IMPLEMENTATION OF LOW COST SOLAR BUILDING STRATEGY ON PRIMARY SCHOOL RECONSTRUCTION AFTER EARTHQUAKE IN SICHUAN PROVINCE, CHINA

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Summary

Wenchuan earthquake in 2008 is really a catastrophe. It almost destroyed everything, especially for those students studying in the classrooms at that time. As thousands of children had no time to escape, they were buried under collapsed floor slabs and walls.

Due to the lesson of Wenchuan earthquake, Chinese Government put the reconstruction of schools as the emphasis of reconstruction after earthquake and put forward the highest demands for school construction. The key problem at present, however, is how to build earthquake-resistant, perdurable, energy-saving and sustainable schools with local restricted conditions of economy and technology. Focusing it and combining with International Solar Building Design Competition, we advanced a design concept of "low cost solar utilization" and collected design schemes of the competition, the subject of which is rebuilt-design of Yangjiazhen School in Mianyang. Later top awarded scheme is optimized and added with some of passive solar technology such as arrangement of viewable wetland and adoption of passive ventilation, planted roof, dual-layer insulation roof, shading board combined with heat collector and moisture isolation floor with air layer from the ground.

The application and implementation of low cost solar buildings strategies has provided not only an easy and comfortable environment for study but a new design thoughtfulness concerning rebuilt-buildings and schools after earthquake.

0 Introduction

After Wenchuan earthquake in 2008, Chinese government rapidly developed reconstruction of disaster area and put school reconstruction as the emphasis. "2009 Delta Cup - International Solar Building Design Competition" (this competition is an important part of the World Solar Energy Conference which is held once every two years, with different design schemes globally collects entries for the competition, in order to correspond with the date of World Solar Energy Conference), with a theme of "Sunlight and Hope" just started up at the same time as the reconstruction after disaster and collect design schemes from the whole world for "Sunlight School" in Yangjiazhen, Fucheng District, Mianyang, Sichuan Province. The implementation scheme is based on first prize work and Chinese Building Design and Research Group deepened and completed construction design and also put it into

construction on the spot.

Technology strategies:

In order to achieve the low cost and Low carbon emissions, the following three strategies should be complied in the project:

1) Low incremental cost of building, high function and comfort level, low operational cost and sustainable operation.

The economy of the area is relatively backward, the cost control of construction and operation processes is essential.

2) Fully consider the characteristics of Mianyang region's climate and the energy demand to run the school.

Mianyang region is hot in summer, humid in winter, the functions of teaching building, dormitory and canteen determines the school's needs: summer ventilation, heat insulation, shading, moisture barrier, winter heating, heat preservation and ventilation.

3) Combined with site conditions and different functions of the building, optimize the layout and architectural space.

Use the site existing height difference to create the elevated space, not only achieves an intensive use of land, also reduces the amount of earthwork before construction.

It has created a new campus space, educational space and highly effective and humanist teaching environment by means of fully utilizing solar energy and other renewable resources and fusing concept of modern education and advanced building technology together.

1 General situation

Project site is rectangular almost 150m×190m. Northeast of it is Shilan Road, northwest is cultural centre of Yangjiazhen (planned), southeast is the dormitory of Yangjiazhen secondary school and southwest is a planned road of Yangjiazhen. The site is a flat depression 3m-4m lower than roads around. It is higher in the north (Fig. 1 and 2).

Fig. 1 Original sight of the land（photo by Yan Zeng）

Fig. 2 Construction site（draw by author）

The primary school is composed with 18 classrooms and 810 students. About 300 students live in the school. It is a three storey building including three parts: teaching and its accessorial building, dormitory building and canteen. Main technical and economic indicators are as following.

Tab. 1 Main technical and economic indicators

Serial No.	Name	Unit	Quantity
1	total floor area of the land	ha.	2.74 (including part of town road)
2	total floor area of the building	m^2	6551
	teaching and its accessorial building	m^2	3712
	dormitory building	m^2	2284
	canteen	m^2	555
3	road and square	m^2	3930
4	playing field	m^2	5600
5	green field	m^2	10010
6	floor area ratio	%	0.24
7	green field ratio (including playing field)	%	36.5
8	building density	%	11.9
9	Parking place for cars	car	10

2 General Layouts

From Land-use planning and functions, the overall layout of the campus is designed, including rational use of site elevation, placement of entrances and exits, and connection between teaching area, living quarters, living assisted area and sports area, at last the traffic flow.

