

12.0 STRUCTURAL DAMAGE CAPABILITY

a. **General.** Structural Damage Capability (SDC) is the attribute of the structure which permits it to retain its required residual strength in the presence of large damage. The overall purpose is to prevent catastrophic failure resulting from damage not accounted for in damage tolerance analysis. SDC is a characteristic of the design of a structure, and is therefore not specifically tied to any one aspect of a maintenance program. Although the requirements of SDC are strictly associated with the design, SDC will inherently augment the ability of routine inspections to find large damage.

Damage tolerance is the ability of structure to sustain anticipated loads in the presence of damage until it is detected through inspection or malfunction, and repaired. It should be emphasized that SDC is not a replacement for damage tolerance – SDC adds robustness to the inherent structural design. SDC addresses unforeseen damage that can occur at any time and complements existing damage tolerance inspection requirements. It does not generate any additional inspection or inspection threshold requirements; these should already be accounted for by existing baseline and damage tolerance based maintenance programs.

Because SDC is an inherent design attribute and complements more formal inspection programs derived through damage tolerance evaluation (DTE), it should exist regardless of the type and source of the damage. At a high level, types of damage could include static and fatigue cracking, wear, environmental deterioration, impact, heat damage, disbond and delamination. General sources of damage could be from loading in service, the environment, accidental damage, maintenance errors, discrete events and manufacturing defects. Specific examples of possible damage scenarios that SDC may protect against include but are not limited to the following:

- Accelerated corrosion of a fuselage skin from a waste spill that was not neutralized
- Failure of a steel fitting due to a manufacturing processing error that causes hydrogen embrittlement
- Severe wear of the fuselage crown skin from vertical stabilizer aerodynamic seals
- Failure of a single frame or single stringer
- Damage to structure from excessive pull-up or mis-drilled holes in manufacturing or maintenance
- Accidental damage in the fuselage skin
- Damage from runway debris
- Damage from departure of small access covers in flight
- Damage from high load events

It should be noted that structure with an SDC design will not be able to withstand damage from all of the above scenarios in all cases – this would be dependent on the severity of the damage.

An SDC assessment should be performed for Principal Structural Elements (PSE) subject to in-flight loads under paragraphs (b)(1) through (b)(5) of §25.571.

b. The evaluation of a given PSE for SDC is intended to ensure that, in the event of damage that results in partial failure of the structure or the full failure of a single

element, the remaining intact structure is capable of carrying the required residual strength loads. The extent of SDC to be demonstrated should be consistent with the type of PSE under evaluation. To this end, the structure is classified as Category A, B or C as follows:

Category A - Single Load Path Structure

Category B - Integrated Multiple Load Path Structure

Category C – Discrete Element or Built up Multiple Load Path Structure

(1) Category A – Single Load Path Structure

By definition, Category A structure does not have inherent SDC capability.

However, for cases where the applicant establishes that Category B or C designs would be impractical, usage of Category A structure subject to in-flight loading may be considered.

- i. Definition: Single load path PSE structure which contains no damage containment features and the failure of which may lead to a catastrophic loss of the aircraft.

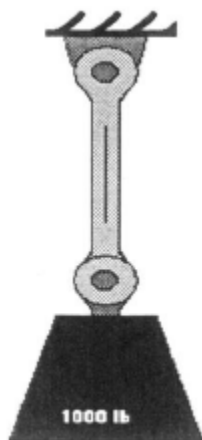


FIG. 1 – Category A single load path structure

- ii. Example: A single element fitting, such as a single link or lug, with no integral features to contain damage and retard propagation, and which upon failure the remaining structure cannot withstand the required residual strength load.

