Storage Cask Drop Test on Reinforced Concrete Slab

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INTRODUCTION

As of the present, no technical standards have been established to ensure the structural integrity of casks for storing spent fuel. It can be assumed that the accident caused by the falling of casks during their handling in the storage facilities is the severest condition structurally, though there have been few demonstration test examples and evaluations made so far with respect to this problem. The object of the present research is to demonstrate and evaluate the structural integrity of casks in case they fall during their handling in the storage facilities. For this purpose, we performed drop tests of full-scale casks on a reinforced concrete (RC) slab representing the floor of the storage facilities, with consideration during storage (cask lifting orientation, drop height, etc.).

Meanwhile, drop analysis was conducted for these drop tests to establish a technique for analyzing the dropping of casks on a reinforced concrete slab. Regarding the results of said research, please refer to other studies (Ito et al., 1992).

TEST CASK

The general view of the cask used in this drop test is shown in Fig.1, and the outline of its specifications is shown in Table 1. Meanwhile, to verify the margin per 3 different types of drop orientation to be described later, drop tests were conducted at a critical height using 3 test casks. Also, it can be considered that the cask for storing BWR-type spent fuel is generally slender as compared with PWR-type spent fuel and generates a larger stress under the same load condition during horizontal and oblique dropping. So, tests were conducted on the casks for storing BWR-type spent fuel.

TEST RC SLAB

Prior to commencing this research, conceptual design of various types of the cask storage house was carried out. All these storage houses were designed as Class-C (Japanese Classification for Seismic Degree). An example of storage houses designed is shown in Fig.2. The RC slab used in this test was designed and manufactured based on the specifications of the floor slab in these storage houses.
The general view of the RC slab used in this drop test is shown in Fig.3, and the outline of its specifications is shown in Table 2.

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TEST CONDITIONS

The test conditions established are shown in Table 3. The major possible drop orientation in case of a cask falling accident in the storage facilities are vertical and oblique. Another possible accident is falling in the horizontal orientation at the time of unloading from a truck. Accordingly, drop tests were conducted in three different falling orientations, i.e., vertical, horizontal and oblique.
Also, drop heights were determined in accordance with the following considerations:

(1) Normal Operating Height
The normal operating height at the time of moving within the storage facilities was determined based on the lifting condition shown in Fig.4.

(2) Maximum Lifting Height
The maximum lifting height in the storage house subjected to conceptual design was determined based on the cask carrying in height shown in Fig.2.

(3) Verification of the Cask Margin
To verify a margin in the structural integrity of casks against a drop accident, a critical drop height which permits maintenance of integrity was determined on the basis of prior drop analysis.

TEST METHOD

The test cask was lifted up to the prescribed drop orientation and height and allowed to drop onto the RC slab for testing use placed on the approximately 1000-ton concrete block representing bedrock. The condition of the drop test is shown in Fig.5. Meanwhile, we carried out the drop tests without fitting an impact limiter because the casks were in storage.

During the drop test, the strain and acceleration in the cask and the RC slab were measured dynamically. Also, to confirm the leak-tightness integrity of the cask, we performed lid leak-tightness tests before and after the drop test. The leakage rate was measured by the He-leak method.

TEST RESULTS AND DISCUSSION

Typical examples of test results obtained during the drop test are shown in the following figure and table.

Fig.6 Relations among drop height, strain and acceleration
Table 4 Results of leak-tightness test

The test results thus obtained may be summarized as follows:

(1) The strain and acceleration during oblique dropping are sufficiently small compared with those during vertical and horizontal dropping. The strain and acceleration due to the secondary collision after dropping are also sufficiently small as compared with those due to the primary collision. For evaluation of integrity against vertical and horizontal orientation, therefore, it can be considered that dropping in the oblique orientation will pose no problem in making such evaluation.

(2) The structural integrity of the cask against its dropping at the normal operating height and up to the maximum lifting height which is determined by the construction of storage facilities was verified.

(3) Since the estimated critical drop height is sufficiently heigh as compared with the above-mentioned drop height, it was verified that the cask had a sufficient margin against a falling accident during operation.

