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MATERIALS AND STRUCTURE DIVISION

SP3 DEPARTMENT

Landing - Flammability - Crash

Research Programme for civil aviation safety

Seat-floor attachment strength

1 - INTRODUCTION

In a crash situation, requirements for occupant survival of impact hazards are mainly the ability of the aircraft to maintain living space for occupants, the intensity and duration of accelerations experienced by occupants, post-crash hazards (fire,…) following the impact sequence and the strength of the equipment linkage preventing occupant from injuries in case of breaking free. Seat floor attachment strength is far concerned with this last consideration.

As part of this preoccupation, FAA has established by 1988 crash sizing regulations after a great deal of studies and tests to preserve a certain level of survivability for aircraft occupants. As a result, seat manufacturers have been developing for many years stiffer seat designs to comply with these regulations. But, this initiative led to a significant augmentation of loads introduced to the floor and to question the validity of regulations. Furthermore, a program research performed by Mr Cherry under the sponsorship of Civil Aviation Authority pointed out that in some accidents involving transport category aircraft, some failures occurred on seat floor attachment.

Following the conclusions of the CAA study and FAA interests, DGAC (French civil aviation authority) decided to sponsor a research program to analyse the interface behaviour between the seat and the cabin floor. Since preliminary investigations presented during the second Triennial International Aircraft Fire and Cabin Safety Research Conference in 1998, CEAT and AIRBUS in co-operation with seat suppliers and the FAA have been keeping on with their investigations on the subject.

2 - SCOPE OF THE STUDY

The main objective of this program is to assess the influence of seat stiffness on cabin floor strength undergoing dynamic solicitations. Thus, criteria likely to account for cabin floors failures have to be analysed to appreciate the compliance of cabin floor crash sizing with respect to the current regulation.

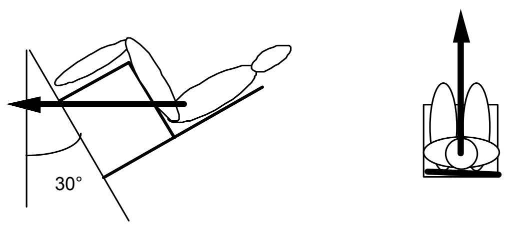
Three main factors are concerned with this topic :

2.1 - CRASH SIZING CRITERIA FOR SEATS AND CABIN FLOORS

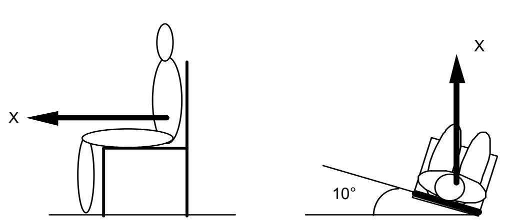
Crash sizing substantiation of cabin floors and seats is demonstrated in two different ways. First ones are statically crash sized (aircraft manufacturer responsibility) while the others are dynamically crash sized (equipment supplier responsibility) :

- Seat solicitations defined by § 25.562 of the Code of Federal Regulations consist on deceleration pulses applied throughout two dynamic tests :

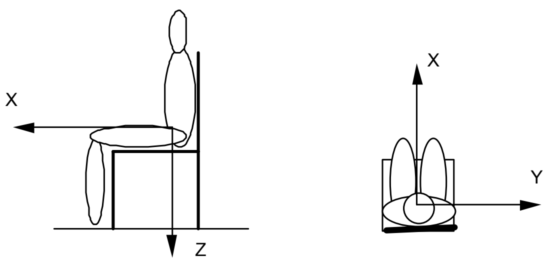
TEST 1 : 14g deceleration



TEST 2 : 16g deceleration



- Cabin floor solicitations defined by § 25.561 of the CFR consist on static loading application. Loading is applied independently at the centre of gravity of the system [seat + occupant] :



Load cases (with application of 1.33 fitting factor) :

9g forward
1.5g rearward
6g downward
3g upward
3g side

In addition, descriptions above are associated with assumptions:

- Seats and occupants are supposed to be rigid in static testing.
  Seats and dummies are flexible and set in motion in dynamic testing.

