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Research on the Environmental Burden Evaluation of Building Construction- Comparing with Different Construction Methods

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Abstract: - - This paper focuses on the influence of energy consumption and CO_2 emission by different building methods during all the process from the producing of material to completion of construction. The research is primarily to understand the impact of ecological environment and human live by the energy and greenhouse gas on earth. Secondly, try to establish the estimation method and calculation procedure by concluding literatures about "Building structure & construction" and "Environmental burden evaluating system".Finally, this paper analyze and compare with the difference of environmental burden generating by the different construction methods by case studying on Taipei municipal athletic field in Taiwan. The main goal of this thesis is to establish the environmental burden assesment tool for calculating and evaluating.

Key-words: - Environmental Burden, Energy Consumption, CO_2 Emission, Prefabricate method

1. Introduction

When the criticism of exhaust of greenhouse gas (GHG)has been made by most industrialized nations of the world, the energy consumption and the emission of carbon dioxide during construction has been priority reviewed.[3,4] However, most environmental burden had been decided at the phase of the building design, arranged by the proposal of the allocation, the type of the structure and the material. The process of building produce and the products that used in building construction has basically made particular influences on the environment.According to the estimation of The Ministry of Economic Affairs, R.O.C.(TAIWAN), most energy consumption of the nation is industry and manufacturing, followed by transportation, and there are only 16% of energy consumption were used in dwelling and commerce. This result hints that the consumption of energy in construction didn't take a critical part in nation energy consumption. However, some consumption of the energy categorized to industry was consumed by the produce of material for building construction, and that categorized to transportation was consumed by the movement of material.[14] The energy consumption in building construction should be underestimated in national energy consumption estimation.

This research hopes to find out the factors that control the consumption of the energy and the emission of CO2 during the construction in building life cycle to assess the structure and the working method in order to reduce the environmental burden of the construction.And tich the following gole:

- Contribute the estimation method to access the energy consumption and CO_2 emission.
- Find out the factors witch influence the environment burden during construction, and throuth wich to eviluate a construction method more friendly to environment.
- Compose a strategy to improve the impact from building contruction for relative institution.
- Provide a basis for constructors to evaluate working method before constrution.
- Offer a evaluation method of construction stratgy to reduce environmental burden.

2. Field of research

It is concluded the life cycle of building into eight phases as Tab. 1. This research would primarily confer the stage of construction to evaluate the burden of environment by different constructional process. The energy consumption and CO_2 emission of the other five stages doesn't show direct relations to constructional process from Tab. 1, thus, this research focus on the stages that relate to process of building production: Material Manufacture, Transprotation and Construction / Fabrication.

Tab. 1 Energy consumption of each phases in building life cycle

Life Cycle	Energy consumption
Material Manufacture	The fossil fuel and electrical power consumed by material processing and manufacture.
Material Transportation	The fossil fuel and electrical power consumed by material transportation and movement.
Building Construction	The fossil fuel and electrical power consumed during construction and fabrication in place.
Operation	The fossil fuel and electrical power that consumed by building operation such as lighting, HVAC, elevator, escalator...etc..
Maintenance and Renovation	The fossil fuel and electrical power consumed by building maintance and renovation.
Demolition	The consumption of fossil fuel and electrical power for demolution.
Waste Treatment	The consumption of fossil fuel and electrical power of waste transportation and treatment.
Reuse and Recycle	The consumption of fossil fuel and electrical power of waste treatment, recycle or reuse.

3. The theory review of environmental burden evaluation system

Comparatively to traditional environmental buerden evaluating system(BREEAM、GBC2000、LEED、GBEST etc.), L.C.A. (Life Cycle Assessment) has been consequently more popular and been developed to a mature environmental burden evaluating system.[5]This research is based on LCA system to evaluate the consumption of energy and exhaust of CO_2 during building construction, the relative evaluate system has collected as Tab. 2.

Tab. 2 The collection of environmental impact system.

Evaluate system	Developer	Primary assessment
Eco-Quantum	University of Amsterdam, Netherlands,1998	An LCA evaluation system based on IVAM LCA Data 3.0 statistics, with quantitative evaluation system to each phases of building life cycle (construction, operation, demolishment).
BaseLineGreen	Pliny Fisk	LCA Calculation of Greenhouse gas、SO2、NH4
AIJ-LCA	Architectural Institute of Japan, 1998	CO2、Energy、SOX、NOX、Ozone
Dwelling LCA assessment	The Association for Environmentally Symbiotic Housing, 1998	CO2、Energy
Building LCA calculator	Building Research Institute Ministry of Construction, 1996	CO2、Energy
EEWH	Architecture and Building Research Institute, Ministry of the Interior, 2003	Nine indicators including: Greenery、Biodiversity、Water soil content、Water conservation、Energy savings(for the building envelop, light and HVAC)、CO2 emission reduction、Construction waste reduction、Garbage and sewage improvements、Indoor environmental quality.

This research is primarily confer the factors that influence the consumption of energy and the emission of CO2 in construction phase of building life cycle by comparing the estimation of energy consumption and CO2 emission between different working methods, with their process and identities.

Find out the critical factors that consume energy and exhaust CO2 to be the basis of evaluation system to reduce the energy consumption and CO2 emission.

4. Topics

This research could confirm the following points as the basis of our topics with reviewing the theory above:

(1) We can use the quantity of CO_2 as quantitative evaluation of "Environmental Burden".

Reviewing the construction of building in Taiwan, most decision of working method was controlled by time limits and the coast of the project. We rarely use the environmental impact as evaluating system.

(2) Domestic building construction method was primarily cast-in-place due to technique and facilities requirement although pre-cast concrete method is more advanced in it's quality, economy and efficiency.

(3) This research will use case study on certain construction, compare with the estimation of energy consumption and CO_2 emission between different working method through out the whole process of construction.

This research choice a permanence or semi-permanence public building, and it's building method would primarily prefabricate or improved cast-in-place, to invest it's energy consumption of material manufacture, transportation and assembling. Convert the energy consumption to CO2 emission to evaluate its environmental impact. Depend on this result, in this research, we wish to find out a environmental amicable working method to improve the energy consumption and CO2 emission.

5. Methodology

The life cycle of ordinary building structure could be divided to eight phases to material manufacture、transportation、fabrication、operation and utilization、renovation、demolition、dispose of west and resource recovery. It would be some different with different structural and material.

