This Sealant Assessment Table can be used to assess and compare different sealants when developing or selecting sealants for a well exposed to CO_2 during CO_2-injection and (geological) storage. Testing conditions, and the selection of relevant tests should be based on expected conditions and research needs for each application separately.
The Key abilities and Critical Properties included in this sheet are based on research performed as part of the ACT-CEMENTEGRITY project (2021-2024). The included properties were selected based on existing regulatory documents as well as own research performed as part of the project. For more information regarding the selection of these properties, see the below reports and papers.

Note that the CEMENTEGRITY project focused on the properties of the cured sealant materials, and did not take into account fluid state properties such as setting time or viscosity. As the fluid state properties are of great importance for sealant emplacement, for any new sealant material or specific application it should be ensured that these properties are also suitable.

References:

Van Noort, R. (2024) Overview of current standards and common other testing methods used in wellbore sealant assessment. CEMENTEGRITY Deliverable 7.1, 2024-01-26.

Van Noort, R., M. Gupta, S. H. Hajiabadi, M. Khalifeh, A. Kvassnes, K. Li, A. Pluymakers, G. Starrs, B. Suryanto, G. Svenningsen, G. Ye (2024) Development and testing of novel cement designs for enhanced CCS well integrity. 17th Greenhouse Gas Control Technologies Conference 2024 (GHGT-17) proceedings, https://ssrn.com/abstract=5010396.

Van Noort, R. (2025) Critical properties and testing methods for sealants in CCS applications. CEMENTEGRITY Deliverable 7.2, 2025-03-27.

NOGEPA (2021) Industry Standard 45: Decommissioning of wells. NOGEPA.

NORSOK (2021) D-010: Well integrity in drilling and well operations. NORSOK.

UK OG (2015) Guidelines on Qualification of Materials for the Abandonment of Wells (GQMAW). Oil & Gas UK.

UK OE (2022) Guidelines on Well Decommissioning for CO_2 Storage – Issue 1. Offshore Energies UK.

Sealant for CCS - key abilities assessment

1) Ability to form and maintain a seal	Assessment methods	Methods notes	Results (description)	Impact of exposure (if done)	References
	Bond strength/shear tests	44 mm ø sealant cylinder pushed out of 50 mm long mild steel casing (wall thickness 3.2 mm) - USA patent US11054353B2. Curing: 80°C, 30 MPa for 3 days; raised to 150 °C in 7 days, held 21 days. Conditioned at 80 °C before measurement.	Average peak shear stress (apparent bond strength) 4.66 MPa. Significant corrosion observed on inner surface of steel casing, likely causing elevated bond strength.	N.D.	
	Bond strength/shear tests	44 mm ø sealant cylinder pushed out of 50 mm long stainless steel casing (wall thickness 3.2 mm) - USA patent US11054353B2. Curing: 80°C, 30 MPa for 3 days; raised to 150 °C in 7 days, held 21 days. Conditioned at 80 °C before measurement.	Average peak shear stress (apparent bond strength) 3.56 MPa, no corrosion.	N.D.	
	Bond strength/shear tests	44 mm ø sealant cylinder pushed out of 50 mm long mild steel casing (wall thickness 3.2 mm) - USA patent US11054353B2. 20°C, 90 days. Accelerated corrosion: with a stainless-steel central rod connected as a cathode and the metal casing enclosure as anode. 9 cycles with 6 days current, 1 day rest.	Average peak shear stress (apparent bond strength) 0.91 MPa, no corrosion.	Accelerated corrosion increased the apparent bond strength to 1.2 MPa (exposed 0.21 mA/cm^2 current) and 3.2 MPa (to 0.42 mA/cm^2 current).	
	Bulk conductivity/electrical tests	44 mm ø sealant cylinder pushed out of 50 mm long mild steel casing (wall thickness 3.2 mm) - USA patent US11054353B2. Curing: 80°C, 30 MPa for 3 days; raised to 150 °C in 7 days, held 21 days. Measurement at 20 °C.	Average bulk conductivity 0.0384 S/m. Note that the electrodes were in the form of 2 strainless-steel rods, 2.4 mm diameter, 15 mm separation.	N.D.	
	Bond strength/shear tests	6 mm ø stainless-steel tube (wall thickness 1 mm) pushed out of 70 mm long, 30 mm ø sealant sheath	Average peak shear stress 2.6 MPa.	See below for thermal exposure.	
	Annular leakage/hydraulic sealability	N_2-flow rate measured along annular contact by applying 0.3 Mpa pressure to one end of cylinder; other end open to atmosphere.	Leakage rates of 0.6-1.2 ml/min. Note that these measurements were performed on an annular contact of sealant around stainless steel with a contact diameter of 6 mm.	See below for thermal exposure.	

