DRY-MASONRY BRICK HOUSE SYSTEM AS AN "ADAPTABLE BUILDING" MODEL FOR SUSTAINABLE HOUSING

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ABSTRACT

There is high tendency for both professionals and the public to associate the term adaptability in housing and its application with technical advances. These misconceptions about adaptability are derived from the outcome of many definitions and interpretations. When houses are designed and built, their designers and builders incorporate into them the technology of their time of construction. When new advances are introduced, the old technologies become obsolete.
The process of constructing and assembling a structure also affects houses' potential for choice and adaptability. Adapting a structural 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.

Dry-masonry[1] Brick House System (DBHS) that utilises a construction method called "Steel Reinforced Brick construction based on Distribution of Unbonded Prestress theory" (SRB-DUP) can be used as an "adaptable building" model to carry out a sustainable housing strategy in Malaysia. DBHS aims to be a sustainable housing system that will be able to achieve high Life Cycle Assessment (LCA) and low Life Cycle Cost (LCC) performance. It is also aimed that with DBHS, a "Green Cycle" can be promoted, waste generation can be minimized and design for post-occupancy adaptability can be encouraged.

Keywords: adaptable building, brick, construction and demolition waste, dismantling, reduce, reuse, recycle, sustainable housing.

INTRODUCTION

"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 paper, besides Japan, DBHS is also a building system that is worth to be emulated in other parts of Asian region due to the rationales presented here.
Therefore this paper is investigating why DBHS should be adapted for Asian markets. This is important because current DBHS's research and technology development (R&TD) is carried out only to suit Japan's market, thus a better understanding of market conditions outside Japan especially those environmental issues related to Sustainable Building Construction (SBC) are essential.

This paper will put emphasis on the link that may occurs between SBC and construction and demolition waste (C&DW) with 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 and also in China and India, the two biggest brick producer in the world where brick is the main building material.
In order to come out with a comprehensive research study, we set aims that will constitute the structure of this paper as indicated below.

(1) To review DBHS based on the practices and experiences accumulated in Japan and current environmental-related issues.
(2) To investigate brick distribution in the world and its relation with Asian markets and later to identify countries that utilized brick as one of the main building materials.
(3) To identify attributes of DBHS as an "adaptable building" model that is worthy for emulation as sustainable housing scheme.

[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.

Table 1. World Database for Housing Stock, Construction and Brick Production

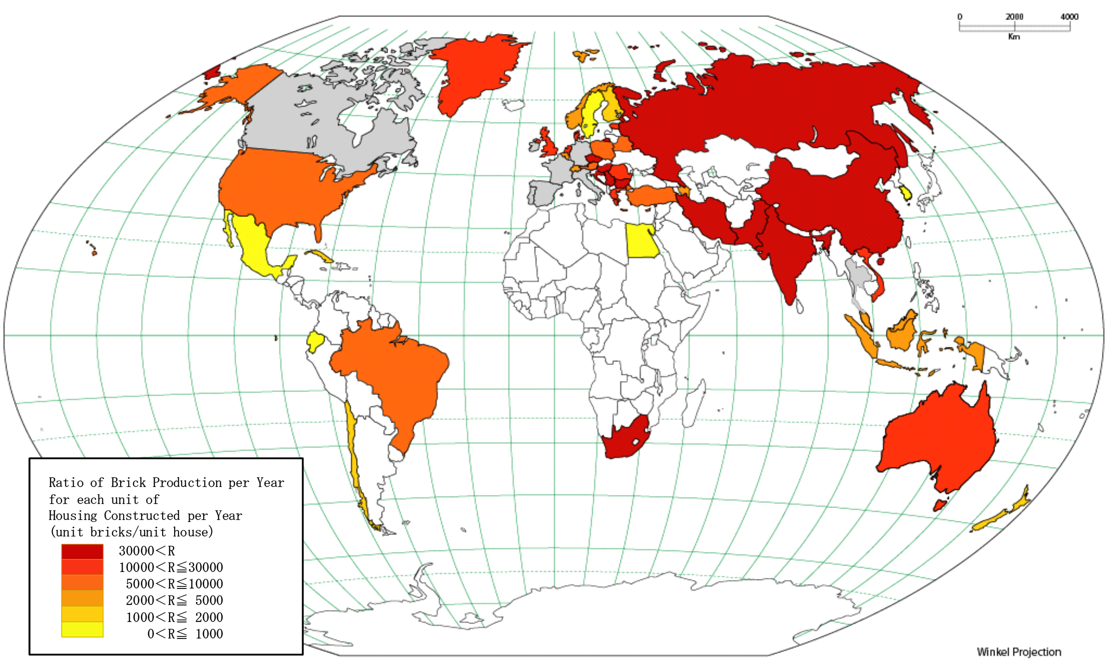
	COUNTRY	AREA (sq.km.)	POPULATION (2002.07.01 est.)	HOUSING STOCK YEAR	HOUSING STOCK TOTAL	HOUSING CONSTRUCTED YEAR	HOUSING CONSTRUCTED TOTAL	BRICK PRODUCTION YEAR	BRICK PRODUCTION TOTAL (million units)
	(Asia)								
1	Azerbaijan	86,600	7,798,497	n.a	n.a.	1993	17,100	1993	64
2	China*	9,596,960	1,284,303,705	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%**						