REFERENCE

Ito et al., "Analysis of DCI Cask Drop Test onto Reinforced Concrete Pad", PATRAM'92, 1992, Yokohama, Japan

Table 1 Cask Specifications

Materials		X-Type Cask	Y-Type Cask	Z-Type Cask
Lid	Inner Lid	Stainless Steel	Stainless Steel	Stainless Steel
	Outer Lid	Stainless Steel	Stainless Steel	Stainless Steel
	Lid Bolt	Stainless Steel	Alloy Steel	Alloy Steel
Body	Wall	Ductile Cast Iron	Ductile Cast Iron	Ductile Cast Iron
	Fin	Ductile Cast Iron	Ductile Cast Iron	Rolled Steel
	Trunnion	Stainless Steel	Stainless Steel	Stainless Steel
Basket Plate		Borated Stainless Steel Stainless Steel	Borated Stainless Steel	Borated Stainless Steel

Weight (ton)		X-Type Cask	Y-Type Cask	Z-Type Cask
Lid	Inner Lid	3.5	4.0	4.8
	Outer Lid	2.2	2.2	2.3
Body		78.7	79.9	74.7
Basket		13.8	6.0	10.0
Spent Fuel (52 Assemblies)		14.6	14.6	14.6
Total Wwight		113.9	106.7	106.4

Test Spec.	X-Type Cask	Y-Type Cask	Z-Type Cask
Number of S.F.	51 (Dummy Weight) 1 (Model of BWR Type S.F.)	52 (Dummy Weight)	51 (Dummy Weight) 1 (Model of BWR Type S.F.)
Measured Weight	107.9 ton	112.0 ton	100.4 ton

Table 2 RC Slab Specifications

Specification	Value		Note
Demension	6m × 6m × 1.2m : 5 Slabs		For Vertical & Oblique Orientation Drop Test
	6m × 8m × 1.2m : 2 Slabs		For Horizontal Orientation Drop Test
Concrete Strength	Design Strength	240 kg/cm²	
	Measured Strength	320 kg/cm²	Standard Curing
		282 kg/cm²	Job-site Air Curing
Reinforcing Bar	JIS Class : SD30A		
	Designation : D22 · D25		
	Reinforcement Ratio : 1.3 %		

Table 3 Test Conditions

Drop Height		Orientation	Cask	Note
Normal Operating Height	1.5m	Vertical	X	Verify the cask integrity for free dro of the normal operating height
		Horizontal	Z	
		Oblique		Drop test was not conducted, because the strain growth during oblique dropping was sufficiently small as compared with that duringngng vertical and horizontal dropping by prior drop analysis.
Maximum Lifting Height Height in Storage House	7.5	Vertical	X	Verify the cask integrity for free dro of the maximum lifting heigh in storag storage house subjected to conceptual design.
		Oblique	Y	
		Horizontal		Drop test was not conducted, because the cask was not lifted up to this height in the horizontal orientation.
Verification of the Cask Margin	17.0m	Vertical	X	Verify a margin in the integrity of casks against a drop accident.
	5.0m	Horizontal	Z	
	17.0m	Oblique	Y	

Performed Drop Test

Table 4 Results of Leak-tightness Test

Orientation	Drop Height (m)	Part	The Leakage Rate (atm · cc/sec)	
			Before Test	After Test
Vertical	1.5	Inner Lid	Less than 1.6×10^{-9}	Less than 4.8×10^{-8}
		Outer Lid	Less than 2.8×10^{-9}	Less than 6.8×10^{-9}
	7.5	Inner Lid	Less than 5.8×10^{-9}	Over measuring range
		Outer Lid	1.3×10^{-9}	5.3×10^{-9}
	17.0	Inner Lid	Less than 2.3×10^{-9}	Over measuring range
		Outer Lid	Less than 1.9×10^{-9}	Less than 2.9×10^{-9}
Horizontal	1.5	Inner Lid	5.7×10^{-9}	2.8×10^{-9}
		Outer Lid	Less than 2.1×10^{-10}	Less than 4.4×10^{-10}
	5.0	Inner Lid	Less than 3.2×10^{-10}	Over measuring range
		Outer Lid	Less than 5.6×10^{-10}	2.2×10^{-8}
Oblique	7.5	Inner Lid	Less than 1.5×10^{-10}	Less than 2.9×10^{-10}
		Outer Lid	Less than 3.8×10^{-10}	Less than 2.1×10^{-10}
	17.0	Inner Lid	Less than 4.3×10^{-10}	Less than 7.5×10^{-10}
		Outer Lid	Less than 3.2×10^{-10}	Less than 6.0×10^{-10}

