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CONSEQUENCES OF THE LARGE COMMERCIAL AIRCRAFT CRASH INTO THE INTERIM SPENT FUEL STORAGE FACILITY

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ABSTRACT

The paper deals with the large commercial aircraft crash into the Interim Spent Fuel Storage Facility building structure as a results of terrorist attack. Importance of this loading rises after September 11 and knowledge of response and realistic resistance of the nuclear facilities structures is required. The paper presents possibilities of application of aircraft crash loading on the building structure, determination of loading parameters (aircraft velocities, angles of impact) and introducing into the FEM models. Information is provided on the analyses results of aircraft crash scenarios performed for Interim Spent Fuel Storage Facility building structure design which is under preparation for Temelin site.

Keywords: impact; aircraft crash; Spent Fuel Storage Facility; building structure

1. INTRODUCTION

It is necessary to consider the aircraft crash into building structure in case where risk of this event occurrence is high or this event could have significant social impacts. The aircraft crash has been considered for instance in design of several highrise buildings and this event is envisaged also in design of safety important buildings of nuclear power plants. Usually the load determination caused by the aircraft crash is based on assumption that it happen due to accident. However, the intended attack by large aircraft crash became prominent problem after September 11, 2001. The change of reasons of aircraft crash has significant impacts on the way used to determine loads based on the aircraft type as well as its velocity and crash direction.

This paper contains discussion on determination of loads caused by large aircraft crash due to intended act. In addition possibilities to introduce these loads into computing model for building structure are provided. The problems are resolved from the point of view of design of safety important building structures in nuclear power plant. Problems are exemplified by calculations carried out within framework of study of upcoming Interim Spent Fuel Storage Facility for Temelin site.

2. DETERMINATION OF LOADS

As mentioned above the loads caused by aircraft crash were usually determined until the September 11th 2001, provided that the aircraft crash occurred due to accident. With this assumption the load parameters are determined based on the data about air traffic as well as based on data about accident frequency of individual aircraft types. Then the probability to hit reviewed building by an aircraft of certain group is determined based on the product of ratio of building to assessed area and accident frequency for this group of aircraft in this region. Based on these analyses the relevant group of planes as well as typical mass of aircraft is identified, which should be considered in structure design. Depending on the aircraft type and on the flight stage also the speed in time of crash and angle of incidence are determined.

However in case of loads caused by intended act the above mentioned methodology can not be used more. This is why that in case of intended attack the behavior can not be determined in correct way. Generally it is possible to say that the absolute protection against the intended attacks can not be provided. Should certain general reference load be determined for each kind of attack the attacker could be forced to carry out the attack either with greater intensity or using other kind of attack not considered so far. This is why the nuclear power plant protection is based on preventive measures and on physical guarding the site of plant reducing risk of intended attack and extending the distance where the possible attack can be carried out from. However in case of attack using large transport aircraft the standard methods of nuclear power plant guarding provide the minimum influence. In such case the risk can be reduced by higher level of security of aircraft and airports what applies after the September 11th 2001.

When determining the aircraft type, which could be used for attack, it is possible to come out from two possibilities. The aircraft type could be determined according to the structure of air traffic in given region or according to the consequences of aircraft crash. When we assume that the aim is to cause as great as possible damage then we need to take into account attack carried out by long-range aircraft. Such airplanes feature with higher mass but particularly the volume of transported fuel is much higher. While in case of the short-range airplanes the share of fuel on the total mass present about 30% in case of the long-range aircraft the share of fuel is over 45%. It resulted from the attack on September, 11th 2001, that fire could be decisive factor in regard to resistance of struck structure – both the World Center Towers have been destroyed due to fire but not due to aircraft hit.

When determining the aircraft speed at the moment of crash the operating parameters as well as parameters of reviewed building and its surroundings are to be accounted. The maximum aircraft velocity depends on power of its motors and on the flight level where the aircraft flies. The maximum aircraft velocity is restricted by strength of aircraft structure (i.e. by its capability to bear up the acting aerodynamic forces). In addition another restrictive factor is the velocity leading to loss of plane control (airflow around the plane and air turbulence cause plane control worsening at higher velocities). It is also necessary to assume that attacker wish to hit him selected building, so he must choose such velocity allowing him to hit building with confidence. Thus, in addition to plane operating parameters the plane velocity in time of crash is significantly affected by the reviewed building parameters and its surroundings (floor plan dimensions and height, barriers in surroundings). Results of investigation FEMA-403 (2002) show that in case of the WTC towers the velocity of crash was 221m/sec for the WTC1 and up to 262m/sec for the WTC2. In case of the attack on Pentagon building the crash velocity is estimated for 350-mph (i.e. 156 m/sec) (NEI 2002). These velocities were determined based on the analysis of different records acquired in time of attack. The plane velocities in case of the WTC towers exceed the maximum velocities provided by producer. Such high velocities were allowed thanks to their height and visibility of hit buildings when flying on the relatively high flight level and the flight direction fine-tuning is not necessary. In case of the Pentagon building crash the plane velocity was substantially lower due to need to perform precision flight close to ground.

