

A study on interlocking brick innovation using recycled plastic waste to support the acoustic and thermal performance of a building

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ARTICLE INFO	ABSTRACT
<p><i>Article history:</i> Received Nov. 30, 2020 Received in revised form Feb. 24, 2021 Accepted June 28, 2021 Available online December 01, 2021</p> <p><i>Keywords:</i> Acoustic Interlock briks Plastic waste Thermal performance of buildings</p> <p>*Corresponding author: Heyder Ahmed Master of Architecture, Faculty of Civil Engineering, Univesitas Islam Indonesia Email: 18922004@students.uui.ac.id ORCID: https://orcid.org/0000-0001-6790-6227</p>	<p><i>The main materials used in producing interlock bricks are clay, sand, and cement as usually applied in the conventional process of making bricks. There is, however, a continuous reduction in the availability of these natural resources due to their non-renewability. Therefore, one of the materials with the ability to support the acoustic and thermal performance of buildings in architecture is plastic. Plastics are categorized as lightweight, non-breakable, non-corrosive, and resistant to weather. Moreover, there is no need for the production of new plastics for this purpose due to the global call for the use of plastic wastes based on their high economic value. Therefore, this research aimed to compile a study on interlock brick innovation using recycled plastic waste to support the acoustic and thermal performance of a building. This was conducted through a review of previous studies on the profile of interlock bricks produced from recycled plastic waste. The findings are expected to provide information on the efficient production of interlock brick innovation using plastic wastes as a component.</i></p>

Introduction

New methods are being introduced to the process of making bricks in the last two decades in order to reduce the weaknesses of the old method and an example of this is the introduction of the interlocking brick (Al-Fakih et al. 2018). This is considered an alternative component for sustainable development in several countries (Watile, Deshmukh, and Muley 2014; Pradono 2019; Prastyatama and Maurina 2018) with its application observed in housing and water infrastructure construction (Susilawati and Tyas 2018). There is, however, a need for sustainable technology in its production such as the use of locally available natural resources to reduce transportation and ensure easy, environmentally friendly, time-efficient, and energy-efficient process (Deepak 2012). This is expected to

produce interlock bricks that are not only superior in terms of method but also sustainable in several aspects.

The choice of building materials should be based on the efficient use of renewable and recyclable resources to reduce excesses (Vebry 2008). One of the best ways to achieve this is through the recycling method which has been reported to be a solution to protect the environment from the harmful effects of materials causing pollution such as plastic wastes (Haque 2019). Reports have shown that the average global production of plastic reaches 150 million tons/year (Puri, Mishra, and Jindal 2019) with Indonesia reported to be producing up to 1.6 tons or 80% of plastic wastes per year (Fajriyanto and Firdaus 2008). Moreover, plastic waste can be used in architecture as alternative materials in concrete mixtures (Rismayasari, Utari, and

Santosa 2016), eco-bricks (Manisha and Singh 2017; Taaffe et al. 2014), paving blocks (Agyeman, Obeng-Ahenkora, Assiamah, and Twumasi 2019), interlock brick (Bernardi et al. 2017), and several others.

Plastic waste is a global problem due to its non-biodegradability and non-degradability for hundreds of years (Manisha and Singh 2017). Some scientists even reported it lasts for 4,500 years without degradation (D et al. 2014). The accumulation of plastic waste cause problems such as (1) occupying the spaces designed for other wastes, (2) having the tendency to be lifted to the surface when landfilled to pollute the environment, (3) releasing harmful substances when burned, (4) blocking of water flow when scattered in drainages (Sahwan et al. 2005). It is, however, possible to recycle pure plastic materials two to three times due to the reduction in its strength at each recycling process by thermal degradation (Singh et al. 2017). Plastics are considered good because they are not easily broken, not corrosive, weather-resistant (Juhana and Sungkono 2018), flexible, and also resistant to chemicals, water, and impact (D et al. 2014).

This material also has the ability to provide thermal insulation apart from being used as a building component and this reduces the use of electrical energy in cooling a room (Safinia and Alkalbani 2016). It is a good alternative in construction due to its ability to reduce the conductive heat by increasing the thermal insulation of the building walls (Mondal, Bose, and Bansal 2019) as well as to reduce noise (Kurniasari et al. 2019). This is very important considering the tropical climate of Indonesia with quite a hot temperature, thereby, making the selection of plastic waste recycling as an alternative building material and a solution in the architectural field to support sustainability and improve the acoustic and thermal performance of buildings.

