CRAFTING THE DISUSED

RESEARCH REPORT

LOCAL WASTE MATERIAL TRANSFORMATION POTENTIAL AND INTEGRATED WASTE MANAGEMENT ON A DECENTRALISED SCALE

Written by:
Frederice Koch
Student Number 4513924

Tutors:
Design tutor: Monique Smit
Research tutor: Jan Jongert
Building technology tutor: Paddy Tomesen

As part of:
The Architectural Engineering
Graduation Studio 17

Master of Architecture, Urbanism and Building Sciences:
Faculty of Architecture
Julianalaan 134
2628 BL Delft

Date:
May 19th, 2017

II ABSTRACT

This research investigates the potential of waste material as building material to support local waste management in Cigondewah but also to find a suitable cost efficient and safe alternative building material. The research consists of two parts. The first part investigates the local context and in particular current waste flows and occurrences, as a basis for the second part, in which a variety of waste building materials and their processes are analysed with respect to their potential suitability for Cigondewah. The first part of research is based on a week long field investigation and locally made observations and interviews conducted, as well as literature research. The second part is solely based on literature research and will subsequently form the basis of physical development of a suitable building material candidate. It consists of comparable analyses and a waste management system case study.

It can be concluded, that a waste management facility is of need and has high potential of positive impact on an environmental level but also as an economical model for the neighbourhood itself (especially if combined with existing sampah bank models), as well as a building production business. The analysed waste material are promising and one has been chosen for further physical engineering towards the particular context. The research results form a design brief with regard to programme and spatial requirements.

This report was written in support of my graduation project.

Keywords:

household waste management, recycle, sampah bank, Bandung

CONTENT

fig 1. (opposite page) Cigondewah life (own image. 2016)

Part I:

Introduction

01 Introduction

In a report from January 2016 the World Economic Forum estimated that by 2050 the ocean will contain more plastic than fish (by weight).[1] The issue of waste pollution is becoming an increasing topic and while this is widely discussed today, pollution is continuing to grow. While the continuous flow of new pollution requires urgent solutions, so does the existing stock of waste within the environment. A cup found along a beach in Canada in November 2016 makes this all the more obvious. The cup, still in good condition, has a logo of the 1976 Olympics held in Montreal. 40 years later and the cup is yet to show degrading signs.[2]

While a permanent solution for these impacts should focus on the rejection of toxic household waste materials and instead on the distribution of bio-based alternatives as a standard measure, in the light of the urgency of the current pollution (especially the water pollution) temporary solutions can offer valuable alternatives to containing the pollution.

The current production of Municipal Solid Waste (MSW) arrives at approximately 3,6 billion kg on a daily basis and is estimated to reach more than 6 billion kg by 2025[3]. The topic of waste recycling or re-purposing is specifically relevant in the Indonesian context. Even though Indonesia has a relatively low waste production rate if compared to other countries, the pollution rates are highly increased. According to a study undertaken by McKinsey & Company and Ocean Conservancy Indonesia (2015)[4] is one of five countries that contribute to 60% of all marine plastic. The country produces approximately 64 million tons of waste every year. Only 7,5% of that waste is recycled (and that only in mayor cities).[5] This can easily lead to a false assumption of 92.5% of waste going to landfills. However, only 69% of the produced waste makes its way to the landfills. In a newspaper article published in 2016 the Jakarta Post proclaimed a state of 'waste emergency' for Indonesia,

only **7.5%**
of waste is recycled (in mayor cities)

69%
of waste goes to landfills

64m tons
of waste produced in Indonesia every year

23.5%
of waste is illegally dumped or burned

1.Neufeld, L., Stassen, F., Sheppard, R. & Gilman, T. (2016). The New Plastics Economy Rethinking the future of plastics. Geneva:World Economic Forum.; 2.Jaeger, K. (December 12, 2016).The Reason Why an Old Yogurt Cup Is Going Viral. ATTN:. Retrieved from http://www.attn.com/stories/13505/why-image-yogurt-going-viraly. [Accessed: December, 13, 2016]; 3. Hoornweg, D., & Bhada-Tata , P. (2012). What a waste - A Global Review of Solid Waste Management. Washington: Urban Development & Local Government Unit - World Bank. 4. McKinsey Center for Business and Environment, Ocean Conservacy (2015). Stemming the Tide: Land-based strategies for a plastic-free ocean. USDC;

triggered by studies that had shown, that most final disposal sites would run out of space by the end of 2016.[6] It is common practice in Indonesia to burn waste in back gardens and to dispose of it in water ways. This is also the case for the location of the graduation project that this research paper accompanies.

Cigondewah, a kampung (village) is located on the outskirts of Bandung, a mayor industry hub and third largest city in Indonesia. The kampung is comparably poor even though home to a variety of entrepreneurial businesses ranging from shops to textile businesses to construction related businesses. **It's rapid and unplanned urbanisation has resulted in an increased amount of self-built houses with insufficient structural properties and a poor living environment due to a heavy waste pollution and a lack of adequate facilities ranging from sanitary systems to public spaces.**

At current waste is dealt with in a particular linear way. Local initiatives have noted that their programmes for the improvement of the environment have shown that one of the key issues contributing to the pollution is a **lack of knowledge of correct waste separation, as well as a lack of appropriate spatial facilities** for this.[7]

Adding to the pollution issue is a further increase in population that Bandung faces in the coming years.[8] This is not only and environmental but also spatial challenge as it requires further densification, yet existing structures are already weak and not suitable for further extension and ground space is limited within the city.

It is the declared intent of the project to develop a suitable waste management model, that concomitantly caters for alternative solutions to waste material transformations into building material in the support of increased and safe new building typologies for Bandung and changes the current stigma of waste as an unwanted material and to recognise its potential. It is not a measure to solve the pollution problem in its core essence, but merely a temporary solution to the health hazardous pollution and a means to introduce a different approach to integrate waste management into day to day living. It's a way of shifting the issue for the time being to produce something useful in support of needed housing

5. & 6. Jong, H. N. (October 9, 2015). Indonesia in state of waste emergency. The Jakarta Post. Retrieved from http://www.thejakartapost.com/news/2015/10/09/indonesia-state-waste-emergency. [Accessed: September, 14, 2016]; 7. Yayasan pengembangan biosains dan bioteknologi . (c2014). YPBB. Retrieved 21 November, 2016, from http://ypbblog.blogspot.nl/; 8. Cococan (2016). Home at work. Welcome to the Fashion Village!. Delft: Delft University of Technology.
8. Cococan (2016). Home at work. Welcome to the Fashion Village!. Delft: Delft University of Technology.

and most importantly to contain the pollution in a confined space and prevent uncontrolled defragmentation in the environment.

The waste management model will form the basis for a new small scaled business model for Cigondewah focusing its energy on the above mentioned processing of waste materials into building materials for new dwellings. For this purpose potential material transformations need to consider cost implications as well as spatial needs. It is to be seen how these can be continued in the long term with a view on the decrease of polluting materials such as plastic and the replacement by for example bio-plastics. This will however not be discussed in detail in this report as it is subject to future alternative developments.

The undertaken research focuses on answering the following question:

'What are Cigondewah's waste flows and the potentials and needs to locally transfer household waste into valuable construction materials that are appropriate to the context?'

Therefore in this paper the current waste management of Cigondewah will be analysed, as well as case studies of waste material transformation that have a potential for further development and implementation in the context. These case studies are compared to currently used materials and furthermore in their suitability with regard to existing building techniques. The case of the 'zero-waste' city of Kamikatsu is also investigated as an epitome of community driven waste management. Starting with an explanation on the methodology (part II) used to approach this research, two parts of results follow (part III and part IV), relating to further sub-questions to the main research question before a combined conclusion is drawn and a discussion on design consequences (part V) taken from the results of the research is given.

The two research result chapters are split into a variety of sub-questions/ focus points resulting from the main research question:

Part III:

- local building techniques/habits and materials used (in order to adjust the resulting design and built towards local techniques and knowledge and to compare material prices to potential waste material prices)

- current waste management including waste occurrences and flows (to identify gaps and lacks that further the current pollution problem and to understand flows and waste resources for potential economical solutions for the kampung)

Part IV:

- potential alternatives for living and building with waste - analysis of 6 case studies of waste transformations into building materials and a comparison of these

- How have other communities addressed this issue? On the hand of the case study of the zero waste city of Kamikatsu.

The resulting data will be used as a basis for an architectural design project and assists with information referring to suitable waste materials and processes, as well as financial and spatial implications.

Part II:

Methodology

02 Methodology

The main purpose of this report is to understand successful existing waste management solutions and waste transformations and their implication and suitability for the context of Cigondewah. For this the report is structured into two parts. The first part of the investigation is focused on the local context and its particular opportunities, but also its challenges or needs and especially on the existing waste management as a basis for a proposed business case in the waste building material production. The second part focuses on potential waste transformations into valuable building material and the requirements with regard to space, cost and knowledge that are necessary for each case study as a means of evaluating its potential for the context of Cigondewah. For the purpose of this research paper and as a start to the exploration into the field of waste management and transformation, research has prevailingly been undertaken on the basis of literature, but also through observations of the context and interviews with local inhabitants especially in the case of part III. (see fig. 4). While part IV of the research is currently solely based on literature, the subsequent stages of the exploration will focus on research by design with this report as its foundation.

The situation of Cigondewah is particular in that it is a rather poor area resulting in a prevailingly informal building sector. In general there is a strong work/life connection within the kampung. Furthermore, extensive waste pollution is causing health issues. So to understand the requirements for any potential future waste transformation in this particular context, part III focuses on the anal-

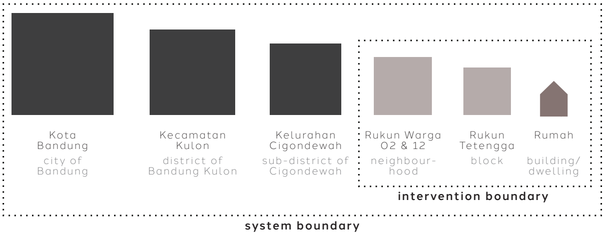


fig 2. System boundary (own image, 2016)

ysis of current building techniques and used building materials, as well as the current procedures of waste handling. The results of this outline current gaps and opportunities and form a set of requirements for the development of waste materials, such as minimal spatial needs, cost efficiency, simple production but also construction processes, etc., which relate directly back to the architectural design of the intended collecting and sorting spaces and live/work environments and define the criteria for potential waste processing (see fig. 2 & 4). This analysis is making use of observations during a week long field trip, exchange with the Department of Architecture at the Institut Teknologi Bandung, as well as interviews with five residents of the kampung ranging from families, to workers and through all income groups (from low income to high income). The analysis makes further use of interview results reached by previous study groups of the TU Delft architectural engineering studio (sources are noted directly where applicable). The investigation into waste flows in particular is based on literature that has gathered its data from local interviews and observations (although more extensive as the personal undertaken field trip), thus accounting for the informal element of the area. A material flow chart derived from the above laid out research approach was used to illustrate current waste flows.

In part IV a wide variety of redesigned waste materials, spanning a diversity of elements of a house, have been analysed and compared to each other to form a catalogue for inhabitants of the kampung to use in future built projects, but also as a basis of potential business opportunities resulting from waste management. During the research 6 examples have transpired as the most promising for the local context and as an opportunity for economical benefit for the

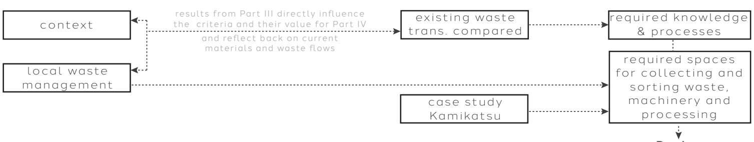


fig 3. Research influence (own image, 2017)

community. These 6 examples have been selected out of 10 that have been studied in depth, due to their variety of application and appropriateness for the context and local waste types. These are included in the report, while other analyses are included in the appendix.

Furthermore, the case study of a zero waste city in Kamikatsu has been investigated as an example of an organisational system and its potential for the context analysed.

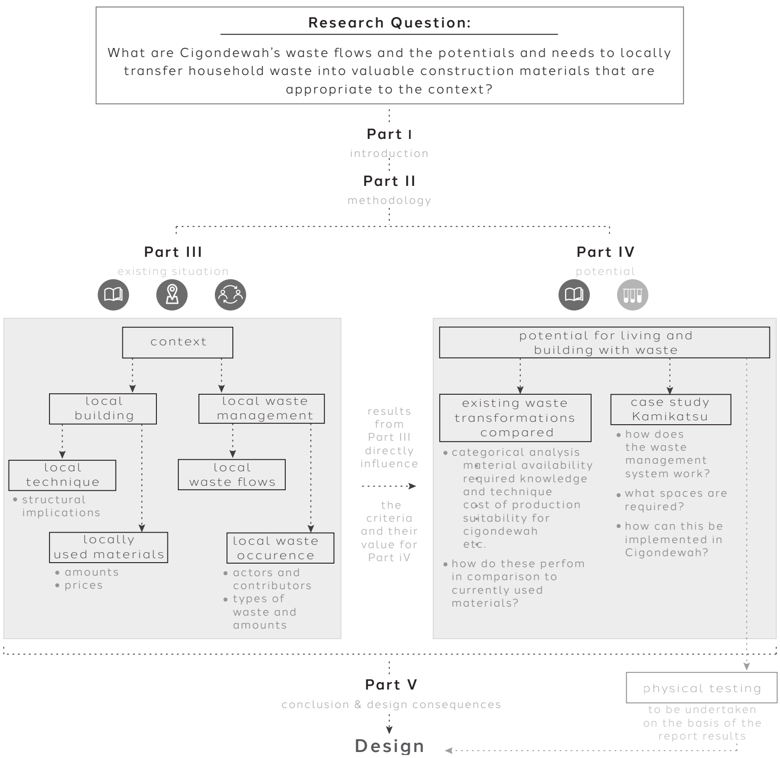


fig 4. Research map (own image,2017)

Part III:

Results Context

03 INTRODUCTION CONTEXT

Indonesia has a population of approximately 250 million. While its overall population is a comparable number, most of Indonesia's population lives on Java, making it the most populace island in the world with a particularly high density in its major cities.