The phase of building construction means the progress between contract to acceptance, including material manufacture、transportation and fabrication, each phase was defined as Tab. 3 . The contents of a construction project were ordinarily including main structure and non-main-structural parts. Main structural means the principal part of the building, including the structure of foundations、beams and columns、load bearing-wall、floors and roof; non-main-structural parts primarily including doors and windows、facilities and decoration, and its characteristic is variety of material and work types、high unit cost, and primarily conveyance and assemble the products.

Tab. 3 The Definition of Building Construction Phases

The phases of building construction	Definition
Material Manufacture	The manufacture of cement、ready mixed concrete、section steel and reinforcing steel. The produce of pre-cast member or assembled components.
Material Transportation	The transportation of material, pre-cast members and assembled components.
Building Construction	The process of construction, fabrication and decoration. (This research limits on the building process of main structure)。

This research confer the cost of environmental burden in method of building construction, for this reason, we focus on the phases of process between material manufacture and building construction. Every phases of the process has different working content, and have different factors to evaluate, the relationship of relative working factors has shown as Figure. 1.

As shown on Figure. 1, the primary factors of each phase are machine and workers. Thus we can estimate the quantity of energy consumption and CO2 emission as basis of environmental burden. According to the difference between the progress of pre-cast and cast-in-place working method, the requirement of the working machine and workers are different, and consequently the factors of environmental burden would also be different. Therefore, this research will focus on the energy consumption of fabrications and workings in construction site.

