Drop Test of a Type B(U)-Package Onto a Real Target Concerning Handling Accident in an Intermediate Storage Facility

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INTRODUCTION

Due to the fact, that in FRG one has to demonstrate, that type B(U)-packagings not only withstand the mechanical loads concerning IAEA-regulations, but also handling accidents in the intermediate storage facility, a drop test with a full scale package on a real target was performed. In this special case, the package has no shock absorbers.

In the past, this verification only was done by an analytical calculation. During the licensing procedure of the NUKEM-THTR-package, the competent authority asked to demonstrate the integrity of the cask during the handling accident by a test.

NUKEM-THTR-PACKAGE

A cask intended for transport and intermediate storage of approx. 2,000 spheres was used for the drop test.

The NUKEM-THTR cask consists of the following main components:

- A basic shell of nodular cast iron with a cast-on bottom and four bolted-on trunnions
- A primary lid, consisting of nocular cast iron
- A secondary lid consisting of nodular cast iron
- The content, due to the realistic weight, consisting of a dummy fuel element canister
- The used seals are such as of the HELICOFLEX-type.

The main dimensions of the cask are as follows:

Length	2,740 mm
Diameter	1,380 mm

Weights	
- shell and bottom	22,160 kg
- primary lid	1,590 kg
- secondary lid	530 kg
- content	800 kg
Total weight	22,080 kg

The cask is illustrated in figure 1.

Theory of Calculation Model

In contrast to the unyielding target required as an impact surface onto which a cask is dropped as specified in the IAEA-regulations /1/ a real (yielding) target is simulated in this drop test. The drop test performed is intended to simulate a handling accident at the intermediate storage facility.

The casks are stacked in the intermediate storage facility in pairs, one on top of the other. The manipulation necessary for stacking is executed without shock absorbers. Maximum lifting height is 3.5 m.

The cask is, as described in /2/, to be regarded as rigid with respect to the yielding target.

The surface reacts to the sudden load with a dynamic resistance, precise determination of which is extremely complex. Normally, this dynamic resistance is conservatively estimated, by multiplying the calculated static resistance by a suitable dynamic factor.

Since it was not possible to simulate an original sole plate from the intermediate storage facility, the sole plate, consisting of ready-made partial slabs, was simulated.

Observation of static resistances is sufficend for comparative observation of the original target and that to be modelled for the test. Inertia and damping forces were not taken into account.

The resistance of the sole plate in the intermediate storage facility consists of the following three components:

- Breakage resistance of the soil
- Penetration resistance of the concrete
- Resistance of the reinforcement

Sole Plate of the Intermediate Storage Facility

- Breakage Resistance of the Soil

  The following conservative and global estimation for soil data for the intermediate storage facility results from /2/:

Angle of repose	$\varphi = 40°$
Cohesion	$c = 25\ kN/m^2$
Relative density	$\gamma = 25\ kN/m^3$

  In accordance with the German Standard DIN 4017, part 1.

$$P_b = \left(\frac{c}{b\ \gamma} N_c\ \gamma_c + \frac{d}{b} N_d\ \gamma_d + N_b\ \gamma_b\right) b^2\ a\ f_{dyn}$$

  results in the breakage resistance of

$$P_{bdyn} = 41.500\ kN$$

  and a penetration depth of

$$S = 0.035\ \sqrt{a\ .\ b} = 0.06\ m$$

$$a = b = D + h = 1.38\ m + 0.35\ m = 1.73\ m$$

  D = cask diameter
  h = thickness of the reinforced concrete slap

- Penetration Resistance of the Concrete

  In accordance with /3/, /4/ and /5/ leads the dimensions applying to the cask and the sole plate, via:

$$P_1 = F_c \cdot \tau_c$$

  F_c = 1,902 m² shearing area of concrete

  τ_c = 2,550 kN/m² shearing resistance of concrete

  in a penetration force of

$$P_1 = 4,850\ kN$$

$$P_{1dyn} = P_1 \cdot f_{dyn} = 6,500\ kN$$

- Resistance of the Reinforcement

  The resistance exerted against the fracture by the reinforcement is

$$P_2 = F_s \cdot \tau_s$$

F_s = shearing area of steel

τ_s = shearing resistance of steel

$$P_2 = 7{,}900 \text{ kN}$$

An installed steel cross-section of 2,629 mm^2/m with a permissible tensile fracture stress of 550 N/mm^2 is assumed.

