"Your Corrosion Inhibitor Partner"

Inhibition of Microbial Induced Corrosion of Concrete using Admixture and Surface Applied Corrosion Inhibitors

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Major Structural Damage
at Surfside Florida Condo Complex due to corrosion of reinforced concrete

June 24, 2021

Concrete structures
Deterioration

Objective of our research program

Corrosion is one of the primary concerns in the durability of structures.

Past 25 years research efforts have been made to find corrosion protection and inhibition processes to prolong the life of existing structures and minimize corrosion damages in new structures.

Research Significance

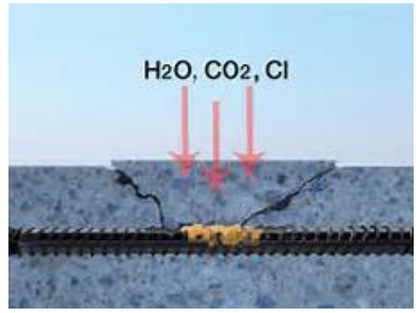
Can we use of admixtures, migrating corrosion inhibitors and surface applied corrosion inhibitors that are very effective in high chloride environment to inhibit MIC?

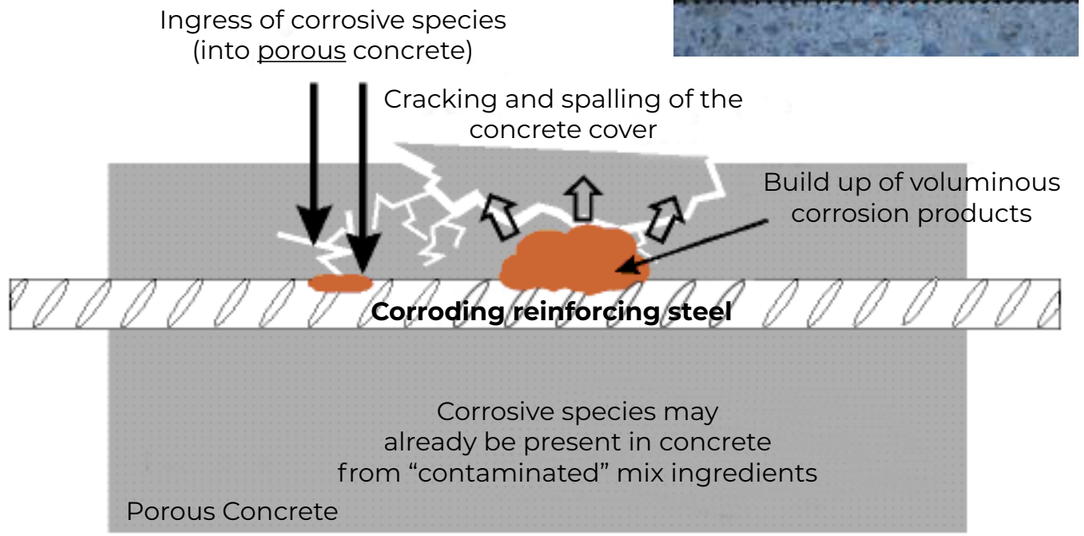
Concrete curing reactions

$2(3CaO.SiO_2) + 6H_2O = 3CaO.2SiO_2.3H_2O + 3Ca(OH)$ (Tricalcium silicate) (Tobermerite gel)	**C_3S hardens rapidly:** responsible for early strength.
$2(2CaO.SiO_2) + 4H_2O = 3CaO.2SiO_2.3H_2O + Ca(OH)_2$ (Dicalcium silicate) (Tobermerite gel)	**C_2S hardens slowly** and responsible for strength gain beyond one week
$3CaO.Al_2O_3 + 12H_2O + Ca(OH)_2 = 3CaO.Al_2O_3.Ca(OH)_2.12H_2O$ (Tricalcium aluminate) (Tetra-calcium aluminate hydrate)	

The water quality is critical not to take away any Ca ions from the binding gel otherwise lower concrete strength.