2.1 Land planning

In planning design, existing condition of the land is fully utilized, that is arranging reserved land, playing field and other activity field on the south part, thus not only avoiding sunlight being blocked to teaching building by southern old monitory building also providing a basic condition for the development of the school in the future. North part of the land is higher than south, so it can be utilized to create such a space environment with various height of buildings. It can realize intensive utilization of the land while reduce the quantity of earthwork in the construction. Main entrance faces the direction from where students are coming. Lesser one will be placed on a road planned to be built. Both of them have squares to meet the demands of evacuation of students in a short time.

2.2 Function division

In the school the land is divided as five parts, they are teaching area, dormitory area, accessorial area, playing field and emergent refuge area for accident disaster. Moreover, a reserved area is located in southwest for further development (Fig. 3).

Teaching area is made up of three relatively independent buildings in the north part. Teaching building and office building are connected by a corridor, thus making all functions as a whole. Two dormitory buildings are located in the west part with a corridor on third floor convenient for management. Both areas are divided by an interior road with a semi-open space for study and playing. It is suitable to the

characteristics of student life to arrange dormitory area, teaching area and playing field as a triangle. Canteen is in the northwest close to dormitory building, that can be also used as a space for big-scale indoor activities or meeting room. Canteen, dormitory and teaching area also form a triangle. The land is used intensively and conveniently without any disturbance to each other.

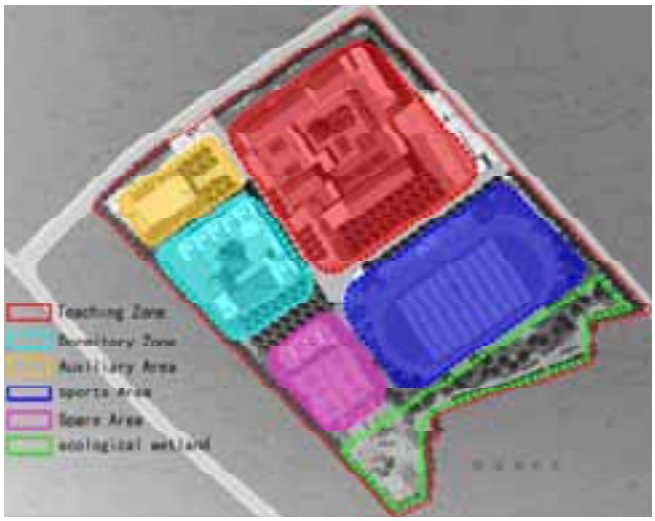


Fig. 3 Analysis on functional division teaching area, dormitory area, accessorial area, playing field, experimental area of ecological activities（draw by author）