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) supplied 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 1 above.

Basis of World Wide Map

In projecting this World Wide Map, we need a basis in order to better understand distribution of brick production. For this purpose ratio (R) that is based on brick production per year for each unit of housing constructed per year to indicate the projected capacity of brick houses of each country is used.
Ratio (R) accumulated and later projected in the World Wide Map is divided into 6 degree of intensity for better understanding. The darkest area in the map which is degree no.6 simply means that if all unit bricks produced in a particular year are used for all houses that were constructed in a particular year, 30,000 or more unit bricks are needed for a unit house. Oppositely, the lightest area in the map which is degree no. 1 indicates that 1,000 and less unit bricks are needed for construction of a unit house. With this understanding, the higher the ratio (R) is, more percentage of brick houses in the building share of the particular country can be presumed. The projection of World Wide Map based on this basis is shown in Figure 1.



In Figure 2 below, we can trace certain kind of trends in relations of building brick production with brick houses of each region, particularly in the European region especially in the eastern part, countries like Croatia, Yugoslavia, Hungary, Bulgaria, Czech Republic, Estonia, Romania, Denmark, Greece and Netherlands is grouped in ZONE A. Although annual housing construction is comparatively low, with high ratio (R) indicates that bricks are also used for other buildings besides houses eventually it will also means that high percentage of brick houses in the building market share of the said countries. On the other hand, countries in Asian region are mostly grouped in ZONE B with countries like China, India, Pakistan, Iran and Indonesia shows high capacity for annual building brick production.
With this understanding, 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 (as per Table 1) and later maps are plotted to find the correlations between these three factors mentioned above with brick production per capita.

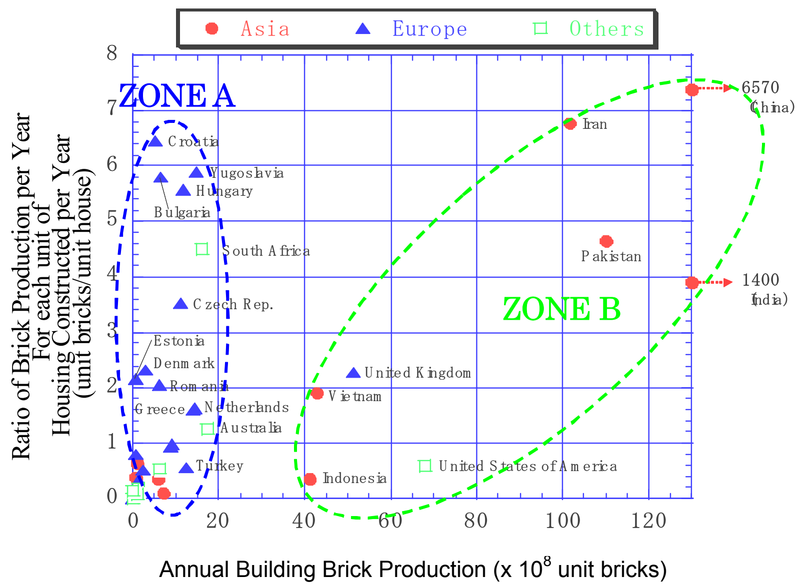


Figure 2. Relations of Building Brick Production with Brick Houses for each region