Corrosion Damages





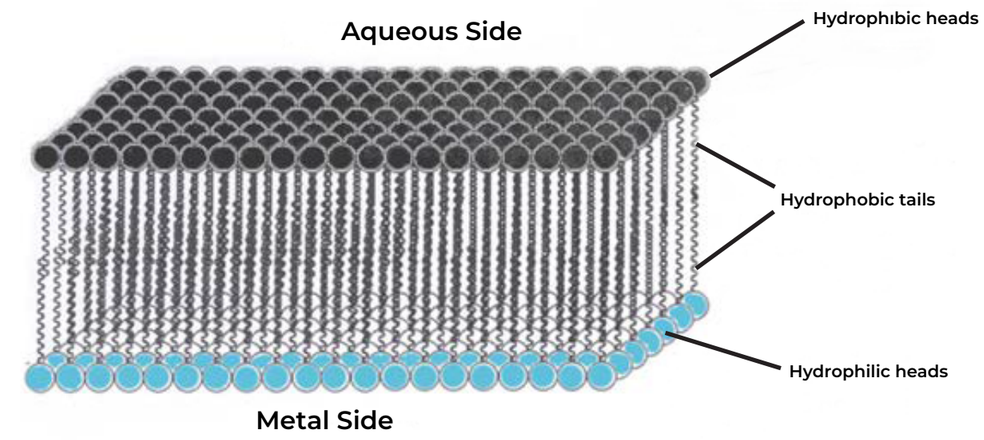
Protection of steel rebar in Concrete

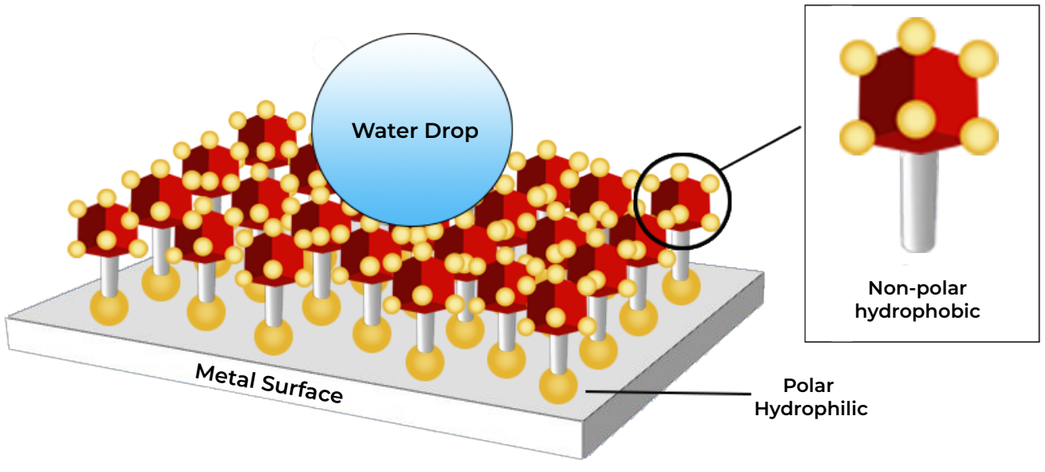
- Clean Concrete
- Cathodic Protection
- Admixtures and Corrosion Inhibitors
- Migrating Corrosion Inhibitors (MCI) or Surface Applied Corrosion Inhibitors(SACI)

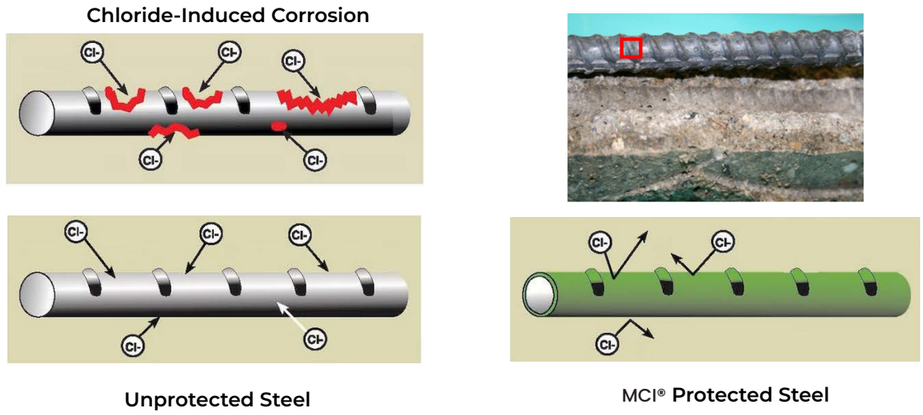
How Admixture/Inhibitor WORKS?