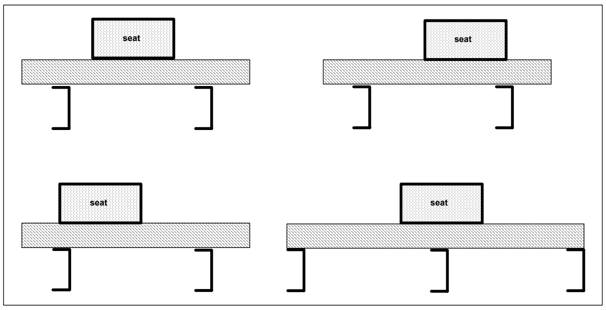
- Cabin floors are composed of cross beams and rails in static testing.
  Cabin floors are infinitely stiff in dynamic testing (only upper part of seat rails considered).
  Besides, floor distortion is simulated in ***TEST 2*** to pre-constraint seat legs.

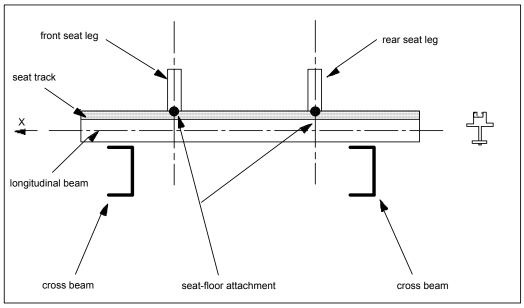
Nevertheless, static loading introduction to the floor structure can not be exactly representative of dynamic effects that occurs during a crash scenario because of the structure dynamic response very hard to be appreciated correctly and peak values associated which could be very critical. On the other hand, dynamic testing only takes into account rail lips strength evaluation but not the structure below.

Those two considerations does not give confidence in the lower structure strength all the more that new seat designs are supposed to induce higher loads in the structure. Thus, the survivability level provided by independent crash sizing substantiation of seats and cabin floors is called into question.

2.2 - INFLUENCE OF SEAT POSITION ON THE CABIN FLOOR

The distribution of loads introduced to the floor can obviously be more or less critical with respect to seat position. Considering one seat and given cross beam pitch, four extreme floor loading cases exist :





Generally, the introduction of seat loads to the cabin floor can affect two or even three cross beams and two rail support beams. In addition, rails can either be fitted on to the rail support beam or directly integrated into the rail support beam.

Secondary cases appear for different kind of seats in terms of stiffness, dimension and pitch. As a result, different seat floor attachment configurations exist and numerous cases should be analysed to determine the whole envelope of the cabin floor resistance.

2.3 - INFLUENCE OF THE NUMBER OF ATTACHMENT POINTS

In case of a crash, the aircraft forward velocity is decreased by numerous impacts on obstacles. These velocity changes lead on application of g-deceleration on occupants who are by the way set in motion. As a result, serious head impacts could happen on any obstacles. Furthermore, loads applied on seats through the restrain system could either broke the seat floor attachment or give excessive harmful residual deformations. All those facts could prevent occupants' evacuation during a crash scenario and so chances of survival.

As highlighted in introduction, some seat manufacturers have been developing stiffer seats to limit these effects. This unavoidably leads to increase the tension loads on rear seat floor attachments and by evidence, the length of linear attachments to ensure a better distribution of the loading on a larger part of the structure.

3 - STUDY PROPOSAL

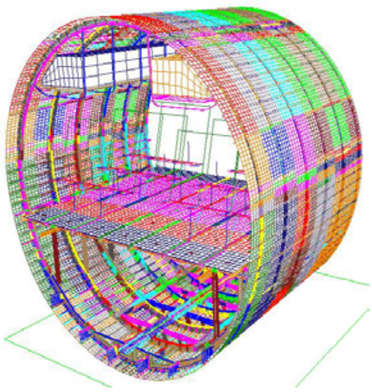
To predict the cabin floor behaviour by taking into account all the configurations a.m., a mixed approach composed of testing and numeric simulation by finite element method was unavoidable. The interest of testing is obvious to verify the model approach and to give an appreciation of the degree of prediction of numerical tools. On the other hand, the interest of using numerical tools is essential to perform some virtual tests with reduced costs by diminishing consumption of aircraft structures. In that way, the aircraft floor modelling associated to realistic load introduction will lead to reliable conclusions on the attachment behaviour.

