EVALUATION OF SEVERITY OF DROP TESTS ONTO REAL TARGETS

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SUMMARY

IAEA transport regulations require the 9m drop test for type B packages. This drop test is required to confirm the integrity at impact in an accident during transport, such as a drop accident or a traffic accident. The target used in this drop test must be unyielding.

However, the real target that the transport package might encounter in an accident during transport is a yielding target, such as concrete, asphalt or soil.

To compare the impact acceleration between a real target and an unyielding target, analyses of the drop test onto a real target and an unyielding target were made.

The evaluation was performed for a spent fuel package. The computer code used in the analysis was "DYNA-3D". The structure under the real target was modeled according to a typical road structure. The drop heights were parameter, which cover some representative real accidents.

The analysis was made and the acceleration for each target was obtained. The results were evaluated by using the acceleration for each target.

It has become clear that the drop height onto the road corresponding to the 9m drop height required by IAEA regulations is about 47m for concrete road surface and is about 51m for asphalt road surface, the impact velocity is about 30m/s for both road surfaces. In case of soft soil, the drop height corresponding to IAEA regulations is about 71m, the impact velocity is about 37m/s.

During normal handling and transport, the package hardly ever encounters these heights and velocity.

So It is judged that the drop height required by IAEA regulation is appropriate test condition.

INTRODUCTION

IAEA transport regulations require the 9m drop test for type B packages. This drop test is required as a test condition to simulate accidents in transport , e.g.,fall , clash of packages. The target provided for this drop test is an unyielding surface , therefore all the kinetic energy of the falling package just before the impact is absorbed by the deformation of the package.

On the other hand , in case of real accidents , the targets are yielding surfaces ,e.g. soil , asphalt , concrete , so that a part of the kinetic energy of the falling package just before the impact is absorbed by the deformation of the targets. This absorption of the kinetic energy alleviates the shock of the package impact on the target. So the behavior of the package impacted on the various targets are different from each other on account of the different characteristics of the targets.

In this study , impact analyses of a drop accident onto the real targets and unyielding target are made.

The real targets are asphalt road surface, concrete road surface, soil, etc. Under the asphalt and concrete road surface, there are soil and ballast. This structure of the road is considered to be a condition of the analysis.

PACKAGE DESCRIPTION

The analyses were made for the package as shown in Figure 1. This package is designed for the transport and storage of light reactor spent fuel assemblies, and satisfied the requirements for type B packages. This package has shock absorbing covers on the top and bottom sides. The shock absorbing covers have alleviated the shock by their own deformation when the package has been subjected to the 9m drop test required by IAEA transport regulations.

The specifications of this package are as follows;

Dimensions : L6.4m× ϕ 2.4m
Weight : 115 tons
Materials : body, bottom, lid-carbon steel
shock absorbing cover-red wood
basket - borated aluminum
neutron shielding-kobesh SR-T

CASE OF IMPACT ANALYSIS

In this study , impact analyses of a drop accident onto the target described in Table 1 are made.

Asphalt and concrete are a surface of roads, and there is soil and ballast under these materials. This structure of the road is considered to be a condition of the analysis.

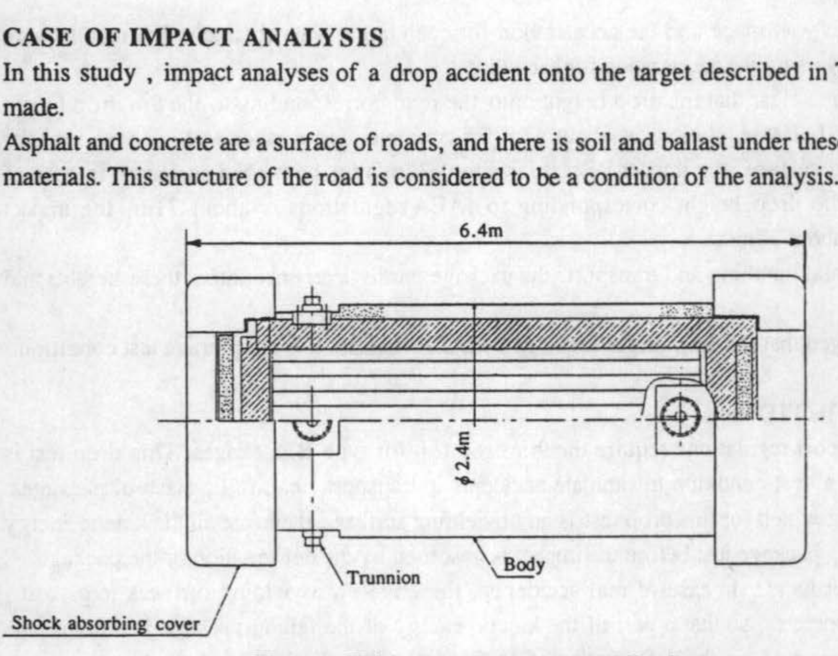

Figure 1 TN 24 transport/storage packaging

IMPACT ANALYSIS

Impact analyses onto various targets are performed by using a LS-DYNA3D(e.g.,John O. Hallquist 1994) computer code. The package is dropped in a horizontal position, and the FEA Model is shown in Figure 2. A package and shock absorbing cover were modeled as an elastic-plastic body by using a solid element and shell element in detail. Targets are modeled by using a solid element (crushable foam of LS-DYNA3D), and transmitting boundaries were used on the boundary of targets in order to consider the infinite domains of targets.

