A Study on the Regional Customize of Modern Construction Methods in Urbanizing Developing Countries

Case Study on Concrete Block Housing in Lusaka, Jakarta, and Manila

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SUMMARY:
Concrete Block housing is widely used in the world. With the rapid recent urbanization in developing countries' urban areas, concrete block is increasingly used as a non-engineering construction. Concrete block is one of the modern construction methods however, the versatility of concrete block leads to easily be customized without modern regulation in developing countries. Under this situation, it is important to define the actors who affects to the performance of the concrete block construction.
First, this study revealed customizations of concrete block usage in housing constructions of the three developing countries' urban areas, Lusaka, Jakarta, and Manila by construction site visits. Then proceeded to conduct field researches to find out how those regionally customized building elements are manufactured. Then it was discussed about how different levels of building elements materials and construction methods affect the performance of local housings.
It was point out that the various differences we observed are relevant to each other to positively define regional construction methods. The reason of differential customization was assumed that both digested adopted one and substituted one which had been used in introduced area. In case the regionally customized concrete block construction is improved, it is efficient to consider not only partial improvement but well-balanced cross-sectional improvement, because it is positively defined and connected from raw material level to construction methods level.

Keywords: Concrete Block, Construction methods, Regional customize, Housing, Field survey

1. GENERAL INSTRUCTIONS

1.1. Background

Currently, phenomenal urbanization is seen in developing countries. While modern regulations, such as building permit, standard for building materials, registration of contractor or supplier, are poorly established, there are huge demands and actual supplies of urban housings are undergone in these countries. Comparing these constructional procedures in developing countries with its developed ones, we scarcely see tangible rules. However if we scrutinize the reason why the developing counties can manage without those modernized rules, we will have a clue of the other system which enable the construction; such as customary craft, individual effort, autonomic regional control systems.
Main raw material of Concrete Block (CB) is cement which is globally supplied under controlled manufacture. However, it combines with local aggregate which has low distribution value. Therefore, CB housing is considered high potential for regional customization. ARYA et al. (2011) gives ideal implementing method for non-engineering building construction. It is important preliminarily facing to implementation of the problem, to understand what kind of the actors join and what kind of construction background affect to establish the regional customization of CB housing construction. Then this paper focuses on regional background beyond the building construction, such as how is it manufactured or how the building system was chosen.

1.2. Purpose

This study assumes that CB housing construction methods are supported by customizing the local knowledge without having to rely on modern regulations. Throughout understanding actual construction methods of the CB housing in developing country where the modern legal system is inadequate, we will understand the building parts where regional customize covered to. By compare the situation with other region how to define the CB construction methods in each region will be clarify.
If the extent of the influence of regional customize, there are possibility to find the way of bottom up improvement in developing country where execution of legal system may difficult.

1.3. Methods

First, it is summarized that common subject and particular subject of the code item in major standards, ASTM, BS, and JIS and understand the modern formal system of standard. Next, we understood the existing CB housing situation in urbanizing developing country by filed surveys.
Target part to compare is block unit and construction methods on wall and foundation. In detail, it is point out the dimension, configuration, and way of forming for block unit and foundation system, wall structure system, and reinforcement for the construction methods. Specifics of the part in each region are recorded by construction site and manufacture site visit.
Under the above, it is summarized that the parts of the customized by region and how the customized parts work on from the raw material level to building level, and discuss about how it defines the performance of the CB housing. Field survey was conducted at urban agglomerated area of developing countries, Lusaka, ZAMBIA, Jakarta, INDONESIA, and Manila, PHILIPINNES. In addition to that, Japanese situation is referenced as a sample.

2. STANDARDS OF CONCRETE BLOCKS

CB had been developed in USA and UK. It is said that the ASTM and BS are major standard. In addition to these two standards, Japanese Industrial Standards (JIS) is checked (Table 1.) for the following reason. Japanese CB was introduced by USA and referenced USA standard, then it have been regionally customized as digested legal system. It may show one aspect of the customization.
Not only value but also items are not accorded between three. It may recognized that the only item of width have a commonality of 100, 150, 190. JIS specifies more item than others and lists many values in one item.