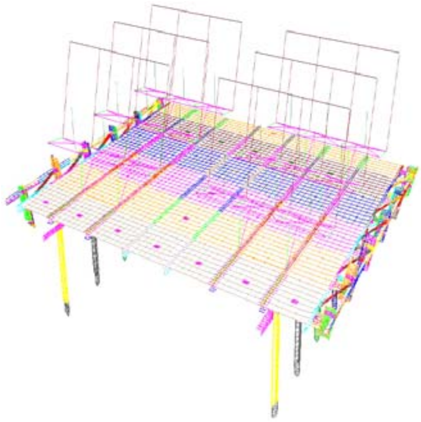
3.1 - AIRCRAFT FLOOR MODELLING

The first common intention of CEAT and AIRBUS was to design half of a six frames "test floor" fitted with only one seat. But preliminary simulations highlighted major displacements on the middle of the structure impossible to be reproduced with the initial test floor. Consequently, the use of a complete floor section was unavoidable but with the advantage of two seat rows tested at the same time.

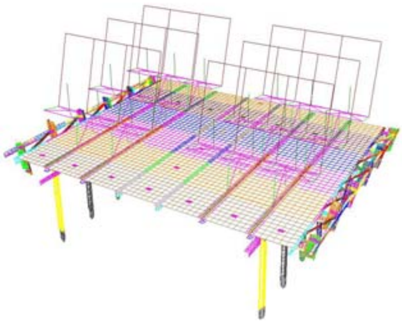
This task included two steps :

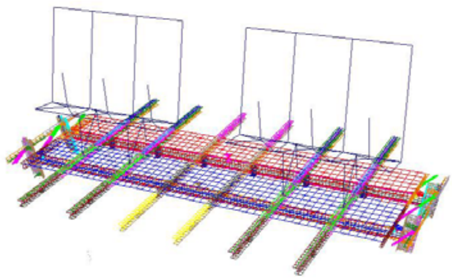
- The utilisation of a whole cabin floor model developed by AIRBUS as part of the European Project "Crashworthiness for commercial aircraft" : a six frames floor model was extracted from a entire aircraft model already validated by drop tests performed at CEAT in 1995 :





- The determination of a two frames "test floor" model instead of six to take into account test facility limitation : AIRBUS developed a two frames floor model capable of reproducing the same behaviour than a representative six frames cabin floor :





Pre-test simulations demonstrated the interest to increase the seat tracks in order to represent the global stiffness of the floor. The load introduction was carried out by a seat model not representative of realistic seats but that could give an acceptable approach in terms of behaviour prediction and boundary conditions.

Thus, AIRBUS simulations showed the good correlation between the "six frames" and the "two frames" models. Loads measured at the seat floor attachment were in accordance with those used to design statically the floor. Afterwards, the model had to be validated by dynamic testing in terms of impact conditions, characteristics of seats, model of passengers and stiffness of the testing rig. Discussions held between partners pointed out the need to set up the floor panels for tests in order to be all the more representative by considering the transmission of shear loads to the X beams located between the fuselage and the floor.

