system where the right hand side aileron loads are reacted by the left hand side aileron, without participation by the pilot(s).

c. In either the taxying condition (controls locked or unlocked) or the parked condition (controls locked), if the control system flexibility is such that the rate of load application in the ground gust conditions might produce transient stresses appreciably higher than those corresponding to static loads, the effects of this rate of application are required to be considered. Manually powered control systems and control systems where the gust lock is located remotely from the control surface are examples of designs that might fall in this category. In such cases the control system loads are required by CS 25.415(e) to be increased by an additional factor over the standard factor of 1.25.

[Amdt 25/2]

CS 25.427 Unsymmetrical loads

ED Decision 2005/006/R

(a) In designing the aeroplane for lateral gust, yaw manoeuvre and roll manoeuvre conditions, account must be taken of unsymmetrical loads on the empennage arising from effects such as slipstream and aerodynamic interference with the wing, vertical fin and other aerodynamic surfaces.

(b) The horizontal tail must be assumed to be subjected to unsymmetrical loading conditions determined as follows:

(1) 100% of the maximum loading from the symmetrical manoeuvre conditions of CS 25.331 and the vertical gust conditions of CS 25.341(a) acting separately on the surface on one side of the plane of symmetry; and

(2) 80% of these loadings acting on the other side.

(c) For empennage arrangements where the horizontal tail surfaces have dihedral angles greater than plus or minus 10 degrees, or are supported by the vertical tail surfaces, the surfaces and the supporting structure must be designed for gust velocities specified in CS 25.341(a) acting in any orientation at right angles to the flight path.

(d) Unsymmetrical loading on the empennage arising from buffet conditions of CS 25.305(e) must be taken into account.

[Amdt 25/1]

CS 25.445 Outboard fins

ED Decision 2003/2/RM

(a) When significant, the aerodynamic influence between auxiliary aerodynamic surfaces, such as outboard fins and winglets, and their supporting aerodynamic surfaces must be taken into account for all loading conditions including pitch, roll and yaw manoeuvres, and gusts as specified in CS 25.341(a) acting at any orientation at right angles to the flight path.

(b) To provide for unsymmetrical loading when outboard fins extend above and below the horizontal surface, the critical vertical surface loading (load per unit area) determined under CS 25.391 must also be applied as follows:

(1) 100% to the area of the vertical surfaces above (or below) the horizontal surface.

(2) 80% to the area below (or above) the horizontal surface.

CS 25.457 Wing-flaps

ED Decision 2003/2/RM

Wing flaps, their operating mechanisms, and their supporting structures must be designed for critical loads occurring in the conditions prescribed in CS 25.345, accounting for the loads occurring during transition from one wing-flap position and airspeed to another.

CS 25.459 Special devices

ED Decision 2003/2/RM

The loading for special devices using aero-dynamic surfaces (such as slots, slats and spoilers) must be determined from test data.

GROUND LOADS

CS 25.471 General

ED Decision 2003/2/RM

(a) *Loads and equilibrium.* For limit ground loads –

(1) Limit ground loads obtained under this Subpart are considered to be external forces applied to the aeroplane structure; and

(2) In each specified ground load condition, the external loads must be placed in equilibrium with the linear and angular inertia loads in a rational or conservative manner.

(b) *Critical centres of gravity.* The critical centres of gravity within the range for which certification is requested must be selected so that the maximum design loads are obtained in each landing gear element. Fore and aft, vertical, and lateral aeroplane centres of gravity must be considered. Lateral displacements of the centre of gravity from the aeroplane centreline which would result in main gear loads not greater than 103% of the critical design load for symmetrical loading conditions may be selected without considering the effects of these lateral centre of gravity displacements on the loading of the main gear elements, or on the aeroplane structure provided –

(1) The lateral displacement of the centre of gravity results from random passenger or cargo disposition within the fuselage or from random unsymmetrical fuel loading or fuel usage; and

(2) Appropriate loading instructions for random disposable loads are included under the provisions of CS 25.1583(c)(1) to ensure that the lateral displacement of the centre of gravity is maintained within these limits.

(c) *Landing gear dimension data.* Figure 1 of Appendix A contains the basic landing gear dimension data.

CS 25.473 Landing load conditions and assumptions

ED Decision 2003/2/RM

(a)For the landing conditions specified in CS 25.479 to 25.485, the aeroplane is assumed to contact the ground:

(1)In the attitudes defined in CS 25.479 and CS 25.481.

