Corrosion Effect on Light Steel Building Elements

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***Abstract*— In addition to the high tensile and compressive strength of the steel, its very good earthquake resistance has recently increased the use of light steel structures. However, corrosion and fire effect are the most important disadvantages of steel. These two effects cause the strength of steel to drop significantly.**

This article presents the results of an experimental study to examine the tensile behavior of mild steel element exposed to corrosion. For this purpose, tensile tests were carried out on corroded steel elements to examine the effect of corrosion damage on tensile behavior. In this study, 0.80 mm and 1.00 mm thick light steel plates are used. The specimens produced were subjected to an axial tensile test after being corroded by 10% and 20% by mass. The specimens subjected to axial tensile test were evaluated in terms of ductility and strength.

As a result of the evaluations made; It was observed that there was a decrease of 18.9% in yield strength, 18.3% in tensile strength and 64.2% in ultimate forcing in samples that were eroded by 10% by mass. Similarly, 33.4% decrease in yield strength, 35% decrease in tensile strength and 80.1% decrease in ultimate stress were observed in samples eroded with 20% mass. According to the results, it was concluded that corrosion in light steel elements significantly reduced both the strength and ductility of the elements.

Keywords*— *light steel structure, corrosion, axial tensile strength.

I. INTRODUCTION

The use of light steel structures has been increasing rapidly in recent years. The most important advantages of light steel structures are fast construction, high tensile and compressive strength as well as economic solutions that are resistant to earthquakes. Compared with the hot-rolled steel, the yield strength of the cold-formed thin-walled steel was increased by more than 50% due to the cold-formed effect, which can save the steel approximately 10%–15% [1-4]. Previous studies of the cold-formed steel were focused mainly on the calculation method and seismic performance of the uncorroded cold-formed thin-walled steel [5-7] and the effect of high temperature on the mechanical properties of steel [8-10]. However, avoiding corrosion by means of protective measures and maintenance systems was usually difficult for many steel structures, resulting in serious corrosion problems [11,12].

A lot of work has been conducted to study the corrosion effects on steel material, components and joins mechanical behaviors. At the corroded material level, a series of axial tensile tests has been performed and many empirical models and evaluation methods have been established to predict its residual mechanical properties [13-23]. Besides, its fatigue and hysteretic performance were also researched [24-25]. As for the corroded steel components and joints, the residual performance of corrosion degraded steel beams and beam-column connection was investigated [26-28]. However, it is a pity that few researchers have made a special study on the fracture properties of corroded steel, although it is of great importance.

Steel structure exposed to aggressive environment for a long time show serious corrosion problems due to the lack of effective protective measures [29-31]. Corrosion is a most predominate damage in existing steel structure [32-33], which results in thickness reduction, uneven surface, strength degradation and brittle failure.

The types of corrosion mechanisms mainly include general and pitting corrosion. The general corrosion often causes a large number of metal losses and greatly reduces the bearing capacity of components. The pitting corrosion usually takes place in a specific position, and the corrosion rate of each part is obviously different. The pitting corrosion causes less metal loss, but more serious damage. The stress concentration caused by the pitting corrosion leads to the decrease ofmechanical properties. In the past, the corrosion degree was generally evaluated by simply measuring weight (thickness), and the mass loss rate (thickness loss rate) was used to characterize the corrosion degree [34-35].

In this study, the effect of corrosion on light steel structural members was investigated experimentally. For this purpose, corrosion formation was achieved with a loss of 10% and 20% by mass in the laboratory environment on light steel plates of 0.8 and 1.0 mm thickness. The samples that were not corroded were subjected to v axial tensile test and the results obtained were interpreted in terms of ductility and strength.

II. MATERIAL METHOD

This study was conducted to investigate the corrosion effect on light steel structural members. Light steel plate samples of 0.8 and 1.0 mm thickness have been corroded at different rates in the laboratory environment. The mechanical properties of the corroded test specimens were obtained by subjecting them to the axial tensile test.

A. *Cold-formed light steel structures*

Light steel profiles are produced by bending and shaping steel plates by means of a press. The names of the profiles used in light steel systems are based on their style. The profiles used in light steel structure production are shown in Fig. 1. The profile tables prepared by the manufacturers are used in light steel structure design. In these tables, according to the cutting lengths of the profiles, moment and carrying capacities, etc. information is found [36].