Analysis Of World Wide Map

Figure 3 shows that in general there is no clear division between brick production in cold areas compared to the hot and humid areas, thus brick houses can be found in these two areas. Since brick production can be found in both climatic condition, it is understood that capacity of brick houses in these areas are not depending on this factor, but rather on other factors such as natural resources or building technology.

Figure 4 shows that brick production exists in both developing countries and developed countries which are made up of EU countries, USA, Canada, Japan, Australia and New Zealand.
Again in Figure 5, we have verified that regardless of their seismic condition, brick production can be found in both seismic prone area and non-seismic prone area. Though typical mortar-cement type of brick houses (conventional construction) is not suitable for seismic prone areas due to its non-resistance towards earthquake, they can still be found in abundance especially in developing countries like China, India, Turkey, Iran and Pakistan. This is because high capacity of local brick production due to the large amount of natural resources that is essentials in this industry. Another factor is because unavailability of alternative housing materials besides brick, e.g. steel or timber due to the lack of technology or high cost construction

On the other hand, in developed countries such as USA (in western coast), New Zealand and Japan where it is prone to seismic area, less brick houses (almost 0% of market share in the case of Japan) exist mainly because of the availability of alternative housing materials with various construction technology at a competitive cost. Furthermore, the enforcement of seismic related statutory is stringently practiced by the authorities in the said countries.

Analysis in Asian Markets

From the above analysis we can now understand the correlations between countries in the world and their characteristics with brick distribution. We also understood that brick can be found in almost all part of the world and in most areas are regarded as the main building material for housing construction.
Despite brick advantages and disadvantages, brick production (thus brick housing) can be found in hot and cold climatic condition, high and low GDP as a reflection of one country's economic condition (thus translates into developed countries and developing countries) and also can be found in high and low risk seismic condition.

A closer look will reveal that all the factors mentioned above are only true and occurred in the countries throughout Asian region. Other region such as in Europe and in North and South America showed more monotonous pattern thus easier to understand. In Asian region for example, although brick is always known as a vulnerable building material for construction in the high risk seismic condition, bricks can still be found in vast areas especially in Pakistan, Iran, Indonesia and China. This is happening due to that brick industry is one of the local industries that support the local community in that particular area.

Meanwhile in Japan (the one and only country in Asia recognized by UN as a developed country status), brick production is no where to be found (almost 0% in terms of market share) and brick houses are regarded as vulnerable and brick construction is not endorsed by the local building code. Since Japan is a developed country, other materials which more often expensive than brick are used and new building technology are being developed to withstand high risk earthquake condition.

