AN ANLYSIS FOR THE DESIGN OF THE HOUSES 户型设计方案解析

注：以501户型为基础方案
Note: Base on House type 501

一、房屋建设方案原型：501户型

1. 501户型基本信息

一层建筑面积：70.44 m²

二层建筑面积：37.58 m²

总建筑面积：108.02 m²

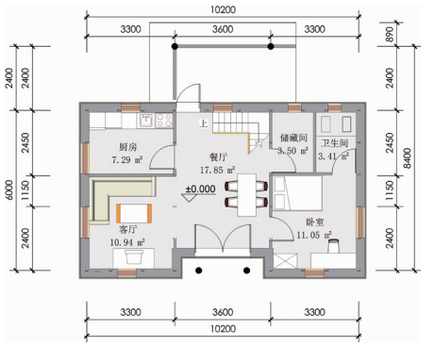
I. House type 501

Basic information of 501:

Building area on the first floor:70.44m²

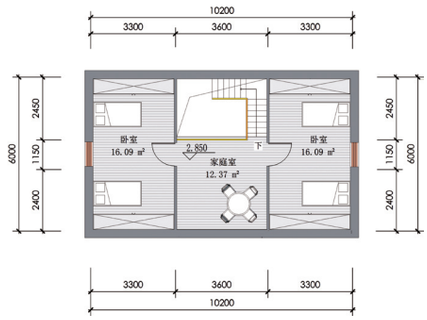
Building area on the second floor:37.58m²

Total building area: 108.02m²



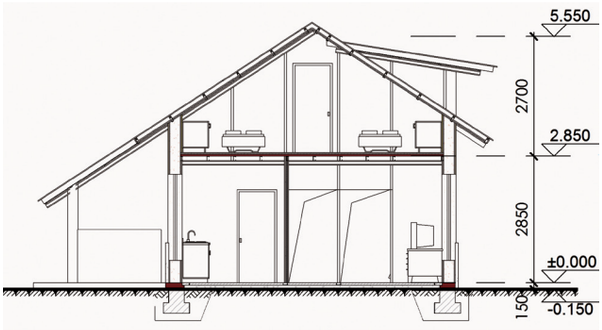
501户型：一层平面图

House type 501: 1st floor plan



501户型：二层平面图

House type 501: 2nd floor plan



501户型：剖面图

House type 501: Sectional Drawing

501户型：北立面图

North Elevation

501户型：东立面图

Eest Elevation

501户型：南立面图

South Elevation

501户型：西立面图

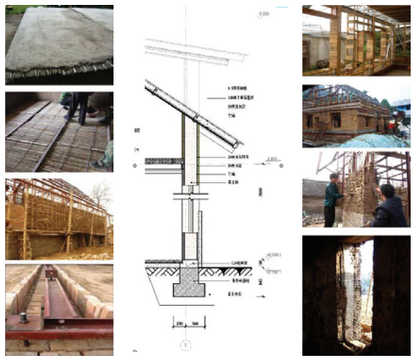
West Elevation

2. 构造图

Structural Drawings

屋顶大样图

Detailed drawing of the roof



屋顶大样图

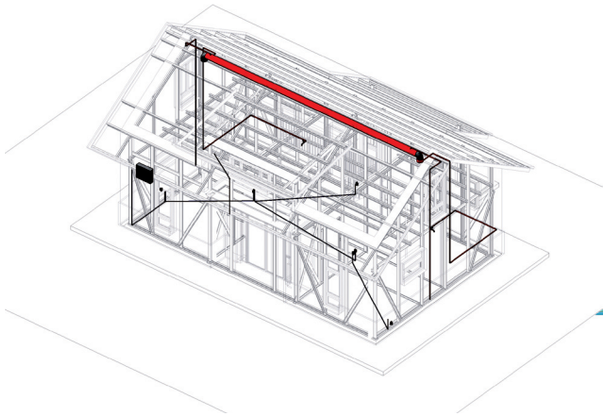
Detailed drawing of the roof

墙身大样图

Detailed drawing of the wall

水电设备图

Drawing of water and electricity facilities



二、延伸户型变化

基于BIM建筑信息模型的技术应用，由于实现了参数化设计，使建筑师可以进行三维精确设计，并可以方便地在原型501的基础上进行户型变化。

空间变化及延展性：参数化控制房间进深开间，相关图纸自动协调一致。

1. 户型 502

户型 502主要是在原型 501的基础上采用双拼结构。

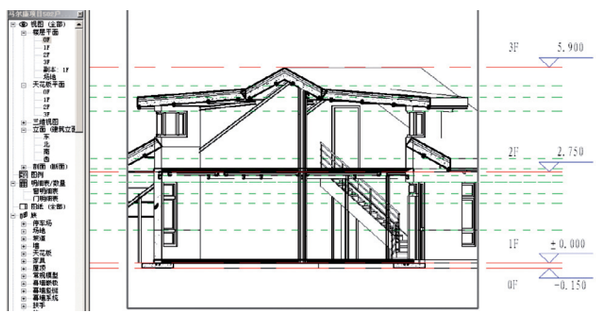
II. Changes of extended house type

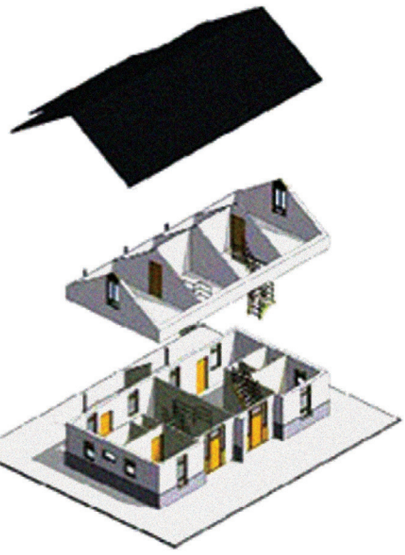
Thanks to the application of BIM, architects could carry out concise 3D digital design through parametric design and make changes on house types based on Type 501.

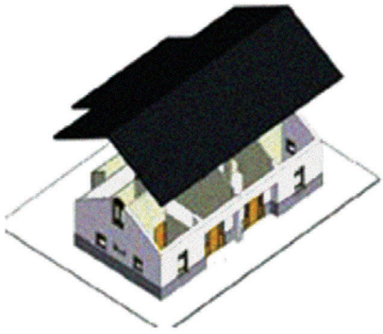
Space change and extension: The width and depth of a house is defined with parameters and all related files could automatically change.

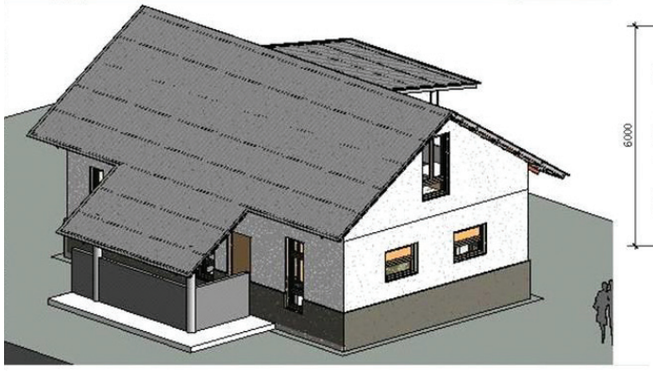
1.House Type 502

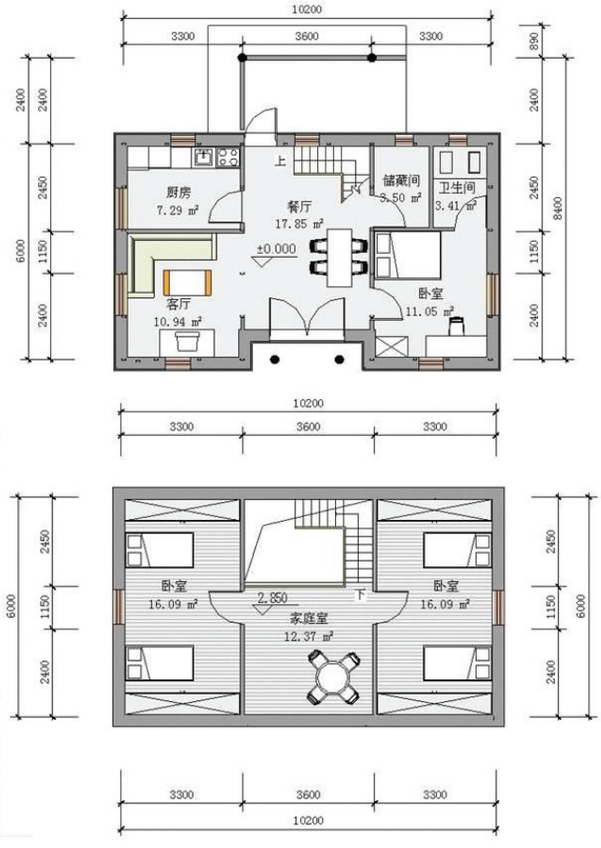
House Type 502 is semi detached building based on Type 501.









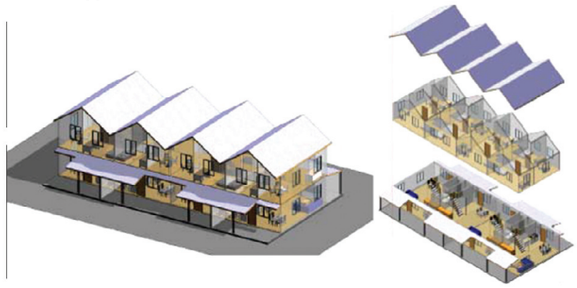


502户型：平面图

House type 502: plan

2. 户型 503

2. House Type 503



三、结构抗震性

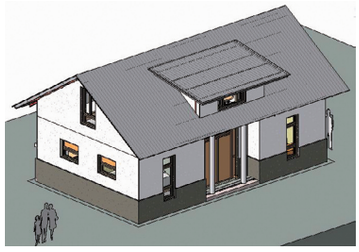
1. 建筑设计与结构计算协同作业

结构体系为轻钢结构，主体结构构件均采用镀锌冷弯薄壁型钢。

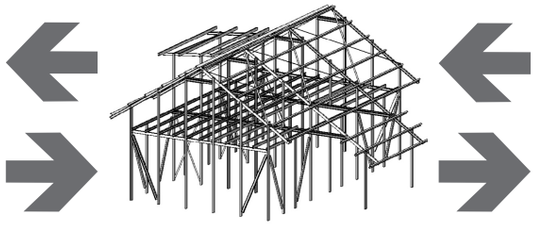
III. Structural anti-seismic performance

1. Synergy of architectural design and structural calculation

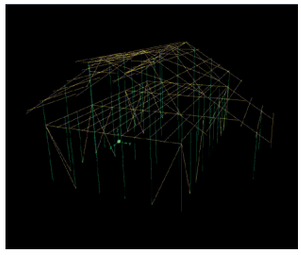
The structural system is light-steel structure, and the components of main structure adopts galvanized cold bending thin-walled sectional steel.



Revit建筑
Revit Architecture



Revit结构
Revit structure



结构计算 ETABS
Structural calculation

2. 技术参数

建筑主体结构、次梁、屋面檩条均采用镀锌冷弯薄壁型钢。

为了现场安装便捷，梁柱节点均为螺栓铰接。

抗侧力体系为柱间支撑，没有计入外围护草土墙的抗侧力性能。

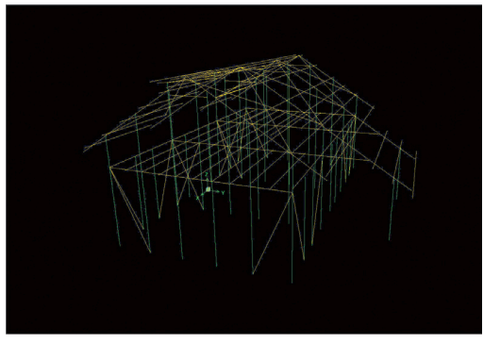
2. Technical Data

In the light steel low-level civil-use housing, all of the main structure,secondary beams, purlins adopt cold-formed thin-walled galvanized steel.

For the on-site installation with extreme convenience, the beamcolumn joints are all hinged bolts.

Lateral Resistant System is the inter-column support. The lateral resisting property of the periphery grass walls is not designed

建筑类别	丁
抗震设防烈度	8
基本地震加速度	0.2g
基本雪压	0.45
结构设计使用年限	50
安全等级	三
设计地震分组	I
场地类别	III
基本风压	0.45



Construction Type	Four
Seismic fortification intensity	8
Basic seismic acceleration	0.2g
Snow reference pressure	0.45
Designed service life	50
Security classification	Three
Classification of design earthquake	I
Site classification	III
Wind reference pressure	0.45

3. 载荷取值　　3.Load Value

	混凝土 g(kN/m³) = Reinforced concrete volume weight	25	钢容重 g(kN/m³) = Steel volume weight	78.00	
	草土墙 Grass walls			14	kN/m³
外墙 External wall			层高 Sorey height	2.75	m
			墙厚 Wall thickness	0.37	m
			自重 / 延米 Self-weight extended meter	14.2	kN/m
外墙 External wall			层高 Sorey height	2.75	m
			墙厚 Wall thickness	0.20	m
			自重 / 延米 Self-weight extended meter	7.8	kN/m
楼板 Floor slab		钢板厚度 (mm) Total coating thickness	1.0	0.0780	kN/m²
		混凝土板厚度 (mm) Concrete slab thickness	60.0	1.5000	kN/m²
		抗震时恒载取值 (mm) Anti-seismic constant loading value		1.5780	kN/m²
屋顶 Roof		抗震时活载取值 Auti-seismic active loading		2.0	kN/m²
		钢板厚度 (mm) Total coating thickness	1.0	0.0780	kN/m²
		草土厚度 (mm) Sward thickness	50.0	0.7	kN/m²
		抗震时恒载取值 Anti-seismic constant loading value		0.7780	kN/m²
		抗震时活载取值 Anti-seismic active loading		0.5	kN/m²

采用 ETABS和 3D3S两个软件进行结构计算。 The structural calculation result is carried out by 2 softwares: ETABS and 3D3S.

4. 分析结果 –周期 (ETABS)

振型质量参与系数超过 90%，满足规范 。

模态 Modal 振型 Vibration Mode	周期 Period 时间 Time	频率Frequency 周期 / 时间Period / Time	圆周频率 Circilar Frenquency 弧度 / 时间 Radian/Time
1	0.70915	1.41013	8.86013
2	0.63009	1.58707	9.97186
3	0.62896	1.58993	9.98982
4	0.61213	1.63364	10.26447
5	0.60061	1.66496	10.46127
6	0.59502	1.68061	10.55960
7	0.35883	2.78680	17.50997
8	0.35354	2.82850	17.77200
9	0.31309	3.19402	20.06862
10	0.29780	3.35794	21.09853
11	0.29590	3.37951	21.23412
12	0.29264	3.41711	21.47036
13	0.27506	3.63561	22.84324
14	0.27280	3.66572	23.03237
15	0.25478	3.92502	24.66161

5. 结构抗震分析结果 – 位移 (3D3S)

最大位移满足弹性层间位移角限值。

（1）地震计算相关参数：

规范：《建筑抗震设计规范》(GB50011–2001)

水平地震影响系数最大值：0.16

计算振型数：9

建筑结构阻尼比：0.050

特征周期值：0.45

地震影响：多遇地震

地震分组：第一组

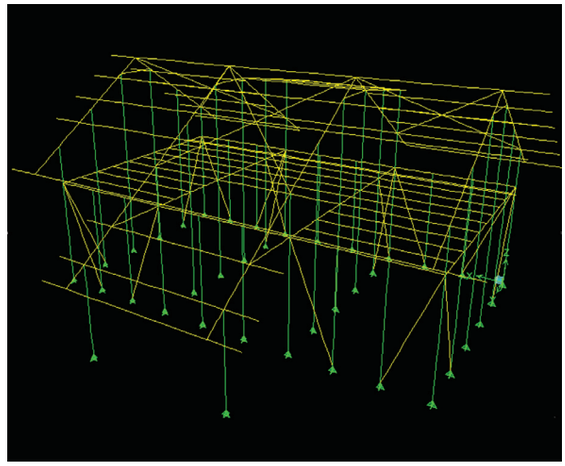
周期折减系数：1.00

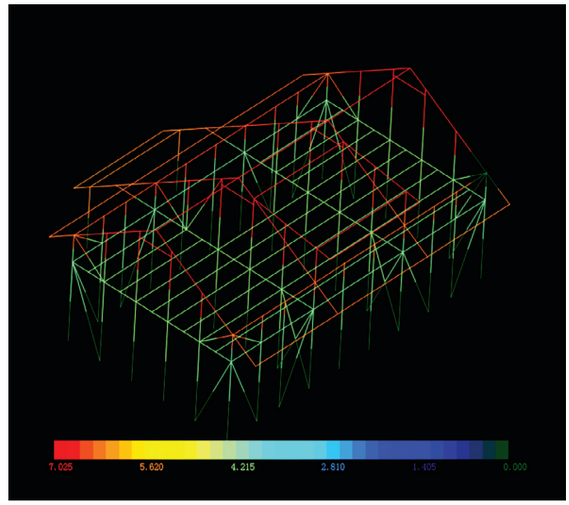
地震力计算方法：振型分解法

振型号 ation Mode No.	周期 （秒）Period (second)
1	0.4313
2	0.4256
3	0.3007
4	0.2341
5	0.1586
6	0.1408
7	0.1230
8	0.1094
9	0.0976

4.Analysis result: period (ETABS)

Vibration mode quality participation coefficient exceeding 90% and meeting the specifications.





