Dry-masonry Brick House System as an "Adaptable Building" Model for Asian Markets

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ABSTRACT

Since 1950, the world population has more than doubled where most of this growth has taken place in developing world. In the next two decades around 98% of world population growth will occur in developing countries and it is estimated that by 2007 half of this mushrooming population will live in urban areas.

In Asia, though it covers only 30.2% of total world landmass, the total share of world population is the highest at 60.7% (*census 2002*). These demographic dynamics (population growth, urbanisation etc) translate into increased demand for buildings and infrastructure in particular demand for shelter especially in the less developed countries. The developing world's share of world construction was only 10% in 1965, increased by almost threefold to 29% in 1988 and still growing.

Studies conducted by utilizing data from 'Database of World Housing Stock & Construction' based on the Housing Settlements Database Version 4 (HSDB4) prepared by United Nations Human Settlements Programme (UN-HABITAT) shows that brick (masonry) remains as the main material in production and building stocks among Asian countries.

It is necessary to note that there are many factors which prevent "adaptable buildings" to be realized and one of the main reasons is that due to the nature of the currently used construction method; various materials used in the construction industry are bonded and mixed to each other. Therefore there is an urgent need to change the currently used masonry construction method to keep abreast with latest sustainable building technology.

Adapting a system that specifically design for the need to assembly and disassembly and also highly promotes "green cycle" that encompasses "reduce-reuse-recycle" is a remedy that may well solve the problems that have been plaguing the construction industry for years.

Since October, 1997, a group of researchers led by Prof. Yasunori Matsufuji of Kyushu University has embarked a R&TD in what is called Dry-masonry[1] Brick House System (DBHS) that utilized a construction method called "Steel Reinforced Brick

Construction based on Distributed Unbonded Prestress Theory" (SRB-DUP) as a tactic to carry out a sustainable strategy to be realized as "adaptable building" model.

This paper discusses some case studies on how countries in Asian region namely Malaysia, Indonesia, China, India, Iran and Afghanistan can adapt DBHS as an "adaptable building" model that may well conform to the overall Sustainable Development Plan of these particular countries.

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[1] Masonry refers to building with bonded construction units of various natural or manufactured products, such as brick, stone or concrete block, usually with the use of mortar as bonding agent (Ching and Adam 2001). The modular aspect (i.e. uniform sizes and propotional relationships) of unit masonry distinguishes it from other building materials in which these units are laid manually (by hand) one by one on site (Milton 1994).

In DBHS, mortar is not used as bonding agent and this enable a kind of dry-work condition with unbonded construction to be applied on the construction site. Thus, the name "Dry-masonry" is derived to closely define this depiction.

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Like any other undertakings, this thesis will not be possible without a great deal of assistance. The author would like to extend his gratitude to individuals and institutions that had in many ways helped and assisted the accomplishment of this thesis. Without them, this thesis would not be as it is intended for.

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CHAPTER 1:

GENERAL INTRODUCTION

1.1 Background

"Adaptable building" in principle is a building that can last while its parts gradually change where it will place a lighter load on natural and human resources and provide value to future generations (Kendall and Ando 2004).

Adaptable building can also mean that a particular building system is capable of adapting (of becoming or being made suitable) to a particular situation or use; such as regional and climatic variances that may include social, cultural and technical differences. Adaptable building model refers to a building system that is worthy of emulation, in the context of this thesis, besides Japan, DBHS is also a building system that is worth to be emulated in other parts of Asian region due the rationales presented here.

Therefore this thesis is investigating in what way and manner, Dry-masonry Brick House System (DBHS here after) can be adapted for Asian markets. This is important because current DBHS's research and technology development (R&TD) is taking place only to suit Japan's market, thus a better understanding of market conditions outside Japan especially those issues related to Sustainable Building Construction (SBC) and environmental problems are essential.