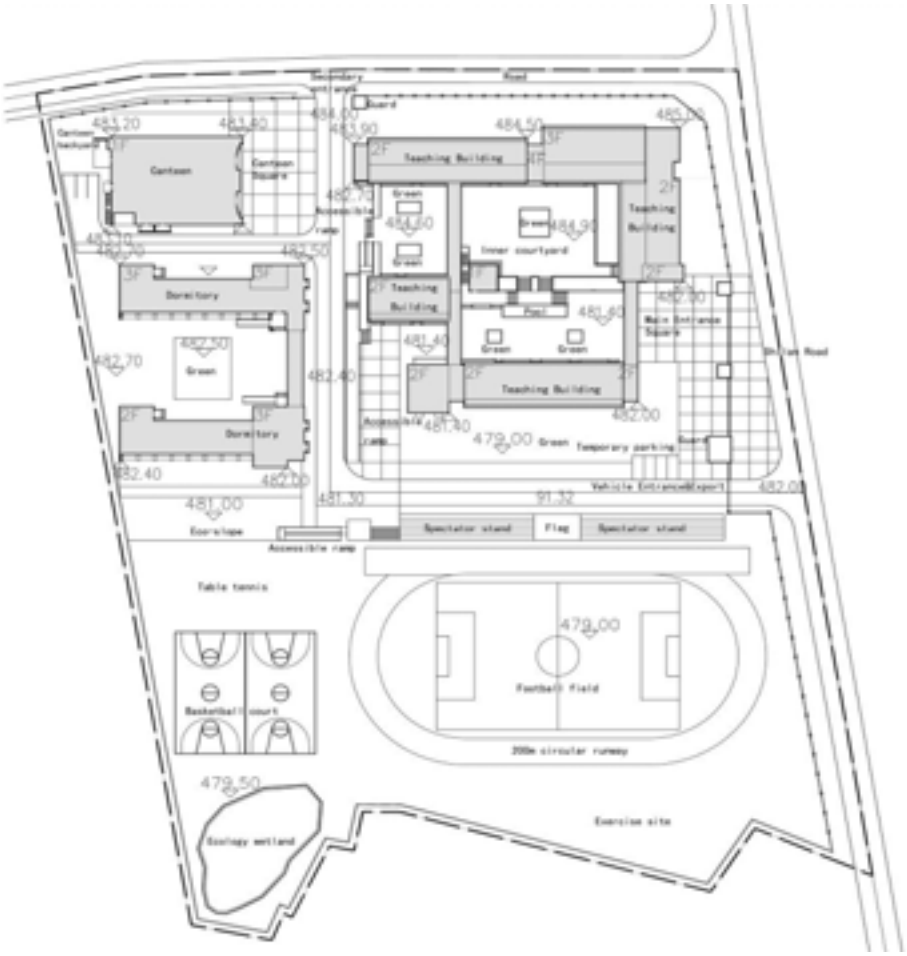


Fig. 4 General plan （draw by Xi Wei）

2.3 Traffic organization

Main entrance is on eastern road facing the direction from where students are coming. Lesser one is on northern road planned as an accessorial entrance. Two squares around both entrances are traffic buffers in order to ensure the safety of students. There is no disturbance between walking road and motor vehicle road in teaching area and playing field. Vehicle road runs through the whole school connecting all of functional areas (Fig. 5).

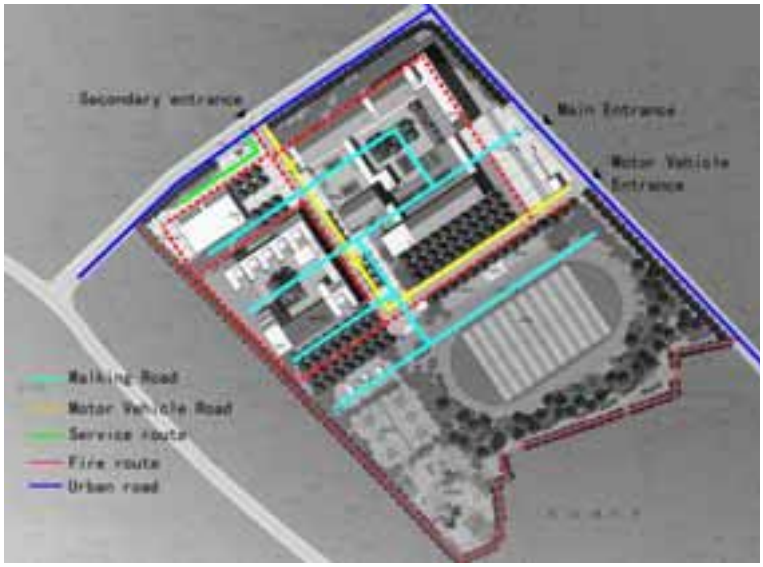


Fig. 5 traffic lines in Delta Sunlight School （draw by author）

2.4 Green landscape

It is an integrated planning on green landscape in the school. The principle is reducing solid pavement while planting more grass and trees, and creating various landscape types of greenery by utilizing original landform and relief. In the southern part original farm land and stream are reformed and protected as an experimental area of ecological wetland and experimental farm land, thus embodying the character of the school in rural area and fully playing the role of educating by environment.

3 Building Design

The new built primary school is a boarding school, the campus includes teaching building, dormitory, canteen three parts, which are interrelated but mutually independent. How to deal with the relationship and flow line of the three parts is the key to building design.