Migrating corrosion inhibitors (MCIs) are developed to protect steel rebar from corrosion in concrete. They were designed to be incorporated as an admixture during concrete batching or used for surface impregnation of existing concrete structures. **Under Chlorine Attack and Carbonatation Attack.**

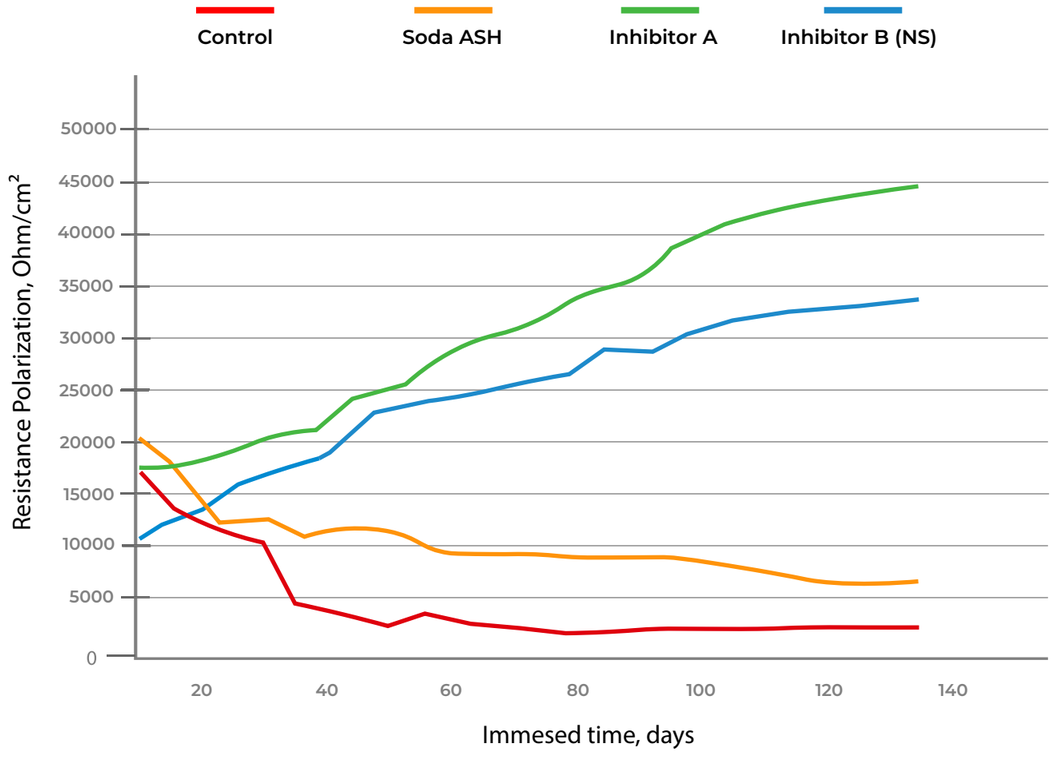
MCI use compounds that work by forming a monomolecular film between the metal and the water. In Film Forming Inhibitors, one end of the molecule is hydrophilic and the other hydrophobic.





