

# The Influences of Strengthened School Buildings Including Physical Environment and Users' Behavior – Two Cases of Teaching Space in Elementary Schools in Taiwan

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*Abstract:* -The research aims to the influences of strengthened reinforcement upon physical environmental factors, which are lighting, wind, and users' behavior. Through the P.O.E. survey, interview and measuring, we collect the objective data. Besides, the computer software is applied to simulate the difference of physical environmental factors, including light environment and wind environment. The results help engineers making the decision of strengthened reinforcement.

*Key-Words:* -Strengthened Construction, Physical Environment, Users' Behavior, Classroom, Wind Field, and Lighting,

## 1 Introduction

Since 921 Jiji Great Earthquake, all records of the heavy earthquakes mention that the RC structure suffers the heaviest destruction. In current researches, current studies focus on recovering the structural functions of buildings. On the other hand, there are few literatures mentioning the influence on physical environment and users' behavior. Therefore, this study aims to the influences of strengthened reinforcement upon physical environmental factors, which are lighting, wind, and users' behavior.

According to the source and spirit of the motive, this study has four purposes:

- (1) Exploring the influences of strengthened reinforcement on the natural lighting in the classroom.
- (2) The influence of the decreasing opening areas on the air exchange and the wind filed.
- (3) Exploring the influences of strengthened

reinforcement on the users' cognition and behavior.

- (4) Basing on 1-3, offering the reference to make decision of strengthened reinforcement in schools.

In order to clarify the influences of strengthened reinforcement upon physical environmental factors and users' behavior, this study aims at literatures of the reinforcement types, physical environment and users' behavior. It is expected to illustrate the influence of the physical environment and users' behavior. This study focuses on the teaching spaces in elementary schools.

As the starting point, this study collects relative literatures including P.O.E. method, strengthened reinforcement, physical environment and users' behavior. The above result is the basis of following surveys. Through interview and observation, we understand the influence of the users' behavior. On the other hand, we carry out the measurement and simulation of physical environmental factors,

including light environment and wind environment.

## 2 Problem Formulation

According to the relative theory of strengthened reinforcement, light, sound, and users' behavior, the different influences of strengthened reinforcement upon physical environmental factors and users' behavior are clearly understood. At first, this study adopts the on-site observation and interview of P.O.E. to analyze users' cognition. We merge the spatial cognition into the interview and collect the teachers' and students' opinions. Next, we measure the natural light before and after the strengthened reinforcement. Finally, we simulate the wind environment with CFD software and compute the air-exchange times and the indoor wind field.

This study generalizes of the influence on natural light and opening vent. These references are important to help the computer simulation.

- (1) There are three dimensions affecting the natural lighting including building dimension (the height of neighboring buildings, distance, length, reflective ratio and the reflective ratio of the outdoor ground), indoor dimension (the height of indoor working level, the reflective ratio of materials and the spatial form), and the windows dimension (the opening form, width, height, type, area, location, shelter and angle).

- (2) The spatial form, spatial size, and the furniture affect the routine of the wind.

Through the literature, we learn that the construction of reinforcement of steel gusset and reinforcement of wing wall outside the teaching spaces affect the light and wind heavily. It is because both of two constructions decrease the opening areas of the windows. This change affects the light and wind directly. In addition, it affects users' action indirectly.

