

AEROSPACE INFORMATION REPORT

SAE AIR4243

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Landing Area/Landing Gear Compatibility - A Brief History of SAE/Corps of Engineers Cooperation

1. SCOPE:

This document discusses the work done by the U.S. Army Corps of Engineers and the Waterways Experiment Station (WES) in support of SAE A-5 Committee activity on Aerospace Landing Gear Systems. It is an example of how seemingly unrelated disciplines can be combined effectively for the eventual benefit of the overall aircraft system, where that system includes the total airfield environment in which the aircraft must operate.

In summary, this AIR documents the history of aircraft flotation analysis as it involves WES and the SAE.

2. BACKGROUND:

The U.S. Army Engineer Waterways Experiment Station is located at Vicksburg, Mississippi. It was established in 1929 as a hydraulics laboratory to help control floods in the lower Mississippi valley. Today, WES is a research, development and testing complex of six internationally recognized laboratories supporting the civil and military missions of the Corps of Engineers and the United States of America. WES currently has a work program funded by 120 sponsors who pay all project costs on a reimbursable basis. The sponsors include the Corps of Engineers, other Federal agencies, and, under special conditions, private industry and foreign agencies/governments.

3. DISCUSSION:

The U.S. Army Corps of Engineers (CE) and the Waterways Experiment Station have been associated with SAE Committees (A-12 and A-5) on Aerospace Landing Gear Systems since 1950. The SAE committees have been concerned with "aircraft ground flotation" since that time.

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3. (Continued):

In January, 1951, a conference on flotation provided information on flexible pavement design and on runway construction time, which contributed to development of a Unit Construction Index or UCI. This led to publication in March 1953 of the Technical Memorandum Report WCLS 53-13, "The Unit Construction Index Chart for Aircraft Ground Flotation Evaluation," by the U.S. Air Force Wright Air Development Center. It was intended that the UCI chart would be placed in the "Handbook of Instructions for Aircraft Designers (HIAD)" and the UCI used to constrain aircraft landing gear design so as to limit the need for airfield upgrading to accommodate each new aircraft.

The SAE landing gear committee had an immediate interest in flotation. The committee included members from many airframe manufacturers, tire and gear component manufacturers, and Air Force procurement and mechanical development elements. However, the committee had little awareness of pavement behavior. CE and WES were invited to attend as committee visitors, and the association has continued to the present. Through the years, this association has provided a valuable forum for exchange of knowledge between the two interacting technologies of landing gear design concerns and landing area load support considerations. The association has contributed to sponsorship of research in aircraft ground flotation and other aircraft pavement interaction matters and has helped to shape research programming toward more useful and valuable results.

The UCI was incorporated into the HIAD but the simplistic basis of its development soon resulted in shortcomings pointed out by SAE committee members. With Air Force support and guidance and CE backing, as the agency responsible for civil engineering support of the Air Force, WES first devised the Construction Index as an improvement of the UCI, but this too was not sufficient. By this time there was Air Force concern for assault field operation of some transport aircraft and the need for HIAD (or equivalent) guidance, which could be used to limit aircraft support requirements for both conventional pavements and for providing capability to operate from bare soil landing strips.

Accordingly, the WES, under guidance and acting for the Air Force R & D Directorate, undertook to produce guidance for limiting flotation requirements of aircraft for both conventional pavements (in the Zone of Interior or ZI) and for expedient military airstrips (in the Theater of Operations or TO). This work was published in December 1961 and revised in July 16, 1965 as WES MP 4-459, "Ground Flotation Requirements for Aircraft Landing Gear" and covered both ZI and TO airfields. With some adjustments by committee negotiation, this flotation guidance was adopted and placed into the HIAD in 1964, replacing the UCI.

The committee indicated concern for landing mat-surfaced airfields in 1962 and WES, through committee meeting participation, provided desired information on landing mat and membrane-surfaced airstrips.

3. (Continued):

Late in 1963 the United States Air Force (USAF), spurred by the SAE landing gear committee activities, provided WES funds to initiate an extensive research effort to improve aspects of aircraft ground flotation on assault type TO airfields. This was related to the CX-X (large cargo-type aircraft) which shortly became the CX-HLS (heavy load system) and ultimately the C-5 aircraft. Following in 1964, the USAF provided substantial funding of Project 410-A, which supported flotation studies resulting in some 20 reports essentially completed by the end of 1966.