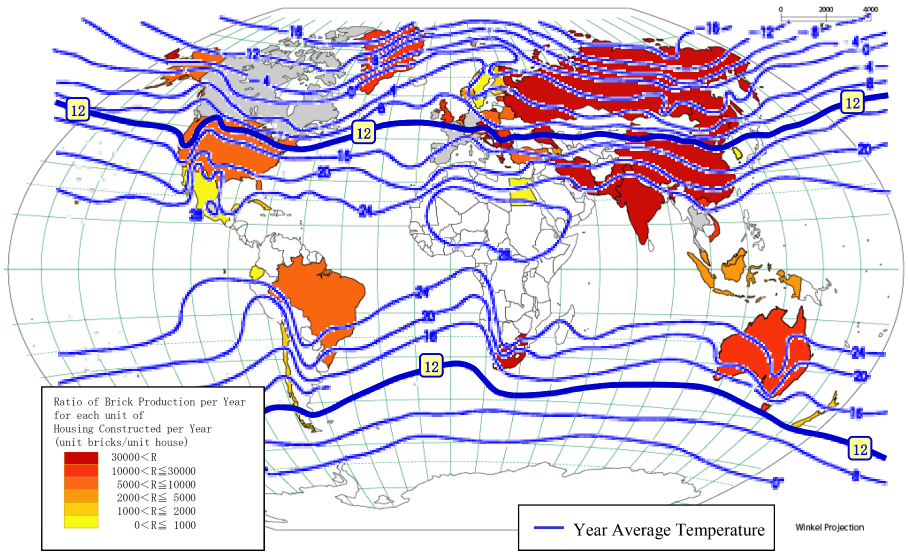


Figure 3. Relations of Building Brick Production with Annual Average Temperature of World Area

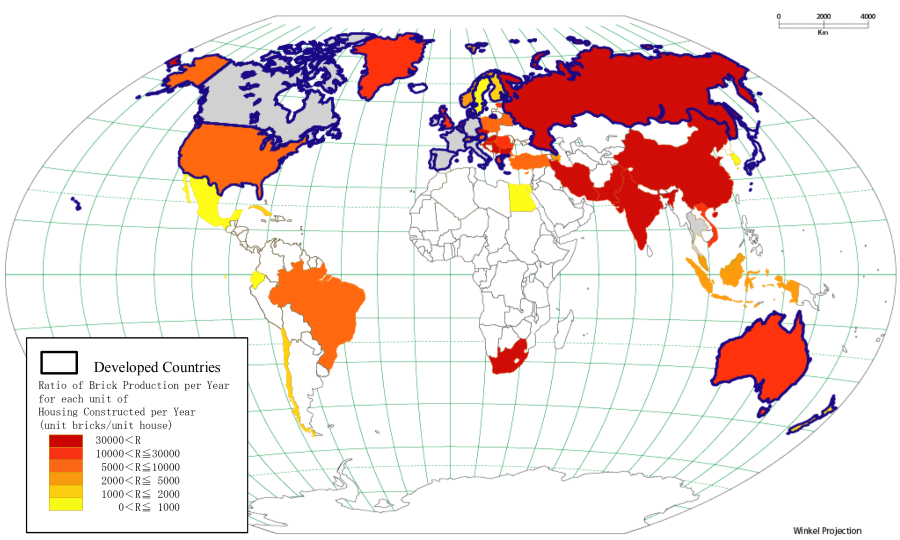


Figure 4. Relations of Building Brick Production with Developed – Developing Countries

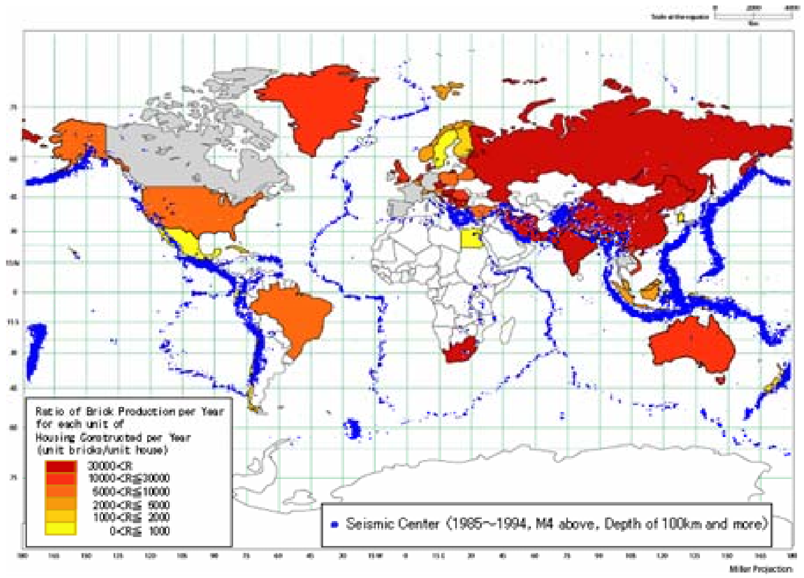


Figure 5:. Relations of Building Brick Production with distribution of World Seismic Center.

