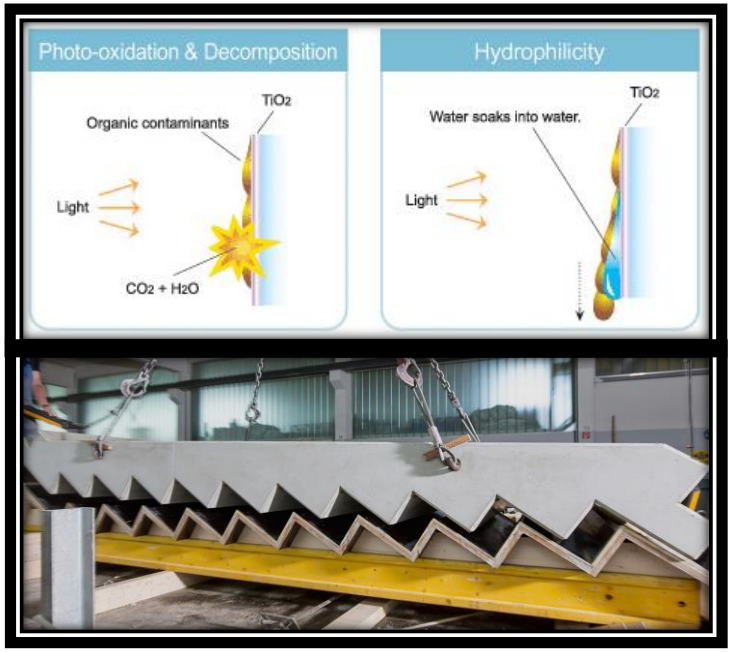
Nano-engineering of releasing agent…

Motivation: Why nano-engineered releasing agent?

Using of releasing agent

- **Sticky** on the surface of mold (viscosity)
- Create **hydrophobic** or **hydrophilic** surface of mold and concrete
- Provide **pathway** for nano-particles



Advantages of nano-technology

- **Nano-silica** pozzolanic material

$$SiO_2 + Ca(OH)_2 + H_2O \longrightarrow C\text{-}S\text{-}H_{(gel)}$$

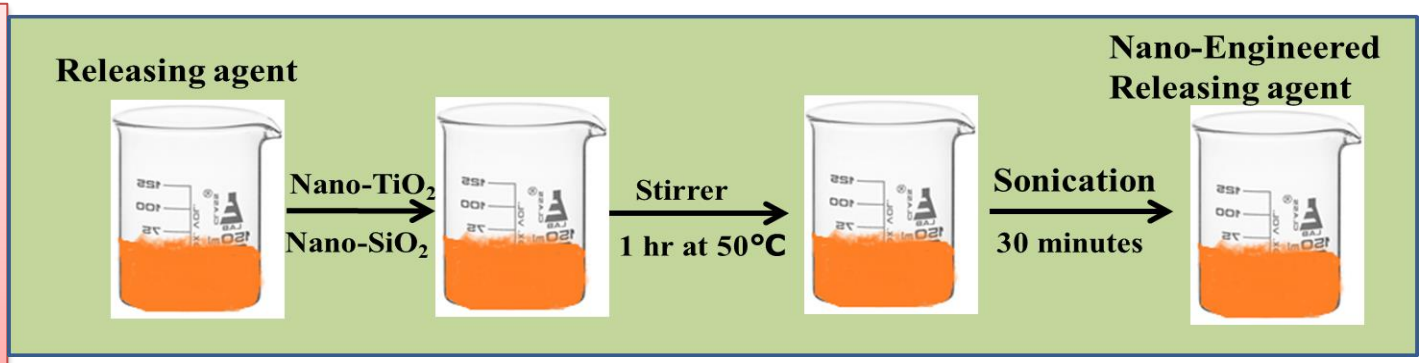
- **Nano-TiO_2** self cleaning properties, filing effect

Preparation of nano-engineered releasing agent

Graphical design of preparation nERa

Raw Materials for (nERa)

- Releasing agent
- Nano-TiO_2
- Nano-SiO_2



Mix proportion of nano-SiO_2, nano-TiO_2 and RA for neRA preparation.