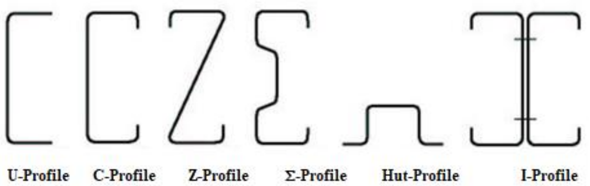

Fig. 1. Cold-formed steel profiles used in light steel structures [36]

Steel plates can be used in light steel frames to increase the connection surface. The thickness of these plates cannot be less than the thickness of the profiles used. Fig. 2 shows the elements used in light steel structure production; trapezoidal sheets are seen in A, various plates and strips are seen in B and fasteners in C.

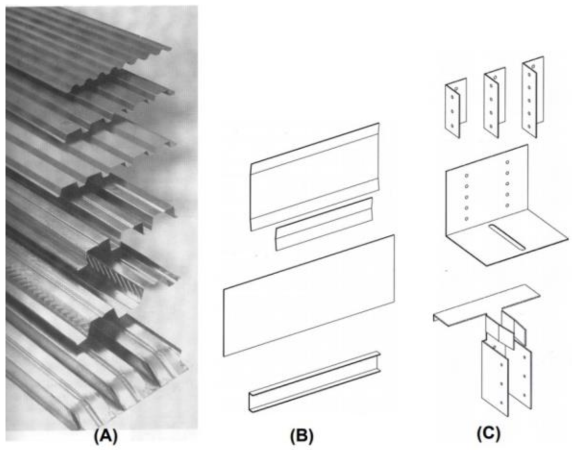

Fig. 2. Plates, trapezoidal sheets and strips used in light steel production

B. *Corrosion effect on steel structures*

One of the most important problems for light steel structures is corrosion. Although coating and insulation are applied to light steel elements, it cannot be a complete solution to corrosion. The corrosion that occurs directly affects the strength of the building. In addition, as a result of corrosion formation, decreases occur in light steel sections. This situation adversely affects the buildings both economically, safety and aesthetically. Corrosion; It is defined as the corrosion of metals as a result of chemical or physical dissolution due to environmental effects. Corrosion is observed wherever there is water, moisture and oxygen. Corrosion primarily causes reductions in the cross-section and thus loss of strength, and consequently, problems arise in terms of safety of the structures.

III. EXPERIMENTAL STUDY

An experimental study was carried out to investigate the effect of corrosion on light steel building elements. The light steel construction elements produced for this purpose were separated into three groups and the reference samples were not corroded, the other two groups were corroded by 10% and 20% by mass. The test specimens that suffered sufficient mass loss were subjected to the axial tensile test. The strength and ductility properties of the tested samples were obtained. Light steel samples of 0.8 and 1.0 mm thickness were used in this study. [37].

A. *Properties of the specimens*

In this study, test specimens were produced using 0.80 mm and 1.00 mm thick light steel plates produced from S235 (F_y=235 Mpa) steel in Fig. 3 [37].

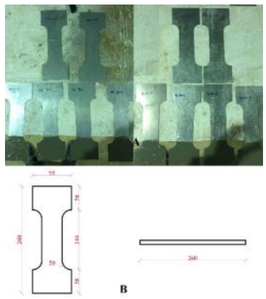

Fig. 3. Properties of test specimens

The parameters discussed in this study are considered as follows.
a. Plate thicknesses: 0.8 mm and 1 mm thick plates
b. Corrosion rate: 10% and 20% loss by mass

For this purpose; Test specimens of 0.8 mm and 1 mm thickness were produced. The produced test samples were divided into 3 groups, 1 group of samples were not corroded, the other two groups were corroded by 10% and 20% by mass. Two samples were produced and tested in each group. The produced test samples are given as samples with combination elements in the following Table 1 [37].

TABLE 1. Test specimens

Specimen	Corrosion rate		
	0% (reference)	10%	20%
0.8 mm thick plate	0.8LR-1 0.8LR-2	0.8L10-1 0.8L10-2	0.8L20 -1 0.8L20 -2
1.0 mm thick plate	1LR-1 1LR-2	1L10-1 1L10-2	1L20 -1 1L20 -2

B. Corrosion process

Solution pool, salt, stainless steel rods, DC power supplies and electric current transfer elements were used to corrode the test elements. In order to corrode the light steel construction elements, salt water solution was put into the glass pools shown in Fig. 4 and then the test samples were placed inside the pools. By using the DC power supply and fasteners, the samples were quickly corroded [37].