Table 1. Item and value of major standard

item		Code unit	ASTM (C90-11a) Loadbearing Concrete Masonry Units	BS (BS EN 771-3) Aggregate concrete masonry units	JIS (JIS A 5406) Concrete blocks for buildings
Dimention (nominal)	Hight	mm		215 (190)	100, 150, 200, 250, 300
	Length	mm		440 (390)	300, 400,050, 500, 600, 900
	Depth	mm	76, 102, 152, 203, 254	75, 90, 100, 140, 190, 215	100, 110, 120, 130, 140, 150, 190
Configuration	Void		thickness of the Web and the Face shell is specify	percentage of the void is specify	langth of the void is specify for rebar space
Physical	Compressive strength	N/mm2	13.1	3.6, 7.3 (2.9～22.5)	8, 12, 16 (20, 25, 30, 35, 40)
	Density	kg/m3	1680, 1680～2000, 2000 more by weight	650～2400	1700, 1900, — by strength
	Water absorption		288, 240, 208 (kg/m3) by weight	not required for UK	10 (%) (8,6,5) by strength
	Water permeability	mL/m2・h		Water vapor permeability not required for UK	—, 300 under by strength
	Cement content	kg/m3			200kg/m3 more
Note;	Classify		classify weight type ①Light weight②Medium weight③ Normal weight		Classify compressive strength ①08②12③16④20⑤25⑥30⑦35⑧40 ⑨45
	Type		Solid, Hollow	Solid, Cellular, Hollow	Hollow(nomal and specific for horizontal rebar)
	System of unit		"Yard-pond system" transformed	SI	SI

( ) : value is minor, —: No value, blank: Not mentioned

3. CASE STUDY

3.1. Overview of the case study regions

This study focuses on CB housing in urbanizing developing country, Lusaka, Jakarta, and Manila. The field survey on construction site is at mass housing area because of the common building system assume to be chosen. To understand overview of the case region, general data, GNI per capita, urban population, urban population growth, climate condition, and sample area were shown in Table2, Figure 1 and 2. Three countries are considered developing country by World Bank. Jakarta and Manila are similar situation in economy, population size, and geographical conditions. Lusaka is half of economy size, population is rapidly growth but absolute population size is two out of ten to Jakarta and Manila. Case study regions have population and economy growth and consider it as urbanizing developing region.

Table 2. General of the cases

Urban area/Country		Lusaka ZAMBIA	Jakarta INDONESIA	Manila PHILIPPINES
GNI per capita 2010	(current US&)	1,070	2,500	2,060
Population of urban agglomerations 2010	(thousand)	1,719	9,630	11,654
Population growth 2005-2010	(%)	26.8	7.1	8.3
Climate Condition	category	Humid subtropical climate	Tropical monsoon climate	Tropical monsoon climate
	hazard	Rain, Wind	Earthquake, Rain, Wind, Ants	Earthquake, Rain, Wind, Ants
Sample housing area	site at	Northgate garden	Jabotabeck	Pampanga
	developped by	National Housing Authority	Private developper	Private developper

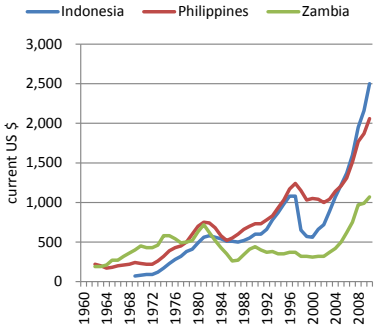


Figure 1. GNI per capita

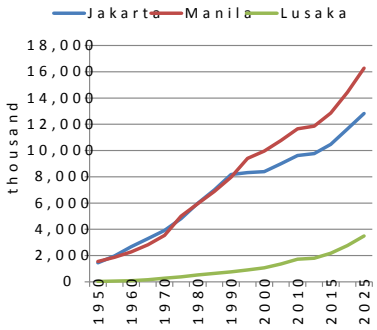


Figure 2. Urban agglomerate

3.2. Specific parts and construction methods by region

To understand the specific of the customization, the parts, block unit, and the construction methods are compared. Based on field survey, the specific parts and construction methods by region are summarized in Table3 and described as follows.