5. Results of analysis of earthquake resistance structure – displacement (3D3S)

Maximum displacement meeting the limit of displacement angle between layers.

(1) Parameters for seismic design

Code: *Code for seismic design of buildings (GB 50011-2001)*
Max value of seismic coefficient: 0.16
Number of Vibration mode: 9
Structural damping ration: 0.050
Characteristic period: 0.45
Influence of seismic: frequent
Seismic design group: first Group
Period time discount factor: 1.0
Method for seismic design: response spectrum

（2）荷载组合

第一种:1.20 恒载 + 1.20 x 0.50 活载工况 1 + 1.30 水平地震

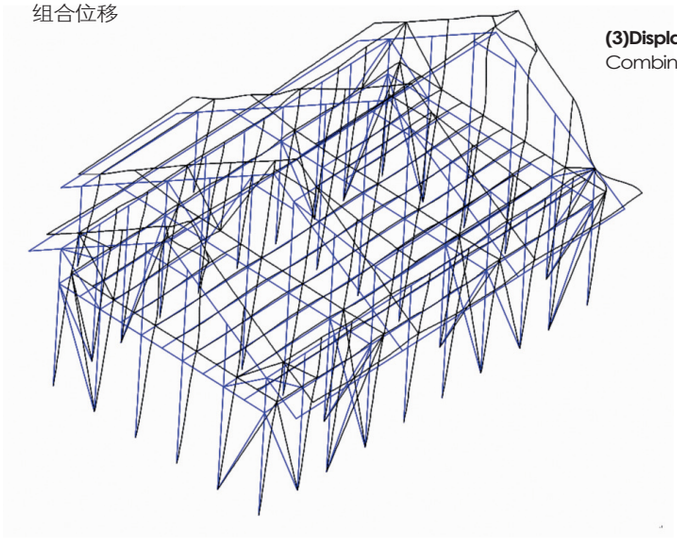
第二种:1.00 恒载 + 1.00 x 0.50 活载工况 1 + 1.30 水平地震

(2) Combination of load

1): 1.20xDL+1.20x0.5xLL+1.30xE
2): 1.20DL+1.20x0.5xLL+1.30xE
DL—dead load
LL—live load
E— Horizontal seismic load

（3）位移

组合位移

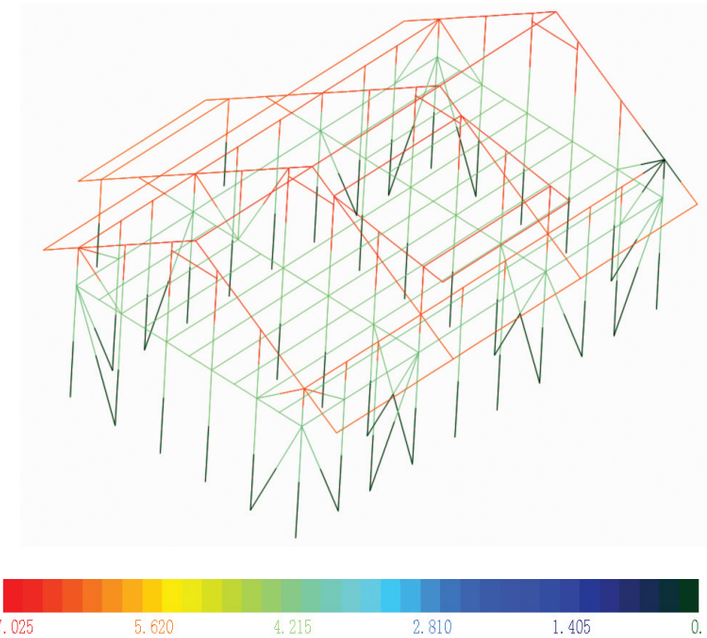


第一种组合：第一种情况位移图（黑点表示最大位移所在节点，单位:mm）

(3)Displacement

Combination displacement

Combination No 1: Displacement map under the first condition (The joints on the max-shifts have been marked, Unit: mm)



第一种组合：第一种情况合位移图（单位：mm）

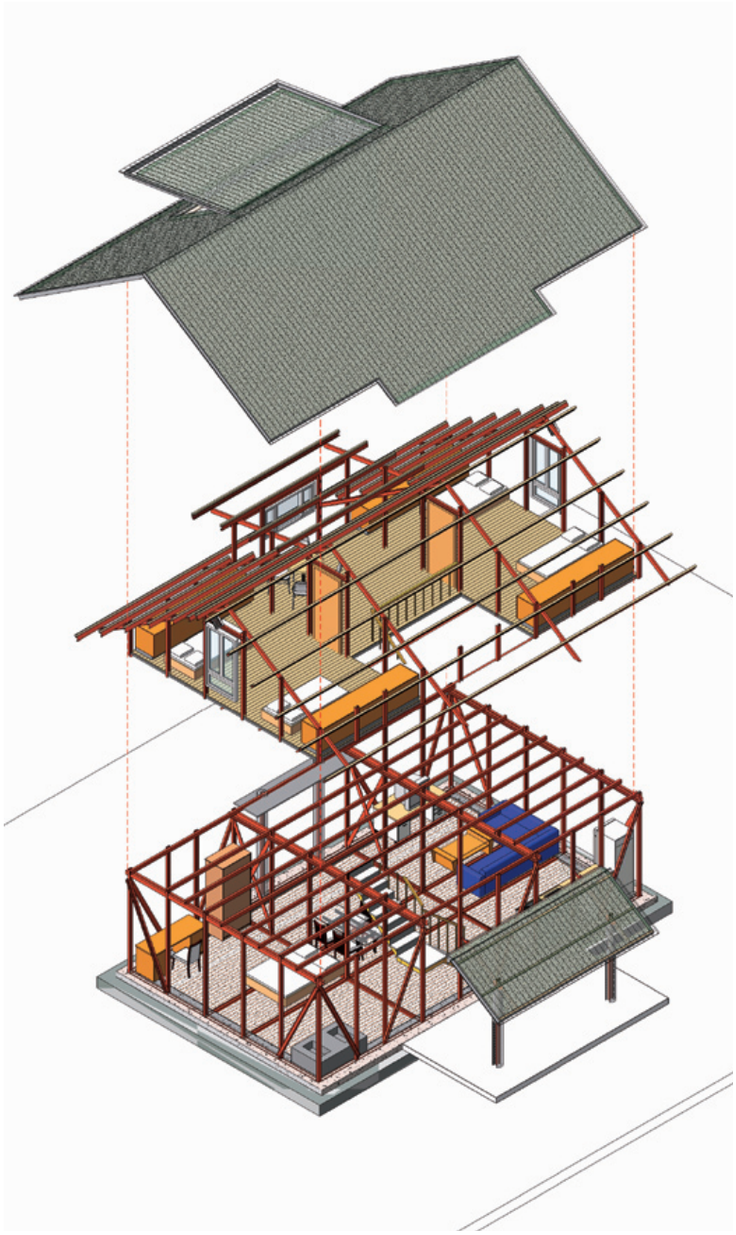
Combination No 1: Sum displacement map under the first condition (Unit: mm)

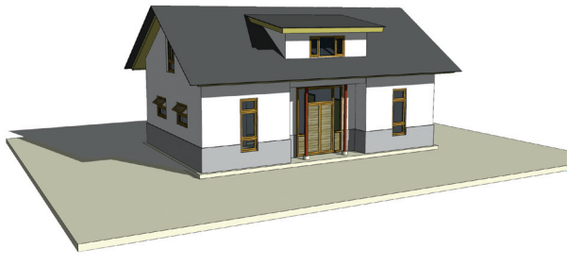
四、成本核算

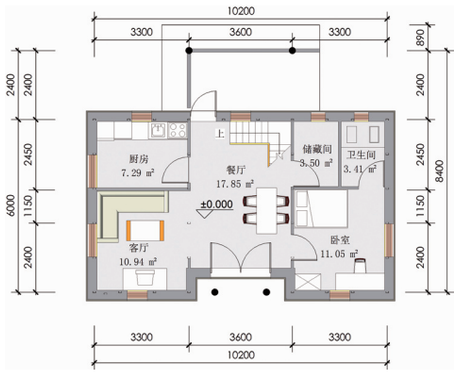
控制建造成本：建筑信息模型导出精确的工程量清单，合理进行备工备料，避免浪费。(表格说明)

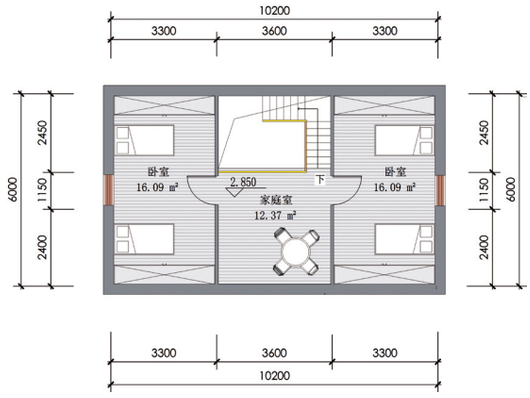
IV. Costing Check

Construction-cost control: The construction information model exports accurate project volume list. Labor and materials should be prepared reasonably to avoid waste.(Description)









类型	类别	类型	小计	合计
B1 C100x50x20x2.5:B1 C100x50x20x2.	结构构架	B1 C100x50x20x2.5	66	124
B2 2C100x50x20x2.5:B2 2C100x50x20x	结构构架	B2 2C100x50x20x2.5	6	
C100x50x20x2.3:B2 2C100x50x20x	结构构柱	C100x50x20x2.3	38	
M_Plate: 4X50	结构构架	4X50	14	

101	平垫圈 GB/T 95 16	外购件	1	644		平垫圈 C级
102	螺栓 GB/T 5782 M16x55	外购件	1	280		六角头螺栓
103	螺母 GB/T 41 M16	外购件	1	356		六角螺母 C级
104	螺栓 GB/T 5782 M16x140	外购件	1	44		六角头螺栓
105	GB50x50x300000002	普通件	200000mm	1	50x50x3	热轧等边角钢 / 尺寸 / 外形 / 重量 / 公差
106	螺栓 GB/T 5782 M16x80	外购件	1	14		六角头螺栓
107	JIS 4225 100x50x20 00000001	普通件	200000mm	1	4225 100x50x20	边缘槽钢
108	GB 50x50x300000003	普通件	100000mm	1	50x50x3	热轧等边角钢 / 尺寸 / 外形 / 重量 / 公差
109	六角螺栓 GB/T 5780 M16 x 55	外购件	1	2		六角头螺栓 C级
110	螺栓 GB/T 5782 M16x130	外购件	1	16		六角头螺栓

类型	类别	类型	小计	合计
B1 C100x50x20x2.5:B1 C100x50x20x2.	结构构架	B1 C100x50x20x2.5	66	124
B2 2C100x50x20x2.5:B2 2C100x50x20x	结构构架	B2 2C100x50x20x2.5	6	
C100x50x20x2.3:B2 2C100x50x20x	结构构架	C100x50x20x2.3	38	
M_Plate: 4X50	结构构架	4X50	14	

101	平垫圈 GB/T 95 16	外购件	1	644		平垫圈 C级
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103	螺母 GB/T 41 M16	外购件	1	356		六角螺母 C级
104	螺栓 GB/T 5782 M16x140	外购件	1	44		六角头螺栓
105	GB50x50x300000002	普通件	200000mm	1	50x50x3	热轧等边角钢 / 尺寸 / 外形 / 重量 / 公差
106	螺栓 GB/T 5782 M16x80	外购件	1	14		六角头螺栓
107	JIS 4225 100x50x20 00000001	普通件	200000mm	1	4225 100x50x20	边缘槽钢
108	GB 50x50x300000003	普通件	100000mm	1	50x50x3	热轧等边角钢 / 尺寸 / 外形 / 重量 / 公差
109	六角螺栓 GB/T 5780 M16 x 55	外购件	1	2		六角头螺栓 C级
110	螺栓 GB/T 5782 M16x130	外购件	1	16		六角头螺栓

（注：以上表格截取自软件） Note: Intercepts from Software

控制建造成本：根据工程量清单，结合当地的材料和人工价格，进行成本核算。

Construction-cost control:Cost accounting will be carried out according to the project volume list, and with combination of the local price of the materials and labor.

一	房屋结构工程								
1	钢料（c100×50×2.5）组装	吨	2.50	6200.00	15500.00		14500.00		20
2	螺栓、角铁、拉杆等五金零件	式	1.00	2000.00	2000.00		2000.00		
3	3cm 水泥楼板（0.5 免拆钢网，5×5 电焊网）	m^2	57.00	60.00	3420.00	免拆网，高强筋网，电焊网	1710.00	710.00	20
4	竹编墙及天花	m^2	360.00	11.00	3960.00			2960.00	20
5	屋顶桁条木方	m^3	0.50	1600.00	800.00			700.00	2
6	屋顶保温层	m^2	120.00	2.50	300.00	稻草	0.00		6
7	屋顶防水隔热层	m^2	120.00	6.00	720.00		620.00		2
8	屋顶彩钢板	m^2	165.00	38.00	6270.00		5770.00		10
9	屋顶钢板折压件	m^2	25.00	37.00	925.00	屋脊，封檐	775.00		3
10	免拆钢网水泥粉刷	m^2	60.00	32.00	1920.00	外墙台度及室内浴厕、厨房	900.00	720.00	6
11	37cm 外墙草土墙	m^3	25.00	60.00	1500.00	草土墙			30
12	楼梯及栏杆一式	式	1.00	700.00	700.00		450.00		5
	房屋结构工程小计				38015.00		26725.00	5090.00	6200.00
二	**门窗工程**								
1	DW 落地门 160×260	樘	1.00	830.00	830.00	含玻璃、纱门及安装		830.00	0
2	W1 80×195	樘	4.00	310.00	1240.00			1240.00	0
3	W2 170×90	樘	2.00	305.00	610.00			610.00	0
4	W3 100×218	樘	2.00	435.00	870.00			870.00	0
5	W4 75×105	樘	3.00	160.00	480.00			480.00	0
6	W5 50×60	樘	2.00	60.00	120.00			120.00	0
7	D1 内门 90×200	樘	5.00	360.00	1800.00			1800.00	0
8	D2 浴室门 75×200	樘	1.00	300.00	300.00			300.00	0
9	D3 户外门 175×200	樘	1.00	700.00	700.00			700.00	0
	门窗工程小计				6950.00			6950.00	–
三	**装修工程**								
（一）	木作工程								
1	楼梯板	m^2	3.00	450.00	1350.00	35mm 厚		1350.00	0
2	封檐板	m	66.00	15.00	990.00	断面 25×200mm		990.00	0
3	门窗框收包边	m	1.00	200.00	200.00			200.00	0
	木作工程小计				2540.00			2540.00	–
（二）	**泥作工程**								
1	墙面白灰粉刷	m^2	390.00	6.00	2340.00			840.00	30
2	天花板	m^2	220.00	7.00	1540.00			540.00	20
3	一楼浴厕厨房地坪粉刷	m^2	10.00	15.00	150.00			100.00	1
4	一楼地坪灰土夯实	m^2	63.00	5.00	315.00	三合土		165.00	3
	泥作工程小计				4345.00			1645.00	2700.00
（三）	**水电工程**								
1	配管配线	坪	120.00	7.00	840.00			840.00	0
2	早厨、洗脸盆、淋浴花洒	套	1.00	200.00	200.00			200.00	0
	水电工程小计				1040.00			1040.00	–
四	其他								
1	营造保险	式	1.00	500.00	500.00			500.00	0
2	废弃物清运	趟	5.00	60.00	300.00			0.00	6
3	脚手架	式	1.00	1200.00	1200.00			450.00	15
	其他工程小计				2000.00			950.00	1050.00
五	合计				61958.00		26725.00	23408.00	11825.00
六	工程设计管理费				0.00				
七	总计				61958.00		26725.00	23408.00	11825.00

以 501 户型的设计方案为计算模型，按照当时的价格，经过理论测算得出成本总计为 61958 元，其中：

结构体系成本测算为 26725 元；

围护体系成本测算为 23408 元（围护体系可根据当地材料状况，灵活控制成本）；

人力成本测算为 11825 元（在条件许可的地方，采取协力建房可以适当降低人力成本）。

五、建筑节能

将 Revit 模型直接导入 PKPM 节能分析软件进行节能分析。

1. 设计依据

《夏热冬冷地区居住建筑节能设计标准》

《四川省夏热冬冷地区居住建筑节能设计标准》

《全国民用建筑工程设计技术措施节能专篇－建筑》

《农村领域抗震救灾实用技术手册》

《地震灾后新农村住房恢复重建技术要点》

《汶川地震灾后农房恢复重建技术导则（试行）》

2. 设计目标

“马尔康行动”是以帮助受灾地区建设节能、省地、抗震、实用的房屋，改善受灾居民居住条件，尽快恢复他们正常居住生活，实现灾后重建为目标和基本出发点，本节特别就建筑围护结构保温隔热技术措施进行设计、计算和分析。

四川省人民政府办公厅曾发布关于进一步做好建筑节能工作的通知（川办函 [2007]82 号），其中对建筑节能提出明确的目标，提倡发展建筑节能自保温体系，鼓励农村建筑参照执行国家节能 50% 的设计标准。

成都市对“十一五”科技发展重大专项之一的建筑节能也作出过规划。根据规划，成都将实现农民新建节能示范住宅的建筑能耗节省达到 30% 的目标。

本项目为薄壁轻钢结构住宅，同时在建筑节能方面，结合国家建筑节能目标和地方政策要求，采用节能环保、就地取材的草土墙和草土保温材料作为墙体和屋顶保温材料，符合 1996 年以来国家一系列政策的引导和支持钢结构建设发展的要求。

3. 建筑围护结构节能设计说明

（1）建筑数据概况

本项目的建筑模型由欧特克公司 Revit 建立的 BIM 建筑信息模型，通过 PBECA2008 建筑节能设计软件计算后，得到建筑数据的概况如下：

朝向：南向（南偏东 15 度至南偏西 15 度范围）

体形系数：0.41

The copulating model is based on House type 501. According to the price at that time, the total cost is RMB 61958 through theoretical testing , including:

Cost for construction system: RMB 26725 ;
Cost for enclosure system: RMB 23408 (the cost control is according to the local situation);
Cost for labor resources: RMB 11825(The labor cost can be reduced by building collaboration when it is possible).