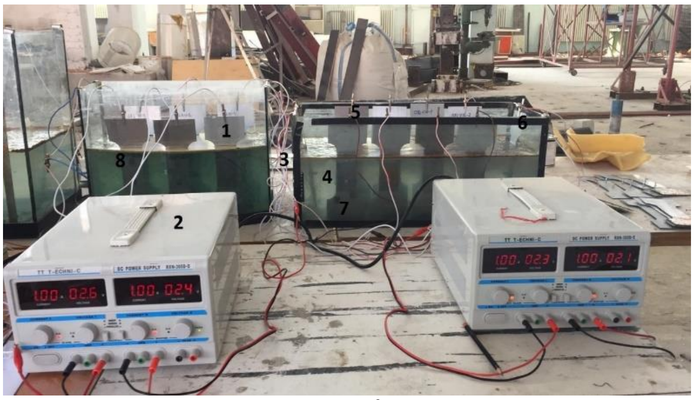

Fig. 4. Corrosion process of test specimens

IV. EXPERIMENTAL RESULTS AND DISCUSSION

The test specimens produced within the scope of the experimental study and corroded desired were subjected to the axial tensile test (Fig. 5).

Fig. 5. Tensile test setup and testing procedures

Test samples prepared in accordance with the parameters determined within the scope of this study; It is divided into 3 groups as non-corrosive, 10% corrosive and 20% corrosive. For each group, 2 samples were subjected to axial tensile tests and the values obtained were averaged. Evaluation of the experimental results is made below [37].

A. 0.8 mm thick non-join speciments

The σ-ε graphs of 0.8 mm thick non-join specimens are given in Fig. 6. The results obtained in the axial tensile test carried out are presented in Table 2-3.

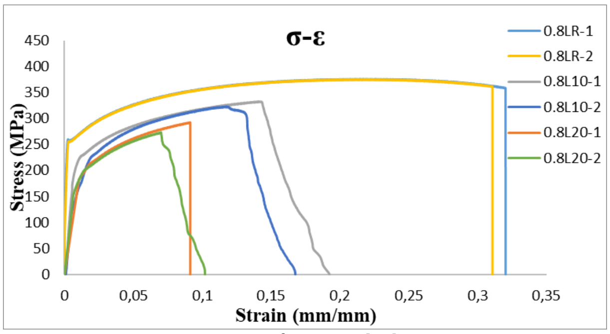

Fig. 6. Stress-strain curves of 0.8 mm thick non-join specimens

TABLE 2. Yield and tensile strength of 0.8 mm thick specimens

Specimen	Yield strenght (MPa)	Average yield strenght (MPa)	Tensile strenght (MPa)	Average tensile strenght (MPa)	Ultimate tensile strenght (MPa)
0.8LR-1	257.2	256.2	371.2	371.4	357.9
0.8LR-2	255.2		371.5		361.1
0.8L10-1	227.2	204.0	322.4	321.9	261.3
0.8L10-2	180.8		321.4		207.9
0.8L20-1	192.5	192.9	292.3	282.4	292.3
0.8L20-2	193.3		272.5		222.3

TABLE 3. Yield and ultimate strain of 0.8 mm thick specimens

Specimen	Yield strain (mm/mm)	Average yield strain (mm/mm)	Ultimate strain (mm/mm)	Average ultimate strain (mm/mm)
0.8LR-1	0.00219	0.00217	0.32035	0.31561
0.8LR-2	0.00214		0.31086	
0.8L10-1	0.0118	0.01225	0.15060	0.14412
0.8L10-2	0.01269		0.13763	
0.8L20-1	0.01277	0.01267	0.09131	0.08427
0.8L20-2	0.01257		0.07723	

When the obtained results are compared with reference samples;

- Average yield strength; 20.4% lower in 10% corroded specimens and 24.7% lower in 20% corroded specimens than reference specimens.
- Average tensile strength; 13.3% lower in 10% corroded specimens and 23.9% lower in 20% corroded specimens than reference specimens.
- Average yield strain; 465% higher in 10% corroded specimens and 484% higher in 20% corroded specimens compared to reference specimens.
- Average ultimate strain; 54.3% lower in 10% corroded specimens and 73.3% lower in 20% corroded specimens compared to the reference specimens.

