Developing shock resistance test methods for flying debris on the cladding

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1. Foreword

Cladding damage comprises much of the damages to building caused by strong winds and wind gusts from tornadoes or typhoons. Apart from damages caused by wind pressure, however, it is also known that substantial damages are also caused by flying debris that strikes the building as a result of the strong winds. Until now, the shock-resistance of cladding was evaluated only with regards to wind pressure resistance, with no evaluating method regarding flying debris. On the other hand, regulations and ISO standards in the United States include shock resistance testing methods of glass in the claddings and openings of buildings. As well, shock resistance under strong winds is evaluated with impact tests, whereupon steel balls and various wood chips of different sizes are collided with a test body at high speeds, which is later subjected to repeated pressure load tests.

Accordingly, NILIM began examining resistance testing methods regarding flying debris upon the cladding in one of its issues: "The development of tornado countermeasures technology" within the comprehensive technological development project called "Developing continuous function technology for disaster base buildings" (in the fiscal years 2013 to 2016). The purpose of this research is to develop a testing method regarding shock resistance of flying debris upon the cladding, for which a standard has yet to be established in our country.

2. Required performances regarding strong wind disasters on buildings

As shown in Table 1, buildings were classified into five groupings (storages or facilities involved with hazardous materials, disaster base buildings, shelters, facilities with a plurality of users, and others) based on its required performance during a disaster. Overviews and case studies of the buildings and facilities, the classification and size of the external force and required performances are also indicated.

Regarding the required performance of disaster base buildings (government buildings, police stations, fire station-related facilities, hospitals and Self-Defense Forces-related facilities etc.), with reference to the 1994 Ministry of Land, Infrastructure and Transport notification 2379 "standard regarding administrative buildings and the position, scale and structure of its ancillary facilities" and the integrated earthquake resistance and anti-tsunami standards of government buildings,

Table 1: Types of disaster base buildings and its required performance towards tornadoes and typhoons

Type of building			Target phenomenon and external force	Required performance
Name	Overview	Example		
I Storages or facilities involved with hazardous materials	Facilities that could severely affect the surrounding area if its function is stopped by a disaster (including leakage of hazardous materials)	Nuclear power plants, oil plants	Collisions of flying debris and wind pressure resulting from F4 tornadoes and the largest typhoons	Continuous function of the facilities
II	Facilities	Police	Collisions of	Securing the

Disaster base buildings	whose continuous function is required during and directly after a disaster	stations, fire station-related facilities, hospitals, government buildings, Self-Defense Forces-related facilities, data centers	flying debris and wind pressure resulting from F3 tornadoes and extremely rare strong winds	safety of human life Continuous function of the facilities
Ⅲ Shelters	Facilities designated as shelters and other similar facilities	Schools, gymnasiums, meeting places, hotels	Collisions of flying debris and wind pressure resulting from F2 tornadoes and extremely rare strong winds	Securing the safety of human life
Ⅳ Facilities with a plurality of users	Facilities where the general public gather	Department stores, stadiums	Collisions and wind pressure resulting from F2 tornadoes and rare strong winds	Securing the safety of human life
V Others		Housing	Collisions and wind pressure resulting from rare strong winds	Securing the safety of human life

Note: F2 to F4 inside the table indicates the Fujita scale.

it was declared that disaster base buildings must "not only secure the safety of the human life, but fulfill its .function as a disaster base building at the time of a disaster." Here, the external wind force was set at the Building Standard Act's limit strength calculation for the maximum wind strength of typhoons (return period corresponding to 500 years) and F3 (Fujita scale 3) for tornadoes. The largest tornadoes in our country's recent history were also of an F3 class, namely in Mobara (1990), Toyohashi (1999), Saroma (2006) and Tsukuba (2012) etc.

Storages or facilities involved with hazardous materials like nuclear power plants and oil plants require a performance greater than disaster base buildings regarding the continuous function of the facility as they could severely affect the surrounding area if its function is temporarily stopped as a result of being struck by a disaster. Accordingly, for storages or facilities involved with hazardous materials, an external force level larger than disaster base buildings was set at F4 for tornadoes with a return period corresponding to 1000 years for typhoons.

Shelters, on the other hand, do not require the same level of functional continuation as disaster base buildings. However, the same performance level is required in terms of securing the safety of human life for those inside the facility. Accordingly, with shelters, the same external force level as disaster base buildings was set at the maximum level for typhoons as set in the Building Standard Act (extremely rare strong winds, with a return period corresponding to 500 years). However, with regards to tornadoes, an F2 class was set, taking into consideration the probability of the disaster to strike a single building unit.