V. Building Energy-Saving

Import Revit model into PKPM energy-saving analysis software for energy-saving analysis.

1. Reference

Energy-saving Standard for Designing Residential Buildings in Regions Featuring Hot Summer and Cold Winter
Energy-saving Standard for Designing Residential Buildings in Sichuan Province Featuring Hot Summer and Cold Winter
Special Section on Energy Conservation - Technical Measures for Design in Civil Building Projects - Building
Handbook of Practical Technologies for Rural Earthquake Relief
Key Technical Points for Recovery and Reconstruction of New Rural Houses after Earthquake
Technical Guidance to Recovery and Reconstruction of Rural Housing after Wenchuan Earthquake (Provisional)

2. Design objective

The Ma'erkang Project aims to help new countryside build energy- and land-saving and anti-seismic practical houses in earthquake-hit regions, to improve the dwelling conditions for disaster-stricken peasants. Its objective and basic points are to realize post-disaster reconstruction. The section will design, calculate and analyze the thermal-insulating technologies and measures adopted by the building enclosure structure.

The Notice for Strengthening and Improving Architectural Energy-saving was issued by General Office of the People's Government of Sichuan Province (Sichuan Province Government Office's letter [2007] 82). It put forward a clear objective for building energy conservation, promoting the development of energy-saving and self thermal heating system of building, and encouraging the rural buildings to comply with the design standard 50% of national energy conservation.

Chengdu made a plan of building energy conservation in major project of scientific development of the Eleventh Five-Year Plan, according to which, Chengdu is expected to achieve 30% building energy conservation.

The project is a residence of thin-walled light steel structure; it complies with the requirements of a series of policies issued by the State since 1996 and supports the development of steel structure construction. Meanwhile, it meets the requirements of national building energy-saving objectives and local policies on building energy conservation; it adopts sward wall and sward materials that are energy-saving and environment-friendly, and takes materials obtained locally as the thermal insulating materials for the walls and the roofs.

3. The energy-saving design description of enclosure
(1) General situations of architectural data

The building model of the project is building information model (BIM) established by Autodesk Revit; after the building model is calculated by the PBECA2008 building energy-saving design software, the following architectural data is obtained:

Orientation: south (the range of south by east 15 degrees to south by west 15 degrees)
Shape coefficient: 0.41

朝向 Orientation	东 East	南 South	西 West	北 North
窗墙面积比 Area ratio of window and wall	0.11	0.08	0.18	0.07

本项目拟建地点为绵阳、德阳等地区，气候分区属于夏热冬冷地区。

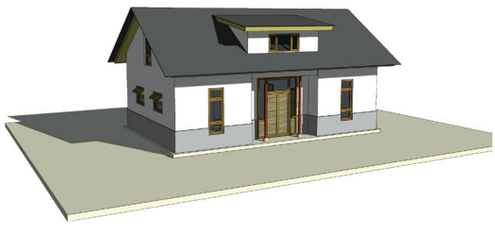
经分析，建筑物朝向合理；作为低层点式建筑，体形系数接近节能设计标准中体形系数 0.40 的限值要求；各朝向开窗面积小，在考虑采光和通风的情况下，窗墙面积比合理。

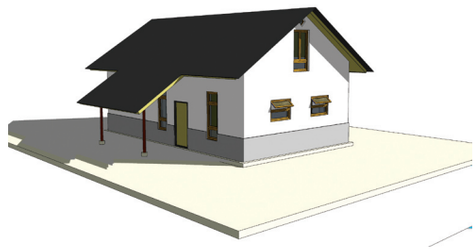
本项目 501房型的模型三维示意图：

The proposed construction sites of the project are Chengdu, Mianyang, and Deyang, and the climate division belongs to the region of hot summer and cold winter.

It is judged that the building orientation is reasonable; as the low-rise architecture, the shape coefficient is close to the threshold of shape coefficient in energy-saving design standards 0.40; the window area of each orientation is small, and the area ratio of window and wall is reasonable in view of the lighting and ventilation conditions

3D schematic diagram of house type 501 model:





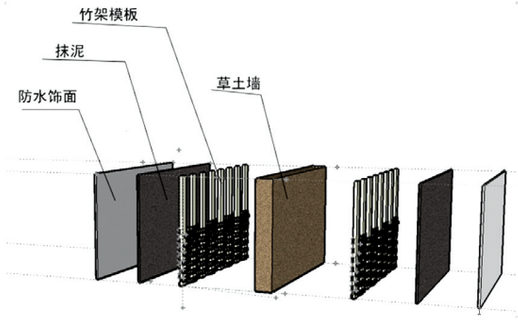
（2）建筑围护结构构造

本项目采用的围护结构构造类型

外墙类型：防水饰面（不计入）+ 抹泥（20mm）+ 竹架板（不计入）+ 草土墙（370mm）+ 竹架板（不计入）+ 抹泥（20mm）+ 抹灰饰面（不计入）

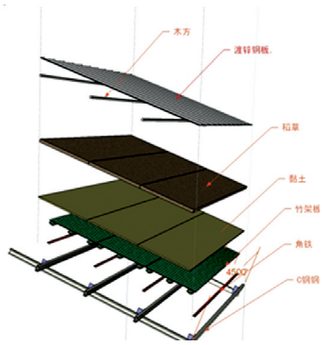
(2) Configuration of enclosure structure

Types of enclosure structure adopted by the project:
Types of external walls: waterproof veneer (not included) +claying (20mm) + bamboo plates (not included) + sward walls (370mm) + bamboo plates (not included) +claying (20mm)+plastering lime (not included)



外墙构造示意

The schematic diagram of external wall configuration



屋顶构造示意

The schematic diagram of roof configuration

屋顶类型：镀锌钢板（不计入）+ 草土保温（150mm）+ 竹架板（不计入）+ 钢架（不计入）

外窗类型：木框自制双层保温窗

地面类型：饰面层（不计入）+ 细石混凝土（60mm）+3：7灰土（100mm）+ 素土夯实（600mm）

内墙类型：抹泥（20mm）+ 草土墙（240mm）+ 抹泥（20mm）

楼板类型：饰面层（不计入）+ 水泥砂浆（30mm）+ 免拆钢模网（不计入）

热桥部位构造类型：防水饰面（不计入）+ 抹泥（20mm）+ 竹架板（不计入）+ 草土墙（370mm）+ 钢材（不计入）+ 竹架板（不计入）+ 抹泥（20mm）+ 抹灰饰面（不计入）

（注：草土墙及草土保温，按三种热工参数分别计算。）

草土墙及草土保温热工参数

本项目采用草土复合材料作为外墙墙体和屋顶保温材料。现场实际施工中，草与土的配比比例不同，将产生不同密度的草土复合材料。参考有关文献，在建筑节能计算时，取三组热工参数：

方案1：草土材料1（密度800kg/m³，导热系数0.25W/m·k）

方案2：草土材料2（密度1000 kg/m³，导热系数0.35 W/m·k）

方案3：草土材料3（密度1200 kg/m³，导热系数0.47 W/m·k）

The types of roof: galvanized steel (not included) + sward thermal insulation (150mm) + bamboo plates (not included) + steel frames (not included)

The types of external windows: self-made double-layer wooden insulation windows

The types of ground: finish coat (not included) + fine aggregate concrete (60mm) + 3:7 lime soil (100mm) + rammed earth (600mm)

The types of internal walls: claying (20mm) + sward wall (240mm) + claying (20mm)

The types of floor slab: screed finish layer (not included) + clement mortar (30mm) + permanent steel mold net (not included)

Configuration of heat bridge part: waterproof veneer (not included) + claying (20mm)+ bamboo plates (not included) + sward walls (370mm) + steel (not included) + bamboo plates (not included) + claying (20mm) + plaster finish (not included)

(Note: Sward walls and sward thermal insulation are calculated respectively according to three thermal parameters.)

Thermal parameters of sward walls and sward thermal insulation

The project adopts straw composite materials as the insulating materials for the external wall and the roof. During on-site construction, different mixing proportion of grass and soil will lead to straw composite materials of different densities. Referring to relevant documents, we take three groups of thermal parameters in the calculation of building energy conservation:

Scheme1: Sward materials I (density 800 kg/m³, thermal conductivity 0.25W/m·k)

Scheme 2: Sward materials II (1000kg/m³, thermal conductivity 0.35W/m·k)

Scheme3: Sward materials III (1200kg/m³, thermal conductivity 0.47W/m·k)

	kg/m³	λ W/mK	c kJ/kgK		S kJ/m³K		b kJ/m²h$^{0.5}$K
			SLL	HLL	SLL	HLL	i.M.
Leichtlehm	300 1)	0.10	1.3	-	400	-	12
	400 1)	0.12	1.2	-	500	-	14
	600	0.17	1.1	1.5	700	900	20
	800	0.25	1.1	1.4	900	1100	28
	1000	0.35	1.1	1.3	1100	1300	37
	1200	0.47	1.0	1.2	1200	1500	45

（注：参数取自《Leichtlehmbau alter baustoff—neuetechnik》，出版商 C.F.Muller）

(Note: The parameters are taken from *Leichtlehmbau Alter Baustoff-neuetechnik, Publisher: C.F. Muller*)

（3）建筑节能方案分析

依据《夏热冬冷地区居住建筑节能设计标准》、《四川省夏热冬冷地区居住建筑节能设计标准》，“马尔康”研发人员应用节能设计分析软件，对不同节能方案模拟本项目 501房型的能耗。

(3) Analysis of building energy-saving scheme

According to *The Design Standard of Building Energy Conservation for Residences in the Areas with Hot Summer and Cold Winter* and *The Design Standard of Building Energy Conservation Residences in Sichuan Province with Hot Summer and Cold Winter*, team members of Ma'erkang Project applied energy-saving design analysis software to simulate the energy consumption by house type 501 to different energy-saving schemes.

A. 农村传统建筑围护结构材料和构造

夏热冬冷地区过去的居住建筑，冬夏两季室内的热环境质量很差。以往居住建筑的设计，不考虑采暖、空调的需要，建筑围护结构的热工性能很差。黏土砖一直是农村新房的主要建筑材料，因其为成品砖，施工较为方便快速。但砖本身的热工性能并不好，且由大量黏土经过高温烧制而成，其生产过程需要消耗大量的煤，同时破坏了大量耕地，也引起了环境污染。

农村传统的建筑主要围护结构构造（方案 4）:

外墙：水泥砂浆（20mm）+ 黏土砖（240mm）+ 水泥砂浆（20mm）

屋顶：小青瓦（不计入）+ 水泥砂浆（25mm）+ 防水层（不计入）+ 水泥砂浆找平（15mm）+ 钢筋混凝土（100mm）

外窗：木单框单层窗（传热系数 4.7 W/m·k）

应用节能设计分析软件，进行建筑能耗模拟，可得建筑单位面积能耗达到 93.98 kWh/m^2。

B. 三种不同热工参数的草土复合材料围护结构构造

本项目采用草土复合材料节能设计时，考虑与农村传统的建筑围护结构进行建筑能耗模拟比较，以对比分析其保温隔热性能。

a）三种方案与农村传统建筑围护结构构造方案（方案 4）计算比较：

方案 Scheme	外墙传热系数Heat transfer coefficient of external wall（W/m·k）	屋顶传热系数 Heat transfer coefficient of roof（W/m·k）	建筑单位面积能耗 Energy consumption per unit building area（kWh/m^2）
1	0.61	1.32	45.99
2	0.80	1.70	53.99
3	1.00	2.10	61.85
4	2.50	3.87	93.98

针对建筑面积计算：

热桥部位计算时，草土保温计算厚度取 270mm，综合考虑草土保温与薄壁轻钢结构结合的最不利情况。

方案1、方案2、方案3与方案4所计算出的建筑能耗比较计算可知，分别可以节能 51.06%、42.55%和 34.19%，节能效果明显。

相对节能率计算方法：

$$\text{相对节能率} = \left(1 - \frac{\text{设计建筑能耗}}{\text{参照建筑能耗}}\right) \times 100\%$$

A. The enclosure structural materials and configuration of traditional rural building

For the residential buildings in the areas with hot summer and cold winter in the past, the thermal environment quality was poor indoor in winter and summer. In the past, regardless of the needs of heating and air-conditioning for the design of residential buildings, the thermal performance of the building enclosure structure was very poor. As product bricks, clay bricks have been always the main building materials for new houses in rural areas, because the construction is more rapid and convenient. However, the thermal performance of the clay bricks are poor, and a large quantity of coal is needed to bake the clay at high temperature, and at the same time, the production of clay bricks has damaged arable lands, and caused environmental pollution.

The main enclosure structural construction of traditional rural building (Scheme IV):

External walls: cement mortar (20mm) + clay brick (240mm) + cement mortar (20mm)

Roof: small grey tile (not included) + cement mortar (25mm) + waterproof layer (not included) + cement mortar leveling (15mm) + reinforced concrete (100mm)

External walls: single-frame and single-layer wooden window (heat transfer coefficient: 4.7W/m·k)

Using energy-saving design analysis software to simulate building energy consumption can attain the result that the energy consumption per unit building area has reached 93.98kWh/m^2.

B. The structure of enclosure made of sward composite materials with three different thermal parameters

When the project adopts the energy-saving design with sward composite materials, it considers the enclosure structure of traditional rural building, and conducts simulated comparison of the building energy consumptions, so as to analyze its heat-insulating performance.

a) Comparison in calculation methods between the three schemes and the scheme for constructing enclosure for traditional rural buildings (Scheme 4):

Calculation based on building area

In calculating heat bridge, the thickness of sward insulation takes 270mm, with comprehensive consideration of the most adverse condition in which the sward insulation is combined with the thin-walled light steel structure.

It is known from the results of building energy consumption calculation for Scheme 1, Scheme 2, Scheme 3 and Scheme 4 that the energy-saving rates are 51.06%, 42.55% and 34.19% respectively, with obvious energy-saving effect.

