CIVIL AVIATION PUBLICATION

AGA 21

FRANGIBILITY REQUIREMENTS FOR OBJECTS SITED ON THE AIRFIELD AREAS (STRIP)

INDEX

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AGA 20

Frangibility Requirements For Objects Sited on the Airfield Safety Area

Table of Contents

1.0 PURPOSE

This Civil Aviation Publication (CAP) contains specifications for the frangible connections usedto support objects located in airfield safety areas (strip). It is based on the performance standards, specifications, and recommendations contained in two primary documents: the International Civil Aviation Organization (ICAO) *AerodromeDesign Manual*, 9157 Part 6, *Frangibility*, and the Civil Aviation Regulations Aerodrome and Ground Aide one *Guidelines for Frangibility.*

These frangibility requirements cover the minimum levels of safety for airfield safetyareas (STRIP). In order to further the overall goal of safety on the airport, it is highly encouraged that these frangibility provisions are incorporated in the areas adjacent to safety areas whenever possible.

2.0 INTRODUCTION

A fundamental goal of the Bahamas Civil Aviation Authority (BCAD) is to improve safety at Aerodromes within the State. Specific “safety areas” have therefore been established on airfields that prohibit the placement of objects that could present a hazard to operating aircraft. However, current technological limitations or operational requirements often require certain types of objects, such as navigationalor visual aids, to be placed within these designated safety areas (runway strips).

In such cases, those objects are required to be of minimal mass and height, mounted as low as possible to the ground, and to be mounted on frangible supportstructures.

3.0 FRANGIBILITY CONCEPTS

Flight Safety Impact. An aircraft in flight (or manoeuvring on the ground) that impacts an object located on an airfield may be susceptible to the following flightsafety risks: (Reference ICAO *Aerodrome Design Manual*, Part 6, Section 4.1.1

Momentum Loss. The amount of momentum lost is calculated by the integral offorce over time. Therefore, to minimize loss of momentum, both the magnitude ofthe impact load and the duration of its contact with a frangible structure should beas small as possible. (Reference ICAO *Aerodrome Design Manual*, Part 6, Section 4.1.2)

Energy Components. The potential for structural damage to the aircraft is relatedto the amount of energy required to move an obstacle. This energy, which should be as low as possible, can be broken down into the following components: (Reference ICAO *Aerodrome Design Manual*, Part 6, and Section 4.1.3)

Failure (or Break-Away) Mechanism. The manner in which an object fails. Considering the energy components previously described, an efficient failure mechanism would be designed to have a limited number of components, be made ofbrittle materials, and have as little mass as possible.

(Reference ICAO *Aerodrome Design Manual*, Part 6, Section 4.1.4)
Impact Area. The structural damage to the aircraft is also related to the contact area between the aircraft and obstacle through which the energy transfer takes place. (Reference ICAO Aerodrome Design Manual, Part 6, Section 4.1.5)

4.0 Failure Mode

To meet the frangibility requirements, different failure mechanisms can be applied. For example, structures can be of modular design, which on impact "open a window" for the aircraft to pass through, or of a one-piece design which on impact does not disintegrate but is deflected away by the aircraft. (Reference ICAO Aerodrome Design Manual, Part 6, Section 4.2.1).

In the case of a modular design, the structure should contain break-away or failure mechanisms which, apart and together, require only a minimum amount of energy for activation. This concept permits moving the least amount of mass out of the way of a colliding aircraft. The sequence of events is easier to predict as the structure behaves in a brittle way, disintegrating preferably at small deflections. The design would be unsuccessful if it allowed a structure to wrap around or entangle an aircraft rather than disintegrating or falling to the ground. This is a difficult design goal to achieve and requires considerable testing to verify. (Reference ICAO *Aerodrome Design Manual*,Part 6, Section 4.2.2)

In the case of a one-piece design, the frangibility must be guaranteed by a complete failure of the structure, which is achieved by the failure of the structural member and not the predetermined break-away or failure mechanism. This implies that the entire structure will eventually be involved in the impact, resulting in a relatively high value of the kinetic energy required to move the structure out of the way. Therefore, this type of failure mechanism seems to be suitable only for lightly loaded structures, i.e., those meant to carry low-mass equipment. Moreover, due to the continuous nature of the structure, the sequence of events is difficult to predict and the tendency to "wrap around" the aircraft should be considered an additional hazard. (Reference ICAO *Aerodrome Design Manual*, Part 6, Section 4.2.3)