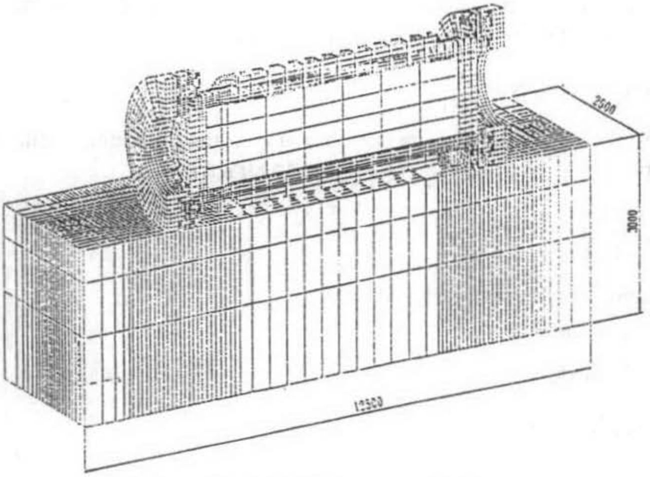

Figure 2 Model of impact analysis

Table 1 Impact analyses

target	drop height (m)
unyielding surface	9, 12, 15, 20
soil(N-value=10)	60
soil(N-value=50)	30, 60
asphalt (road surface)	9, 40, 60
concrete (road surface)	9, 30, 60

PROPERTIES OF SOIL ROADBED

Sandy fine soil (SF) was assumed to be the soil in this survey. The properties of SF are estimated by using N-value, and they are shown in Table 2.

The Mohr-Coulomb yield condition is applicable to the property of the soil.

$$\tau = C + \sigma_n \cdot \tan \phi$$

ϕ : internal friction angle (degree)
C : Cohesion
τ : shear stress
σ_n : normal stress

When the N-value is given, ϕ will be estimated by using the following empirical formula.(e.g.,The Japanese geotechnical society)

$$\phi = \sqrt{20 \times N} + 15$$

The following measured value of C(e.g.,Target effect on package response, SAND86-2275) was used for this survey.

$$C = 0.211 \times 10^{-2} \ (\mathrm{kgf/mm^2})$$

When the N-value is given, the elastic modulus E will be estimated by using the following empirical formula.(e.g.,The Japanese geotechnical society)

$$E\ (\mathrm{kgf/mm^2}) = 28 \times N \times \frac{1}{100}$$

The stress-strain relations of the soil are not obvious, so the following elastic relations were assumed.(e.g.,Target effect on package response, SAND86-2275)

$$e = -\ln\left(1 - \frac{P}{K}\right)$$

e : cubical strain (logarithmic strain)

P : hydrostatic pressure

K : bulk modulus $= \dfrac{E}{3(1-2\nu)}$

ν : poisson's ratio

Table 2 Properties of sandy fine soils (SF)

N value	10(soft)	50(hard)
elastic modulus E (kgf/mm^2)	2.8	14.0
density γ (tf/m^3)	1.90	2.10
poisson's ratio ν	0.25	
bulk modulus K (kgf/mm^2)	1.87	9.33
stress-strain relations	$e = -\ln\left(1 - \frac{P}{K}\right)$	
cohesion C (kgf/mm^2)	0.211×10^{-2} (3 psi)	
internal friction angle ϕ (degree)	29.1	46.6

PROPERTIES OF ASPHALT ROAD SURFACE

The properties of the asphalt road surface used in this survey are shown in Table 3. The road is constructed from asphalt, an upper roadbed, a lower roadbed, SF (N-value=10), and SF (N-value=50).

Mises yield condition was applied to the asphalt, and the tensile strength 0.45kgf/mm^2(e.g.,J.Minegishi. et al. 1993) was used in this survey.

The elastic modulus of asphalt is obtained by using the following formula.(e.g.,J.Minegishi. et al. 1993)

$$E(\mathrm{kgf/cm^2}) = -4997T + 111762 \quad (0℃ \leqq T \leqq 20℃)$$

The above modulus has a high sensitivity as a function of temperature, and the value at 0℃ is 1118kgf/mm^2, and the value at 20℃ is 118kgf/mm^2. The temperature in this survey was assumed at 20℃ as a standard temperature. If the temperature is assumed at 0℃, the elastic modulus of asphalt will be close to that of concrete, and it is expected that the numerical results of asphalt will be close to those of concrete.

The properties of the upper or lower roadbed were determined by using the empirical values.(e.g.,Handbook of soil mechanics and foundation engineering, 1982)

PROPERTIES OF CONCRETE ROAD SURFACE

The properties of the concrete road surface used in this survey are shown in Table 4. The road is constructed from concrete, a roadbed, SF (N-value=10), and SF (N-value=50).