Among others, this thesis will put emphasis on the link that may occurs between SBC and construction and demolition waste (C&DW) with Dry-masonry Brick House System (DBHS) as an "adaptable building" model for C&DW minimization strategy among developing countries especially in Malaysia and Indonesia of the South East Asian region. For other countries in the Asian region we will focus on other environmental and socio-economic related issues such as brick as the main material building in China and India, coping with seismic condition in Iran and last but not least dealing with shortage of housing and limited resources in Afghanistan.

In order to come out with a comprehensive research study, we set aim of the thesis and this will constitute the structure of this thesis as indicated below.

1.2 Aim of the thesis

The main aim of the thesis is to find a link between Dry-masonry Brick House System (DBHS) with various environmental and socio-economic issues in Asian countries particularly Malaysia and Indonesia, and also countries like China and India (biggest brick producer in the world), Iran and Afghanistan. Where applicable this thesis tries to investigate in depth but due to limited data and statistics available for reference, part of the relevant issues are only covered in breadth.

In order to translate the above aim into practical steps, the following objectives are set and summarised as follows:

(1) To review DBHS based on the practices and experiences accumulate in Japan and related current environmental issues.

(2) To investigate brick distribution in the world and its relation with Asian markets and later to identify countries that utilised brick as one of the main building materials.

(3) To identify attributes of DBHS as an "Adaptable Building" model that is worth for emulation in other countries outside Japan.

(4) To assess the current DBHS used in Japan's market and its adaptability to be applied in local market conditions in Malaysia and Indonesia, which among others include aspects of design for local structural and climatic condition. For further research we proposed design modifications that are significant for both Malaysian and Indonesian markets.

(5) For other Asian countries, we have identified China, India, Iran and Afghanistan as potential markets where DBHS can be adapted to improve quality of environment and their local socio-economic condition.

(6) Finally, we present the key findings and further works for future research.

1.3 Structure of the thesis

The proposed structure of the thesis is made up of 4 parts and 7 chapters, and it follows the list of objectives set under the aim of the thesis. These are summarised as below.

PART I:

CHAPTER 1: GENERAL INTRODUCTION

General introduction to the thesis which focuses on the background, aim and structure of the thesis.

PART II:

CHAPTER 2: BRICK DISTRIBUTION IN ASIAN MARKETS

In this chapter we investigate brick distribution in the world and its relation with Asian markets and later identify countries that utilised brick as one of the main building materials as potential countries worthy for further investigations

CHAPTER 3: DBHS AS AN "ADAPTABLE BUILDING" MODEL

In this chapter we identify relevant attributes of DBHS as an "adaptable building" model that is worth for emulation in other countries outside Japan. We also distinguished DBHS's sustainable strategy that emphasises C&DW minimization as the key factor in promoting DBHS as an "adaptable building" model in Asian markets.

PART III:

CHAPTER 4: CASE STUDY IN MALAYSIA

Among others, in this chapter we made assessment at Malaysian laws and standards especially those related to structural quality. We also assessed current DBHS used in Japan's market and its adaptability to be applied in local market conditions in Malaysia, which include aspects of design for local structural and climatic condition. For further research we proposed DBHS design modifications that are significant for Malaysian markets.

CHAPTER 5: CASE STUDY IN INDONESIA

Just like in CHAPTER 4, we used the same methodology for Indonesian market. Among others, in this chapter we made assessment at Indonesian laws and standards especially those related to structural quality. We also assessed current DBHS used in Japan's market and its adaptability to be applied in local market conditions in Indonesia, which include aspects of design for local structural and climatic condition. Special attention is given to Indonesia's severe earthquake distribution. For further research we proposed DBHS design modifications that are significant for Indonesian markets.

CHAPTER 6: POTENTIAL MARKETS IN OTHER ASIAN COUNTRIES

Based on the analysis in CHAPTER 2, for other Asian countries, we have identified China, India, Iran and Afghanistan as potential markets where DBHS can be adapted to improve quality of environment and their local socio-economic condition. Current related issues are discussed and rationales are given for DBHS to be adapted in these markets condition.