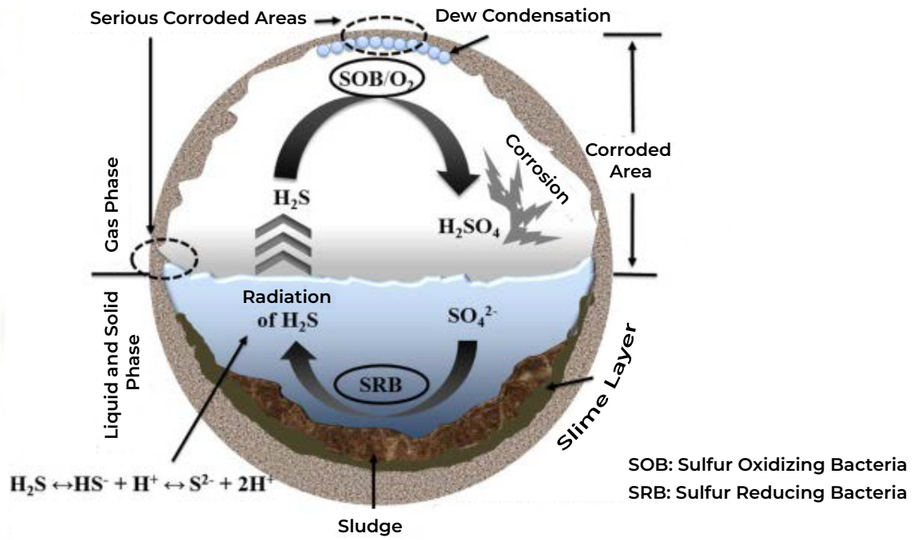


Polarization Resistance (Rp) Versus Time; Comparison of Inhibitor treated concrete with Control concrete samples.

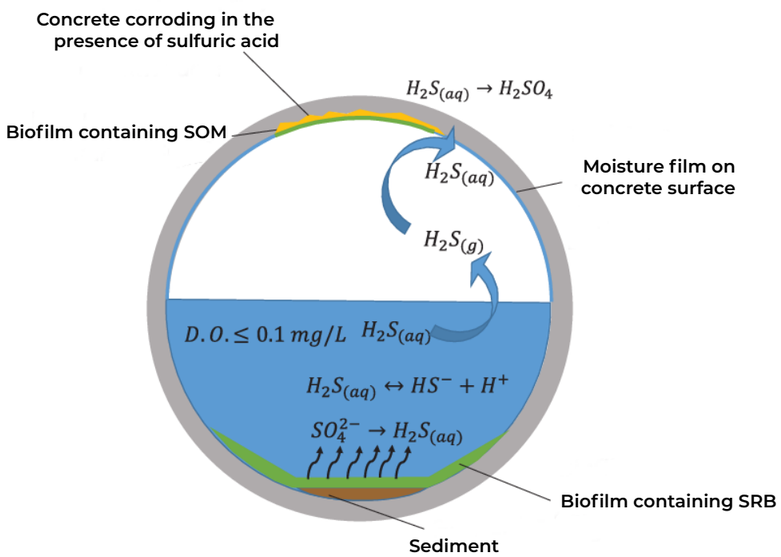


Current Research Project

Microbially-induced corrosion of Concrete Structures



SOB: Sulfur Oxidizing Bacteria
SRB: Sulfur Reducing Bacteria



MIC effects: Production of hydrogen sulfide and concrete-destroying sulfuric acid, SRB (Sulfate Reducing Bacteria)

$$SO_4^{2-} + 2\,H^+ + 4\,H_2 \rightarrow H_2S\uparrow\ (H^+/HS^-) + 4\,H_2O$$

Formation of gypsum is an expansive reactions (white powdery deposits) , lower concrete strength, overstressing, cracking and spalling, mainly due to SOB reactions

Within the slime:	1	$SO_4^{2-} \rightarrow S^{2-} + 4\,O$	(First Stage)
Withiin the liquid:	2	$2S^{2-} + 3H^+ \rightarrow HS^- + H_2S$	(Second Stage)
	3	$H_2S + 2O_2 \rightarrow H_2SO_4$	(Stage three)
	4	$H_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4 + 2H_2O$	
	5	$H_2SO_4 + CaO.SiO_2.2H_2O \rightarrow CaSO_4 + Si(OH)_4 + H_2O$	
	6	$3CaSO_4 + 3CaO.Al_2O_3.6H_2O + 26H_2O \rightarrow 3CaO.Al_2O_3.3CaSO_4.32H_2O$	

Sewer system Rehabilitation cost ~ $4 billion for LA County

Worst-Case Scenario for Sulfate attacks in sewer systems

The conditions that lead to excessively high sulfide/sulfate production are listed below :

Warm annual sewage temperatures (Average > 70 oF)

Long force mains and/or flat sewers with debris

High BOD, (biochemical oxygen demand) wastewater (> 250 mg/L)

High sulfate wastewater concentrations (> 50 mg/L)

Deterioration of reinforced concrete in sewer environments

Billions of dollars are being spent worldwide on the repair and maintenance of sewer systems and wastewater treatment plants. Microbially-induced corrosion causes damage via micro-organisms. Deterioration is caused by acid excretion which etches the surface of concrete, penetrating the mortar surface, especially in sewer systems. The mechanisms of concrete and reinforcement deterioration in sewer environments and microbially-induced corrosion (MIC) is very complex.