(2) With a limit descent velocity of 3·05 m/sec (10 fps) at the design landing weight (the maximum weight for landing conditions at maximum descent velocity); and

(3) With a limit descent velocity of 1·83 m/sec (6 fps) at the design take-off weight (the maximum weight for landing conditions at a reduced descent velocity).

(4) The prescribed descent velocities may be modified if it is shown that the aeroplane has design features that make it impossible to develop these velocities.

(b) Aeroplane lift, not exceeding aeroplane weight, may be assumed, unless the presence of systems or procedures significantly affects the lift.

(c) The method of analysis of aeroplane and landing gear loads must take into account at least the following elements:

(1) Landing gear dynamic characteristics.

(2) Spin-up and spring back.

(3) Rigid body response.

(4) Structural dynamic response of the airframe, if significant.

(d) The landing gear dynamic characteristics must be validated by tests as defined in CS 25.723(a).

(e) The coefficient of friction between the tyres and the ground may be established by considering the effects of skidding velocity and tyre pressure. However, this coefficient of friction need not be more than 0·8.

CS 25.477 Landing gear arrangement

ED Decision 2003/2/RM

CS 25.479 to 25.485 apply to aeroplanes with conventional arrangements of main and nose gears, or main and tail gears, when normal operating techniques are used.

CS 25.479 Level landing conditions

ED Decision 2003/2/RM

(a) In the level attitude, the aeroplane is assumed to contact the ground at forward velocity components, ranging from V_{L1} to 1·25 V_{L2} parallel to the ground under the conditions prescribed in CS 25.473 with:

(1) V_{L1} equal to V_{S0}(TAS) at the appropriate landing weight and in standard sea-level conditions; and

(2) V_{L2}, equal to V_{S0}(TAS) at the appropriate landing weight and altitudes in a hot day temperature of 22.8°C (41°F) above standard.

(3) The effects of increased contact speed must be investigated if approval of downwind landings exceeding 19 km/h (10 knots) is requested.

(b) For the level landing attitude for aeroplanes with tail wheels, the conditions specified in this paragraph must be investigated with the aeroplane horizontal reference line horizontal in accordance with Figure 2 of Appendix A of CS-25.

(c) For the level landing attitude for aeroplanes with nose wheels, shown in Figure 2 of Appendix A of CS-25, the conditions specified in this paragraph must be investigated assuming the following attitudes:

(1) An attitude in which the main wheels are assumed to contact the ground with the nose wheel just clear of the ground; and

(2) If reasonably attainable at the specified descent and forward velocities an attitude in which the nose and main wheels are assumed to contact the ground simultaneously.

(d) In addition to the loading conditions prescribed in sub-paragraph (a) of this paragraph, but with maximum vertical ground reactions calculated from paragraph (a), the following apply:

(1) The landing gear and directly affected structure must be designed for the maximum vertical ground reaction combined with an aft acting drag component of not less than 25% of this maximum vertical ground reaction.

(2) The most severe combination of loads that are likely to arise during a lateral drift landing must be taken into account. In absence of a more rational analysis of this condition, the following must be investigated:

(i) A vertical load equal to 75% of the maximum ground reaction of CS 25.473(a)(2) must be considered in combination with a drag and side load of 40% and 25%, respectively, of that vertical load.

(ii) The shock absorber and tyre deflections must be assumed to be 75% of the deflection corresponding to the maximum ground reaction of CS 25.473(a)(2). This load case need not be considered in combination with flat tyres.

(3) The combination of vertical and drag components is considered to be acting at the wheel axle centreline.

CS 25.481 Tail-down landing conditions

ED Decision 2003/2/RM

(a) In the tail-down attitude, the aeroplane is assumed to contact the ground at forward velocity components, ranging from V_{L1} to V_{L2}, parallel to the ground under the conditions prescribed in CS 25.473 with:

(1) V_{L1} equal to V_{S0} (TAS) at the appropriate landing weight and in standard sealevel conditions; and

(2) V_{L2} equal to V_{S0} (TAS) at the appropriate landing weight and altitudes in a hot-day temperature of 22.8°C (41°F) above standard.

The combination of vertical and drag components is considered to be acting at the main wheel axle centreline.

(b) For the tail-down landing condition for aeroplanes with tail wheels, the main and tail wheels are assumed to contact the ground simultaneously, in accordance with Figure 3 of Appendix A. Ground reaction conditions on the tail wheel are assumed to act –

(1) Vertically; and

(2) Up and aft through the axle at 45° to the ground line.