In comparison Amsterdam City has a density of 4.900 inhabitants per square kilometre, while Bandung City as the third largest city of Indonesia has a density of 15.000 inhabitants per square kilometre. Bandung currently has a population of approx. 2,6 million, which is expected to increase to 4 million within the next 15 years, affectively adding to the current housing shortage (see fig. 5).[9]

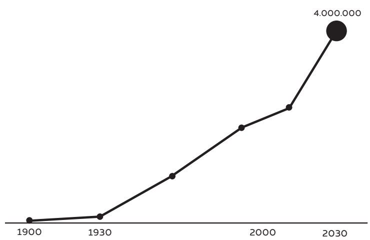


fig 5. Estimated growth of urban population in Bandung (x-time; y-population) - data source: Cococan (2016)

History

Once the garden city to Jakarta, Bandung has been subject to rapidly increased urban growth in the past decades with the arrival of large scale textile and garment industries in the 1970's. This has had a large effect on the area of Cigondewah Kaler, a kampung along the outskirts of Bandung. It is characterized by the local textile factories, who are not only a large influence on the local employment sector but furthermore own an increased amount of public land within the kampung.

Administrative structure

A characterising aspect of Indonesia's tradition is the strong social cohesion within neighbourhoods. While the predominant administrative structures are similar to that of western countries, Indonesia has a unique system of neighbourhood organisation that developed out of the need to work with emerging unplanned settlements such as kampung's (see fig. 6). To allow for the informal to work within the formal context, locally organised and elected Rukun Warga's (neighbourhood leader's), as well as Rukun Tetengga's (block leader's) are taking on admin-

9. Cococan (2016). Home at work. Welcome to the Fashion Village!. Delft: Delft University of Technology.

istrative roles for those entities. An even more dominating aspect of Indonesian culture is the distinguished respect towards neighbours, and in particular more experienced and elderly, as was apparent during the field trip to the location. The Indonesian mentality is that of humbleness and consideration.

President (national)
Mayor (city)
Kecamatan (borough)
Kelurahan (sub-borough)
Rukun Warga (neighbourhood)
Rukun Tetengga (block)
Inhabitants

fig 6. Administrative structures (data source: Rossen, K. (2014)

Location

The city of Bandung is located on the island of Java in the West Java province (see fig. 7). The city is divided by the Cikapundung river that runs from north to south and merges into the Citarum river. The ground soil is prevailingly of andisol soil nature due to long term volcanic activities in the surrounding areas, making the soil extremely fertile. Bandung's climate is dominated by monsoon climate with an average precipitation of 2120mm yearly and an average yearly temperature of 26.8°C. Its more central location on Java provides a slightly lower temperature of that of Jakarta, making it initially attractive as garden city. The city has an area of 167.67km2 with its metropolitan area stretching over 3292km2.[10]

Cigondewah Kaler is an urban industrial kampung and is located along the south-west border of Bandung city (see figure 8-10). It consists of 14 Rukun Warga's (RW's) which are subdivided into a total of 47 Rukun

	Indonesia	Bandung Metropol..	Bandung City	Cigondewah Kaler	Netherlands	Amsterdam City
Population (in mil)	249.9	8.6	2.6	0,02	8.6	0.83
Area (in km^2)	1.904.569	3.392	167.7	1,4	3.392	165.8
Density (per km^2)	124	2326	15000	14850	2326	4900

table 1. Demographics compared - data source: Guratman, H. D. H. (2016) & Cococan (2016)

10. Cococan (2016). Home at work. Welcome to the Fashion Village!. Delft: Delft University of Technology.

fig 7. Map of Indonesia (indicating Bandung in yellow) (own image, 2016)

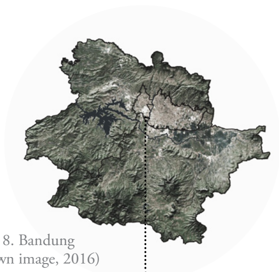


fig 8. Bandung
(own image, 2016)

fig 9. Cigondewah
(own image, 2016)

fig 10. Cigondewah
RW 02 & RW 12 (own image, 2016)

Tetengga's (RT's). The area of the kampung neighbourhoods in the focus of this research - RW02 and RW12 (subdivided into 5 and 4 RT's respectively), is 0.12km2 combined. The RW's are surrounded by a toll road (along the southeast end) and a main road (along the northern edge) in a triangle (see fig. 10). The access to the kampung is restricted and only open from the main road along the northern edge. The Cigondewah river runs through the middle of the kampung (see fig. 11) and is connected to Citarum river, which was named the world's dirtiest river by the Asian Development Bank in 2008.[11]

11.Asian development bank. (2008). Asian Development Bank. Retrieved 17 November, 2016, from https://www.adb.org/news/clean-future-worlds-dirtiest-river

Landscape/Public Space

A low amount of public space is available within the area. This is limited to an open field that is home to a football field as the only larger usable space, a graveyard, as well as rice fields, a remains from agricultural times. The open field is the main waste deposit and sorting location and owned by a local textile industry.

Infrastructure

While the kampung sits next to a motorway and is surrounded by main roads, the infrastructure within the kampung is of basic nature and mostly takes shape in the form of walked desire paths rather than planned and made ways. Often 'paths' are simply the space between two buildings.

Built Environment

The built fabric is dense and yet low rise. Large numbers of dwellings are sitting alongside heavy industry, particularly of the textile and garment sector (e.g. Kahatex). The kampung is rapidly densifying, leading to a scarcity of ground space and raised numbers of inhabitants per dwelling.

Kampung

The kampung is home to a large number of factory workers, in part migrant workers. This has opened up opportunities for local inhabitants to sublet spaces as a means of income. Within the kampung a limited number of small scale warehouse businesses relating to textile recycling and in small parts cardboard and plastic recycling can be found along the outskirts. Textile waste from the factories form the basis of most of the income for the area.

Waterways

The Cigondewah river (north to south running)is passing through the centre of the kampung. Before entering the kampung it runs through the industrial area, where it is subject to heavy factory pollution. Despite this the river is used locally for household waste disposal, as well as for sewage purposes, while also acting as a source of water for washing facilities and agricultural watering.

- landscape
- field
- factory
- dwelling
- mosque
- warehouse (c&p)
- warehouse (t)
- rice field
- infrastructure
- waterways

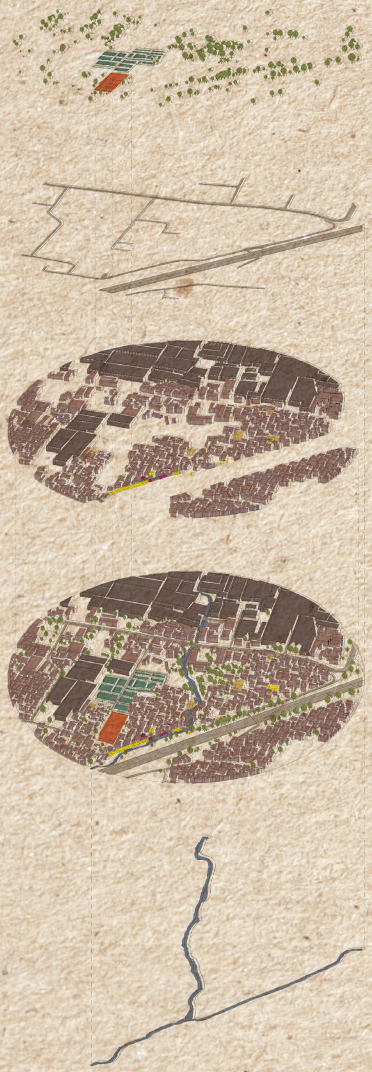


fig 11. Cigondewah Elements (own image, 2016)

Demographics

The considered area of the kampung stretches over two Rukun Warga's - RW 02 and RW12, with a combined area of 12 hectares. They have a population of approximately 3100. What is striking is the relationship of local families and migrant factory workers in population numbers. Each RW is home to approximately 50% migrant factory workers (see table 2).

	RW 02	RW 12	Total
Population	1788	1313	3101
Families	50%	60%	-
Migrants Workers	50%	40%	-
Area (in Ha)	8,1	3,9	12

table 2. Demographics of RW02 & RW12 - data-source: Sakina, B et al. (2015) & Guratman, H. D. H. (2016)

Economy

Cigondewah's economy is built around the fashion industry (see fig. 11), in particular the Kahatex factory, and accommodates for all levels of income from factory managers down to migrant workers and kampung workers who process textile waste bought from local factories.

But despite the heavy fashion industry boosting the economy, Bandung's and Cigondewah's income levels are low (see table 3). The consequences of these limited private but also public funds are dwellings built with unskilled but cost efficient labour, resulting in the production of structurally insufficient and unsafe buildings, as well as poor public space and amenities. The latter in particular is causing pain to the kampung with the lack of adequate waste storage facilities.

	< 6.750.000 Rp (approx. 481€)		6.750.000 Rp - 13.500.000 Rp (approx. 481€ - 962€)		> 13.500.000 Rp (approx. 962€)	
	number	%	number	%	number	%
Bandung City	1.716.000	66	754.000	29	130.000	5
Cigondewah Kaler	13.722	66	6.029	29	1.040	5
RW02 & RW12	2.047	66	899	29	155	5

table 3. Income levels compared - no direct data for Cigondewah was available and Bandung's percentage projected onto it - data source: Surahman, U. et al. (2015)

Life in Cigondewah

The presence of textile factories is imprinted on the identity of Cigondewah Kaler. While residential land is still mainly owned by old families, nearly 50% of the residents are migrant workers. These are often housed within factory provided housing or within rooms of local family houses, therefore being a source of income. The majority of life takes place outside even though public space is rare. Yet, no matter the income level or dwelling size, inhabitants take proud in ownership of dwellings and invest in decorative elements especially for more public areas of their dwelling.

Needs

It has transpired during conducted interviews but also through observation, that a suitable central waste collection is needed and wanted. The kampung is struggling with the quality of their sanitary facilities and regular flooding, partially caused by blocked drainage as a result from waste pollution.

04 BUILDING MATERIALS AND TECHNIQUES

Informal and unplanned construction is dominating the built environment of Cigondewah. Approximately 70-80% of kampung dwellings are built by the informal sector.[12]

Construction procurement

Observations during the field trip, as well as interviews made obvious, that the majority of the building in the kampung is done by inhabitants themselves with the help of the community were available. While a very few families with larger income hire a 'senior skilled' worker (kepala tukang) to undertake construction work (see fig. 12), it is more common for a 'skilled' member (which in most cases is the most knowledgeable member of the community relating to a certain field), to set the tone and quickly train other community members to construct a building. These 'skilled' members have commonly learned their trade through older generations passing on their knowledge. Licences are not required to construct a building and the appointment of a formal contractor is not common. Due to the informal nature of the building process architects are usually not involved either. The builder or 'client' designs the building. The aspect of community involvement runs through all elements of construction. Every resident with the intent to build, has to propose their plan to the RT and RW leader for approval.

An interview conducted during the field trip also highlighted the informality of the building process within the kampung, especially in the case of community buildings. Community structures are often built without a timeline and with vernacular materials provided by the community, depending on left overs rather then acquired from local material shops. Building commences at any time, whenever a community member has time at hand.

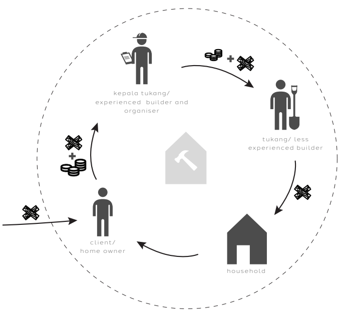


fig 12. Simplified building procurement route (own image, 2017)

12. Benjamin, S., Ali Arifin, M., & Sarjana, F. P. (1985). The Housing Costs of low income Kampung dwellers. HABITAT INTL, 9(1);
fig 14. Building site in Cigondewah (own image, 2016)

Material & technique

While traditional Indonesian building techniques and materials evolve around the use and crafting of timber and brick, modern kampung building focuses on the use of concrete for a load baring frame with an infill, commonly bricks. Yet, the building approach for the 'new' method of construction with concrete appears to imitate the traditional timber approach, with concrete frames being set up in a way more appropriate to timber houses (see fig. 12).

During the field trip an increased amount of dwellings with deformed concrete frames were observed (sometimes this phenomenon occurred even before construction had finished), making the use of concrete as primary structural component worrisome with current building techniques. While the current built environment is of low rise nature and rarely exceeds two storeys, the current local approach to concrete construction is not workable for a facilitation of vertical expansion. Other building materials used as primary construction and/or as wall infill are cement blocks. However, brick is the prevailingly used material for wall infill's. The application of this however, is characterized by ample use of mortar, often reaching a thickness close to the height of the brick row itself, as well as partially missed rows. Brick waste, such as half bricks or smaller parts are commonly used in walls. The walls are afterwards commonly covered with mortar. Brick walls are commonly 'half-brick' thick. This is a partially the result of a lack of funds and acts as a cost cutting measure, but also routed in the believe of the kampung inhabitants that a 'one-brick' wall would have negative impacts on the climate with particular respect to heat.

The use of gable roofs is most common, relating to the heavy rainfall experienced in Indonesia during raining season, however sloped roofs are also visible in the area. While the structure is often of timber nature, cladding materials are most commonly corrugated sheets (zinc or asbestos) or more cost intensive terracotta roof tiles (see fig. 12).