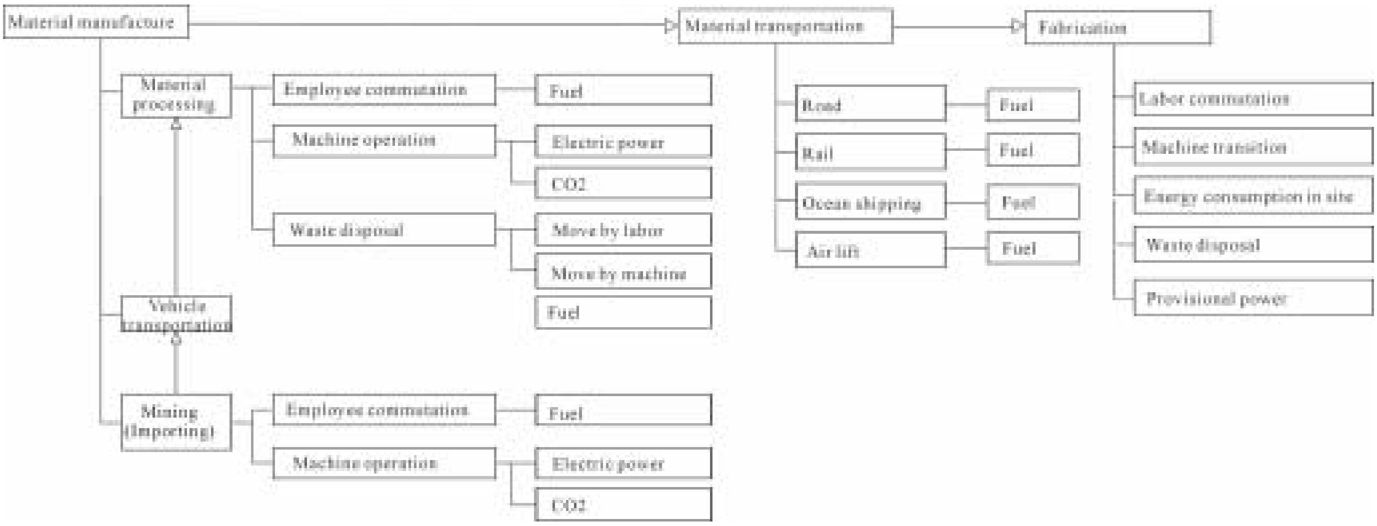

Figure. 1 The Factors of Building Construction

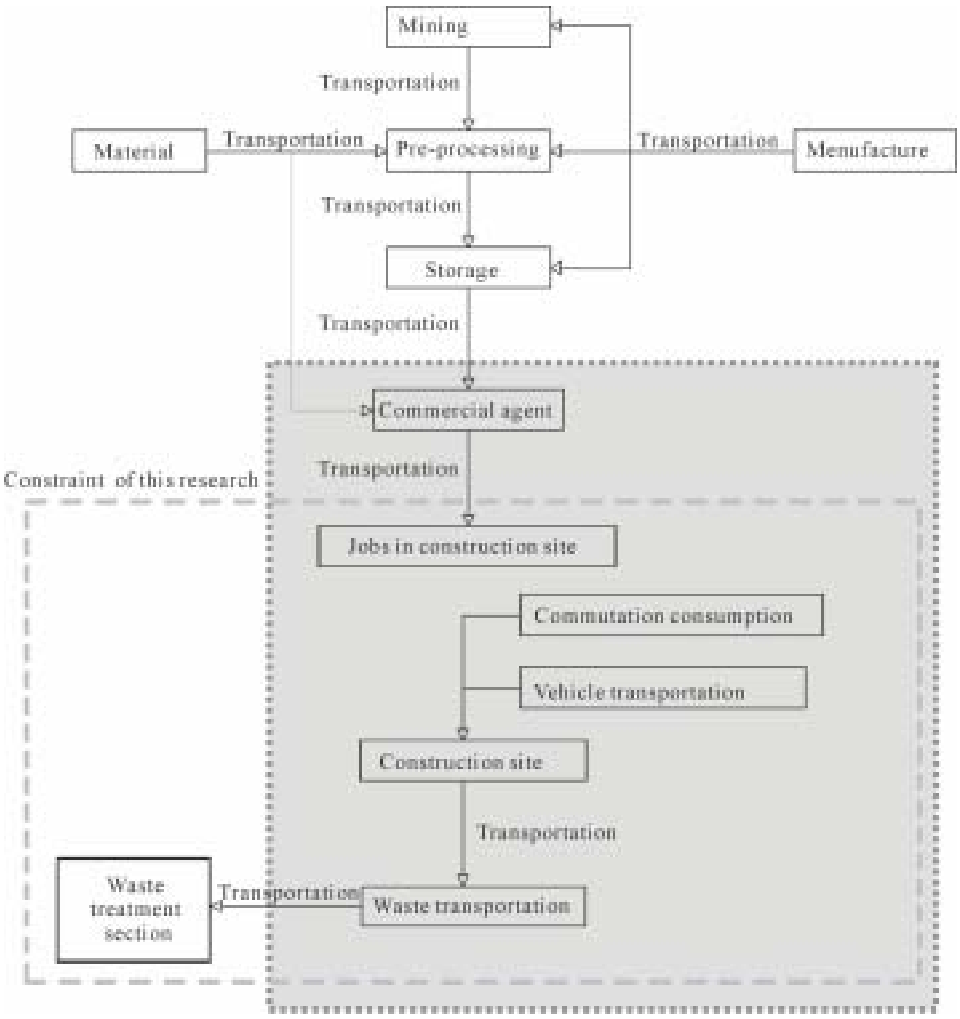

Figure. 2 Constraint of cast-in-place method

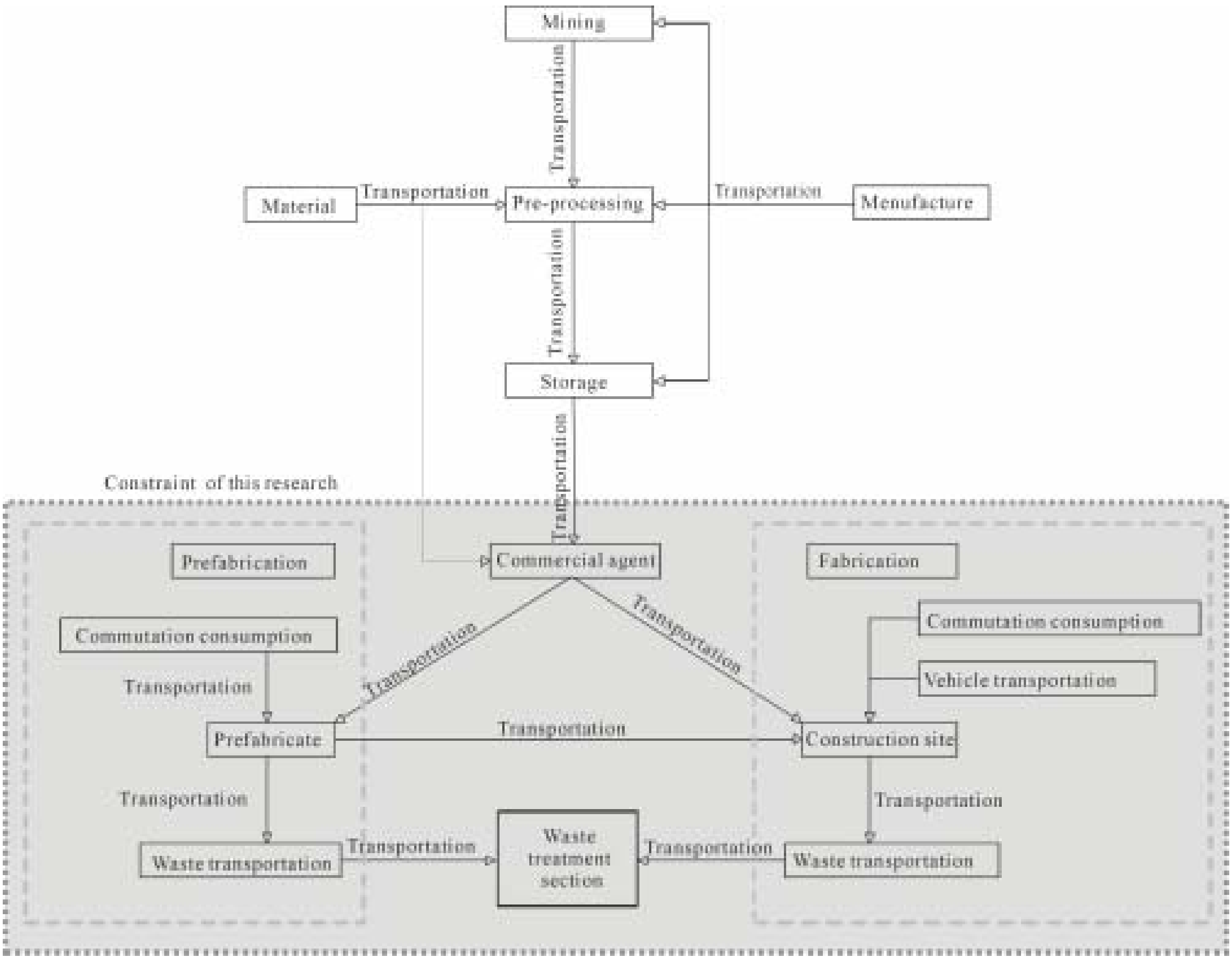

Figure. 3 Constraint of prefabricate method

6. Establish the evaluation system

The process of building construction include three phasese - Material menufacture, Material transportation, and Construction / Fabrication. Every phases of this process could cause the enviromental burden with the usage of energy and resources, and it's impact to Earth could be evaluate with the energy consumption and the GHS emission. Acording to the factors in Figure. 3 and Figure. 2, this research establish an environmental burden assessment model of construction as following Figure. 4 and Tab. 4：