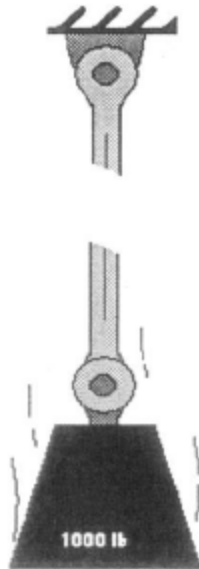


FIG. 2 – Category A single load path structure does not have SDC capability

- iii. For cases where usage of Category B or C designs are established to be impractical, the applicant may consider usage of Category A structure provided the following are considered:
- Perform a fatigue test or complete fatigue analysis based on test to demonstrate no detectable cracks in the operational life with 99% reliability and 95% confidence.
 - Develop a manufacturing process control and tracking plan document

(2) Category B – Integrated Multiple Load Path Structure:

- i. Definition: Integral multiple load path structure with damage arrest or crack retardation features, *i.e.* monolithic metallic or bonded composite structures which incorporate ‘damage containment features’.

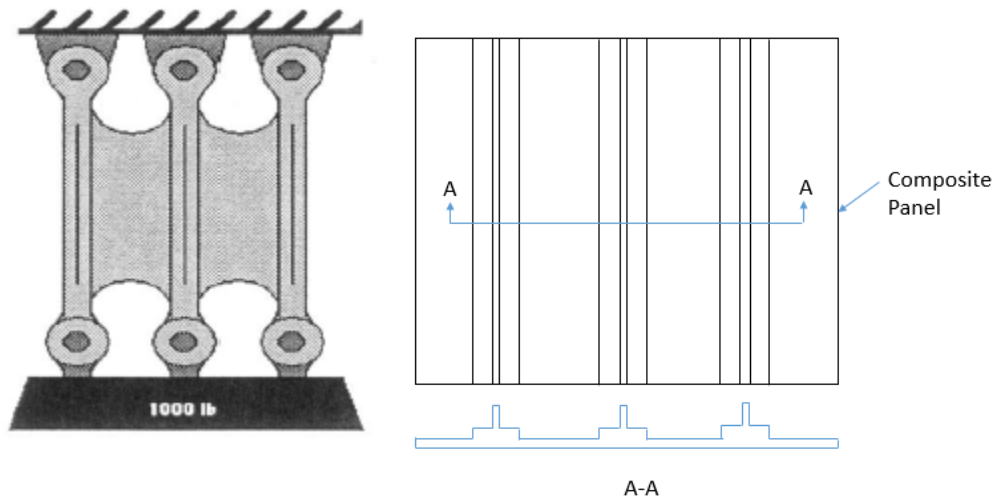


FIG. 3 – Category B integral structures with damage containment features

- ii. Examples:
 - A machined integral structure where features are machined into it for the purpose of restricting possible damage to a size whereby the remaining un-cracked structure can sustain residual strength loads
 - A co-cured, co-bonded or secondarily bonded composite panel with stiffening elements that are intended to preclude detrimental damage growth, i.e. contain the damage to an area/size that allows the structure to retain its residual strength capability
- iii. Level of SDC – Capability to withstand the loads defined in paragraph a with the following level of damage (each condition should be evaluated separately):
 - Loss of a damage containment feature
 - Loss of the portion of structure between damage containment features

Each assessment should include active damage tips/sites.

