# WEATHERING STEEL AND COMPOSITE STRUCTURES : BANGLADESH PERSPECTIVE

**A.K.M. Ruhul Amin*[1], Md. Khasro Miah[2] and Md. Nazrul Islam[3]**

[1] Ph.D Student, Department of Civil Engineering, DUET, Bangladesh,e-mail: ruhul69@yahoo.com
[2] Professor, Department of Civil Engineering, DUET, Bangladesh,e-mail: mkhasro@duet.ac.bd
[3] Professor, Department of Civil Engineering, DUET, Bangladesh, e-mail: nazrul2100@duet.ac.bd

## ABSTRACT

*Weathering steel is a high strength low alloy steel with corrosion resist property under normal atmospheric condition. This type of steel does not require painting or any protective coating for rust proofing as any mild steel require rust proof coating. Generally Structural steels which are exposing in weather like bridge, railing, and fencing are galvanized steel or stainless steel. Most of our baily bridges are hot rolled galvanized mild steel. Using protective coating is requiring maintenance and recoating after a sudden period as per weather condition. The painting process is depend on the weather condition like normal weather the paint is enamel type paint and for the saline weather it require epoxy type paint with thick coat, which is very costly. Weather steel rusting once in its life time and that rust prevent further rusting in the expose surface. This paper describes the technic of rusting process and the protection of further rusting of the weather steel alloy. It is also describe the cold rolled galvanize steel and composite structure and steel concrete joints. The fabrication process of structural steel is developing day by day and the use of structural steel is increasing in Bangladesh. Mostly industrial sheds, railway platform, power plants/Houses are made with mild steel of ASTM A36 category. Now the structural steel of ASTM A572 low carbon steel alloy with 40-50 grade strength is use in building system. Very recently weather steel of ASTM A588 of 50 grade steel alloy plate box girder is being used in Rampura ULOOP flyover with composite deck system, the first weather steel bridge made in Bangladesh.*

**Keywords**: *Weather, corrosion, steel properties, protective coat, composite, cold rolled, hot rolled*

## 1. INTRODUCTION

Weathering steels (WS), is a low alloy steels with a carbon content of less than 0.2 wt. % to which mainly Cu, Cr, Ni, P, Si and Mn are added as alloying elements to a total of no more than 3-5 wt. % (Murata, 2000). In 1930s united states steel developed weather steel to resist corrosion. The trade name of the steel was "COR-TEN" which was first used in building construction in 1964. Since then weather steel spread worldwide and in Europe it is use as structural steel with improve atmospheric corrosion resistance. In 1967 UK first use weather steel in a footbridge and from that the materials is use in many bridge around UK in the following 30 years. The use of weathering steel on bridges has increased significantly since 2001. It is now the materials of choice for a wide range of bridge decks. The American Society for Testing and Materials (ASTM) has standardized different alloy steel compositions for WS, from an initial 1.5% total weight of alloying elements added in the first standardized WS A-242 (ASTM A-242/A-242M-04, 2007) to 5% in the last standardized WS A709-HPS 100W (ASTM A709/A709M, 2009). Table 1 sets out the chemical composition of two commonly used WS (ASTM A-242/A-242M-04, 2007; ASTM A588/A588M, 2005). Nippon Steel was successfully clarify the mechanism of protective rust formation for the purpose of improving the seaside corrosion resistance of steel. Based on this acquired knowledge, Nippon Steel developed "NAW-TEN", a nickel-added weathering high-tensile steel, another version of COR-TEN.

ASTM A588 grade A is the most common "COR-TEN" weathering steel materials. This materials group was developed to eliminate the need of painting and form a stable rusty aesthetic view in its exposed surface for several years. Bangladesh weather condition changes around the year and it is fond dry, cold, hot, rainy and monsoon type. For the higher humidity the structural steel surface of Bangladesh require painting for rust proofing. There are some saline areas where atmosphere contain sea salts and require special epoxy painting or galvanized steel to protection of rust. In those weather condition of Bangladesh, weathering steel can use widely to protect corrosion and sustain several years without maintenance.