The role of hydrogen sulfide and micro-organisms(SRB and SOB) in the deterioration of concrete in sewer environments and of repair and rehabilitation measures, including the following preventative measures:

(a) Modification of the materials used in construction of sewer pipes;

(b) Coatings;

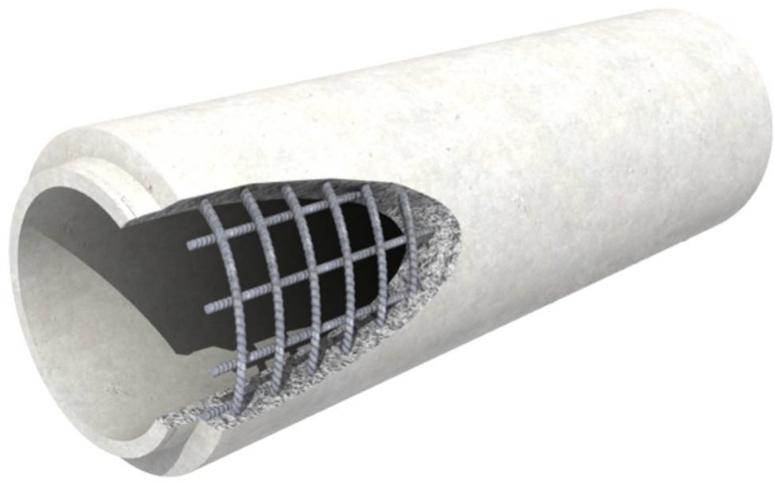
(c) Sewer treatments.

How to protect concrete against MIC?

- Chlorine compounds such as bleach, sodium hypochlorite, calcium hypochlorite and ferric chloride and calcium nitrate salt are examples of chemicals that are effective in controlling H2S in wastewater collection systems and used by municipalities to control hydrogen sulfide-related odors and corrosion on a daily basis. However, chloride rich compounds can promote corrosion of reinforcement rebars.

- Migrating corrosion inhibitors and Surface applied Corrosion inhibitors appear to be a better alternative than nitrate and chloride rich compounds and more environmentally friendly chemical.

- In this research project, Commercially available Inhibitors and Admixture were evaluated.



EXPERIMENTAL PROCEDURE

- A concrete mixture (4 Aggregate: 2 Sand: 1 Portland Cement type II with moderate sulphate resistant hydraulic cement) was used to make the concrete (0.5 W/C ratio). The premixed concrete was used to cast 5x10 cm (2 inch x 4 inch) cylinders. Curing and compression tests were done per ASTM C31 and ASTM C39 standards, the compressive strength was on average 5,400 psi after four weeks of curing.

- Four types of samples were prepared: 1) samples surface coated with migrating corrosion inhibitor; 2) samples made with admixtures; 3) samples made with 5% admixtures and coated with surface applied migrating corrosion inhibitors; and 4) control samples (no admixtures, no corrosion inhibitor coatings).

- Three layers of the surface applied migrating corrosion inhibitor (SACI-A and SACI-B) were applied to the cylindrical samples after curing and prior to the immersion corrosion tests.