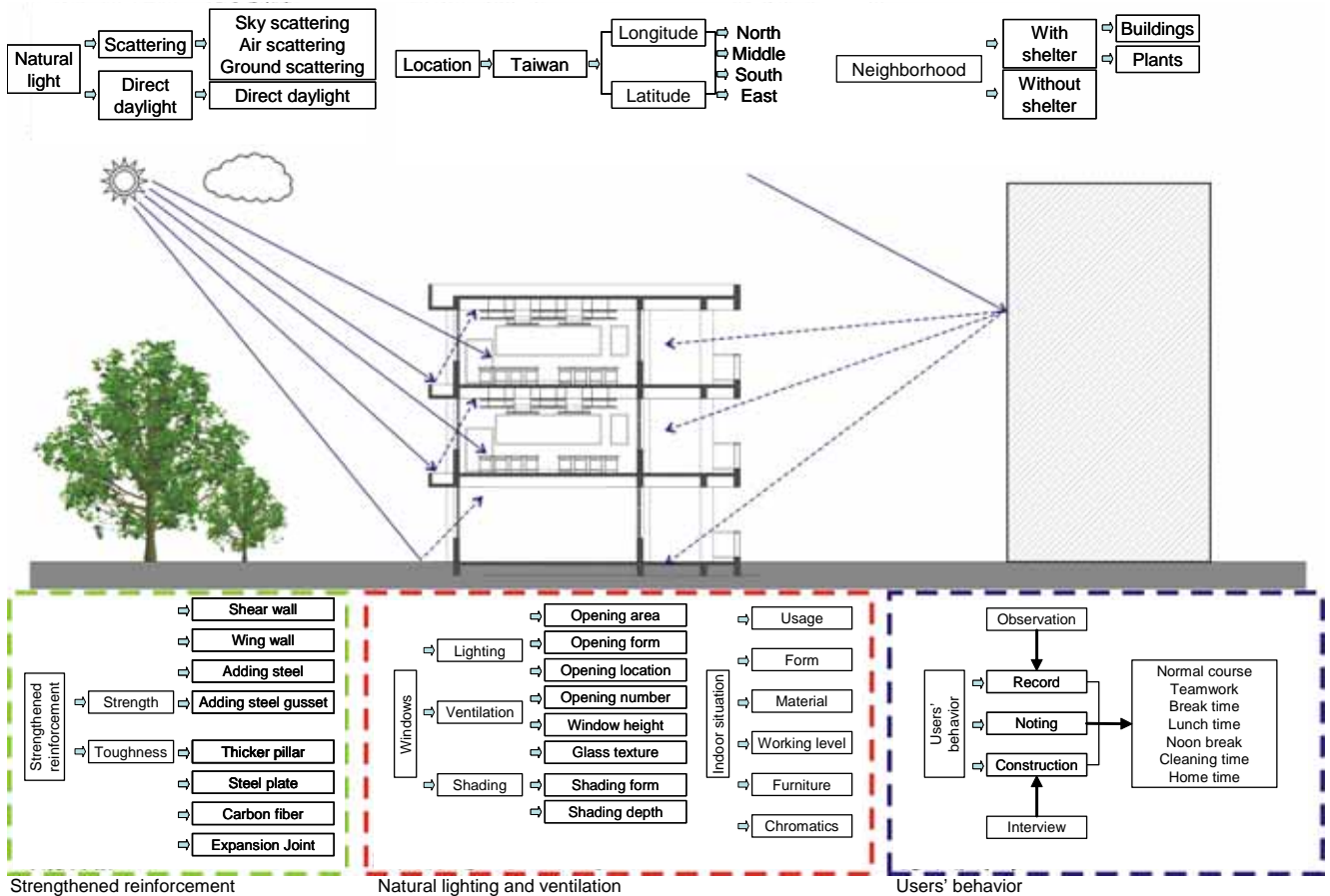


Fig. 1 The illustration of the strengthened reinforcement, physical environment and users' behavior

This study selects the cases with reinforcement of steel gusset and reinforcement of wing wall in teaching spaces. These spaces have following conditions:

- (1) Permanent or semi- permanent buildings rather

then temporary ones.

- (2) The construction locates indoors and at arm's length.
- (3) Allowing the circulation of teaching activities.

### 3 Problem Solution

#### 3.1 Influence of Steel Gusset and Reinforcement of Wing Wall on Opening Areas

The volumes of construction are calculated to explore the loss resulted from steel gusset and reinforcement of wing wall. Table3 shows the decrease after constructing.

#### 3.2 Exploring the Current Situation of Decoration Materials

It is usually ignored that decoration materials affect the natural lighting reflection and users' perception directly. In the survey, we find that school buildings

adopt original decoration after strengthened reinforcement construction. It cannot solve the problems of cables, audio facilities, and storages. Engineers should consider more than the structural strength. For example, considering the users' behavior and requirement brings more suitable and comfortable teaching environment.

#### 3.3 Influence of Strengthened Reinforcement

After the reinforcement of steel gusset and reinforcement of wing wall, the affected light environment, wind environment and users' behavior in the classroom. We summarize the results briefly:

Table1. The evaluation of the different influences on light, wind and users' behavior

Construction		Location	Influence on light	Influence on wind	Influence on users
Strength	Shear wall	Partition wall	○*	○	
	Reinforcement of wing wall	Partition wall	○	○	
		Outer wall	●	●	●
	Steel	Pillar side	○	○	
	Steel gusset	Partition wall	○	○	
Outer wall		●	●	●	
Toughness	Thicker pillar	Thicker pillar/beam			○
	Steel plate	Thicker pillar/beam			○
	Carbon fiber	Thicker pillar/beam			○
	Longer pillar	Windowsill	○	○	○

\*○: without influence; ○: part influence; ●: serious influence

Table 2 The layout and elevation of strengthened reinforcement

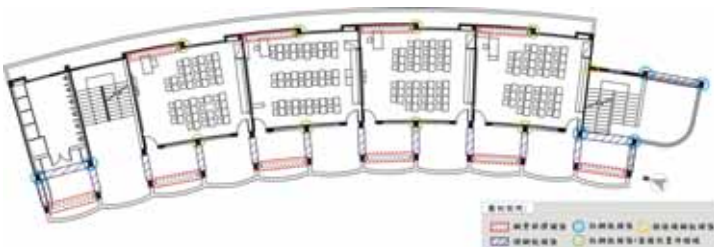

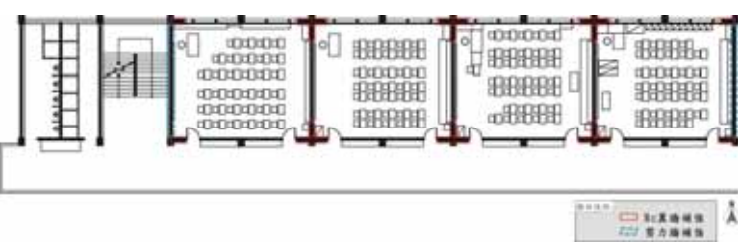
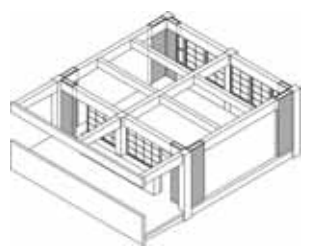
	layout	elevation
steel gusset		
wing wall		