Sample ID	RA (g)	Nanoparticle (g)	Nanoparticle *wt* % of RA
RA	100 g	0	0%
M5T4	96 g	4 g nano-TiO_2	4% nano-TiO_2
M5T16	84 g	16 g nano-TiO_2	16% nano-TiO_2
M5S2	98 g	2 g nano-SiO_2	2% nano-SiO_2
M5S4	96 g	4 g nano-SiO_2	4% nano-SiO_2

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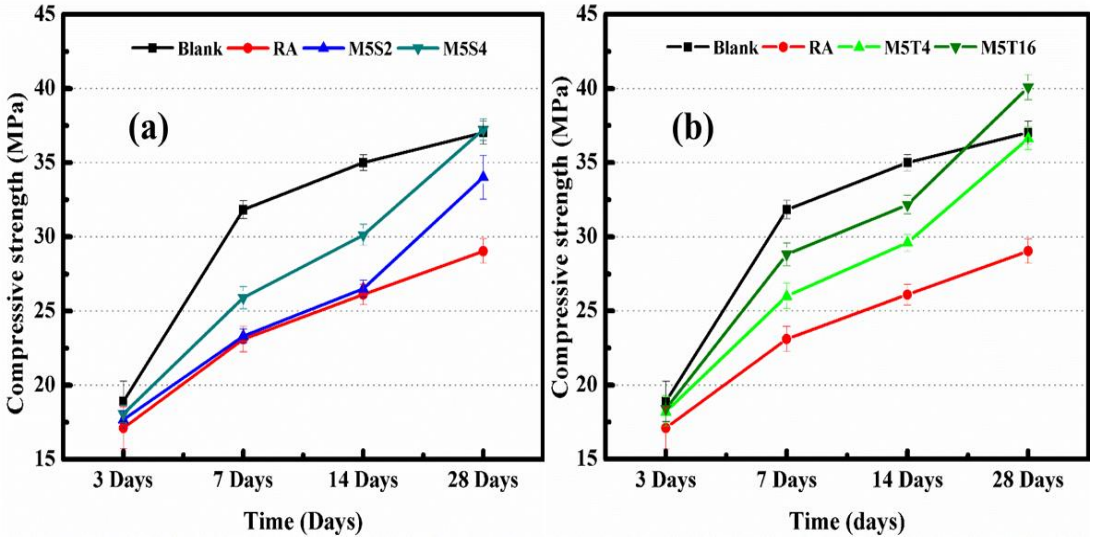
Addition of nERA on strength development

Compressive strength with and without (Ra, nERa)

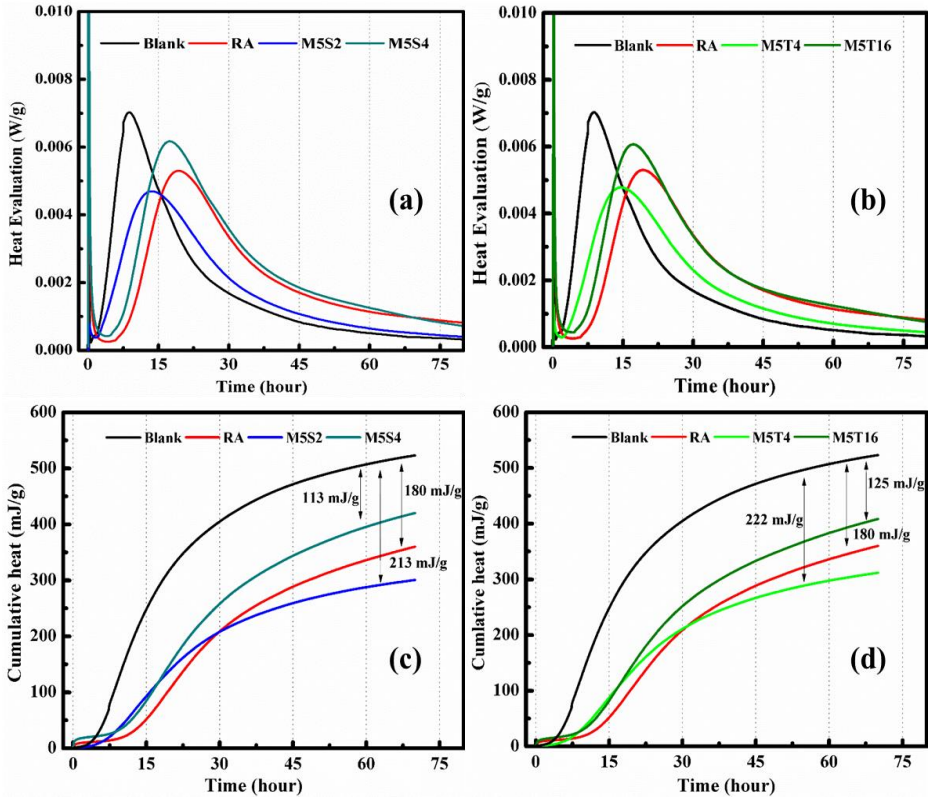
Ra decrease the early age strength 27.4% due to prevent early hydration