CURRENT ENVIRONMENTAL ISSUES

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 (WRI/UNEP/WBCSD 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 (UNEP/CIB/CSIR/CIDB 2002).

Construction activities will definitely have impact to the environment. Of course, the impacts of building and construction are not all negative. Well planned structures built with sustainable methods and materials can be highly beneficial to communities and workers, let alone the environment. Thus, sustainable building and construction (SBC) which is a holistic and multidisciplinary approach must be reconsidered in the current building and construction practice and its entire process.
Among the various environmental issues related to SBC, three issues that are i) CO^2 emissions, ii) minimization of construction and demolition waste (C&DW) and iii) prevention of indoor air pollution were given the top main priorities (OECD 2003).

Municipal Solid Waste (MSW) Generation in Asia

The impact of urbanization and economic development in Asia is very much felt in particular managing solid waste. Today, the urban areas of Asia produce about 760,000 tonnes of MSW per day, or approximately 2.7 million m^3 per day. In 2025, this figure will increase to 1.8 million tonnes of waste per day, or 5.2 million m^3 per day (Hoornweg 1999). These estimates are conservative; the real values are probably more than double.

MSW includes waste generated from residential, commercial, industrial, institutional, construction, demolition, process and municipal services. Often only residential waste is referred to as MSW. It is important to define the composition of municipal waste stream in clear and consistent fashion. For example, if MSW includes C&DW, the quantity of waste is predicted to be double in volume.

In the building related waste generation, there are three sources of C&DW. The first two is material removed from buildings when they are demolished and refurbished that generally account for a significant proportion of C&DW. The third is the waste generated at construction sites, such as surplus materials and packaging.

Waste generation rates are affected by socio-economic development such as the greater the economic prosperity and the higher the percentage of urban population, the greater the amount of MSW generation as shown in Table 2 below and there is indeed an urgent need to address this issue before it is too late.

Table 2. 1995 and 2025 Urban Per Capita MSW generation in Asian Region

Country	1995					2025				
	GNP per cap[1] (US $)	Population		MSW Generation		Pre-dicted GNP per cap[1] (US $)	Predicted Population		MSW Generation	
		Total[2] (millions)	Urban[2] (%ofTotal)	Genera-tion Rate (kg/cap/day)	Total Waste (tonnes/day)		Total[2] (millions)	Urban[2] (%ofTotal)	Genera-tion Rate (kg/cap/day)	Total Waste (tonnes/day)
Malaysia	3,890	20.1	53.7	0.81	8,743	9,440	31.6	72.7	1.4	32,162
Indonesia	980	193.3	35.4	0.76	52,005	2,400	275.6	60.7	1.0	167,289
China	620	1,200.2	30.3	0.79	287,292	1,500	1,526.1	54.5	0.9	748,552
India	340	929.4	26.8	0.46	114,576	620	1,392.1	45.2	0.7	440,460

[1]World Bank, 1997 / [2]United Nations, 1995

SUSTAINABLE STRATEGY FOR C&DW MINIMIZATION

It is necessary to note that there are many factors which prevent the reuse and recycling of C&DW 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 mixed together when building's parts are demolished. One of the possible contributions to prohibit dumping of these materials is integral chain management; that is to keep the building materials as long as possible in their own cycle (Dorshorst and Kowalczyk 2001).

Adapting a dismantling (disassembly) and recycling friendly building methods is a remedy that may well solve the problems that have been plaguing the construction industry for years. Therefore appropriate considerations must be given in all building stages, but two stages are of the utmost priority: the design-stage and demolition-stage.

