FACTORS IMPACTING CEMENT INTEGRITY

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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

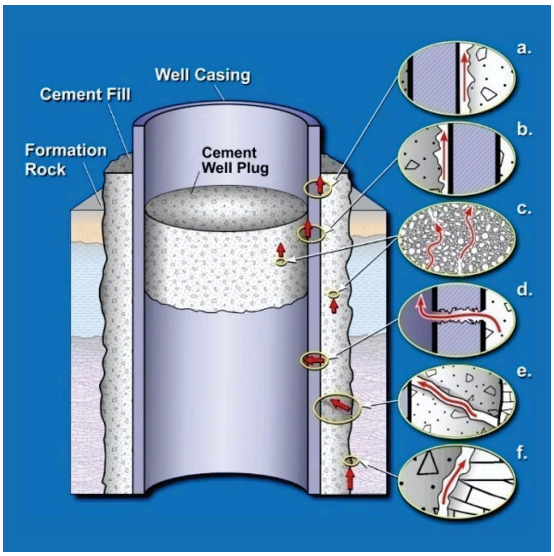
Types of Cement

Various types of cement are used in oil wells, the most common being Class G Portland cement.

API Class	Depth		Temperature		Composition
	ft	m	°F	°C	
A-C	60000	1830	80 - 170	27 - 77	Low C3A No retarder
F	10000 - 16000	3048 - 4877	230 - 320	110 - 160	Low C3A Retarder present
G, H	-	-	80 - 200	27 - 93	Coarse - grained Type II & Type V portland cement No retarder
J	> 20000	> 6100	> 350	> 177	Essentially beta dicalcium silicate & pulverized sand

Potential Leakage Pathways

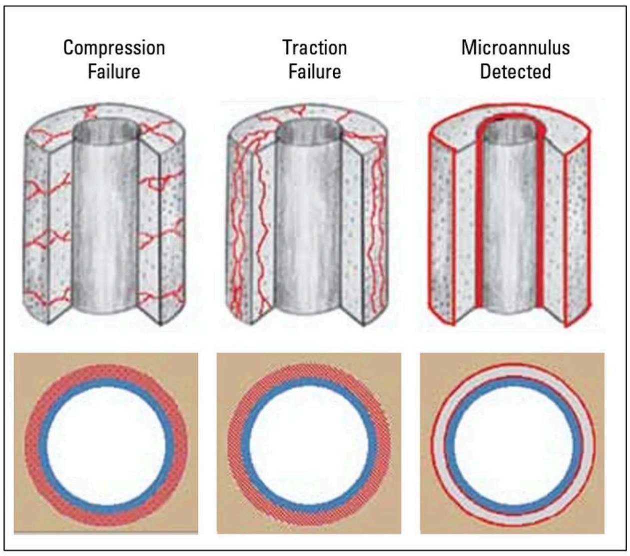
Several potential leakage pathways can occur along cased holes and/or abandoned wells.



Gasda et al., 2004 and 2005

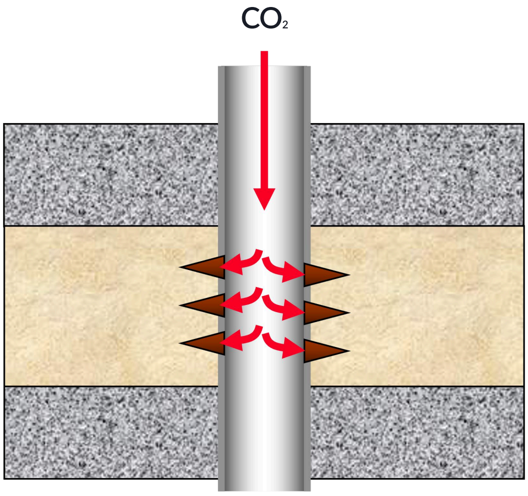
Factors Impacting Cement Integrity

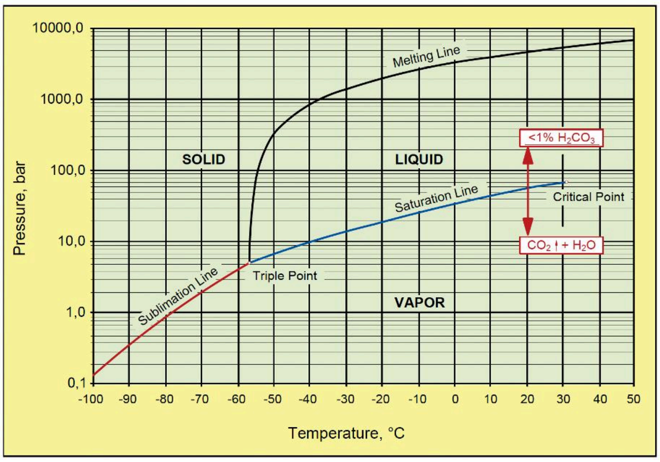
The gas flow model is used for evaluating and testing cement slurries for use in oil and gas well applications.