Method of calculating relative energy-saving rate:

$$\text{Relative energy-saving rate} = \left(1 - \frac{\text{Designed building energy consumption}}{\text{Reference building energy consumption}}\right) \times 100\%$$

b）三种方案与建筑节能 50% 标准限值计算比较：

b) The calculation comparison between the three schemes and the standard limit value of building energy conservation (50%):

方案 Scheme	外墙传热系数 Heat transfer coefficient of external wall （W/m·k）	屋顶传热系数 Heat transfer coefficient of roof （W/m·k）	建筑单位面积能耗 Energy consumption per unit building area （kWh/m²）	节能率 Energy-saving rate
1	0.61	0.55	32.69	41.82%
2	0.80	0.55	34.54	31.69%
3	1.00	0.55	36.27	21.75%
节能 50% 标准限值 50%Energy-saving standard limit value	1.00	0.80	39.52	50%

针对建筑面积计算

节能率计算方法：

$$\text{实际节能率} = [\,1 - \frac{\text{设计建筑能耗}}{\text{参照建筑能耗}/(1-\text{目标节能率})}\,] \times 100\%$$

以方案 2为例：

$$\text{节能率 2} = [\,1 - \frac{53.99}{39.52/(1-50\%)}\,] \times 100\% = 31.69\%$$

Calculation based on building area

Method of calculating energy-saving rate:

$$\text{Actual energy-saving rate} = [\,1 - \frac{\text{Designed building energy consumptio}}{\text{Reference building energy consumption/ (1- target energy-saving rate)}}\,] \times 100\%$$

To take Scheme 2 as an example,

$$\text{Energy-saving rate 2} = [\,1 - \frac{53.99}{39.52/(1-50\%)}\,] \times 100\% = 31.69\%$$

从以上计算结果可知，采用草土墙和草土保温，可以接近或达到建筑节能 30%。

It can be known from calculation that adopting the thermal-insulating of sward wall and sward can near and reach 30% building energy conservation.

C．建筑节能 50%设计

建筑围护结构构造经计算可知，屋顶的构造未能满足节能50%标准的要求，具有节能潜力。

本项目设计了几种屋顶构造，其中在屋顶中填充稻草也是经济实用的方案，且具有良好的热工性能，其构造：

镀锌钢板（不计入）+ 稻草（100mm）+ 薄草泥（不计入）+ 竹架板（不计入）+ 钢架（不计入）

C. The design of 50% building energy conservation

It can be known from the calculation of building envelope that the roof construction falls short of the requirements of 50% energy-saving standard, and has energy-saving potential.

The project designs several roof structures, wherein, filling rice straw in the roof is also an economic and practical scheme, and has good thermal performance. Its construction:

galvanized steel sheet (excluded) + straw (100mm) + thin sod (excluded) + bamboo frame plate + steel frame (excluded)

三种方案计算结果：

The calculation results of three schemes:

方案 Scheme	外墙传热系数 Heat transfer coefficient of external wall （W/m·k）	屋顶传热系数 Heat transfer coefficient of roof(W/m·k)	建筑单位面积能耗 Energy consumption per unit building area （kW/m²）
1	0.61	0.55	32.69
2	0.80	0.55	34.54
3	1.00	0.55	36.27
节能 50% 标准限值 50%Energy-saving standard limit value	1.00	0.80	39.52

方案1、方案2、方案3 所计算出的建筑能耗均小于节能50%的标准限值，达到了节能50% 的设计要求。

通过以上计算可知，进一步提高本项目的围护结构构造热工性能，本项目可以实现建筑节能 50% 要求。因而本项目具有可扩展性，通过改变其热工性能，可适用于夏热冬冷地区、寒冷严寒地区以及气候条件各不相同的灾区。

4. 结论

◆ 采用草土保温围护结构的建筑节能设计，与农村传统围护结构材料和构造相比较，节能效果明显，将有助于改善受灾居民的居住条件，实现灾后重建的目标。

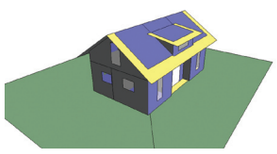
◆ 本项目采用薄壁轻钢结构住宅，结合草土保温围护结构建筑节能设计，在夏热冬冷地区，可接近或达到建筑节能 30% 要求。

◆ 本项目采用草土保温围护结构，具有可扩展性，可实现建筑节能 50% 要求。

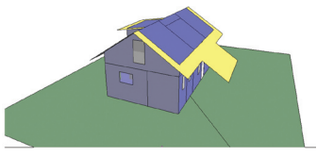
六、热工、能耗、减排、舒适度

1. 室内环境质量及冷热负荷分析

环境分析模型

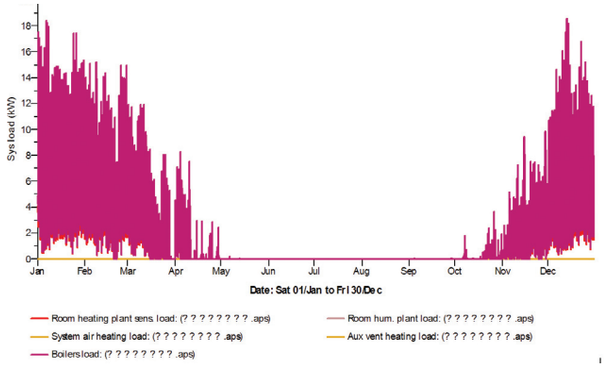


南面 South orientation



北面 North orientation

（1）负荷分析



全年热负荷分布

Annual heat load distribution

The calculated building energy consumptions in scheme 1, scheme 2 and scheme 3 are all less than the standard value of 50%, thereby reaching the design requirements of 50% energy conservation.

It can be known from the above calculation that the thermal performance of enclosure in the project is further improved, and the project will meet the requirements of 50% energy conservation. So the project is extendible, and after changing its thermal performance, can apply to the disaster areas with different climate conditions, including regions with hot summer and cold winter, cold regions and extremely cold regions.

4. Conclusion

◆ The sward thermal-insulating envelope structure is adopted for building energy-saving design. Compared with traditional rural envelope structural materials and structure, it has an effective energy-saving effect, and will help improve the residential conditions of peasants in the disaster area and realize post-disaster reconstruction.

◆ The project adopts thin-walled light steel structure residence, combines the building energy-saving design of sward thermal-insulating enclosure, and can near or reach 30% building energy conservation in regions with hot summer and cold winter.

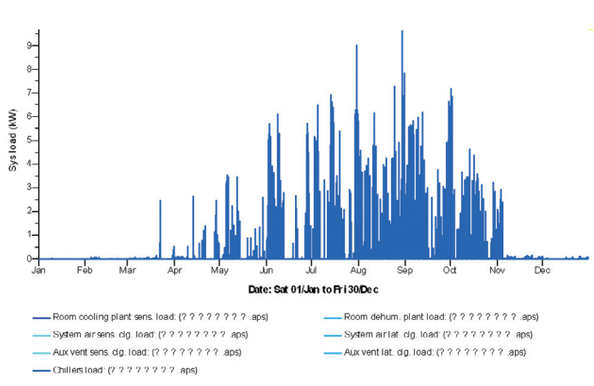
◆ The project adopts sward thermal-insulating enclosure, has extendibility and can meet the requirements of 50% building energy conservation.

VI. Heat power, energy consumption, emisasion reduction and comfort degree

1. Analysis of indoor environment quality as well as cold and heat load

Environmental analysis model

(1) Load analysis

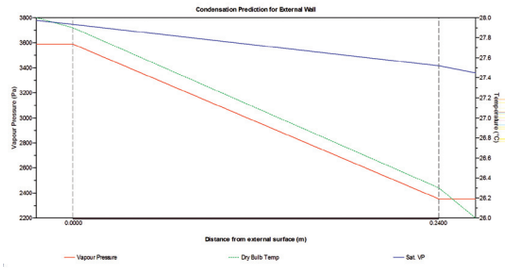


全年热负荷分布

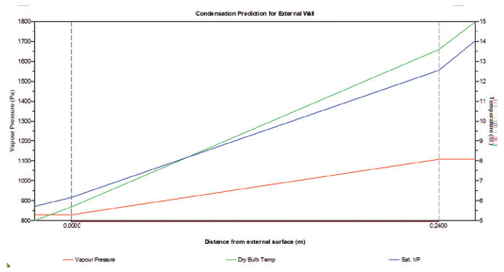
Annual cold load distribution

由于该项目为乡村农宅，室内热湿负荷主要由人员负荷和围护结构负荷构成，无空调系统，此处负荷计算仅作为后续室内环境分析的基础。

As the project is aimed at rural farmhouse, indoor thermal and humid load is mainly composed of personnel load and skin load without air-conditioning system. The load calculation herein only serves as the base for subsequent indoor environmental analysis.



闷热潮湿天气结露分析
Dew analysis in sultry and humid weather



寒冷潮湿天气结露分析
Dew analysis in cold and humid weather

草土墙结构由于良好的透气性和隔热性，使其在四川典型的黄梅气候下，依然不会出现结露现象。

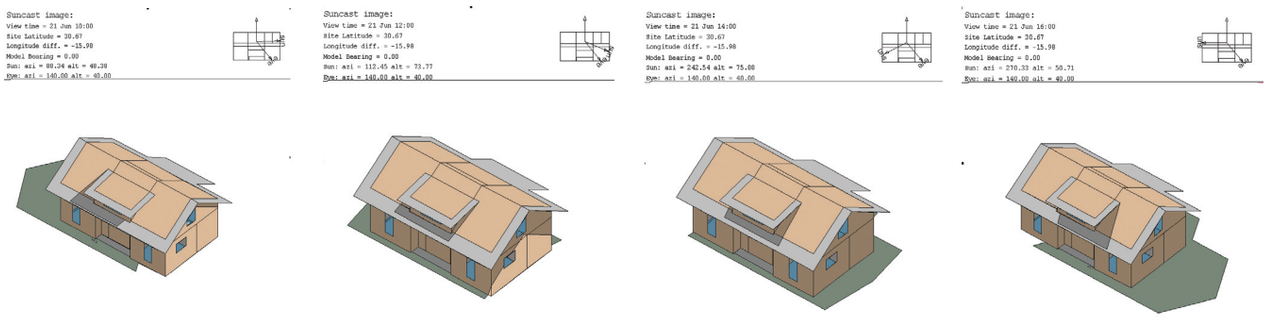
Because of the air permeability and heat resistance of sward walls, there would be no water coagulating on the sward wall structure even in plum rain season typical in Sichuan.

2．日影分析

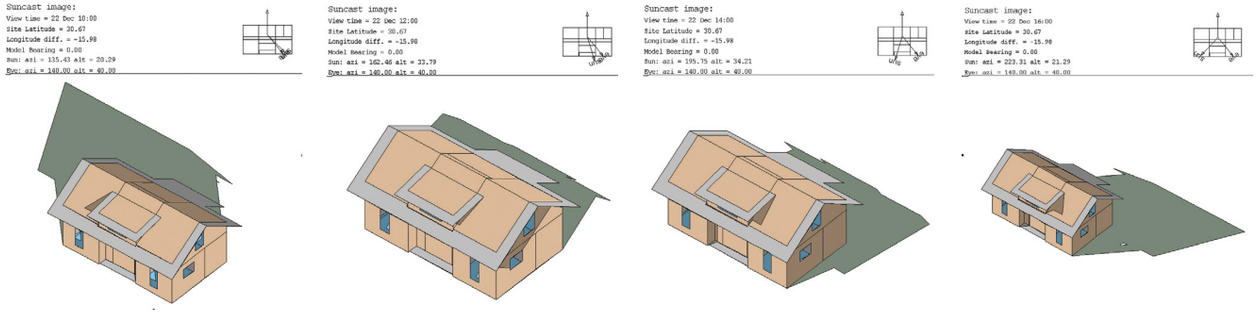
本方案中的大屋檐设计能够在夏季较好地挡住炽热的阳光，减少了南面房间的日照得热，而在冬季，又能让太阳顺利进入室内，提高房间温度。

2. Sun shadow analysis

The major-eave design in the scheme can keep out the blazing sunlight in summer, reduce the sunlight heat obtained by south rooms, and in winter, let sunlight enter the room and increase the room temperature.



夏至日 10：00am~16：00pm日影分布　Sun shadow distribution at 10: 00am ~16: 00pm on summer solstice



冬至日 10：00am~16：00pm日影分布　Sun shadow distribution at 10:00am ~ 16:00pm on winter solstice

3 . 室外风场分析

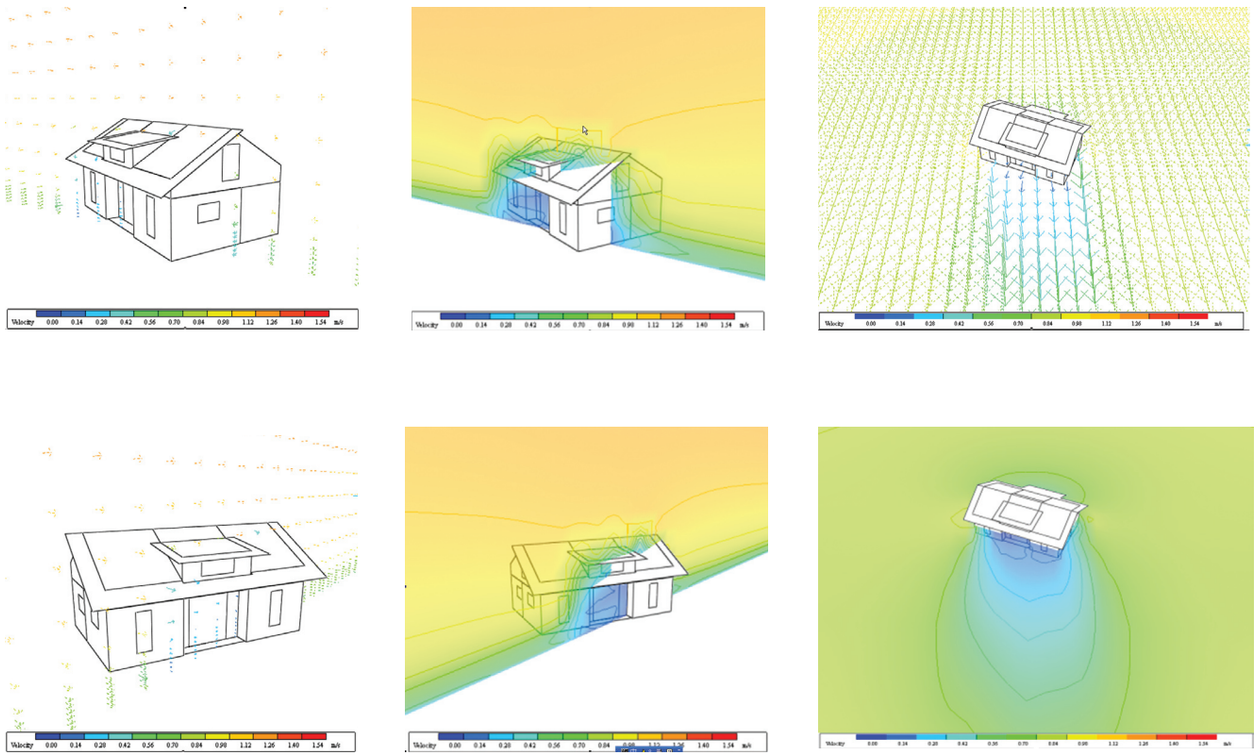
成都冬、夏季室外主导风向为 NNE，全年平均风速1.2m/s。采用IES的CFD模块对住宅的室外风场进行模拟分析。

近地面 1.5m处室外风速场分布，图中不同颜色代表了风速的大小。

3. Analysis of outdoor wind field

The outdoor prevailing wind direction in summer and winter in Chengdu is NNE; the annual average wind speed is 1.2m/s. The simulation analysis of outdoor wind field is conducted by adopting CFD model of IES.

Distribution of wind speed field at 1.5m near-surface: the different colors in the pictures stand for different wind speeds.