## 2. PROPERTIES OF WEATHER STEEL(WS)

Weathering steel forms an adherent protective rust "patina" in its surface and that protect the further corrosion on the surface. The property of the steel is creating a thin oxide film with the reaction of atmospheric condition. "Weathering" refers to the chemical composition of these steels, allowing them to exhibit increased resistance to atmospheric corrosion compared to other steels. This is because the steel forms a protective layer on its surface under the influence of the weather. The corrosion-retarding effect of the protective layer is produced by the particular distribution and concentration of alloying elements in it. The layer protecting the surface develops and regenerates continuously when subjected to the influence of the weather. In other words, the steel is allowed to rust in order to form the 'protective' coating. The addition of phosphorous, copper, chromium or nickel is deemed useful for corrosion protection in general atmospheric environments. Early versions of United State Steel(USS) Cor-Ten steel were based on Fe-Cu-Cr-P system, to which Ni was later added in order to improve corrosion resistance in marine environments. USS Cor-Ten steels presents two specifications, A and B, whose main difference lay in the amount of phosphorus present in their compositions. NAW-TEN is another version of Cor-Ten in which nickel is added. Another improved version of WS for bridge building is High Performance Steel (HPS).

Table 1: Chemical compositions ( weight %) of commonly used Weathering Steel

| Weathering Steel | C | Si | Mn | P | S | Cu | Cr | Ni | V |
|---|---|---|---|---|---|---|---|---|---|
| ASTM A-242 (CORTEN A) | ≤ .15 | | ≤1.0 | ≤0.15 | <0.05 | ≥0.20 | | | |
| Typical concentrations | | | | ≤0.15 | | 0.25-0.40 | 0.50-0.80 | 0.50-0.65 | |
| ASTM A-588 Gr.A (CORTEN B) | ≤ 0.19 | 0.30-0.65 | 0.80-1.25 | ≤0.04 | <0.05 | 0.25-0.40 | 0.40-0.65 | ≤0.40 | 0.02-0.10 |
| Typical concentrations | | | | ≤0.04 | | 0.30-0.40 | 0.60-1.00 | 0.02-0.03 | |

## 3. HOW WEATHERING STEEL WORKS

In the presence of moisture and air, all low alloy steels have a tendency to rust, the rate of which depends on the access of oxygen, moisture and atmospheric contaminants to the metal surface. As the process progresses, the rust layer forms a barrier to the ingress of oxygen, moisture and contaminants, and the rate of rusting slows down. The rust layers formed on most ordinary structural steels are porous and detach from the metal surface after a certain time, and the corrosion cycle commences again. Hence, the rusting rate progresses as a series of incremental curves approximating to a straight line, the slope of which depends on the aggressiveness of the environment. With weathering steel, the rusting process is initiated in the same way, but the specific alloying elements in the steel produce a stable rust layer that adheres to the base metal, and is much less porous. This rust 'patina' develops under conditions of alternate wetting and drying to produce a protective barrier that impedes further access of oxygen, moisture, and pollutants. The result is a much lower corrosion rate than would be found on ordinary structural steel. The corrosion loss between weathering steel and ordinary steel as shown in Figure 1.

### 3.1 Corrosion Mechanism of Weathering Steel

Environmental conditions are the key factors to influencing the formation of oxide film on the WS. The appearance, texture and maturity of this coating depend on three interrelated factors: time, degree of exposure and atmospheric environment. With time, the oxide coating changes from a rusty red-orange to dark purple-brown patina. The weathering process extends over a period of time. As has been mentioned, the enhanced corrosion resistance of WS is due to the formation of a dense and well-adhering corrosion product layer.

Experiments carried out in 1969 by Schmitt and Gallagher with low alloy steel (Cor-Ten A) indicated that the texture of the oxide layer was dependent upon the washing action of rainwater and the drying action of the sun (Schmitt and Gallagher, 1969).