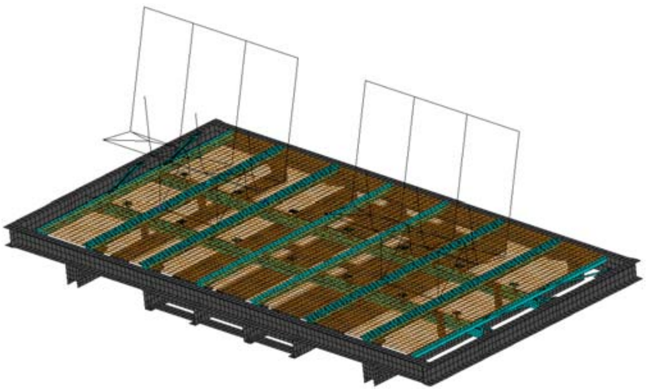
3.2 - SEAT DEFINITION

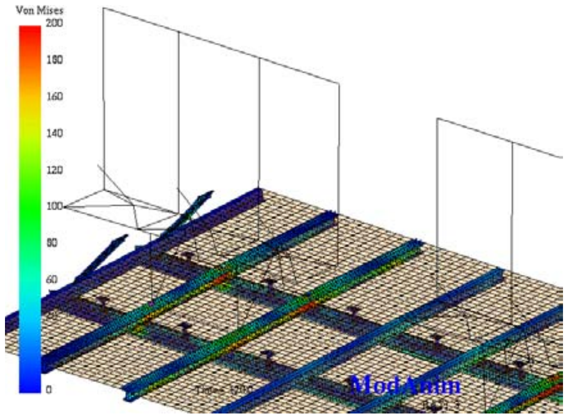
Documents on crash expertise do not clearly highlight which seat design are concerned by seat floor attachment failures pointed out throughout the inquiry sponsored by the CAA. As a result, it was possible to use a very stiff dummy seat to enable partners to work without involving a product from seat manufacturer. Nevertheless, a non representative seat would have limited the impact of the program results.

Consequently, after agreement between each partner of the program, triple tourist class seats were chosen because the more loaded as usually three people are sat on it and the most statically used in transport aircraft. As a consequence, SICMA AEROSEAT and KOITO seat suppliers were involved in the program for co-operation in terms of delivering to CEAT realistic triple seats equipped with different number of rear studs attachments, assuming that KOITO seats fitted with more anchoring points were stiffer than SICMA seats.

3.3 – DETERMINATION OF DYNAMIC LOAD SPECTRA

Discussions held between partners finally led to the definition of an agreed test program. The main issue was to assess the load introduced during a dynamic test with representative floor and real seat attachment on the cabin floor :





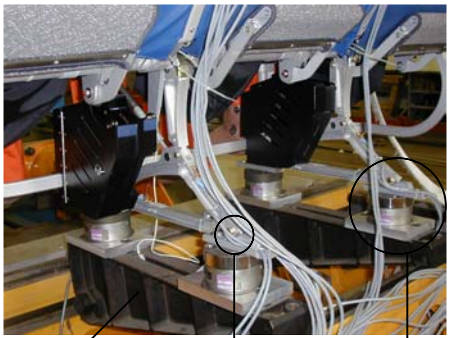
The issue was that direct measurement of loads introduced to the cabin was not possible because the interposition of loads transducers between seat legs and floor structure would have modified the real interface nature. As a result, intermediate tests had to be performed to calibrate the deformation of seat legs with regards to loads introduced to the floor : in that way, seats were to act as load transducers.

Other measurement equipment were installed on the testing platform to have sufficient test data to perform the correlation with the numerical model. Accelerometers and strain gages were installed on seats and floor at significant areas. Videos and high speed cameras recorded every step of the impact sequences. Anthropomorphic dummies equipped with seat belt transducers were located on each seat to simulate the presence of occupants.

Preliminary calibration tests :

- TEST 1: infinitely rigid floor, seat with three rear anchoring points – 9g deceleration pulse
- TEST 2: infinitely rigid floor, seat with three rear anchoring points – 9g deceleration pulse
- TEST 3: infinitely rigid floor, seat with four rear anchoring points – 9g deceleration pulse
- TEST 4: infinitely rigid floor, seat with four rear anchoring points – 16g deceleration pulse
- TEST 5: infinitely rigid floor, seat with four rear anchoring points – 16g deceleration pulse

Test rig installation



Load transducer

Infinitely rigid floor

Strain gage on rear leg seat

As only two triple tourist seats by supplier were available, it was essential to avoid failures on the seats during first calibration tests. It was the reason why 9g-deceleration pulse was applied for ***TEST 1*** and ***TEST 2*** on SICMA seats (in the same way ***TEST 3*** for KOITO seats).