Table 3 The loss of spatial areas

		reinforcement of steel gusset		reinforcement of wing wall	
		Area loss	Opening loss	Area loss	Opening loss
layout	Unit area	2.12m <sup>2</sup>	--	9.9m <sup>2</sup>	2.96m <sup>2</sup>
	Layer area	10.6m <sup>2</sup>	--	39.6m <sup>2</sup>	11.84m <sup>2</sup>
	Total area	53m <sup>2</sup>	--	158.4m <sup>2</sup>	47.36m <sup>2</sup>
elevation	Unit area	6.54m <sup>2</sup>	--	29.11m <sup>3</sup>	5.18m <sup>2</sup>
	Layer area	32.08m <sup>2</sup>	--	116.44m <sup>3</sup>	20.72m <sup>2</sup>
	Total area	160.4m <sup>2</sup>	--	465.76m <sup>2</sup>	82.88m <sup>2</sup>

(1)Light environment

According to the practical measurement, in the classroom with reinforcement of steel gusset, the outer seats are lightful enough. It is not necessary to set artificial lighting. The reinforcement of steel gusset does not decrease the opening areas, but it still affects the ambient lighting. Through computer simulation, we find the reinforcement of steel gusset reduce 23% of natural lighting. The inner seats require the artificial lighting to match the standard. In this classroom, the electronic circuit of these lights is not suitable, so opening the lights might waste the energy.

(2)Wind environment

Through CFD simulation, we find the times of air exchange reduce 1.8%. The steel gusset makes the wind field complex and affects teachers and students. The steel gusset is set at a distance of 25 cm. It does not reduce the opening areas, but affects the wind speed, especially the opening near the steel gusset. With reinforcement of steel gusset, when we open the left-below and right-below windows, the routine of air will change. It is helpful to bring away the suspended particles at the level of students' noses.

(3)Users' behavior

When engineers design the strengthened reinforcement in the school, they pay attention to enhance the structural functions. In other words, they never consider the users' requirement in teaching spaces. Because the interview, we learn that personal and public storage spaces are required. Through the observation, we learn that the users percept the steel gusset more than reinforcement of wing wall. The reinforcement of wing wall is set at four corners and affects the circulation of entering and exiting. There is not serious influence on other behaviors.

**4 Conclusion and Suggestion**

In this study, we establish the theme, review literatures, survey the cases and analyze them. We generalize the conclusion and suggestion.

**4.1 Conclusion**

**(1)Reinforcement of steel gusset :**

The reinforcement of steel gusset does not decrease the opening areas but reduce the ambient lighting. The reinforcement of steel gusset affects the light environment, wind environment and users' behavior.

- A. The reinforcement of steel gusset reduces 21%-23% of natural lighting. Because the reinforcement of steel gusset brings larger shade, it might increase the ratio of nearsightedness.
- B. Because the reinforcement of steel gusset does not decrease the opening areas, the times of air exchange are not affected. However, the wind speed drops. The average wind speed at the level of students' noses is getting lower and there is a vortex formed behind the teaching space.
- C. It is the most serious problem that the classroom is lacking in personal and public storage spaces. Besides, the reinforcement of steel gusset is set in the classroom, the corridor and the balcony. It results in 66% students' injury.

**(2)Reinforcement of Wing Wall :**

The reinforcement of wing wall reduces 2.205 m2 of the opening areas. Also, the reinforcement of wing wall affects the light environment, wind environment and users' behavior.

- A. The reinforcement of wing wall reduces 11% of natural lighting. The shadow of wing wall results in the blackboard lacking in lighting.
- B. CFD simulation shows that the times of air exchange decreases 30%. The wind field at the

front area of the classroom is affected by the reinforcement of wing wall so that the air changes its routine. This performance remains the suspended particles in front of seats. It damages teachers' and students' health.

- C. There is lacking the personal and public storage spaces. Because the reinforcement of wing wall is set on four corners of the classroom, it does not affect the normal behavior. Engineers do not plan the usage of corners and it results in waste.

## 4.2 Suggestion

After the survey and analysis, this study offers the following suggestions:

### **(1)The strengthened reinforcement do not decrease the opening areas**

Engineers should consider more than the structural strength. For example, they have to consider the users' behavior and keeping the lighting and ventilation.

### **(2)Engineers should enhance their aesthetical sense**

Because of the limit of budget, schools improve the structural functions rather than other functions. Engineers should offer a long-term planning including spatial layout.

### **(3)The improvement of Users' behavior in teaching spaces**

Closing the windows might result in the obstructed ventilation. This study suggests opening all the windows. It is helpful to bring the pollutant and heat away.

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