B. 1.0 mm thick non-join speciments

The σ-ε graphs of 1.0 mm thick non-join specimens are given in Fig. 7. The results obtained in the axial tensile test carried out are presented in Table 4-5.

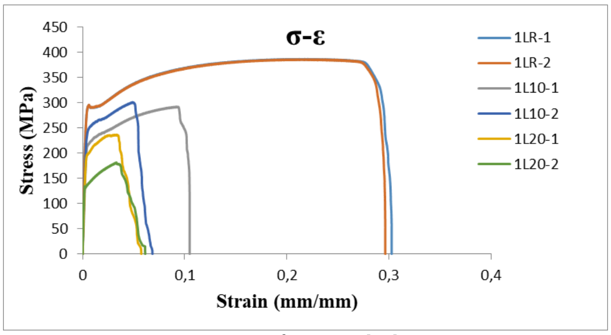

Fig. 7. Stress-strain curves of 1.0 mm thick non-join specimens

TABLE 4. Yield and tensile strength of 1.0 mm thick specimens

Specimen	Yield strain (mm/mm)	Average yield strain (mm/mm)	Ultimate strain (mm/mm)	Average ultimate strain (mm/mm)
1LR-1	0.00445	0.00444	0.29123	0.28954
1LR-2	0.00443		0.28785	
1L10-1	0.00640	0.00626	0.09843	0.07520
1L10-2	0.00611		0.05179	
1L20-1	0.00701	0.00640	0.03553	0.03800
1L20-2	0.00579		0.04046	

TABLE 5. Yield and ultimate strain of 1.0 mm thick specimens

Specimen	Yield strenght (MPa)	Average yield strenght (MPa)	Tensile strenght (MPa)	Average tensile strenght (MPa)	Ultimate tensile strenght (MPa)
1LR-1	285.6	285.3	385.9	385.7	328.4
1LR-2	285.0		385.4		327.8
1L10-1	220.6	235.7	291.8	296.2	253.7
1L10-2	250.7		300.6		288.3
1L20-1	198.7	165.5	235.1	208.0	228.5
1L20-2	132.2		180.8		152.0

When the obtained results are compared with reference samples;

- Average yield strength; 17.4% lower in 10% corroded specimens and 42.0% lower in 20% corroded specimens than reference specimens.
- Average tensile strength; 23.2% lower in 10% corroded specimens and 46.1% lower in 20% corroded specimens than reference specimens.
- Average yield strain; 41% higher in 10% corroded specimens and 44.1% higher in 20% corroded specimens compared to reference specimens.
- Average ultimate strain; 74.0% lower in 10% corroded specimens and 86.9% lower in 20% corroded specimens compared to the reference specimens.

Within the scope of this study, for the test samples subjected to the axial tensile test, the comparison of the results obtained for the samples corroded with 10% and 20% by mass for all parameters is presented in Table 6. The average values of 0.8 mm and 1 mm thick plates were taken for comparison. The + placed in front of the percentages indicates an increase and - indicates a loss.

TABLE 6. Comparison of specimens with 10% and 20% corrosion by mass compared to reference specimens

Specimen	Corrosion rate	Average yield strenght	Average tensile strenght	Average yield strain	Average ultimate strain
Non-joint specimens	**%10**	-%18.9	-%18.3	+%253.0	-%64.2
	%20	-%33.4	-%35.0	+%264.1	-%80.1

V. CONCLUSION

Within the scope of this study, the results obtained as a result of the tensile test of light steel, which were corroded by 10% and 20% by mass, were compared. As a result of these comparisons, the following results have been reached.

- As the amount of corrosion on the plates increases, both material strength and ductility decrease significantly.
- According to reference samples; the yield strength was 18.9%, the tensile strength was 18.3% and ultimate strain was 64.2% less in 10% corroded plate specimens.
- According to reference samples; the yield strength was 33.4%, the tensile strength was 35% and ultimate strain was 80.1% less in 20% corroded plate specimens.
- Due to the intense pitting corrosion that occurred, some samples broke brittle without carrying a significant load.

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