Drop Test of Reinforced Concrete Slab onto Storage Cask

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INTRODUCTION

When storing spent fuel in cask, seismic resistance equivalent to Class-As (Japanese Classification for Seismic Degree) can be expected to be obtained in the cask; hence the storage house of Class-C in aseismic priority classification may be sufficient. In case an earthquake of Class-S2 in reference seismic motion occurs during cask storage, therefore, it can be assumed than an accident causing heavy objects to drop onto the cask due to a collapse of the storage house may occur. As of the present time, however, no technical standards have been established in regard to structural integrity and there have been few demonstration test examples, and no sufficient evaluation has also been carried out in this respect.

In this research, drop tests onto full-scale casks considering the specifications of a falling object (weight, construction, drop height, etc.) demonstrate and evaluate the integrity of casks in case a heavy object drops into the storage facilities.

TEST CASK

In this test, among the three casks used in the "Storage Cask Drop Test on Reinforced Concrete Slab" (Kato et al. 1992), the X-Type cask used in the vertical drop test which showed the least effect on the lid was employed. As for other casks, it can be considered that integrity evaluation can be performed according to the information obtained in the test. 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.

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 aseismic Class-C. A simple analysis was conducted on the conceptually designed storage house shown in Fig.2 was selected as the one which is liable to suffer collapse most easily.
Also, as a result of prior study, the roof slab of a storage house was selected as one of the various possible heavy drop objects, which gives the most serious effect on the integrity of casks. The reinforced concrete (RC) slab used in this test was designed and manufactured based on the specifications of the roof slab in this storage house. The general view of the RC slab used in this drop test in 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. Drop heights were determined in accordance with the following considerations:

(1) Maximum Drop Height Equivalent to the Roof Height

A dynamic response analysis was conducted on the aforementioned storage house. As are sult, the maximum velocity of the roof slab at the time of collapse was calculated by increasing the seismic acceleration until the house collapses, because said house does not collapse with an earthquake of Class-S2. The drop height was determined by considering this velocity in reference to the roof height of a storage house.

(2) Limit Height Giving No Damage to the Cask Sealing Boundary

The growth of plastic strains at various drop heights and the cask parts if there are such strains were examined by prior drop impact analysis. This analysis is shown in Fig.2. From this figure, it was consequently found that in the drop test from a height of 17.1m equivalent to a roof height of a storage house, the cask sealing function could be maintained without causing plastic strains in the sealing boundary between the inner lid and the cask body. Furthermore, when assumed to be dropped from a height of 20m, it can be considered that the cask sealing function can be maintained without plastic strain. On the other hand, if the drop height is reduced up to 5m, there is no growth of plastic strains in both sealing boundaries between the innner lid and outer lid and the cask body, and the sealing function of the cask is maintained in both parts. In the test, this drop height was established as a height giving no damage to the cask sealing boundary.

TEST METHOD

The test RC slab was lifted up to the prescribed drop height and allowed to drop onto the test cask placed longitudinally on the RC slab of 1.2m thick installed 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 wihtout fitting an impact limiter because the caks were in storage.

During the drop test, the strain in the cask and the acceleration 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 and strain

Table 4 Results of leak-tightness test

The test results thus obtained may be summarized as follows:

(1) The structural integrity of the cask in case of the falling of a heavy object from a height equivalent to the roof height of storage house was verified.

(2) In the aforementioned drop test, it was verified that the cask had a sufficient margin against a falling of a heavy object because much greater permissible height is expected as a result of strain and leak-tightness test.