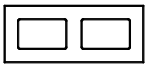
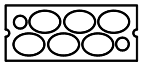
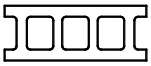
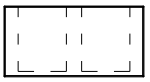
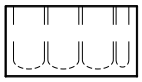
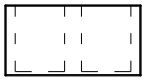
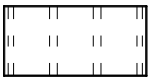
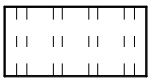
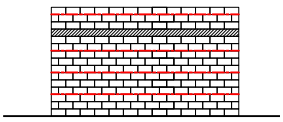
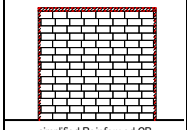
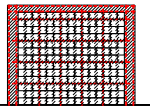
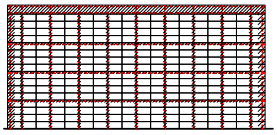
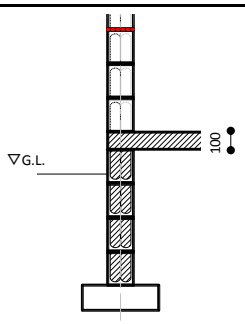
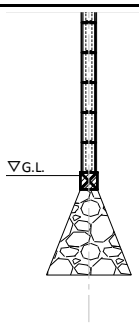
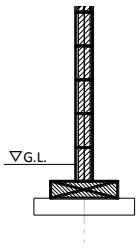
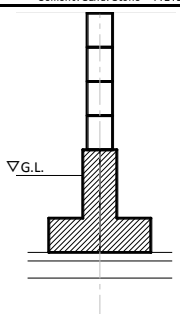
3.2.1 Lusaka (A)

The target mass housing area is supplied by the National Housing Authority.

Scale of the house is single floor, two or three bed room and the housing type is semidetached or detached (Table3, A-④). Foundation system is CB continuous footing. CB is laid facing up and the hole filled with concrete stacking four courses. Above the continuous footing, there is 100 mm thickness RC slab (Table3,A-③). Above the slab CB is laid facing down the hole with cement mortar for joint connection. The brickforce wire placed in each three course and ring beam is placed for stabilize the masonry wall system, three course under the top. Wall surface is finished by cement mortar(Table3, A-②). The block size is six-inch, the holes do not fully penetrate. Length is

approximately 390 mm and height is approximately 190 mm. In configuration, it classified into two. One is two holes in box shape, and the other is round multi-hole one. Aggregate mainly use quarry dust of limestone which can be obtained in the city's topsoil. It is a little who uses gravel and sand. It is used semi-automatic machine, manual machine for forming. Forming system is pull down and formed block is lay down on the ground(Table3, A-①). Multi-hole one is manufactured by the machine which introduced from Middle East. It means that this configuration is not customized in region but keeping the specification of introduced region.

