Study on the Relation Between Mockup Test and Lifecycle of Curtain Wall Construction - Case Study in Taiwan

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ABSTRACT

The performance of curtain wall could be simply divided into two parts: one is performance of material and another is performance of system. When we think about the durability of curtain wall, we shall consider the life of curtain wall. Lifecycle theory is one of the important method for studying constructions and materials of sustainable building. Lifecycle of curtain wall construction has been divided into several parts, including plan, design, test, manufacture, installation, usage, maintaining, renew, and recycle.

Mockup performance test is common method to make sure of objective by phases of lifecycle. Development of Pre-fabricated curtain wall in Taiwan is over 30 years. In the meantime, the economy of Taiwan is on the decline. And the bidding of Construction changed from Best Value Contracting (BVC) to Lowest Price Contracting (LPC). Recently, the price of material has raised a lot. With factors mentioned above, some management problems were discovered, such as some contractors would never fabricate according to drawings, and they change the design by themselves.

Mockup test is one of the full-size performance tests of exterior wall and it is one of the macro methods to control quality of the construction. In this study, the results and applications of 30 test cases were investigated. Results of this study included wrong test attitude of constructor, workers of installation in test and in site were not the same, and the results of tests did not feeding back to designer and manufacturer, etc.

KEYWORDS

Mockup test, Curtain wall, Quality management, Lifecycle, Sustainable construction

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1 INTRODUCTION

Curtain wall is one kind of Building exterior wall. Development of Pre-fabricated curtain wall in Taiwan is over 30 years. In the meantime, the economy of Taiwan changed from the highest to the lowest. And the bidding of construction changed from Best Value Contracting (BVC) to Lowest Price Contracting (LPC). Recently, the price of material has raised a lot. With above factors, some problems of management were discovered, such as some contractor never made according to drawing and changing the design by themselves. With all this problems, it direct affected the system performance of curtain wall. The relation between results of mockup test with initial performance of curtain wall will be discussed in this study.

2 METHOD

This study use two methods, literature review and case study. Method of literature review is used to search and collect data of curtain wall, including definition, category, performance, installation, test and lifecycle of curtain wall. Method of case study is use to collect cases of mockup test and their tracing data when the building finish constructing.

The cases shall conform to following:
a. Building located in Taiwan.
b. Completed Project.
c. Test items follow total laboratory procedure of CNS 14280 or AAMA 501.

3 LITERATURE REVIEW

3.1 Definition of Curtain Wall

According to Republic of China Building Construction Regulations [Government of TAIWAN, Republic of China 2007], the definition of curtain wall is “exterior wall of frame-construction building, which only bearing self weight, wind load and earthquake load, and un-bearing or no-passing other loads.” In another word, exterior wall which is not load-bearing wall is curtain wall.

A standard curtain wall contains 4 kinds of components: surface material, supporting frame, connector for stress passing, and filler. [Fig. 1]

![Figure 1. Components of a standard curtain wall [Chi & Chen 2003].](image-url)
3.2 Lifecycle of Curtain Wall

Lifecycle of curtain wall has been divided into several parts, including plan, design, test, manufacture, installation, usage, maintaining, renew, and recycle. [Fig. 2]

![Lifecycle of Curtain Wall Diagram](image)

**Figure 2.** Lifecycle of Curtain wall.

In the area of sustainable curtain wall, 2 important control points shall be focused:

a. System plan:
In this phase, the total cost, construction and main materials, and lifecycle of curtain wall will be setting. Decisions in system plan phase have great effect upon the lifecycle of curtain wall.

b. Performance test:
Mockup test is one of the full-size performance tests of exterior wall and it is one of the macro methods to confirm the system function of the curtain wall. The result will determine the possible lifecycle setting.

3.3 Performance of Curtain Wall

Performance of curtain wall could be divided into two parts [Chi and Chen 2003], performance of materials and performance of physics (knows as system).

a. Performance of materials:
Including metals (e.g. aluminum, steel, stainless, etc.), precast concrete (e.g. concrete, rebar, aggregate, etc.), glass (e.g. plate glass, glass brick, etc.), sealant (e.g. fixed form sealing, non-fixed form sealing, etc.), and others (e.g. skirt, fire stopping, etc.).

b. Physical performance (system performance):
This performance include wind pressure resistance, watertight, storey deformation absorption, and airtight.

