# Forth Lecture

# ALUMINUM

## ADVANTAGES OF ALUMINUM AS A BUILDING MATERIAL

Aluminum made tremendous advances as a structural construction material in the last thirty years. To understand the reasons why, it is necessary to develop an appreciation for the basic fundamentals that make it so well suited for many construction applications.

The following is an item by item review of the reasons:

**Non-Rusting:** "Rust" is by definition iron oxide formed by oxidation of iron, or steel containing the element, iron (Fe). Since there is no iron in aluminum building products, by definition, they will never "rust". Aluminum will oxidize forming an Aluminum Oxide film on the surface. Competition, however, tries to draw a parallel between the oxidation of steel (rusting) and the oxidation of aluminum. As a matter of fact, the oxidation action is similar, but the results are totally different. Iron oxide (rust) is very porous, allowing moisture to penetrate the film of rust and thus permitting additional rusting until over time, structural failure results. Aluminum oxide, on the other hand, is a dense, tight film covering that effectively forms a barrier to moisture, resulting in the protection of the metal underneath against further oxidation. Thus, the oxidation rate of aluminum decreases rapidly as the film builds.

An actual bare-aluminum roof installation exposed to salt air with no applied barrier coating or maintenance, had an oxide penetration of only 0.002-inch in 40 years. At this rate, it would require 200 years to penetrate 0.010-inch . . . halfway through a 0.020-inch sheet of aluminum.

**Penetration Tests:** Results of exposure tests for aluminum by the American Society for Testing Materials, in nine locations (including industrial, sea coast, and rural) indicated an average penetration of only 0.00002-inch per year . . . or 500 years to penetrate midway through an 0.020-inch thick sheet of aluminum.

By contrast, it is not uncommon for rust to completely penetrate 29-gage (0.014-inch) galvanized steel sheet within 8 years after the galvanizing has ceased to provide protection . . . and some new galvanized roofs exhibit the characteristic red-brown tint of rust within a week or two of application.

**Surface Marking:** Shearing, bundling, shipping, fabrication, and erection of any building products are bound to produce a certain amount of surface marking. It is difficult to erect galvanized roofing without scratching, chipping, breaking, or peeling off some of the galvanizing, exposing the underlying metal to moisture, which causes rust. Fastener holes in particular offer effective starting points for rust, regardless of how careful the application.

Deterioration here is particularly harmful to the roofing, siding, and flashing.

Aluminum, however, being a homogeneous material, has no protective coating to come off. Any scratches that may be produced are quickly protected by the natural protective coating of aluminum oxide. Fastener holes similarly provide their own protection. Thus, holes in aluminum are not weak points for deterioration.

**Corrosion of Aluminum:** Competition attempts to point out that while aluminum does not “rust”, it does corrode. That is true, but we need to understand the principles of the corrosion.

The corrosion of aluminum is easily controlled and need never be serious. Here are some common occurrences that you may incur in this connection

**Watermarking:** Pure water allowed to pond on aluminum does not produce a water spotting.

However, it is an unfortunate fact that most water (even moisture condensing from the  (atmosphere) contains some chemicals, enough to react with aluminum, and its alloying elements, to form gray or white salts, if the water is allowed to pond on the aluminum for an appreciable length of time. These salts will mark the surface of the aluminum.

It should be emphasized that this attack is superficial, hardly being enough to mark the top layer.

However, these spots or streaks may be unsightly. Such marks are easily removed by mechanically abrading the surface with a power driven wire brush or using some cleanser such as Simonize cleaner, etc. A warm caustic solution or commercial etching compounds also may be used, but acids should not be used.

Watermarking can be prevented by simply not allowing water to pond on the aluminum. Store fabricated aluminum in a place where it is protected from rain. Prevent rapid changes in atmospheric temperature that may cause condensation. If the sheets get wet, stand them on end and separate them so they may dry out. Protection in outside areas include covering sheets with breathable tarps, but not plastics or solid polyethylene

**Salt Air Attack:** Aluminum will withstand exposure to the salt air encountered near seacoasts, provided an aluminum alloy is used that contains no copper. The high strength alloys such as 2024 used in aircraft

contain copper, so stock of this type gave aluminum a bad name when used
on coastal installations.

Today, most aluminum building products are made from alloys containing no copper, so they are not subject to this corrosion. They can be relied upon to give long life on seacoast installations, as well as elsewhere.

Industrial atmospheres contain comparatively large amounts of chemicals which will increase the tendency to watermark. Aluminum roofs and siding may develop streaks from uneven flow of water over them in such areas. These marks may be removed by suitable cleaners and further marking retarded by correct selection of treating solution. Remember that other roofing materials such as galvanized iron and steel also develop similar markings under these conditions.