PART IV:

CHAPTER 7: SUMMARY AND CONCLUSIONS

In this chapter, we summarised all the relevant conclusions. As addition we also present the key findings and potential further works for future research.

CHAPTER 2:

ASIAN MARKETS

AND BRICK DISTRIBUTION

2.1 Introduction of methodology

In the early stage of the thesis, we tried to justify the link between brick as a building material with various factors that directly influence housing pattern and its mechanism. Therefore, this study is carried out as a foundation understanding in order for DBHS to be introduced to the world markets in the near future. This scope is later narrowed down to the Asian markets for the benefit of this thesis.

The study is carried out in a few steps as indicated below:

(1) We gathered the 'housing stock' and 'housing construction' data of countries throughout the world and also the capacity of brick productions locally produced in countries where brick industry is available.

(2) Collected data in (1) is analyzed to understand the relationships between countries where brick industries are available and 'housing stock & construction' data of these countries in terms of projected percentage of brick house construction.

(3) Later collected data in (1) is also analyzed and then we projected a World Wide Map that is based on ratio (R) of brick production per year applied for each unit of housing constructed per year to indicate the projected capacity of brick houses of each country.

(4) While understanding this World Wide Map, we try to find the relations of the capacity of building brick production per capita (by dividing with its total population) of each country between characteristics of the country namely with i) the relations of the climatic condition (year average temperature), ii) economic condition (gross domestic product by purchasing power parity per capita) and iii) seismic condition (peak ground acceleration). In each case, related data is taken and later graphs were plotted to find the correlations between these 3 factors with brick production per capita.

(5) By using this World Wide Map in (3), we managed to illustrate the relations of the capacity of building brick production of each country between

characteristics of the country namely;

i) cold area versus hot and humid area,

ii) developed countries versus developing countries and

iii) seismic prone area versus non-seismic prone area

to better understand the trend that may occur according to specific characteristics of each region.

2.2 Database of World Housing Stock and Construction

Data collected in this 'Database of World Housing Stock & Construction' are mostly based on the Housing Settlements Database Version 4 (HSDB4) prepared by United Nations Human Settlements Programme (UN-HABITAT). However for countries where related data were not available in HSDB4, other reliable sources are referred to and noted. It is also important to note that out of 235 countries listed by the UN, we managed to collect data for only 62 countries where apparently covered about 76% of the world population and 65% of the world area as shown in Table 2.1.

Diagram 2.1 below simplified the 'World Population Map' for easy understanding where only countries with a population over 10 million people are shown. The yellow-coloured box indicates countries that are covered in this 'Data Research'. The big-sized box of China and India means a country with more than 1 billion people, followed by medium-sized box of USA and Indonesia that is a country with more than 200 million people. The small-medium-sized box of Russia, Mexico, Brazil, Pakistan, Japan, Bangladesh and Nigeria means a country between 100 and 200 million people. The small-sized box indicates a country between 40 and 100 million people, followed by the smallest-sized box means a country between 10 and 40 million people.

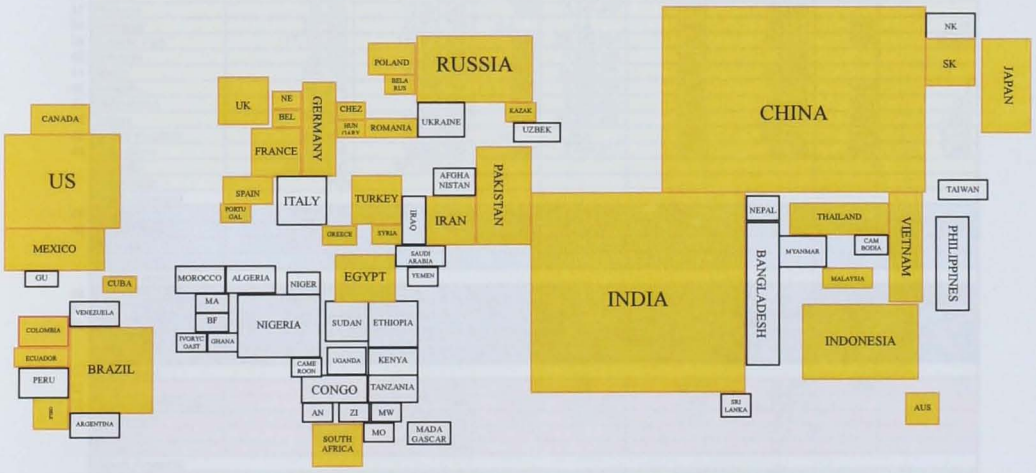

Diagram 2.1: World Population Map of areas covered in the 'Data Research'