Compressive strength after 3-, 7-, 14- and 28-days of curing age of (a) NS (nERa) (b) NT (nERa) cement mortar samples.

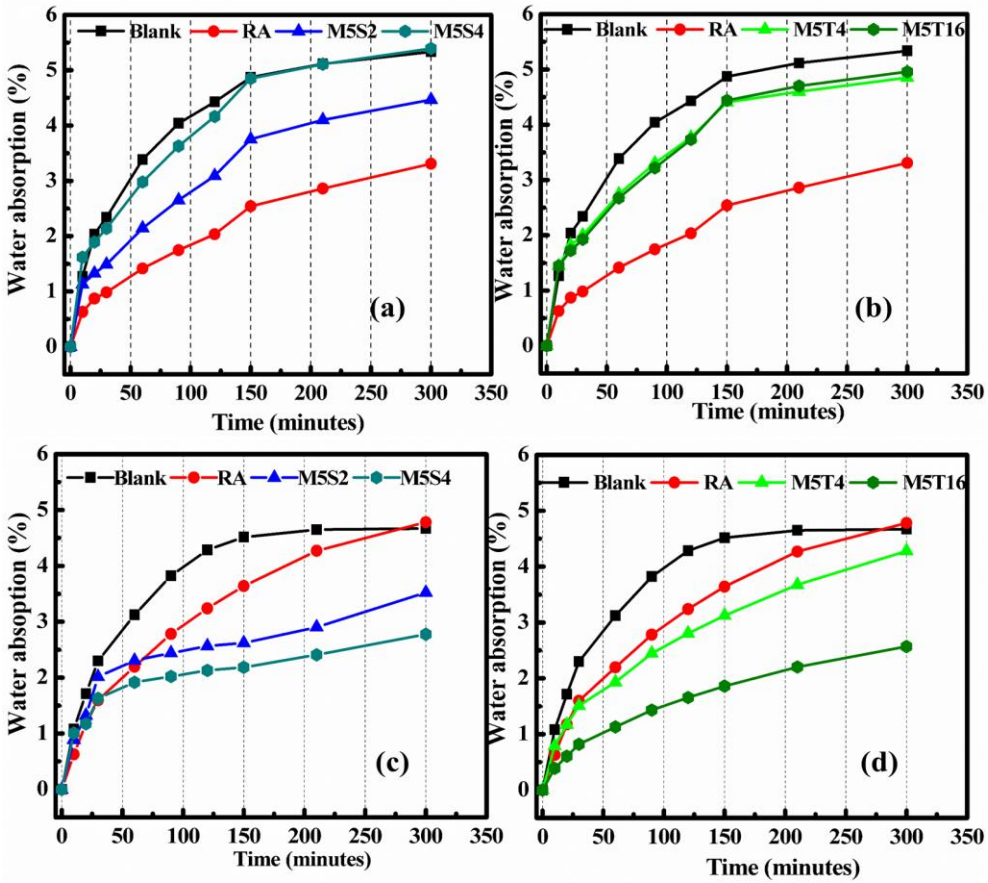
Addition of nERA on hydration heat

Heat of hydration with and without (Ra, nERa)



Thermal calorimetry results of (a,c) NS (nERa) samples (b,d) NT (nERa) samples.