CO2 Injection (EOR)

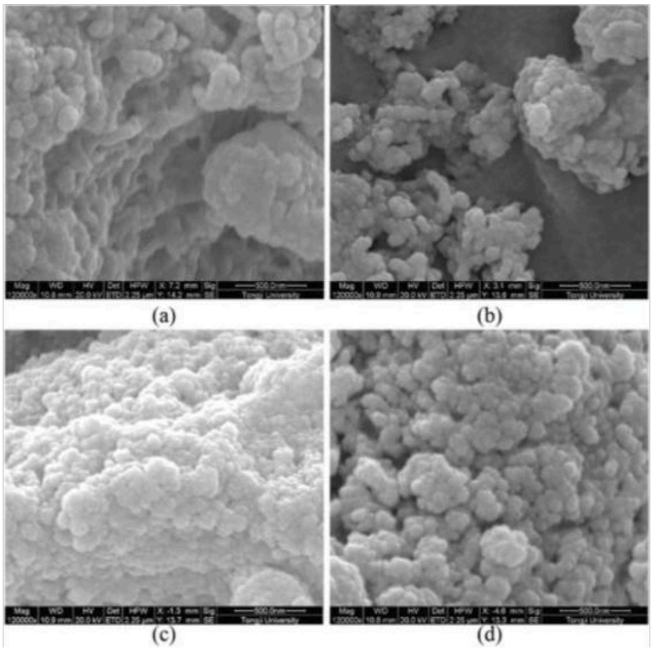
CO_2 injection is a proven EOR technique (± 45 years). The most of the technologies developed through the last 44 years of CO2 EOR experience have been successfully applied in GS (geologic sequestration) for CCS (carbon capture and storage) in saline aquifers (Sweatman et al., 2009).

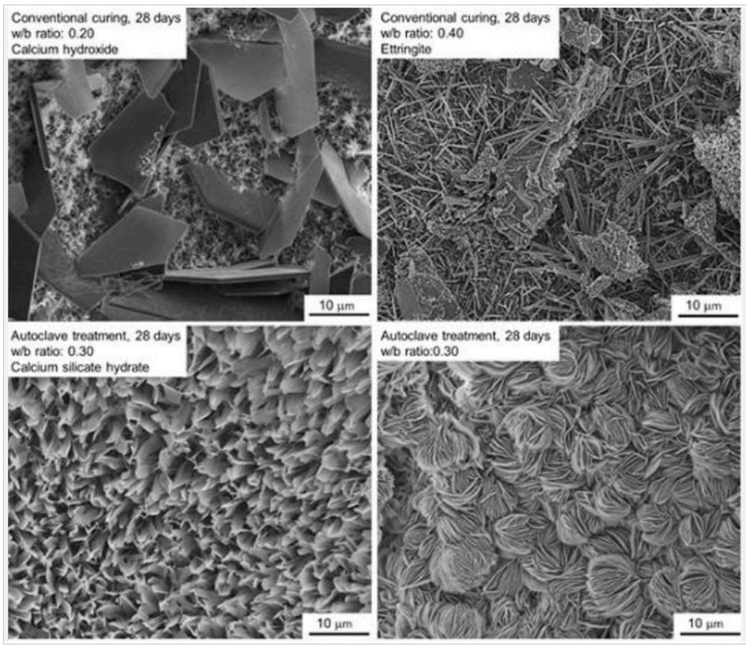




What is set cement?

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 (H2S)

Chemical formulas.

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

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

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Specially formulated cement slurry

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

Material which replaces Portland cement, helping compaction

Density (kg/m³)	Cement	Wanter	Fluid Loss Reducer	Retarder	Dispersant	Slica Fume (Mesh)	Weighting Agent (Mn)	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