Alloy content greatly influences susceptibility of aluminum to attack. Today, most aluminum building products are made from the purer alloys (3004, 3003, etc.) which are most resistant to chemical attack. When an incident of corrosion of aluminum is brought to your attention, inquire as to the alloy involved and point out the deleterious effect of high alloy contents such as those of 2024, etc., especially a high copper content.

**Electrolytic Reactions:** Competition says, “Care must be taken to protect aluminum against electrolytic action. The use of non-aluminum fasteners or lapping sheets of aluminum and other metals is particularly dangerous.” There are several distortions of fact in this statement.

First, let’s see what we mean by “electrolytic reactions”. Any two dissimilar metals in an electrolyte (conductive solution) sets up an electrolytic cell (electric battery). If the two metals touch each other or immersed in this solution, an electric current will flow, causing one of the metals to go into solution (be dissolved), resulting in pitting and corrosive attack.

For such electrolytic action, the two metals must possess widely differing solution potentials, they must actually contact each other, the contact points must be wet or moist, and these conditions must exist for a sufficient period of time to produce pitting.

**Solution Potentials:** Therefore, electrolytic action can almost never be serious where aluminum contacts galvanized iron or galvanized steel because the zinc coating has practically the same solution potential as aluminum. Likewise cadmium-plated bolts, screws, and fittings may be used in contact with aluminum, for the same reason.

**Industrial and Seacoast vs. Rural Atmospheres:** The higher salt content of moisture condensing from industrial and seacoast atmospheres makes such moisture a better electrical conductor, thus promoting electrolytic action.

**Mechanical Contact:** Since mechanical contact is necessary for electrolytic action, separating the adjoining metals afford an easy method of protection. Thus, where it is necessary for aluminum to contact black sheet iron, cover the iron with aluminum paint, zinc dust paint, or some non-metallic material such as asphalt or bituminous paint, building paper, or asbestos paper.

**Immune to Most Chemicals:** Aluminum is unaffected by many chemicals and acids that seriously attack galvanized steel and iron. Sulfur fumes that necessitate replacement of ordinary galvanized roofing every few months have no effect whatever on aluminum roofing which has withstood years of use in the same plant.

**Alkali Attack:** Aluminum is subject to attack by the free alkali in cement, plaster, and mortar where the aluminum contacts are likely to be moist for extended periods, as on wall, roof, and chimney flashing. In such applications, protect the aluminum by coating the contacting areas with asphalt or bituminous paint. No attack will occur if so protected. From the above, it is evident that the non-rusting characteristic of

aluminum is an important feature of real value. The deleterious effect of dissimilar metal contacts, oxidation, and corrosion are all relatively unimportant as they are either easily avoided or do insignificant damage.

**No Painting:** Competition says, "Aluminum engineers recommend that the same protection be given aluminum as that used for other materials". That is not true. Aluminum manufacturers advertise, sell, and recommend the use of bare untreated aluminum for all sorts of building products including roofing and siding of many different types. Painting is not necessary to protect aluminum.

**Easy to Handle … Lighter Roof Loads:** Competition says, "The difference in weight is not considered important in roofing". While it may not be important to the man selling steel roofing, it is important to the warehouse, applicator, and user of roofing sheet. To say that a reduction of
nearly 200 lbs. for every 100 lbs. of aluminum used is unimportant is just plain distortion of fact.

Labor involved in application is a definite and large factor in cost of a roof. The favorable difference in weight of aluminum can be important in reducing the installed cost.

**Comparison of Weights:** A 10' sheet of 29-gage galvanized weighs 16-3/4 lbs. A 10' sheet of aluminum 0.019" thick (35% thicker than the galvanized) weighs only 6-1/4 lbs. A barn roof requiring 30 squares of sheet would weigh 1.25 tons in galvanized, but only 937 lbs. in aluminum. This great weight of galvanized accounts for the sagging roofs readily found in many installations. A sagging roof distorts and leaks. To say that a lighter roof load is unimportant completely disregards the importance of leaks.

Lapping Sheets of aluminum over galvanized sheets can be done without undesired reactions because the zinc coating has approximately the same solution potential as aluminum. However, perfect guarantee against any reaction can be had simply by applying common asphalt roofing paint to one of the contacting surfaces. In average Steel density is 2.9 greater than aluminum density.

**Heat Reflectivity … Means Cooler Buildings:** Aluminum is much superior to other metals in its ability to reflect the infra-red or heat rays of the sun. And this high reflectivity (up to 95%) is reduced only very slightly as the aluminum weathers and loses its brilliance. Remember that light reflectivity (up to 85% for aluminum) has little relation to heat reflectivity.

On the other hand, galvanized steel rapidly loses its heat reflectivity as it weathers. Here are the figures: Aluminum, 90-95% when bright; 85-94% when weathered. Galvanized steel, 92% when bright; 55-65% when weathered. Carbon steel heat reflectivity 50% new to 20% oxidize Don't let anyone tell you that aluminum and galvanized steel have the same reflectivity.