Table 3. Customized parts and construction methods

		A Lusaka (ZAMBIA) residential estate/National Housing Authority		B Jakarta (INDONESIA) residential estate/developper	C Manila (PHILIPPINES) residential estate/developper	D JAPAN Japanese Standard
①Block Unit	Section					
	Face					
	L×H×W	390×185×150	380×190×150	380×175×80	390×190×90	390×190×150
	Compressive	2～5 N/mm2*	7～10N/mm2*	-	1.45N/mm2**	4N/mm2＜
	Aggregate	Lime quarry dust, Fine aggregate+coarse aggregate		—	Lahar（volcanic sand）	Fine aggregate+coarse aggregate
	Forming					
		Manual	Semiautomatic	Manual	Manual	
		Pull under (Egg-laying)	Pull under	Pull under	Pull up	
	Curing	Watering	Watering	None	None	
②Wall	appearance					
	Structure system Brickforce Rebar Concrete scale 500 0 1,000					
		Masonry		simplified Reinforced CB	Confined Masonty + Reinforced CB	Reinforced CB
	Stacking Method	stretcher bond		stretcher bond	stretcher bond	stretcher bond
	Stacking Pattern	break joint		break joint	break joint	straight joint
	Reinforcement	Brickforce@3course Ringbeam(4-D12)		Vertical 8φ @ wall crossing	D8@600 grid All hole filled by Concrete Vertical stiffener: 300×100, 4-D18 lintel: 200×100, 4-D8	Corner: 1-D13, D10@800 less(grid) filling concrete at rebar position Gerder: 150×250, 4-D16 around
	Finishing	Motar		Motar	Motar	water proof paint
	Hight	15 course		14 course	13course	3.5m>
	Distance	5m		3m	3m	45m2 or 60m2>Area
	Joint	Cement motar		Cement motar	Cement motar	Cement motar(sand: cement＝1：2.5～3.0)
	Filling Concrete	-		-	Cement: Sand: Stone＝1：3：4	Cement: Sand: Stone＝1：2：2
③Foundation	Foundation system					
		CB continuous footing		simplified RC continuous footing＋stone	RC continuous footing+footing	RC continuous footing
④House	Floor	1 floor		1floor （＋1floor）	1floor （＋1floor）	1～3 floor
	Type	detached, semidetached		row house	row house	detached

＊ by test
＊＊ by local understanding(100Psi)

Source; field survey and Japanese standards

3.2.2 Jakarta (B)

The target mass housing area is low cost housing estate supplied by private developer.

When it constructs it is single floor. However, some existing house shows some may extension one more floor. Type of house is row house (Table3 B-④). Foundation is 100 mm dimension RC continuous footing on stone(Table3, B-③). Wall crossing point, vertical rebar 8φ is placed and filled with mortar for reinforcement. The blocks are stacked by cement mortar and top of that 100 mm dimension RC element is placed. Except the wall crossing there are no vertical reinforcement, so it is understand it simplified reinforced CB system. Wall surface is finished by cement mortar(Table3 B-②). Block is four-inch but only has 80mm width. Configuration is two holes and not fully penetrate. Pull down, manual machine have been used (Table3, B-①).

3.2.3 Manila (C)

As well as Jakarta, the target mass housing area is low cost housing estate supplied by private developer.

When it constructs it is single floor. However, some existing house shows some may extension one more floor. Type of house is row house (Table3, C-④). Foundation is RC thin continuous footing with footing on the corners(Table3, C-③). Wall is framed by RC element and is placed D8 rebar in each 600mm both directions. Not only rebar placing but every hole filled with concrete. Wall surface is finished by cement mortar (Table3, C-②). Block is four-inch and has three holes fully penetrate. Pull up manual machine have been used. They do not use coarse aggregate and use lahar, volcanic sand as fine aggregate. Lahar is abundant there but some block is fragile as broken only holding up(Table3, C-①).

3.2.4 Japan (D)

As for referenced example, the Japanese legal system is taken for the case. It is referenced by JIS and offered construction system by the Architectural Institute of Japan (Table3, D-①②③④).

3.3. Regional Customization: by part

It is pick up the matters of regional or common characteristics by part for preparing to discussion.

① Block unit

・Face size is almost accorded value in each region.
・Width of the CB classified into 100 or 150 mm in nominal size.
・Number of the hole and fully penetrate or not relate to the existence of vertical element, rebar or filled concrete.
・Multiple hole CB in Lusaka is left of the specific of introduced region.
・Aggregate is used the material easy to get the region.
・Manufacture machine classify by which direction CB forming, pulled up or down.
・Manufacture machine classify by that is moving or fixed.
・Moving machine needs flat slab for laying block directly for manufacture and curing.
・Fixed machine needs the block to move once it formed and stack for dry. It reduces work space and work under the roof.