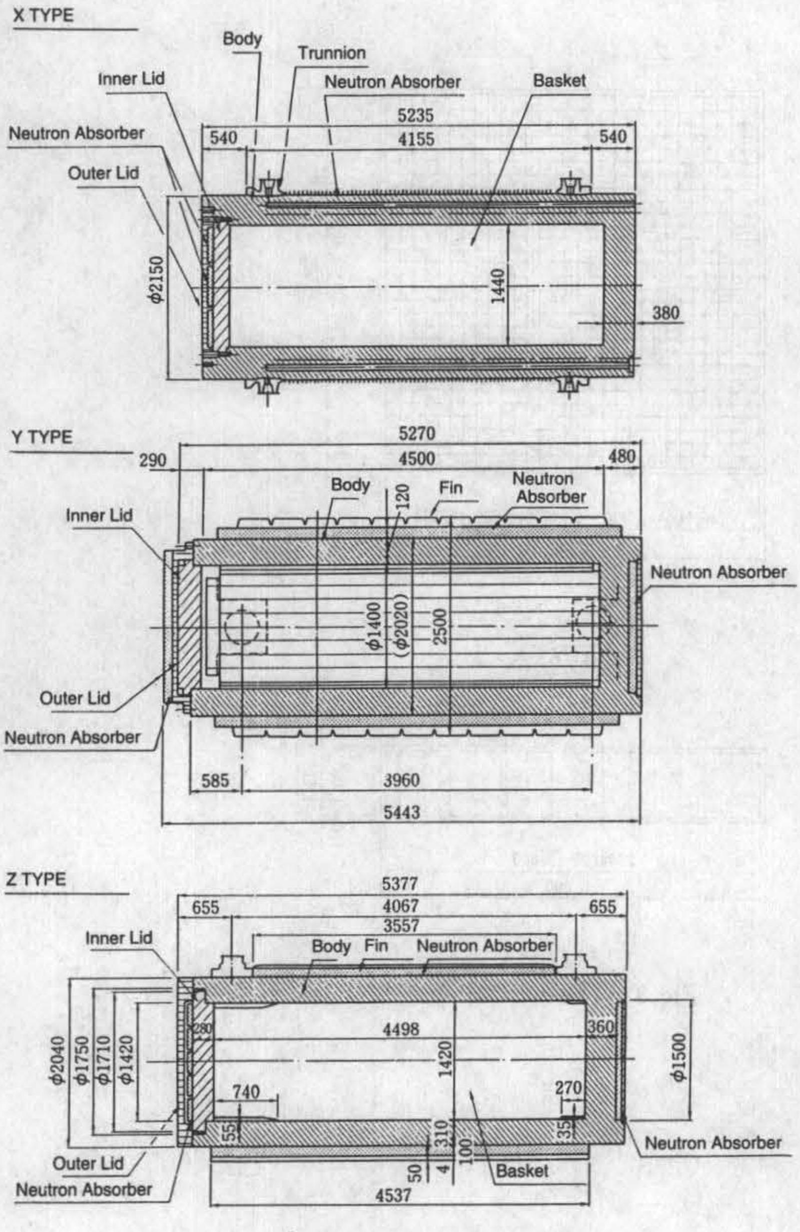


Fig.1 Test Cask

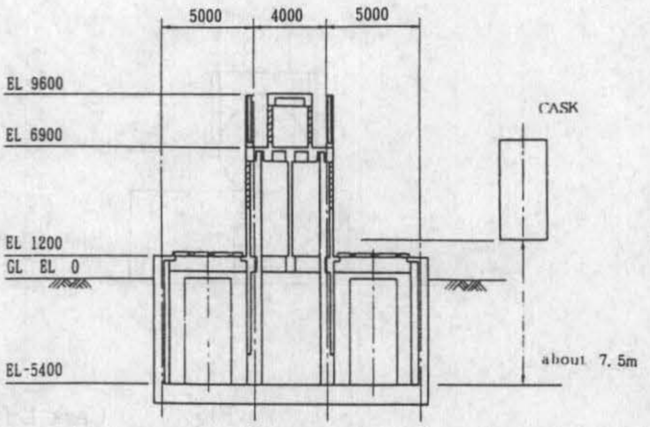