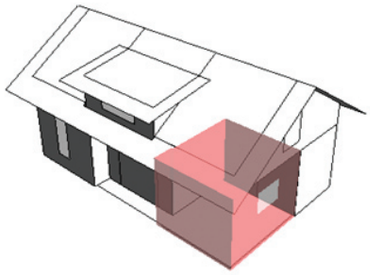
剖面风场分布 Section wind field distribution

4 . 典型房间室内环境品质分析

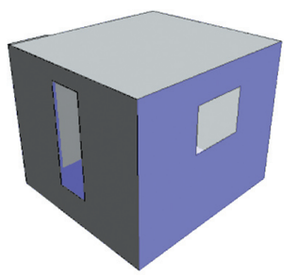
（1）一楼东侧卧室

4. Indoor environment quality analysis for typical rooms

(1) Eastern bedroom on the first floor



该房间在整个楼房中的位置
Location of the room in the whole building



房间形状
Room shape

日照：南侧墙和地面全年接收日照的百分比。全年均能获得日照，夏季少，秋冬季节较多。

Sunlight: The annual percentage of sunlight absorption by southern side wall and the ground; sunlight could be obtained the year round, but is less in summer, more in autumn and winter.

sp-16卧_16卧
Surface 8
Area=8.44 (m?
Show results by
Area (m2)
Percent Area
Insolation type
External
Internal

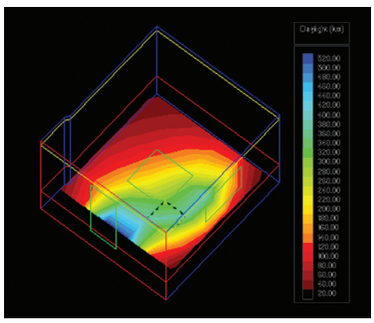
Month	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00
Jan									100.0	94.2	89.5	87.2	86.4	86.7	88.2	91.6	97.7	100.0						
Feb								100.0	94.8	86.8	82.0	80.2	79.4	79.6	80.7	83.1	87.4	97.5						
Mar								99.4	83.1	74.2	68.1	66.6	66.4	66.5	66.9	67.8	69.8	74.6	100.0					
Apr							0.0	0.0	73.0	46.9	38.3	35.9	37.3	36.3	32.2	21.2	0.0	0.0	0.0					
May							0.0	0.0	0.0	40.1	15.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
Jun							0.0	0.0	0.0	0.0	16.9	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
Jul							0.0	0.0	0.0	44.2	18.8	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
Aug							0.0	0.0	75.1	43.1	18.0	11.9	15.5	13.0	1.8	0.0	0.0	0.0	0.0					
Sep							0.0	95.7	72.9	63.8	57.7	57.0	57.2	57.0	56.4	55.1	52.0	41.3	0.0					
Oct								96.5	86.8	80.1	76.8	75.7	75.5	76.0	77.4	80.2	85.6	100.0						
Nov								100.0	96.3	89.7	86.4	85.0	84.7	85.4	87.3	91.4	98.9	100.0						
Dec								100.0	100.0	94.8	90.8	88.6	88.0	88.6	90.8	94.7	100.0	100.0						18.17

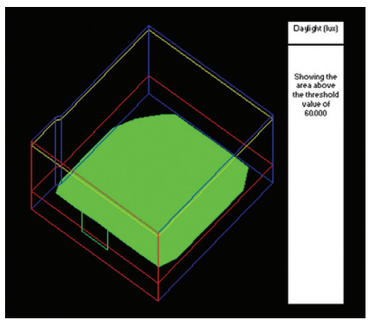
sp-16卧_16卧
Surface 2
Area=-12.59 (m?
Show results by
Area (m2)
Percent Area
Insolation type
External
Internal

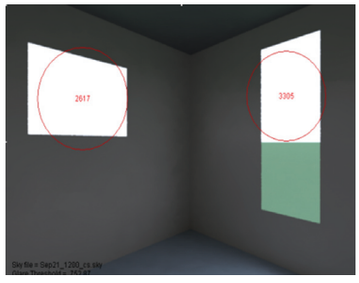
Month	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00
Jan									0.0	-2.3	-8.0	-14.5	-13.6	-13.8	-12.2	-4.9	-0.2	0.0						
Feb								0.0	0.0	-4.2	-8.9	-11.0	-9.1	-9.2	-9.6	-5.0	-1.3	0.0						
Mar								0.0	-0.4	-11.8	-10.4	-7.4	-4.8	-4.8	-4.9	-3.8	-1.3	0.0	0.0					
Apr							0.0	0.0	-7.3	-8.8	-5.3	-2.3	-0.9	-0.8	-0.5	0.0	0.0	0.0	0.0					
May							0.0	0.0	-11.1	-7.2	-4.2	-0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
Jun							0.0	-0.1	-10.7	-6.8	-4.2	-1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
Jul							0.0	0.0	-10.5	-7.3	-4.5	-2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
Aug							0.0	0.0	-8.0	-8.5	-4.8	-1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
Sep							0.0	0.0	-5.7	-11.1	-7.9	-3.7	-3.0	-3.0	-2.9	-2.5	-0.8	0.0	0.0					
Oct								0.0	-1.2	-8.7	-10.9	-7.5	-7.4	-7.6	-7.0	-3.0	-0.2	0.0						
Nov								0.0	-0.2	-4.4	-11.3	-12.5	-12.2	-12.7	-8.4	-3.0	0.0	0.0						
Dec								0.0	0.0	-3.2	-9.7	-15.4	-14.9	-15.3	-10.4	-3.6	0.0	0.0						-3.62

光环境：室内自然采光分布，照度达到 60Lux的区域面积超过95%。室内眩光分布良好。

Light environment: Daylight is naturally distributed inside the house; regions with illumination degree of 60Lux cover an area over 95% . The indoor dizzy light is well distributed.

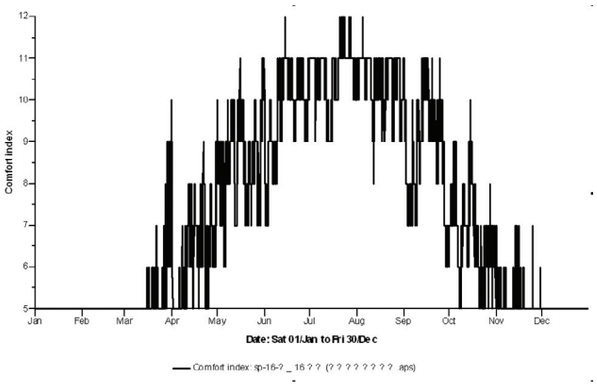


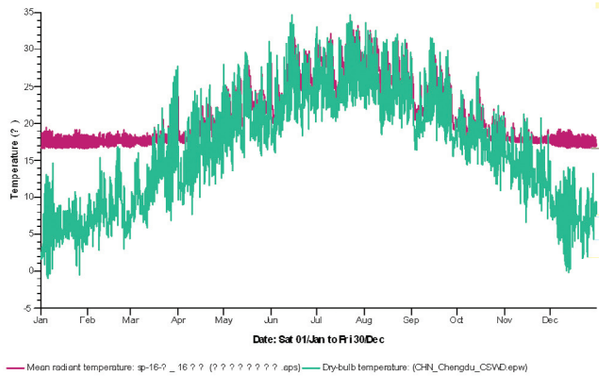




热环境：非空调状态下，全年舒适度指标分布。除 7月份、8月份偏热以外，全年舒适度较高，平均辐射温度较为稳定。

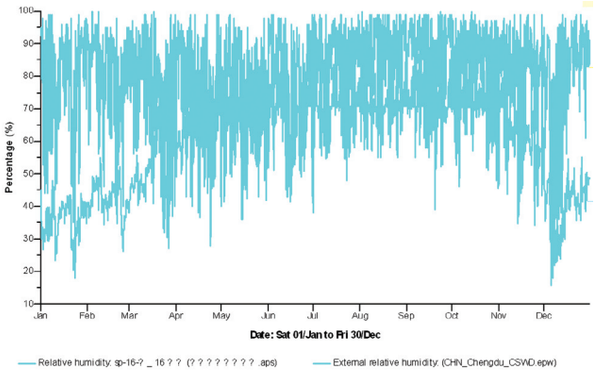
Heat environment: Annual comfort index distribution without air-conditioning. The annual comfort degree is high except for hot months of July and August. The average radiant temperature is relatively stable.

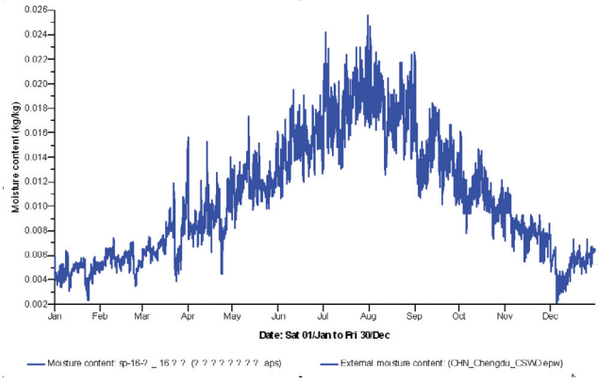




湿环境：非空调状态下，全年室内外相对湿度比较，由于墙体构造具有良好的吸湿功能，全年湿度分布稳定在 70%左右。

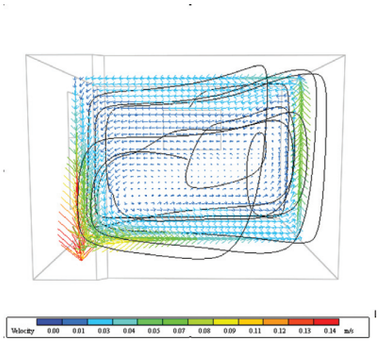
Humid environment: Annual comparison of indoor and outdoor relative humidity. The annual humidity distribution is stabilized around 70% because of the favorable moisture absorption function of the wall structure.

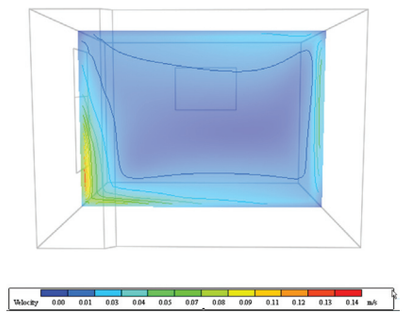




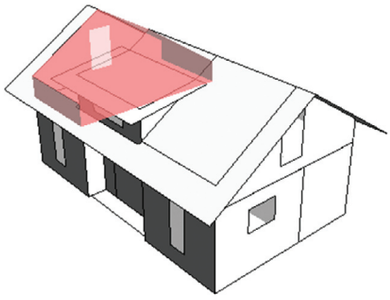
风环境：窗户底部产生的自然对流风，改善了室内的空气品质状况。

Wind environment: Natural ventilation produced at the bottom of the window has improved the indoor air quality.



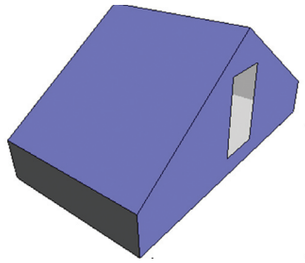


（2）二楼西侧卧室



该房间在整个楼房中的位置
Location of the room in the whole building

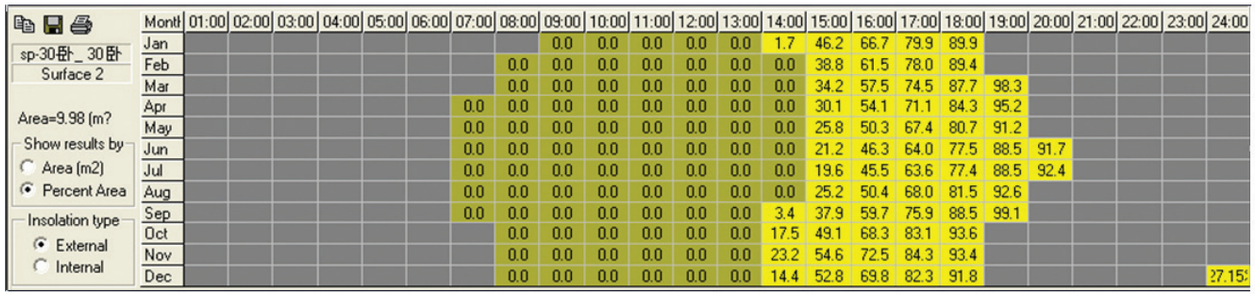
(2) Bedroom at the west side of the second floor



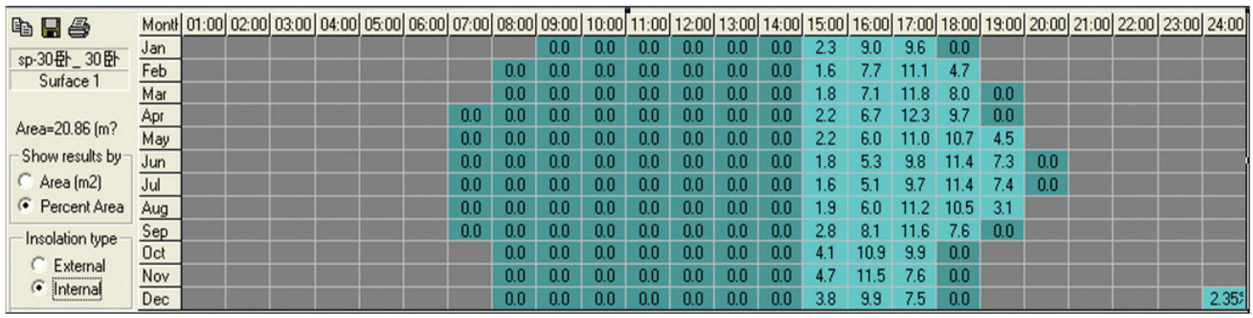
房间形状
Room shape

日照：西侧墙和地面全年接收日照的百分比。全年比较均匀，均只在每天下午能够获得短时间的日照。

Sunlight: sunlight reception percentage of the west door and the ground throughout the year. It is balanced through out the year, both sides could only could receive sunlight in every afternoon for a short period of time.



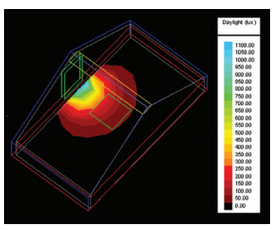
Month	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00
Jan									0.0	0.0	0.0	0.0	0.0	1.7	46.2	66.7	79.9	89.9						
Feb								0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.8	61.5	78.0	89.4						
Mar								0.0	0.0	0.0	0.0	0.0	0.0	0.0	34.2	57.5	74.5	87.7	98.3					
Apr							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.1	54.1	71.1	84.3	95.2					
May							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.8	50.3	67.4	80.7	91.2					
Jun							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.2	46.3	64.0	77.5	88.5	91.7				
Jul							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.6	45.5	63.6	77.4	88.5	92.4				
Aug							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.2	50.4	68.0	81.5	92.6					
Sep							0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	37.9	59.7	75.9	88.5	99.1					
Oct								0.0	0.0	0.0	0.0	0.0	0.0	17.5	49.1	68.3	83.1	93.6						
Nov								0.0	0.0	0.0	0.0	0.0	0.0	23.2	54.6	72.5	84.3	93.4						
Dec								0.0	0.0	0.0	0.0	0.0	0.0	14.4	52.8	69.8	82.3	91.8						27.15

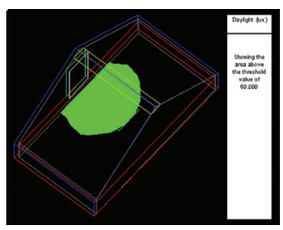


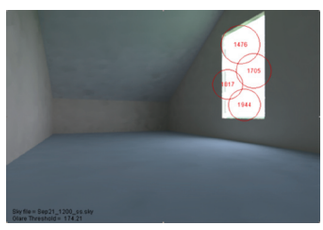
Month	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00
Jan									0.0	0.0	0.0	0.0	0.0	0.0	2.3	9.0	9.6	0.0						
Feb								0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	7.7	11.1	4.7						
Mar								0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	7.1	11.8	8.0	0.0					
Apr							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	6.7	12.3	9.7	0.0					
May							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	6.0	11.0	10.7	4.5					
Jun							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	5.3	9.8	11.4	7.3	0.0				
Jul							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	5.1	9.7	11.4	7.4	0.0				
Aug							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	6.0	11.2	10.5	3.1					
Sep							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	8.1	11.6	7.6	0.0					
Oct								0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	10.9	9.9	0.0						
Nov								0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	11.5	7.6	0.0						
Dec								0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	9.9	7.5	0.0						2.35

光环境：室内自然采光分布，照度达到 60Lux的区域面积超过95%。室内眩光分布良好。

Light environment: for the distribution of indoor natural lighting, the regional area of illumination that reaches 60Lux exceeds 95%. The indoor glare is well distributed.