This research aimed to determine the innovative interlock brick model previously

applied in architecture using recycled plastic waste that supports both acoustic and thermal performance of a building. It also investigated different types and profiles of interlocking bricks, the materials with the characteristics to support the acoustic and thermal performance of buildings, and the methods used in the research.

Method

A library research method was used in this study and this involved collecting empirical data from previous studies to obtain the best findings. This is considered scientific systematic bibliographic research which includes the collection of bibliographic material related to the research objectives using literature review followed by the organization and presentation of the data obtained (Danandjaja 2014).

Secondary data were obtained from previous studies in the form of books and scientific journals related to the acoustic and thermal performance of buildings based on the use of recycled plastic waste as a component in the interlocking brick. Moreover, similar data were grouped based on the themes and research topics determined by the researchers and arranged according to the order of the year of publication to follow the development of the topic over the years. The data were, therefore, presented in the form of a point table and described using a diagram to clarify the grouping of themes and topics based on the findings from the literature reviewed.

Result and discussion

Literature review concerning the discussion topics

The studies reviewed were observed to have discussed the following research topics:

Table 1. Research topics in the literature review

No	References	Study focus						Point
		Innovation of brick component profile development		Utilization of plastic waste in components		Testing components in supporting space performance		
		Component types determination	Brick component assembly system	Plastic material types determination	Material stress/strength test	Thermal resistance/water absorption components	Component acoustic test	
1	(Fajriyanto and Firdaus 2008)	1		1	1			3
2	(Kintingu 2009)	1	1		1			3
3	(Huff and Shouldice 2010)	1	1					2
4	(Pratikto 2010)			1	1			2
5	(Rai et al. 2012)			1	1			2
6	(Sina et al., 2012)			1	1			2
7	(Deepak 2012)	1	1		1			3
8	(Kasmudjiastuti and Yuniari 2012)			1	1	1		3
9	(Arslan and Arslan 2013)				1	1	1	3
10	(Sinarep, Catur, and Hafidzul 2014)			1			1	2
11	(D et al. 2014)	1		1	1			3
12	(Kurniawan 2014)		1				1	2
13	(Watile, Deshmukh, and Muley 2014)	1	1					2
14	(Taaffe et al. 2014)	1		1	1		1	4
15	(Aubé et al. 2015)	1	1					2
16	(Jasvi and Bera 2015)	1	1					2
17	(Sommerhuber, Welling, and Krause 2015)			1	1			2
18	(Sudarmono et al.i, 2015)	1		1	1			3
19	(Pati, Homma, and Iki 2015)	1		1				2
20	(A. Raut, et al, 2015)	1		1		1		3
21	(Wahid, Rawi, and Desa 2015)	1		1	1	1		4
22	(Ge, Yue, and Sun 2015)	1		1	1	1		4
23	(Mansour and Ali 2015)	1		1	1	1		4
24	(Chen 2016)	1			1	1		3
25	(Ghofrani, et al, 2016)	1					1	2
26	(Previatti et al. 2016)	1	1	1	1	1		5
27	(Rismayasari, Utari, and Santosa 2016)			1	1	1		3
28	(Safinia and Alkalbani 2016)	1		1	1			3
29	(Said and Sungkono 2016)	1		1	1	1		3
30	(Satito 2016)	1		1		1		3
31	(Muyen, Barna, and Hoque 2016)	1	1	1	1			4

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32	(B. Shanmugavalli, et al, 2017)			1	1			2
33	(Martins et al., 2017)			1		1		2
34	(Prमितasari 2017)	1				1		2
35	(Wariyatno, Haryanto, and Sumiyanto 2017)	1	1					2
36	(Antico et al. 2017)	1		1	1	1		3
37	(Bernardi et al. 2017)	1	1	1				3
38	(Manisha and Singh 2017)	1		1	1	1		4
39	(Muttaqim and Anggono 2017)			1	1	1		3
40	(Purwanto and Darmawan 2017)	1	1	1	1			4
41	(Susilawati and Tyas 2018)	1	1					2
42	(Mageswari, Chiranjeevi, and Magesh 2018)	1		1	1	1		4
43	(Mufika, Dewi, and Arifi 2018)	1		1	1			3
44	(Sukhwal et al. 2018)	1		1	1			3
45	(Patil et al. 2018)	1		1	1			3
46	(Maowa and Rashid 2018)	1		1	1			3
47	(Sormunen and Kärki 2019)	1		1		1		3
48	(Ni mah, et al, 2019)			1	1			2
49	(Agyeman et al. 2019)			1	1			2
50	(Nugroho et al. 2019)	1		1		1		3
51	(Amir et al. 2019)	1		1				2
52	(Hakim 2019)			1	1	1		3
53	(Rahmadiny et al. 2019)			1	1			2
54	(Kurniasari et al. 2019)			1			1	2
55	(Amijaya 2019)			1	1			2
56	(Asriza et al. 2019)			1		1		2
57	(Chaurasia and Gangwar 2019)	1		1	1	1		4
58	(Bhushaiah, Mohammad, and Rao 2019)	1		1	1	1		4
59	(Intan and Santosa 2019)	1		1	1	1		4
60	(Awoyera and Adesina 2020)	1		1				2
61	(Dewangan et al. 2020)	1						1