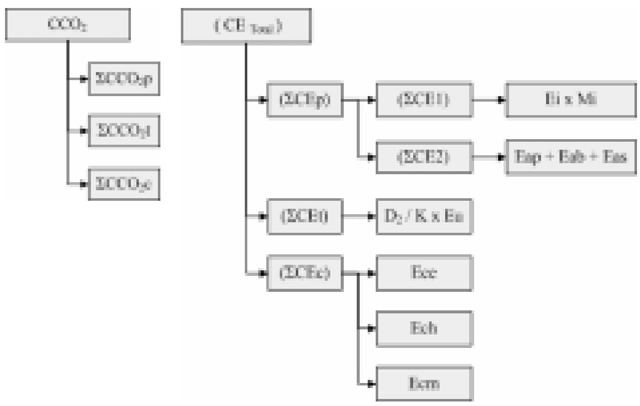

Figure. 4. Structure of environmental burden assessment model

Tab. 4 The Definition of parameters in assessment model

Environmental burden assessment model of constructional CO2 emission (CCO2)	
Formula	**Parameter**
$CCO_2=\Sigma CCO_2p +\Sigma CCO_2t +\Sigma CO_2c$	$C CO_2$：The CO_2 emission during construction. (MT-CO_2) $\Sigma C CO_2p$：The CO_2 emission of materials and components that manufacture and fabricate in factories. (MT-CO_2) $\Sigma C CO_2t$：The CO_2 emission of materials and components that transfer to construction site. (MT-CO_2) $\Sigma C CO_2c$：The CO_2 emission of workers and machines in construction site. (MT-CO_2)
Environmental burden assessment model of constructional energy consumption (CETotal)	
Formula	**Parameter**
CEtotal=ΣCEp +ΣCEt +ΣCEc	CEtotal：The energy consumption during construction. (TJ)。 ΣCEp：The energy consumption of materials and components that manufacture and fabricate in factories. (TJ)。 ΣCEt：The energy consumption of materials and components that transfer to construction site. (TJ)。 ΣCEc：The energy consumption of workers and machines in construction site. (TJ)。
The energy consumption of materials and components that manufacture and fabricate in factories (ΣCEp)	
Formula	**Parameter**
ΣCEp=ΣCE1+ΣCE2 ΣCE1=Ei × Mi ΣCE2= Eap + Eah + Eas	ΣCEp：The energy consumption of fabrication. (TJ) ΣCE1：mining and preprocessing. (TJ) ΣCE2：fabrication. (TJ) Ei：unit consumption of energy of each material Mi：quantity of use of each material Eap：energy consumption from machine in factory. (TJ) Eah：energy consumption from employee in factory. (TJ)。 Eas：energy consumption from transportation of waste. (TJ)。
The energy consumption of materials and components that transfer to construction site(ΣCEt)	
Formula	**Parameter**
ΣCEt= D2 ÷ K x Eu	ΣCEt：The energy consumption of materials and components that transfer to construction site. (TJ)。 D2：Transportation distance (km)。 K：Vehicle efficiency. (km/l)。 Eu：Original unit of energy consumption. (kcal/unit)。
The energy consumption of workers and machines in construction site(ΣCEc)	
Formula	**Parameter**
ΣCEc= Ece + Ech + Ecm	ΣCEc：The energy consumption of workers and machines in construction site (TJ)。 Ece：The consumption of electrical power in construction site. (TJ)。 Ech：The energy consumption of workers' commute. (TJ)。 Ecm：The energy consumption of machine. (TJ)。
Note:1cal=4.186J;1TJ=1012J	

The energy consumed by building construction primarily be fossil fuel and electrical power, and it can be quantitated with the calorific unit of TJ; and the environmental burden can be quantitated with the weight of emitted CO2 with the unit of kg-CO2 or MT-CO2. The prosses of building construction, material pre-procession, manufacture, transportation and fabrication would consume the energy of fossil fuel that contributed by it's components primarily be hydrocarbon, which emit CO2 after combustion.

This research must realize the energy consumption during material and prefabricate units (components) manufacture, and invest its fuel consumption during transportation.

7. Evaluation and Analysis of Case

7.1. Introducing

The 21th Summer Deaflympics, 2009 will be held in Taipei. Taipei county government would demolish the old Taipei Stadium and build a new one, 4 floors above the ground and 1floor underground with the area of 45,899㎡ in total, and has conformed to first class of International Athletic Association. This research performs an investigation and estimation on the process of construction in main structure of the athletic field.

The working process of the case has shown as Figure. 5. The structure of bleachers is made of semi-prefabricate method- base and column was constructed with traditional concrete method. Beams between B1F to 2F was constructed with prefabricate method manufactured in factory at Yang-mei and all components will connect with pre-installed bolts. The floor of B1F to 2F is made of deck system.

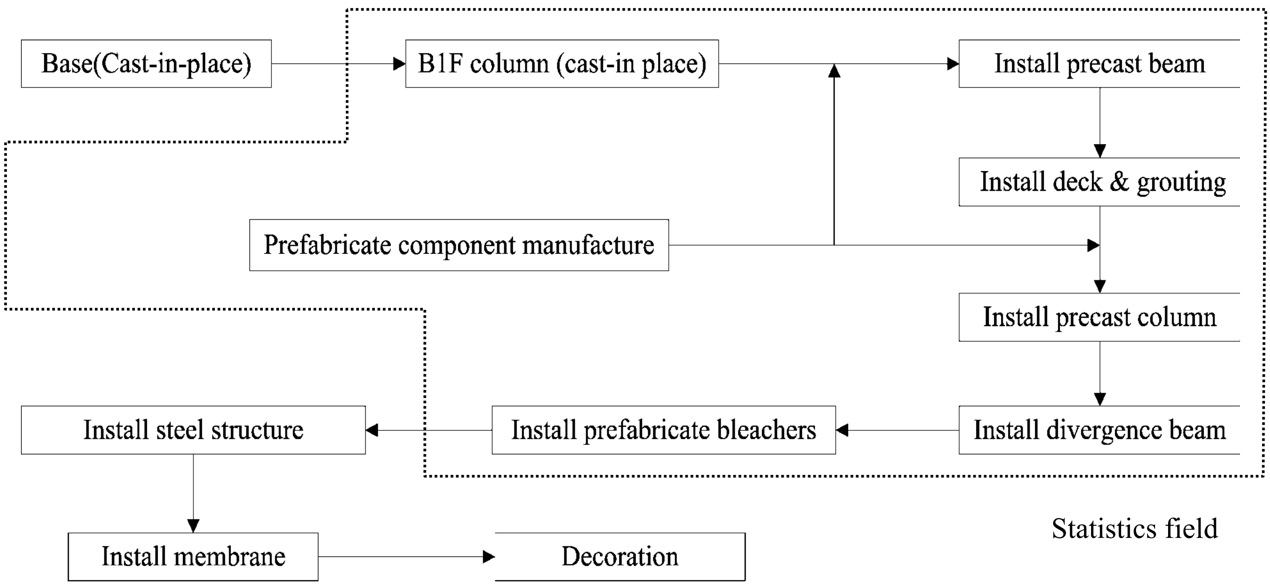

Figure. 5 Working process of study case

7.2. Statistics

This case works with semi-prefabricate method. We put the results of investigation in the Environmental Burden Assessment Model of Construction, we can statistic the energy consumption and CO_2 emission as following result:

(1) Manufacture（ΣCEp）

Energy consumption (ΣCE1’)		CO_2 emission (ΣCC1’)	
3,628,322,893(Kcal)/15.19(TJ)		1,635 (MT- CO_2)	
Energy consumption (ΣCE1”)		**CO_2 emission (ΣCC1”)**	
37,135,717,315.25 (kcal)=155.45 (TJ)		16,942 (MT- CO_2)	
Energy consumption (ΣCE2)		**CO_2 emission (ΣCC2)**	
Eap	8.04(TJ)	Cap	138.42(MT-CO_2)
Eah	0.45(TJ)	Cah	30.88(MT-CO_2)
Eas	0(TJ)	Cas	0(MT-CO_2)
ΣCEp=ΣCE1+ΣCE2		**ΣC CO2p=ΣCC1’+ΣCC1”**	
42,791,528,462.25 (kcal) =179.13 (TJ)		18,746(MT- CO_2)	

(2) Transportation（ΣCEt）

Energy consumption (ΣCEt)	CO2 emission (ΣC CO_2t)
5.25(TJ)	359.97 (MT-CO_2)

(3) Fabrication（ΣCEc）

Energy consumption (ΣCEc)	CO2 emission (ΣC CO_2c)
29.7 (TJ)	1,600 (MT- CO_2)

(4) The result of estimation

Total consumption of energy ΣCEtotal=ΣCEp +ΣCEt +ΣCEc	Total emission of CO_2 CCO_2=ΣCCO_2p+ΣCCO_2t+ΣCCO_2c
51,139,928,521 (kcal)/214.08 (TJ)	20,706 (MT- CO_2)

8. Analysis of energy consumption and CO_2 emission on each phase of construction

We find, from Tab.5, that the manufacture phase has taken the largest ratio of the total energy consumption and CO2 emission, and the transportation has take the least. Therefore, we have to emphasize on reducing environmental burden efficiently.

Tab.5. The ratio of energy consumption and CO_2 emission in each phase of construction

Item	Manufacture	Transportation	Fabrication	TOTAL
Energy consumption(TJ)	179.13	5.25	29.7	214.08
Ratio of energy consumption	83.67%	2.45%	13.88%	100%
CO_2 emission(MT- CO_2)	18746	360	1600	20706
Ratio of CO_2 emission	90.53%	1.74%	7.73%	100%

Tab.6. Ratio distribution of energy consumption and CO2 emission during construction with pre-cast method (first-grade material process is excluded)

Item	ΣCEp	ΣCEt	ΣCEc			CEtotal
	ΣCE2		Ece	Ech	Ecm	
Energy consumption (TJ)	8.49	5.25	11.17	2.25	16.28	43.44
Ratio of Energy Consumption	19.54%	12.09%	25.71%	5.18%	37.48%	100%
Items	**ΣCCO_2p**	**ΣCCO_2t**	**ΣCCO_2c**			**CCO_2**
	ΣCC2		**Cce**	**Cch**	**Ccm**	
CO_2 Emission ($MT\text{-}CO_2$)	169	360	187.4	242.9	1169.4	2128.7
Ratio of CO_2 Emission	7.94%	16.91%	8.80%	11.41%	54.94%	100%

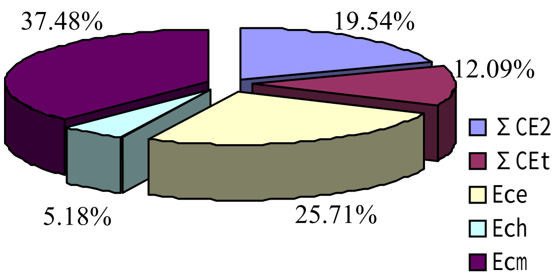

Figure. 7 Ratio of energy Consumption

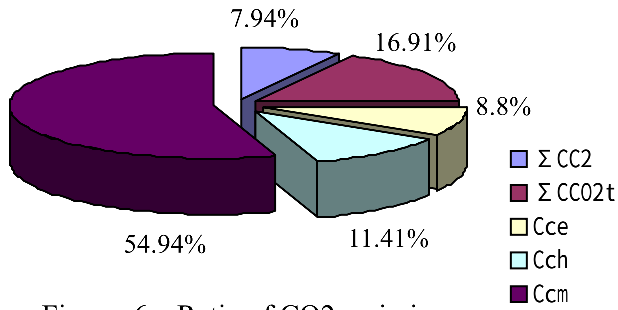

Figure. 6 Ratio of CO2 emission

9. Analysis of simulate comparison

On purpose of comparison, we consult "The Labor and Material Analyzes Manual of Construction Engineering" (Building Administration Office of Taipei City Government,1986) and "The Construction Engineering Quotation Bids"(Wang yui, CHAN'S ARCH BOOKS CO., LTD.,1996) to simulate and analyze the same working requirements with cast-in-place method, and calculate its energy consumption and CO2 emission with three phases. We find the result as following.

10. Estimations of simulate comparision:

(1) Manufacture

Energy consumption (ΣCEp)		**CO2 emission ($\Sigma C\ CO_2p$)**	
ΣCE1	40,764,727,077 (kcal)/170.64 (TJ)	ΣCC1	18,577.21 ($MT\text{-}CO_2$)
ΣCE2	0	ΣCC2	0
40,764,727,077 (kcal)/170.64 (TJ)		18,577.21 ($MT\text{-}CO_2$)	

(2) Transportation

Energy consumption (ΣCEt)	**CO2 emission (ΣCCO_2t)**
1,316,258,298 (kcal)/5.51 (TJ)	378 ($MT\text{-}CO_2$)

(3) construction

Energy consumption (ΣCEc)		CO2 emission (ΣCCO_2c)	
Ece	2,668,795,000 (kcal) = 11.17 (TJ)	Cce	187.4 (MT-CO_2)
Ech	1,610,362,388 (kcal) = 6.74 (TJ)	Cch	727.9 (MT-CO_2)
Ecm	1,321,996,240 (kcal)	Ccm	381.6 (MT-CO_2)
5,601,153,628 (kcal)/23.45 (TJ)		1,296.9 (MT-CO_2)	

(4) The result of estimation

Total Consumption of Energy (ΣCEtotal=ΣCEp +ΣCEt +ΣCEc)	Total emission of CO_2 $CCO_2=\Sigma CCO_2p+\Sigma CCO_2t+\Sigma CCO_2c$
47,682,139,003 (kcal)/199.6 (TJ)	20,252 (MT- CO2)

11. Analysis of energy consumption and CO2 emission in each phase of construction

Tab.7. The ratio of energy consumption and CO_2 emission in each phase of construction