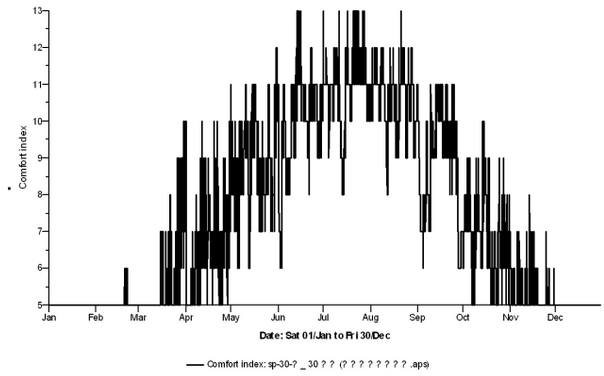


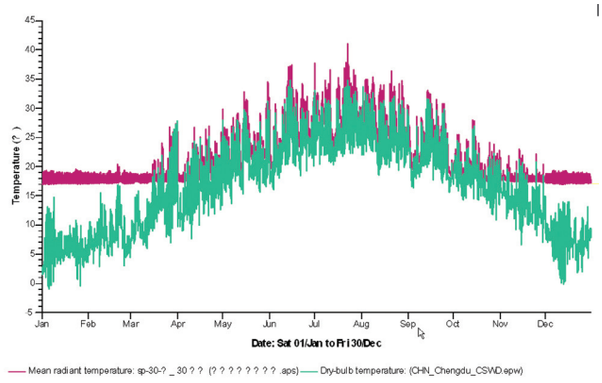




热环境：非空调状态下，全年舒适度指标分布。除 7月份、8月份偏热以外，全年舒适度较高。平均辐射温度较为稳定。

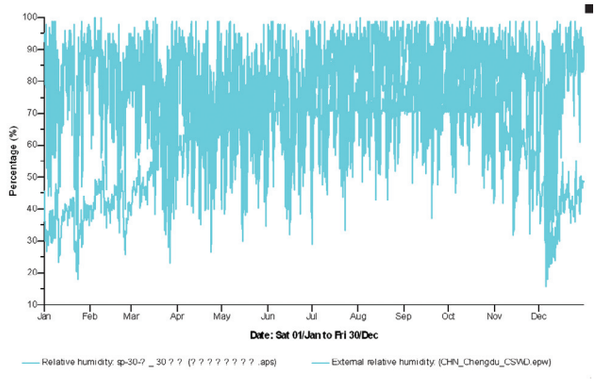
Thermal environment: distribution of indexes of comfort degree all the year round without air conditioners. The comfort degree is higher all the year round except in July and August. The average radiation temperature is stable.

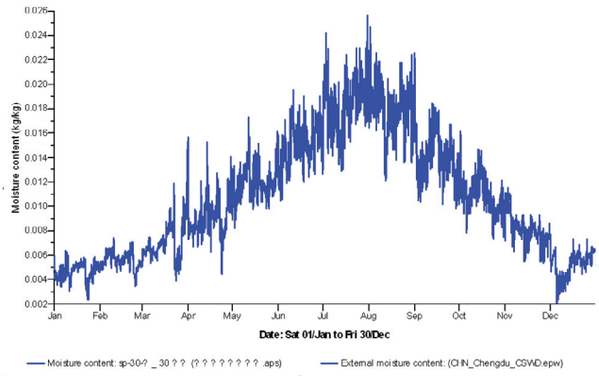




湿环境：非空调状态下，全年室内外相对湿度比较，由于墙体构造良好的吸湿功能，全年湿度分布稳定在 70%左右。

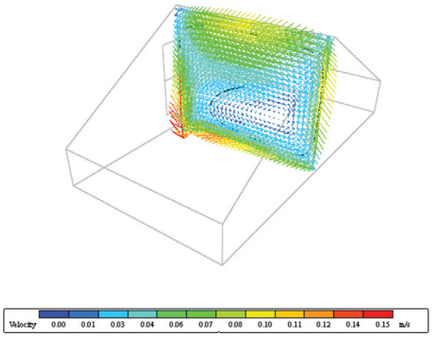
Humid environment: comparison of the indoor relative humidity throughout the year without air conditioners. As the wall structure has good moisture absorption; the humidity distribution can remain steady at about 70% all the year round.

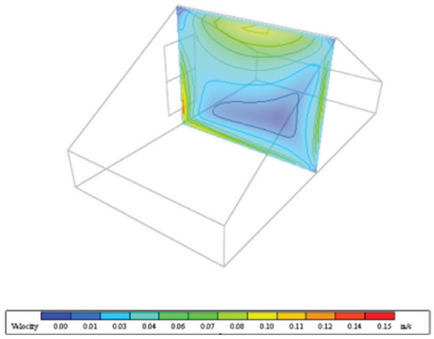




风环境：窗户底部产生的自然对流风，改善了室内的空气品质状况。

Wind environment: Natural ventilation produced at the bottom of the window has improved the indoor air quality.





5. 环境效益—CO_2排放量

注：按营建体系计算，本项目中所有强度系数均取自于论文《建筑材料环境负荷指标及评价体系的研究》，赵平、同继锋、眷荣，中国建筑材料科学研究院。

（1）基本假设

在建筑物能源消耗的构成比例中，一般施工阶段的能耗占10%~15%，建材生产阶段的能耗占50%~80%，在总能耗中所占比例最大，而且此阶段的能耗数据来源可靠性比较强。而用于运输的能量对于不同运输方式差别很大，因而在本计算中暂不予考虑。

建材生产阶段 CO_2排放来源于三部分，一是矿物或固态燃料燃烧产生的 CO_2，二是电力消耗转化的 CO_2排放，三是来自于硅酸盐材料化学反应分解排放的 CO_2。因此，从能源的使用量与建材生产原料的含碳量可以估算建材产品的 CO_2排放量。我国目前消费 1度电所产生的平均 CO_2排放量为 0.95kg。将燃料燃烧和电能所产生的 CO_2量及碳酸盐材料分解排放的 CO_2三者相加，即可计算出建材产品生产阶段的 CO_2排放量 (t–CO_2/t建材)。（见下表所示）

5. Environmental benefit: the calculation of CO_2 emission

Note: It is calculated according to construction system, all strength coefficients of the research are taken from the research paper of *Research on Building Materials Environmental Load Index and Evaluation System* by Zhao Ping, Tong Jifeng, and Juan Rong at China Building Materials Academy.

(1) Basic hypotheses

Of the energy consumption by buildings, the energy consumption at the general construction stage accounts for 10%-15%, and the energy consumption at the stage of producing building materials accounts for 50% - 80%. The latter stage accounts for the largest proportion in the total energy consumption, and the sources of energy consumption data at the latter stage is much more reliable. For energies used for transportation, the energy efficacy varies significantly between different means of transportation, so it is not considered in the calculation.

CO_2 emission during the stage of producing building materials consist of three parts: first, CO_2generated from combusting minerals or solid fuel; second, CO_2transformed by power consumption; third, CO_2 emitted from the chemical reaction of silicate material. Therefore, the CO_2 emission by building materials can be estimated according to energy consumption and carbon content of the raw materials for building materials production. Currently, the average CO_2emission by consuming one kW of electricity is 0.95kg. The CO_2 produced by fuel combustion, plus CO_2generated by electric energy, plus the CO_2 emitted from the chemical reaction of silicate material add up to the CO_2 emission by building materials during the production stage (t- CO_2/t building materials).（*Please refer to the form as below*）

我国建筑材料生产过程中，资源消耗、能源消耗和 CO_2排放量列表

Resource consumption, energy consumption and CO_2 emission during the process of producing building materials in China

建筑材料名称 Name of building material	资源消耗量 Resource consumption(t/t)	能源消耗量 Energy consumption(GJ/t)	CO_2 排放量 CO_2 emission(t/t)
水泥 Cement	1.6	5.5	0.9
钢材 Steel material	1.8	29.0	2.0
铝材 Aluminum material	4.5	180.0	9.5
建筑玻璃 Building glass	1.4	16.0	1.4
木材 Lumber	0.1	1.8	0.2
建筑卫生陶瓷 Construction sanitary ceramics	1.3	15.4	1.4
黏土砖 Clay brick	1.9	2.0	0.2
混凝土块 Concrete block	1.2	1.2	0.1

根据全生命周期的观点，计算建筑材料资源消耗、能源消耗和 CO_2 排放时必须考虑建筑材料的可再生性。材料的可再生性指材料受到损坏但经加工处理后可作为原料循环再利用的性能。具备可再生性的建筑材料包括：钢筋、型钢、建筑玻璃、铝合金型材、木材等。通过对国内相关产品的调查，给出下列可再生材料的回收系数。建筑玻璃和木材虽然可全部或部分回收，但回收后的玻璃一般不再用于建筑，木材也很难不经处理而直接应用于建筑中。因此，本项目计算时不考虑玻璃和木材的回收再利用因素。

In view of life circle, the calculation of resource consumption, energy consumption and CO_2 emission of building materials should take into account the renewable capacity of building materials. The renewable capacity of materials means that when the materials are damaged, they can be recycled after being processed. The building materials with renewable capacity include steel bar, sectional steel, building glass, aluminum alloy sections, lumber etc. The recovery coefficient of renewable materials should be given by surveying related domestic products. Although the building glass and lumber can be recovered completely or partly, the recovered glass usually can not be used in buildings. It is difficult for lumber to be used in building without being processed. Therefore, the calculation of the research does not take into account the recycling factors. (See form below)

可再生材料的回收系数列表 *The recovery coefficient of renewable materials*

型钢 Sectional steel	钢筋 Reinforcing steel bar	铝材 Aluminum material
0.9	0.50	0.95

考虑回收后的建材环境负荷指标列表 *Consideration of the environmental load indexes for recycled building materials*

建筑材料 Building materials	资源消耗强度 Resources consumption（t/t）	能源消耗量 Energy consumption（GJ/t）	CO_2 排放量 CO_2 emissio（t/t）
型钢 Sectional steel	0.18	13.30	1.40
钢筋 Reinforcing steel bar	0.90	20.30	0.92
铝材 Aluminum material	0.23	19.30	1.02

本项目实际估算所采用的指标，如下表所示：

The indexes adopted by the project based on actual estimation are shown in the following Table:

材料名称 Names of materials	重要指标 Important indexes		
	碳排放强度 Carbon emission intensity t/t	资源消耗强度 Resource consumption GJ/t	能源消耗强度 Energy consumption intensity GJ/t
水泥 Cerement	0.9	1.6	5.5
型钢 Sectional	1.4	0.18	13.3
钢筋 Reinforcing steel bar	0.92	0.9	20.3
铝材 Aluminum	1.02	0.23	19.3
玻璃 Glass	1.4	1.4	16
木材 Lumber	0.2	0.1	1.8
陶瓷 Ceramics	1.4	1.3	15.4
黏土砖 Clay	0.2	1.9	2
混凝土砌块 Concrete	0.1	1.2	1.2
干草 Hay	0	0	0
泥 Mud	0	0	0
竹编 Bamboo	0	0	0

（2）计算方法

A．建筑物的资源消耗

计算建筑物单位建筑面积所用建筑材料生产过程中消耗的天然及矿产资源量 C（t/m²）。

$$C = \sum_{i=1}^{\theta} X_i B_u (1-\alpha) / S$$

其中：

X_i ——第 i种建材生产过程中单位重量资源消耗量指标（t/t）

B_i ——单体建筑用第 i 中建材的总重量（t）

S ——单体建筑的建筑面积（m²）

α——单体建筑所用第 i 种建材的回收系数

(2) Calculation method

A. The resource consumption by buildings

Calculating the natural and mineral resource amount consumed in the process of producing building materials used on unit building area of a building C (t/m²)

$$C = \sum_{i=1}^{\theta} X_i B_u (1-\alpha) / S$$

Where in:

X_i — Unit weight resources consumption index in the production process of i building material (t/t)

B_i — Gross weight of i building material used in single building (t)

S — Building area of a single building (m²)

α — Recovery coefficient of i building material used in a single building

B . 建筑物的材料能源消耗

计算建筑物单位建筑面积所用建筑材料生产过程中消耗的能源量 E（GJ/m² ）

$$E = \sum_{i}^{\theta} B_i \left[X_i (1-\alpha) + \alpha X r_i \right] / S$$

其中：

X_i——第 i 种建材生产过程中单位重量能源消耗指标（GJ/t ）

B_i——单体建筑用第 i 中建材的总重量（t ）

S_i——单体建筑的建筑面积（m² ）

α——单体建筑所用第 i 种建材的回收系数

Xr_i——单体建筑所用第 i 种建筑材料的回收再利用过程中的生产能耗指标（GJ/t ）

$$P = \sum_{i}^{\theta} B_i \left[X_i (1-\alpha) + \alpha X r_i \right] / S$$

C . 建筑物对环境的影响

计算建筑物单位建筑面积所用建筑材料生产过程中排放的 CO_2 量 P（t/m² ）。

其中：

X_i ——第i 种建材生产过程中单位重量 CO_2 排放指标（t/t ）

B_i ——单体建筑用第 i 中建材的总重量（t ）

S ——单体建筑的建筑面积（m² ）

α——单体建筑所用第i 种建材的回收系数

Xr_i ——单体建筑所用第i 种建筑材料的回收再利用过程中的 CO_2 排放指标（t/t ）

（3）计算结果

采用以上方法和数据，经详细计算，该样板房与同建筑面积的砖混结构的楼房相比，在营建过程中：

可减少碳排放 70.08–11.90=58.18 吨

资源消耗强度、能源消耗强度仅为砖混结构住房的 10%、14.6%。

B. The material energy consumption by buildings

Calculating energy amount consumed in the process of producing building materials used on unit building area of a building E (GJ/m²

$$E = \sum_{i}^{\theta} B_i \left[X_i (1-\alpha) + \alpha X r_i \right] / S$$

Where in:

X_i —— Unit weight energy consumption index in the production process of i building material (GJ/t)

B_i —— Gross weight of i building material used in single building (t)

S_i —— Building area of a single building (m²)

α —— Recovery coefficient of i building material used in a single building

Xr_i —— Production energy-consumption index in the process of recycling i building material in a single building (GJ/t)

$$P = \sum_{i}^{\theta} B_i \left[X_i (1-\alpha) + \alpha X r_i \right] / S$$

c. The impact of buildings on the environment

Calculating CO_2 emission during the process of producing building materials used on unit building area of a building P(t/m²).

Wherein:

X_i — Unit weight CO_2 emission index in the process of producing i building materials (t/t)

B_i —— Gross weight of i building material used in a single building(t)

S —— Building area of a single building (m²)

α —— Recovery coefficient of i building material used in a single building

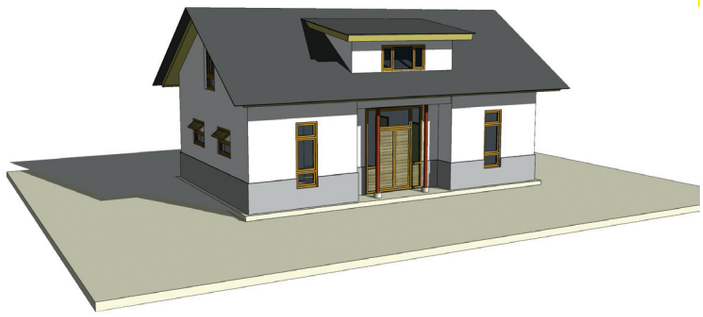
Xr_i —— CO_2 emission index in the process of recycling i building material used in a single building (t/t)

(3) Calculation results

The sample house is compared with other masonry-concrete buildings with the same building area by the above method through detailed calculation, in the construction process:

58.18 tons of carbon emission can be reduced.

The resource consumption intensity, and energy consumption intensity of the sample house are only 10% and 14.6% of masonry-concrete structure houses.



计算结果如下表所示：

For calculation results, you can refer to the attached Table 1 and Table 2:

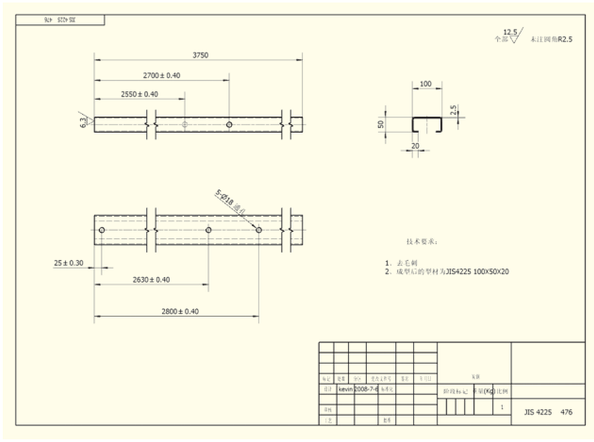
	碳排放强度 t/t Carbon emission intensity t/t	资源消耗强度 t/t Resource consumption intensity t/t	能源消耗强度 GJ/t Energy consumption intensity GJ/t
典型砖混结构平房 Typical masonry–concrete bungalow	70.08	333.63	696.00
典型马尔康项目 Typical Ma'erkang Project	11.90	33.70	101.59

七、施工管理流程

1. 钢料加工

工艺流程：设计数据导入→成型→打孔→钢料截断→局部加工→整套房钢结构打包

单件钢条工程图如右：



VII. Construction management process

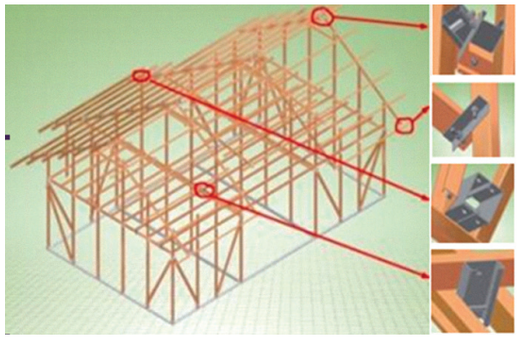
1. Steel processing

Process: Importing design data → molding → hole punching → truncating steel materials → partial processing → packing the steel structure of the entire house

The construction drawing is attached:

Inventor机械制造模型

Inventor mechanical manufacture model



工艺特点：

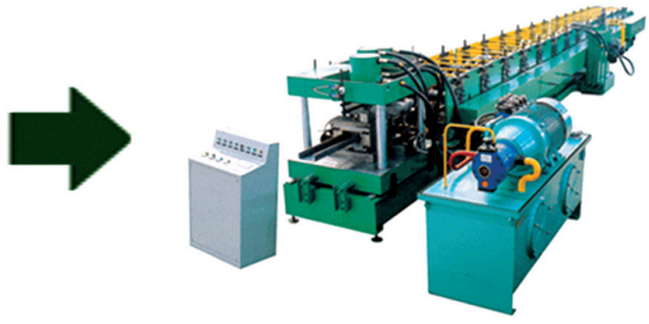
（1）一次成型，效率高。

（2）无边角废料，成本低。

（3）精度高，能耗低。

威华 YX00KY50/80–80/300后切断电脑冲孔 C型钢机组

Weihua YX00KY50/80-80/300 later-stage cutting off computerized punching C-type sectional steel unit



Process features:

(1) Quick molding, high efficiency.