No	References	Study focus					Point	
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		Component types determination	Brick component assembly system	Plastic material types determination	Material stress/strength test	Thermal resistance/water absorption components		Component acoustic test
62	(Widyawati and Haqqi 2020)	1		1	1		3	
63	(Sultan, et al., 2020)	1		1	1		3	
64	(Sultan, Jaiswal, Jaiswal, Sahu, Devannand, et al. 2020)	1		1	1		3	
Previous studies in accordance with the research parameters		45	13	50	42	24	6	

A study usually discusses one to five predefined parameters and this means there is a need to trace the studies to obtain points on each parameter and determine the literature in line with the objectives of this research.

The literature reviewed showed 64 studies discuss the same topic as this research. It was also discovered that the parameters used in determining the type of components for buildings were discussed in 45 studies while brick component assembly systems were discussed in 13 studies and both concepts were discussed in 12 studies. Moreover, the parameters to determine the types of plastic materials to be used were discussed in 50 studies while the material stress/strength test was in 42 studies and both concepts were discussed in 38 studies. It was also observed that the parameters of thermal resistance/water absorption of components were discussed in 24 studies while the acoustic test of components was discussed in 6 studies and only 1 study discussed both concepts.

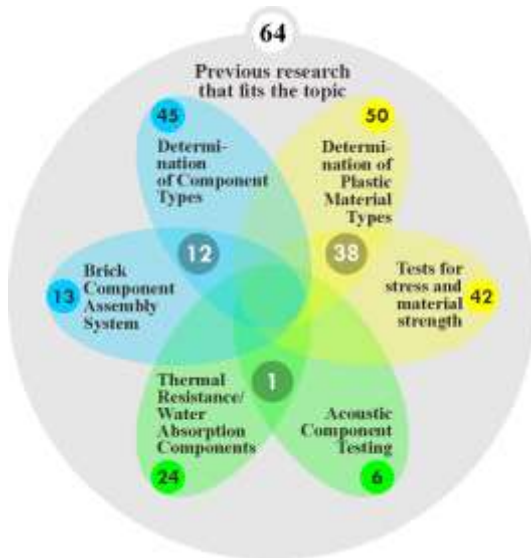


Figure 1. Diagram of variables and parameter findings from the literature study

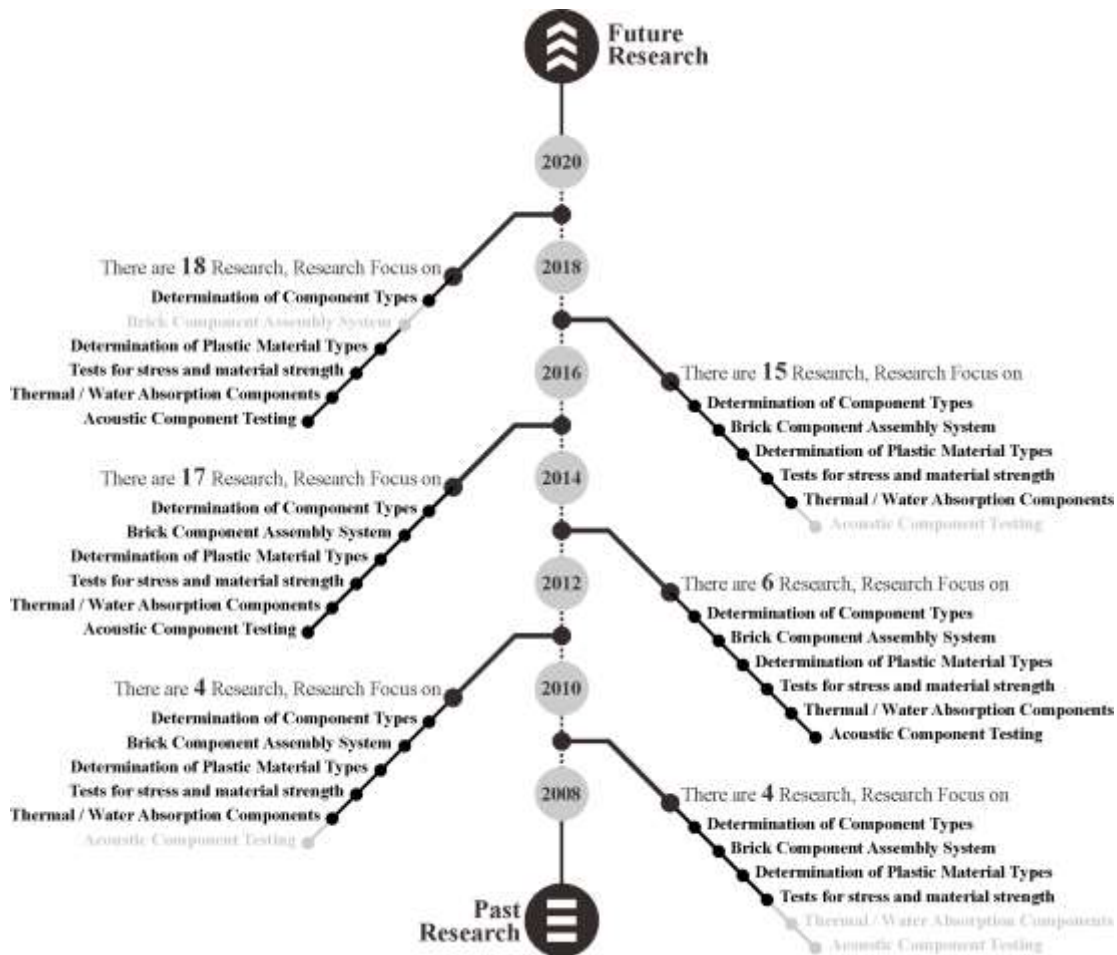


Figure 2. Fishbone diagram of the research literature

Figure 2 shows the number and focus of research in each year and 4 studies were observed to have discussed four research parameters in 2008-2010, 4 studies with thermal parameters added in 2011-2012, all parameters were discussed in 2013-2016 but there was no discussion of thermal parameters in 2017-2018, and brick assembly system was not discussed anymore in 2019-2020.

Review of the methods used

The method used is based on the focus of each study as described by the data collected and some of them include:

- Theoretical modeling methods supported by simulation designs and drawings
- Laboratory experimental methods
- Simulation experimental methods
- Methods of literature and secondary data
- Quantitative method using a scientific paradigm

- Qualitative methods in gaining the advantages of the development system

Review of analysis related to indicators in research parameters

A. Component Types Determination

Analysis of 65 studies on the parameters for determining the type of component showed only 7 of them met the specifications which is the use of interlock brick components in constructing walls.

B. Brick component assembly system

Analysis of 13 studies which discuss the parameters of brick component assembly systems showed 2 met the specifications which involve the use of the pin-pin assembly system which does not require adhesive media.

C. Plastic material types determination

Analysis of 50 studies which discuss the parameters of the type of plastic material showed only 10 met the specifications which involve using plastic and waste materials with light density and processed by heating.

D. Material stress/strength test

The material stress/strength test parameters were analyzed using the test model to produce compressive strength in line with the standard required for wall construction with the density value recorded to be between 240 - 800 kg/m³ while the compressive strength was between 0.35 - 7 MPa (Widiantoro and Ma'arif 2014). It was discovered that 23 out of the 42 studies analyzed discussed the material stress/strength test.

E. Thermal resistance/water absorption components

Analysis of 24 studies which discuss the test parameters of thermal resistance/water absorption components showed only 10 met the specifications by using plastic-based waste materials considered to be superior to conventional materials.

F. Acoustic component test

Analysis of 6 studies which discussed the acoustic component parameters showed only 3 met the specifications by using plastic-based waste materials considered to be superior to conventional materials.

The studies were selected using two indicators with predetermined criteria for each parameter and those filtered from the analysis results are presented in the following figure 3.