Foundations are generally constructed of larger river stones in combination with concrete forming shallow platforms. Often raised fence walls are integrated into the platform to prevent flooding.

fig 13. Building site in Cigondewah (own image, 2016)

fig 14. Concrete frame structure (van Splunter, M. 2016)

fig 15. Bamboo column being concealed (van Splunter, M. 2016)

fig 16. Concrete covering of brick wall (own image, 2016)

Even though widely available bamboo is culturally regarded as a cheap material and rarely part of visible structures although still used in woven cover form. Nevertheless, it is often used as scaffolding and sometimes left to be concealed, for example in brick work (see fig. 15).

Although building techniques are related to need rather than craftsmanship and funds are limited, appearances are of high importance to residents. A high amount of self appropriation and individual creative design solutions or paint work have been observed on site. This is further reflected in the importance of higher quality building for public areas of the house in comparison to private areas. For example roofs of entrance areas are often covered in roof tiles, while the rest of the house is covered in corrugated zinc or asbestos.

The limitation of funds is further reflected in the incremental approach to building in the kampung. Often cheaper infill's are put up first, before funds become available and the once temporary solution is replaced with a more permanent material. Costs of building materials are thus an important factor for the building sector. Any alternative materials would need to be able to compete with current material prices as can be seen in table 4. The data reflects material prices as recorded from a local shop and from interviews conducted by research groups in 2014 and 2015.

	unit	cost (in Rupia - IDR)	cost (in Euro - €)
Primary and Secondary Construction:			
Stone:			
Gravel	1m³	300.000	21,30
Cement	1kg	1400	0,10
Brick:			0,00
Hollow Cement Blocks (height of block 7,5cm)	1m³	730000	51,83
*estimate with hoolow block prices from Hussain mohdabbas-block factory llc (c2017)	1kg	7300	0,52
Regular red brick (unexposed) 4x10x20 cm *estimate with brick prices from Hargamaterialxyz (2017)	4cm x 10cm x 20cm	350	0,02
Red Brick (exposed) 4,5x11x22 *estimate with brick prices from Hargamaterialxyz (2017)	4cm x 10cm x 20cm	1.100	0,08
Sand:			
River Sand	1m³	350000	24,85
Black Sand	1m³	300000	21,30
White Sand	1m³	350000	24,85
Timber:			
Bamboo - treated	6m long	60000	4,26
Bamboo - untreated	6m long	5.000 - 12.000	0,36-0,85
Wood - Jati (teak)	1m³	15000000	1.065,00
Wood - Borneo	1m³	5000000	355,00
Wood - Recycled	1m³	2000000	142,00
Wooden Block - Size A	4cm x 6cm x 400cm	30000	2,13
Wooden Block - Size D	6cm x 12cm x 400cm	85000	6,04
Wooden Block - Size E	8cm x 12cm x 400cm	90000	6,39
Wooden Flooring Board - Size B	3cm x 20cm x 4000cm	90000	6,39
Metal:			
Zinc Sheet - corrugated	per sheet	40000	2,84
Steel Rebar - Size A	ø 6mm, 12m long	24000	1,70
Steel Rebar - Size B	ø 8mm, 12m long	40000	2,84
Steel Rebar - Size C	ø 10mm, 12m long	60000	4,26
Steel Rebar - Size D	ø 12mm, 12m long	90000	6,39
Steel Rebar - Size E	ø 16mm, 12m long	150000	10,65
Steel Channel - Profile - light steel	6m long	80000	5,68
Steel Channel - Profile - medium light steel	6m long	50000	3,55
Terracotta:			
Roof Tiles	42cm x 33cm x 0.6cm	4000	0,28
Internal:			
Dry Wall	120cm x 240cm	60000	4,26
Services:			
Drainage:			
Plastic Tubes	ø 100mm, 4m long	180000	12,78

table.4. Existing Building Material Prices - data source: Remmerswald, N. (2014), Rossen, K. (2014), Hussain mohdabbas - block factory llc. (c2017) & Hargamaterialxyz. (2017)

05 LOCAL WASTE OCCURRENCES

According to the State Ministry of Environment (2008) the waste collection of households accounts to more than double of the Municipal Solid Waste (MSW).[13] The results given here focus on household waste and in part on house industry waste in acknowledgement of some of the waste being mixed into household waste given the nature of the industries location.

Bandung's generated household waste consists to a large part of organic waste (51,9%), as well as plastics (12,1%), paper or cardboard (9,8%), textile waste (3,5%) and amounts of a variety of other waste materials such as rubber, wood, etc. (see table 6).[14] For the context of Cigondewah the local textile industries need to be taken into account, largely increasing this aspect of waste for the area. No measured data is available for the particular case of Cigondewah. Waste compositions for the area are estimated on the basis of the data relating to Bandung's waste in combination with locally made observations.

The research has shown that RW02 and RW12 produce 66 tons of household waste per month (see table 5). Organic waste makes up approximately 34 tons per month of this, inorganic waste 21 tons, while other waste accumulates to 11 tons a month. The calculations show that the neighbourhood produces an approximate 7 tons of plastic waste per month, 5,5 tons of paper waste and 5 tons of textile waste. While this sets the basis for potential waste up-cycling, it is important to note that not all of the above mentioned waste is suitable for recycling. For the purpose of the report calculations will be based on the total amounts of accumulated waste. It is notable that an increased amount of waste was found floating in waterways and lying along pathways, but also burning along sideways and central open spaces as previously assumed (see fig. 17 & 18).

13.State Ministry of Environment, The Republic of Indonesia (2008). Indonesian Domestic Solid Waste Statistics. Jakarta: JICA.
14. Damanhuri E, Padmi T. (2008). Waste recycling capacity in Bandung City, Indonesia. The 5th Asian-Pacific Landfill Symposium, October 22–24, Sapporo.

	Bandung (2011)		**Cigondewah RW02&12 (2011)**	
	in ton	in m^3	**in ton**	**in m^3**
day/cap.	0,0007	0,0019	**0,0007**	**0,0019**
day	1.800	4.952	**2**	**6**
week	12.601	34.664	**15**	**41**
month	54.760	150.639	**66**	**179**
year	657.051	1.807.473	**792**	**2.151**

table 5. Waste accumulation (data source: Rahayu, N. & Yudoko, G. (2012)

Waste Composition	Bandung		**Cigondewah RW02&12**	
	ton	%	**ton**	**%**
Organic	6539,9	51,9	**7,9**	**51,9**
Inorganic	3893,7	30,9	**4,7**	**30,9**
Plastic	1524,7	12,1	**1,6**	**10,7**
Glass	453,6	3,6	**0,3**	**2,3**
Paper	1234,9	9,8	**1,3**	**8,4**
Textiles	441,0	3,5	**1,2**	**8,0**
Rubber	75,6	0,6	**0,1**	**0,5**
Metals	163,8	1,3	**0,2**	**1,0**
Other	2167,4	17,2	**2,6**	**17,2**
Total per week (in ton)	12.601,0	100,0	**15,2**	**100,0**

table 6. Waste composition on weekly basis (data source: Damanhuri, E. et al. (2009)

fig 17. Land pollution (own image, 2016)

fig 18. Cigondewah river pollution (own image, 2016)

fig. 19. (next page) Informal waste point (own image, 2016)

fig. 20. (next spread) Waste being burned next to football field and playing children (own image, 2016)


SUPER SOCCER
DJARUM

06 CURRENT WASTE FLOW MANAGEMENT

In 2005 a landslide on the landfill site Leuwigajah in the surrounding area of Bandung killed 143 people (see fig. 21 in yellow).[15] The disaster initiated a national interest in waste management organisation and the first national waste management law was instigated in 2008 on the basis of the concept of 'reduce, reuse and recycle'. Nevertheless, final disposal sites continue to struggle with the amounts of waste to be processed on a daily basis.

only **10**%
of Indonesia's landfills are sanitary[19]

30-40%
of produced MSW never arrives at final disposal sites

3-10k Rp
are paid by each rukun warga on a weekly basis to cater for household waste distribution

Site observations and interviews have dispersed that a key challenge contributing to the issue of waste pollution in Cigondewah is the lack of a central collection point. Local initiatives[16] have further stated, that the majority of residents do not know how to recycle and would require education on this aspect.

Waste flow

The current waste flows are as informal as the building sector, yet organised (see fig.22). 'Managed' household waste is collected ones a week at a cost of 3000-10.000 Rupiah per Rukun Warga.[17] The infrastructure of the kampung and lack of suitable alleys/paths makes the access to the kampung difficult. Larger waste trucks (grobak's) have no means of access to the inner kampung and distribution of waste is therefore to a large part organised by hand carts. The waste produced is temporarily stored at informal collection points in baskets, bin bags or sacks and is picked up by a janitor in the case

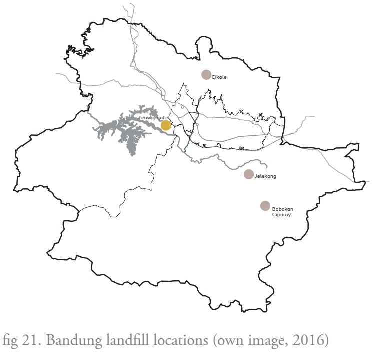


fig 21. Bandung landfill locations (own image, 2016)

15. Macmillan, N. (2007) Community Solutions fo r Indonesia's Waste . Ottawa: International Development Research Centre.; 16. Yayasan pengembangan biosains dan bioteknologi. (c2014). YPBB. Retrieved 21 November, 2016, from http://ypbblog.blogspot.nl/; 17. Saiful, A., Nurhijrah, Dewi, R., Saraswati, T. & Dadang, H. (2015). Housing & Waste-Green Cycle. Bandung: ITB.

fig 22. Waste distribution ways (own image, 2017)

of very inaccessible alleys and transported to a more accessible informal collection point. From here waste is transported via hand carts along the mobile scavenger routes towards one of the two main (yet still temporary) collection points - the football field or an area along the northern edge main road. The waste is subsequently picked up by waste trucks and transported to the local disposal site TPA, before moving on to one of the four final disposal sites outside of the city of Bandung (see fig. 21). Only 60-70% of the total Municipal Solid Waste production arrives at those landfills.[18] This is reflecting 30-40% of 'unmanaged' waste. To a part consisting of household waste that is either dumped locally or in rivers. The most disturbing habit widely practised is the burning of household waste, when pollution takes on too large amounts and space becomes scares. This action is often executed in back gardens but also on public fields. Few higher income households have an agreement with mobile scavengers to collect the waste ones a week directly from the residence.

Another aspect to the waste handling is the commercial waste that is coming into the kampung for further processing or selling on. So are left overs from the surrounding textile factories bought by local entrepreneurs and sorted by colour and type, before either being processed into new garments or discarded and sold to yarn producers. Large amounts of commercial cardboards and plastics are also locally recycled, however not further processed despite being cleaned, dried and stacked. They are stored in local warehouses (often ground floor space of dwellings), before being sold on to dealers.

Local scavenging/recycling

Scavenger sorting of household waste occurs on several moments in time during this process, however outside of the kampung (or system boundary as per fig. 24). While the sorting of textile waste specifically acquired from surrounding factories is practised on the open field, household waste scavenging prevailingly occurs on disposal sites and is undertaken by specific site scavengers. Yet recycling makes up only 7,5% of the total household waste.[20] During interviews conducted it was noted by residents, that there is a strong wish for a kampung central collection point to overcome the irregular disposal of waste, yet residents are

18. Jong, H. N. (October 9, 2015). Indonesia in state of waste emergency. The Jakarta Post. Retrieved from http://www.thejakartapost.com/news/2015/10/09/indonesia-state-waste-emergency. [Accessed: September, 14, 2016]; 19.Jong, H. N. (October 9, 2015). Indonesia in state of waste emergency. The Jakarta Post. Retrieved from http://www.thejakartapost.com/news/2015/10/09/indonesia-state-waste-emergency. [Accessed: September, 14, 2016); 20. Jong, H. N. (October 9, 2015). Indonesia in state of waste emergency. The Jakarta Post. Retrieved from http://www.thejakartapost.com/news/2015/10/09/indonesia-state-waste-emergency. [Accessed: September, 14, 2016]

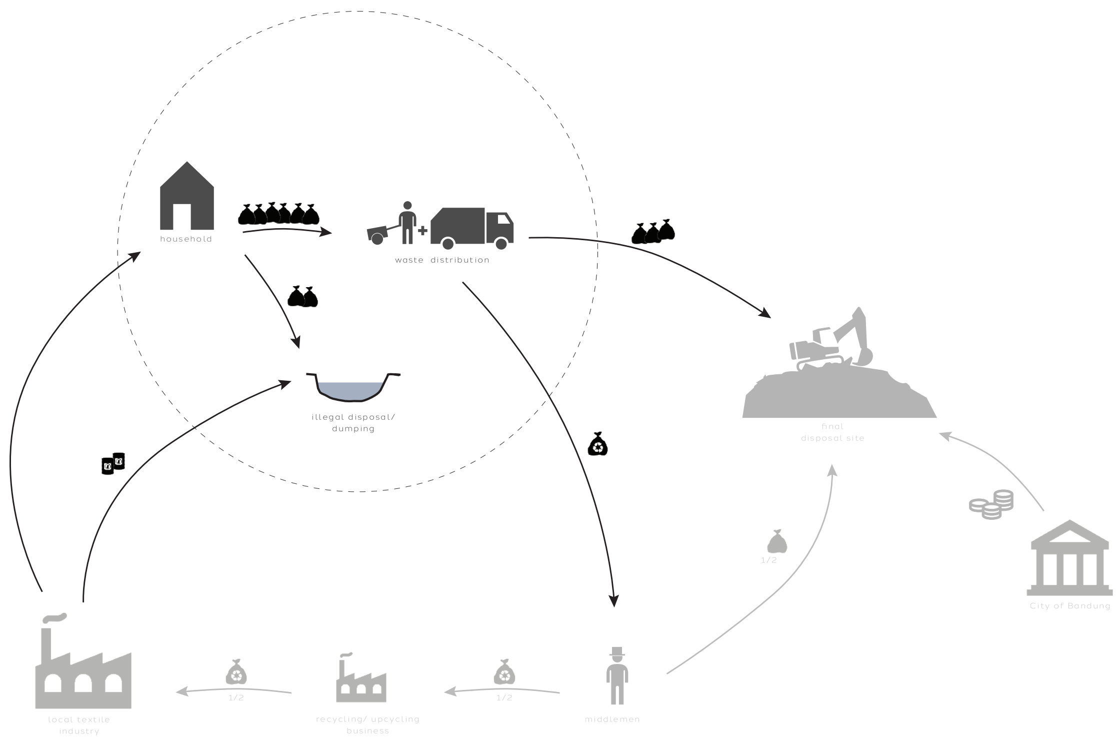


fig 23. Simplified waste flows (own image, 2017)

relying on Bandung wide initiatives to provide the organisation of such. No active household waste recycling is being undertaken by the residents directly. According to an article on the recycling of plastic packaging waste in Bandung, 96% percent of the respondents of a conducted interview was willing to separate their waste if a depot is available. From the interviews it was concluded that the willingness of waste separation at source will increase if the municipality keeps the waste separate and re-processes it.[21] The interview conducted during the field trip showed similar result. However, higher income households have noted less interest in the recycling as their waste is being picked up directly from scavengers and they are less involved in dealing with the waste. There is a limit of 5-10 minutes that residents considered workable to get to a central collection point.