(2) No waste materials, low cost.

(3) High precision, low energy consumption.

2. 现场施工

（1）启动阶段重点工作流程

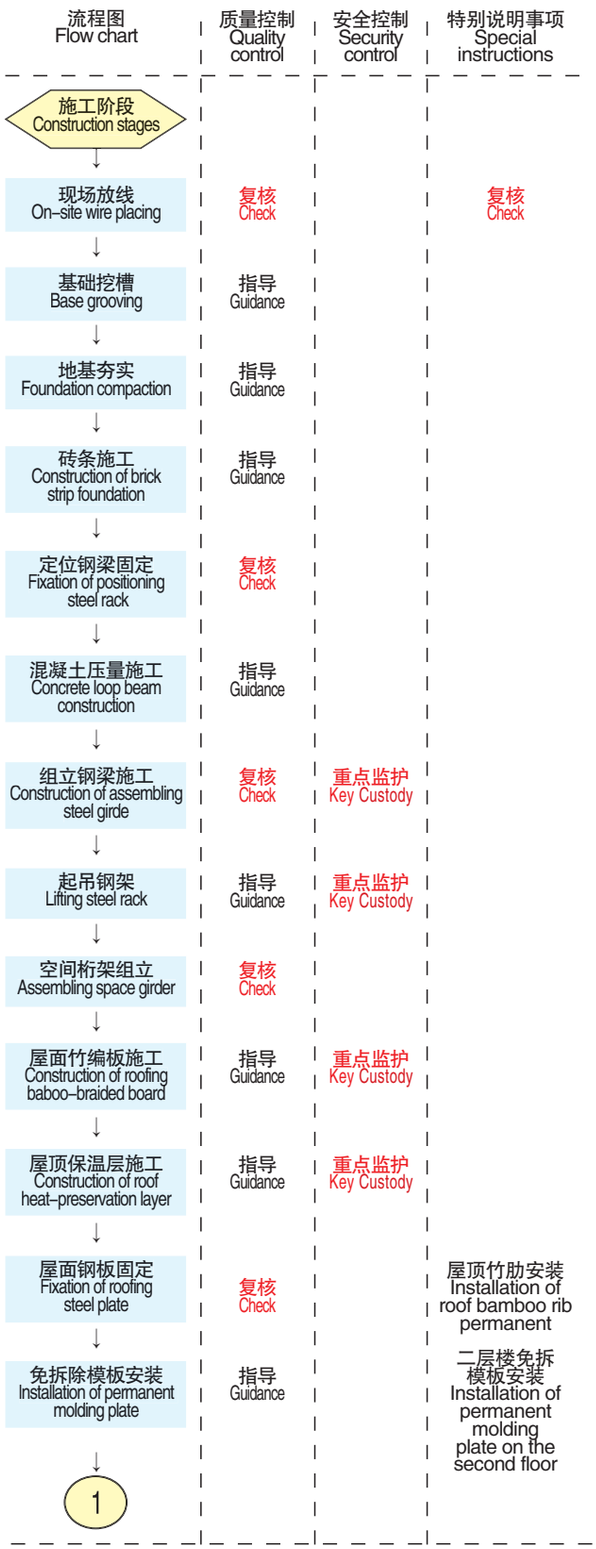
2. Construction management

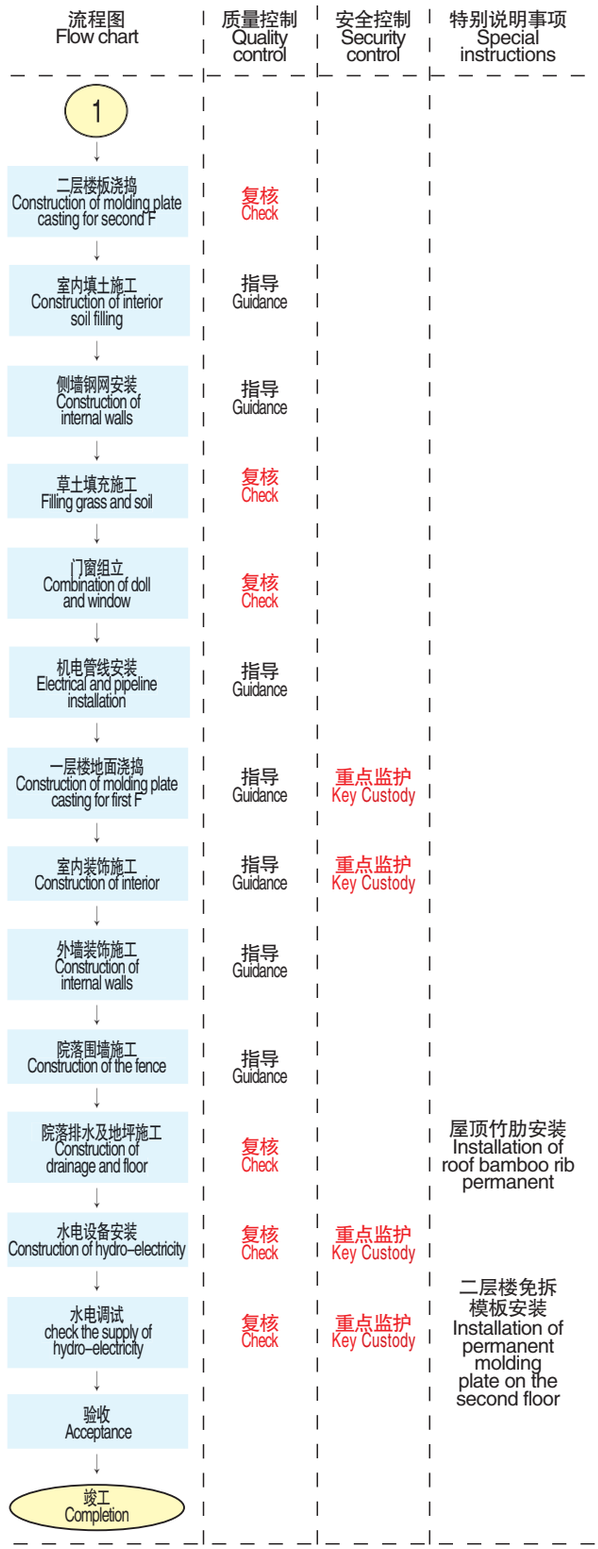
(1) Construction management process

流程图 Flow chart	工作说明 Desription of work content	责任人 Responsible person	谢英俊团队 Hsieh Ying Chun team
启动阶段 Start up stage			
前期选址 Pre–stage address selection	依托政府，规划选定新建房基地 Planning and selecting the base for the new building relying on	各级政府 / 户主 Governments at all levels householder	推动方案，组织资金 Promotion organizational funds for plans
户型选定 House type selection	户主选定户型 House type selection by householder	户主 Householder	完善户型方案协助户主选型 Improving house type plan to help householders with the house type selection
设计调整 Design adjustment	根据户主需求微调方案 Micro–adjustment of the plan according to householder's requirements	户主 Householder	协助 Assistance
材料准备 Materials preparation	申请资金，购买材料 Fund application, materials purchase	户主 Householder	提供材料清单，协助团购 Householder providing material lists to help householders with their group purchase
劳力组织 Labor organization	排定施工计划，组织劳力 Arranging construction plan, organizing labor	各级政府 / 户主 Governments at all levels householder	协助 Assistance
技术培训 Technical training	进行工序、工法、技能培训 Carrying out trainings in processes, techniques and skills		主办 Sponsored by
安全培训 Security training	进行施工安全教育培训 Carrying out trainings in construction security		主办 Sponsored by
准备开工 Preparing to start construction			

（2）施工阶段主要工作流程及工作内容说明

(2) The main workflow and job description at the construction phase





（3）详细工序工艺说明

i. 现场放线

工具材料：工程线、皮卷尺（20米）、石灰、铁锹。

工艺说明：拉工程线、确定直角，按图纸放样，撒石灰。

控制要点：统一按中心线放样，房屋朝向视当地习惯及宅基地的现状。放好样后拉对角线进行尺寸复核。

ii. 基础挖槽

工具材料：挖掘机、铁锹。

施工说明： 使用挖掘机或人工按基础尺寸挖掘成槽，挖土深度控制在 600mm~900mm（视当地土质情况决定），开挖宽度在 600mm 以内，坑底宽度不小于 500mm。

控制要点：标高控制好，尽量不要超挖。

iii. 地基夯实

工具材料：夯实机或自制工具、白石灰。

施工说明：坑底散撒一层石灰（厚度约 3mm 左右，现场控制，均匀撒布一层即可），随后每回填 300mm 土再撒一层石灰，夯实，找平。回填土高度 300mm~600mm（视开挖深度决定）。

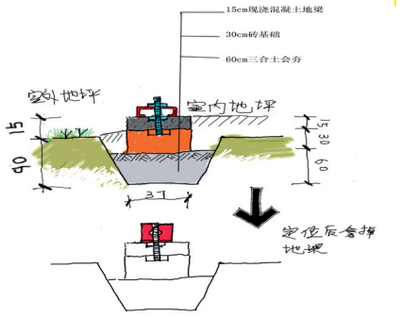
控制要点：最上层务必夯平。

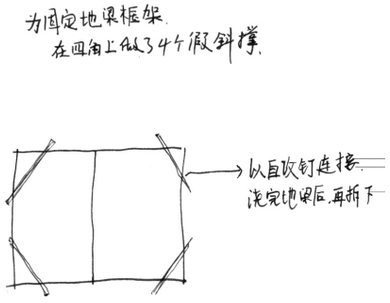
iv. 砖条基施工

工具材料：砖、水泥、中粗砂、砖刀、尖铲、工程线、砂网、铁锹。

施工说明：砖条基采用 370mm 砖墙，1:3 水泥砂浆砂砌筑，高度 5 皮砖。最上皮砖根据图纸的螺栓位置预留螺栓洞口。

控制要点：砖墙转角注意咬合砌筑，预留空位要准确，专人复核。





(3) Description of detailed process and techniques

i. On-site wire placing

Tools and materials: engineering line, tape (20 meters), lime and shovel.
Process description: drawing the engineering line, deciding the right angle, placing the sample according to the chart, liming.
Key control points: placing the sample according to the center line; deciding the facing of the building according to the local custom and the conditions of the current foundation; drawing the diagonal to check the size after the sample is placed.

ii. Base Grooving

Tools and materials: excavating machine, shovel.
Construction specifications: carrying out excavation according to basic size using machine or manpower; the excavating depth shall be controlled within 600mm to 900mm (decided by the local earth quality); the excavating width shall be within 600mm, while the width at the bottom shall be no less than 500mm.
Key control points: keeping the elevation under sound control and avoiding excessive excavation.

iii. Foundation Compaction

Tools and materials: Compactor or self-made tools and materials, white lime.
Construction specifications: Casting a layer of lime at the bottom (the thickness is about 3mm, on-site control, and one even layer is enough), casting a layer of lime when backfilling 300mm earth, tamping and leveling off; the backfilling height is from 300mm to 600mm (according to the excavating depth).
Key control points: The top layer must be tamped.

iv. Construction of brick strip base

Tools and materials: brick, cement, medium coarse sand, brick axe, sharp shovel, engineering line, sand screen and shovel.
Construction specifications: The brick strip base adopts a 370mm brick wall, and is built by laying bricks made of cement mortar with the proportion of 1:3 and the height of 5 bricks. Bolt holes shall be reserved on the top brick according to the positions of bolts on the drawing.

v. 定位钢架固定

工具材料：手电钻、自攻螺丝、螺栓、C 型钢、找平水管、皮卷尺、扳手。

施工说明：就地组立定位钢架，确定各边垂直度后进行临时加固；C 型钢下底面与砖条基表面保持 150mm 距离，调整水平后临时固定；预埋螺栓安装就位。

控制要点：要保证钢架各边的垂直度，严格控制整体钢架的水平度，尽量保持螺栓垂直度，要有专人复核上述控制要点。

vi. 混凝土压梁施工

工具材料：水泥、石子(30mm~50mm)、中粗砂、铁锹、过滤纱网、小推车。

工艺说明：模板采用木模或砖模（参考右侧附图），采用水泥 1：石子 2：砂 3 的级配，浇捣高度与 C 型钢下口平齐。混凝土初凝后将 C 型钢定位钢架拆除，钢架拆除后混凝土表面要找平。

控制要点：混凝土采用现场搅拌，要拌和均匀。混凝土初凝后立即拆除。务必保证混凝土表面的水平度（尤其是地脚螺栓附近）。浇捣前用塑料袋包覆好地脚螺栓，浇捣过程中要做好保护工作，不要使螺栓跑位。

vii. 组立钢架施工

工具材料：螺栓、C型钢、找平水管、皮卷尺、扳手。

施工说明：根据图纸轴线，在地面相应位置按照图纸编号组立钢架，对齐孔位锁好螺栓。钢架组立可参见装配动画。

Key control point: paying attention to the occluding construction at the brick wall corner, the reserved positions shall be accurate and checked by special personnel.

v. Fixation of positioning steel rack

Tools and materials: electric hand drill, tapping screws, bolts, C-type sectional steel, leveling water pipe, tape and wrench.
Construction specifications: assembling the positioning steel rack on the spot; carrying out temporary fixation after confirming the uprightness on every side; a distance of 150mm shall be kept between the lower surface of C-type sectional steel and the brick strip base surface; fixing temporarily after adjusting to level; installing pre-embedded bolts on their positions.
Key control points: ensuring the uprightness on every side of the steel rack; controlling the level degree of the entire steel rack; keeping the uprightness of the bolts where possible; all the above key control points shall be checked by special personnel.

vi. BConstruction of concrete loop beam

Tools and materials: cement, carpolite (30mm~50mm), medium coarse sand, shovel, filtering mesh and cart.
Process specifications: The molding plate shall adopt wood or brick board (referring to the atatched graph on the left); using a grade matching proportion of cement1: carpolite2: sand3; the casting height shall be equal with the lower entry of the C-type sectional steel; dismantling the C-type sectional-steel positioning rack after the concrete coagulating; the concrete surface shall be made level after the steel rack being dismantled.
Key control point: The concrete adopts the on-site beating up and should be dismantled immediately after the concrete coagulating; keeping the level degree of the surface (especially near the foundation bolts); wrapping the foundation bolts before casting with plastic bags; paying attention to protect the bolts during the casting process; keeping the bolts in their positions.

vii. Assembling space girder

Tools and materials: screws, bolts, C-type sectional steel, leveling water pipe, tape and wrench.

Construction specifications: assembling the girder according to the drawing coaxial cables; locking bolts in the right perforations; referring to the assembling animation for girder assembling.