REFERENCES

Kato et al., "Storage Cask Drop Test on Reinforced Concrete Slab", PATRAM'92, 1992, Yokohama, Japan

Table 1 Cask Specifications

Test Cask			X-Type Cask
Materials	Lid	Inner Lid	Stainless Steel
		Outer Lid	Stainless Steel
		Lid Bolt	Stainless Steel
	Body	Wall	Ductile Cast Iron
		Fin	Ductile Cast Iron
		Trunnion	Stainless Steel
	Basket Plate		Borated Stainless Steel Stainless Steel
Weight (ton)	Lid	Inner Lid	3.5
		Outer Lid	2.2
	Body		78.7
	Basket		13.8
	Spent Fuel (52 Assemblies)		14.6
	Total Weight		113.9
Test Spec.	Number of S.F.		51 (Dummy Weight) 1 (Model of BWR Type S.F.)
	Measured Weight		107.9 ton

Table 2 RC Slab Specifications

Specification	Value		Note
Dimension	6m × 6m × 162.5mm : 2 Slabs		
Concrete Strength	Design Strength	240 kg/cm^2	
	Measured Strength	280 kg/cm^2	Job-site Air Curing
Reinforcing Bar	JIS Class : SD30A		
	Designation : D10 · D13		
	Reinforcement Ratio : 1.0 %		

Table 3 Test Conditions

Drop Height		Note
The Limit Height giving no damage to the cask sealing boundary	5.0m	Verify our evaluation method of the cask integrity.
The Maximum Drop Height equivalent to the roof height of the Storage House	17.1m	Verify the cask integrity for free drop of the RC slab forming the roof of the storage house as a result of earthquake-related collapse.

Table 4 Results of Leak-Tightness Test

Drop Height (m)	Part	The Leakage Rate (atm· cc/sec)	
		Before Test	After Test
5.0	Inner Lid	Less than 9.0×10^{-8}	Less than 9.8×10^{-7}
	Outer Lid	Less than 2.1×10^{-8}	Less than 1.1×10^{-8}
17.1	Inner Lid	Less than 4.4×10^{-8}	Less than 4.2×10^{-6}
	Outer Lid	Less than 1.6×10^{-8}	5.1×10^{-8}