Impact load. The impact load is a rapidly changing dynamic load of short duration. Typical loading and response times are in milliseconds. The impact load influences the frangibility performance in two ways. First, the maximum impact load may adversely affect the structural integrity of the aircraft. Second, the integral of the impact load over the duration of the impact may lead to a change of momentum (including direction) of the aircraft. (Reference ICAO *Aerodrome Design Manual*, Part 6, Section 4.3)

5.0 Energy Transfer

During an impact, energy will be transferred from the aircraft to the obstacle, resulting in aircraft damage proportional to the amount of energy transferred. The energy transfer is estimated as follows: (Reference ICAO *Aerodrome Design Manual*, Part 6, and Section 4.4.1).

The energy required to cause a break-away mechanism to fracture is determined in a laboratory on a component scale; this amount of energy must be multiplied by the number of mechanisms to be broken;

The energy required for plastic and/or elastic deformation is calculated or determined by simple tests; this energy is often negligible when stiff and brittle materials are applied in a modular design; and

The kinetic energy required for acceleration of the fragments, or the total structure inthe case of a one-piece design, is calculated using the known mass and the representative aircraft velocity.

The estimation should be done for all different scenarios of an aircraft impacting the structure. (Reference ICAO *Aerodrome Design Manual*, Part 6, Section 4.4.2)

6.0 PERFORMANCE STANDARDS

The performance standards listed in this section are focused on the frangible connections used to support equipment located in airfield safety areas. A wide varietyof equipment exists in airfield safety areas. As such, general frangibility requirementsare provided, while the specific requirements for different classes of airfield structures(such as elevated lights, signs, and navigational aids, etc.) are specified when applicable.

7.0 REQUIREMENTS

Equipment located in airfield safety areas to be mounted on frangible supports to ensure the structure will break, distort, or yield in the event of an accidental impact by an aircraft. The materials selected must preclude any tendency for the components, including the electrical conductors, etc., to "wrap around" the colliding aircraft or any part of it. (Reference ICAO Aerodrome Design Manual, Part 6, Section 3.3.1)

The frangible structure must include effective failure mechanisms, such as those containing a limited number of parts, brittle or low-toughness members and connections, and/or low-mass members. Various design concepts exist, each with its own advantages and disadvantages. Designs may incorporate one or more concepts in order to ensure frangibility. (Reference ICAO Aerodrome Design Manual, Part 6, Section 4.5.1

8.0 STRUCTURAL INTEGRITY

Should be designed to withstand the static and operational wind or jet blast loads with a suitable factor of safety but they should break, distort, or yield readily when subjected to the sudden collision forces of a 6,600-pound (lb.) (3,000 kg) aircraft moving on the ground at 31 mph (50. km/h or 27 knot) or airborne and traveling at 87 mph (140 km/h or 75 knot);

Not to impose a force on the aircraft in excess of 13,000 pounds force (lbf) (58.0 kN). The maximum energy imparted to the aircraft as a result of the collision must not exceed 40,500-foot pounds (ft-lbs) (55.0 kJ) over the contact period (approximately 100 milliseconds) between the aircraft and the structure. To allow the aircraft to pass, the structure should mechanically fail by fracturing or buckling. (Reference ICAO *Aerodrome Design Manual*, Part 6, Section 4.9.20); and To provide for a frangibility point no greater than 3.0 inches (76 mm) above the surrounding grade. Structural foundations (e.g. concrete blocks) must be made flush with the surrounding grade (or as close as possible if there is a need to mitigate wateraccumulation/ponding).

9.0 SPECIFIC REQUIREMENTS

Equipment that shall meet frangibility.

- Signs, Runway and Taxiway
- Low-impact Resistant (LIR) Structures (ILS)
- Light Fixtures, Runway and Taxiway
- PAPIs and REILs
- Wind direction indicators

Any design using frangible mechanisms has to ensure that no slippage or change in shape occurs from cyclic (repeated) loading. For example, in a design using interconnecting tubes, aero elastic flutter on a tube caused by a jet blast or wind could loosen or separate it from its matching part. (Reference ICAO Aerodrome Design Manual, Part 6, Section 4.5.8)

10.0 BREAK-AWAY OR FAILURE MECHANISMS.

The location of break-away or failure mechanisms must be such that disintegration results in components of predictable mass and size, which, in case of a secondary impact, do not present a greater hazard than they present as part of the undamaged structure. It is desirable that break-away or failure mechanisms are independent of the strength required for withstanding wind loads, and other environmental loads. In addition, the mechanism must not be prone to premature fatigue failure. (Reference ICAO Aerodrome Design Manual, Part 6, Section 4.6).

