



THE STUDY OF DEGRADATION CONDITION OF HIGH-RISE BUILDING EXTERIOR WALL

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In recent years in Taiwan, some pedestrians were injured by falling external wall tiles. Exterior wall tile fell down for the temperature or other effects of seismic forces, becoming a potential public safety crisis. Office of Building Administration of Taoyuan City Government started inspecting high-rise buildings, which were over eleven stories and constructed before 1995 in Taoyuan city from 2015 to 2016. This study is a contract research. We inspected 298 high-rise buildings' external wall tiles in Taoyuan City for city government. In this study, we classified the risk of buildings from Level A to E. D and E, which were regarded as the dangerous buildings and in need of repair immediately. D and E accounted for 41.6% percent of total buildings. We also concluded the data in the viewpoints of building age, story, exterior material, direction, and district. The authors hope the conclusion of this study could be submitted as reference material of inspection system, as well as give a significant suggestion to the periodic inspection approach in the future.

Keywords: External wall tiles, City government, Taoyuan city, Periodic inspection, Public safety, Degradation condition.

1 INTRODUCTION

In recent years in Taiwan, some pedestrians were injured by falling external wall tiles. Exterior wall tile fell down for the climate temperature or other effects of seismic forces, becoming a potential public safety crisis. According to "Account and Residence Census Report", number of householders in Taoyuan City have two peaks.¹ One is 27,362 householders in 1995, another is 23,122 householders in 2006. Buildings built in the peak of the 1995's were more than 20 years old. How to maintain and manage existing buildings with high housing age has become an important topic for discussion in Taiwan society today.

The Office of Building administration of Taoyuan City Government in Taiwan started inspecting high-rise buildings, which were over eleven stories and constructed before 1995 in Taoyuan City. This study is a contract research. Our team inspected 298 high-rise buildings' external wall tiles in Taoyuan city for city government from September 2015 to May 2016.

¹We organized the data of Account and Residence Census Report from 1980 to 2015. The data were published by "Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Taiwan" and "Construction and Planning Agency Ministry of the Interior".

Tile is one of the most popular materials for housing building exterior wall construction in Taiwan, especially for reinforced concrete and steel reinforced concrete structure. In this cooperative survey, 75% of the objects use tiles. Mosaic, brick square, *nikogake* and half of *nikogake* are most commonly used in Taoyuan City. The purpose of this study is to confirm building age, story, exterior material, direction, and district. I hope the conclusion of this study could be submitted as reference material of inspection system, as well as give a significant suggestion to the periodic inspection approach in the future.

2 SUBJECT OF STUDY

Our team inspected 298 high-rise buildings' external wall, which were over eleven stories and constructed before 1995 in Taoyuan City from September 2015 to May 2016. There are thirteen districts in Taoyuan City. Sixty buildings are surveyed every month from October 2015 to January 2016. We were also responsible for the 1999 cases of emergency notification.² Our team consists of a university professor, three architects, two civil engineers and three master students. We used the visual inspection to inspect these high-rise buildings.³

2.1 Classification Level - A, B, C, D, and E

In this study, we classified the risk of buildings from Level A to E. D and E, which were regarded as the dangerous buildings and in need of repair immediately. 109 objects were rated as Level C, up to 36% (Figure 1). Following are the definitions of the grade:

- A: Exterior wall without setting any attached objects, the walls clean and flawless.
- B: No C, D, E status.
- C: There is sporadic degradation of tile peeling and floating. Serious water leakage and efflorescence of the wall. Objects which were rated as D and E will be changed to C, while protective eaves, iron windows, protective net were setting up.
- D: Floating tiles area below 4 and the not more than 5 m². Significant cracks below 4.
- E: Floating tiles area above 5 and the more than 5 m². Significant cracks above 5.

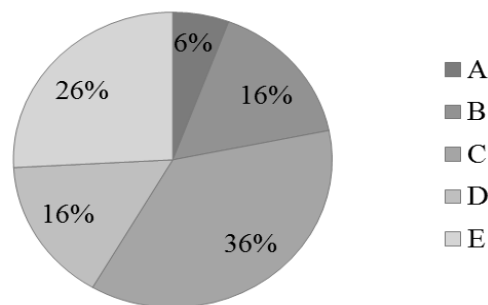


Figure 1. The grading proportion of the research objects.

²1999 notification is a 24-hour City Hall hotline. If there is a public notification, we must arrive within two hours of notification and inspect exterior wall immediately.

³Experts using the naked eye, binoculars, high-power single-eye cameras to investigate the deterioration of the external walls at the site.

2.2 Investigation Form

Three architects and two civil engineers were responsible for the main investigation. Investigators must communicate adequately with the management committee and residents. Investigators return information to professors at the University of Kaohsiung, the professor then integrated into the city government information to manage. Investigators must complete the investigation form when conducting the survey. Following are the information of the form.