The main objectives of these tests were :

- To demonstrate the measurement repeatability with the same kind of seat,

- To rely on the possibility to obtain calibration curves by the way of special post-processing (loads versus seat rear leg deformation values),

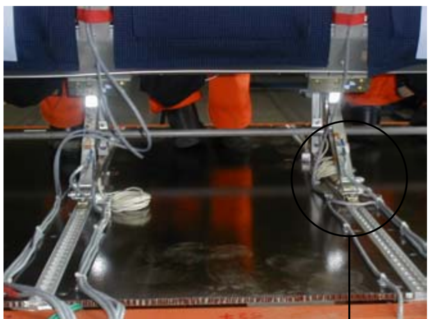
- To validate strain gages location on the vicinity of anchoring points to get useful measurements.

- To deduct loads by the interpretation of calibration curves a.m.

TEST 4 and ***TEST 5*** performed at 16g-deceleration pulse led to dynamic calibration of strain gages for the final representative 16g test.

The last representative 16g test was performed with SICMA and KOITO seats equipped with different numbers of studs to bring out the influence of the number of attachment points and the difference of seat stiffness during the same test.

Test rig equipped with two triple tourist seats fitted with different number of rear studs



Seat floor attachment representative of a real aircraft configuration

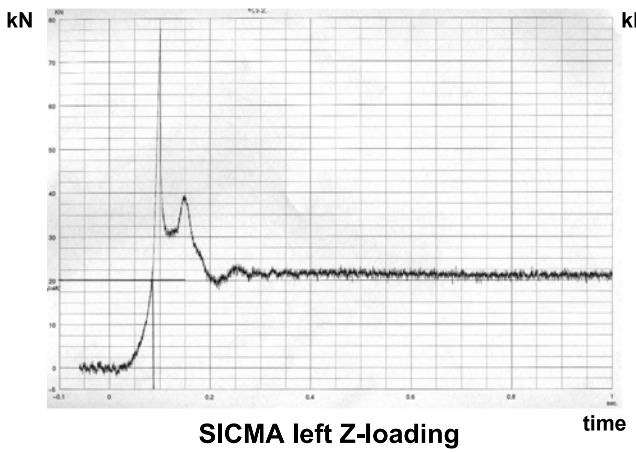
3.4 – PRELIMINARY RESULTS

First calibration tests at 9g deceleration pulse performed with infinitely rigid floor showed that the behaviour of each seat was quasi-linear : a quasi zero-deformation was observed once loads cancelled. Nevertheless, the difference of seats stiffness did not seem to be significant whereas similar level of loads were measured by transducers with identical dynamic loading applied in each case.

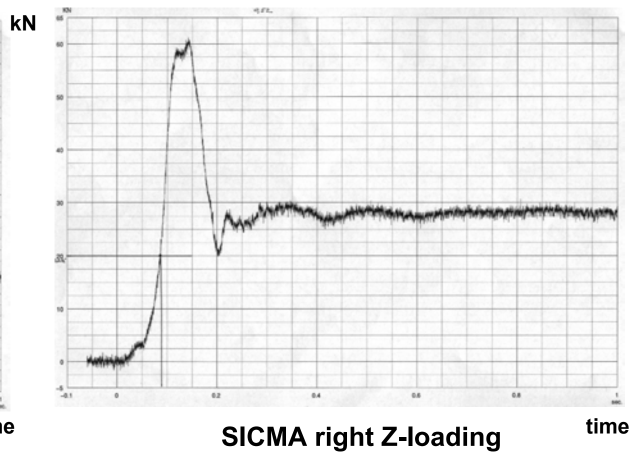
Calibration tests at 16g deceleration pulse seemed to confirm that stiffness difference was not so significant for higher loading. For each kind of seat, plastic deformation occurred for a comparable level of solicitation.

Concerning the last 16g test with cabin floor representative of a real structure, no rupture nor plastic deformation of any cabin floor part was observed in the area of seat floor attachment.

