Design and Construction of Flagpoles

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Introduction

While the flag is a prominent and recognizable symbol of any country, we often overlook an important part of its display: the flagpole.

As might be expected, the design and fabrication of flagpoles is not arbitrary. However, there are no specific Indian standards for the design of flagpoles. The designers often use their own judgment for calculating the wind load on flag, though wind load on pole body may be calculated using IS 875-Part 3[1]. In USA, the National Association of Architectural Metal Manufacturers (NAAMM) has published a guide specification that has been approved by the American National Standard Institute (ANSI)[2]. This guide outlines the design requirements for metal flagpoles. In this note, let us take a look at some of the world's tallest flagpoles and investigate some important aspects of flagpole design. Though materials such as wood, aluminum and fibreglass can be used for smaller flagpoles, steel is the material of choice for the world's tallest flagpoles and hence we are concerned with steel poles only in this article.

Some Tall Flagpoles

The 86m (282 ft) tall flagpole in Vancouver, Canada, was considered as the tallest till 2000. The United States has built several tall flagpoles recently. For example, a 94m (308-ft) flagpole was dedicated in Laredo, Texas at Laredo National Bank on Memorial Day of 2002. This is 1m taller than another symbol of America, the Statue of Liberty. People on either side of the U.S.-Mexico border can see the 30m x 15m (100 ft by 50 ft) American flag flying from the Laredo pole[3].

However, the small town of Sheboygan, Wisconsin claims the distinction of having the tallest freestanding flagpole in the U.S. The flagpole was raised by Acuity Insurance in time for Independence Day in 2005. This 103m (338-ft) tall pole is made of tubular steel sections having a diameter of 2m at the base that decrease in diameter as the height increases[3]. Overall, the pole weighs 66 tonne of steel and supports a 36.5 m x 18.25 m (120 ft x 60 ft) flag weighing bout 136 kg.

The record for the tallest unsupported flagpole is held by the 133m (436 ft 4 in) tall pole at Ashbagad in Turkmenistan. Inaugurated on 29^{th} June 2008, it carries a flag as large as two tennis courts (with an area of 1,837 m^2)! This stainless steel tapered pole is 2.6m (8 ft 6 in) wide at the bottom and 0.75 m (2 ft 5 in) at the top. The total weight of this pole is 135 tonnes without the flag. The individual pieces of this 11-piece pole were fabricated in Dubai, UAE, and shipped to Ashgabad by trucks. A 500-tonne crane was then used to join them together[4]. At 133m, the flagpole is taller than the tallest statue: Tokyo Buddha (120 m) and tallest airport control tower: Kuala Lumpur International Airport (130 m) in the World!

The next tallest pole is the Aqaba Flagpole in Aqaba, Jordan (130m tall pole built in 2004). Note that the flagpole in North Korea is tallest; however it is supported by a truss structure, Figure 1. The tallest flagpole on a building stands at 183m on a building towering over Sydney, in Australia. Figure 1 shows several of these world's tallest flagpoles, all made of steel.

Statistics about Indian flagpoles are not readily available, although a number of tall flagpoles have been built in India. Figure 2 shows the steel flagpole for Rajeev Gandhi Memorial at Sriperambathur, Chennai, designed by the author.

Specifications for Flagpole Design

There are two loading types that must be considered when designing a flagpole:

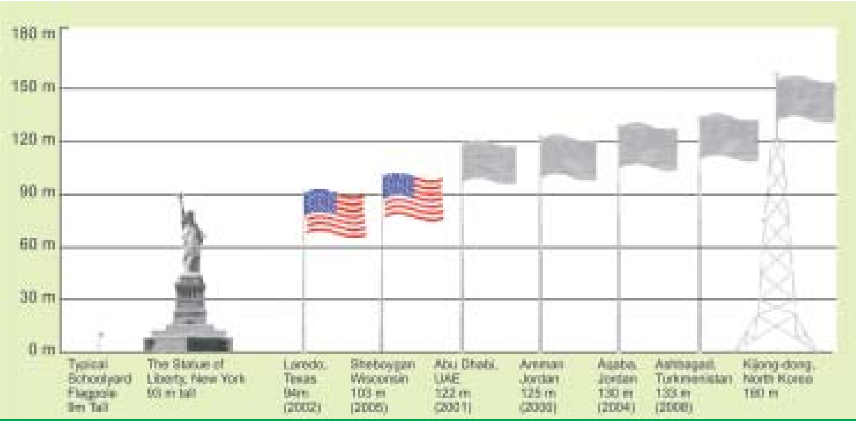

Figure 1: Height comparison of the world's tallest flagpoles[3]

- Flagpole loadings, and
- Flag loadings

Flagpole loadings consist of dead loads and wind loads. The dead loads include the weight of the flagpole, the weight of the flag, and the weight of any hardware and accessories that will be attached. The flagpole wind loads consist of the pressure on the flagpole due to the wind and the wind drag on the flag.