(c) For the tail-down landing condition for aeroplanes with nose wheels, the aeroplane is assumed to be at an attitude corresponding to either the stalling angle or the maximum angle allowing clearance with the ground by each part of the aeroplane other than the main wheels, in accordance with Figure 3 of Appendix A, whichever is less.

CS 25.483 One-gear landing conditions

ED Decision 2003/2/RM

For the one-gear landing conditions, the aeroplane is assumed to be in the level attitude and to contact the ground on one main landing gear, in accordance with Figure 4 of Appendix A of CS-25. In this attitude –

(a) The ground reactions must be the same as those obtained on that side under CS 25.479(d)(1), and

(b) Each unbalanced external load must be reacted by aeroplane inertia in a rational or conservative manner.

CS 25.485 Side load conditions

ED Decision 2003/2/RM

In addition to CS 25.479(d)(2) the following conditions must be considered:

(a) For the side load condition, the aeroplane is assumed to be in the level attitude with only the main wheels contacting the ground, in accordance with Figure 5 of Appendix A.

(b) Side loads of 0·8 of the vertical reaction (on one side) acting inward and 0·6 of the vertical reaction (on the other side) acting outward must be combined with one-half of the maximum vertical ground reactions obtained in the level landing conditions. These loads are assumed to be applied at the ground contact point and to be resisted by the inertia of the aeroplane. The drag loads may be assumed to be zero.

CS 25.487 Rebound landing condition

ED Decision 2003/2/RM

(a) The landing gear and its supporting structure must be investigated for the loads occurring during rebound of the aeroplane from the landing surface.

(b) With the landing gear fully extended and not in contact with the ground, a load factor of 20·0 must act on the unsprung weights of the landing gear. This load factor must act in the direction of motion of the unsprung weights as they reach their limiting positions in extending with relation to the sprung parts of the landing gear.

CS 25.489 Ground handling conditions

ED Decision 2003/2/RM

Unless otherwise prescribed, the landing gear and aeroplane structure must be investigated for the conditions in CS 25.491 to 25.509 with the aeroplane at the design ramp weight (the maximum weight for ground handling conditions). No wing lift may be considered. The shock absorbers and tyres may be assumed to be in their static position.

CS 25.491 Taxi, take-off and landing roll

ED Decision 2016/010/R

(See AMC 25.415)

Within the range of appropriate ground speeds and approved weights, the aeroplane structure and landing gear are assumed to be subjected to loads not less than those obtained when the aircraft is operating over the roughest ground that may reasonably be expected in normal operation.

[Amdt 25/18]

AMC 25.491 Taxy, take-off and landing roll

ED Decision 2003/2/RM

1. PURPOSE. This AMC sets forth acceptable methods of compliance with the provisions of CS-25 dealing with the certification requirements for taxy, take-off and landing roll design loads. Guidance information is provided for showing compliance with CS 25.491, relating to structural design for aeroplane operation on paved runways and taxy-ways normally used in commercial operations. Other methods of compliance with the requirements may be acceptable.

2. RELATED CERTIFICATION SPECIFICATIONS. The contents of this AMC are considered by the Agency in determining compliance with CS 25.491. Related paragraphs are CS 25.305(c) and CS 25.235.

3. BACKGROUND.

   a. All paved runways and taxy-ways have an inherent degree of surface unevenness, or roughness. This is the result of the normal tolerances of engineering standards required for construction, as well as the result of events such as uneven settlement and frost heave. In addition, repair of surfaces on an active runway or taxy-way can result in temporary ramped surfaces. Many countries have developed criteria for runway surface roughness. The Inter-national Civil Aviation Organisation (ICAO) standards are published in ICAO Annex 14.

   b. In the late 1940's, as aeroplanes became larger, more flexible, and operated at higher ground speeds, consideration of dynamic loads during taxy, landing rollout, and take-off became important in aeroplane design. CS 25.235, CS 25.491 and CS 25.305(c) apply.

   c. Several approaches had been taken by different manufacturers in complying with the noted regulations. If dynamic effects due to rigid body modes or airframe flexibility during taxy were not considered critical, some manufacturers used a simplified static analysis where a static inertia force was applied to the aeroplane using a load factor of 2.0 for single axle gears or 1.7 for multiple axle gears. The lower 1.7 factor was justified based on an assumption that there was a load alleviating effect resulting from rotation of the beam, on which the forward and aft axles are attached, about the central pivot point on the strut. The static load factor approach was believed to encompass any dynamic effects and it had the benefit of a relatively simple analysis.