- Building information: Building address, license, construction, number of buildings, use and file code.
- Investigators, contract institution, and building visit information: Architects, civil engineers, University of Kaohsiung, management committee shall sign and date the form.
- Evaluation of wall and attachment: Checking the material of the exterior wall (tile, stone, Close lightly pebble, monolithic finish or others) and attachments (railing, Air conditioning equipment, eaves, iron windows). Comprehensive rating buildings as A (good), B (be careful), C (suggested improvement), D (potential danger, recommend temporary facilities), or E (immediate danger, have warning belt and temporary facilities).
- Recommend the temporary protection facilities.
- Record of damage status of each floor.
- Current status photos.
- Plan and elevation diagram.

3 BUILDING BASIC INFORMATION

In this section, we showed the building basic information – construction year, number of stories and types of exterior wall.

3.1 Construction Year

Figure 2 shows the age of the object buildings. Approximately 85% of the object buildings are 20 to 25 years old, 11% are 26 to 30 years old. 4% of the object buildings are more than 30 years old.

3.2 Number of Stories

Figure 3 showed the floor height of the object buildings. Approximately 74% of the object buildings are 11 to 15 stories, and 17% are 16 to 20 stories. 3% of the object buildings are less than 11 stories and 6% are more than 20 stories.

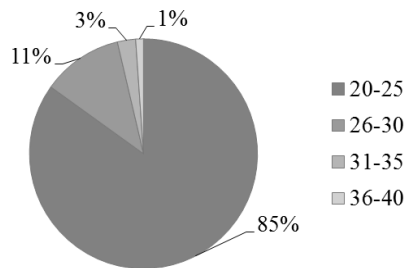


Figure 2. The age of the object buildings.

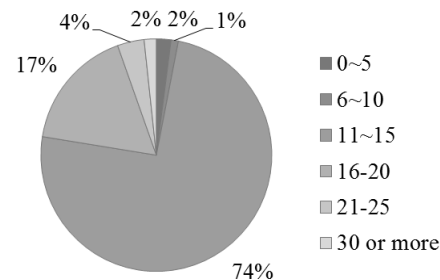


Figure 3. The floor height of object buildings.

3.3 Exterior Wall Types

Figure 4 showed the exterior wall types of the object buildings. Approximate 5% of the object buildings use mosaic, 45% are brick square, 20% are *nikogake*, 5% are half of *nikogake* which means that the use of tiles accounted for 75%. Other materials are monolithic finish, stone, curtain wall and decorative plates. Table 1 showed the common sizes of tiles in Taiwan.

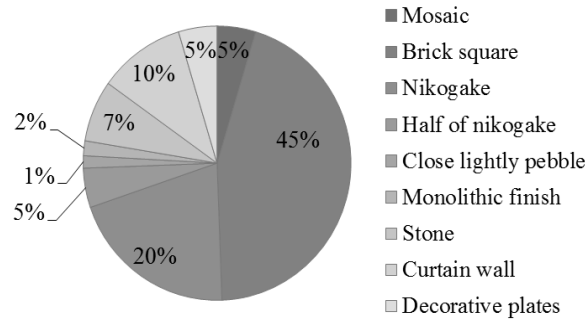


Figure 4. The types of object exterior wall.

Table 1. The common sizes of tiles in Taiwan (Peiyee 2008).

Types of tiles	Size (mm)
Mosaic	18x18 / 24x24 / 50x50 / 55x55 / 60x120
Brick square	75 x75/ 80x80 / 90x90 / 95x95 / 100x100
<i>Nikogake</i>	230x60 / 230x50 / 210x55 / 227x60 / 240x52
Half of <i>Nikogake</i>	173x40 / 190x40 / 195x35 / 200x32

4 THE DEGRADATION CONDITION OF THE EXTERIOR WALL TILE

In this section, we showed the deterioration of buildings and the relationship between building age, story, exterior material, direction, and district. Table 2 shows the deterioration of object buildings and the relationship between building age.

Table 2. The deterioration of object buildings and the relationship between building age.

Level	Proportion	The age of buildings			
		20-25	26-30	31-35	36-40
A	6.0%	13	3	1	0
B	16.3%	41	2	2	1
C	36.9%	85	17	1	1
D	16.7%	44	2	1	0
E	24.1%	54	7	5	2
Total	100.0%	84.0%	11.0%	3.6%	1.4%

The deterioration of object buildings and the relationship between building stories, exterior wall types, directions and districts could be checked at table 3, 4, 5 and 6.