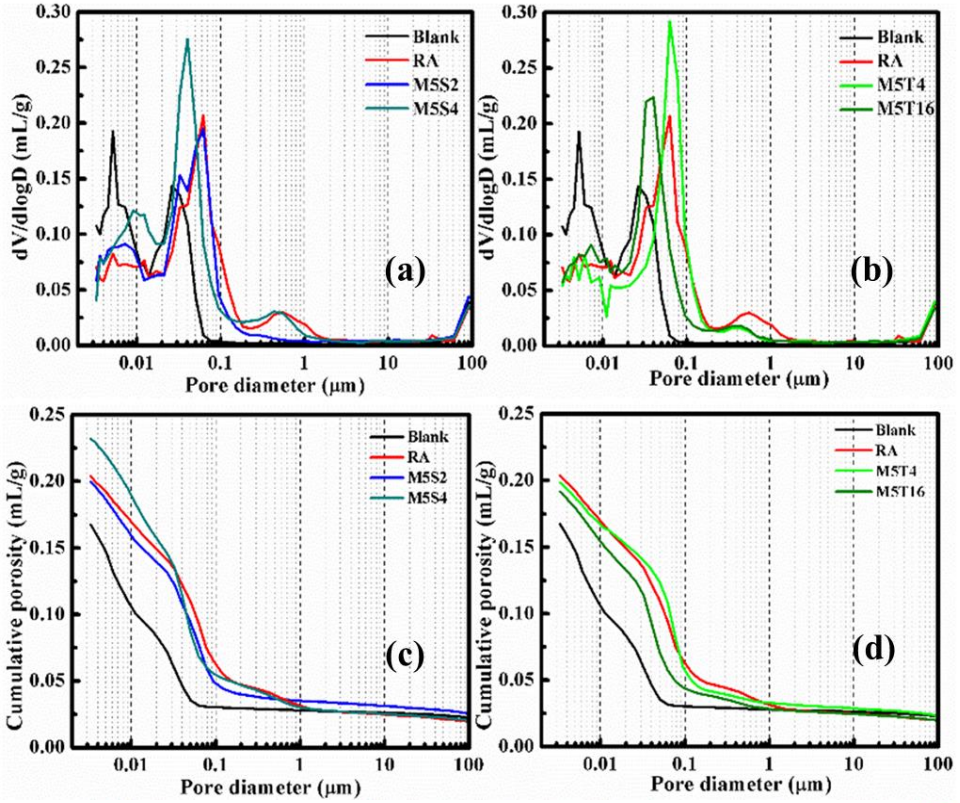
Addition of nERA on water absorption



Water absorption rate % (**a**) NS sample after 7-days (**b**) NT sample after 7-days, (**c**) NS sample after 28-days (**d**) NT sample after 28-days.

Addition of nERA on pore size distribution

- **Increase the NS and NT dosage decrease threshold pore diameter**
- **The addition of NS in RA, can decrease the number of larger pores and also reduce the detrimental pores size which convert to harmless pores**
- **NT decreases the size of pores in the range of 0.1–1 μm due to filling the larger pores size and refining the sample's microstructure**



Mercury intrusion porosimetry curves for (**a, c**) NS and NT (**b, d**) cement paste samples.

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Modified cement concrete surface by nano-engineered releasing agent