The individual parameters of these equations are shown in /7/.

The resistance curve for the sole plate and the soil is shown in figure 2. Since the elastic energy absorption of the sole plate has been ignored, under deformation the penetration force P_{1dyn} take effect.

Simulated Sole Plate

The following equivalent variables were determined for the soil and sole plate in accordance with /2/ and /6/ for the test:

- Soil Layer

  Layer thickness $t = 1$ m
  Angle of repose $\varphi = 40°$

  Due to the influence of the side banks of the embankment, an area of 9 m x 9 m had to be provided on the crown of the embankment. The material - sandy gravel - was applied in layers and compacted.

- Concrete Slap

  The assembly shown in figure 3 was determined as an equivalent for the 0.45 m thick reinforced-concrete slab actually present in the intermediate storage facility (0.35 m steel-reinforced concrete and 0.10 m non-reinforced concrete):

  . Three layers 9 m x 9 m with offset joints;
  slab size 3 m x 3 m x 0.15 m (27 items).
  This arrangement of ready-made slabs simulates the actual sole plate for the intermediate storage facility.

  . Additional three layers 9 m x 9 m with offset joints;
  but with a clearence of 2 m x 2 m in the center;
  slab size 2 m x 3 m x 0.15 m (6 items);
  3 m x 3 m x 0.15 m (18 items)
  These three upper layers, arranged in the form of a coller, act principally as a top load and thus help to ensure that the substructure cannot move to the side or buckle upon impact of the cask.

Theoretical Penetration Depth and Maximum Acceleration

From the drop energy of the cask respectively the deformation energy transferred into the sole plate of

$$E_{pot} = m\ g\ H$$

a maximum penetration depth for the test body can be calculated of about

$$S_{max} = 0.040\ m$$

The resistance force occuring from the sole plate and the soil of

$$P_{max} = 35{,}500\ kN$$

leads to a maximum acceleration of the cask of

$$a_{max} = 140\ g$$

TEST SET-UP

The set-up for the test is shown in figure 4. The drop orientation of the cask was selected in such a way that maximum acceleration could be anticipated.

The drop was performed with the cask dropping onto its base, as agreed with the Bundesanstalt für Materialforschung und -prüfung (BAM).

The cask was fitted with three accelerometers, which were mounted in the lid area. The arrangement of the transducters can also be seen in figure 3.

TEST RESULTS

An acceleration of 80 g was determined for a drop of the cask onto the real target. Penetration of the cask into the simulated sole plate and soil was 5 - 6 cm.

The results of the test and the calculations performed thus manifest good accordance with one another, since the maximum possible resistance is always of interest in theoretical observations, in order to obtain maximum accelerations. For this purpose, the dynamic factors and the angle of repose of the truncated-cone-shaped fragment punched out were conservatively estimated.

The standard helium leak rate measured for the five HELIOCOFLEX metal gaskets which were used on the cask for this test were less than 1 E-8 barℓs-1 both before and after the drop test.

There were no effects on the barrier system of the transport and storage cask. Nor was there any mechanical damage to the base of the container.