84.0% of the object buildings are 20 to 25 years old, most of the proportions are at Level C, E and D. 73.5% of the object buildings are 11 to 15 stories, most of the proportions are at Level C and E. With 74.5% of the object buildings using tile materials (mosaic, brick square, *nikogake*, half of *nikogake*) most of the proportions are at brick square (44.8%) and Level C. The

degradations were most often seen at east (15.0%), northeast (14.3%) and south (14.1%) directions. 44.3% of the degradation buildings were located at Taoyuan district, 26.5% were located at Chungli district. Figure 5 shows the 12-story reinforced concrete object building (file code: 10410-2) which was constructed in 1989. This building is located at Taoyuan district and uses the common tile style brick square.

Table 3. The deterioration of object buildings and the relationship between building stories.

Level	Proportion	Stories of buildings					
		0-5	6-10	11-15	16-20	21-25	Above 30
A	5.7%	0	0	10	2	3	2
B	16.1%	0	0	39	4	4	1
C	36.6%	2	2	83	18	2	2
D	15.8%	0	0	37	9	1	0
E	25.8%	7	2	50	17	1	0
Total	100.0%	3.0%	1.3%	73.5%	16.8%	3.7%	1.7%

Table 4. The deterioration of object buildings and the relationship between exterior wall types.

Proportion	Types of exterior wall									
	Mosaic	Brick square	Niko-gake	Half of niko-gake	Close lightly pebble	Monolithic finish	Stone	Curtain wall	Decorative plates	
A	6.7%	0	2	6	2	1	0	0	7	5
B	16.6%	2	16	15	2	1	2	3	12	4
C	38.1%	4	66	26	5	3	2	14	8	3
D	12.2%	3	25	5	1	0	1	2	4	1
E	26.5%	7	45	18	6	0	1	6	5	3
Total	100.0%	4.7%	44.8%	20.3%	4.7%	1.5%	1.7%	7.3%	10.5%	4.7%

Table 5. The deterioration of object buildings and the relationship between directions.

Level	Proportion	Direction of degradation location							
		East	West	South	North	northeast	southwest	southeast	northwest
A	1.4%	5	0	0	1	0	0	0	0
B	6.8%	5	5	1	3	4	6	4	1
C	39.4%	21	24	26	20	28	22	9	18
D	19.5%	11	15	15	8	11	6	8	9
E	32.9%	22	15	18	18	18	19	21	9
Total	100.0%	15.0%	13.8%	14.1%	11.7%	14.3%	12.4%	9.9%	8.7%

Table 6. The deterioration of object buildings and the relationship between districts.

Proportion	District										
	Tao-yuan	Chun-gli	Lu-zhu	Long-tan	Ping-zhen	Daxi	Yang-mei	Gui-shan	Guan-yin	Bade	
A	5.7%	9	1	2	0	0	2	0	0	3	
B	16.1%	14	12	6	1	4	0	0	10	1	
C	36.6%	47	30	9	0	5	0	2	6	9	
D	15.8%	21	18	2	1	1	1	0	1	2	
E	25.8%	41	18	4	0	10	0	0	3	1	
Total	100.0%	44.3%	26.5%	7.7%	0.7%	6.7%	1.0%	0.7%	6.7%	0.3%	5.4



Figure 5. Photo of 12-story reinforced concrete object building (left) photo of brick square (right).

5 CONCLUSION

In this study, we inspected high-rise buildings, which were over eleven stories and constructed before 1995 in Taoyuan City. 16% of the research objects were rated as Level D, 26% were Level E. 84.0% of the research object buildings are 20 to 25 years old. 74.5% of the object buildings using tile materials, which were mosaic, brick Square, *nikogake* and half of *nikogake*. 44.3% of the degradation buildings were located at Taoyuan district. Citizen who lived in the 11 to 15 stories housing in Taoyuan district, which used brick square over twenty years, should check the changes at the external walls. The government should also establish inspection system for these buildings to prevent falling. Following are the features of the degradation objects:

- Level D and E buildings: We classified the risk of buildings from Level A to E. D and E, which were regarded as the dangerous buildings and in need of repair immediately. 16% of the objects were rated as Level D, 26% are Level E. It is means that 42% high ratio of the object buildings needed to be repaired or set temporary protection facilities.
- Degradation building age and story: Construction peak in Taoyuan City was in 1995. 84.0% of the object buildings are 20 to 25 years old. 73.5% of the object buildings are 11 to 15 stories. Citizen should be take care buildings complying with these conditions.
- Tile materials of exterior wall: 74.5% of the object buildings using tile materials, most of the proportions are brick square. How to enact regular tile inspection system and maintain these existing buildings with high housing age has become an important topic.
- Degradation building at Taoyuan district: 44.3% of the degradation buildings were located at Taoyuan district. The Taoyuan district was developed earlier and the population was double than other districts.

Acknowledgments

This study was funded by the Office of Building Administration of Taoyuan City Government.

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