   d. As computers became more powerful and dynamic analysis methods became more sophisticated, it was found that dynamic effects sometimes resulted in loads greater than those which were predicted by the static criterion. Some manufacturers performed calculations using a series of harmonic bumps to represent a runway surface, tuning the bumps to excite various portions of the structure at a given speed. U.S. Military Standard 8862 defines amplitude and wavelengths of 1-cosine bumps intended to excite low speed plunge, pitch and wing first bending modes.

   e. Some manufacturers used actual runway profile data to calculate loads. The runway profiles of the San Francisco Runway 28R or Anchorage Runway 24, which were known to cause high loads on aeroplanes and were the subject of pilot complaints until resurfaced, have been used in a series of bi-directional constant speed analytical runs to determine loads. In some cases, accelerated runs have been used, starting from several points along the runway. The profiles of those runways are described in NASA Reports CR-119 and TN D-5703. Such deterministic dynamic analyses have in general proved to be satisfactory.

f. Some manufacturers have used a statistical power spectral density (PSD) approach, especially to calculate fatigue loads. Extensive PSD runway roughness data exist for numerous world runways. The PSD approach is not considered practical for calculation of limit loads.

g. Because the various methods described above produce different results, the guidance information given in paragraphs 4, 5, and 6 of this AMC should be used when demonstrating compliance with CS 25.491.

4. RUNWAY PROFILE CONDITION.

a. Consideration of airframe flexibility and landing gear dynamic characteristics is necessary in most cases. A deterministic dynamic analysis, based on the San Francisco Runway 28R (before it was resurfaced), described in Table 1 of this AMC, is an acceptable method for compliance. As an alternative means of compliance, the San Francisco Runway 28R (before it was resurfaced) may be used with the severe bump from 1530 to 1538 feet modified per Table 2. The modifications to the bump reflect the maximum slope change permitted in ICAO Annex 14 for temporary ramps used to transition asphalt overlays to existing pavement. The points affected by this modification are outlined in Table 1.

b. Aeroplane design loads should be developed for the most critical conditions arising from taxy, take-off, and landing run. The aeroplane analysis model should include significant aeroplane rigid body and flexible modes, and the appropriate landing gear and tyre characteristics. Unless the aeroplane has design features that would result in significant asymmetric loads, only the symmetric cases need be investigated.

c. Aeroplane steady aerodynamic effects should normally be included. However, they may be ignored if their deletion is shown to produce conservative loads. Unsteady aerodynamic effects on dynamic response may be neglected.

d. Conditions should be run at the maximum take-off weight and the maximum landing weight with critical combinations of wing fuel, payload, and extremes of centre of gravity (c.g.) range. For aeroplanes with trimable stabilisers, the stabiliser should be set at the appropriate setting for take-off cases and at the recommended final approach setting for landing cases. The elevator should be assumed faired relative to the stabiliser throughout the take-off or landing run, unless other normal procedures are specified in the flight manual.

e. A series of constant speed runs should be made in both directions from 37 km/h (20 knots) up to the maximum ground speeds expected in normal operation (V_R defined at maximum altitude and temperature for take-off conditions, 1.25 V_{L2} for landing conditions). Sufficiently small speed increments should be evaluated to assure that maximum loads are achieved. Constant speed runs should be made because using accelerated runs may not define the speed/roughness points which could produce peak dynamic loads. For maximum take-off weight cases, the analysis should account for normal take-off flap and control settings and consider both zero and maximum thrust. For maximum landing weight cases, the analysis should account for normal flap and spoiler positions following landing, and steady pitching moments equivalent to those produced by braking with a coefficient of friction of 0.3 with and without reverse thrust. The effects of automatic braking systems that reduce braking in the presence of reverse thrust may be taken into account.

5. DISCRETE LOAD CONDITION. One of the following discrete limit load conditions should be evaluated:

   a. With all landing gears in contact with the ground, the condition of a vertical load equal to 1.7 times the static ground reaction should be investigated under the most adverse aeroplane loading distribution at maximum take-off weight, with and without thrust from the engines;

   b. As an alternative to paragraph 5.a. above, it would be acceptable to undertake dynamic analyses under the same conditions considered in paragraph 4 of this AMC considering the aircraft response to each of the following pairs of identical and contiguous 1-cosine upwards bumps on an otherwise smooth runway:

      (i) Bump wavelengths equal to the mean longitudinal distance between nose and main landing gears, or between the main and tail landing gears, as appropriate; and separately:

      (ii) Bump wavelengths equal to twice this distance.