Land coverage near NPP building affects not only velocity in the instant of crash but also determination of directions and angles allowing to hit the assessed building. Determining directions and angles allowing hitting building it is necessary to take into account plane maneuverability as well as hijacker professionalism. In case of inexperienced hijacker or hijackers with small experience with given type of plane the attack rather from free approachable directions could be expected where significant flight correction is not necessary. Similarly also an angle of crash can be determined assuming that attacker will wish to keep direct visibility of target. The tests were carried out on the flight simulator B737 located in the CSA Training Center within framework of study of bellow described Spent Fuel Storage Facility for Temelin site. The plane descent times from the routine flight levels and possibilities to hit target as well as expected angles of incidence on roof and walls were verified. Results from these tests show that in case of freestanding building the most unfavorable angle (perpendicular hit) could be expected on walls. In case of roof the hit angle depends on hijacker professionalism. Regarding an uncontrollable increase of velocity in case of dive flight it is necessary to start the final plane descent from horizontal flight in small height above ground. In such case the roof hitting is possible up to the angle no more than 20 ° from horizontal plane observing direct visibility of target. (direct visibility is restricted by front part of plane). For any greater angle in proximity of target the hijacker will lose direct visibility thus the probability the target remain unaffected increases. In case of experienced pilot the target hit could be possible even at angle of 35 degrees. For higher angles the pilot has not enough time to perform correcting maneuvers and the plane would fall outside the target.

3. INTRODUCTION OF LOADS INTO CALCULATION

The loads caused by aircraft crash can be introduced into the calculation of response of impacted building in several ways. In case of perpendicular hits to relatively rigid structures the published loading curves can be often used, which are determined based on experimental tests or based on simple computing models. For example, the load curve for crash of Boeing B707 aircraft with mass of 90 tons is frequently used curve in calculation of large transport aircraft. This curve was derived assuming hit with velocity of 100 m/s to rigid barrier (Riera 1968). The load curve is given in the Figure 1.

The load curve was determined with simplified assumptions based on aircraft velocity in instant of hit and aircraft mass distribution and plane structure stiffness distribution over its length. It is possible to determine such load curve in the same way for other plane types as well as for higher hit velocities.

When the hit structure is not rigid the forces acting between structure and aircraft will differ. In such case it is necessary to use an adequate computing model of aircraft and the task need to be resolved for each case individually as interaction of both bodies. It is possible to model the aircraft for example by simplified mass model or by FEM detail model.

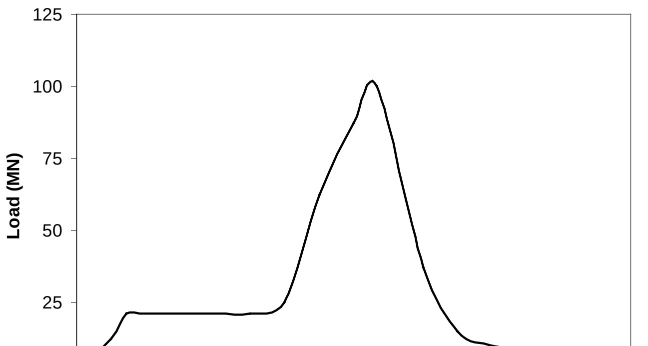

Figure 1 Load curve derived for Boeing B707 aircraft and for velocity 100m/s

4. EXAMPLE OF REAL STRUCTURE

The Spent Fuel Storage Facility designed in several options within the study for Temelin site has been chosen as example for presentation of large commercial aircraft crash into NPP building structure. This building serves for interim storage of spent fuel containers. The storage part of this building is a two-bay hall with span 2 x 22 m and length of 72 m and height of 25 m. The storage part is divided lengthwise to two dilatation units, the third separate dilatation unit is the reception room. The load-bearing structure is made from monolithic reinforced concrete. The cross section schemes of two analyzed options of structure are in the Figure 2 and 3.