3.1 Function of buildings

3.1.1Teaching building

Teaching area is made up of three parallel buildings in the north part including all class rooms and accessorial rooms, the latter is located in right side of class rooms and encloses a space combined with corridor and entrance together. Also the corridor connects all teaching rooms together as an integrated traffic system, which is convenient to run for people and effective to prevent from wind and rain (Fig. 6). Southern building is one story lower than northern two building. Combining with open space and closed courtyard together three buildings form a lively and interesting exterior space for activities. The toilets in the southwest is located in the leeward, it can escape bad smell flying into the class

rooms. Furthermore, it has high utilization being able not only to serve teaching area but also playing field (Fig. 7).

Fig. 6　Teaching building plan on 3.6m level （draw by author）

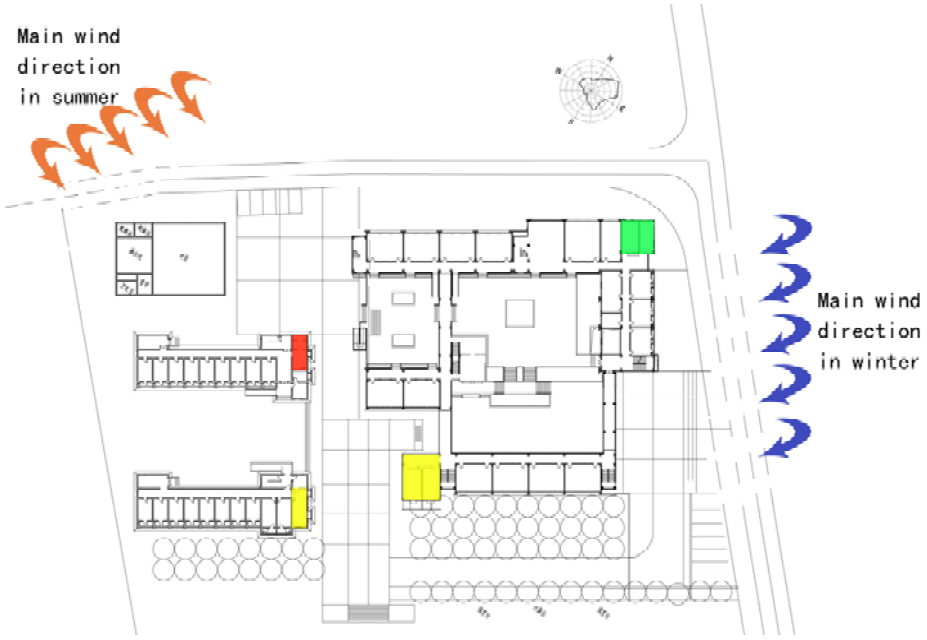


Fig. 7 relation between the location of toilets and wind direction （draw by author）

In Fig. 7 those with red, yellow and green colors are toilets in teaching building and dormitory building. Green ones have small high windows that can reduce odour blowing in winter and have no influence of odour in summer because they will be in leeward. Yellow ones are in leeward either in summer or in winter, so they have no odour blowing into rooms.

3.1.2 Dormitory building:

Dormitory building as a “U” type is made up of two parts for schoolboys and schoolgirls. Both parts are connected with corridor on third floor and formed a semi-closed space.

Dormitory for subtends and for teachers and other employee are arranged separately in order to manage conveniently and avoid disturbing to each other (Fig. 8).