REFERENCES

/1/ Regulations for the Safe Transport of Radioactive Materials, 1985 Edition, International Atomic Energy Agency (IAEA), Vienna 1985

/2/ Gutachten der BAM
Aktenzeichen: 1.02/2358 TA: 2.31/1042
Stellungnahme zum Versuchsaufbau für die Simulation des Handhabungsstörfalles für den NUKEM-THTR-Behälter im Lager Ahaus

/3/ Experimentelle Unterzeichnungen zum Trag- und Verformungsverhalten von Balken und Platten aus Stahlbeton unter stoßartiger Belastung
12. Forschungskolloquium des Deutschen Ausschusses für Stahlbeton,
E. Limberger, März 1981, BAM-Berichte, Berlin

/4/ DIN 1045, Beton und Stahlbeton, Bemessung und Ausführung, Dezember 1978

/5/ Grenztragfähigkeit von Stahlbetonbauteilen unter Stoßeinwirkung
12. Forschungskolloquium des Deutschen Ausschusses für Stahlbeton,
K. Brandes, März 1981, BAM-Berichte, Berlin

/6/ Gutachten der BAM
Aktenzeichen: 1.02/2358 TA: 2.31/1044
Modifizierung des Versuchsaufbaues für einen Fallversuch mit einem NUKEM-THTR-Behälter

/7/ Berechnung der maximalen Aufschlagbeschleunigung beim Absturz des Transport-/Lagerbehälters NUKEM-THTR 1/II D vom Kran des Zwischenlagers
TN 8716, Mai 1987, NUKEM GmbH