11.0 MATERIAL SELECTION

Materials and configurations for frangible structures must be suitable for the intended use and should result in the lightest structure possible. Structures may be fabricated from metallic or non-metallic materials that are not adversely affected by outdoor environmental conditions. Materials selected to meet frangibility requirements must bestrong, lightweight, and have a low modulus of toughness. Minimum weight is important to ensure that the least amount of energy is expended to accelerate the mass to the speed of the impacting aircraft. (Reference ICAO *Aerodrome Design Manual*, Part 6, Section 4.7.1)Standard, commercially available materials provide the most cost-effective design.

Non-metallic materials can be specially designed to provide excellent frangibility characteristics; however, their structural behavior may be difficult to analyze because ofuncertainty about their elastic modulus. All materials must be able to withstand or be protected against environmental effects including:

- Temperature fluctuations;
- Solar radiation;
- Vibration;
- Weathering (salt spray, wind, relative humidity); and
- Corrosion (dueto rain, sand, grit,) typically encountered in the airfield environment.

12.0 ELECTRICAL COMPONENTS

The strength of electrical conductors incorporated in the design of frangible structures as well as the fire hazard presented by the arcing of disrupted conductors must be considered in the overall design. It is recommended that conductors be designed such that they do not rupture but disconnect at predetermined points within the limits for frangibility of the structure. This is accomplished by the provision of connectors that require a lower tensile force to separate than that required to rupture the conductor. In addition, the connectors should be protected by a break-away boot of a size commensurate with the voltage employed in order to contain any possible arcing at disconnection. Break-away connector assemblies are commercially available. (Reference ICAO *Aerodrome Design Manual*, Part 6, Section 4.8.2.

13.0 MAINTENANCE EQUIPMENT DESIGN

A frangible structure no longer meets requirements if the structure itself is used as a climbing frame or is denigrated by the addition of a fixed ladder. The total structure should be maintained either by equipment that can be easily moved into position or by lowering the structure to the ground. (Reference ICAO *Aerodrome Design Manual*, Part6, Section 7.2.2)

Portable maintenance stands are recommended to maintain airfield lighting structures. It may be possible to convert a permanent stand into a portable stand by installing a threaded can into the foundation, which allows for the stand to be temporarily screwedinto place whenever needed.

14.0 TYPES OF FRANGIBLE CONNECTION

In a frangible connection design, frangibility is incorporated in the connection, which carries the design load but fractures at impact. The structural member is not designed to break but rather to transfer the impact force to the connection. A stiff, lightweight member provides efficient load transfer to the connection and minimizes the energy absorbed from bending and mass acceleration. The connection should break at low energy levels, as determined by impact tests. Types of frangible connections include neck-down or fuse bolts, special material or alloy bolts, countersunk rivets or tear- through fasteners, and gusset plates with tear-out sections. (Reference ICAO Aerodrome Design Manual, Part 6, Section 4.5.2)

15.0 Fuse Bolts (Including Frangible Or Neck-Down Bolts).

Failure of this type of connection is induced by providing a "stress raiser," due to removal of material from the bolt shank. One method used to achieve this is to machine a groove to reduce the bolt diameter or to machine flats in the sides of the bolts, making it weaker in a specific direction. Shear strength is maintained, and tensile strength is reduced by machining a hole through the bolt diameter and locating it out of the shear plane. Fuse bolts must be carefully installed to ensure they are not damaged or overstressed when tightened. One disadvantage of fuse bolts is that the stress raiser may shorten the fatigue life of the bolt or may propagate under service loads and fail prematurely. Fuse bolts with machine grooves are commercially available. See **Figure 1** as an example of the application of such fuse bolts. (Reference ICAO *Aerodrome Design Manual*, Part 6, Section 4.5.2.a)

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Figure 1. Application of fuse bolts

Common applications of fuse bolts include use as the frangible connections for localizers(typically five-eighth or 0.625-inch (15.88 mm) diameter bolts) and for approach light towers (typically three-quarter or 0.75-inch (19.1 mm) diameter bolts).