In the design-stage, a dismantle-able building system (structure) can be chosen, where all the elements and components can be reused after a building is dismantled. This design-stage is called Design for Dismantling (DFD). Another building system is called Design for Recycling (DFR) where considerations (during design-stage) are given to building materials (that cannot be reused) so that they are easy to separate during demolition process and after further processing (e.g. crushing) can be used as a raw material for the production of new building materials. In order to achieve high C&DW minimization rate as the final goal, DFD and DFR must be considered *vis a vis* in the design-stage. This strategy is illustrated in Figure 6 below:

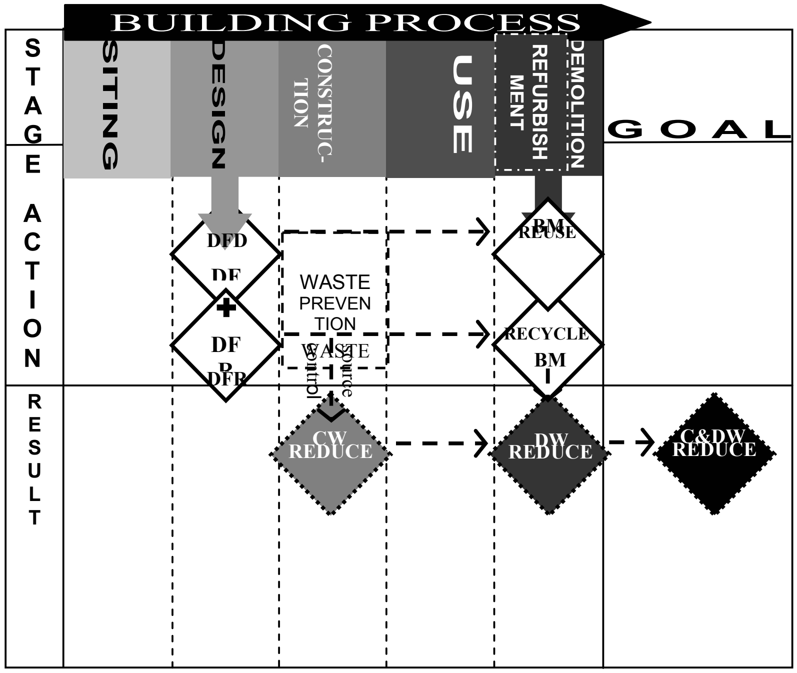


Figure 6. Relations of Building Brick Production with distribution of World Seismic Center.

This model fits well with the waste hierarchies which are usually established to identify key elements of an integrated solid waste management (ISWM) plan. The hierarchy according to sequence of preference is comprised in the following order as depicted in Figure 7.

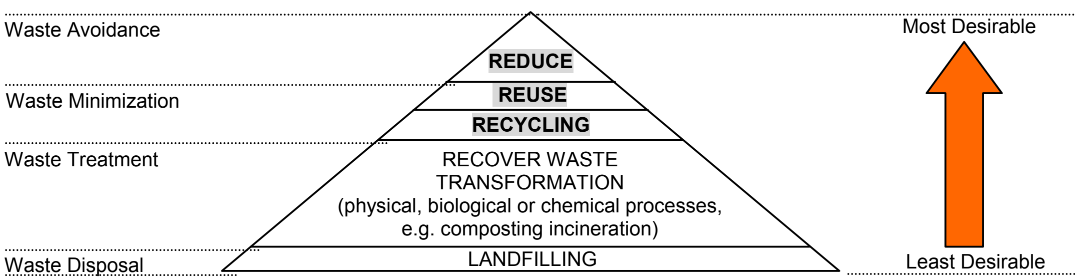


Figure 7. Hierarchy of ISWM plan.

Figure 7. Double storey DBHS Experimental House and 3D-view of clay bricks used in the project.

DRY-MASONRY BRICK HOUSE SYSTEM

Dry-masonry Brick House System or its acronym DBHS is a new innovative brick house system currently being developed in Japan that utilized a new construction method called SRB-DUP or "Steel Reinforced Brick construction based on Distribution of Unbonded Prestress theory". This is a system that suggests "*materials of different kinds (heterogeneous) shall not be bonded*" as a pre-condition in a set-up that will enable reuse and recycling in construction becomes easier.

At present, a double-storey DBHS experimental house situated in Kumamoto Prefecture has been built as shown in Figure 8. The second experimental house located at the reclamation development of Hakata Bay, known as Island City in the Fukuoka Prefecture has also been completed in January, 2005.

Unbonded Structural System

In DBHS, wall structural system proposed is of unbonded structural system or in short is called SRB-DUP method. Since in this method, mortar is not required, a dry-masonry kind of wall construction is possible.