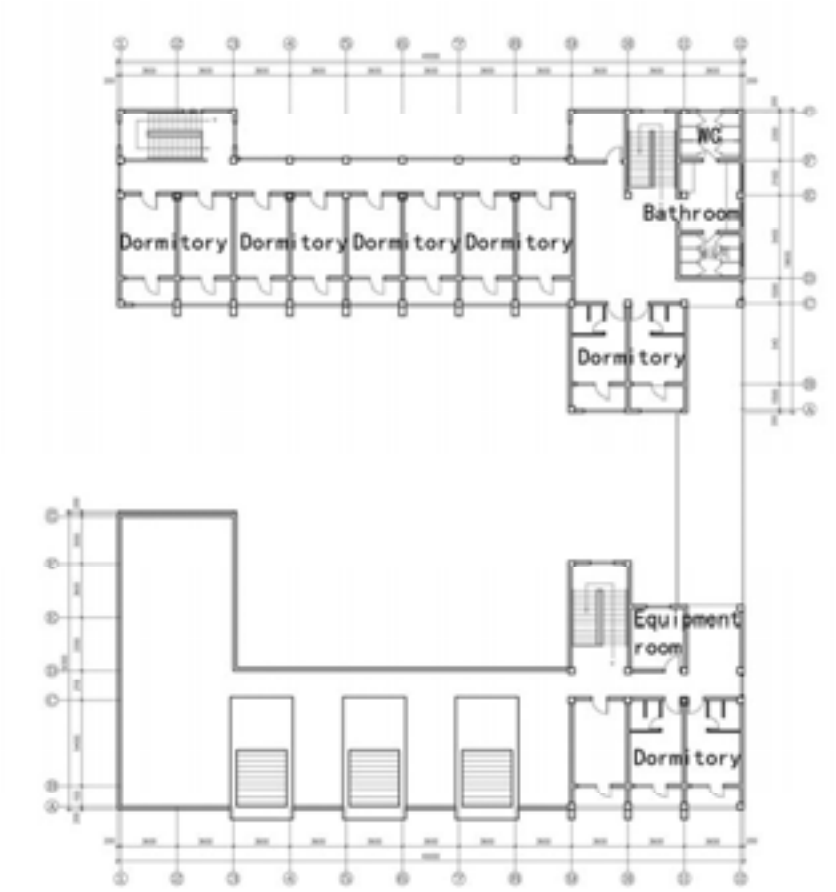


Fig. 8 Dormitory building plan on 7.2m level （draw by author）

3.1.3 Canteen

Canteen is in the northwest of the land including kitchen (left) and a dining hall (right). It is suitable to the characteristics of student life to arrange dormitory area, teaching area and playing field as a triangle. Also in canteen bath rooms and boiling water provision are set up for students.

3.2 Building form

The building characteristics of “Sichuan culture” are epitomized and adopted in building form of the school. Combined with modern expression and fused with the concept of passive energy saving, the building form with modern and local style is created. In the mean while, sunlight is guided into rooms, through the abundant layers of light and shade, a space of studying and living that is much closer to sunshine is created for the children.

4 Technical Strategies

Due to Mianyang region’s climate is characterized by hot summer, humid winter, and low incremental construction cost and operation cost control requirements, adopts a technology strategy that is based on

passive solar technology, and supplemented by active solar technologies.

4.1 Passive solar building design

When designing passive solar building, a full to partial design concept is applied. Based on the climate characteristics in Mianyang area, that is sultry in summer and damp in winter, and usage character of the buildings, passive solar technology is adopted as follows: mainly in summer the techniques of ventilation, heat insulation, shading and wet isolation are adopted, while in winter the techniques of heat collection, heat preservation and ventilation are adopted. Passive solar technical design is going on deeper and deeper from building group to joint structure.

4.1.1 Passive solar design for the whole of the school

1) Organization of wind environment of building group

According to main wind direction and wind speed, a simulation how the landform around affects wind environment of the school has processed by simulation software, based on the data of which school planning and space composition of the building group have been optimized. Good composition of building spaces creates a good wind environment, that is profitable to natural ventilation in summer and can block off cold wind in winter (Fig. 9 and 10).