2) Ability to resist CO_2-containing fluids	Exposure method	Conditions and fluid used	Results (description)	Impact of compound exposure (if done)	References
	Batch	12 mm ø, 30 mm long cylinder; wet supercritical CO_2, 80 °C, 10 MPa.	Full carbonation of free $Ca(OH)_2$ within 4 weeks. At 16 weeks, further chemical and microstructural alteration in outer 500 µm.	N.D.	
	Batch	12 mm ø, 30 mm long cylinder; CO_2-saturated water, 80 °C, 10 MPa.	Full carbonation of free $Ca(OH)_2$ within 4 weeks. At 16 weeks, further chemical and microstructural alteration in outer 2000 µm, with degradation in outer 150 µm.	N.D.	
	Batch	12 mm ø, 30 mm long cylinder; wet supercritical CO_2 with 1.6 mol% H_2S, 80 °C, 10 MPa.	Full carbonation of free $Ca(OH)_2$ within 4 weeks. At 16 weeks, further chemical and microstructural alteration in outer 620 µm. S enrichment throughout the sample, but especially in the outer 400 µm.	N.D.	
	Batch	12 mm ø, 30 mm long cylinder; CO_2-saturated water, 1.6 mol% H_2S in CO_2-phase, 80 °C, 10 MPa.	Full carbonation of free $Ca(OH)_2$ within 4 weeks. At 16 weeks, further chemical and microstructural alteration in outer 2940 µm, with degradation in outer 2600 µm, where H_2S appears to have reduced carbonate precipitation compared to clean CO_2. S-enrichment throughout the sample, but less so between 250-2700 µm from the surface, where Ca is strongly depleted.	N.D.	
	Batch	12 mm ø, 30 mm long cylinder; supercritical CO_2 equilibrated with concentrated H_2SO_4, 80 °C, 10 MPa.	Full carbonation of free $Ca(OH)_2$ within 4 weeks. At 16 weeks, further chemical and microstructural alteration in outer 1000 µm, with some degradation in outer 150 µm. S content somewhat enriched throughout sample.	N.D.	
	Flow-through	38 mm ø, 80 mm long cylinder; wet supercritical CO_2, 80 °C, 13.8 MPa Pconf, 11.7 MPa Pup; 8.1 MPa Pdown.	Slowly decreasing, relatively constant flow over full duration. Increased hardness in carbonated matrix; depth to unaffected 20 mm at 180 days.	N.D.	
	Flow-through	38 mm ø, 80 mm long cylinder; CO_2-saturated water, 80 °C, 13.8 MPa Pconf, 6.2 MPa Pup; 1.0 MPa Pdown.	Strong drop in flow to near-zero after first days. Increased hardness in carbonated matrix; depth to unaffected 10 mm at 90 days; 15 mm at 180 days. Some mechanical degradation at injection surface; to 2 mm depth at 180 days.	N.D.	

3) Ability to withstand thermal shocks and cycles	Exposure method	Exposure conditions	Results (description)	Impact of compound exposure (if done)	References
	Unconfined, solid sealant cylinder	Sample length 70 mm, ø 30 mm. 120 °C sample shocked in 20 °C water bath, 8 cycles	CT-scanning shows crack formation due to thermal shock. UCS reduced by ~41 %	N.D.	
	Unconfined, solid sealant cylinder with channel drilled along axis	Sample length 70 mm, ø 30 mm, drilled hole diameter 4 mm. 120 °C sample flushed with 20 °C water, 8 cycles	CT-scanning shows crack formation due to thermal shock. UCS reduced by ~19 %	N.D.	
	Confined, solid sealant cylinder with channel drilled along axis	Sample length 70 mm, ø 30 mm, drilled hole diameter 4 mm. 120 °C sample confined at 1.5 or 10 MPa, flushed with 20 °C water, 8 cycles	No crack formation seen in CT-scans. ~5.6 % (at 1.5 MPa) to 6.4 % (at 10 MPa) increases in UCS after confinement and thermal shocking, due to confinement.	N.D.	
	Unconfined, sealant cylinder cast around stainless-steel tube	Sample length 70 mm, ø 30 mm, tube diameter 6 mm. 60 °C sample flushed with 5 °C water through tube, 16 cycles	No crack formation seen in CT-scans. Leakage rates increase by ~4.0x. Shear stress needed to separate tube from annular seal decreased by ~31 %.	N.D.	
	Confined, sealant cylinder cast around stainless-steel tube	Sample length 70 mm, ø 30 mm, tube diameter 6 mm. 60 °C sample confined at 1.5 MPa, flushed with 5 °C water through tube, 8 cycles	No crack formation seen in CT-scans. Minor decrease in leakage rate likely due to confinement. Shear stress needed to separate tube from annular seal increased by ~43 %.	N.D.	