Aluminum is far superior, especially in heat reflectivity, the factor that makes for cooler buildings. Tests have shown an aluminum roof will often reduce inside temperatures by as much as 15º F.

**Emissivity:** On the other hand, aluminum has lower emissivity than other metals including galvanized steel … but this is good, and here's why: Emissivity means heat radiating power, the ability to dissipate heat by radiation. If two solid blocks of metal, the same size, one of aluminum, the other of galvanized steel, are both heated to the same temperature and allowed to stand, the aluminum will stay hot longer because it radiates less heat.

But radiation of heat through the roof and sidewalls of a building is not

the way to cool any building. It is much better to reflect the heat off the roof and prevent the building from getting hot in the first place. That's what an aluminum roof does, it prevents it from getting hot.

**Fire Protection:** Competition says, "Steel has an advantage over aluminum; aluminum melts at about 1220º F., steel at about 2700º F. Also, aluminum is more combustible than steel." Both statements are misleading.
Any fire that melts aluminum (1200º F. approx.) will also damage the galvanizing (or painted steel) that the galvanized steel will be worthless because the zinc coating melts at 787º F. The fact that the steel doesn't melt till 2500º F. therefore is of no importance. Once the galvanizing is gone, the steel is of no value as a building material and very little as scrap. On the other hand, damaged aluminum has a high scrap value.

During a fire in a contiguous tank is more likely that the steel roof reaches the melting point first than aluminum. The reasons for that are:
a) Reflectivity: Most of the radiation heat will be reflected by the aluminum (95% to 85%)

b) The heat conductivity for aluminum is in average 3 times larger than steel, therefore when exposed to fire it takes much longer to heat aluminum to its limit temperature than it does steel (the heat is concentrate rapidly in one spot). This property is especially important with respect to the fire safety of the roof structural frame.

c) The specific heat of aluminum is almost twice as great as that of steel. The specific heat is the amount of heat required to raise 1 pound of metal 1 oF. Thus a pound of aluminum will absorb almost twice as much heat as a pound of steel for a given rise of temperature Combustibility of aluminum vs. steel is unimportant because neither will burn unless in finely
divided powder form. Even the thinnest aluminum foil (0.00017" thick) cannot be made to burn, it simply melts.
**Strength at high temperature**: Aluminum maintains at high degree of

strength at high temperature. If the metal is held at 400 of for one hour its tensile strength will drop approximately 5%. If it is held at 400 of for 16 hours its tensile strength will drop approximately 10%. Niether of these reductions in strength will be critical to the Aluminum dome since the dead weight of the structure (approximately 3 pounds per square foot) is about 17.5 of its live load design capacity (20 pounds per square foot). It is also a fact that aluminum return to almost 100% of its original strength, this fact is not true for steel. This property is also especially important with respect to the fire safety of the roof structural frame.

**Less Rigidity:** Aluminum is more flexible than steel, having a modulus of elasticity (a measure of its rigidity) about one-third that of steel. However, aluminum sheet can be made as rigid as steel by increasing its thickness approximately 40%. But if the aluminum is embossed it is possible to obtain the same rigidity with the same thickness … offering important additional economies. The embossed pattern greatly strengthens the sheet structurally.

The owner of a building is not so much interested in elasticity figures as he is in maintenance and replacement costs. Remember too, that in cases where the span of the roof sheet or purling spacing is a factor, as in industrial buildings, ample rigidity can easily be obtained by using more deeply corrugated sheet designs which are available. Greatly increased load-carrying ability can be had with only a small amount of added material.

**Initial Cost:** Many distorted pictures of the cost of aluminum vs. galvanized steel have been presented.
In the first place, equal rigidity may not be required at all. Minimum steel thicknesses are determined by rolling and galvanizing costs. In other words, a thinner steel sheet would not cost less because cost of rolling and galvanizing would more than offset the saving in reduced amount of steel. Since aluminum roofing and siding is homogeneous material, these factors do not enter and it is only necessary to use a sheet of sufficient thickness to give the actual strength required.

Many such cost comparisons disregard the economies possible from use of aluminum, its light weight and ease of application, substantially reducing erection costs; its immunity to rust assuring longer life and less maintenance; the complete elimination of any need for painting or repainting, etc. So watch the initial cost comparisons.

**Quiet . . . No Excessive Noise From Wind, Rain, Etc.:** Aluminum is acoustically dead material; that is, it tends to deaden sound waves and not transmit them as freely as other metals.

The net result is that a building covered with aluminum roofing and siding is noticeably quieter than one covered with other metallic materials.

Finally, aluminum has been in the building construction market place for many years now. New paint coatings and surfaces have added aesthetics to a substrate that only needed these coatings and surfaces for good looks, not protection from the elements.