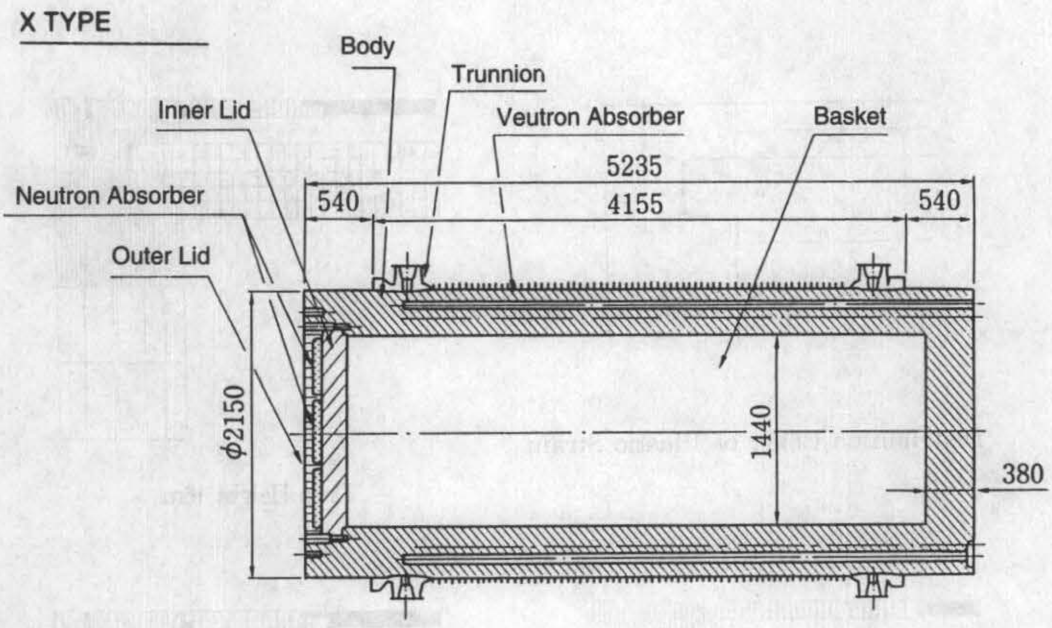

Fig.1 Test Cask

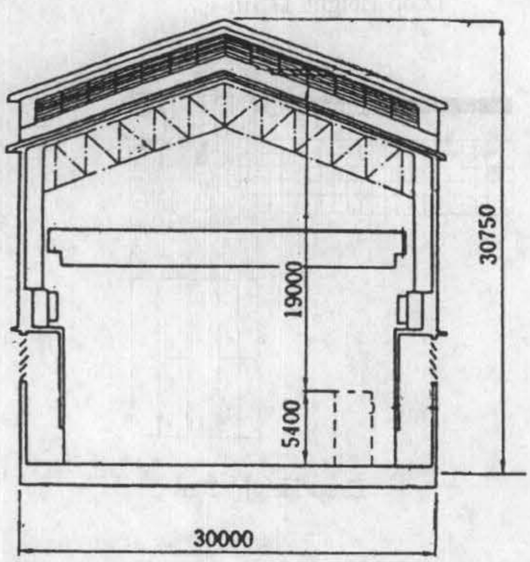

Fig.2 Example of Storage House

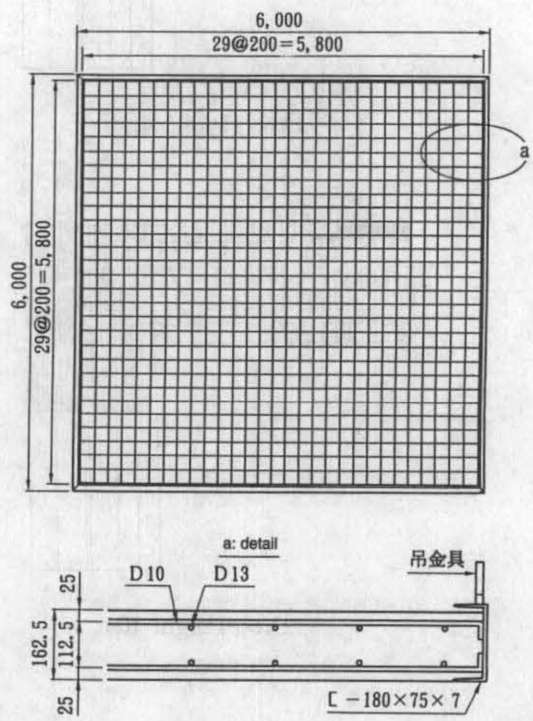

Fig.3 Test RC Slab

