wellnova

CEMENT INTEGRITY

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ouronova | Repsol Sinopec

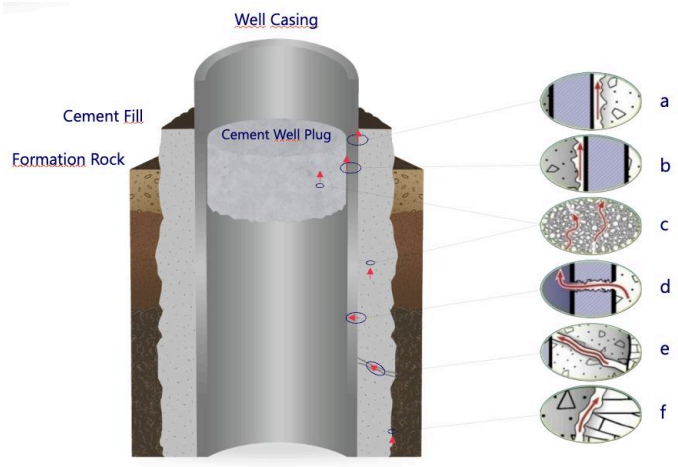
Clinker Composition

Major mineral components of Portland cement clinker.

Compound	Abbreviation	Chemical Formula	%	Contribution on performance
Tricalcium Silicate (Alite)	C_3S	3 CaO. SiO_2	45 - 60%	Durability and total resistance
Dicalcium Silicate (Belite)	C_2S	2 CaO. SiO_2	15 - 30%	Long term durability
Tricalcium aluminate	C_3A	3 CaO. Al_2O_3	5 - 12%	Durability and early setting
Tetracalcium aluminoferrite	C_4AF	4 CaO. Al_2O_3 Fe_2O_3	6 - 12%	No effect on durability
Gypsum (added during grinding)	CSH_2	$CaSO_4$ $2H_2O$	2 - 10%	Prevents early setting

Potential Leakage Pathways

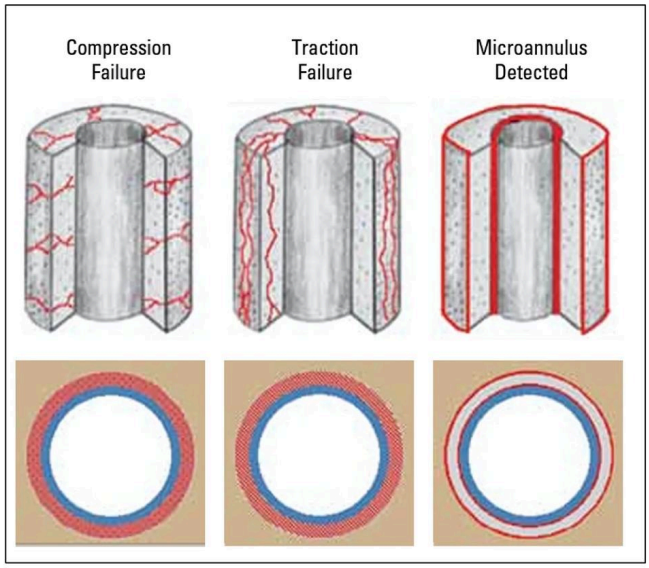
Several potential leakage pathways can occur along cased holes and/or abandoned wells.