There are six main components in SRB-DUP method. Beside bricks, steel plates function as horizontal reinforcement element and steel bolts act as vertical reinforcement element. In order to tie these layers of bricks together, steel nut, round and spring washer are used. Figure 8 above illustrates this composition. The horizontal and vertical reinforcement will also act as a structural system that possess high-resistance against earthquake and wind force.

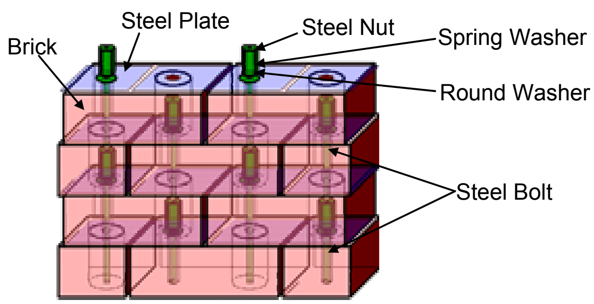


Figure 8. Composition of DBHS Wall with SRB-DUP Method.

Sustainable Housing System

DBHS aims to be a sustainable housing system that can achieve high Life Cycle Assessment (LCA) and low Life Cycle Cost (LCC) performance. It is aimed that with DBHS, an environmental-friendly cycle, namely A Green Cycle that encompass of "3R" scheme, i.e. REDUCE – REUSE – RECYCLE may be introduced as a new housing system to the housing market, thus will further enhance its attribute as an "adaptable building" model.

DBHS is a dismantle-able building system (structure) that incorporates DFD and DFR in its design-stage. As a result, we have learned that during the construction of the experimental house in Kumamoto Prefecture, a significant reduction of C&DW quantity is achievable in a sense that 98.34% of bricks used in the construction is reusable with the balance 1.66% can be recycled (Takasu 2001). Other parts used in DBHS like steel bolts, nuts and plates (although they can hardly be reused) can 100% be recycled after demolition since these components can be easily recovered and separated.

CONCLUSION

The demographic dynamics (population growth, urbanisation etc) that occurs in the developing world has resulted in high demand for shelter and this explained the rapid increment of construction activities in the developing countries. Growth in construction activities increases the rate of C&DW generation, thus its reduction becomes important. In Malaysia, Indonesia, China and India, MSW quantity (though C&DW was not included in it) is predicted to increase more than three fold in total waste (tonnes/day) from 1995 to 2025.

A dismantle-able building system that incorporates DFD and DFR can be used as a sustainable housing scheme that emphasizes C&DW minimization in the building process, where reduce-reuse-recycling can be achieved in the construction industry, hence enhances its application as an "adaptable building" model.

As countries throughout Asia still utilize bricks as the main building material for housing construction, adapting DBHS is indeed very relevant for overall improvement in environmental quality in this region. This will be vital towards achieving sustainable housing scheme in developing countries throughout Asia.

REFERENCES

Dorshorst, B.J.H. te and Kowalczyk, T. 2001, To dump or not to dump - reuse of apartment buildings: A case study. CIB TG 39, Wellington.

Hoornweg, D.T.L. 1999, What a waste: Solid waste management in Asia. The International Bank for Reconstruction and Development, World Bank, Washington D.C.

Kendall, S. and Ando, M. 2004, Theory and methods in support of adaptable buildings. Academic discussion for SB05 Tokyo supplied at http://www.sb05.com/academicE.html , MLIT/CIB/iiSBE and UNEP, Tokyo.

OECD, 2003, Environmentally sustainable buildings: Challenges and policies. (Paris,).

Takasu, K., 2001, A basic research on environmental strategy by utilizing brick as structural material for sustainable housing. Ph.D. Thesis, Kyushu University, Fukuoka (in Japanese).

UNEP/CIB/CSIR/CIDB, 2002, Agenda 21 for sustainable construction in developing countries: A discussion document, Pretoria.

WRI/UNEP/WBCSD, 2002, Tomorrow's markets: Global trends and their implication for business, Paris.