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 the 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 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.
ACKNOWLEDGEMENTS

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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I am also deeply appreciative of the financial support I have received during my long sojourn as a graduate student in Kyushu University, in particular the Japanese Government (MEXT or Monbukagakusho) and also in the final year of the programme from my employer, Kolej Universiti Teknologi Tun Hussein Onn, Malaysia.

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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>
<thead>
<tr>
<th>Country</th>
<th>Area (sq.km)</th>
<th>Population (000)</th>
<th>Housing Stock (000)</th>
<th>Housing Construction (000)</th>
<th>Brick Production (000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>83,858</td>
<td>8,166,902</td>
<td>9,117,669</td>
<td>7,850,876</td>
<td>5,020,698</td>
</tr>
<tr>
<td>Belgium</td>
<td>30,528</td>
<td>10,774,589</td>
<td>11,267,703</td>
<td>10,020,396</td>
<td>6,620,896</td>
</tr>
<tr>
<td>France</td>
<td>66,020</td>
<td>6,956,459</td>
<td>7,553,327</td>
<td>6,303,928</td>
<td>3,952,817</td>
</tr>
<tr>
<td>Germany</td>
<td>80,851</td>
<td>8,246,368</td>
<td>8,755,187</td>
<td>7,509,936</td>
<td>4,860,712</td>
</tr>
<tr>
<td>Greece</td>
<td>132,190</td>
<td>10,539,136</td>
<td>11,359,051</td>
<td>10,113,044</td>
<td>6,587,824</td>
</tr>
<tr>
<td>Italy</td>
<td>116,770</td>
<td>5,856,972</td>
<td>6,458,825</td>
<td>5,210,428</td>
<td>3,253,321</td>
</tr>
<tr>
<td>Japan</td>
<td>3,779,784</td>
<td>121,500,000</td>
<td>129,000,000</td>
<td>114,500,000</td>
<td>72,000,000</td>
</tr>
<tr>
<td>Portugal</td>
<td>90,000</td>
<td>14,250,000</td>
<td>15,000,000</td>
<td>13,500,000</td>
<td>8,500,000</td>
</tr>
<tr>
<td>Spain</td>
<td>506,999</td>
<td>40,710,000</td>
<td>45,260,000</td>
<td>41,760,000</td>
<td>26,500,000</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>242,402</td>
<td>63,542,000</td>
<td>69,000,000</td>
<td>64,500,000</td>
<td>40,900,000</td>
</tr>
<tr>
<td>United States</td>
<td>9,634,000</td>
<td>281,421,000</td>
<td>300,000,000</td>
<td>275,000,000</td>
<td>175,000,000</td>
</tr>
</tbody>
</table>

**Note:** The table above shows the population, housing stock, housing construction, and brick production for various countries. Each country is represented with its area in square kilometers and population in thousands. The housing stock, housing construction, and brick production are also listed in thousands.