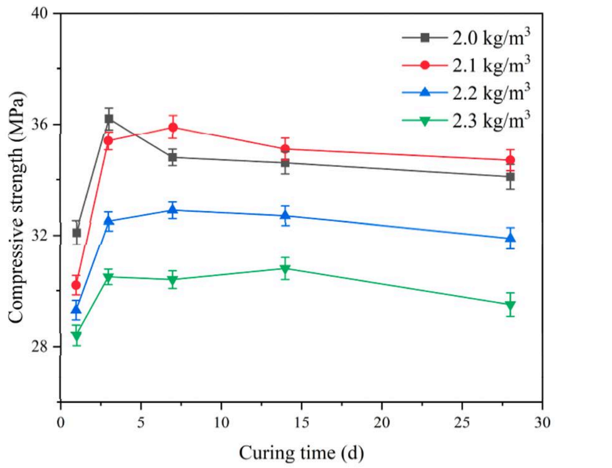
100 mesh: 150μ m ; 300 mesh: 48μm

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

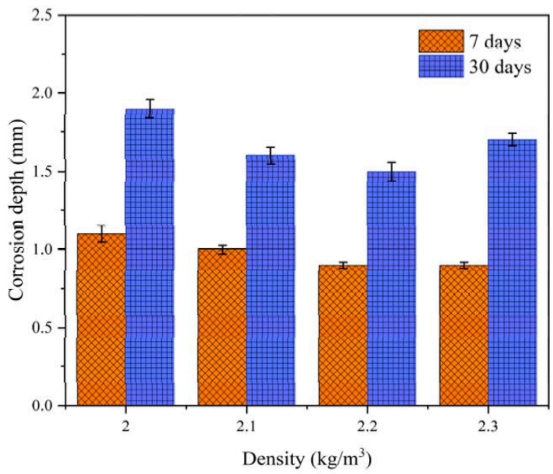
Specially formulated cement slurry

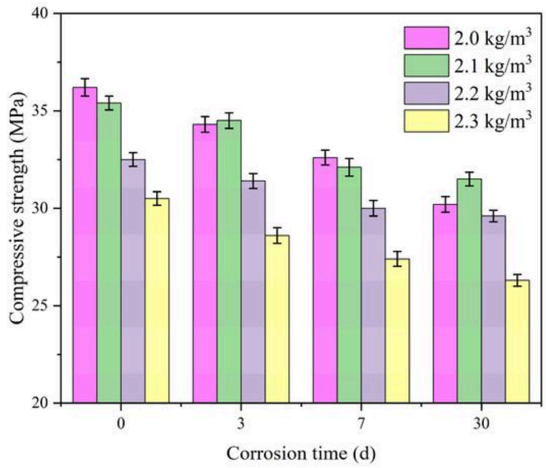
By evaluating the compressive strength of cement paste cured at high temperatures for different times and analyzing the changes in compressive strength, it is possible to study the stability of the mechanical properties of cement paste at high temperatures.



Efeito do Ataque Químico

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.

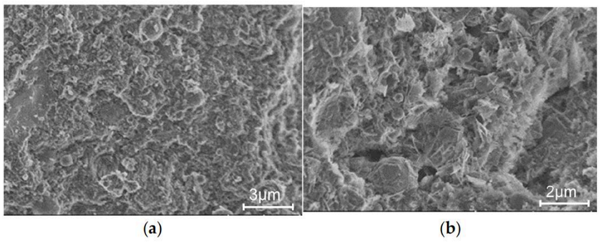


Figure 13. Morphology of 2.0 kg/m^3 cement sample: (**a**) non-corroded; (**b**) corroded.

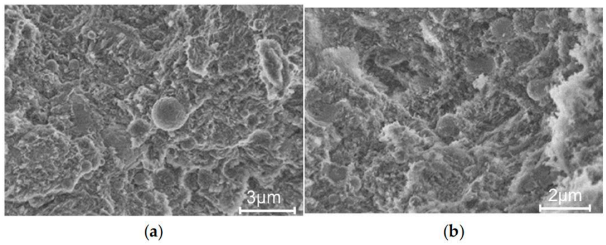


Figure 14. Morphology of 2.3 kg/m^3 cement sample: (**a**) non-corroded; (**b**) corroded.

The importance of centralizers

Centralizers are essential elements in oil wells to ensure proper cementing of the casing, which is crucial for the stability and safety of the well.

	Transition Joint	Fish # 11
Well depth (m)	119.2-131-5	251.7-263.8
Final length (m)	9.36	10.56
Min. Sand off (m)	0.01057	0.01250
Max. Eccentricity %	70	64

Shallow depth (low temperature)

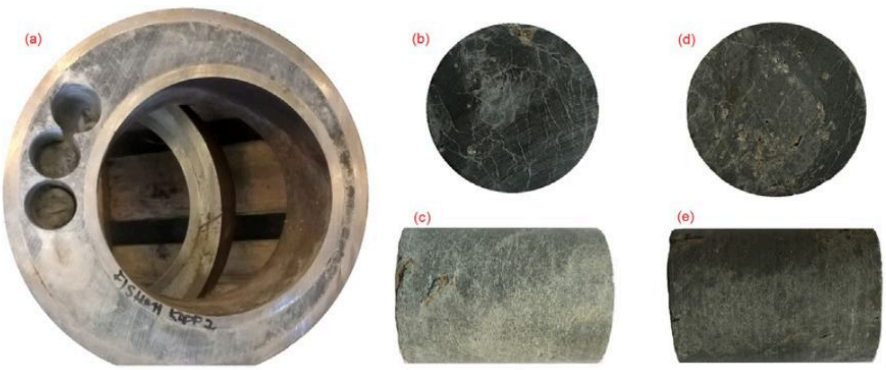


Fig. 3. Core plugs obtained from Fish 11 (Bottom). (a) Drilling of core plugs, (b) FB 64 top view, (c) FB 64 lateral view, (d) FB 132 top view and (e) FB 132 lateral view.