Normal concrete

nERA concrete

Surface porosity analysis by MIP

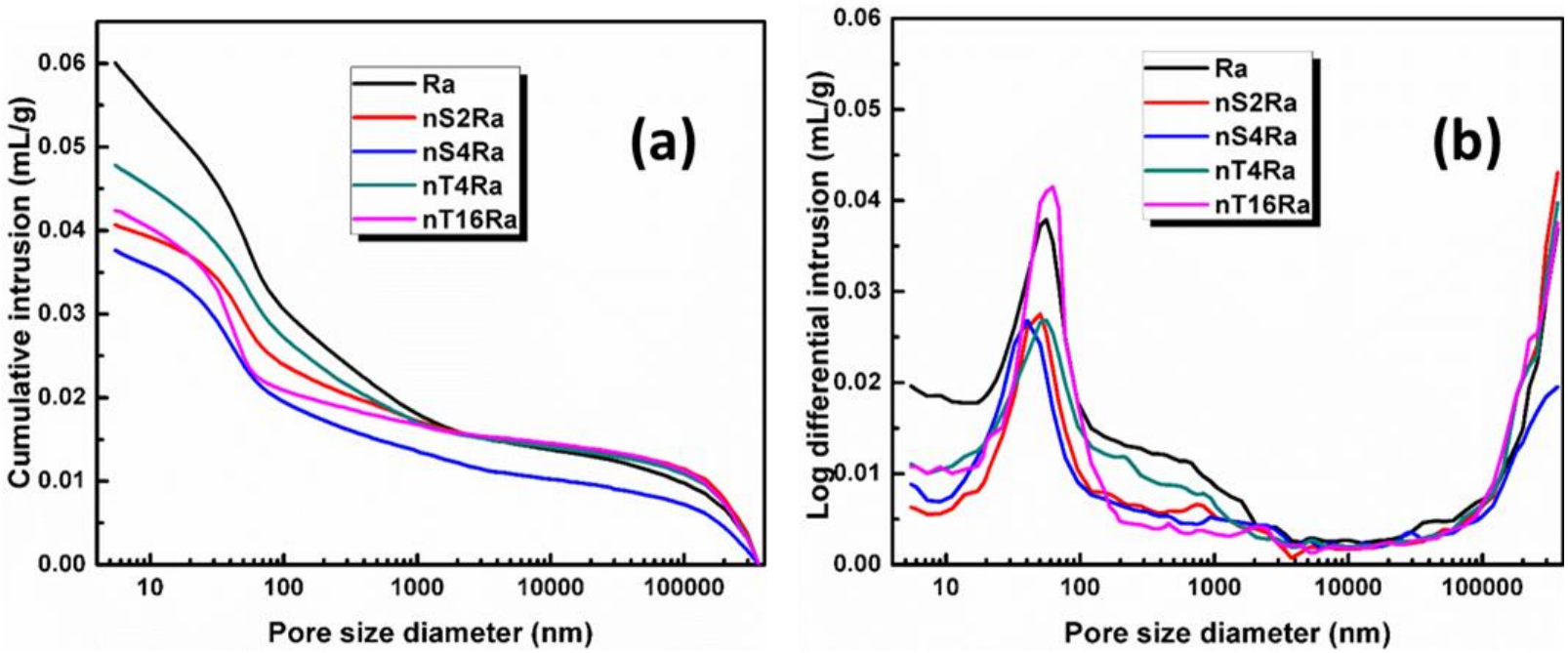
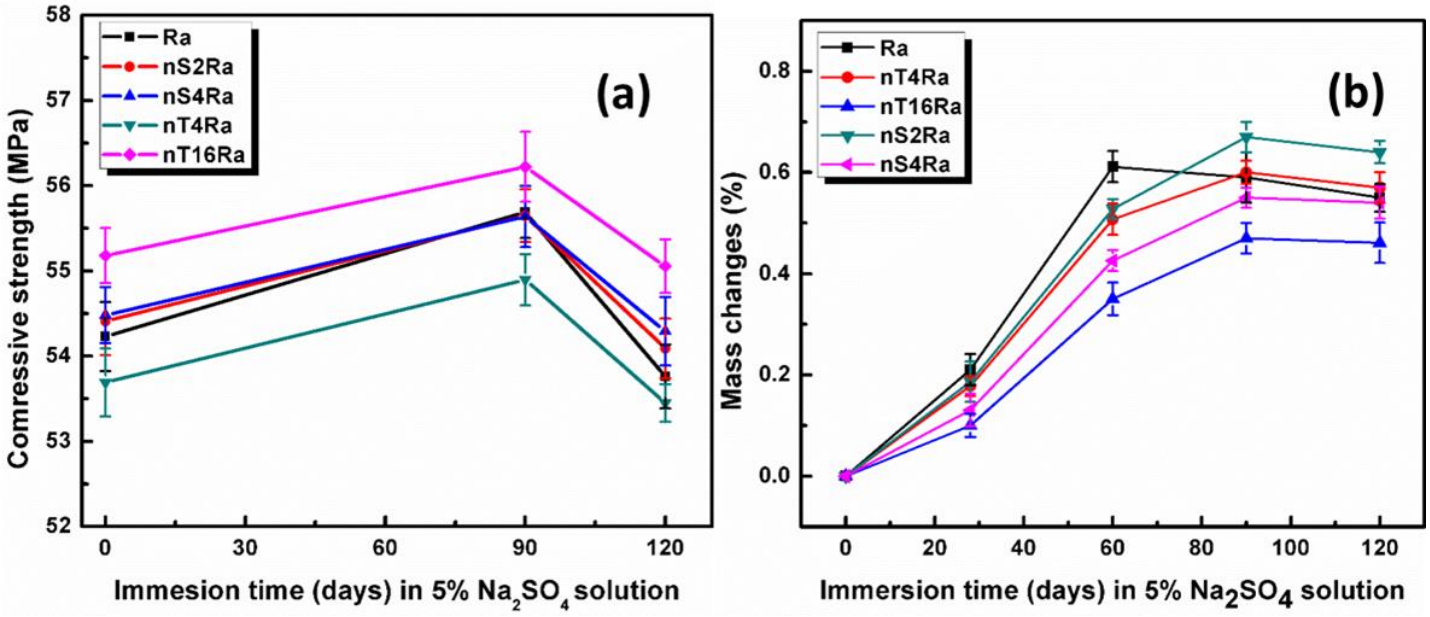