3.4 Classification of Curtain Wall

There are many types of curtain wall, and many kinds of sorting ways, in general it is classified according to Surface materials, Frame materials, Functional, Structural, System, Building appearance and etc. At present in Taiwan, Architects and owner prefer to classify by Cladding materials, but most of the curtain wall contractors classifies by system and frame materials. However, for students and researchers, system classification is the most common used. Chi and Chen [2003] offered a sounder definition of System classification: stick, unitized, semi-unitized (unit-and-mullion and column-cover-and-spandrel), panel, and structure glass. [Figs. 3 –8]
3.5 Mockup Test

The purpose of mockup test is to confirm whether the required performance of curtain walls is satisfied and thereby back up the safety and working function of the products. According to CNS14280 [Government of TAIWAN, Republic of China 2007] or AAMA 501[American Architectural Manufacturers Association 2007] requirement, the major test items include: test for air infiltration (CNS 13971, ASTM E 283), test for water penetration with static pressure (CNS 13974, ASTM E 331), test for water penetration with dynamic pressure (CNS 13973, AAMA 501.1), test for structure under static pressure (CNS 13972, ASTM E 330), and test for storey deformation (CNS 14281, AAMA 501.4). [Figs. 9 –13]
4. CASE STUDY

4.1 Sample of Case

According to the limitation in this case study, we have selected 30 samples, from 2001 to 2006 [Fig. 14]. From the selected samples, the ratio of government buildings to private buildings is almost one to one [Fig. 15].

Figure 16 showed the ratio of various curtain wall systems. Stick curtain wall is the most popular system in the market, because it is the ancient system that use in most building and lower price due to its simple component, which make it more competitive compare to the other system. Figure 17 showed
there are 8 cases of different workers use in laboratory and in the site. The reason of the first 2 samples is because the company laboratory is far apart from the construction site (i.e. different country). The reason for the remaining 6 samples is due to the misleading project time, where they have to test on time, but they had not found a sub-contractor at the same time.

4.2 Data Analysis

Figure 18 showed only 30% of samples passed the prepare test for water penetration with static pressure when they finished mature time. In other words, these curtain walls might be unsuccessful in sites, if they did not conduct the test. This also shows that mockup test is important. 67% of samples passed all test items during one time [Fig. 19]. It means that there still 1/3 of the samples have problems during the mockup test. 90% of these problems are water penetration [Fig. 20]. It means that the biggest problem for curtain wall system design came from water penetration. 78% of water penetration samples failed in first time of test for water penetration with static pressure [Fig. 21]. 45% of prepare test failing samples failed in first time of test for water penetration with static pressure (Figure 22). Although CNS, AAMA, ASTM test standards allow curtain wall manufacturers to repair test specimens in site, the rate of success for repair is still too low.
4.3 Result of Samples Tracing

40% of 30 samples repeated water penetration at test area in the site [Fig. 23]. 80% of passing test samples (i.e. all test items) had not found water penetration in the site [Fig. 24]. This indicates that mockup test is helpful. Figure 25 showed 94% of 80% samples workers work in both laboratory and in the site. We have found 3 points:

a. The mockup test is helpful to check the performance of curtain wall.

b. It can help manufacturers to train their workers during the test before quantity installation in the site.

c. Same workers in the laboratory and in the site are easier to share experience. Different workers might let test become only paper work, the results of test are helpless to building.

Figure 20. Ratio of problems during the test of test failing samples.

Figure 21. Ratio of water penetration problems.

Figure 22. Ratio of 1st water penetration of prepare test failing samples.

Figure 23. Ratio of watertight test in site of 30 samples.

Figure 24. Ratio of water penetration in the site of passing test samples.

Figure 25. Ratio of workers work both in laboratory and in the site of no water penetration in site samples.
5. CONCLUSION

Setting of lifecycle is necessary for constructions and materials of sustainable building. The main points of control the lifecycle of curtain wall are the system plan phase and the performance test phase. We set the period of lifecycle of curtain wall in system plan phase, and we make sure the setting is correct in performance test phase.

Recently in Taiwan, almost all bidding of construction is Lowest Price Contracting (LPC). This make the lifecycle of curtain wall short, hence it is important to make sure the lifecycle of curtain wall will not be shorter for performance level down.

Mockup test is one of macro methods to control early day performance and quality of exterior wall. These performances directly influence life of every material, and these might shorten the whole life of curtain wall.

From the results of samples and their tracing data, we can conclude follow points:

a. Curtain wall manufacturer in Taiwan should pay more attention on preventing water penetration.
b. The attitude of curtain wall manufacturer can be seem from the way they selected the worker, and it effect the result of performance of curtain wall in both laboratory and the site.
c. The successful rate of passing prepare test for water penetration when finishing mature is too low. This shows that pre-education and training is very important before the installation work start.
d. During water penetrating, the success rate of repair/ reinforce is too low. It is better to check all over the system again rather than only repair the positions of penetrating.
e. If the mockup test is passed, 80% guaranty that the job is successful in the site. Thus, mockup tests certainly a good tool to check lifecycle of curtain wall.

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