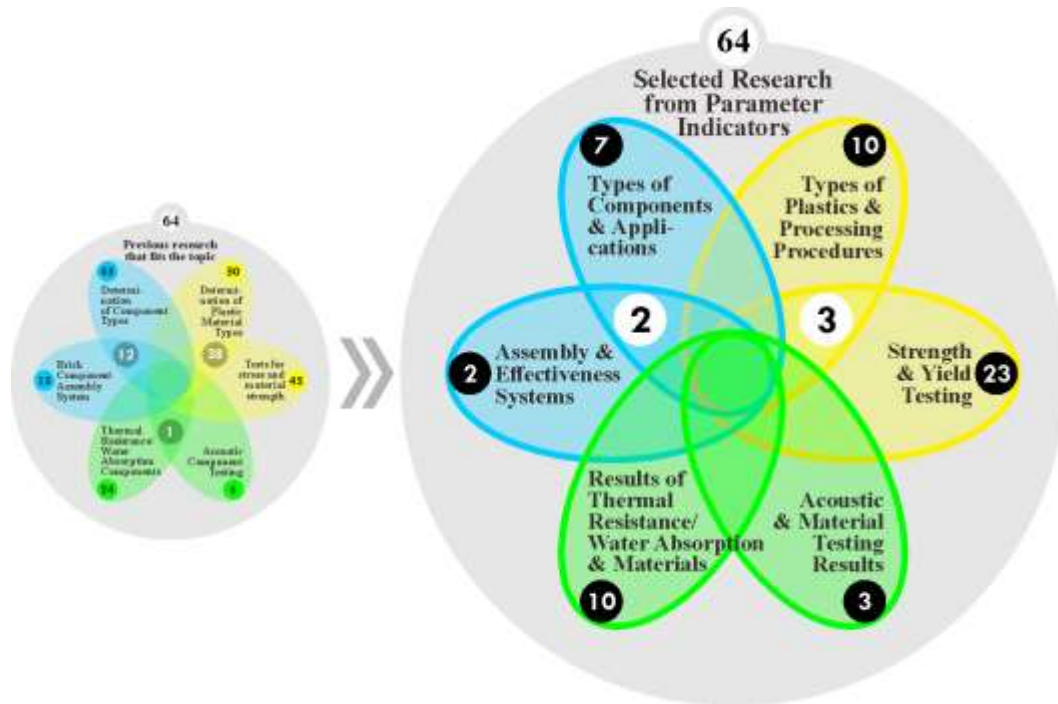


Figure 3. The selected study screening diagram based on parameter indicators

This screening was conducted to narrow the findings in order to determine the studies considered relevant to the research topic and theme.

Authenticity in literature achievement

Each study was summarized based on the method and purpose as well as the discussions related to the parameters in this research after which the findings were compiled in Microsoft Excel to indicate the authenticity of the secondary data obtained.

This linking model is expected to serve as a reference for the production of an interlock brick component using recycled plastic waste with the capacity to support acoustic and thermal performance in buildings.

Conclusion

The following conclusions were obtained from the analysis conducted: (a) There are already quite a lot of studies on building components made from plastic waste as well as the application of the material in interlock bricks but there is none on the acoustic and thermal performance of buildings. Therefore, further studies need to test room performance based on the acoustic and thermal aspects of a building constructed using interlock bricks made with recycled plastic wastes;

(b) The variables formulated in this research were divided into three aspects and each was further split into two parameters as shown in table 1; (c) The methods used in the studies reviewed include modeling, laboratory experiment or simulation, literature review as well as quantitative and qualitative analyses; (d) The research linkage model to determine the design compositions required to design interlock bricks produced from recycled plastic waste and with the ability to support the acoustic and thermal performance of a building was produced from this study; (e) The library data collected showed 3 studies can be used as a reference for material composition, 2 studies for interlock brick designs, 3 studies for coating materials to support room acoustics, and 10 studies for coating materials to support thermal comfort of buildings.

The authenticity of the recommended studies can, however, be traced through the contents section of the bibliography.

The findings from this literature review can be used as a guideline for further research on determining the components required for the design of interlock bricks from recycled plastic waste with the ability to support the acoustic and thermal performance of buildings.

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- Heyder Ahmed** contributed to the research concepts preparation, methodologies, investigations, data analysis, visualization, articles drafting and revisions.
- Sugini** contribute to the research concepts preparation and literature reviews, data analysis, of article drafts preparation and validation.