The design process presented by ANSI/NAAMM FP1001-97 consists of selecting a flagpole size, determining the flag size to be flown, calculating the loadings on the flagpole, and performing a stress analysis to ensure the design meets the specification[2]. The flagpole specification uses ASCE 7 to compute the wind loads on the flagpole[7].

To the author's knowledge no Indian Code provisions exist for calculating the wind load acting on the flag. However the provisions of IS 875-Part 3 may be used for calculating the wind load acting on the pole body (while designing the flagpole tower at Sriperambathur, we calculated the wind load by considering the full area of the flag and multiplying it with a drag coefficient of 1.25).

Flag Loading

The earliest formula for calculating the wind load on flag was developed by the U.S. Navy and appears in the American Civil Engineer's Handbook[5]. It is strictly an empirical formula and was arrived at through some wind tunnel testing at the Naval Yard in Washington, D.C. According to this formula

Force exerted by flag: $F = 0.0003*A*V^{1.9}$

F = pounds

A = flag area in ft^2

V = wind velocity in mph.

Another formula was developed by Hoerner and used extensively[6]. According to this the force exerted by the flag is given by

$F = 0.000218*A*V^2$

Where the F, A, and V are the same as defined earlier. The results of this formula were tested for flags having a Length/Width ratio of 1.5.

Compared to some other formulas available, these seem to give comparable results for smaller flags (say, 4 ft x 6 ft), but become very conservative for larger ones or high wind velocity. By the way, if a flag is mounted on a very tall building (or a pole exceeding 10m height), then one must add a height and gust factor to these equation.

According to the guide specification, flag loading is a result of the wind acting on the flag, which in turn results in loading on the pole[2]. The formulas used in the flagpole specification for flag loadings are empirical and are based on actual data taken from flight testing of different-sized flags and different materials. Testing consisted of connecting the test flag to a tow line, which was then connected through a load cell to an airplane. This allowed for continuous readings of the drag force on the test flag. Wind load data was recorded at different air speeds. The empirical formulas in the specification provide results that reasonably match the data recorded during testing.

The code provides formula for calculating the wind load for nylon, cotton and polyester flags as below[2].

For nylon and cotton: $F = 0.0010 (1.3\ V)^2$ “$A_f\ C_h$

For polyester: $F = 0.0014 \times (1.3V)^2$ “$A_f\ C_h$

where V= design wind velocity in mph.

Figure 2: Flagpole at the Rajiv Gandhi Memorial at Sriperumbudur, designed by the author

Table 1: Approximate size of Tubular Flagpole

Exposed Height (m)	Overall length (m)	Bottom Dia. (mm)	Top Dia. (mm)	Wall Thick. (mm)	# of Sec.	Field Welds	Max. Wind W/Flag (KmpH)	Max Rec. Flag size (m x m)
27.4	30.2	275	115	10	5	2	125.5	7.5 x 12
30.5	33.5	325	140	10	5	2	142	9.1 x 15.2
33.5	36.9	355	170	10	5	2	140	9.1 x 15.2
36.6	36.9	355	170	10	5	2	136.5	9.1 x 15.2
39.6	40.2	457	170	10	6	3	142	9.1 x 15.2

A_f = flag area in sq.ft.
C_h = 2.01 x $(H/900)^{á}$ where H = height of the pole in feet, and á = (2/9.5)

Flagpole Design

The flagpole loadings and the flag loadings are used to calculate shear, bending moment, and axial compressive forces on the flagpole. The wind loadings are used to determine the shear force and the bending moment, and the dead load is used to calculate the axial compressive force. These forces are then used to determine the actual stresses on the flagpole. It is simple to calculate the stresses as the flagpole is a simple cantilever. A stress analysis may be performed to ensure that the calculated stresses are within the permissible limits as specified in ANSI/NAAMM FP1001-97 or IS 800:2007. The values given Table 1 may be used as guidance for arriving at the size of flagpole member. This table is based on the U.S. manufacturing data on flagpoles.

Recently Ha (2006) proposed a design formula for non-constrained flagpoles. For Long poles it may be necessary to check the tip deflection.