Item	Manufacture	Transportation	Fabrication	TOTAL
Energy consumption (TJ)	170.64	5.51	23.45	199.6
Ratio of Energy Consumption	85.49%	2.76%	11.75%	100%
CO_2 Emission (MT-CO_2)	18577.21	378	1296.9	20252
Ratio of CO_2Emission	91.73%	1.87%	6.4%	100%

Tab. 8 Ratio distribution of energy consumption and CO_2 emission during construction with pre-cast method (first-grade material process is excluded)

Item	ΣCEp	ΣCEt	ΣCEc			CEtotal
	ΣCE2		Ece	Ech	Ecm	
Energy consumption (TJ)	0	5.51	11.17	6.74	5.54	28.96
Ratio of Energy Consumption	0%	19.03%	38.57%	23.27%	19.13%	100%
Item	ΣCCO_2p	ΣCCO_2t	ΣCCO_2c			CCO_2
	ΣCC2		Cce	Cch	Ccm	
CO_2 Emission (MT-CO_2)	0	378	187.4	727.9	381.6	1674.9
Ratio of CO_2Emission	0%	22.57%	11.19%	43.46%	22.78%	100%

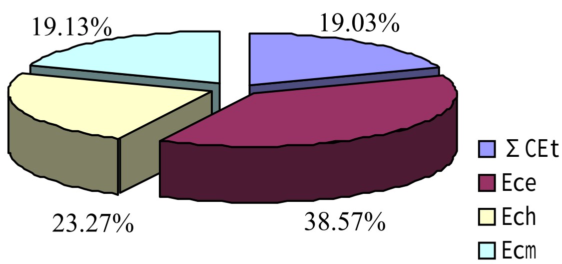

Figure. 9 Ratio of energy Consumption

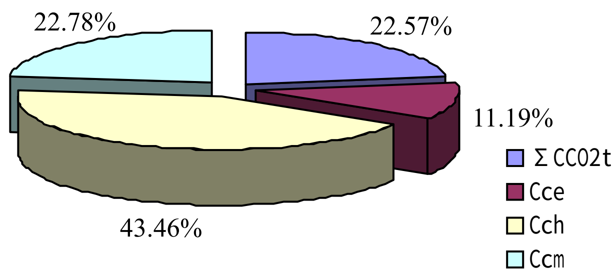

Figure.8 Ratio of CO_2 emission

12. Comprehensive Analysis

12.1. The result of compare to investigation and simulation

After estimation of semi-prefabricate method and cast-in-place method, we compare the relations between parameters as Tab.9,Tab.10. Contemporary construction method used in Taiwan is cast-in-place, this research based on cast-in-place method, and the ratio of energy consumption and CO2 emission between two methods is 1.07：1 and 1.02：1. Eliminate the parameter of first grade of material reprocess the ratio of energy consumption and CO2 emission between two methods would be 1.5：1 and 1.27：1.

Tab.9 Parameters of Semi-prefabricate method and cast-in-place method in energy consumption.(Unit：TJ)

<table>
<tr><th colspan="2">Item</th><th>Semi-prefabricate (A)</th><th>Cast-in-place (B)</th><th>Differences (B-A)</th><th colspan="2">Ratio (A:B)</th></tr>
<tr><td rowspan="2">ΣCEp</td><td>ΣCE1</td><td>170.64</td><td>170.64</td><td>0</td><td>1:1</td><td rowspan="2">1.05:1</td></tr>
<tr><td>ΣCE2</td><td>8.49</td><td>0</td><td>-8.49</td><td>-</td></tr>
<tr><td colspan="2">ΣCEt</td><td>5.25</td><td>5.51</td><td>0.26</td><td colspan="2">0.95:1</td></tr>
<tr><td rowspan="3">ΣCEc</td><td>Ece</td><td>11.17</td><td>11.17</td><td>0</td><td>1:1</td><td rowspan="3">1.27:1</td></tr>
<tr><td>Ech</td><td>2.25</td><td>6.74</td><td>4.49</td><td>0.33:1</td></tr>
<tr><td>Ecm</td><td>16.28</td><td>5.54</td><td>-10.74</td><td>2.94:1</td></tr>
<tr><td colspan="2">CEtotal</td><td>214.08</td><td>199.6</td><td>-14.48</td><td colspan="2">1.07:1</td></tr>
<tr><td colspan="2">CEtotal-ΣCE1</td><td>43.44</td><td>28.96</td><td>-14.48</td><td colspan="2">1.5:1</td></tr>
</table>

Tab.10 Parameters of Semi-prefabricate method and cast-in-place method in CO_2 emission.(Unit：MT-CO_2)

<table>
<tr><th colspan="2">Item</th><th>Semi-prefabricate (A)</th><th>Cast-in-place (B)</th><th>Differences (B-A)</th><th colspan="2">Ratio (A:B)</th></tr>
<tr><td rowspan="2">ΣCO_2p</td><td>ΣCC1</td><td>18577</td><td>18577</td><td>0</td><td>1:1</td><td rowspan="2">1.01:1</td></tr>
<tr><td>ΣCC2</td><td>169</td><td>0</td><td>-169</td><td>-</td></tr>
<tr><td colspan="2">ΣCCO2t</td><td>360</td><td>378</td><td>18</td><td colspan="2">0.95:1</td></tr>
<tr><td rowspan="3">ΣCCO_2c</td><td>Cce</td><td>187.4</td><td>187.4</td><td>0</td><td>1:1</td><td rowspan="3">1.2:1</td></tr>
<tr><td>Cch</td><td>242.9</td><td>727.9</td><td>485</td><td>0.33:1</td></tr>
<tr><td>Ccm</td><td>1169.4</td><td>381.6</td><td>-787.8</td><td>3.06:1</td></tr>
<tr><td colspan="2">CCO_2</td><td>20705.7</td><td>20251.9</td><td>-453.8</td><td colspan="2">1.02:1</td></tr>
<tr><td colspan="2">CCO_2-ΣCC1</td><td>2128.7</td><td>1674.9</td><td>-453.8</td><td colspan="2">1.27:1</td></tr>
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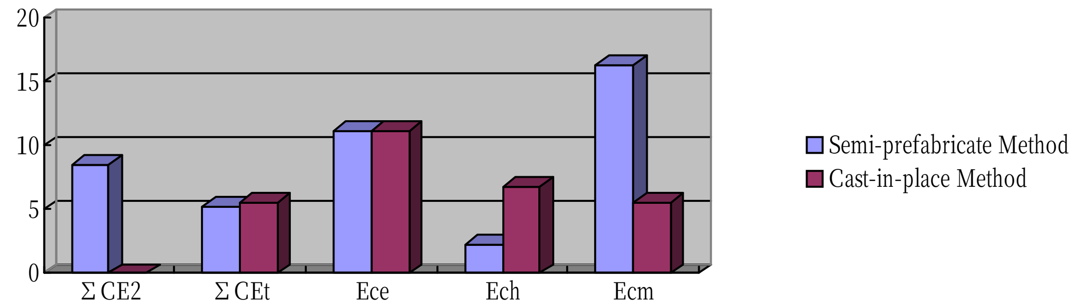