② Wall

・Structure system is various, masonry, confined masonry, reinforced CB including simplified one.
・Except Japan, wall finished by cement mortar it may works reinforcement as well.
・Reinforcement is by brick force, rebar, filling concrete to the hole, RC stiffener.
・Pitch of rebar position and ratio of filling concrete is differ.
・Stacking methods is common in single leaf, stretcher bond.
・Stacking pattern is break except Japan. Japan uses this system because vertical rebar connection is

not allowed.

③ Foundation

・Continuous footing is common. Details are differed as using filled CB, common RC, and RC with stone.

④ House

・Original number of the floor is single. Japanese standards take into count for maximum there floor to control the wall thickness, compressive strength of the block, and size of the garter.

4. DISCUSSION

Here we discussed about how the differences of the parts that understood in chapter 3 define the construction methods in each region.

4.1. Lusaka (A)

There is not earthquake in Lusaka, and there is no vertical reinforcement such as column, rebar, and filled concrete. However, width of the block is six inch, thicker than earthquake-prone country Jakarta and Manila, and stabilized by ring beam. It is expected the effect from the conventional adobe masonry or brick masonry by British colonial period. Because they do not have vertical reinforced element, closed hole is better for working on joint mortar. It is expected the reason to use moving machine is following. There is vacant space left the block on the ground and watering such as needed the region by climate is easier. Multi-hole type is expected to leave the specific from introduced region.

4.2. Jakarta (B)

Nominal size of the block four-inch is only 80 mm width. It is expected that the width is effect from the conventional brick which has around 75 mm in width. Vertical rebar is only placed at the wall crossing, the block has two closed hole. Except the corner, blocks joint only by cement mortar. However the width of the block in less than four-inch, the thickness of the web is thicker than Manila where four-inch also used.

4.3. Manila (C)

Earthquake-prone area however, they use four-inch block thinner than the Lusaka where is no earthquake. In addition, thickness of the web is thin and block which use lahar for the aggregate is fragile one. On the other hand, as a wall, it has a RC stiffener frame and infill-wall in reinforced by rebar in each 600 mm both direction, and every vertical hole is filled with concrete. It is expected that the wall construction methods is customized to compensate the fragile block unit which manufactured the region. In addition, thinner web has larger hole, so if it is filled with concrete thinner one has chosen for strength as the wall. In using the broken joint pattern, for not interfering, web and the vertical element, rebar or filled concrete, the hole is fully penetrate and the number of the hole is three.

4.4. Relevance of the parts

Regional differences have reasons relevant to the region and each of the part in different building level such as available aggregate, molding methods, reinforcement, are related to each other. The customized construction methods are conformed multi layered by different parts and define the performance of the regional construction methods.

5. CONCLUSION

5.1. Understanding

It is understood followings by field survey on CB housing at three cities in developing countries where urbanization rapidly growth.

・Face size is almost accorded. 390 mm in length and 190 mm in height is minor dimension of BS.
・CB configuration except face size, there are various differences in raw material, manufacture methods, width for the load bearing wall.
・Construction methods in wall and foundation is various.
・Above differences are relevant to each other in the region. We recognized that the parts relevant to each other like one part compensate to other part and define the regional construction methods.
・Since the customized construction methods are based on complex of the parts, it is not sufficient to change one part but needed to consider about cross-sectional improvement.
・The factor of the regional difference is assumed two reasons. One is digested based on the conventional understanding. And the other one is substitute the specification which had been used in introduced area.

5.2. Future prospects

For more systematical understandings, the following should be considered.

It is necessary to compare how the existing customized construction methods satisfy to criteria.
In case the considered target is extend, target area (e.g. cold climate area), target scale (e.g. multi story house), and target part (e.g. reinforcement for window opening), other customize methods may understood.

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