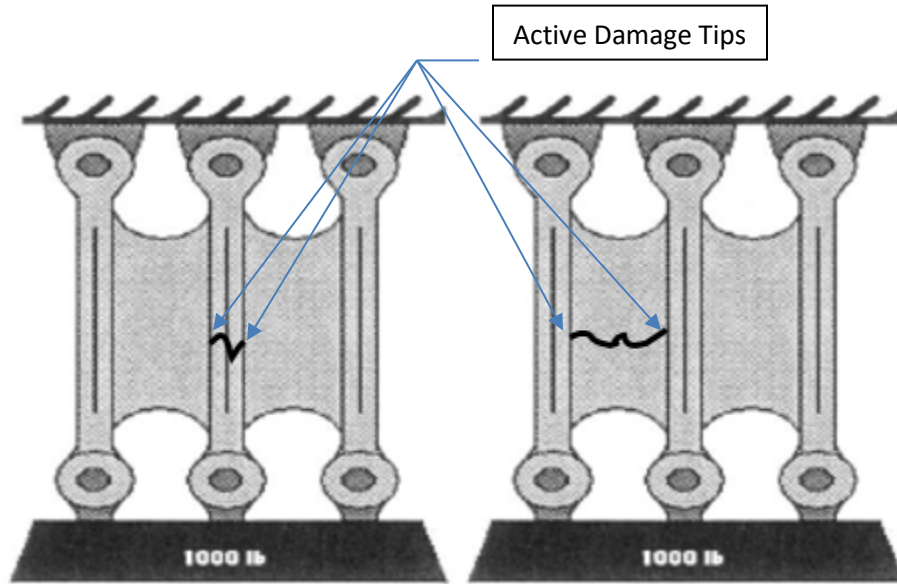


FIG. 4A – Example of the level of SDC for Category B integral structure with damage containment features. Assessment would include both damage scenarios shown.

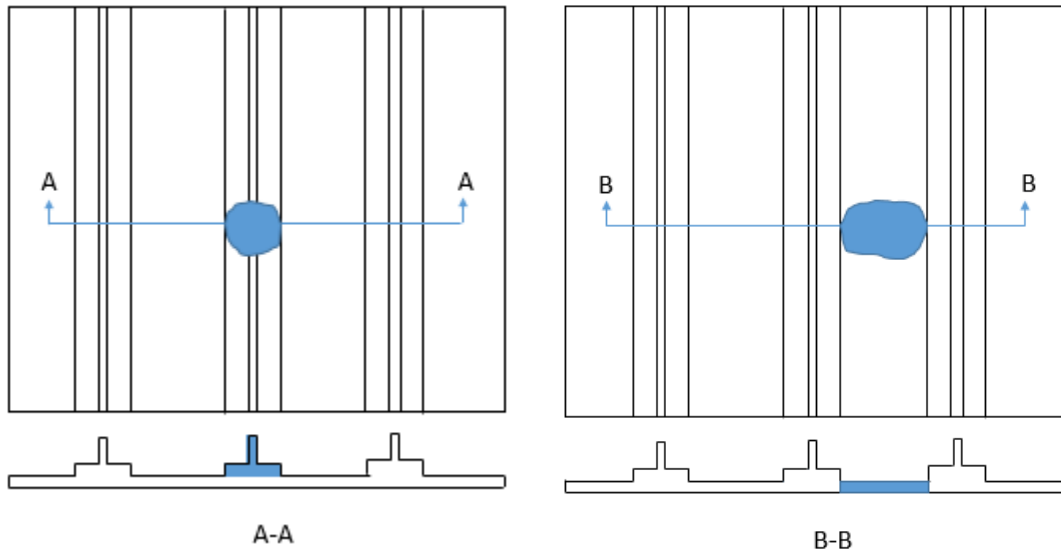


FIG. 4B – Example of level of SDC for Category B composite panel – Assessment would include both damage scenarios shown.