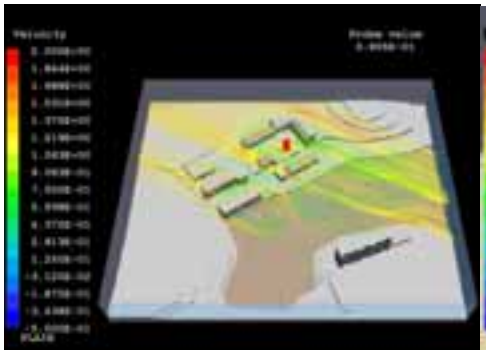


Fig. 9 Flowage of ventilation in the summer

（draw by Yongfei Lu）

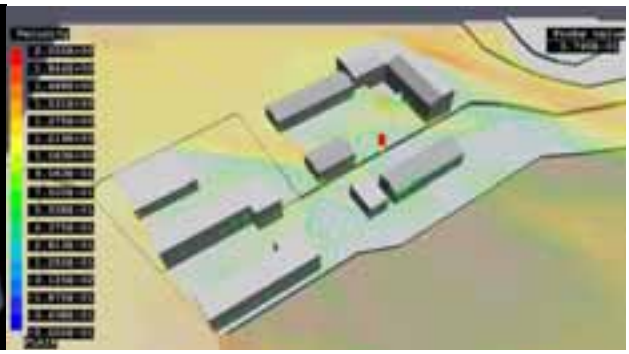


Fig. 10 Vector of wind speed in the summer

（draw by Yongfei Lu）

2) Ecological wetland and treatment of life sewage

Utilizing the character of landform, life sewage of teaching building and dormitory is lead flowing to the place around ecological wetland in southwest without dynamic. After treated by man-made wetland ecological treatment technology life sewage will infiltrate into the ground and achieve the aim of zero emission (Fig. 11).

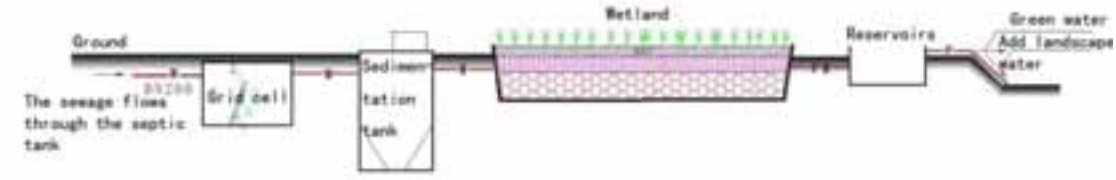
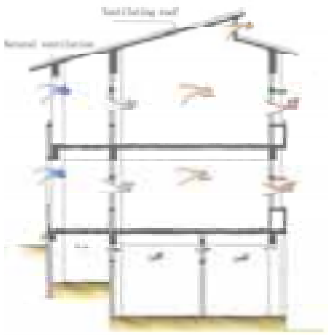


Fig. 11 Principle on sewage treatment of resource type conversion with man-made wetland（draw by Yongfei Lu）

4.1.2 Ventilation of buildings

In teaching building one-sided corridor is adopted good for ventilation. On the top level classrooms with clerestories on the roof may strengthen the ventilation of the rooms and improve muddy situation

in summer (Fig. 12). In staircase of office area and the north of dormitory solar chimneys are arranged, which may upgrade capability of indoor ventilation owing to the principle of heat pressure (Fig. 13 and 14).



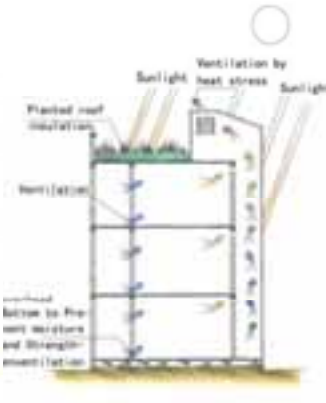


Fig. 12 Classroom ventilation （draw by Yongfei Lu） **Fig. 13 Solar chimney in dormitory （draw by Yongfei Lu）** **Fig. 14 Top of chimney （photo by Wei Luo）**

4.1.3 Heat preservation and insulation design for envelope structure

Regular form and low cost system of heat preservation and insulation are adopted in the school buildings. Envelope walls are multiplex ones, on exterior surface of the walls multiplex material is used for improving the performance of heat preservation and insulation. Except multiplex material another buffer space is adopted on the roofs of teaching building, office building and dormitory in order to strengthen roofs' role on heat preservation in summer and heat insulation in winter. Besides, the top of dormitory is a planted roof, which can create another interesting space for students and help heat preservation and insulation (Fig. 15 and 16)(Peng ,2006).

Fig. 15 Palatable roof in construction（photo by Wei Luo） Fig. 16 Buffer layer on the roof of teaching building（photo by Wei Luo）

4.1.4 Daylighting design

In teaching building on upper part of southern windows an installation united by sunshade board and reflection board is adopted, which forms an integrated shade system combined with the eaves. Utilizing angle difference of incident sunlight in Mianyang area, it can play the role of shading in summer and letting in more light in winter. In winter more of sunlight can enter and reach deeper place of the room with help of the reflection of reflection board and ceiling, thus create an evenly lighting environment (Xu, 2006).