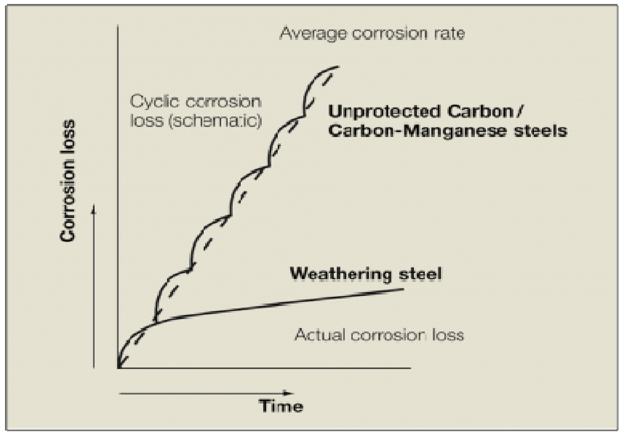


Figure 1: Schematic comparison between the corrosion loss of weathering steel and ordinary structural steel

Surfaces sheltered from the sun and rain tended to form a loose and non-compact oxide while surfaces openly exposed to the sun and rain produced strongly adherent layers. On north-facing surfaces the protective layer developed somewhat more slowly as a result of receiving less sunlight. Matsushima et al. (1974) subsequently studied the role of a large number of environmental and design variables in the behavior of WS in architectural applications, verifying the decisive influence on the formation of the protective patina of whether or not the metallic surface was exposed to the rain, or whether or not areas where moisture was liable to accumulate were drained. These effects were more intense in atmospheres with higher pollution levels, in which case the protective patina may not fully form. Figure 2 shows the mechanism of corrosion control. Chloride ions($Cl^-$) transform into hydrochloric acid, causing abnormal corrosion. Sodium ions (Na+) trasform into alkaline sodium hydroxides, retarding the further development of corrosion.

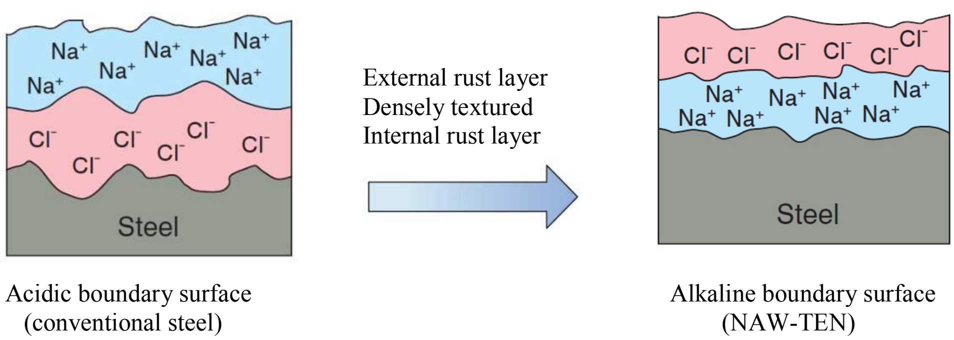


Figure 2: Mechanism of Corrosion Control by Means of Alklifying the boundary face of the Matrix (NAW-TEN)

Extensive research work has thrown light on the requisites for the protective rust layer to form. It is now well accepted that wet/dry cycling is necessary to form a dense and adherent rust layer, with rainwater washing the steel surface well, accumulated moisture draining easily, and a fast drying action (absence of very long wetness times). Structures should be free of interstices, crevices, cavities and other places where water can collect, as corrosion would progress without the formation of a protective patina. It is also not advisable to use bare WS in continuously moist exposure conditions or in marine atmospheres where the protective patina does not form ([Larrabee and Coburn, 1961; Leygraf and Graedel, 2000; Feliu and Morcillo, 1982). Figure 3 shows atmospheric corrosion of Cor-Ten B and its evolution with exposer time in the industrial atmosphere of Kearny (Larrabee and Coburn, 1961). Comparison with Cu-bearing steel and plain carbon steel (CS). The typical plots of corrosion versus exposure time for weathering steels ASTM A-242(a) in Figure 4 according to Schmitt and Gallagher (1969). On the other hand, Figure 5 shows typical plots of corrosion versus exposure time for weathering steels ASTM A-588(b) suggested by Townsend and Zoccola (1982) and Shastry, Friel and Townsend (1988) in different types of atmospheres.