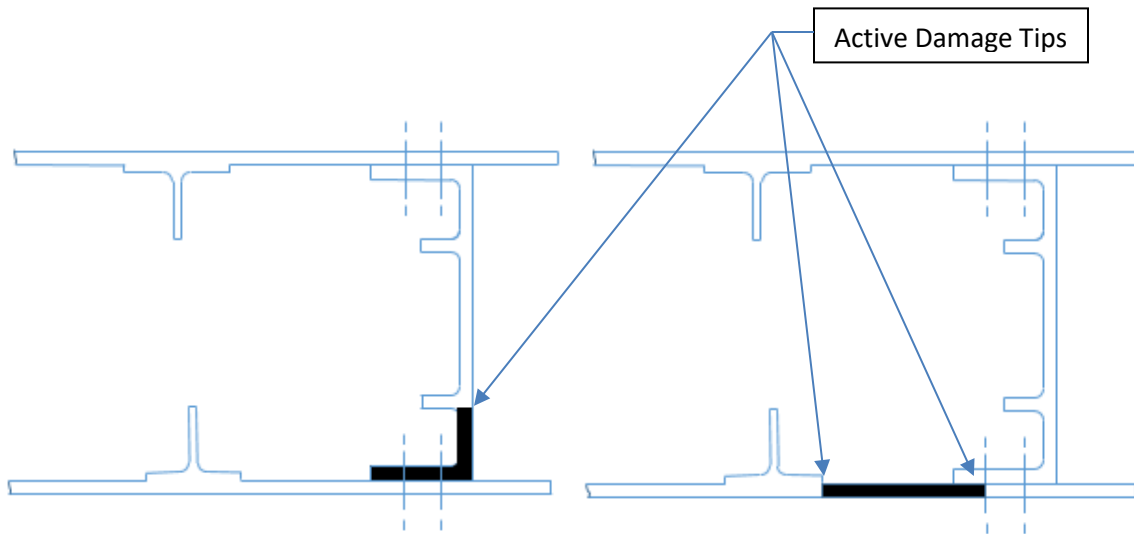


FIG. 4C – Example of level of SDC for integral spar with damage containment features. Assessment would include both damage scenarios shown. The pictures do not show all of the damage scenarios to be considered.

(3) Category C – Discrete Element or Built-Up Multiple Load Path (MLP) Structure:

- i. Definition: Structure made up of multiple, independently fastened or bonded structural members that are part of a larger redundant system with multiple load paths; the remaining damage free members can carry the required load. There are two types of Category C structure:
 - Type 1: Discrete Element MLP Structure, i.e. multiple independent element structure where one member of that system could be completely broken.
 - Type 2: Built-up MLP structure (includes structure consisting of discrete stiffening members and a continuous element).

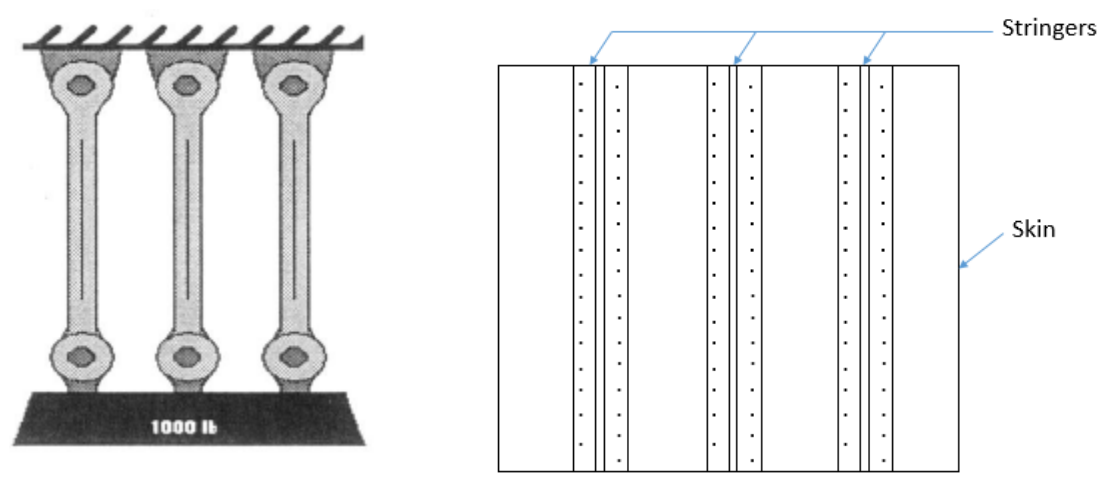


FIG. 5 – Category C multiple load path structures

ii. Examples:

Type 1 -

- Back-to-back or multiple redundant lugs and fittings.
- Multiple redundant attachments for structure such as control surface hinge ribs, engine strut attachments, thrust reverser attachments and door latches, stops and hinges.
- Finite width fastened multiple panels where required loads can be maintained with the loss of one panel.

Type 2 -

- Stiffened panels with separately fastened stiffening members such as stringers, longerons or frames, or separately bonded or fastened structural damage containment features such as metallic tear straps (where damage in the skin does not propagate into the tear straps). Note that each individual skin bay between stiffeners or damage containment features is assumed to be a separate load path.
- Built-up structure such as doorway frames and spars with separately fastened skins, chords, webs and straps.

iii. Level of SDC -

Type 1 - It should be ensured that the multiple load path design includes sufficient structural redundancy to allow for the failure of one complete load path. Analysis should be performed and limited to the static assessment of the ability of the remaining intact load paths to carry the loads defined in paragraph a.