Fig.2 Example of Storage House

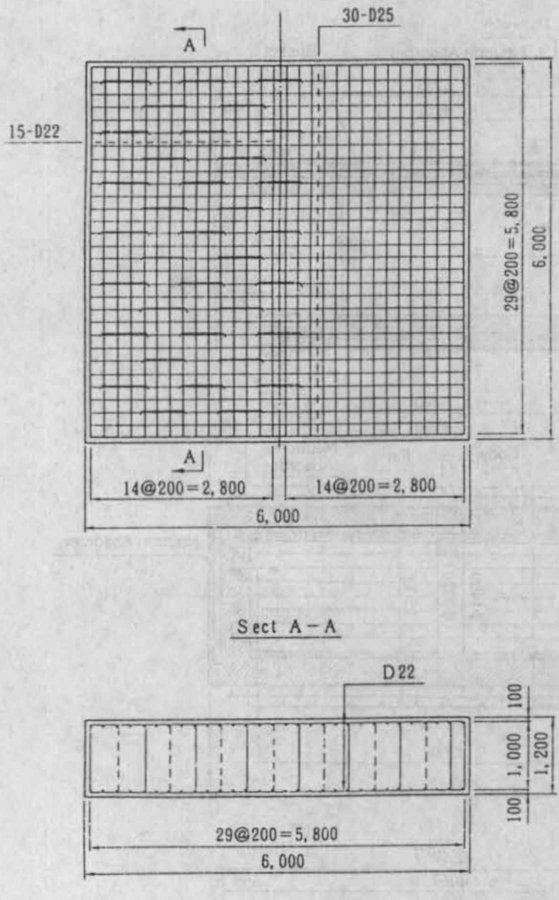


Fig.3 Test RC Slab