Wind Induced Vibrations

When the wind speed matches the natural frequency of the pole, there will always be resonance. When there is no flag on the pole, it is quite common to hear cables banging against the pole. This is due to vibration of the pole (However, when there is flag at the top of the pole, the wind loading applied to the flag acts to dampen the resonant movement of the pole, eliminating the banging sound). The geographic features such as unobstructed flat land or low-level mountains, where wind can be channeled through an area, may contribute to pole resonance[10]. Turbulence created by aircraft or vehicular traffic also cause resonance. AASHTO LTS specifications (2001) indicate that common light poles do not normally exhibit fatigue problems. However, Manis and Jones (2008) note that such failures do occur. The flagpoles have different foundation anchoring system (especially short flagpoles may not have base plates or welds) and hence fatigue may not be a problem. Round and octagonal tapered poles are less susceptible to vibration than square ones (The natural frequency of a tapered pole varies along its length, which makes it less likely to develop overall resonance from a constant wind). This problem may also be minimized by using factory or field installed dampers. Periodic maintenance and inspection of a flagpole can help determine if wind induced vibration is a concern.

When a base plate is provided for long flagpoles, it is important that the details of the attachment of the pole to the base plate be such that "stress raisers" are avoided, or, at least minimized. A simple circumferential weld, of adequate size, is usually the best. The use of vertical fins, occasionally welded between flagpole and base plate, so as to reinforce the base plate, can be very damaging to the flagpole, due to the stress raiser effects caused, where structural fatigue effects occur.

Flagpole Foundation

Foundation design must be performed to meet applicable building codes, and designers should exercise good engineering judgment when designing flagpole foundations. The Most common type of flagpole installation is the in-ground foundation sleeve method which calls for 300mm of the flagpole to be encased in the ground sleeve for each 3m of exposed flagpole height. The diameter of the sleeve should be at least 50mm greater than the outside diameter of the flagpole with the area between the flagpole and the sleeve filled with dry sand. Sleeves with a 150mm diameter are supplied with a base plate and grounding spike (see Figure 3). Sleeves with a diameter of greater than 150mm are supplied with a base plate, support plate, grounding spike and, for ease of vertical alignment, steel centering wedges welded to the inside of the base plate. For tall flagpoles, the overturning of the foundation will be critical and hence has to be checked properly[11].

Fabrication and Erection

After the design work is completed, fabrication can begin. Flagpole fabrication consists of rolling, forming, and welding different steel sections. Because each flagpole is unique, the fabrication process is not limited to these tasks. Flagpoles may also be fabricated from seamless steel tubing. Diminishing sections, welded together, form a graceful tapered appearance. Steel flagpoles are mechanically cleaned and chemically etched to provide a smooth surface. A finishing coat is

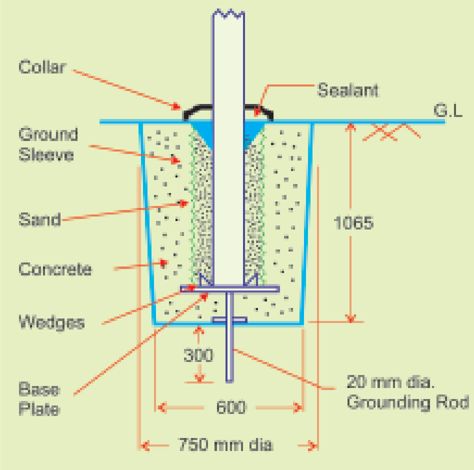

Figure 3: Simple to Install Flagpole base for short flagpoles

applied to the steel for maintenance and aesthetics. Often it consists of two coats of two-part polyurethane primer and two polyurethane finish coats. The standard colors often used are: Aluminum (silver), Light Bronze, Medium Bronze, Dark Bronze, Black or White. After fabrication is complete, the flagpole is shipped to its final destination and erected.

Summary

Flagpoles are often constructed to display flags of countries or even flags of political parties. Many companies in USA offer readymade flagpoles of different sizes which can be bought and installed with ease. As the flag is a prominent and recognizable symbol of any country/party, the demand for higher flagpoles is growing. Already flagpoles having a height of more than 130m have been built. These tall flagpoles require proper specifications for their design and construction. In USA, the National Association of Architectural Metal Manufacturers (NAAMM) has published a guide specification that has been approved by the American National Standard Institute (ANSI)[2]. This guide outlines the design requirements for metal flagpoles. In India, such guidelines are not available, though the wind load on flagpole body can be calculated using IS 875-Part 3. The important aspects of design of flagpoles and their foundation along with their construction are discussed, which will be useful to those involved in flagpole construction.

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