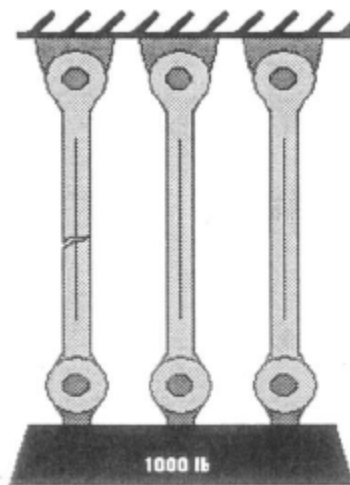


FIG. 6 – Example of level of SDC for Category C Type 1 multiple load path structure – Level of SDC is failure of one complete load path

Type 2 - The structure should have capability to withstand the loads defined in paragraph a with the following level of damage (each condition should be evaluated separately):

For stiffened panels:

- The failure of an individual stiffening element (refer to Fig. 7A Section A-A and Fig. 7B Section C-C)
- The failure of an individual skin element between fastener lines or stiffeners as appropriate (refer to Fig. 7A Section B-B and Fig. 7B Section D-D). The assessment should account for active damage tips.

For other built-up structure, the failure of an individual element (refer to Fig. 8).

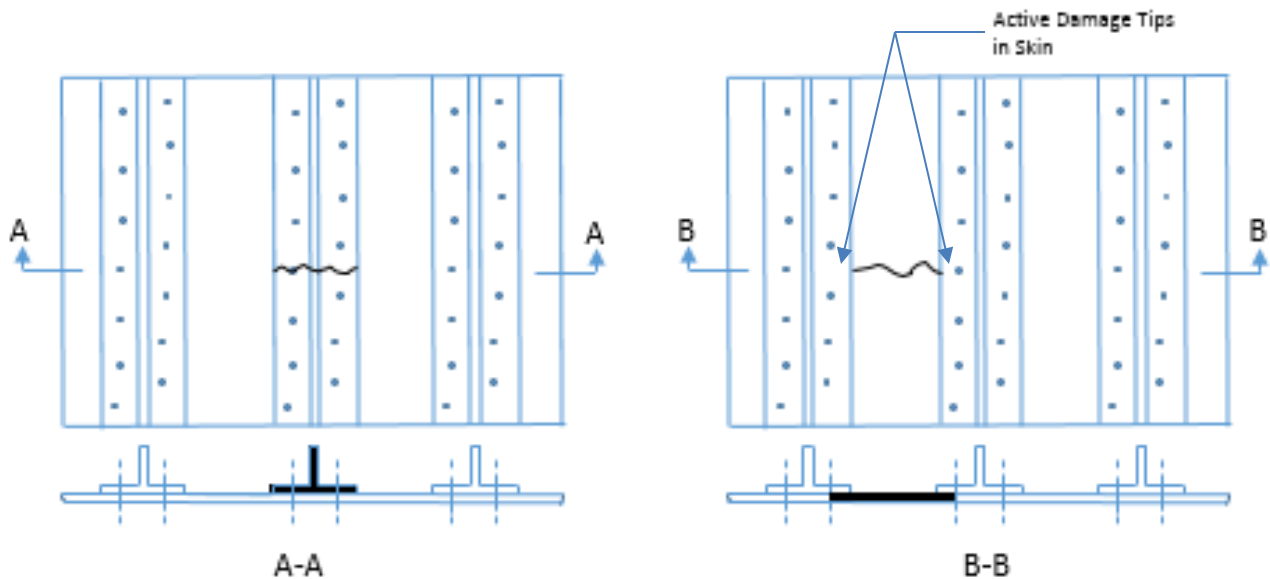


FIG. 7A – Example of level of SDC for Category C Type 2 multiple load path structure – SDC assessment would include both damage scenarios shown for the fastened panel