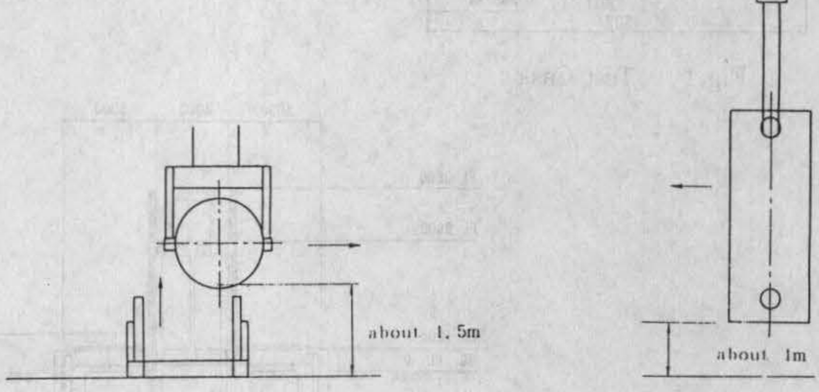
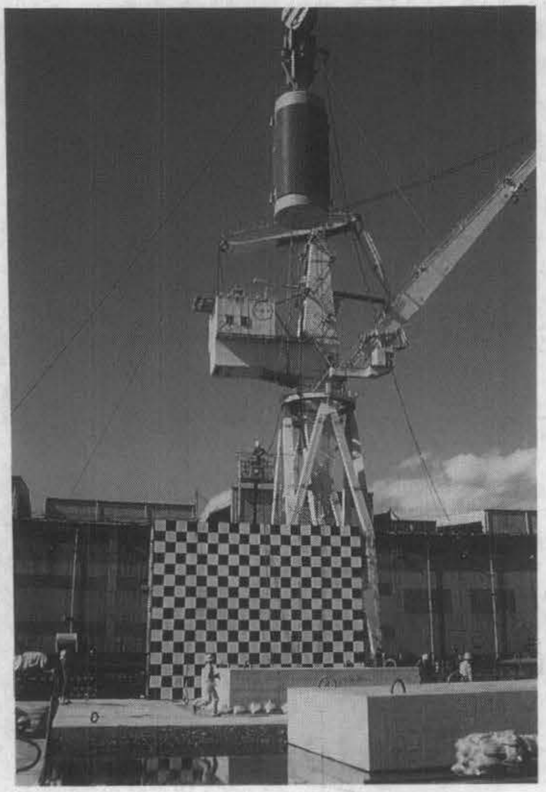
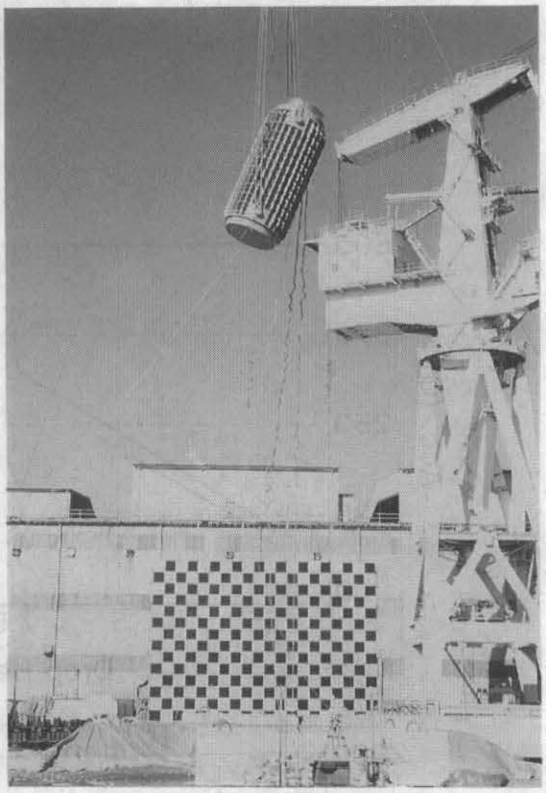