With regards to facilities where large groups of the public gather, like department stores and stadiums, the safety of human life for those inside the facility is also required. However, since typhoon-related information is provided prior to the storm by the Meteorological Agency, it is believed that those facilities would not be used when there are rare outbreaks of extremely strong winds. Consequently, the securing of the safety of human life for those inside the facility was determined a requirement with regards to flying debris and wind pressure caused by gusts of wind from tornadoes etc., as well as its structural resistance to withstand flying debris and wind pressure resulting from strong winds (rare strong winds) as established by the Build Standard Act regarding typhoons.

In terms of housing, houses are required to secure the safety of human life for those inside the rooms against strong winds (rare strong winds) as established by the Build Standard Act and any resulting flying debris. However, in this case, the effects of wind gusts from tornadoes did not have to be taken into consideration.

3. Shock resistance of flying debris on the cladding for disaster base buildings etc.

Regarding the shock resistance of flying debris upon the cladding of disaster base buildings etc. it was considered that there should "not be any damaged cladding that may be a hindrance to the disaster base building in performing its required performance at the time of a disaster." Specifically, the following functions of the cladding were required as indicated in Table 1.

(1) The cladding must protect the room from flying debris penetrating the room in the assumed event of strong wind gusts from a tornadoes and typhoons. However, as long as there is no remarkable damage to the room inside the cladding, damage to the outside of the cladding is permitted. Remarkable damage refers to damages that will cause a hindrance to activities inside the room resulting from wind and rain penetrating the room, following damage to the cladding.

(2) Furthermore in the event of a typhoon, the damage to the cladding by flying debris should not escalate, thereby resulting in a large opening beyond a certain size, with regards to a specified wind pressure.

4. Shock resistance test for flying debris

In the shock resistance test for flying debris, a test equipment as shown in Figure 1 was used to confirm the shock resistance of flying debris on the cladding. As shown in Figure 2, two experiments were conducted for tornadoes and typhoons. The specifications for each of the objects colliding into the buildings and facilities were established in the classifications listed in Table 1. The specifications for the colliding objects are defined in Table 3, based on overseas standards and possible examples of flying debris in our country. The F scale in the table represents the Fujita scale in the assumed event of a wind gust from a tornado, and the specifications of each colliding object and Fujita scale rank was associated with a numerical simulation.

5. Conclusion

Henceforth, one of the issues of our integrated technology development project "Developing continuous function technology for disaster base buildings," the shock resistance test method for flying debris on the cladding was presented.

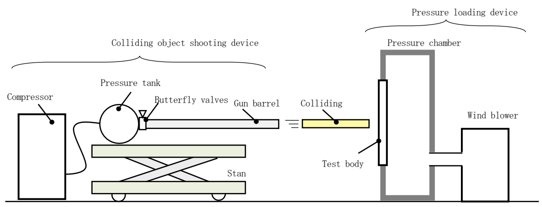

Figure 1: Example of the test equipment for the shock resistance test for flying debris on the cladding

Table 2: The return period of the type and wind load of the required colliding object

Type of building	A. Tornado test		B. Typhon test		
	Colliding object		Colliding object		Wind pressure return period (years)
	10m≦h	h >10m	10m≦h	h >10m	
I Storages or facilities involved with hazardous materials	⑥	⑤	⑤	④	1000
II Disaster base buildings	⑤	④	④	③	500
III Shelters etc.	④	③	③	②	500
IV Facilities with a plurality of users	④	③	②	①	50
V Others	−	−	②	①	50

h is the cladding height (m) Number ○ is the colliding object number in Table 3

Table 3: Specifications of the colliding object

Colliding object	Presumed F scale	Mass (kg)	Speed (m/s)	Operating energy (J)	Corresponding existing standards	
①	Below F0	0.91	15	Approx.100	ASTM-B	
②	F0	2.0	12	Approx.200	ASTM-C	ISO-B
③	F1	4.1	15	Approx.500	ASTM-D	ISO-C
④	F2	4.1	24	Approx.1000	ASTM-E	ISO-D
⑤	F3	6.8	22	Approx.2000		ISO-E
⑥	Over F3	6.8	35	Approx.5000	FEMA361, ICC-500 (tornado) lower limit	