Studies undertaken by Damanhuri, E. et al have shown that the low-income sector is more likely to engage in the separation of waste, but it has been noted by the authors that the reason for this is more likely to be an interest in the additional income factor generated from recycling as an economical resource rather than conscious environmental awareness. This reasoning is supported by findings during the field trip, as well as conducted interviews.[22]

Scavenging activities show an income level of 1.405.716 Rp - 2.870.895Rp (approximately 100€-200€) as per table 7. Looking at selling prices taken from a scavenger price list at the Bantar Gebang dumpsite near Jakarta[23] and comparing this with waste production of

* prices taken from dumpsite scavengers relate to the Bantar Gebang dumpiste near Jakarta

	prices of dumpsite scavengers in 1000Rp/kg	RW02 & RW12 - weekly waste accumulation in kg	**RW02 & RW12 - potential weekly revenue in 1000Rp**
Plastics:	0,72	1600,00	**1157,92**
Paper & Cardboard Waste	0,34	1300,00	**439,40**
Textile Waste	0,41	1200,00	**496,80**
Glass	3,80	300,00	**1140,00**

table 7. Potential economical benefit of waste dealing for RW02 and RW12 based on dumpsite scavenger prices (data source: Sasaki et al. (2014)

21. Chaerul M., Fahruroji, A. R., & Fujiwara, T. (2014). Recycling of plastic packaging waste in Bandung City, Indonesia. Journal of Material Cycles and Waste Management, 16(3), 509,518.; 22. Damanhuri, E & Padni, T. (2000). Reuse and recycling as a solution to urban solid waste problems in Indonesia. International Symposium on Waste Management in Asia Cities, 23 – 26 Oktober, Bandung.

Cigondewah a theoretical recycling revenue can be derived for the kampung. The potential weekly surplus generated could reach approximately 3.200.000 (see table 7). Yet, factors such as handler contacts would need to be taken into account. The intent of economical benefit for the kampung achieved by community wide recycling however constitutes a basis of a wide spread network and this aspect should therefore theoretically not have a large impact.

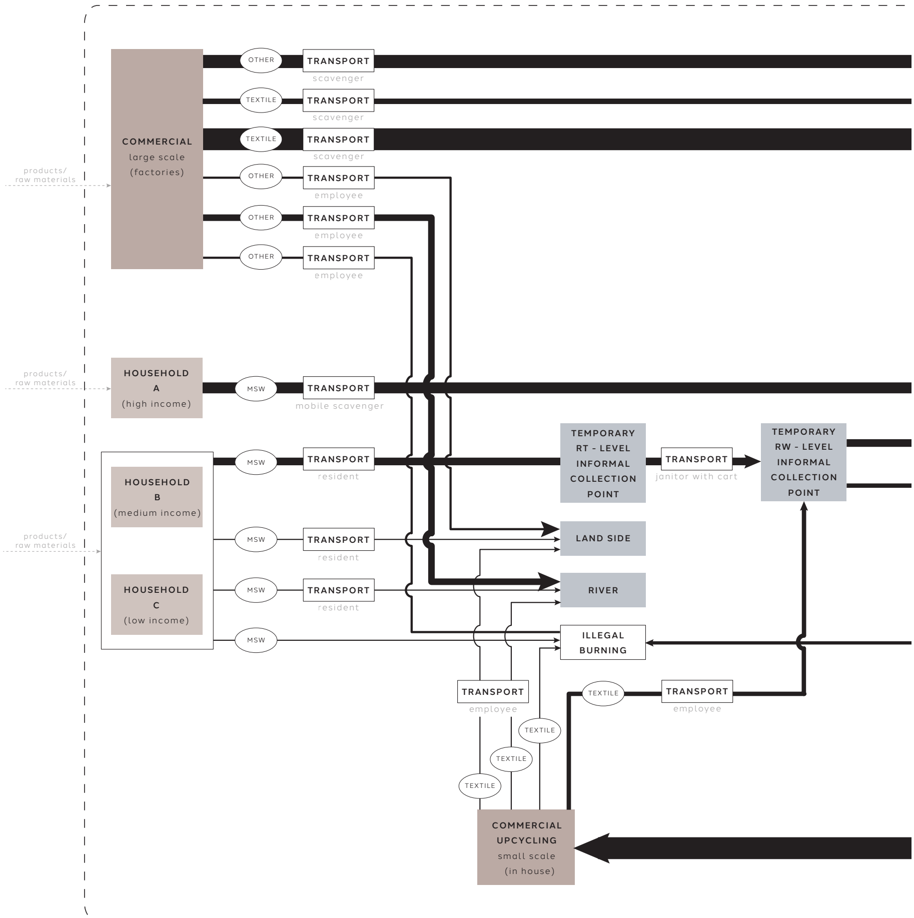
Bank Sampah

In 2008 under the nationally adapted model of 'reduce, reuse and recycle' the first sampah (waste) bank was founded in Yogyakarta. A sampah bank works like a bank in its core. Cleaned and sorted waste can be deposited. The weight is recorded and noted. At the end of the month it is sold by the bank to middleman for recycling and up-cycling and the revenue noted towards the depositors sampah bank account, minus a small administration charge (approximately 15%) to cover administration & employee costs. The depositor can then withdraw the money.

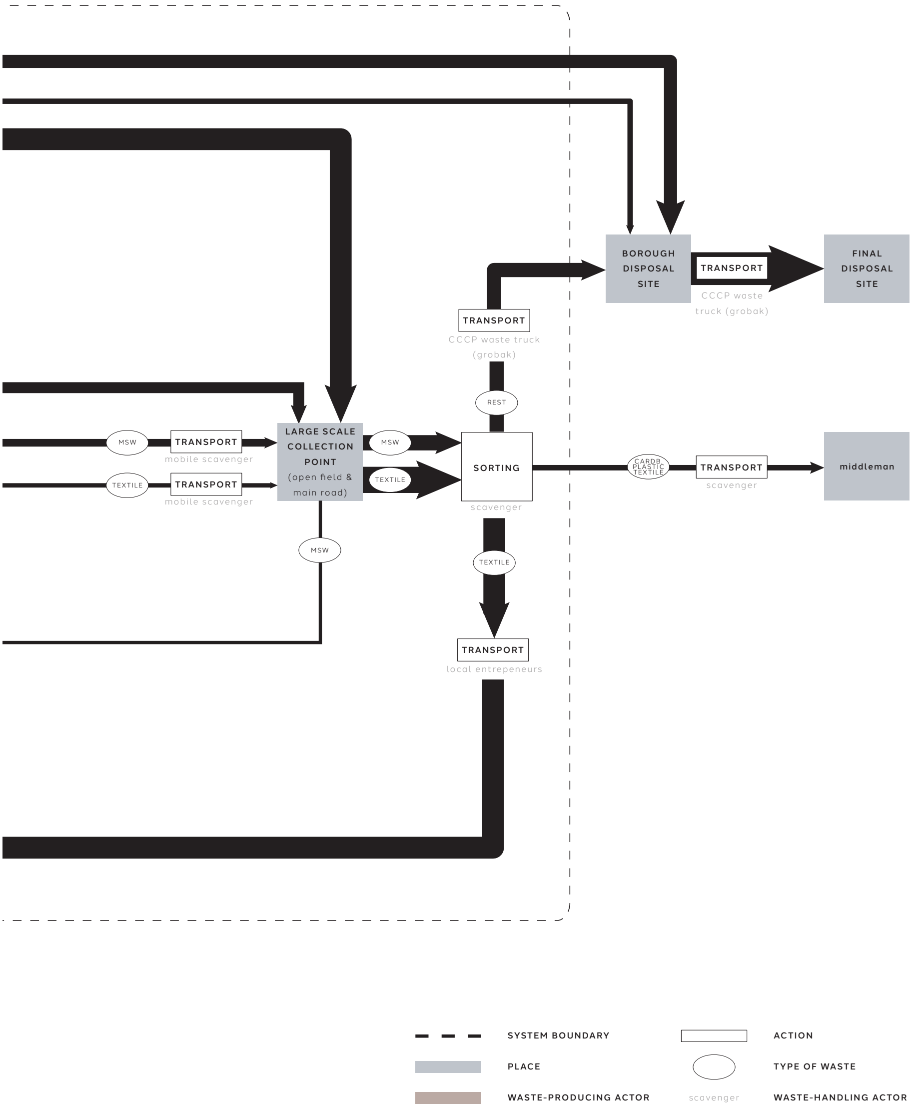
The sampah bank concept has since its initiation grown exponentially and in June 2012 Indonesia counted 728 banks that generated 31.2 million Rupiah on a monthly basis3 which amounts to approximately 3€ per month per bank (conversion rate from the 21 December 2016). The banks are often run by low income groups that make use of this gap as an opportunity to raise their income. Each waste bank serves approximately 1000 residents. To be able to service the whole of Bandung's Metropolitan Area a total of 8.600 banks would be required. For the context of the kampung in Cigondewah 3 banks would be needed to serve the entire population. Based on the revenue of existing sampah banks, a total of approximately 130.000Rp could be generated for RW02 and RW12 stretching over three sampah banks.[24]

23. Sasaki, S., Araki, T., Tambunan, A. H. & Prasadja, H. (2014). Household income, living and working conditions of dumpsite waste pickers in Bantar Gebang: Toward integrated waste management in Indonesia. Elsevier: Resources, Conservations & recycling; 24. Temesi compost. (c2017). Temesirecyclingcom. Retrieved 03 January, 2017, from http://temesirecycling.com/waste-banks/

fig 24. Waste flow diagram (own image, 2016)



Waste flow; line thicknesses indicate estimated relations of accumulated waste amounts


BOROUGH DISPOSAL SITE
TRANSPORT
CCCP waste truck (grobak)
FINAL DISPOSAL SITE
TRANSPORT
CCCP waste truck (grobak)
REST
MSW
TRANSPORT
mobile scavenger
TEXTILE
TRANSPORT
mobile scavenger
LARGE SCALE COLLECTION POINT (open field & main road)
MSW
TEXTILE
SORTING
scavenger
CARDB PLASTIC TEXTILE
TRANSPORT
scavenger
middleman
MSW
TEXTILE
TRANSPORT
local entrepeneurs
SYSTEM BOUNDARY
ACTION
PLACE
TYPE OF WASTE
WASTE-PRODUCING ACTOR
scavenger
WASTE-HANDLING ACTOR

07 SUMMARY PART III

The research has transpired five key issues that Cigondewah is dealing with that will form the basis for the design project and for the following analysis of part IV:

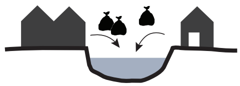
1.
The waste pollution challenge is regarded as the most pressing considering the imminent negative impact on the health of residents and therefore defines the underlying theme of the graduation project.

2.
It is necessary to consider the income of the residents for the aspect of costs relating to waste transformation and a potential market price for waste building materials within the following analysis.

3.
Following on from that, the lack of structural quality is another critical aspect that will need to be addressed to ensure the safety of residents and also as a cost saving measure in light of an increased life span of buildings.

4.
Bandung's population growth in the near future will require a large number of additional housing. The already limited ground space in RW02 and RW12 will have to see a vertical densification. This is a challenge that is directly linked to the above mentioned lack of structural quality.
It is considered important for the residents to preserve the minimal available public open space and enable vertical expansion of future dwellings.

5.
The situation of sanitary facilities is poor and could benefit from updating to avoid further heath complications.



waste pollution
household and commercial waste is burned and/or dumped locally, adding to health issues and environmental problems

lack of funds
while the income level differs throughout the kampung, the mean is comparably low in income, leaving little funds for construction and the overall improvement of the kampung

lack of structural quality
prevailingly self-built houses in combination with a lack of construction knowledge resulting in structurally poor and unsafe dwellings

housing shortage
the current low stock of houses and the expansion of the factories are indicating an additionally needed stock of housing in the midst of the predicted rise in population in Bandung

lack of basic necessities
minimal sanitary facilities of poor quality and subject to heavy pollution (drainage blockage, water pollution) are causing health issues. The water is not drinkable.

fig 25. Key problems of Cigondewah (own, 2016)

Part IV:

RESULTS WASTE TRANSFORMATION

08 POTENTIAL WASTE TRANSFORMATION

During interviews conducted, all participants noted that they would be inclined to use waste materials for construction if these where offered and could compete with the costs of current building materials. A prototype of the listed 'Squarry' plastic tiles (p. 43) shown to the interviewees was perceived with interest and all participants confirmed their interest on using waste materials on the hand of this sample.