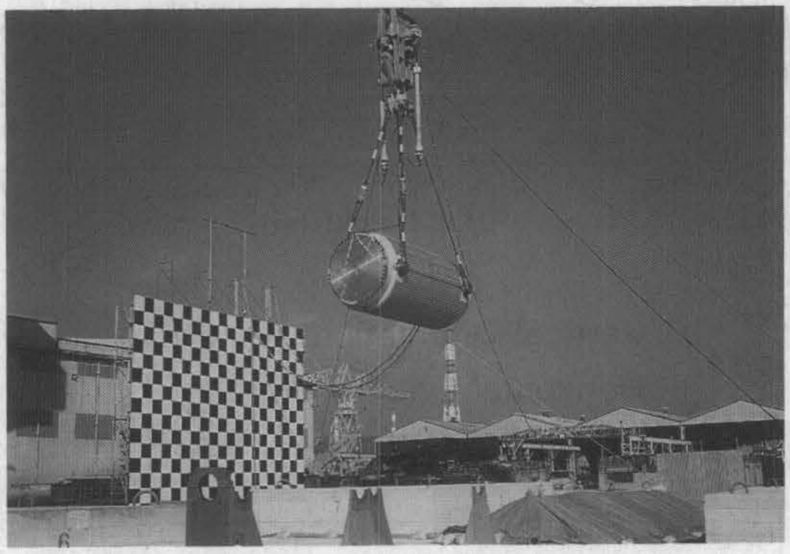
Fig. 4 Cask Lifting Condition



Vertical Orientation



Oblique Orientation



Horizontal Orientation

Fig. 5　Condition of the Drop Test

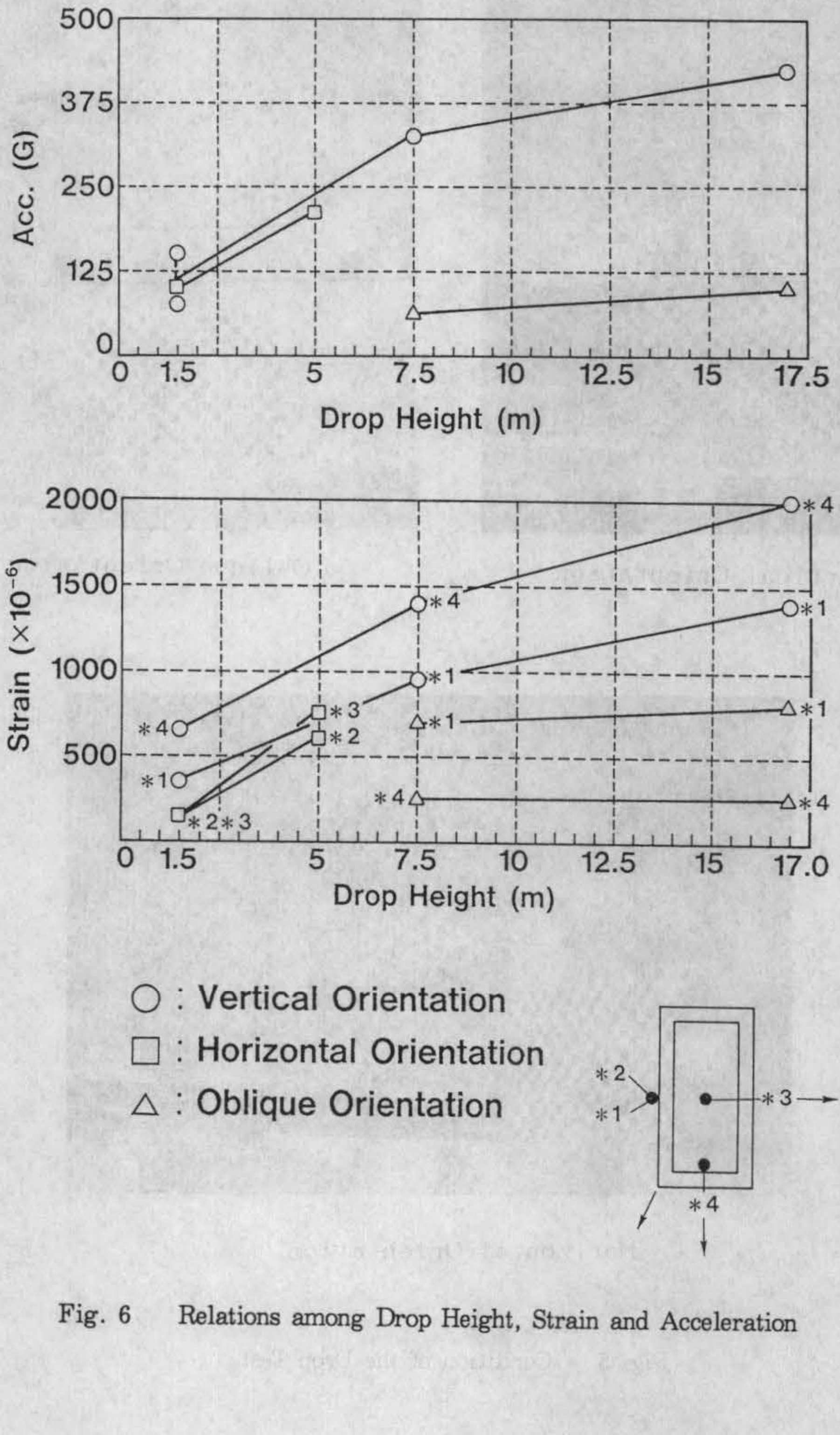


Fig. 6 Relations among Drop Height, Strain and Acceleration