Figure. 10 Parameters of Semi-prefabricate method and cast-in-place method in energy consumption (eliminateΣCE1) Unit：TJ

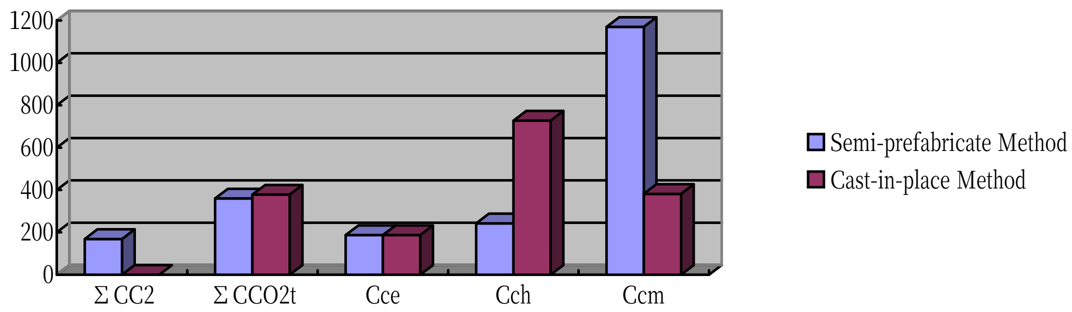

Figure. 11 Parameters of Semi-prefabricate method and cast-in-place method in CO_2 emission (eliminate Σ CC1) Unit：MT-CO_2

According to above-mentioned statistical results to discuss the method of construction production, the influence variable of environmental burden has more conspicuous difference in material that reprocessed more then twice(ΣCE2,ΣCC2), operator's commute trips(Ech, Cch) and machinery equipment (Ecm, Ccm).

12.2. Strategy of improvement

Base on three phases evaluation structure, material production phase, material transportation phase, and On site construction phase, the strategy of amendment for each phase as following:

1.Material production phase:
(1)Reducing weight of construction materials.
(2)Selecting low energy consuming and low carbon dioxide emission materials.
(3)Simplify architecture form and selecting reasonable structure.
2.Material transportation phase:
(1)Reducing material transportation distance.
(2)Selecting energy efficient transportation vehicle with heavy loading capacity.
(3)Selecting gasoline efficient vehicle.
3.On site construction phase:
(1)Energy conserving plan on site.
(2)Efficient manpower plan and reducing working shift.
(3)Selecting energy efficient machines and well planning of working machine.

12.3. The result of revision

The result of construction method adjustment presents as Tab. 11. For construction method on environment burden, after adjustment of working method, semi-prefabricating method reducing 9.44% energy consuming and 15.63% of carbon dioxide emission comparing to original result, and cast-in place working method reducing 10.39% energy consuming and 12.47% of carbon dioxide emission comparing to original result .

Tab. 11 Environmental burden of working method

Item	Unit	Working methods					
		A	B	C	D	E	F
CEtotal	TJ	214.08	199.6	156.1	156.06	142.71	115.29
CCO2	MT- CO2	20706	20252	12624	12632	12291	11677
Ratio of energy consumption (base on cast-in-place method)	-	1.07	1	0.78	0.78	0.71	0.58
Ratio of CO2 emission (base on cast-in-place method)	-	1.02	1	0.62	0.62	0.61	0.58
Energy consumption of method	TJ	43.44	28.96	39.34	39.3	25.95	32.7
CO2 emission of method	MT- CO2	2128.7	1674.9	1796	1804.2	1466	1771

A: Semi-prefabricating(Original method)
B: Cast-in-place (simulate)
C: Semi-prefabricating (Improvement)
D: Prefabricating in site (Improvement)
E: Cast-in–place(Improvement)
F: Steel(Improvement)

Note：
1.Qualified factor of green method is 0.82。
2.Improve result of semi-prefabricate method, energy consumption=(43.44-39.34)/43.44=9.44%, CO2=(2128.7-1796)/2128.7=15.63%。
3. Improve result of cast-in-place method, energy consumption=(28.96-25.95)/28.96=10.39%, CO2=(1674.9-1466)/1674.9=12.47%。