The following is a comparable overview of case study projects that qualify for potential application in Cigondewah. While the main focus of potential waste material transformation is set on polluting materials, to assist with the purification of the public environment, organic household waste was also considered. The first part consists of case study analyses prevailingly chosen on the basis of the waste material used and generally on their potential for the context but also to reflect a variety of differing approaches or material uses. This is followed by a second part of a comparison of the analysed case studies performances in relation to the categories distinguished from the context research, as well as a calculation of production costs.

In the first part of the following chapter case studies have been analysed with regard to the availability of the to-be-recycled material, the implicated costs and spaces for processing the material, as well as it's transformation simplicity and its suitability and durability as building material. For this a ranking system has been derived. The individual analyses have been listed in order of their overall scoring for the purpose of the report. Each analysed material has been given an overall scoring number indicating their suitability for a beneficial implementation in Cigondewah. This number is calculated by multiplying the scoring value (see figure in the appendix) assigned with a pre set value given to each category depending on its importance for the context of Cigondewah. All sums are subsequently added up and form the overall scoring number. This way the material can be pre-compared by means of a singular number while given consideration to the variation of importance of the categories. The overall scoring number is indicated at the top right of each analysis sheet. The different categories have been ranked in respect to material availability, production, construction, business value, building performance and impact on the purification of the environment. For this the focus was set on the five previously identified key issues of Cigondewah, particularly the aspects of the environmental waste pollution improvement, structural quality of housing and limited funds. The aspect of time has been given low priority due to the fact that residents have larger amounts of time at hand. Furthermore, the criteria have been rated with respect to their influence on valid entrepreneurial models in order to make businesses based on waste building materials economically valuable. Physical properties of the prospective building material relating to durability and safety have been given priority.

Despite the ranking, each material has been looked at individually and considered in the context of all circumstances and its suitability to the particular context of Cigondewah.

In the second part of the chapter total product costs were calculated according to current buying prices of recycled material and estimated production costs. These are then compared with currently used building materials. This study was undertaken in order to compare the suitability of each new 'model' as business model for the life/work environment of Cigondewah by means of calculating the revenue thresholds.

It is important to note that the following analyses of existing applications and or transformations of waste materials are based on the material itself and do at this point not specifically state additional means for construction (e.g. reinforcement) in the given listing of materials used, as this is commonly used in construction and needed for the majority of case studies. No consideration has been given to the bio-degradability of the potential products as it is the core incentive of the project to make use of polluting, non-degradable waste materials.

fig 26. Process indicating symbols (own image, 2017)

The symbols in figure 27 indicate processes required by the case study to arrive at the either transformed material or approach to reusing of waste material. The process ‘other amendments’ ranges per the particular project and indicates further processes that are described in the text directly. Most commonly this relates to hand tool amendments to the material.

The case studies are arranged in order of building element, starting with structural elements, followed by cladding material and wall filling/insulation material.

A more extensive list of possible transformations can be found in the appendix. This part of the appendix in combination with this analyses will form a separate catalogue as an informative document for local inhabitants of Cigondewah with an increased variety of possibilities to *‘make a living out of cleaning up their own environment.’*

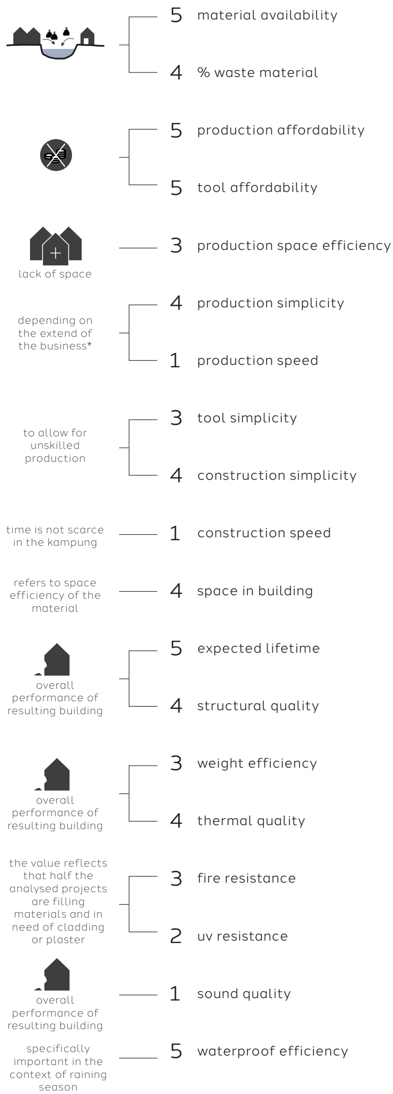


fig 27. Rating of categories for case study analyses (own image, 2017)

data source: Build abroad. (c2017). Buildabroadorg. Retrieved 03 January, 2017, from https://www.buildabroad.org/2016/08/18/eco-blocks/; fig. 28. image retrieved from: https://1.bp.blogspot.com/-86aPo0NH_dk/V2B3SyhoWJI/AAAAAAAAMEY/hUvhzYsxOn481qwiAEgyFMVpP1shSoFzACLcB/s1600/12439181_515920521925717_5403923886328847569_n.jpg

Colombian architect Oscar Mendez started developing the Conceptos Plásticos bricks during his master studies in a bid to offer cheap housing for the 40% of homeless Colombians.

The bricks are formed of plastics. For this all types of plastics can be used, making sorting unnecessary.

Construction is made easy and assisted by grooves on top of the bricks themselves, which make modules stackable like Lego bricks. In addition this eliminates the need for adhesive, making dismantling and future reuse just as easy. The bricks slide into a frame structure made of the same material and are simply constructed with the aid of a hammer.

The long but narrow form of the brick make it space efficient and quick to assemble. According to the architect it take four men approximately 5 days to construct a 40m2 house. The structure is currently designed to only suffice as a single story structure, but could be adapted for vertical extension. Other building elements such as roof structures could be formed in a similar way.

material availability	●●●●●	tool simplicity	●●●○○	thermal quality	●●●○○
% waste material	●●●●●	constr. simplicity	●●●●●	fire resistance	●●●●●
product. afford.	●●●○○	constr. speed	●●●●●	uv resistance	●●●●○
tool afford.	●●●○○	space in building	●●●●●	sound quality	●●●○○
product. space eff.	●●●○○	expected lifetime	●●●●●	waterproof eff.	●●●●●
product. simplicity	●●○○○	structural quality	●●●●●	usable for	structure, roofing, access
product. speed	●●●○○	weight efficiency	●●●○○		

General Information:

development/ implementation: Colombia
developed by: Conceptos Plásticos
building element: structure, wall
material: plastic, fire-resistant additive
size (HxLxW in mm): approx. 150 x 500 x 100
density (in kg/m3): unknown

BYFUSION BRICKS 250

data source: Hebel, D. E., Wisniewska, M. H. & Heisel, F. (2014). Building From Waste - Recovered Materials In Architecture And Construction. Basel: Birkhaeuser Verlag GmbH. p.114-115
fig. 29. Squarry (images retrieved from: http://www.byfusion.com/)

Byfusion bricks were developed as a response to the current plastic pollution challenge. The process allows unsorted plastics to be used in a mix. The complexity and spatial needs of the manufacturing process are dependant on the scale of production. In any case a cleaning and drying facility is needed, as well as a tool for shredding and an oven with incorporated compression function. The waste material is hackled and then heated and compressed into shape. The mould for this particular design caters for simple construction, with the addition of raised parts that allow for the modules to be stackable and constructed without further need of adhesive.

The flexibility with regard to the pressed shapes make this technique a viable method to produce all sorts of building materials. In some cases these will need extra support however. So can for example a wall made from the bricks that is compressed between too plates become structurally viable.

material availability	●●●●●	tool simplicity	●●●○○	thermal quality	●●●●○
% waste material	●●●●○	constr. simplicity	●●●●●	fire resistance	●●○○○
product. afford.	●●●●○	constr. speed	●●●●●	uv resistance	●●●○○
tool afford.	●●○○○	space in building	●●●●○	sound quality	●●●○○
product. space eff.	●●●○○	expected lifetime	●●●●○	waterproof eff.	●●●●●
product. simplicity	●●●○○	structural quality	●●●●●	usable for	structure, facade, roofing, insul., access
product. speed	●●●○○	weight efficiency	●●●○○		

General Information:

development/ implementation: New Zealand
developed by: Byfusion Limited
building element: building blocks
material: all types of plastic
size (HxLxW in mm): 200 x 400 x 200
density (in kg/m3): 375-625

REMATERIALS ROOF PANELS

285

Keen on finding a solution for both the waste pollution on streets, as well as limited funds of many residents resulting in poor or broken roofing Hasit Ganatra and Swad Komanduri developed ReMaterials roof panels. The panels comprise of packaging material organic waste as a binder.

The packaging is first shredded and mixed with water into a pulp mass. The organic waste fiber are then added as a reinforcement element, before the paste is cast into panels and cold compressed into hard panels. In a subsequent step these panels are subjected to heat in their respective compressed form as a means of drying out. As a final touch a waterproofing coating is applied. Although, a variety of different steps is required for the production process, the method is comparably simple and requires little craftsmanship.

The panels have an interlocking design and are easily applied to a roof.

material availability	●●●●●	tool simplicity	●●●●●	thermal quality	●●●●○
% waste material	●●●●●	constr. simplicity	●●●●●	fire resistance	●●●○○
product. afford.	●●●●●	constr. speed	●●●●●	uv resistance	●●●●○
tool afford.	●●●●●	space in building	●●●●●	sound quality	●●●●○
product. space eff.	●●●●○	expected lifetime	●●●●○	waterproof eff.	●●●●●
product. simplicity	●●●●○	structural quality	●●○○○	usable for	facade, roofing, internal tiling
product. speed	●●●●○	weight efficiency	●●●○○		

data source: Hebel, D. E., Wisniewska, M. H. & Heisel, F. (2014). Building From Waste - Recovered Materials In Architecture And Construction. Basel: Birkhaeuser Verlag GmbH. p.82-83
fig. 30. Hebel, D. E., Wisniewska, M. H. & Heisel, F. (2014)

General Information:

development/ implementation: India
developed by: Hasit Ganatra, Swad Komanduri, ReMaterials
building element: roofing
material: packaging and agricultural waste
size (HxLxW in mm): 610 x 610 x 25
density (in kg/m3): unknown

SQUARRY 262

fig 31: image retrieved from: http://www.squarry.org/
data source: Better future factory. (c2016). Squarry.org. Retrieved 02 January, 2017, from http://www.squarry.org/

Squarry is a tiling material developed from recycled plastic as a business opportunity for local entrepreneurs while supporting the clean up of local environments. It can be produced from PET, which is due to its very specific melting temperature a rather difficult material to recycle. Key is an exact melting temperature. For this the designers have developed a simplified version of the high-tech process in form of a commercially available mini-shredder and oven. Both are small in size and can theoretically fit into any normal household. The manufacturing process is comparably simple: shredding, melting, casting.

A sample squarry tile was presented to residents of the Cigondewah kampung to test its acceptance. The tile was approached in a curios manner and was well perceived. The interviewed residents noted that they would use the plastic tile in their house if the product would match current material prices.

material availability	●●●●●	tool simplicity	●●●●○	thermal quality	●●●○○
% waste material	●●●●●	constr. simplicity	●●○○○	fire resistance	●●●●○
product. afford.	●●●●○	constr. speed	●●○○○	uv resistance	●●●●○
tool afford.	●●●●○	space in building	●●●●●	sound quality	●●○○○
product. space eff.	●●●●●	expected lifetime	●●●●●	waterproof eff.	●●●●●
product. simplicity	●●●●○	structural quality	●○○○○	usable for	facade, roofing, internal tiling
product. speed	●●●●○	weight efficiency	●●●●○		

General Information:

development/ implementation: Angola, 2016
developed by: Better Future Factory
building element: tiles
material: plastic
size (HxLxW in mm): 100x100x8
density (in kg/m3): unknown

data source: Walker, B. (2015). Bethanywalker. Retrieved 02 January, 2017, from http://www.bethanywalker.com/
fig. 32. Walker, B. (2015).

Though the trinket series was developed as an art project by Bethany Walker, the practical translation of combining concrete and textile is of interest. Concrete as a material is an important part of the kampung building culture. However, environmental effects of concrete mixtures are problematic and reduced use of concrete preferred. Using waste materials such as textiles as an aggregate for the mixture can assist in the reduction of CO2 emissions by reducing the need for concrete while aiding as a semi flexible reinforcement element. In the context of Cigondewah this could be specifically interesting as it reflects the particular identity relating to textile waste and ornamentation. In the case of the trinket series cement is cast over elements of fabric, making this a generally simple production method with little tools necessary. The trinkets could be implemented as tiles for the context of Cigondewah.