Fig.3 MIP results of cement mortar samples after 28 days of curing age

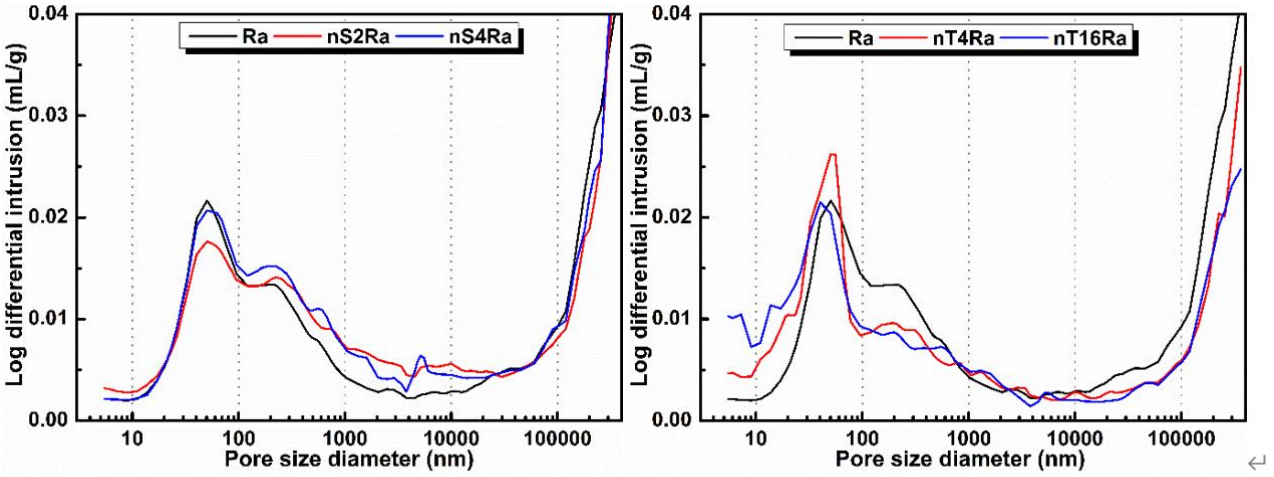
Sulfate resistivity analysis



Weight and strength changes after 120 days in Na_2SO_4 solution

After 120 days	Ra	nS2Ra	nS4Ra	nT4Ra	nT16Ra
Mass loss (%)	0.55	0.57	0.461	0.64	0.54
Strength loss (%)	0.87	0.59	0.34	0.46	0.23