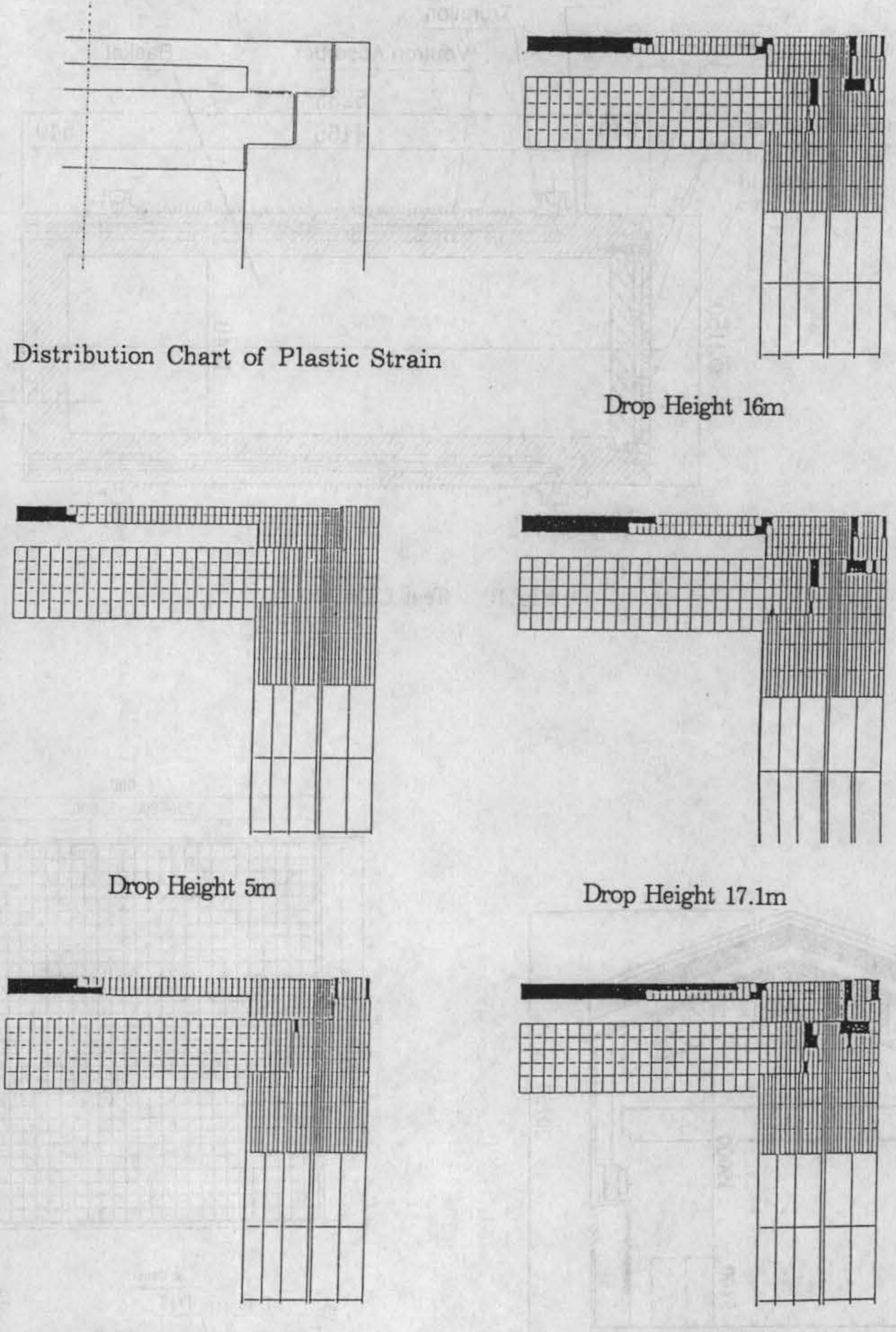

Fig.4 Results of Prior Drop Analysis

5 m

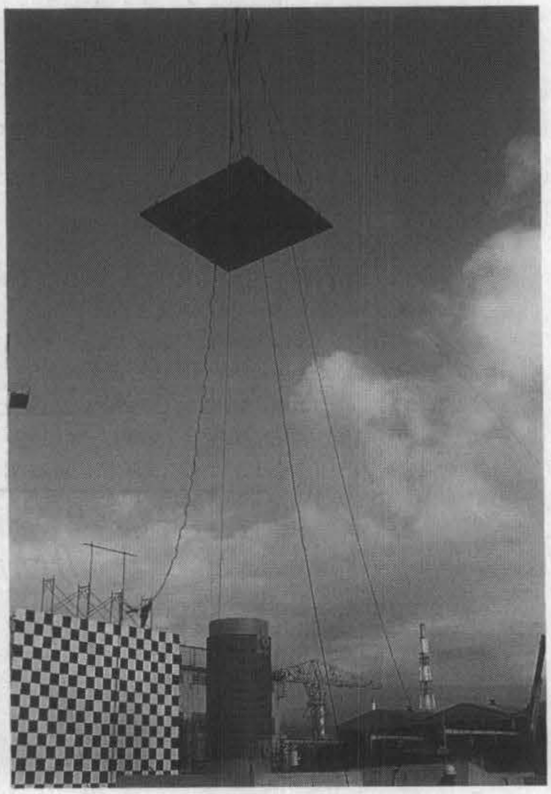

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Fig.5 Condition of the Drop Test