The nature of concrete will act as a passive cooling element if used for tiling and is waterproof. The addition of textile within the composite improves further improves thermal and sound performances.

material availability	●●●●○	tool simplicity	●●●●●	thermal quality	●●●●●
% waste material	●●●○○	constr. simplicity	●●●○○	fire resistance	●●●●●
product. afford.	●●●●●	constr. speed	●●●○○	uv resistance	●●●●●
tool afford.	●●●●●	space in building	●●●●●	sound quality	●●●●○
product. space eff.	●●●●●	expected lifetime	●●●●●	waterproof eff.	●●●●●
product. simplicity	●●●●●	structural quality	●○○○○	usable for	facade, roofing, internal tiling
product. speed	●●●●○	weight efficiency	●●○○○		

General Information:

development/ implementation: England
developed by: Bethany Walker
building element: artwork
material: cement, textile
size (HxLxW in mm): 10 x 10 x 2
density(in kg/m3): unknown

BIMA MICRO LIBRARY

212

data source: Archdaily, (2016). ArchDaily, Retrieved 02 January, 2017, from http://www.archdaily.com/790591/bima-microlibrary-shau-bandung
fig. 33. own image, 2016

Shau architect's Bima Micro library utilises locally found ice cube buckets for its facade. The alternative solution for the facade addresses the local climate in a natural way via a balance of perforated and closed buckets. Buckets are angled to divert rainfall. For high humidity situations during heavy rainfall, lightweight transparent sliding doors can be used to close the internal space off. The library uses a total of 2000 buckets, that were prepared by local community members.

While the material poses an interesting alternative approach to reusing waste material, the necessary frame structure makes the construction more complex and less cost efficient, thus balancing the saved cost from the waste material out in this case. However, the system could be amended to a simpler frame structure with a different material.

Note: for the point evaluation the system is considered as a whole including the steel frame. The material availability is rated in the consideration of the wider Cigondewah context and the potential of similar though different materials that could be found in the area to replace the particular ice cream buckets.

material availability	●●○○○	tool simplicity	●●●●●	thermal quality	●●●○○
% waste material	●●●○○	constr. simplicity	●●●●○	fire resistance	●●●○○
product. afford.	●●○○○	constr. speed	●●●●○	uv resistance	●○○○○
tool afford.	●●●○○	space in building	●●●○○	sound quality	●○○○○
product. space eff.	●●●●○	expected lifetime	●●●●○	waterproof eff.	●●○○○
product. simplicity	●●●●●	structural quality	●●●○○	usable for	facade
product. speed	●●●●●	weight efficiency	●●●●●		

General Information:

development/ implementation: Indonesia
developed by: Shau architects
building element: facade
material: ice cream buckets, steel framing
size (HxLxW in mm): unknown

09 ANALYSES COMPARISON

General

The direct comparison of all analysed case studies as per table 12 (see appendix p. 61) shows that all analysed materials generally perform well within their respective building element category. 'ReMaterials' scores highest, yet the artistic aspect of the 'Trinket Series' directly engages with the context and the local preferences of external decoration with colour, texture and pattern.

Revenue

In table 9 the estimated potential revenue per analysed material example has been analysed. Material costs have been based on the concept of supporting local business and governmental subsidies to promote recycling and re-suing on a local scale and have been assumed at 20% of scavenger prices as shown in table 7 on p. 31. The simulation shows that the majority of the analysed examples have a positive outcome. However, this calculation serve solely as conceptual testing of potential economic value of the particular materials for the kampung and are highly subjected to local fluctuations of material prices and waste availability. The production costs have not been calculated (as it is difficult to gather data for this in the context) and will need to be deducted from the calculated potential revenue. Fur-

	Conceptos Plásticos	By fusion Bricks	ReMaterials Roof Panels	Squarry	Trinket Series	Bima Microlibrary
Waste Material	plastic	plastic	cardboard, organic waste***	plastic	60% textile, 40% cement	plastic
Estimated amount of waste material used for produced material in kg/m³	1040	1040	532,5	1080	1665	1080
Produced waste per week in kg	1600	1600	2600	1600	2400	1600
Maximum possible to produce per week based on resources in m³	**1,54**	**1,54**	**4,88**	**1,48**	**1,44**	**1,48**
Potential production costs and earning gap per week* in Rp/m³	**892.677**	**892.677**	**1.631.042**	**273.304**	**-213.428**	**851.081**

* based solely on waste amounts produced in RW02 & RW12

table 8. Respective case study material costs (own graphic, 2017)

	Conceptos Plásticos	By fusion Bricks	ReMaterials Roof Panels	Squarry	Trinket Series	Bima Microlibrary
Waste Material	plastic	plastic	cardboard, organic waste***	plastic	60% textile, 40% cement	plastic
Estimated amount of material used for produced material in kg/m³	1040	1040	532,5	1080	******1665	1080
Waste material costs* in Rp/kg	144	144	cardboard 68 organic 0	144	textile 82 cement 1400	144
Total material costs Rp/m³	149.760	149.760	5.950	155.520	488.066	155.520
Cost of comparable existing material			5950			
hollow cement block in Rp/m³	730.000	730.000				
regular brick in Rp/m³						730.000
teracotta roof tiles n Rp/m³			340.000	340.000	340.000	
Potential production costs and earning gap per m³ produced material in Rp/m³	**580.240**	**580.240**	**334.050**	**184.480**	**-148.066**	**574.480**
initial one off cost for machinery	high	high	low	medium	low	low

* based on 20% of scavenger prices. Reduced waste material price as part of a subsidy from the cleaning the communty up scheme. materi

** Average cost of comparable exisitn gbuilding material minus total production costs of waste material

*** Balance of material not given - estimated at 50% each

**** ubunto blocks slightly less well compressed -

***** half the price of cardboard as organic waste is for free

table 9. Respective case study revenue potential per week(own graphic, 2017)

thermore, initial machine costs have been ignored. These may potentially be lend by the government as part of the cleaning up scheme. 'Conceptos Plásticos' and 'Byfusion' have achieved the highest possible revenue in the simulation. The 'Trinket Series" has as only example shown a negative potential revenue for production. This is however subject to material composition and largely dependent on the percentage of cement used. Context fitting engineering of the material in respect to material compositions could largely influence this number.

Overall it can be said that keeping in mind the estimated numbers and variables, and the fact that the calculated monthly income is solely based on the waste production of RW02 and RW12, the majority of case studies proof to be economically valuable business models. Depending on production efficiency, running costs and sourcing of waste material from surrounding areas, the monthly revenue could be increased. Not to forget however, that the material prices are based on subsidized prices.

10 CASE STUDY - KAMIKATSU

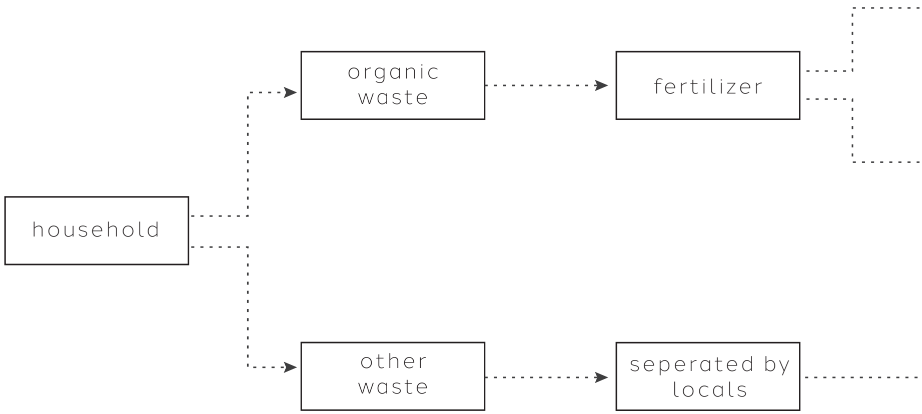
Kamikatsu in Japan, is a small village of approximately 1700 inhabitants. Similarly to Cigondewah, burning and dumping of waste was here once the most common form of waste disposal. In the 90's Kamikatsu invested in two incinerators as primary waste disposal method. Both incinerators were shut down a few years after first operating due to health concerns, Kamikatsu needed a solution to the high cost associated with waste disposal in neighbouring facilities. The community subsequently decided to make a change and started recycling. As of 2016 Kamikatsu achieves an 80% recycling rate within the village and is now thriving towards a completely zero waste lifestyle by 2020.[25] The residents achieve this high rate by drastically reducing waste production, as well as recycling and reusing items. What originally started with 9 categories of waste, is as of 2016 sorted into a total of 34 categories.

The local kuru-kuru (meaning circular) shop exchanges peoples discarded items for other items and also offers new products that locals produced from waste material. Organic waste is to a 100% composted. Local farmers are provided with compost, while external farmers can buy it.

Unlike Cigondewah, Kamikatsu has the advantage of having a large amount of open space available for the storing and processing of separated waste. The storing takes place in covered outdoor spaces with the help of a variety of recycled containers.

What is notable is the strong community unity in this case. Every resident commits to recycling their waste meticulously. Nevertheless, there is also economic value to the lifestyle. The village now saves the cost of waste disposal and further generates income via produced new items, but also from educational tours offered to tourists.

25. World economic forum. (c2017). World Economic Forum. Retrieved 10 September, 2016, from https://www.weforum.org/agenda/2015/04/zero-waste-a-small-towns-big-challenge/


household
organic waste
fertilizer
other waste
seperated by locals

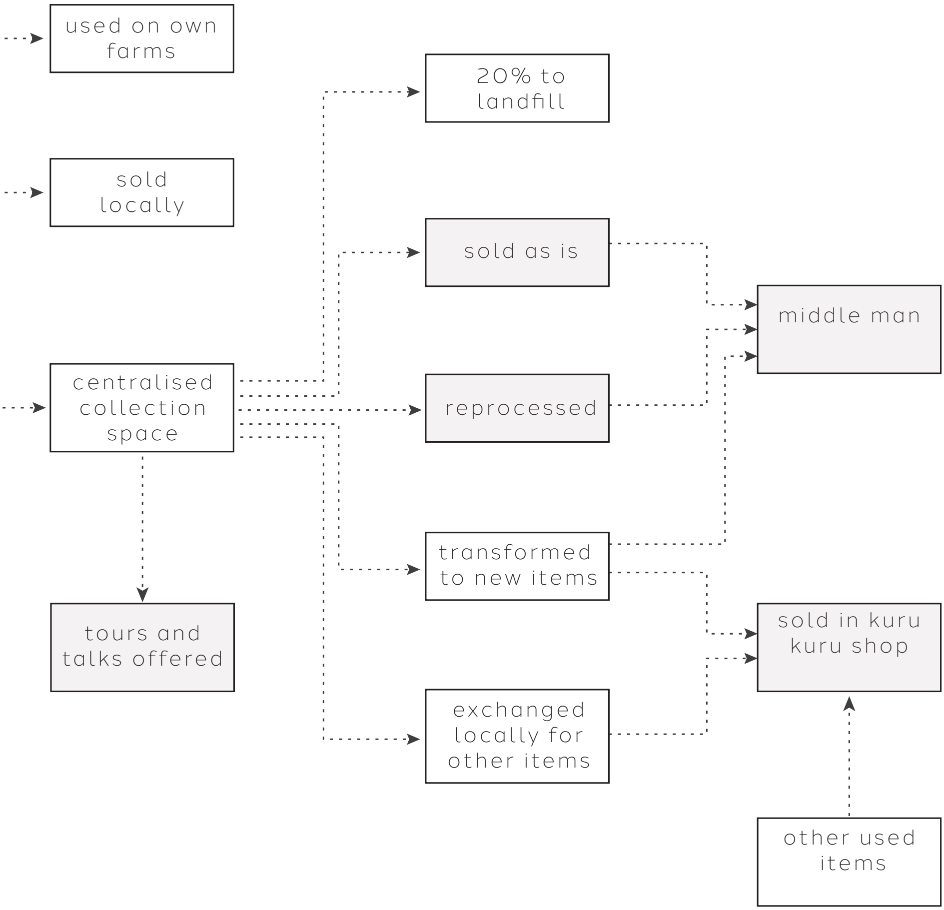


fig. 34. Waste flows in Kamikatsu (own image, 2016)

fig 35: Kamikatsu waste sorting

Part V:

CONCLUSION

11 CONCLUSION AND DISCUSSION

The research results show that current waste handling in Cigondewah is insufficient and causes environmental but also health issues for residents. The expected population growth in the next 15 years will intensify the situation and ground work for appropriate waste management but also safe building and sufficient sanitary infrastructure should be laid now to form a solid base for future densification. This is in particular of relevance for Cigondewah in the midst of turning from a peri-urban kampung into an urban kampung, given its location along the edge of the city of Bandung. Developing a working and decentralised waste management should also be a focus of the city government in light of already low capacities of final waste disposal sites around Bandung.

From the context research (part III) gaps but also opportunities for waste handling improvement, economical benefit and construction alternatives have transpired. While an informal distribution system is in place in Cigondewah, no official collection/disposal point is available, resulting in insufficient waste disposal. Furthermore, household waste recycling is not undertaken by residents themselves. The current state leaves large room for improvement. The concept of sampah banks as a decentralised waste management system is a valid and economical alternative to waste disposal and could be implemented in the kampung, as a measure to reduce waste but also as an economical model with the potential of generating a surplus of 130.000Rp per week and reducing existing weekly janitor and scavenger costs. Reduced waste amounts will lift the pressure of final disposal sites. An official collection point is needed and wished for by residents. The current local distribution practice makes such a point valid along the two main temporary collection points namely the football field and the main road. The main road point however has limited space and would not be able to cater for an incorporated bank sampah prototype. The football field could likely be a workable location for a bank sampah, as well as further processing as part of a life/work balance in combination with housing, yet the shortage of public space should be kept in mind and potentially occupied space on the open field be kept to a minimum. Any form of offered waste recycling should be made easy and well explained.

The analyses of case studies (part IV)

show that while the pollution is an important problem to be addressed, in combination with densification of the area and needed housing stock, it forms an opportunity in the form of building material resources and economical benefits. Limited funding being a present challenge throughout all aspects of the life in Cigondewah, a facilitation of recycling and reusing may not only address the waste pollution issue, but also generate income for the neighbourhood. However, though all of the analysed waste material case studies have a potential for successful community and environment supportive implementation, neither one manages to address all key aspects of waste pollution reduction, affordability, production and construction ease, building material qualities and comfort and visual preferences of local inhabitants at the same time.