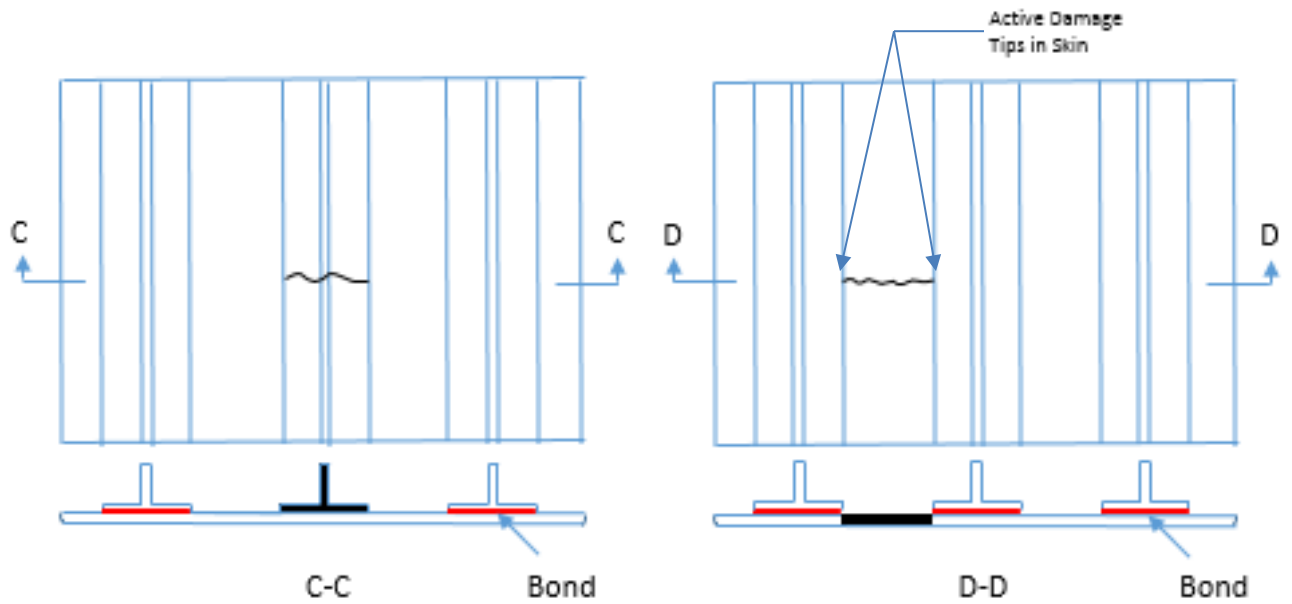


FIG. 7B – Example of level of SDC for Category C Type 2 multiple load path structure – SDC assessment would include both damage scenarios shown for the bonded panel

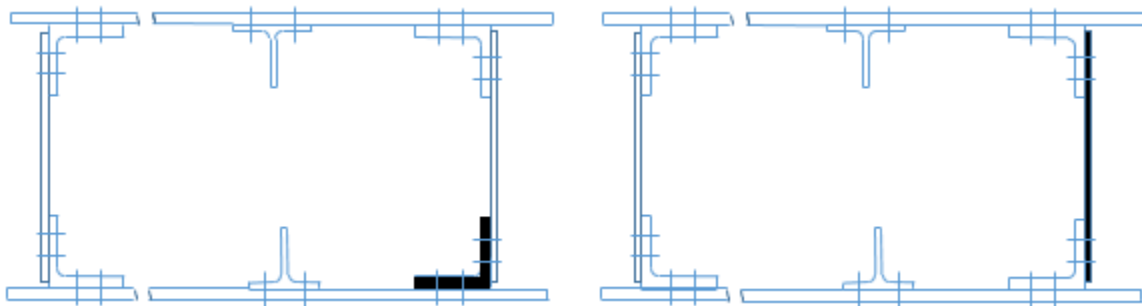


FIG. 8 – Example of level of SDC for Category C Type 2 multiple load path structure – SDC assessment would include both damage scenarios shown for the built-up spar. The pictures do not show all of the damage scenarios to be considered.