控制要点：严格按照编号及尺寸选定型钢，孔位不对使用备料，现场不得擅自对加工料进行切割、打孔、挪用。

viii. 起吊钢架

工具材料：角铁连接件、C型钢备件、麻绳、滑轮、手电钻、自攻螺丝、扳手。

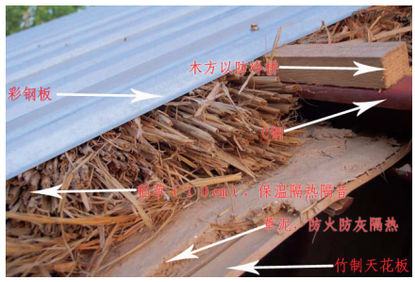
施工说明：起吊前先在预埋地脚螺栓处安装角铁连接件：根据图纸轴线标号，依次起吊钢架，钢架与预埋地脚螺栓通过角铁连接件固定，用 C 型钢备件对钢架进行临时斜撑固定。

控制要点：注意事先要检查绳索及接头强度，起吊时要统一指挥，钢架两边同时用绳索拉紧，所有施工人员戴好安全帽，钢架下严禁立人。

ix. 空间桁架组立

工具材料：角铁连接件、C型钢备件、麻绳、手电钻、自攻螺丝、扳手、脚手架木板。

施工说明：按照图纸编号组立桁架，对齐孔位锁好螺栓。桁架组立可参见装配动画。组立完成后进行水平度及垂直度复核，调整完成后依次锁紧螺栓。



控制要点：施工时要注意安全，高空作业要系好防护绳。螺栓一次固定时不要太紧，待调整完水平度及垂直度后再依次锁紧。水平度及垂直度要有专人复核。

x. 屋面竹编板施工

工具材料：钢钉枪、气泵、竹片。

施工说明：对竹片进行防虫处理，在地面编制竹编板，参见动画。将预制好的竹编板固定在屋顶檩条上，固定方式参见附图。

控制要点：竹条要烟熏或沸水煮泡进行灭虫，高空作业要系好安全带。

Key control points: choosing the sectional steel in strict accordance with the number and dimensions; preparing backup materials when perforations are mismatched and no unauthorized actions should be made to cut □ punch and appropriate the processing materials

viii. Lifting steel rack

Tools and materials: angle iron connecting parts, C-type sectional-steel spare parts, ropes, chain wheels, electric hand drills, tapping screws and wrenches.

Construction specifications: Installing angle iron connecting parts in the position of the pre-embedded foundation bolts before lifting; lifting the steel rack and fixing it with pre-embedded foundation bolts by angle iron connecting parts; fixing the steel rack temporarily by inclined supporting with C-type sectional-steel spare parts.

Key control points: checking the strength of the rope and the joint; carrying out unified direction when lifting; fastening both sides of the steel rack via ropes; all operators shall wear safety helmets; standing under the steel rack is strictly prohibited.

ix. Assembling space girder

Tools and materials: angle iron connecting parts, C-type sectional steel spare parts, ropes, electric hand drill, tapping screws, wrench and scaffold board.

Construction specifications: assembling the girder according to the drawing number; locking bolts in the right hole positions; referring to the assembling animation for girder assembling; checking the level degree and rightness after the assembling completes; locking bolts in sequence after adjustment.

Key control points: paying attention to safety during the construction; wearing protective ropes when operating in high altitude; the lock bolts should not be too tight while fixing at a time; locking them tight in order after the adjustment of level degree and rightness; the level degree and rightness must be checked by special personnel.

x. Construction of bamboo-braided board

Tools and Materials: steel nail spear, air pump, woven bamboo.

Construction specifications: conducting anti-pest treatment to the bamboo plates and braiding them on floor (see animation); fixing the braided bamboo to the roof purlins; the method of fixation is shown in attached Figures.

Key control point: Bamboo braches should be placed in boiling water to kill pests; workers performing work high above the ground should wear safety belts.

xi. 屋顶保温层施工

工具材料：干草、泥浆、草叉。

施工说明：将干草铡到 200mm 以下长度，与泥浆拌和，填充到竹编板上，檩条之间，填充厚度约 150mm。

控制要点：施工时要注意安全，高空作业要系好防护绳。干草和泥浆的比例约为 3 :1，泥浆不要太厚，有粘滞性，但可流淌。

xii. 屋面钢板固定

工具材料：50mm 木方、彩钢板、手电钻、自攻螺丝、耐候胶、止水胶条、脚手架木板、麻绳、梯子、安全带。

施工说明：在檩条上按图纸标注固定木方，木方间距根据彩钢板宽度确定。用自攻螺丝锁定彩钢板，彩钢板搭接宽度，自攻螺丝间距参照厂商技术参数，自攻螺丝处用耐候胶密闭处理。彩钢板搭接处设置止水胶条。

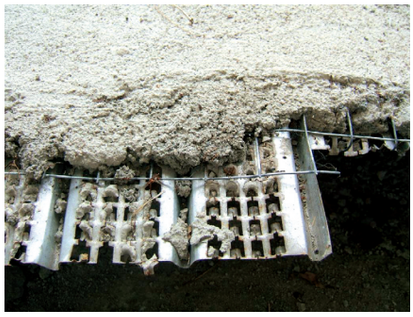
控制要点：施工时要注意安全，高空作业要系好防护绳。自攻螺丝处必须作防锈处理，专人检查。

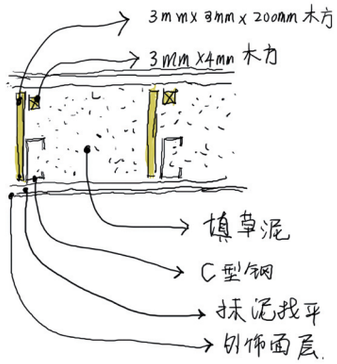
xiii. 二层楼板免拆模板及混凝土浇捣施工

工具材料：免拆钢网模板、钢丝网片（50mm×50mm）、水泥、砂、石子、麻绳、手电钻、自攻螺丝、扳手、脚手架木板、铁锹。

施工说明：在地面上用 1:3 的水泥砂浆在免拆钢网模板下抹平（使免拆钢网模板下底面有 10mm 水泥砂浆保护层），待水泥砂浆干燥后进行免拆钢网模板的安装施工（免拆钢网的固定方式见附图）。免拆钢网固定完成后，进行钢丝网片的施工，随后用 1:2:3 的细石混凝土现场整浇，浇捣厚度为 30mm。

控制要点：注意施工时不要直接踩踏在免拆钢网上，用木脚手板作跳板，保证一定面积的均匀受力，受力点在 C 型钢梁上；浇捣混凝土时要随时拎起钢丝网片，保证钢丝网片在混凝土上方





xi. Construction of roof heat-preservation layer

Tools and Materials: hay, mud, pitchfork.
Construction specifications: Hay should be cut into less than 200mm in length and mixed with mud; putting the mixture into the space between bamboo-braided boards and purlins; the filling thickness is approximately 150mm.
Key control points: taking care when constructing; wearing a protective rope when working high above the ground; the proportion of hay and mud is about 3:1; the mud should not be too thick and should be viscous and pappy.

xii. Fixation of Roof Steel Plate

Tools and materials: 50mm wooden boards, color steel plates, electric hand-drills, tapping screws, weathering plastics, water-stop slips, wooden scaffoldings, hemp ropes, ladders and safety belts.
Construction specifications: marking the fixation of wooden boards on purlins in accordance with the blueprint; the distance among wooden boards depends upon the thickness of color steel plates; fixing color steel plates with tapping screws; the width of the lap between two steel plates and the distance between tapping screws are determined by the technical parameters provided by manufacturers; the tapping screws should be subjected to airtight treatment with water-stopping slips.
Key control points: following safety precautions during construction; wearing a protective rope when working high above the ground.
Tapping screws must be subjected to anti-rust treatment by specially assigned operators.

xiii. Construction of Permanent Molding Plate and Concrete Casting

Tools and Materials: permanent steel templates, steel wire net(50mm×50mm), concrete, sand, stones, hemp ropes, electric hand-drills, tapping screws, spanners, wooden scaffoldings, shovels.
Construction specifications: mixing the concrete and the sand in the proportion of 1:3 and putting the mixture onto permanent steel templates; make sure the surface is smooth - there is a protection layer which is made of the mixture of concrete and sand, and is 10mm thick under permanent steel templates; when the mixture of concrete and sand is dry, installing permanent steel plates, whose fixation is shown in attached Figures; after the installation of the permanent steel plates, building in steel wire net and casting the whole construction with the mixture of stones, sand and concrete in the proportion of 1:2:3; the thickness of casting is 30mm.
Key control points: stomping on the permanent steel net is prohibited; taking a wooden scaffolding as a pedal to assure level stress on a certain surface and the stress point is on the C-type sectional-

（保留 10mm 保护层厚度）。

xiv. 室内地坪填土施工

工具材料：塑料薄膜、石灰、铁锹。

施工说明：基底散撒一层石灰（厚度约 3mm 左右，现场控制，均匀撒布一层即可），随后每回填 300mm 土再撒一层石灰，夯实，找平。回填夯实到地梁上表面以下 50mm 时铺贴塑料薄膜防潮层，上部再回填夯实至地梁上表面平。

控制要点：塑料薄膜施工时要细心，尽量不要撕破，薄膜搭接宽度不小于 50mm。

xv. 外墙免拆钢网，填草土施工

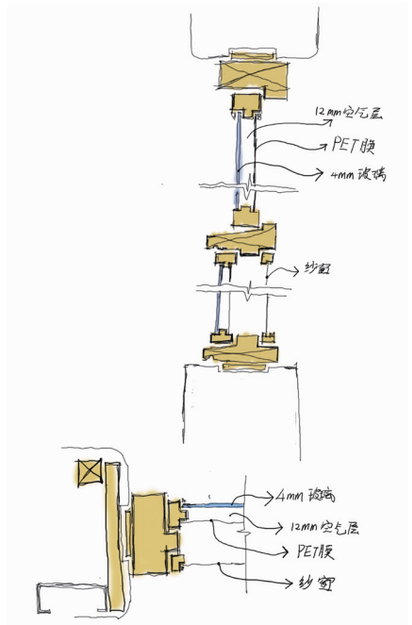
工具材料：免拆钢网、30mm × 30mm 木条、秸秆草、黏土、铡草机、草叉、木工刨床、气钉枪、气泵、脚手架、脚手板。

施工说明：外墙内侧的固定免拆钢网用气钉枪固定在 C 型钢侧板上，外侧用 30mm × 30mm 木条做龙骨，具体方式见附图，然后将免拆钢网用气枪钉固定在木龙骨上。每 600mm 高度的内外免拆钢网固定好后就开始草土填充施工，一层外墙草土比例为 1:1，二层外墙草土比例为 2:1，填充时用木棍捣实。外墙饰面抹泥，第一皮抹泥厚度控制在 30mm，第二皮抹泥厚度控制在 10mm 左右，饰面采用白灰膏抹平，厚度控制在 10mm 左右。离地 900mm 高度以下挂钢丝网，表面用1:3的防水砂浆抹平，厚度约20mm。

控制要点：施工时要注意安全，高空作业要系好防护绳。免拆钢网要固定牢靠，防止爆模，草土填充时要务必捣实，屋檐下口外墙要手工塞实。

xvi. 内墙施工

工具材料：竹条、秸秆草、30mm



steel girder; picking up the steel wire net on time to ensure that the steel wire net is located above the concrete (retaining a 10mm protection layer).

xiv. Construction of indoor terrace filling

Tools and materials: plastic film, lime, shovels.
Construction specifications: spraying a layer of lime on the base (3mm thick; on-site control; evenly spraying); installing 300mm soil and then spraying lime; laying a solid foundation and leveling the surface; the process goes on until the upper surface of ground girder reaches 50mm; laying plastic film as a damp-proof layer; repeating the process of installing until the upper surface of ground girder is level.
Key control points: being careful when laying the plastic film; keeping it from being torn; the width of the lap of plastic film is no less than 50mm.

xv. Installation of permanent wire net of external walls and filling grass and soil

Tools and materials: permanent wire nets, 30mm× 30mm wooden post, straw stalk, clay, straw cutters, pitchforks, carpentry mechanical slicers, pneumatic spear, air pump, scaffold, scaffold plank.
Construction specifications: fixing the solid permanent steel wire, which is on the inner side of the external walls, onto the C-type wire board with pneumatic spear; the outer part is made of 30mm ×30mm wooden post (see attached Figures); fixing permanent wire net onto the wooden frame; when the height of net fixed reaches 600mm, installing grass and soil; the proportion of grass and soil in the first outer door is 1:1 and in the second is 2:1; at the same time of installing, solidifying the mixture with wood sticks; plastering the outer door with mud; the first layer is within 30mm, and the second 10mm; plastering the surface with lime in 10mm thickness; hanging wire net from the height of 900mm above the ground; plastering the surface with 1:3 waterproof sand paste in the thickness of 20mm.
Key control points: following safety precautions during construction; wearing protective rope when working high above ground; the permanent wire net should be tightly fixed and prevent frame destruction.

xvi. Construction of Internal walls

Tools and materials: bamboo strips, straw stalk, 30mm×30mm wooden posts, lime, pneumatic spear, air bump, wooden scaffolds.
Construction specifications: drilling holes at every 600mm on the C-type sectional-steel posts; passing the bamboo plates through these holes and vertically braiding the bamboo plates (referring to the assembly animation for braiding the bamboo plates); plastering the woven bamboo plate with mud; the first layer is 30mm, and the second 10mm; plastering the surface with lime in 10mm thickness.

×30mm 木方、白灰、气钉枪、气泵、脚手架木板。

施工说明：在 C 型钢立柱上每600mm 打孔，将竹片肋条穿过，再竖向编织竹片。编织竹片可参见装配动画。编织完成后即可抹泥，第一皮抹泥厚度控制在 30mm，第二皮抹泥厚度控制在 10mm 左右，饰面采用白灰膏抹平，厚度控制在 10mm 左右。

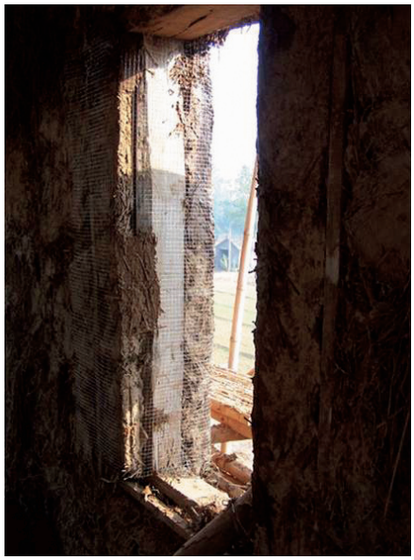
控制要点：施工时要注意安全，高空作业要系好防护绳。抹泥务必分层完成，防止开裂，脱落。第一皮抹泥加秸秆草，第二皮采用砂土混合。

xvii. 门窗施工

工具材料：50mm×100mm 木方，50mm×50mm 木方、玻璃、PET 膜、30mm 厚木板、木工刨床、气钉枪、气泵、木工手工工具。

施工说明：门窗采用木制，在轻钢桁架组立完成后根据门窗尺寸用木龙骨做框，加工好门窗框后固定在木龙骨上，用钢钉固定。外墙完工后安装窗扇、门扇及门窗五金。窗采用玻璃及PET 膜，当中有 12mm 的空气隔热层。外墙在开窗处特别处理，两侧预埋钢丝网片，水泥砂浆粉刷，外窗台作台度，下有滴水线。详见附图。

控制要点：PET 膜制作时要注意，尽量拉平。木窗制作时要考虑木材的湿涨干缩变形问题，防止受潮后无法开启。



Key control points: following safety precautions; wearing protective rope when working high above ground; the process of plastering must be performed by steps, each of which has its own thickness in case of hiatus; the first layer of mud is mixed with straw stalk, and the second with sand and soil.

xvii. Construction of Doors and Windows

Tools and materials: 50mm×100mm wooden posts, 50mm×50mm wooden posts, glass, PET film, 30mm wooden board, carpentry mechanical slicer, pneumatic spear, air bump, carpentry hand-tools.

Construction specifications: Doors and windows are made of wood; after the assembly of a light girder, making a frame with wooden keel according to the sizes of doors and windows; fixing the frame of doors and windows to the keel with steel nails; after the construction of external walls, installing window sashes, door sashes and hardware of doors and windows; windows are made of glass and PET film, in which an 12mm air layer for heat insulation is arranged; conducting special treatment to the window opening part on the external doors; pre-embedding steel wire net along the two sides of the window and plastering it with cement slurry; taking the outer windowsill as a dado, below which the drop-water line is arranged (See attached Figure for details)

Key control points: leveling PET film as much as possible during fabrication; taking into consideration the deformation and shrinkage of wood when making wooden windows in case the window can not be opened due to dampness.

总结

谢英俊的灾后重建设计理念是投入有限的资金，让受灾居民参与自建，在同心协力的重建中实现社区与自我文化的认同，同时实现节能减排、绿色环保的理念。

“马尔康行动”努力探索空间配置、建筑结构、新的施工方法以及重建中的施工管理，我们相信这种努力会为灾区的农村建设带来新的面貌。

Conclusion

The notion of after-quake reconstruction Mr. Hsieh Ying Chun sticks to is to use money within limits, and to allow residents to work on their own. In the spirit of unity, residents could achieve the recognition of both self identity and community culture, at the same time to achieve energy saving and environmental friendliness.

'Ma'erkang Project' seeks to optimize space allocation, technology of architectural structure, new ways of construction and management of reconstruction. We believe our efforts will bring a promising future to the rural areas.