Furthermore, the case studies were not able to support future vertical densification for more than three storeys, or if they did were not workable in relation to required footprint in the context of low ground space availability. Yet, vertical expansion will be unavoidable in the future. As a result it is concluded that a building frame structure will be required to facilitate building elements from recycled materials such as wall infill's, cladding, roofing or internal fittings. This conclusion is further supported by current construction methods.

As the use of concrete for the structural elements of buildings is however common practice nowadays, a system of safe construction technique/process would be of benefit. Furthermore, the use of a structural frame makes the infill adaptable and free from structural consideration.

It also offers an opportunity for direct future planning by means of providing an increased frame structure for future situations that can be adapted in an incremental way once need occurs and funds have been made available. Nevertheless, the level of potential generated income from waste processing into building materials could allow for more funds being allocated towards higher quality materials for a safer structure, thus directly improving the housing situation, while adding a special character to the built environment. The 'waste to material' concept is concomitantly impacted by any areas waste. Type of most suitable transformation options may differ and so will visual appearances (colour, texture) of waste building materials depending on the waste composition of any particular area.

The analysis of ReMaterials roof panels has proven to perform best in the evaluation. The method is very applicable to the context and its climate, yet it is not a structural solution and the least economical. However, local tendency of personalisation of the outer skin of dwellings could be well supported by this approach. The general method of combining existing material stock with waste material is a valid approach to working with waste material as building material and is worth investigating further by means of direct physical testing.

Limitations and reflection

While theoretical thought has been given to the aspect of individual executive actors involved within the new waste handling management and processing, no explicit investigation into this subject has been undertaken at this point. Furthermore, the impact on the role of the mobile scavenger that is reduced by the new approach should be investigated and potential incorporation of this role into the new waste handling approach be considered.

It is notable that only waste materials with high pollution rates such as plastic, cardboard and paper, textiles, but also organic waste have been considered for building material application. While organic waste is naturally compostable and causes less of a threat to the environment and health of residents, it makes up a high percentage of the total of household waste produced and is therefore a large littering and space factor in the inappropriate disposal of waste in the neighbourhood.

The literature and observation based research was particularly limited in respect to exact data for the context, which is to a large due to the informal character of the neighbourhood resulting in limited available data. The literature research of the material case studies forms a good basis of understanding of the direction and potential of waste processing into building materials, but as described above would benefit from physical experimentation in order to be streamlined towards the particular context situation, especially with regard to material costs. Overall, the chosen method of a combination of literature research, and local observations and interviews as laid out in Part II appears appropriate and gives great insights into the subject and context and key problem and opportunities.

12 DESIGN CONSEQUENCES

From the research a design programme of three prevailing parts has transpired:

1. A decentralised waste management and recycling facility - sampah bank

2. a processing facility (most likely attached to sampah bank)

3. and an inclusive future proof housing model based on safe construction and local resources.

In part attempting to design social behavior, as well as laying ground work for safe building structures and servicing infrastructure. The concept of the programme is based on a co-operation of kampung inhabitants (as initiator, user and maintainer) and the city government (as facilitator - on a financial and infrastructure level), as well as in part local factories as stakeholders in the well being of migrant workers and the creation of a safe work and life environment in light of global perception of the industry (as a financial sponsor/ partner) as illustrated. Overall the developed theoretical framework and programme present a positive alternative for waste handling and inclusive construction approaches as illustrated in figure 38.

Required spaces for the sampah bank and processing facility are shown in table 10. The conclusions made on the construction method will require an appropriate frame structure as the basis of all construction work. For this purpose the application of the 'Cast' system developed by Nadia Remmerswald will be further investigated in conjunction with design processes.

table 10. Spatial needs (own graphic, 2017)

	RWO2&12 accumulating waste amounts in ton per week	spatial requirements /dimensions of waste m^3	spatial requirements in m^2 on the basis of 2 metre height
Reception & Bank Administration			**6**
Initial Collecting & Sorting			
Organics* not cleaned	7,90	8,88	5
Plastic (mixed)* seperate containers in execution	1,60	1,78	1
Glass	0,30	0,83	0,5
Cardboard & Paper	1,30	13,00	7
Textile	1,20	0,86	1
Rubber* not cleaned	0,10	0,01	0,5
Metals (mixed)* not cleaned	0,20	0,01	0,5
Rest Household Waste* not cleaned	2,60	21,67	11
Total Collection/ Sorting & Admin - incl. work space (8m^2)		**47,03**	**40**
Processing on the scale of maximum weekly production			
Cleaning			20
Drying			40
Shredding			8
Heating			10
Compressing			10
Cooling			15
Casting			8
Finishing			9
Total Processing - incl. work space (15m^2)			**75**
Trading			
Storing			**20**
Selling			**5**
Total Collection/ Sorting & Admin - incl. work space (15m^2)			**25**
TOTAL			**140**

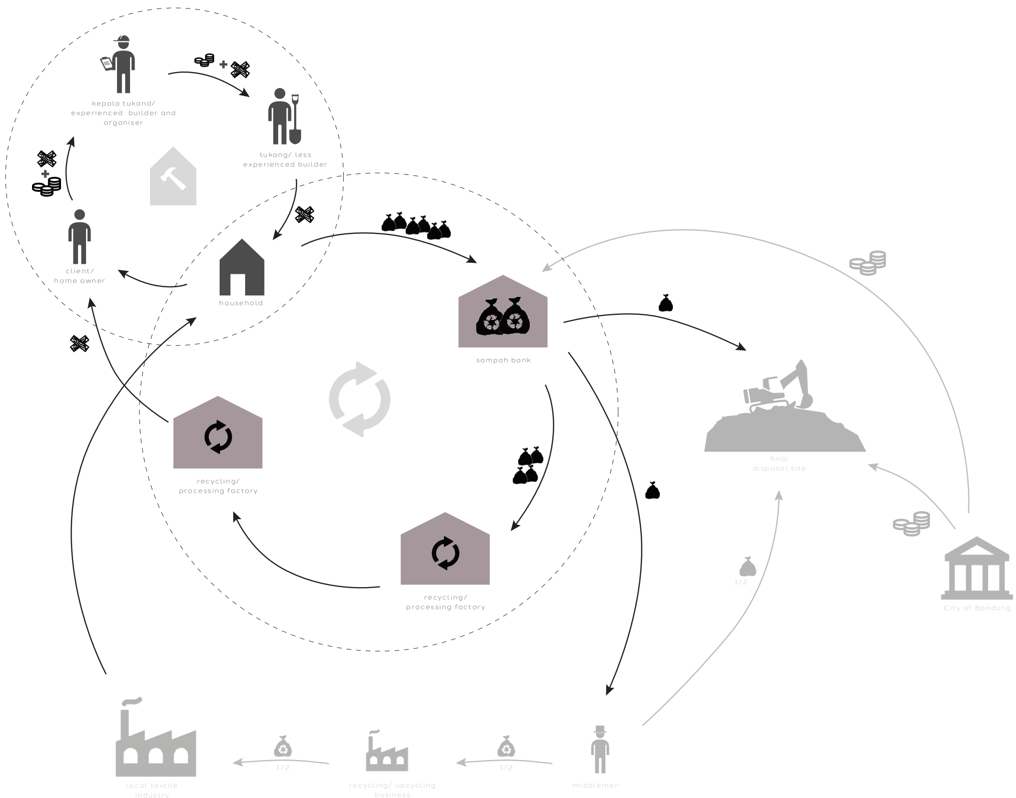


fig. 36. Combined flows For Cigondewah (own image, 2016)

13 LITERATURE

Archdaily. (2016). ArchDaily. Retrieved 02 January, 2017, from http://www.archdaily.com/790591/bima-microlibrary-shau-bandung

Agamuthu, P., Khidzir, K. M. & Hamid, F. S. (2009). Drivers of sustainable waste management in Asia. Kuala Lumpur: Institute of Biological Sciences, University of Malaya.

Benjamin, S., Ali Arifin, M., & Sarjana, F. P. (1985).The Housing Costs of low income Kampung dwellers. HABITAT INTL, 9(1).

Better future factory. (c2016). Squarryorg. Retrieved 02 January, 2017, from http://www.squarry.org/

Borden, G. P. & Meredith, M. (2012). Matter Material Processes in architectural production. New York: Routledge.

Build abroad. (c2017). Buildabroadorg. Retrieved 03 January, 2017, from https://www.buildabroad.org/2016/08/18/eco-blocks/

California Integrated Waste Management Board (1996). Recycling Data Report, Sacramento: California Integrated Waste Management Board.

Cococan (2016). Home at work. Welcome to the Fashion Village!. Delft: Delft University of Technology.

Damanhuri, E. (2005). A future prospect of municipal solid waste management in Indonesia. The 5th Asian-Pacific Landfill Symposium, October 22–24, Sapporo.

Damanhuri, E. (2005). Some principal issues on municipal solid waste management in Indonesia. Expert Meeting on Waste Management in Asia-Pacific Islands, Oct 27–29, Tokyo.

Damanhuri, E. (2010). Informal Collectors of Recyclable Waste and Used Goods in
Indonesin, in Kojima, M. (ed.), 3R Policies for Southeast and East Asia. ERIA Research
Project Report 2009-10, Jakarta: ERIA. pp.71-101.

Damanhuri, E., Wahyu, I. M., Ramang, R. & Padmi, T. (2009). Evaluation of municipal solid waste flow in the Bandung metropolitan area, Indonesia. Bandung: Springer.

Damanhuri, E & Padmi, T. (2000). Reuse and recycling as a solution to urban solid waste problems in Indonesia. International Symposium on Waste Management in Asia Cities, 23 – 26 Oktober, Bandung.

Damanhuri E, Padmi T. (2008). Waste recycling capacity in Bandung City, Indonesia. The 5th Asian-Pacific Landfill Symposium, October 22–24, Sapporo.

Damanhuri, E., Padmi, T. (2009). Current Situation of Waste Recycling in Indonesia, in Kojima, M., E. Damanhuri, E. (eds.), 3R Policies for Southeast and East Asia. ERIA Research Project Report 2008-6-1, Jakarta: ERIA. pp.23-52.

Dawson, B. and Gillow, J. (1994). The traditional architecture of Indonesia, London, Thames and Hudson Ltd.

Dunais, M.-.A & Kramer, Dr. R. (2009). Cost benefit analysis of aseptic carton recycling in Bandung, Indonesia. Durham: Nicholas School of the Environment of Duke University.

Frick, H. (1995). Strukturformen Indonesischer Bautechnik. Eindhoven. Bouwstenen Publikatieburo Bouwkunde.

Geiser, K. (2001). Materials Matter: towards a sustainable materials policy. U.S.A., Massachussets Institute of Technology Press.

Guratman, H. D. H. (2016). Data RW SE-Kecematan Bandung Kulon. Bandung.

Hakkens, D. (c2017). Hakkens, D. (c2017). Preciousplastic. Retrieved 04 January, 2017, from https://preciousplastic.com/en/

Hargamaterialxyz. (2017). HargaMaterialXYZ. Retrieved 03 January, 2017, from http://www.hargamaterial.xyz/harga-bata-merah-bata-ringan-batako/Hussain MohdAbbas - Block Factory LLC. (c2017). Hussain MohdAbbas - Block Factory LLC. Retrieved 03 January, 2017, from http://www.hablocks.com/hollow_blocks.php

Hebel, D. E., Wisniewska, M. H. & Heisel, F. (2014). Building From Waste - Recovered Materials In Architecture And Construction. Basel: Birkhaeuser Verlag GmbH.

Hoornweg, D., & Bhada-Tata , P. (2012). What a waste - A Global Review of Solid Waste Management. Washington: Urban Development

& Local Government Unit - World Bank.

Jaeger, K. (December 12, 2016).The Reason Why an Old Yogurt Cup Is Going Viral. ATTN:. Retrieved from http://www.attn.com/stories/13505/why-image-yogurt-going-viraly. [Accessed: December, 13, 2016]

Jong, H. N. (October 9, 2015). Indonesia in state of waste emergency. The Jakarta Post. Retrieved from http://www.thejakartapost.com/news/2015/10/09/indonesia-state-waste-emergency. [Accessed: September, 14, 2016]

Kardono, P. D. (2007). Integrated Solid Waste Management in Indonesia. Jakarta: Damanhuri, E. et al. (2009). Evaluation of municipal solid waste flow in the Bandung metropolitan area, Indonesia Paper presented at the EcoTopia Science.

Lavigne, F., Wassmer, P., Gomez, C., Davies, T. A., Hadmoko, D. S., Iskandarsyah, T., Gaillard, J.C., Fort, M., Texier, P., Heng, M. B., Pratomo, I. (2014). The 21 February 2005, catastrophic waste avalanche at Leuwigajah dumpsite, Bandung, Indonesia. Geoenvironmental Disasters, 1(10).

Neufeld, L., Stassen, F., Sheppard, R. & Gilman, T.
(2016). The New Plastics Economy Rethinking the future of plastics. Geneva:World Economic Forum.

MacMillan, N. (2007). Community Solutions fo r Indonesia's Waste . Ottawa: International Development Research Centre.

McKinsey Center for Business and Environment, Ocean Conservacy (2015). Stemming the Tide: Land-based strategies for a plastic-free ocean. USDC.

Rahayu, N. & Yudoko, G. (2012). Backcasting Integrated Municipal Solid Waste Management in Bandung City: A Literature Review. Bandung: ITB. As part of the 3rd International Conference on Technology and Operations Management, July 4-6, Bandung.

Remmerswald, N. (2014). Technical research paper: Tra-digital hybrid. Delft: Delft University of Technology.

Rossen, K. (2014). Local waste potential: Turning Bandung's household waste into building elements. Delft: Delft University of Technology.

Saiful, A., Nurhijrah, Dewi, R., Saraswati, T. & Dadang, H. (2015). Housing & Waste-Green Cycle. Bandung: ITB.