Surface porosity after sulfate attack

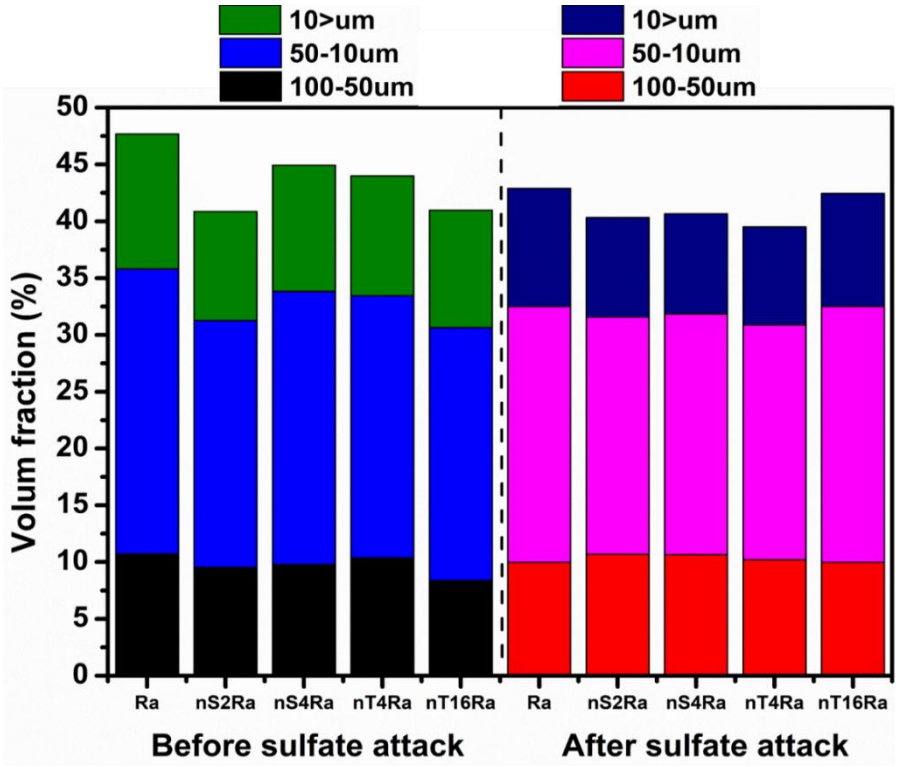


MIP results of 28 days of curing age mortar samples (after immersion in 5% Na_2SO_4 solution)

Total porosity % (before and after) sulfate attack

Samples	Ra	nS2Ra	nS4Ra	nT4Ra	nT16Ra
Before	11.85	10.16	9.5	10.82	9.61
After 90 days	10.64	9.21	8.67	9.76	8.76
Changes %	10.21	9.3	8.73	9.79	8.84

Surface porosity after sulfate attack



After the sulfate environment the samples shows lower porosity due to formation of expansive product

Rapid chloride penetrability test (RCPT)

The curing age of samples were 28 days (ASTM C1202)

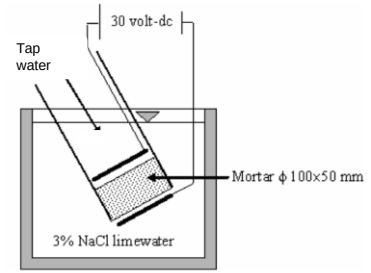
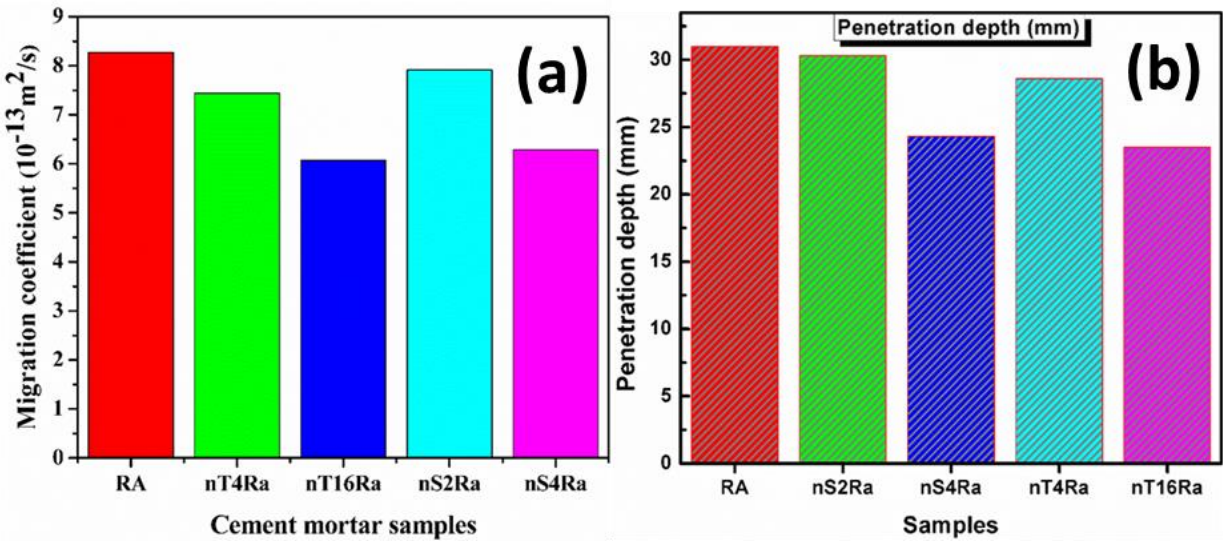
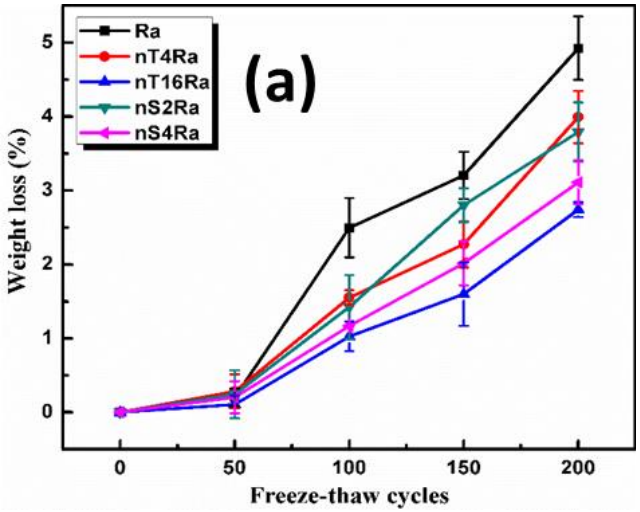