16.0 SPECIAL MATERIAL BOLTS (ALSO ALLOY BOLTS).

Use of fasteners manufactured from special materials eliminates the need for extensive machining or fabricating and allows the basic design to consist of conventional cost- effective techniques. The fasteners are sized to carry the design loads but are made from material with low-impact resistance. Materials such as steel, aluminum, and plastic should be selected based on strength and minimum elongation to failure.

Because frangibility is based on material selection, it is extremely important to purchase hardware with guaranteed compliance of physical properties. (Reference ICAO Aerodrome Design Manual, Part 6, Section 4.5.2.b)

17.0 FRANGIBLE COUPLINGS

A frangible connection for cylindrical or tubular objects is often obtained through the use of frangible couplings. Frangibility is achieved in these devices by modifications that reduce the circumference of the coupling at a given point or through the machining of holes or other elements that reduce the effective strength of the coupling at a given point.

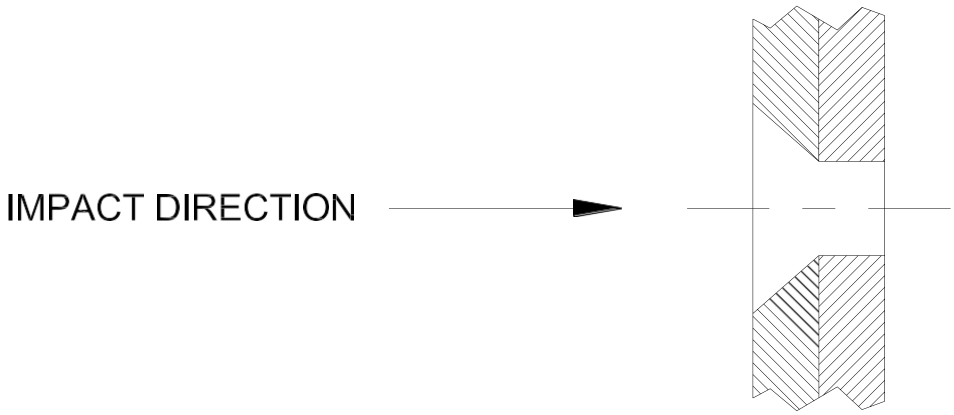
Common applications of frangible couplings (Figure 2) are found in light posts, masts, and electrical metallic tubing (EMT) supports for runway and taxiway lights. It is important to recognize that many types of frangible couplings are available, and only those types approved for the purpose or application originally intended should be used

Figure 2. Examples of Frangible Couplings

18.0 TEAR-THROUGH FASTENERS (ALSO COUNTERSUNK RIVETS).

Fasteners such as countersunk rivets (**Figure 3**) can be used to sustain shear loads but tear through the base material if the impact force creates a tension load. The hole in the base material is accurately machined to grip a minimum amount of the area under the head of the fastener. The taper of the countersunk head also helps initiate the pull-through. This technique relies heavily on the manufacturing process and requires extensive quality inspection. (Reference ICAO *Aerodrome Design Manual*, Part 6, Section 4.5.2.c)

Figure 3. Examples of a Tear-through Fastener (or Countersunk Rivet)



19.0 FRANGIBLE MECHANISMS

Frangibility can be incorporated into the support structure by means of a mechanism that slips (e.g., slip-bases), breaks, or folds away on impact and removes the structural integrity of the support. A frangible mechanism can be designed to withstand high wind loads but remain very sensitive to impact loads. Frangible mechanisms tend to be directional in strength, i.e. they carry high tension and bending but very low shear. (Reference ICAO Aerodrome Design Manual, Part 6, Section 4.5.5).

Friction joints used as frangible mechanisms can supply high strength normal to the sliding surface but slip when the force is applied parallel to the sliding surface. In a support structure, impact forces are predominantly horizontal. Friction joints should be designed so that the slip plane is horizontal and complete failure occurs if impacted in any direction in that plane. This is achieved by using flange-type couplings on the ends of tower legs or interconnected tubes that slide apart on impact. (Reference ICAO Aerodrome Design Manual, Part 6, Section 4.5.6)

‘Swing-away” support members can also be used as frangible mechanisms. These are incorporated into the structure to provide stability but if broken away on impact, leave the structure unstable and allow it to fracture. This type of design, however, may require large amounts of mass to be moved out of the way before failure. (Reference ICAO *Aerodrome Design Manual*, Part 6, Section 4.5.7)