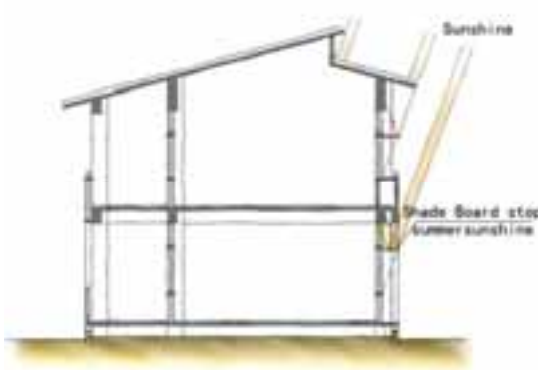


Fig. 17 Day lighting analysis in summer

（draw by Yongfei Lu）

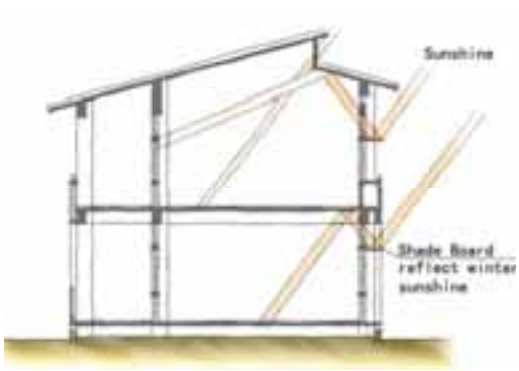


Fig. 18 Day lighting analysis in winter

（draw by Yongfei Lu）

Fig. 19 Clerestories of classrooms （photo by Wei Luo）

Fig. 20 Classroom with clerestories（photo by Wei Luo）

4.1.5 Wet isolation design

In teaching building and dormitory building, there are a space layer under the floor slab on first storey and some holes on the walls, and moisture will be taken away owing to flowing air. It may prevent rooms from moisture entering and keep envelope structure from being cauterized (Fig. 21 and 22).

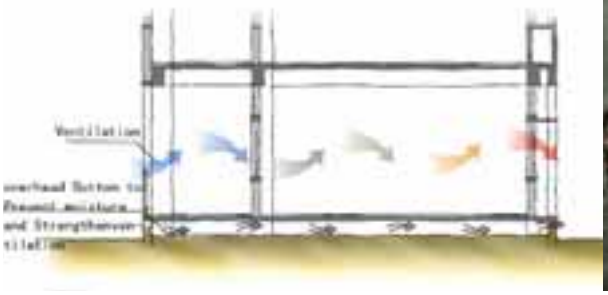


Fig. 21 Space layer for wet isolation

（draw by Yongfei Lu）

Fig. 22 Space layer in construction

（photo by Wei Luo）

4.2 Active solar building design

Bathrooms and boiling water provision is set up in canteen, adopted active solar hot water system for students, teachers and other employee (Fig. 23).

Fig. 23 Heat collectors on canteen's roof（photo by Wei Luo）

5 Conclusions

After more than two years of design work and construction, Eventually Sunlight School was completed and put into use in March, 2011 (Fig. 24 - 31). Guided by design concept that passive solar energy is the first priority and buildings must be harmonious with natural surroundings, rebuilt school after the disaster has been not only constructed as a study place but also a spirited homestead where physical culture and humanist spirit exist together harmoniously. The motto "thanks to sunshine, thanks to love" is the common thinking of all students of Sunlight School coming from their hearts. The influence of new buildings to people is strengthening friendly interaction of users and environment, bringing up the sense of environmental protection and energy saving and sustainable attitude and way of life for students and all people. Thus, campus construction and rural education will be going ahead together while "education development" and "environmental protection" will be in process harmoniously. It is out of question that sustainable green school will be beneficial to this land and all of posterity on this land for a long time.

Fig. 24 The courtyard of the school （photo by Wei Luo）

Fig. 25 Scene inside the school（photo by Wei Luo）

Fig. 26 Scene inside the school（photo by Wei Luo）

Fig. 27 Scene inside the school（photo by Wei:Luo）

Fig. 28　Campus of Sunlight School

（photo by Wei Luo）

Fig. 29　Campus of Sunlight School

（photo by Wei Luo）

Fig. 30　Students on playing field　（photo by Wei Luo）Fig. 31　Students in classroom（photo by Wei Luo）

Acknowledgement

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6 References

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