

**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-masonry¹ 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 proportional 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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CHAPTER 1:
GENERAL INTRODUCTION



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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**



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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.



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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.

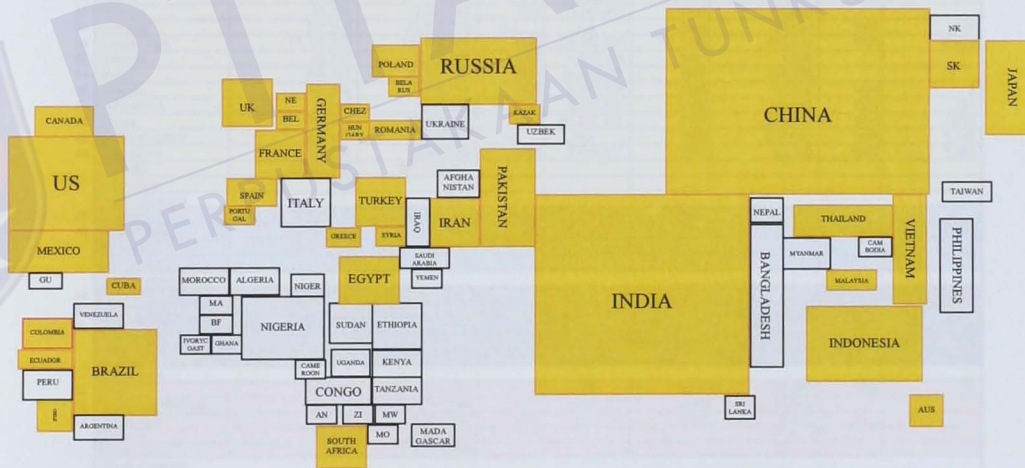


Diagram 2.1: World Population Map of areas covered in the 'Data Research'

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

COUNTRY	AREA (sq.km.)	POPULATION (2002.07.01 est.)	HOUSING STOCK		HOUSING CONSTRUCTED		BRICK PRODUCTION	
			YEAR	TOTAL	YEAR	TOTAL	YEAR	TOTAL
(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	41,528	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	144,878,573	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	1,219,812	43,647,858	1996	9,059,593	1985	35,600	1993	1,599
Sub-total	2,221,262	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%						

Based on the data computed in Table 2.1, we can project the quantity of brick house to be constructed in a certain country. By applying a 'model house' of 10,000 units of brick per house we can calculate the possible number of construction of brick houses projected by referring to the amount of brick production produced in each country. Thus, this projection number of construction of brick house when divided by amount of housing construction per annum, we can get the percentage of this projection. The extracts of this data is shown in Diagram 2.2.

By applying this method of projection it is obvious that countries in Asian and European region in particular, are dominating the graph. Countries like China, India, Iran in the Asian region and Bulgarian, Croatia, Hungary and Yugoslavia in the East European region shows enormous percentages that are at least 400% and more. However it is also important to note that this projection is not accurate due to various factors such as i) economic downturn (slump) that may abandon new housing construction and ii) occurrence of war that may damage the current housing stocks

For further investigation, we streamlined the data from 62 countries (as in Table 2.1) to only 43 countries (as in Table 2.2) that possessed both data on Brick Production and Housing Constructed per indicated year. These both data are further used to form the basis of World Wide Map projection of Building Brick Production.

Diagram 2.2: Projection of buildable brick house (%) for each country



Table 2.2: World Database for Housing Constructed & Brick Production

	COUNTRY	AREA (sq.km.)	POPULATION (2002.07.01 est.)	HOUSING CONSTRUCTED		BRICK PRODUCTION	
				YEAR	TOTAL	YEAR	TOTAL (million units)
1	Azerbaijan	86,600	7,798,497	1993	17,100	1993	64
2	China	9,596,960	1,284,303,705	1999	8,900,000	1993	657,446
3	India	3,287,590	1,045,845,226	1990	3,600,000	1995	140,000
4	Indonesia	1,919,440	231,328,092	1992	1,158,908	1987	4,100
5	Iran	1,648,000	66,622,704	1984	150,000	1992	10,167
6	Korea, South	98,480	48,324,000	1990	750,400	1993	714
7	Malaysia	329,750	22,662,365	1996	171,900	1993	592
8	Pakistan	803,940	147,663,429	1988	237,600	1991	11,000
9	Singapore	693	4,452,732	1990	14,200	1986	90
10	Thailand	514,000	62,354,402			1996	250
11	Vietnam	329,560	81,098,416	1993	225,000	1992	4,274
12	Austria	83,858	8,169,929	1993	43,400	1993	226
13	Belarus	207,600	10,335,382	1989	94,400	1993	916
14	Belgium	30,510	10,274,595	1993	47,500	1993	105
15	Bulgaria	110,910	7,621,337	1993	11,000	1993	637
16	Croatia	56,542	4,390,751	1993	8,300	1992	536
17	Cyprus	9,250	767,314	1992	7,800	1993	62
18	Czech Republic	78,866	10,256,760	1993	31,500	1993	1,112
19	Denmark	43,094	5,368,854	1993	13,000	1992	302
20	Estonia	45,226	1,415,681	1993	2,400	1993	52
21	Finland	337,030	5,183,545	1993	30,000	1993	61
22	Greece	131,940	10,645,343	1985	88,500	1992	1,415
23	Hungary	93,030	10,075,034	1993	20,900	1993	1,163
24	Netherlands	41,526	16,067,754	1993	87,700	1998	1,435
25	Norway	324,220	4,525,116	1993	15,900	1987	33
26	Poland	312,685	38,625,478	1993	94,400	1993	871
27	Romania	237,500	22,317,730	1993	30,100	1993	618
28	Russian Fed.	17,075,200	144,978,573	1991	49,400	1993	18,959
29	Sweden	449,964	8,876,744	1993	35,000	1991	3
30	Switzerland	41,290	7,301,994	1992	40,000	1991	134
31	Turkey	780,580	67,308,928	1991	228,000	1993	1,253
32	United Kingdom	244,820	59,778,002	1992	227,000	1993	5,142
33	Yugoslavia	102,350	10,656,929	1992	25,200	1992	1,486
34	United States	9,629,091	280,562,489	1993	1,192,700	1993	6,804
35	Mexico	1,972,550	103,400,165	1995	580,000	1993	42
36	Cuba	110,860	11,224,321	1985	74,400	1989	142
37	Brazil	8,511,965	176,029,560	1985	115,900	1993	624
38	Chile	756,950	15,498,930	1985	58,800	1993	71
39	Ecuador	283,560	13,447,494	1985	34,300	1992	3
40	Egypt	1,001,450	70,712,345	1985	148,300	1992	105
41	South Africa	1,219,912	43,647,658	1985	35,600	1993	1,599
42	Australia	7,686,850	19,546,792	1990	137,700	1993	1,722
43	New Zealand	268,680	3,908,037	1996	10,449	1993	14
	TOTAL	87,825,247	4,719,050,851				
	WORLD TOTAL	134,135,067	6,215,000,000				
	PERCENTAGE	65%	76%				

Fig. 2.1: World Wide Map with distribution of Brick Production

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PTTA UTHM
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