Table 2.1: World Database for Housing Stock, Construction & Brick Production

	COUNTRY	AREA (sq.km.)	POPULATION (2002.07.01 est.)	HOUSING STOCK YEAR	HOUSING STOCK TOTAL	HOUSING CONSTRUCTED YEAR	HOUSING CONSTRUCTED TOTAL	BRICK PRODUCTION YEAR	BRICK PRODUCTION TOTAL
									(million units)
	(Asia)								
1	Azerbaijan	86,600	7,798,497	n.a	n.a.	1993	17,100	1993	64
2	China*	9,596,960	1,284,303,705	n.a	n.a.	1999	8,900,000	1993	657,446
3	Hong Kong, SAR	1,092	7,303,334	1996	1,862,231	1991	77,500		
4	India*	3,287,590	1,045,845,226	n.a.	n.a.	1990	3,600,000	1995	140,000
5	Indonesia*	1,919,440	231,328,092	1990	38,921,160	1992	1,158,908	1992	127
6	Iran	1,648,000	66,622,704	1996	12,398,235	1984	150,000	1992	10,167
7	Israel	20,770	6,029,529	1995	1,773,624	1991	42,600		
8	Japan	377,835	126,974,628	1993	40,970,700	1985	1,409,100		
9	Kazakhstan*	2,717,300	16,741,519	1995	4,417,800	1993	48,000		
10	Korea, South	98,480	48,324,000	1995	12,974,194	1990	750,400	1993	714
11	Macau SAR	25	461,833	1996	121,692	1991	9,700		
12	Malaysia	329,750	22,662,365	1991	3,526,675	1996	171,900	1993	592
13	Pakistan	803,940	147,663,429	1998	19,344,232	1988	237,600		
14	Singapore	693	4,452,732	1995	733,722	1990	14,200	1986	90
15	Syria	185,180	17,155,814	1994	2,196,084	1990	32,500		
16	Thailand*	514,000	62,354,402	1996	15,002,591			1996	250
17	Vietnam	329,560	81,098,416	n.a.	n.a.	1993	225,000	1992	4,274
	Sub-total	21,917,215	3,177,120,225						
	Percentage	69%	84%						
	(Europe)								
18	Austria	83,858	8,169,929	1991	3,013,006	1993	43,400	1993	226
19	Belarus	207,600	10,335,382	n.a.	n.a.	1989	94,400	1993	916
20	Belgium	30,510	10,274,595	1991	3,953,125	1993	47,500	1993	105
21	Bulgaria	110,910	7,621,337	n.a	n.a.	1993	11,000	1993	637
22	Croatia	56,542	4,390,751	1991	1,544,892	1993	8,300	1992	536
23	Cyprus	9,250	767,314	1992	185,459	1992	7,800	1993	62
24	Czech Republic	78,866	10,256,760	1991	4,051,583	1993	31,500	1993	1,112
25	Denmark	43,094	5,368,854	n.a.	n.a.	1993	13,000	1992	302
26	Estonia	45,226	1,415,681	1998	657,000	1993	2,400	1993	52
27	Finland	337,030	5,183,545	1998	2,247,000	1993	30,000	1993	61
28	France	547,030	59,765,983	1999	23,815,164	1992	299,000		
29	Germany*	357,021	83,251,851	1998	34,865,300	1993	302,900		
30	Greece	131,940	10,645,343	n.a.	n.a.	1985	88,500	1992	1,415
31	Hungary	93,030	10,075,034	1996	3,869,480	1993	20,900	1993	1,163
32	Ireland	70,280	3,883,159	1996	1,127,318	1993	21,500		
33	Lithuania	65,200	3,601,138	1999	1,400,000	1993	8,200		
34	Netherlands	41,526	16,067,754	1998	6,606,000	1993	87,700	1998	1,435