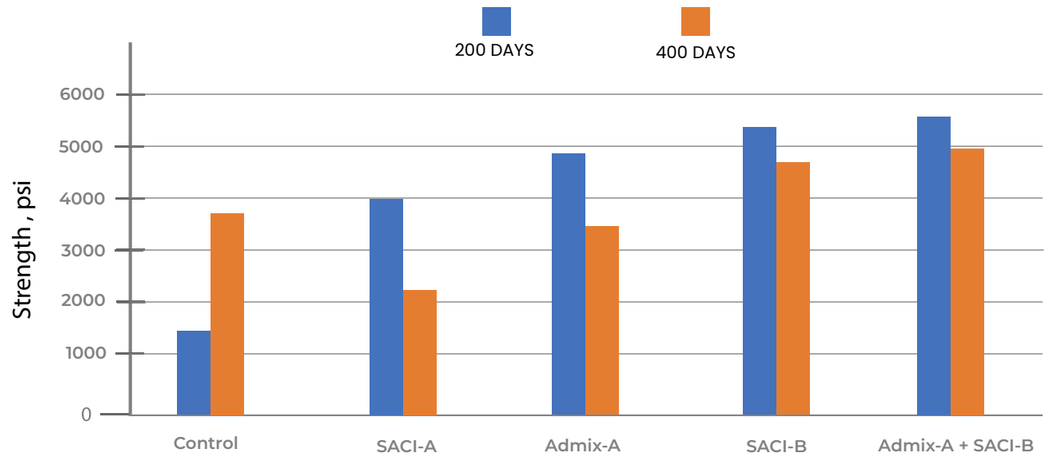
400 DAYS

Sulfate attack layer thickness after 400 days exposure to highly acidic solution shows that Admix-A+SACI-B have the lowest sulfate reactions

750 DAYS

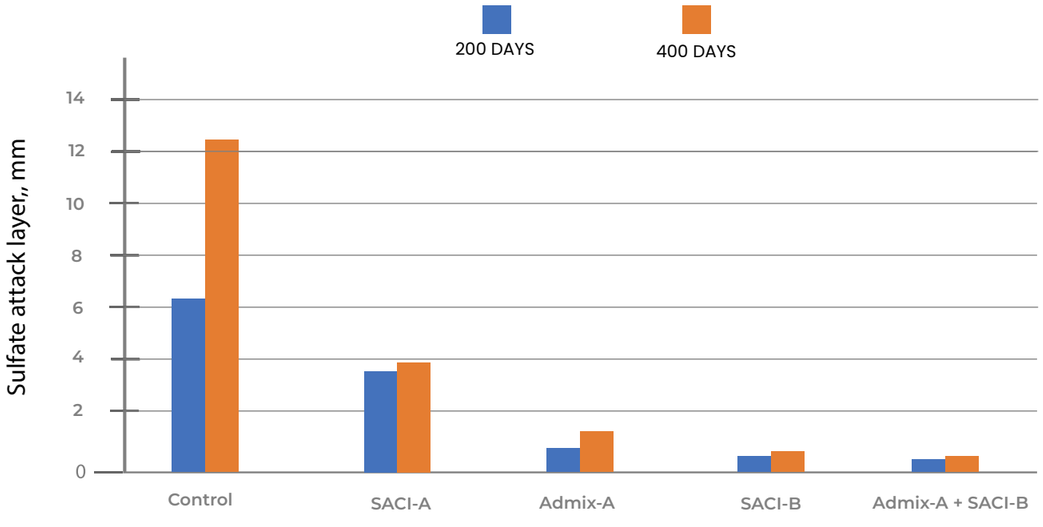
Sulfate attack layer thickness after 750 days exposure to highly acidic solution shows that Admix-A+SACI-B and SACI-B still maintained their strength

Concrete strength loss due to MIC and sulfate attacks, Control strength = 5,400 psi



Comparison of compressive behavior for concrete samples after 400 days of immersion tests. The combination of Admix-A +SACI-B had the best performance in highly acidic solution.

Concrete Sulfate Attack During Immersion Tests



Comparison of sulfate attacks for 200 and 400 days exposure to highly acidic solution. SACI-B and Admix-A have the lowest sulfate attack reactions.

THE PELJESAC BRIDGE

Croatia's Adriatic coastline. July 2022

The USD $500M, 2.4-kilometre beam and cable-stayed structure, protected by Surface Applied Corrosion inhibitor and Migrating Corrosion Inhibitor admixture.

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DEYAP
ABOUT US

Deniz Yapi Sanayi ve Tic. A.S. in 1992 to carry out corrosion prevention and surface cleaning works, DEYAP is the Turkish distributor and licensor of Cortec Corporation and Mykal, the leading companies in the world.

Our company, which realized the supply (1992), production and project design (1995) of VpCI for the first time in Turkiye, provides the production of VpCI film and paper products specific to the demands of its customers in its 2500 m² production area located in Kocaeli Dilovası and the supply of anti-corrosion chemicals, dehumidifiers, surface cleaning chemicals and auxiliary packaging materials. All of its production is carried out under ISO - 9001:2015 quality system.

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