In February 1965, the USAF issued SEFL-165A, based on information then in the HIAD, but supplemented by other WES information. The title is "Evaluation of C-5A Aircraft Ground Flotation Characteristics for Operation from Flexible Pavements." This treated flotation limitations in relation to conventional bituminous surfaced pavements.

In March 1967, the USAF issued SEFL-167, based on WES unsurfaced airstrip criteria and results of the extensive (Project 410-A) forward area airstrip flotation study effort just completed. The title is, "Evaluation of Aircraft Landing Gear Ground Flotation Characteristics for Operation from Unsurfaced Soil Airfields." As the title indicates, this treated flotation limitations in relation to unsurfaced soil airstrip operations and was needed in relation to the C-5A aircraft development.

In mid-1967 SST development required Boeing and Lockheed to assure that the aircraft would be compatible with 15 major airports. This provided airplane designers their first real concern for design constraints to protect or to avoid required strengthening of existing airfields. Airport Operators Council International (AOCI) became party to an exercise directed at establishing a rational means for showing compatibility. The SAE committee was, therefore, required to work with the industry groups that strongly influenced the International Civil Aviation Organization (ICAO) efforts toward uniform aircraft weight bearing reporting of airfield capacities.

It was also in mid-1967 that the advent of the Boeing 727 aircraft, with its capability to operate into shorter runways, was creating an extensive problem of overload distress. This problem added emphasis to ground-flotation concerns.

The Boeing 747's complex 16-wheel main landing gear was obviously influenced by WES flotation information made available through the SAE committee activities and associations. The 747 aircraft, at over twice the weight of the heaviest prior commercial jet, did not require extensive strengthening of runways, and all subsequent wide-body aircraft have made use of flotation criteria. Responsible WES engineers (R. G. Ahlvin and D. N. Brown) were accorded the Arch T. Colwell Merit Award in May 1968 by the SAE for this flotation work.

3. (Continued):

In October 1968, WES reported to the SAE committee on the preparation of a Many-Wheel Heavy Gear Load (MWHGL) test section. This was undertaken to examine the effects of 747 and C-5A gear loads on conventional flexible and rigid pavements, and was a joint effort of the Army, Air Force, and FAA.

Completion of these tests provided a basis for adjustment of design relations to accommodate the loadings associated with aircraft similar to C-5 and 747. A rigid pavement longitudinal joint problem developed and, as a result of further studies, the conservatism of directly extrapolated prior design relations was adjusted. All these operations were reported to the SAE committee.

In the following years, WES studies of interest to the SAE committee included lateral distribution of aircraft during taxiing, takeoff, and landing; aircraft dynamic load studies; an Aircraft-Pavement Compatibility Study attempting to examine the trade-off between requiring good aircraft ground flotation and requiring airfield pavement upgrading; porous friction course developments for skid control; predicting aircraft performance on unsurfaced soil from observed behavior of typical military ground vehicles; nondestructive pavement test developments leading to the FAA and ICAO accepted DSM (Design stiffness modulus) methods; development of airfield evaluation curves for C-5, C-141, DC-10, 747, 727, L-1011, DC-9, etc.

In November 1973, Mr. Harry H. Ulery, Jr. was invited to become the WES liaison representative on Committee A-5, with D. M. Ladd as an alternate.

In April 1979, a comprehensive summary of WES pavement research covered aspects of new concern for rapid repair and restoration of war-damaged runways. This work was coincident with the U.S. Air Force Rapid Runway Repair Program conducted by the Tyndall AFB Engineering and Services Center which includes the "Have Bounce" program for roughness effects on aircraft. Smoothness of runway repairs was of particular concern.

Also in April 1979, the SAE committee discussed the confusion caused by four diverse methods being used for determining aircraft ground-flotation limitations. It was pointed out that the Defense Mapping Agency had adopted the revised British load classification number (LCN)¹ for flotation reporting in Aeronautical Information Publications (AIP) and the Air Force was following this lead. Mention was made of the new international guide about to be presented; a reference to the subsequently adopted ACN/PCN (aircraft classification number/pavement classification number) developed by ICAO. It was intended to be the only acceptable flotation reporting means for use in AIP documents.

3. (Continued):

¹ The British devised the LCN, which achieved wide acceptance, especially in Europe. This was the original LCN, which was significantly modified in the mid-1970's and became the basis of the British LCG. It is the earlier version, which has been widely used, but the revised version is the LCN adopted by the Defense Mapping Agency in St. Louis. Hopefully the ICAO ACN/PCN method will replace all LCN and other weight bearing reporting methods.