Sealant for CCS - critical properties assessment

Property		**Relevance (Req; KII; FSM; CO2; TSC)**	**Reference sample**	**CO2-exposed**	**Exposed to thermal shocks/cycling**
Permeability		Req; KII; CO2			
	Water, constant flow		0.12-0.14 x 10-18 m2 (after curing) 0.10 x 10-18 m2 (180 days reference)	0.01 x 10-18 m2 (180 days CO_2-sat H_2O); 0.04 x 10-18 m2 (180 days sc. CO_2)	N.D.
Mechanical properties					
	Compressive strength	Req; KII; FMS; TSC	104-109 MPa	95 MPa (90 days CO_2-sat H_2O) to 92 MPa (180 days CO_2-sat H_2O)	99 MPa for unexposed reference sample. 54-61 MPa (after 8 unconfined quenches) to 80 MPa (after 8 unconfined flushes). 105-106 MPa (after 8 confined flushes at 1.5-10 MPa confining pressure).
	Tensile strength	Req; KII; FMS; TSC	7.6-8.9 MPa	7.1 MPa (90 days CO_2-sat H_2O) to 7.3 MPa (180 days CO_2-sat H_2O)	N.D.
	E-modulus	Req; KII; TSC	17.1-17.5 GPa	18.5 GPa (90 days CO_2-sat H_2O) to 17.8 GPa (180 days CO_2-sat H_2O)	N.D.
	Poisson ratio	Req; KII; FMS; TSC	0.22-0.25	0.26 (90 days CO_2-sat H_2O) to 0.24 (180 days CO_2-sat H_2O)	N.D.
	E/C-ratio	Req; KII; TSC	160-167	195 (90 days CO_2-sat H_2O) to 193 (180 days CO_2-sat H_2O)	N.D.
Volumetric behaviour					
	During curing	Req; FMS	N.D.	-	-
	Over time	Req; FMS	N.D.	N.D.	N.D.
Thermal properties					
	Thermal diffusivity	TSC	0.492 (mm2/s)	N.D.	N.D.
	Expansion coefficient	TSC	6.89 (10-6/K)	N.D.	N.D.
Mass/density					
		KII; CO2	1.90-1.94 g/ml (water-saturated, measured on ~1.2 cm diameter, 3 cm long cylinders) 1.48 g/ml (dried)	Exposed to wet sc. CO_2, 4-8-16 weeks: 2.06 g/ml. Exposed to CO_2-saturated water, 4-8 weeks: 2.07-2.08 g/ml; 16 weeks: 1.93 g/ml. Exposed to wet sc. CO_2 with H_2S, 4-16 weeks: 2.03-2.06 g/ml. Exposed to CO_2-saturated water with H_2S, 4 weeks: 2.07 g/ml; 16 weeks: 1.84 g/ml. Exposed to sc. CO_2 with H_2SO_4, 4-8-16 weeks: gradual decrease from 1.93 to 1.91 g/ml.	N.D.
Composition		Req; CO2			
	Chemical, Mineralogical, Microstructure		Homogeneous, dense CSH gel surrounding remaining grains of quartz and unreacted clinker.	Exposure to wet supercritical CO_2 caused carbonation with densification and increased Ca/Si-ratio at the exposure surface (batch) or carbonation front (flow-through). Little to no leaching or other chemical change. No (significant) degradation observed. Extrapolated carbonation depth after 1000 years 0.9 m. Exposure to CO_2-saturated water caused significant leaching (removal of Ca), with some degradation at the exposure surface, up to ~2mm after 16 weeks (batch) or ~2mm after 180 days (flow-through). Strong degradation in outer ~150 µm (16 weeks batch). Extrapolated carbonation depth after 1000 years 0.7 m.	CT-scanning (32 µm/voxel resolution) showed increase in voids from 0.4% to 2.6% (after 8 unconfined quenches) or 1.3% (after 8 unconfined flushes). No change observed after confined flushing.

Req: Required property (Norsok D010, GQMAW, and/or Nogepa45)
KII: Key integrity indicator (Norsok D010, and/or GQMAW)
FMS: Ability to Form and Maintain a Seal
CO2: Ability to resist exposure to CO2-containing fluids
TSC: Ability to withstand Thermal Shocks or Cycling