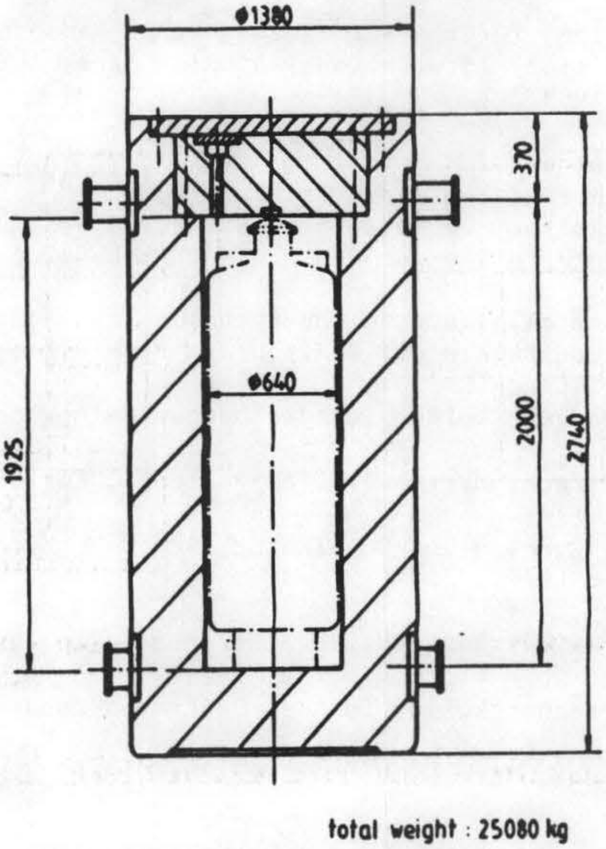

Fig.1 NUKEM-THTR-Cask

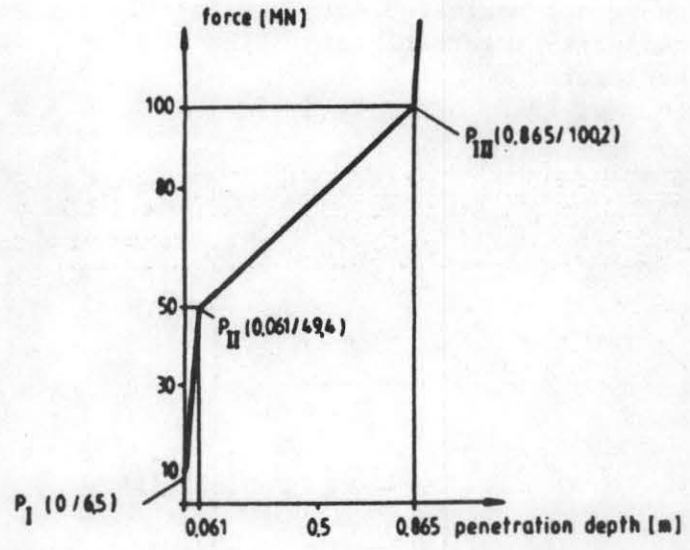

Fig.2 resistance curve for the sole plate

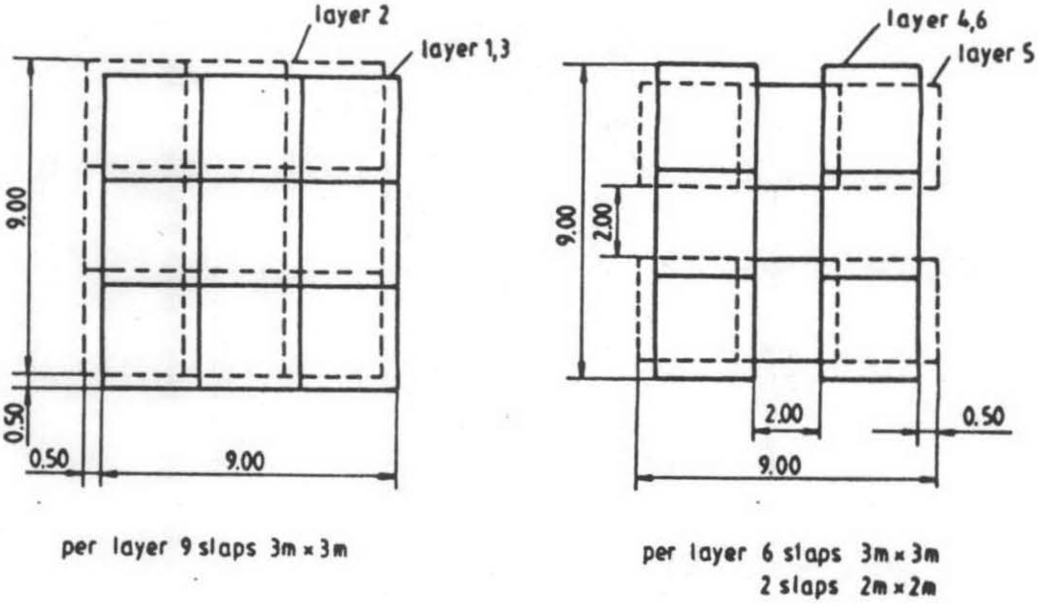

Fig. 3 Arragement of the Cancrete Slaps

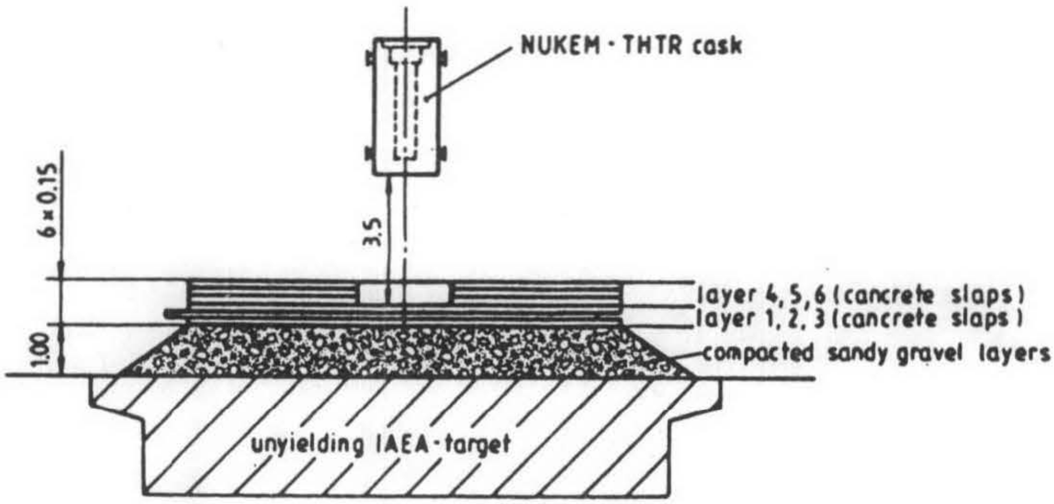

Fig. 4 Real Target - Test Set-Up

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