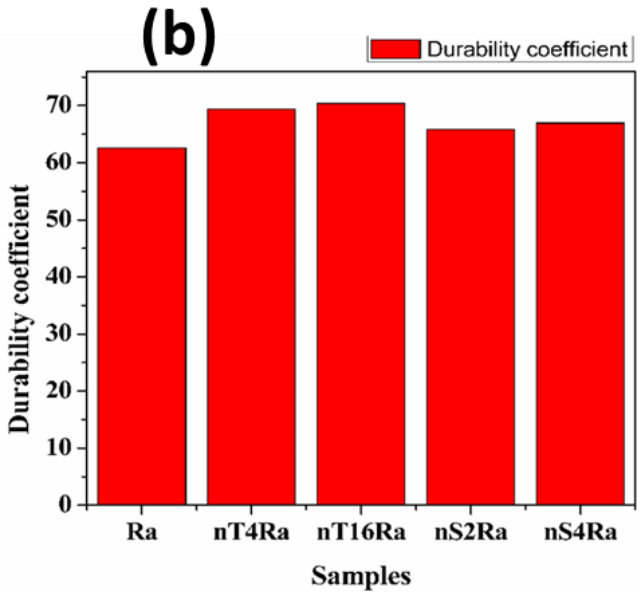
Fig. 1. Schematic diagram of accelerated chloride depth with rapid migration test (RMT) [21].

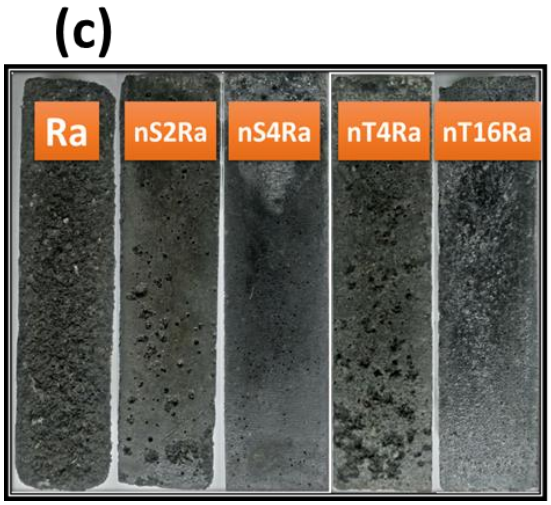


- **The nERa modified sample shows best resistivity against chloride penetrability.**
- **The migration coefficient of nS2Ra and nT16Ra 23.6%, 26.6% compared to RA.**

Freeze-thaw cycle results (F/T cycles)







- The total number of F/T cycle was 200 and every cycle duration was 4 hours.

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Conclusions

- ✓Counterbalance of the adverse side effects of releasing agent on the properties of cementitious materials with nano-particles
- ✓Economical and efficient improvement of concrete durability through surface modification with nano-engineered releasing agents

1. F. Muhammad, et al., Cem. Concr. Compos. 125 (2022) 104300
2. F. Muhammad, et al., Constr. Build Mater, under review

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