Experimental study on strength and ductility of underwater fillet welds in repairing offshore steel structures

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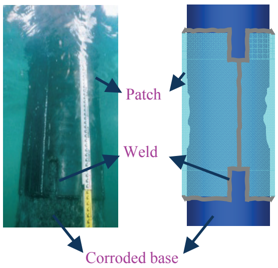
Introduction

Underwater wet welding is commonly used to repair corroded offshore steel structures. The study presents an investigation on strength and ductility of underwater fillet-welded joints. Fourteen different types of weld assemblies are tested to failure, and weld hardness and microstructures are investigated. Differences between underwater and in-air fillet welds are examined in terms of strength, ductility, and failure modes. Weldability of base steels in the underwater wet environment is also evaluated.

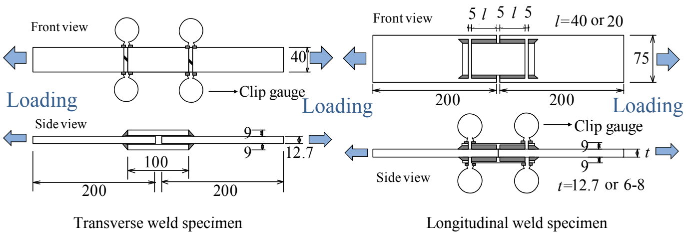
Corroded offshore steel structure

Underwater welder



Repaired by welding patch plates

Experiment program



Specimen configuration

Material properties of steels

Material	Mechanical properties: Young's modulus, E(GPa)	Poisson's ratio, ν	Yield stress, σ_y (MPa)	Ultimate stress, σ_u (MPa)	Elongation, $\Delta\ell$ (%)	Chemical compositions (wt-%): C	Si	Mn	P	S
SY295	213	0.29	273	497	41	0.30	0.06	0.72	0.016	0.020
CSY295	212	0.29	349	531	34	0.27	0.02	0.96	0.013	0.019
SYW295	213	0.28	392	513	42	0.10	0.23	1.41	0.020	0.005
STK400	203	0.28	362	394	41	0.12	0.10	0.56	0.013	0.006
Electrode	-	-	410	460	30	0.10	0.10	0.43	0.015	0.007

T Y A

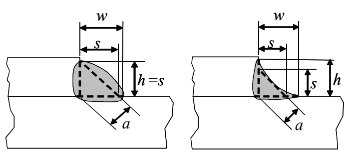
Weld orientation
T: transverse
L: longitudinal

Base steel
Y: SY295 W: SYW295
S: STK400 C: Corroded SY295

Welding environment
A: in air
W: underwater

CSY295: Corroded SY295. t: 6-8 mm, l: 20 mm.

Specimen designation



w, h =weld leg length, s =weld size, a=weld throat

Definition of weld size

Ductility factor

$$\Delta l = \frac{\Delta_f}{s}$$

Δ_f: fracture deformation of the first fractured weld
s: Weld size

Ductility factor

$$\sigma_w = \frac{P_{max}}{n a l}$$

σ_w: Weld strength
P_{max}: Maximum load of the specimen
n: Number of welds in the specimen
a: Average throat thickness
l: Average weld length

Weld strength

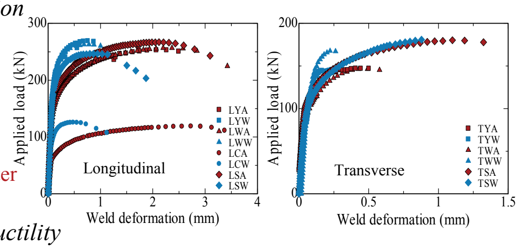
Results

- *Load-deformation*

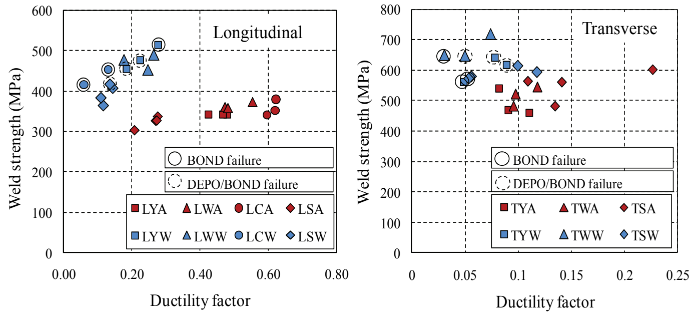
Ultimate load ↑

Fracture deformation ↓

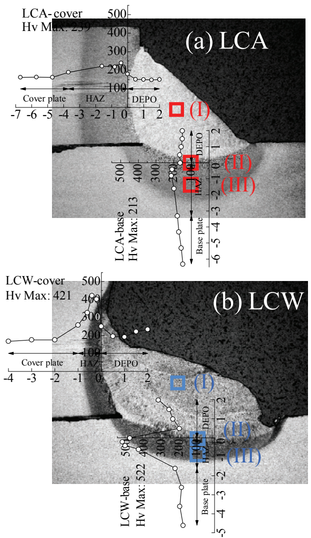
Effect of underwater environment

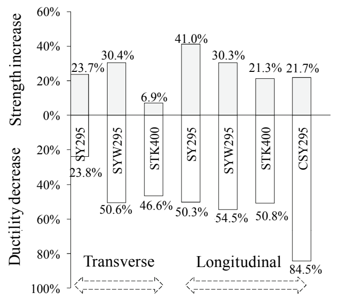


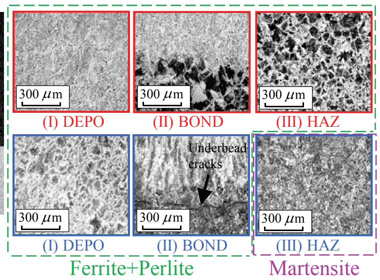
- *Strength and ductility*



- *Hardness and microstructure*







Conclusions

(1) Underwater fillet welds have larger strength but smaller ductility when compared with in-air welds. Strength increase ranges from 6.9% to 41.0%, while ductility decrease is nearly the same at 50%.

(2) Underwater fillet welds on corroded SY295 steels show a drastic ductility decrease of 84.5%, resulting from mechanical mismatching and underbead cracks.

(3) The weldability of SY295 steel is undesirable in underwater welding due to its high carbon equivalent.

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