      The bump height in each case should be defined as:

$$H = A + B\sqrt{L}$$

      Where:

      H = the bump height

      L = the bump wavelength

      A = 1.2, B = 0.023 if H and L are expressed in inches

      A = 30.5, B = 0.116 if H and L are expressed in millimetres

6. COMBINED LOAD CONDITION. A condition of combined vertical, side and drag loads should be investigated for the main landing gear. In the absence of a more rational analysis a vertical load equal to 90% of the ground reaction from paragraph 5 above should be combined with a drag load of 20% of the vertical load and a side load of 20% of the vertical load. Side loads acting either direction should be considered.

7. TYRE CONDITIONS. The calculation of maximum gear loads in accordance with paragraphs 4, 5, and 6, may be performed using fully inflated tyres. For multiple wheel units, the maximum gear loads should be distributed between the wheels in accordance with the criteria of CS 25.511.

[Amdt 25/2]

ED Decision 2003/2/RM

TABLE 1

SAN FRANCISCO RUNWAY 28R

ONE TRACK
LENGTH: 3880 FEET
NUMBER OF POINTS: 1941
POINT SPACING: 2 FEET
ELEVATIONS: FEET
REFERENCE SOURCE: REPORT TO NASA (EFFECTS OF RUNWAY UNEVENNESS ON THE DYNAMIC RESPONSE OF SUPERSONIC TRANSPORTS), JULY 1964, U. OF CALIF. BERKELEY.

RUNWAY ELEVATION POINTS IN FEET (READ ROW WISE):

Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.
0.00	10.30	2.00	10.31	4.00	10.30	6.00	10.30	8.00	10.31	10.00	10.32	12.00	10.33	14.00	10.34
16.00	10.35	18.00	10.36	20.00	10.36	22.00	10.37	24.00	10.37	26.00	10.37	28.00	10.38	30.00	10.39
32.00	10.40	34.00	10.40	36.00	10.41	38.00	10.41	40.00	10.42	42.00	10.43	44.00	10.43	46.00	10.44
48.00	10.44	50.00	10.44	52.00	10.44	54.00	10.44	56.00	10.45	58.00	10.46	60.00	10.47	62.00	10.47
64.00	10.48	66.00	10.49	68.00	10.49	70.00	10.50	72.00	10.50	74.00	10.50	76.00	10.50	78.00	10.50
80.00	10.50	82.00	10.49	84.00	10.49	86.00	10.49	88.00	10.49	90.00	10.50	92.00	10.50	94.00	10.51
96.00	10.51	98.00	10.52	100.00	10.52	102.00	10.52	104.00	10.53	106.00	10.53	108.00	10.54	110.00	10.54
112.00	10.55	114.00	10.55	116.00	10.55	118.00	10.55	120.00	10.54	122.00	10.55	124.00	10.55	126.00	10.56
128.00	10.57	130.00	10.57	132.00	10.57	134.00	10.57	136.00	10.57	138.00	10.58	140.00	10.57	142.00	10.57
144.00	10.58	146.00	10.57	148.00	10.56	150.00	10.56	152.00	10.56	154.00	10.56	156.00	10.56	158.00	10.56
160.00	10.56	162.00	10.56	164.00	10.55	166.00	10.55	168.00	10.55	170.00	10.56	172.00	10.57	174.00	10.57
176.00	10.57	178.00	10.57	180.00	10.56	182.00	10.55	184.00	10.55	186.00	10.55	188.00	10.55	190.00	10.55
192.00	10.56	194.00	10.56	196.00	10.56	198.00	10.56	200.00	10.55	202.00	10.54	204.00	10.53	206.00	10.52
208.00	10.52	210.00	10.52	212.00	10.52	214.00	10.52	216.00	10.52	218.00	10.53	220.00	10.52	222.00	10.52
224.00	10.51	226.00	10.52	228.00	10.52	230.00	10.51	232.00	10.52	234.00	10.52	236.00	10.53	238.00	10.53
240.00	10.53	242.00	10.53	244.00	10.53	246.00	10.53	248.00	10.53	250.00	10.53	252.00	10.53	254.00	10.52
256.00	10.53	258.00	10.54	260.00	10.54	262.00	10.54	264.00	10.54	266.00	10.54	268.00	10.54	270.00	10.55
272.00	10.55	274.00	10.54	276.00	10.55	278.00	10.55	280.00	10.56	282.00	10.57	284.00	10.58	286.00	10.59