35	Norway	324,220	4,525,116	1990	1,751,363	1993	15,900	1987	33
36	Poland	312,685	38,625,478	1995	12,500,802	1993	94,400	1993	871
37	Portugal	92,391	10,084,245	1991	3,147,447	1992	55,000		
38	Romania	237,500	22,317,730	n.a	n.a.	1993	30,100	1993	618
39	Russian Fed.*	17,075,200	144,978,573	1993	25,460,000	1993	418,000	1993	18,959
40	Slovakia	48,845	5,422,366	1991	1,832,484	1991	1,800		
41	Spain	504,782	40,077,100	1991	11,736,376	1993	206,400		
42	Sweden	449,964	8,876,744	1990	3,830,035	1993	35,000	1991	3
43	Switzerland	41,290	7,301,994	1990	2,841,850	1992	40,000	1991	134
44	Turkey	780,580	67,308,928	1994	13,382,841	1991	228,000	1993	1,253
45	United Kingdom	244,820	59,778,002	n.a.	n.a.	1992	227,000	1993	5,142
46	Yugoslavia	102,350	10,656,929	1991	2,648,617	1992	25,200	1992	1,486
	Sub-total	22,523,540	671,027,615						
	Percentage	95%	84%						
	(North America)								
47	Canada*	9,976,140	31,902,268	1998	11,690,000	1993	162,000		
48	United States	9,629,091	280,562,489	1997	99,487,000	1993	1,192,700	1993	6,804
	Sub-total	19,605,231	312,464,757						
	Percentage	98%	98%						
	(Central America)								
49	Guatemala	108,890	13,314,079	1994	1,591,823	1981	87,600		
50	Mexico	1,972,550	103,400,165	1995	19,848,319	1995	580,000	1993	42
51	Panama	78,200	2,882,329	1990	526,456	1985	3,900		
	Sub-total	2,159,640	119,596,573						
	Percentage	87%	85%						
	(Caribbean)								
52	Cuba	110,860	11,224,321	n.a.	n.a.	1985	74,400	1989	142
53	Dominican Republic	48,730	8,721,594	1993	1,662,256	1985	16,200		
54	Puerto Rico	9,104	3,957,988	1990	1,054,924	1985	8,000		
	Sub-total	168,694	23,903,903						
	Percentage	72%	65%						
	(South America)								
55	Brazil	8,511,965	176,029,560	1998	41,929,992	1985	115,900	1993	624
56	Chile	756,950	15,498,930	n.a.	n.a.	1985	58,800	1993	71
57	Colombia	1,138,910	41,008,227	1993	7,159,842	1985	86,800		
58	Ecuador	283,560	13,447,494	n.a.	n.a.	1985	34,300	1992	3
	Sub-total	10,691,385	245,984,211						
	Percentage	60%	70%						
	(Africa)								
59	Egypt	1,001,450	70,712,345	1996	18,691,143	1985	148,300	1992	105
60	South Africa	1,219,912	43,647,658	1996	9,059,593	1985	35,600	1993	1,599
	Sub-total	2,221,362	114,360,003						
	Percentage	10%	17%						
	(Oceania)								
61	Australia	7,686,850	19,546,792	1996	7,195,170	1990	137,700	1993	1,722
62	New Zealand	268,860	3,908,037	n.a.	n.a.	1991	17,500	1993	14
	Sub-total	7,955,710	23,454,829						
	Percentage	93%	73%						
	TOTAL	**87,247,777**	**4,687,912,115**						
	WORLD TOTAL	**134,135,067**	**6,215,000,000**						
	PERCENTAGE	**65%**	**76%**						