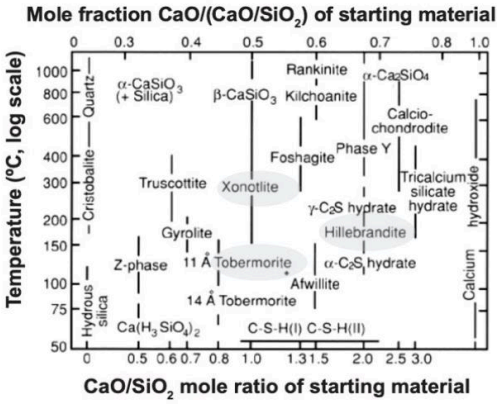
Gasda et al., 2004 and 2005

Factors Impacting Cement Integrity

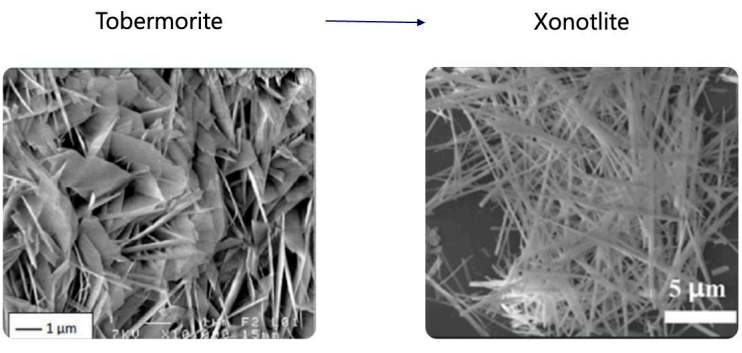
Application of pressure inside casing can lead to micro cracks in the cement matrix, both in the radial as well as tangencial directions.



Integrity Threat : HPHT Conditions



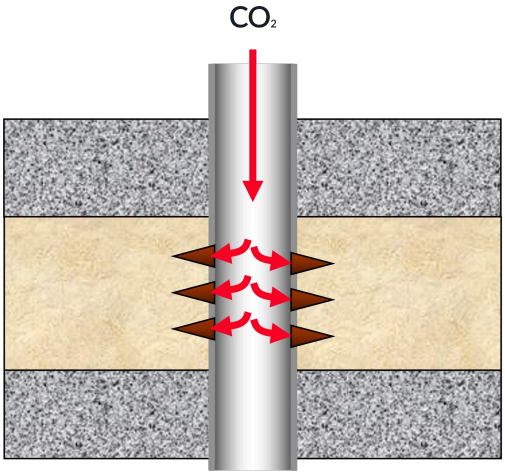
Phase changes in Portland cement submitted to elevated temperatures.

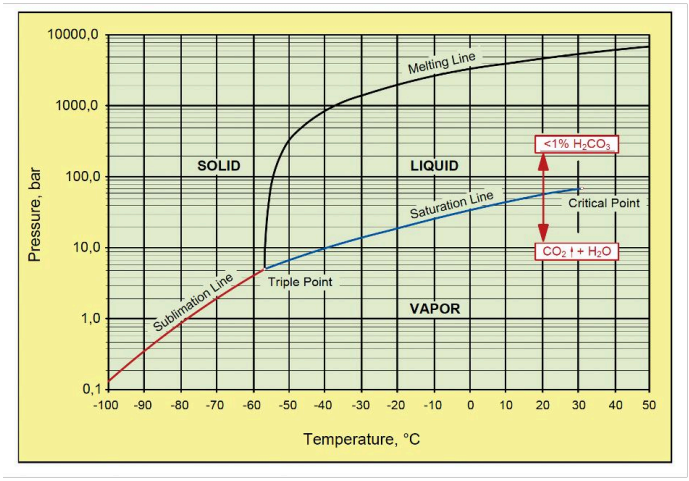


Xonotlite is formed at higher temperatures than Tobermorite

CO_2 Injection (EOR)

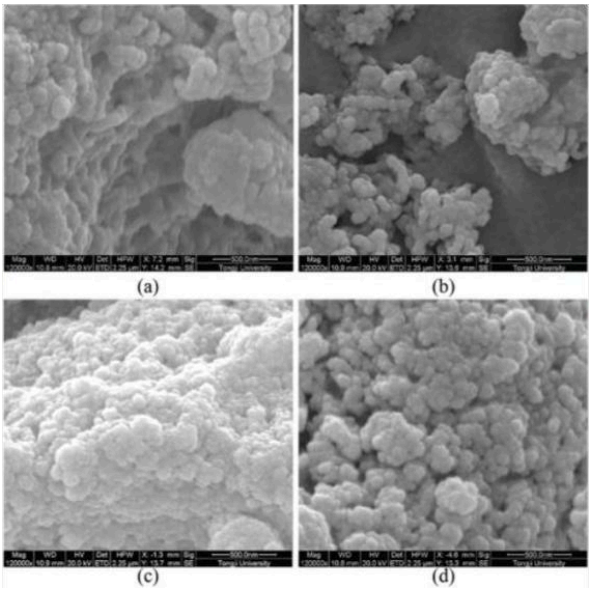
CO_2 injection is a proven EOR technique (± 45 years). The most of the technologies developed through the last 44 years of CO_2 EOR experience have been successfully applied in GS (geologic sequestration) for CCS (carbon capture and storage) in saline aquifers (Sweatman et al., 2009).