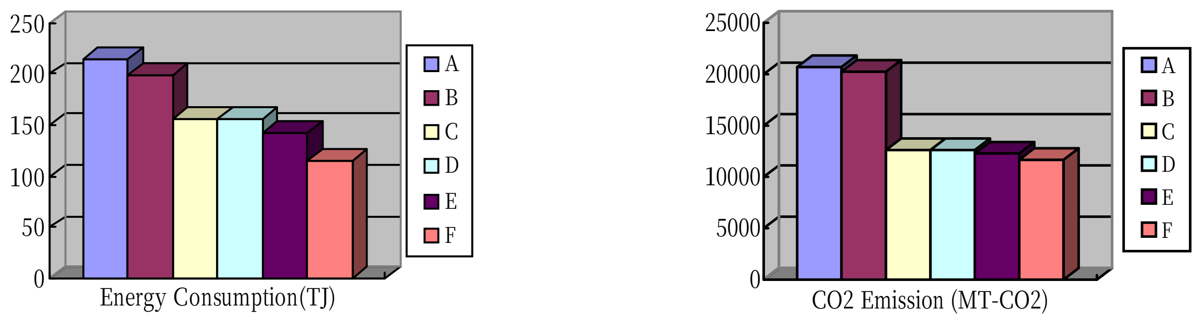

Figure. 12 Comparisons of environment burden between different working methods

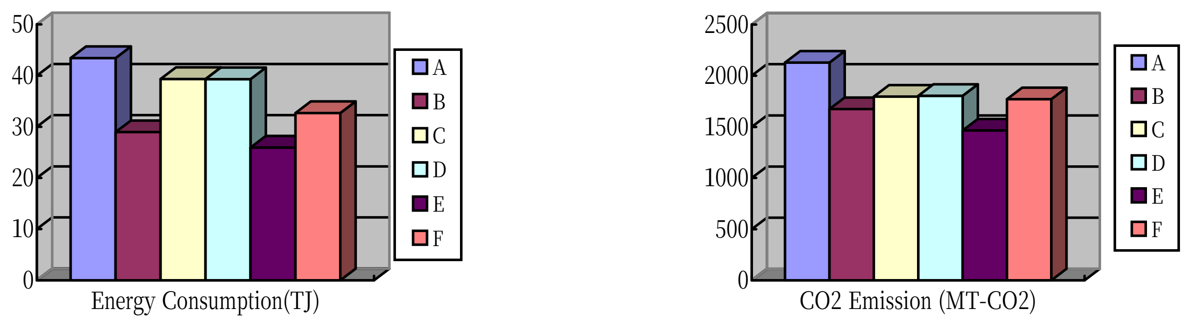

Figure. 13 Comparisons of environment burden between different working methods (first-grade material process is excluded)

12.4. Analysis of variables

The evaluation results of each working method are concluded as Tab. 12. The lowest energy consuming fabricating method (ΣCEp) is steel structure of 82.59TJ. The lowest energy consuming of material transportation(ΣCEt) is 1.22TJ. Cast-in-place method is the lowest energy consuming (ΣCEc) with 23.4TJ. Steel structure costs the lowest environment energy consumption with 115.3TJ. Cast-in-place method is the lowest environment energy consumption if exempt from first grade of material reprocess (ΣCE1) of 25.95TJ.

Tab. 12 Compare of CO_2 emission between working methods (Unit：MT-CO_2)

Item		Working Methods					
		A	B	C	D	E	F
ΣCCO_2p	ΣCC1	18577	18577	10828	10828	10825	9906
	ΣCC2	169	0	169	0	0	0
ΣCCO_2t		360	378	166	175	175	84
ΣCCO_2c	Cce	187.4	187.4	187	326	187	187
	Cch	242.9	727.9	243	274	728	293
	Ccm	1169.4	381.6	1030	1030	377	1207
CCO_2		20705.7	20251.9	12624	12632	12291	11677
CCO_2-ΣCC1		2128.7	1674.9	1796	1804	1466	1771

A: Semi-prefabricating(Original method)
B: Cast-in-place (simulate)
C: Semi-prefabricating (Improvement)
D: Prefabricating in site (Improvement)
E: Cast-in–place(Improvement)
F: Steel(Improvement)

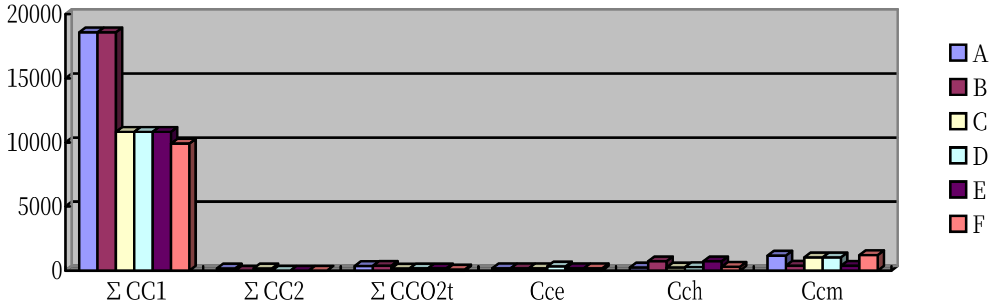

Figure. 14 Comparisons of CO2 emission between methods; Unit：MT-CO2

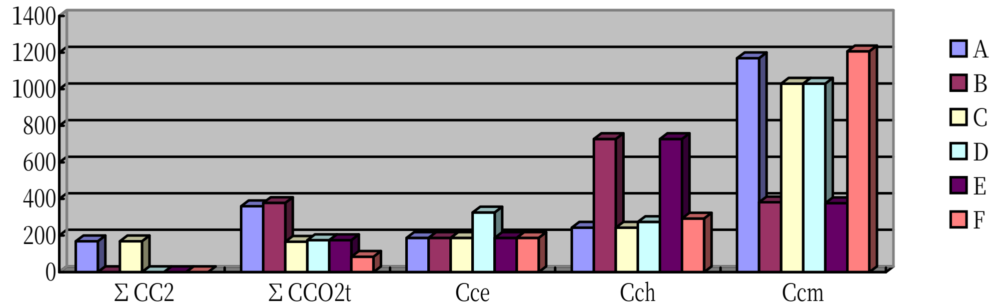

Figure. 15 Comparisons of CO_2 emission between methods; Unit：MT-CO_2 (first-grade material process is excluded)

13. Conclusion

With the investment above, we can conclude this task as following:

1. Establish an assessment method in base of environmental burden to provide the professionals as evaluation before construction.

This research find out the factors that effect energy consumption and CO_2 emission during construction for professionals to evaluate the structure method and working method before construction that may reduce environmental burden.

The method we established in this article provide a assessment to evaluate environmental burden before bid for construction and planning the process of construction. We make the environmental burden as an important factor to choice working method and to avoid environmental load during construction.

2. To conclude the case we can find that steel structure consumes lower energy and emitted less CO_2 to RC structure in first grade material process, but cast-in-place method is obviously consumes lower energy and emitted less CO2 to prefabricate working method after first grade procession of material to fabricate in place.

In case we studied, the ratio of first grade material process between original structure and steel structure in energy consumption is 2.07:1, and in CO2 emission is 1.88:1. This result had been proved in many thesis of domestic research that steel structure is more friendly to environment.

The evaluation of domestic construction method will mostly consider the duration and the cost of construction. This research focus on the environmental burden during construction, and we can find out that Cast-In-Place method is more friendly to earth. To conclude the statistics of the case, the ratio of semi-prefabrication method (original) and Cast-In-Place method in energy consumption is 1:0.6, and in CO2 emission is 1:0.69.

The evaluation objects of green building environment loading are restricted on first-grade material reprocess. During the construction process, the environment loading of procurement and assembling of materials are not in the evaluations, nor with evaluation standard for reference. The research provides factors of environment loading on construction process for erect an evaluation standard in the future. The suggestion of following research might be a development of a simple evaluation chart on quantitative basis for best working method selection on site

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