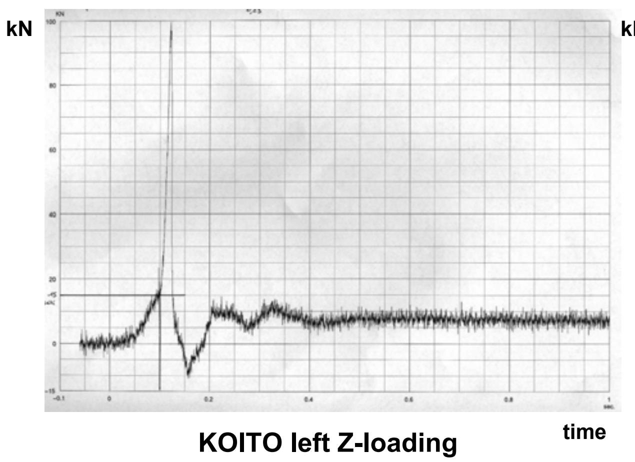
Calibration curves (*deformation versus loading*) and strain measurement recorded on rear part of legs seats during the last test will enable CEAT to determine the evolution of loads versus time in the three directions X, Y and Z. At the moment, only Z-direction data are available :



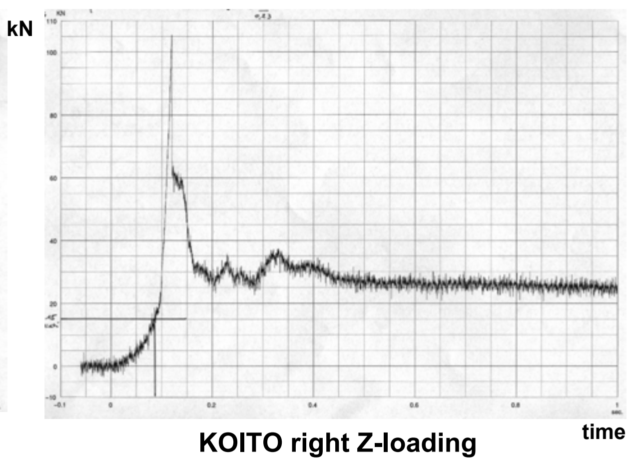
SICMA left Z-loading



SICMA right Z-loading



KOITO left Z-loading



KOITO right Z-loading

As a very first approach, Z-loading values observed on these results seem to be higher for KOITO seats than for SICMA. This could means that higher loads are theoretically introduced by KOITO seats to the floor. Nevertheless, difference on peak values is not so evident all the more that peaks duration is very brief. Z-loads combined with loads in X and Y-directions need to be analysed to complete this preliminary analysis.

4 – CONCLUSION

Test measurements will enable AIRBUS to validate pre-test simulations and the FE floor modelling. This will aim at performing virtual tests to analyse the influence of different parameters such as seat location, stiffness, pitch on the cabin floor resistance. Afterwards, these conclusions should be extrapolated to a whole aircraft cabin floor as a final stage.

As a first approach, tests and simulations showed that the floor structure was sized properly. But at the moment, the influence of the seat stiffness on the cabin floor behaviour is not so evident. Nevertheless, 16g dynamic tests according to § 25.562 of CFR are performed with a floor distortion (10° pitch and 10° roll applied on each rail). With this consideration, we can wonder if such configuration would be or not essential in terms of seat rigidity and would modify seats strength during dynamic solicitation. CEAT investigates at the moment the possibility to obtain from seat suppliers the results of certification ***TEST 2*** to assess this difference.

Those primary investigations will lead to know if the cabin floor structure below rail lips is still able to withstand loads applied by new seat designs and whether the survivability level provided by such seats is coherent with the cabin floor crash sizing regulation.

The other point is that deceleration levels obtained during crash scenarios investigated by Mr Cherry were higher than those taken into account for seat crash sizing. So, even though failures occurred on seat floor attachment would not have been necessarily avoided by the use of crash sized seats in some cases, higher levels in crash sizing regulations should perhaps be considered.

At a final stage, conclusions of this program could even more be used to draw up a list of structure modifications which would be necessary to ensure the seat floor attachment strength. Data base of Mr Cherry's study among others will give assessment of potentially saved lives what could lead to analyse costs and advantages of such considerations.

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