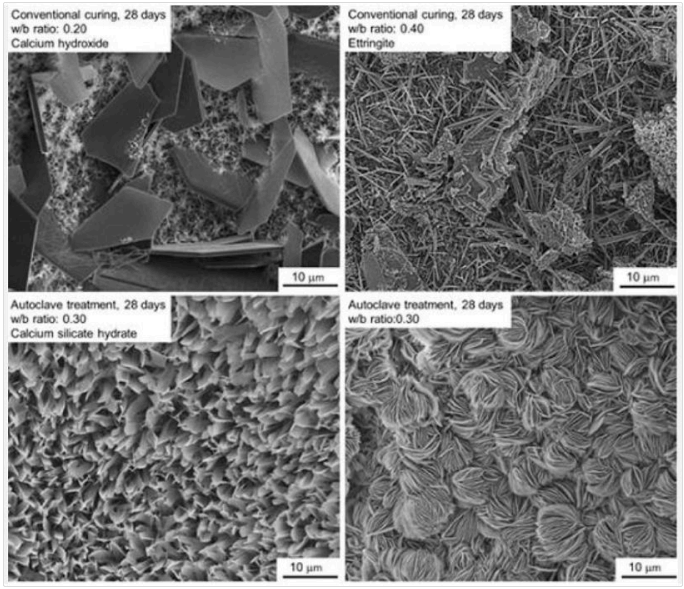




What is set cement?

C-S-H (Calcium Silicate Hydrate) is the main phase which keeps the cement particles binded together, providing cohesion and resistance. It does not have a defined chemical formula and is amorphous.





Related Chemical Reactions (H_2S)

Chemical formulas.

$$H_2S + Ca(OH)_2 \rightarrow CaS + 2H_2O$$

$$CaS + 2H_2O + CO_2 \rightarrow CaCO_3 + H_2S\uparrow$$

Specially formulated cement slurry

Composition of high-density cement slurries. Unit wt. %.

Material which replaces Portland cement, helping compaction

Mesh Mn

Density (kg/m³)	Cement	Wanter	Fluid Loss Reducer	Retarder	Dispersant	Slica Fume	Weighting Agent	Slag	Resin
2.0	100	41	7	2.5	2	35	16	20	8
2.1	100	42	7	2.5	3	35	32	18	8
2.2	100	44	6	2.2	4	35	52	18	8
2.3	100	45	6	2	4.5	35	79	16	10

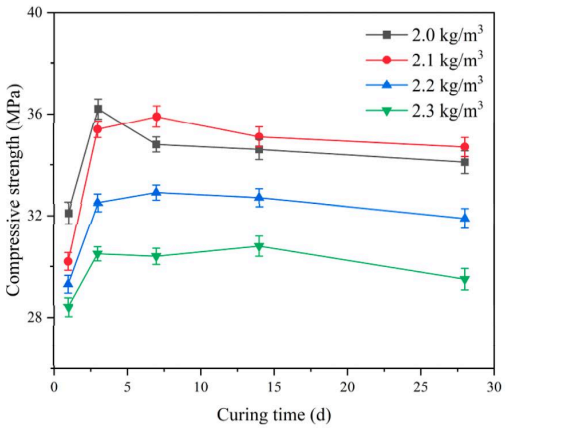
100 mesh: 150μ m ; 300 mesh: 48μm

Added material which in high temperatures, reacts with cement hydrated silicates to generate tobermorite and xonotlite, reducing the ratio of C/S from 2 to 3:1 to approximately 1:1