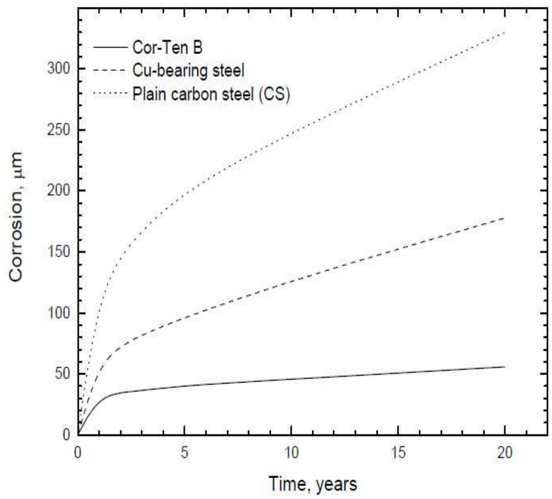


Figure 3: Atmospheric corrosion of Cor-Ten B steel and its evolution with exposure time in the industrial atmosphere

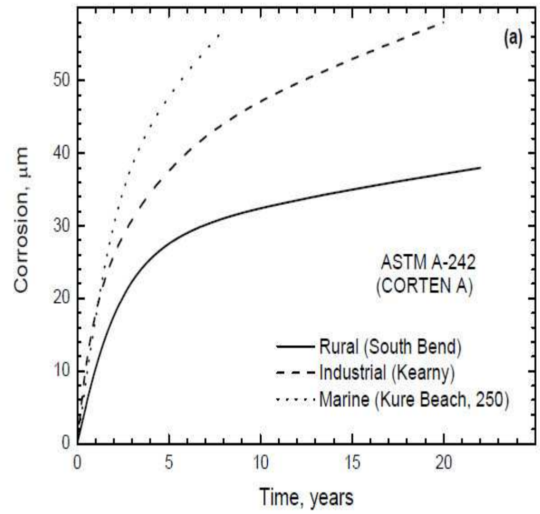


Figure 4: Typical plots of corrosion versus exposure time for weathering steels ASTM A-242(a)

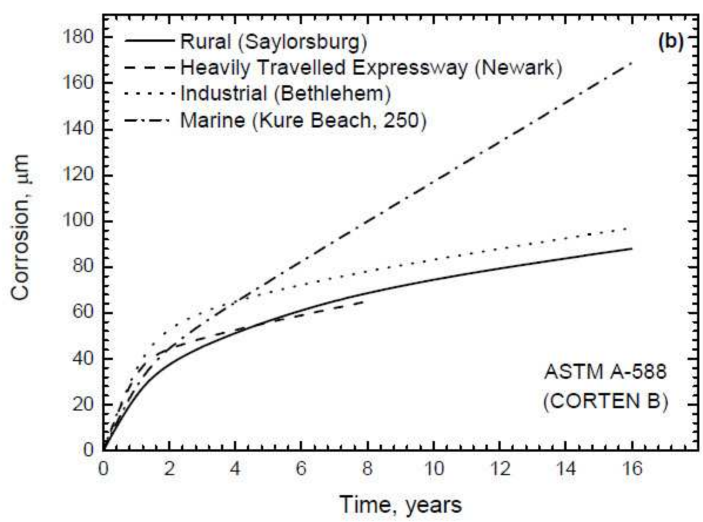


Figure 5: Typical plots of corrosion versus exposure time for weathering steels ASTM A-588(b)

### 3.2 Availability of Weathering Steel

Availability of WS in small quantities is an important consideration. Minimum mill quantities are available, but quantity vary with the specific grade(s) required. Normally rolled sections are no longer available in manufacture. Plates are available but manufacturers are start production after got specification and work orders. For bridge works WS plate is use to make built-up section and main girders. Cold rolled section like purlin C type or Z type, C channels and angles are use in different size for prefabricated steel building system. For construction of Rampura ULOOP flyover in Dhaka WS built-up box girder is fabricate from plate of different size and thickness. Nippon steel Japan, Tata Steel India are manufacturing WS hot rolled plates.

### 3.3 Workability of Weathering Steel

COR-TEN can be subjected to cold working, hot working, shearing and gas cutting in a similar way as ordinary steel with the same strength level. Welded, bolted and rivet joint are used for the jointing of the members with each other like other steel.