Sakina, B., Kasman, T., Kurniati, F., Sofia, I. & Haristianti, V. (2015). Typo-Morphology And Quality Analysis. Bandung: ITB.

Sasaki, S., Araki, T., Tambunan, A. H. & Prasadja, H. (2014). Household income, living and working conditions of dumpsite waste pickers in Bantar Gebang: Toward integrated waste management in Indonesia. Elsevier: Resources, Conservations & recycling.

Sasaki, S & Tetsuya, A. (2014). Estimating the possible range of recycling rates achieved by dump waste pickers: The case of Bantar Gebang in Indonesia. Waste Management & Research, 32(6), 474-481.

Spanjer, W. and P. A. v. Wijk (2014). Sustainable buildings Transformational Innovations. Delft, The Green Village, TU Delft.

State Ministry of Environment, The Republic of Indonesia (2008). Indonesian Domestic Solid Waste Statistics. Jakarta: JICA.

Surahman, U., Higashi, O. & Kubota, T. (2015). Evaluation of current material stock and future demolition waste for urban residential buildings in Jakarta and Bandung, Indonesia: embodied energy and CO2 emission analysis. Japan, Springer

U.S. Environmental Protection Agency (1997).Measuring Recycling: A Guide for State and Local Governments, Washington: U.S. Environmental Protection Agency.

Walker, B. (2015). Bethanywalker. Retrieved 02 January, 2017, from http://www.bethanywalker.com/

Waterson, R. (1993). The living house. Singapore. Oxford University Press.

World economic forum. (c2017). World Economic Forum. Retrieved 10 September, 2016, from https://www.weforum.org/agenda/2015/04/zero-waste-a-small-towns-big-challenge/htmldownload-doi=10.1.1.629.9583&rep=rep1&-type=pdf

14 ILLUSTRATIONS

15 TABLES

16 APPENDIX

		Density		Strength		Thermal Properties			
		t/m³	t/m³ middled	tensile in psi	compressive in psi	TM in °C	Tg in °C	Td in °C	Cte in ppm/°C
Mixed Household Waste***			0,12						
Organic - food mixed			0,89						
Plastic*									
1- PET - crushed	low	1,29	1,35	7000	1100	245	73	21	65
	high	1,40		10500	15000	265	80	38	-
whole/ unflattened bottles			0,02						
2 - HDPE	low	0,95	0,96	3200	2700	130	-	79	59
	high	0,97		4500	3600	137	-	91	110
4 - LDPE	low	0,92	0,93	1200	-	98	-25	40	100
	high	0,93		4550	-	115	-	44	220
5 - PP	low	0,90	0,91	4500	5500	168	-20	107	81
	high	0,91		6000	8000	175	-	121	100
6 - PS	low	1,04	1,05	5200	12000	-	74	68	50
	high	1,05		7500	13000	-	105	96	83
Cardboard**						-			
Mixed Paper			0,29						
Corrugated Cardboard			0,06						
Textile						-			
Nylon****	low		1,14			215			
	high					221			
Polyester****	low		1,38			260			
	high					-			
Polyethylene****	low					274			
	high					-			
Cotton***** (dry)	low	1,54	1,55			150 - (gradual			
	high	1,56				246 - (rapid deterioration)			
Glass ** - whole/ unflattened bottles (0-10% broken)			0,36						
Metal**									
Aluminium cans			0,04			660			

table 11: Waste material properties (data source: U.S. Environmental Protection Agency (1997); California Integrated Waste Management Board (1996) California Integrated Waste Management Board (1996) Recycling Data Report, Sacramento: California Integrated Waste Management Board. Hakkens, D. (c2017).

c.s.		Conceptos Plásticos		By fusion Bricks		ReMaterials Roof Panels		Squarry		Trinket Series		Bima Microlibrary	
		p. s.	v. t.	p. s.	v. t.	p. s.	v. t.	p. s.	v. t.	p. s.	v. t.	p. s.	v. t.
5	Material availability	5	25	5	25	5	25	5	25	5	20	2	10
4	% of waste material	5	20	4	16	5	20	5	20	5	20	3	12
5	Production aff.	3	12	4	20	5	25	4	20	4	20	2	10
5	Tool affordability	3	15	2	10	5	25	4	20	4	20	3	15
3	Production space eff.	3	12	3	9	4	12	5	15	5	15	4	12
4	Production simplicity	2	10	3	12	4	16	4	16	4	16	5	20
1	Production speed	3	15	3	3	4	4	4	4	4	4	5	5
3	Tool simplicity	3	12	3	9	5	15	4	12	4	12	5	15
4	Construction simplicity	5	25	5	20	5	20	2	8	2	8	4	16
1	Construction speed	5	25	5	5	5	5	2	2	2	2	4	4
4	Space in building	5	10	4	16	5	20	5	20	5	20	3	12
5	Expected lifetime	5	10	4	20	4	20	5	25	5	25	4	20
4	Structural quality	5	20	5	20	2	8	1	4	1	4	3	12
3	Weight efficiency	3	6	3	9	3	9	4	12	4	12	5	15
4	Thermal quality	3	12	4	16	4	16	3	12	3	12	3	12
3	Fire resistance	5	5	2	6	3	9	4	12	3	9	3	9
2	UV resistance	4	4	3	6	4	8	4	8	4	8	1	2
1	Sound quality	3	9	3	3	4	4	2	2	2	2	1	1
5	Water proof	5	25	5	25	5	25	5	25	5	25	2	10
	TOTAL multiplied with categroy ranking	**272**		**250**		**286**		**262**		**254**		**212**	
	Usable for	structure, roofing, access		structure, facade, roofing, insul., access		facade, roofing, internal tiling		facade, roofing, internal tiling		facade, roofing, internal tiling		facade	

c.s. - category score
p.s. - project score
v. t. - value total (value total= category score x project score)

table 12. Case study matrix (own image, 2017)

UBUNTUBLOX 249

Originally designed to utilize plastic waste as building material for emergency shelters after the 2010 Haiti earthquake, the blocks have a high structural quality. The machine developed for the manufacturing process is easily handleable by an individual and requires no additional energy other than human energy.

Economics of the product however have been put into question, due to the large amounts of plastic needed and its local value for selling on. New waste materials have been tested, resulting in blocks of local vetiver roots. The same machine is being used for this process.

The manufacturing process is easy but requires a simple extra tool for ease of tightening of the metal wires to avoid expansion. All plastic is wrapped into plastic bags before insertion to allow for the rough wire strapping as the only means of form keeping. The bags are no UV resistant, but this can be helped with the addition of cladding to improve durability.

material availability	●●●●●	tool simplicity	●●●●○	thermal quality	●●●●○
% waste material	●●●●○	constr. simplicity	●●●●●	fire resistance	●○○○○
product. afford.	●●●●○	constr. speed	●●●●●	uv resistance	●○○○○
tool afford.	●●●●●	space in building	●●○○○	sound quality	●●●○○
product. space eff.	●●●●○	expected lifetime	●●○○○	waterproof eff.	●●●●●
product. simplicity	●●●●●	structural quality	●●●●○	usable for	structure,
product. speed	●●●●●	weight efficiency	●●○○○		facade, insul.

data source: Hebel, D. E., Wisniewska, M. H. & Heisel, F. (2014). Building From Waste - Recovered Materials In Architecture And Construction. Basel: Birkhaeuser Verlag GmbH. p.40-41; fig. 37. Hebel, D. E., Wisniewska, M. H. & Heisel, F. (2014)

General Information:

development/ implementation:: Haiti, 2010
developed by: Harvey Lacey
building element: building blocks
material: all types of plastic, compression wire, (vetiver roots)
size (HxLxW in mm): 200 x 400 x 200
density (in kg/m3): 225

DECAFE TILES 223

Indonesia is one of the largest coffee producers in the world. While Cigondewah is not per se known for this, the consumption of coffee by Indonesians is generally high and with that the amounts of discarded coffee ground. Initially designed for small scale interior items, designer Raul Lauri went on to experiment with the possibility of tiles made from coffee ground. The production is relatively simple. The discarded coffee ground is mixed with a natural binder and subsequently compressed into shape under influence of heat in desire shaped moulds. Differences in coffee ground coarseness and pressure applied during the manufacturing may lead to different densities and surface qualities. Consistency in both is therefore needed if a homogeneous production line is desired. The used binding agent is not declared by the designer. Perhaps a tannin based agent would be applicable. Manufacturing requires a constant heat source with an integrated compression function. The production speed is dependant on the efficient use of moulds. The tiles are designed to be used internally due to poor water proof performance. This could potentially be improved by means of addition of a water proofing layer, making the implementation of the material more flexible.

material availability	●●●●●	tool simplicity	●●●●○	thermal quality	●●●○○
% waste material	●●●●○	constr. simplicity	●●●●○	fire resistance	●●●●●
product. afford.	●●●●○	constr. speed	●●●●○	uv resistance	●○○○○
tool afford.	●●●○○	space in building	●●●●●	sound quality	●●●○○
product. space eff.	●●●●●	expected lifetime	●●●○○	waterproof eff.	●○○○○
product. simplicity	●●●○○	structural quality	●○○○○	usable for	facade, internal tiling
product. speed	●●●○○	weight efficiency	●●●○○		

data source: Hebel, D. E., Wisniewska, M. H. & Heisel, F. (2014). Building From Waste - Recovered Materials In Architecture And Construction. Basel: Birkhaeuser Verlag GmbH. p.60-61; fig. 38. Hebel, D. E., Wisniewska, M. H. & Heisel, F. (2014)

General Information:

development/ implementation: Spain
developed by: Raul Lauri
building element: tiles
material: coffee grounds, natural binding agent
size (HxLxW in mm): 300 x 300 x 20
density (in kg/m3): varies

PHZ2

277

PHZ2 was developed by Dratz & Dratz architects as a response to current procedure of cardboard recycling. Discarded cardboard is usually stacked and compressed for space saving purposes during he recycling process. PHZ2 follows the same procedure to create their building blocks. Cardboard discard is compressed into bales and held together with metal straps, making the production incredibly simple. The highly dense modules have a strong structural capacity and can be stacked up to 30m high without additional support (besides a layer of glue to connect and even out top layers of each bale). However, the increased depth of the bales is using valuable ground space. This would need to be engineered to fit the Cigondewah context. Furthermore, the weight of approx. 500kg per bale makes this a heavy object and difficult to distribute in a kampung context with little alleyways. In the rainy climate of Indonesia covering would need to be considered as well. While a bale with top coverage can withstand European amounts of rain easily and dries up quickly, the yearly precipitation of Indonesia would pose a challenge. On the other hand the low production and materials cost is significant for the materials trade value.

The material as used in the case study was not treated, resulting in a low scoring in material performance. This could be counter balanced with treatment or facade covering.

material availability	●●●●●	tool simplicity	●●●●●	thermal quality	●●●●●
% waste material	●●●●●	constr. simplicity	●●●●●	fire resistance	●●○○○
product. afford.	●●●●●	constr. speed	●●●●●	uv resistance	●●●●○
tool afford.	●●●●○	space in building	●○○○○	sound quality	●●●●●
product. space eff.	●○○○○	expected lifetime	●●○○○	waterproof eff.	●○○○○
product. simplicity	●●●●●	structural quality	●●●●●	usable for	structure
product. speed	●●●●●	weight efficiency	●○○○○		

data source: Hebel, D. E., Wisniewska, M. H. & Heisel, F. (2014). Building From Waste - Recovered Materials In Architecture And Construction. Basel: Birkhaeuser Verlag GmbH. p.44-45; fig. 38. Hebel, D. E., Wisniewska, M. H. & Heisel, F. (2014)

General Information:

implementation: Germany, 2010
developed by: Dratz & Dratz architects
building element: building blocks
material: cardboard, compression wire
size (HxLxW in mm): 1100 x 1400 x 800
density (in kg/m3): unknown

ULTRATOUCH DENIM 218

data source: Hebel, D. E., Wisniewska, M. H. & Heisel, F. (2014). Building From Waste - Recovered Materials In Architecture And Construction. Basel: Birkhaeuser Verlag GmbH. p.90-91; fig. 39. Hebel, D. E., Wisniewska, M. H. & Heisel, F. (2014)

The insulation consists of 80% denim textile and 20% other natural fibres.The denim textile is seperated from other by products of garments such as buttons, zippers, etc., before it is shredded. In a next process fibres are seperated and subsequently treated with a borate solution for fire protection and added mould protection. The mix of denim and natural fibres then goes thorugh a final process of baking and pressing into the desired thickness before being cut to size.

While the application of the product is simple and fast, the production is more complicated and requires particular machinery. The textile nature of the insulation however poses a viable solution for Cigondewah and it's textile waste. A large amount of small parts of textile sare not suitable for further textile production and even though usually sold onto yarn makers, often ends up wihtin the environment. Although, Ultratouch Denim Insulation is based on natural fibres only, the procedure could be amended to suit polyester based fabrics. Though with reduced health properties.

material availability	●●●●●	tool simplicity	●○○○○	thermal quality	●●●●●
% waste material	●●●●●	constr. simplicity	●●●●●	fire resistance	●●●●○
product. afford.	●●○○○	constr. speed	●●●●●	uv resistance	●●●○○
tool afford.	●●○○○	space in building	●●●●●	sound quality	●●●●●
product. space eff.	●●●○○	expected lifetime	●●●●○	waterproof eff.	●○○○○
product. simplicity	●○○○○	structural quality	●○○○○	usable for	insul.
product. speed	●○○○○	weight efficiency	●●●●●		

General Information:

development/ implementation: Arizona
developed by: Bonded Logic Inc.
building element: insulation
material: textile
size (HxLxW in mm): 381/584 x 1220/ 2320/ 9750
density (in kg/m3): 15.83-21.32