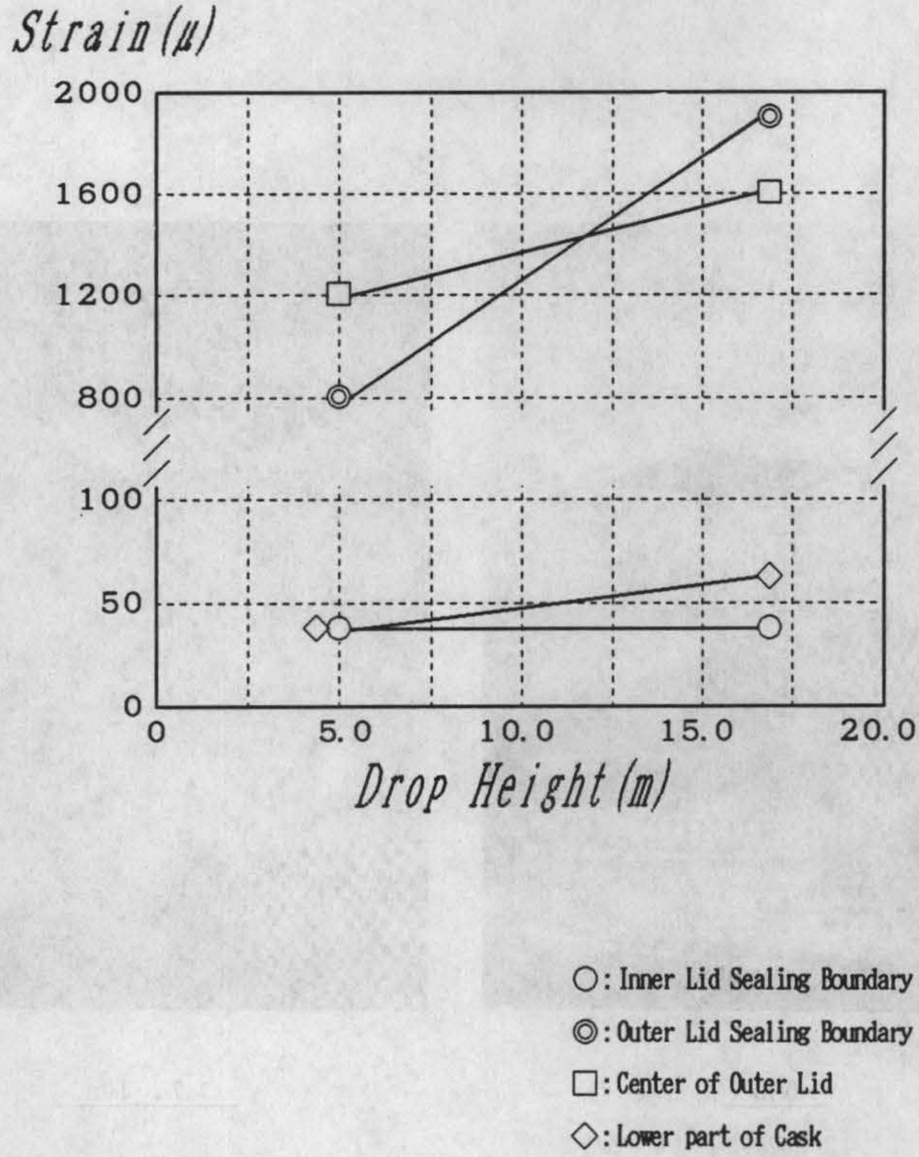

Fig.6 Relations among Drop height and Strain