### 3.4 Weldability of Weathering Steel

Welding is easy for the WS as like other ordinary steel. All type of welding process can be applied like manual welding, Auto welding, submerged arc welding, flux cored arc welding, etc. TIG welding, MIG welding, spot welding are used for thin materials. But the welding electrode is different for WS. It is depend on the WS specifications and strength. In Rampura flyover flux cored arc welding was used and the electrode code was E81T1W2C. The welding code was AWS bridge welding code applied.

## 4. DESIGN PARAMETERS

Weathering Steel (WS) has a natural oxide coating when fully mature is dense, tightly adherent and relatively impervious to further atmospheric corrosion. Any damages to this oxide coating heals itself, therefore, maintenance is greatly reduced. WS is suitable for many atmospheric environments, including moderate industrial and marine exposures. It is compatible with other construction materials like brick, stone, wood and glass with appropriate detailing in the design. There are 50 ksi, 70 ksi, and 100 ksi strength WS is available for the designer to design any lighter sections. WS is suitable for Composite deck of bridge, roof and any other structures. It is also use in for design of composite column and beam, encase column,  and encase tube, architectural cladding, fencing and other aesthetic beautification.

Important studies of design parameters and the formation of protective corrosion product layers were conducted by Satake et al. (1970) and Matsushima et al. (1974) respectively. These researchers constructed models with the anticipated configurations of WS structures: H-shaped pillars and beams, ceilings, window frames, louvers and stairs. They point out that during the design and maintenance of WS, special attention must be paid to crevice areas that can retain moisture much longer time than open surfaces and in which more aggressive electrolytes may from.

In Bangladesh the first use of WS is in Hatirjheel Connecting ULOOP fly over in Rampura at Dhaka. It is a composite deck box girder bridge design by Dr. Ali Murtuza under the consultation of Acumen consultant Uttata Dhaka. The brigde is design with 4 span of 57 segments. Each segment is box with WS and connected with other segment with nut-bolt and welding joint system. Designer use hot rolled plates and sections for the box girder and for the road, composite deck slab is use to transfer the load to the bridge. There are two degree of curvature in the bride, Vertical curvature include cambering and supper elevation horizontal curvature for the geometry of bridge U shape. The bridge is constructed by Bangladesh army and  Buildtrade Engineering limited is the contractor for the fabrication and erection of the bridge. All the WS hot rolled plates and sections were imported from China and India as per the specification made by the consultant of the project.

The procedure established to determine rust layer stabilization times and steady-state corrosion rates have been as follows:

The available corrosion rate, $y$, is plotted against the exposure time, $t_1$ and fitted to an exponential decrease equation:

$$y = A_1 \exp\left(\frac{-x}{t_1}\right) + \ y_0 \tag{1}$$

Most of the experimental atmospheric corrosion data has been found to adrere to the following kinetic relationship:

$$C = A(t)^n \tag{2}$$

Where C is the corrosion after the time t, A and n are constants. Corrosion penetration data is usually fitted to a power model involving logarithmic transformation of the exposure time and corrosion penetration.

$$logC = \log A + n \log t \tag{3}$$

This power function (also called the bilogarithmic law) is widely used to predict the atmospheric corrosion behavior of metallic materials even after long exposure times, and its accuracy and reliability have been demonstrated by a great number of researchers viz.  Bohnenkamp et al. (1973), Lefault and Preban (1975), Pourbaix (1982), Feliu and Morcillo (1982), and Benarie and Lipfert (1986) among others.

## 5. CONCLUSIONS

The following conclusions can be drawn from the information of weathering steel:

i. Weathering steel is very effective for the bridge and other expose structural works where maintenance or periodic painting is require.
ii. Weathering steel is the best steel materials for rural, urban, suburban, industrial and see shore are in Bangladesh where the structure is require periodic painting/maintenance.
iii. The selection of weathering steel for the Rampura ULOOP Fly over is best selection of steel materials and more ULOOP fly over can be constructed by the same.
iv. In Bangladesh perspective (Govt. sector) all electric pole, city corporation fence, foot over bridge, railway plate form, high way protection structure, traffic sign materials and billboard support structure can be fabricated with weathering steel.
v. In Bangladesh perspective (private Sectors) High rise buildings, factory buildings, factory sheds can be constructed with weathering steel.

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