Material which protects cement matrix, mitigating corrosion

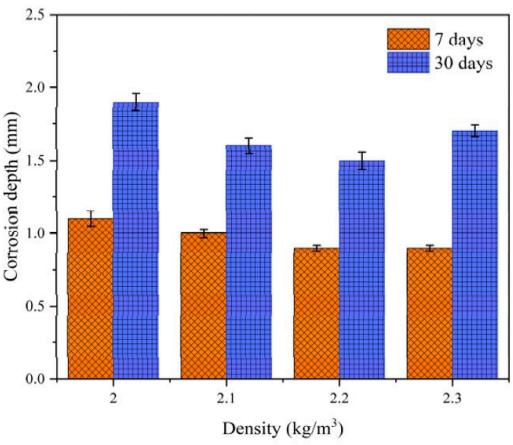
Specially formulated cement slurry

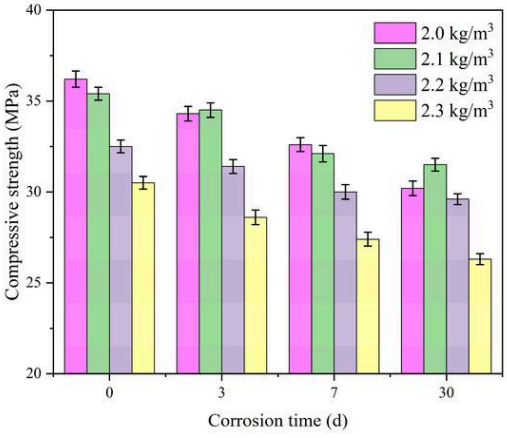
By evaluating the compressive strength of cement paste cured at high temperatures for different times and analyzing the changes in compressive strength, it is possible to study the stability of the mechanical properties of set cement at high temperatures.



Effect of chemical attack

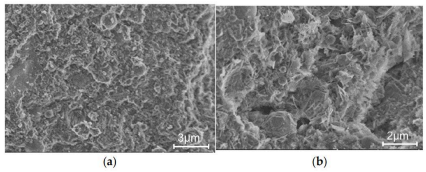
To evaluate the resistance of different high-density cement slurries to carbon dioxide and hydrogen sulfide, the corrosion performance of cement samples subjected to different lengths of time at high temperature was evaluated.





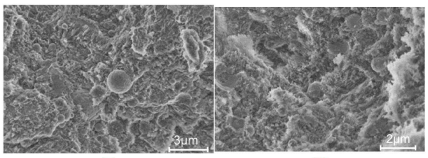
Preserving the Integrity of Cement

As more manganese ore powder is added to the cement slurry, the cement slurry becomes reddish brown. When the cement slurry encounters phenolphthalein after being corroded, the color of the cement slurry becomes deeper. The corrosion depth of the cement sample can be measured from the corrosion morphology.



(a) (b)

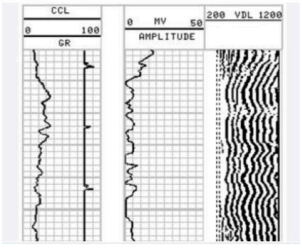
Figure 13. Morphology of 2.0 kg/m^3 cement sample: (**a**) non-corroded; (**b**) corroded.



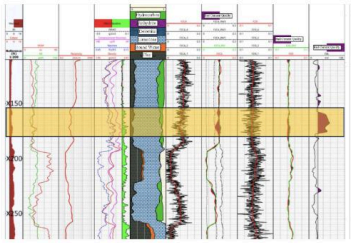
(a) (b)

Figure 14. Morphology of 2.3 kg/m^3 cement sample: (**a**) non-corroded; (**b**) corroded.

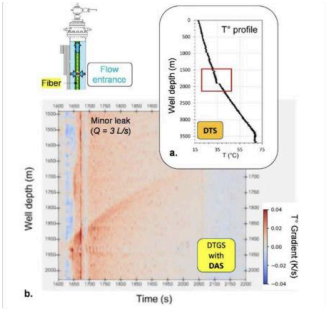
Cement Evaluation Tools Overview



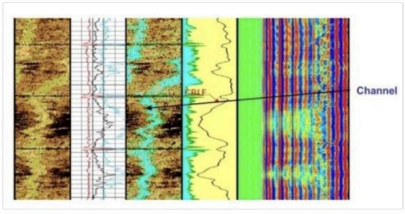
CBL & VDL



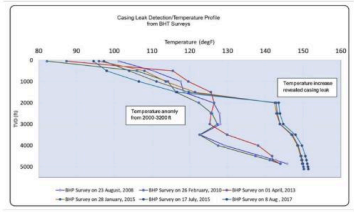
Pulse Neutron Logs



Fiber Optics Sensing



USIT



Pressure & Temperature Sureveys

Tool Comparison Table

Tool	Detect Bond?	Good for Light Cement?	Notes
CBL	Yes	No	Good for hard cement
VDL	Yes (waveform)	No	Qualitative only
USIT	Yes	Yes	Good for gas zones
PNL	Indirectly	Yes	Requires base log
DAS	Yes (fluid flow)	Yes	Real time detection

Cement Design Simulators