Mises yield condition was applied to the concrete, and the stress-strain relations shown in Figure 3 were used. The compressive strength of concrete is 2.4kgf/mm^2 , this value is generally used for the design value of compressive strength of concrete. The real compressive strength of concrete is more than this value. As the compressive strength adopted for the analysis increases, the G value resulted from the drop analysis goes up. In this survey, design value is adopted for the analysis as the representative value.

The properties of the the roadbed were determined by using the empirical values.(e.g.,Handbook of soil mechanics and foundation engineering, 1982)

RESULTS OF IMPACT ANALYSES

G values were obtained from the numerical results of acceleration at the center part of the package by using the low-pass-filter (72Hz), and these values are shown in Figure 4.

The drop height and the velocity, which cause the same impact as those for a 9m drop test onto an unyielding target, are shown in Table 5.

CONCLUSION

G values occurring on the package when it encountered a drop accident onto a real target were obtained from a numerical survey using LS-DYNA3D.

From this survey of these analyses, the following valuable knowledge has been obtained;

The surface of the road is usually concrete or asphalt, both of which are very hard. But, there is soil, sand,etc. under these materials, so the impact of a drop accident is relatively small.

It has become clear that the drop height onto the road corresponding to the 9m drop height required by IAEA regulations is about 47m for concrete road surface and is about 51m for asphalt road surface, the impact velocity is about 30m/s for both road surfaces. In case of soft soil, the drop height corresponding to IAEA regulations is about 71m, the impact velocity is about 37m/s.

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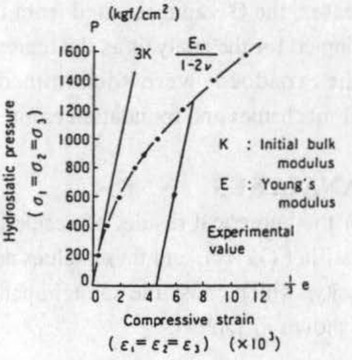

Figure 2 Stress-Strain Relations of Concrete under Hydrostatic Compression$^{6)}$

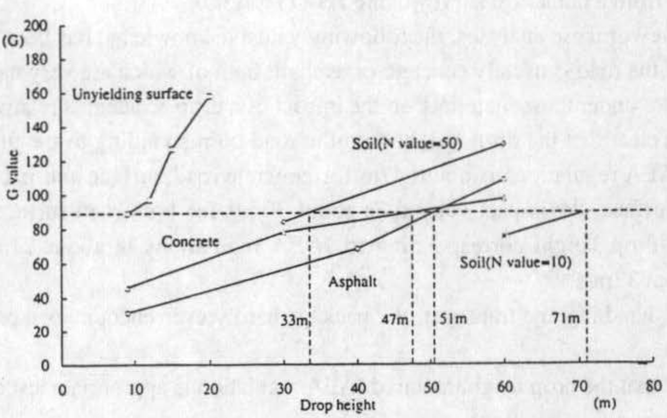

Figure 3 Relationship between G value and drop height

Table 3 Properties of asphalt roadbed

	asphalt	upper roadbed	lower roadbed	sandy fine soil (N value=10)	sandy fine soil (N value=50)
depth (mm)	0～170	170～320	320～620	620～820	820～∞
elastic modulus (kgf/mm^2)	118 (at 20℃)	100 (CBR=100%)	80 (CBR= 80%)	2.8	14
density γ (tf/m^3)	2.12	1.99		1.9	2.10
poisson's ratio ν	0.35	0.2		0.25	
bulk modulus K (kgf/mm^2)	131	55.6	44.4	1.87	9.33
stress-strain relations	$e = -\ell n\left(1 - \frac{P}{K}\right)$				
cohesion C (kgf/mm^2)	—	0.211×10^{-2}			
internal friction angle ϕ (degree)	—	50		29.1	46.6
tensile strength (kgf/mm^2)	0.45	—		—	
yield condition	Mises yield condition	Mohr-Coulomb			

Table 5 Drop height and impact velocity corresponding to 9m drop test

target	drop height(m)	velocity(m/s)
unyielding surface	9	13
SF (N-value=10)	71	37
SF (N-value=50)	33	26
asphalt roadbed	51	32
concrete roadbed	47	30

Table 4 Properties of concrete roadbed

	concrete	roadbed	sandy fine soil (SF) (N value=10)	sandy fine soil (SF) (N value=50)
depth (mm)	0～250	250～550	550～800	800～∞
elastic modulus E (kgf/mm^2)	2300	100	2.8	14
density γ (tf/m^3)	2.3	1.99	1.90	2.10
poisson's ratio ν	0.167	0.20	0.25	
bulk modulus K (kgf/mm^2)	1151	55.6	1.87	9.33
stress-strain relations	Fig.3	$e = -\ell n\left(1 - \frac{P}{K}\right)$		
cohesion C (kgf/mm^2)	—	0.211×10^{-2}		
internal friction angle ϕ (degree)	—	50	29.1	46.6
compressive strength (kgf/mm^2)	2.4	—		
tensile strength (kgf/mm^2)	0.3	—		
yield condition	Mises yield condition	Mohr-Coulomb		

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