Sustainable management and technologies for recycled construction demolition waste in Vietnam

N H Giang¹, N H Tan¹, N T Quang², N X Hien³ and K Kawamoto⁴

¹ Faculty of Building and Industrial Engineering, National University of Civil Engineering, 55 Giai Phong street, Hanoi, Vietnam.
² Vietnam Paper Corporation, 25A Ly Thuong Kiet street, Hanoi, Vietnam.
³ Department of Science, Technology and Environment, Ministry of Construction, 37 Le Dai Hanh street, Hanoi, Vietnam.
⁴ Saitama University, 255 Shimookubo, Sakura Ward, Saitama, 338-8570, Japan.

Abstract. This study introduces the series of activities and results that are contributing for the CDW recycling industry in Vietnam especially for the implementation of the recently introduced Circular No.08/2017/TT-BXD. The equation for estimation of the amount of CDW generated from building demolition was introduced. New management regulations which are guideline for demolition, sorting, transportation and treatment and new Vietnamese standard for specification of testing and acceptance for CDW recycling materials are highlighted. The properties of recycling concrete from a pilot project were tested. The research designed a circle of recycling business that results from research are contributing for the sustainable management and technologies in Vietnam. These activities and contributions will significantly support for the implementation of Government’s new regulation, reducing the solid waste to meet the National strategies for environment as well as open for a new important recycling industry in Vietnam.

1. Introduction
Vietnam has recently experienced the remarkable growth in economy and together with its rapid construction development of about 9.2% in 2019 according to Ministry of Construction of Vietnam. This construction boom especially in mega cities such as Hanoi and Hochiminh have generated a huge amount of Construction Demolition Waste (CDW). According to report of ATI, Ministry of Construction, Vietnam produces about 38,000 Tons/day of urban municipal solid waste in 2014 with an increase of 12% per year from 2011 to 2015. Only Hanoi and Ho Chi Minh generate 6,420 Tons/day and 6,739 Tons/day respectively. Thus, it is estimated the amount of urban municipal solid waste is about 60,000 Tons/days [1].
According to State of Environmental Report 2011 on Solid Waste management (MONRE), CDW generated each day in major cities in Vietnam are shown in Table 1.
Table 1. Current generation of Construction and Demolition Waste (CDW)

| Cities        | Amount of CDW generated (tons/day) | Percent of CDW collection (%) |
|---------------|-----------------------------------|------------------------------|
| Hanoi         | 1000 – 1500                       | 70                           |
| Ho Chi Minh   | 2000 – 2500                       | 75                           |
| Hai Phong     | 400 – 450                         | 40 - 45                      |
| Da Nang       | 500 - 600                         | 60                           |
| Other cities  | 100 - 200                         | 20 - 30                      |

Among Solid waste shown in Table 1, Construction Demolition Waste (CDW) contributes a large amount of this quantity. It is estimated that about 3,000 Tons/day generated each day in both Hanoi and Ho Chi Minh. Some research has been carried out to study about the quantity and policies regarding management and utilization of this CDW in Vietnam such as Manowong and Brockmann, 2010 found that about 1 million tons of CDW was generated in Vietnam in 2004 [2] and Kien et al., 2013 took the investigation and concluded the number was 1.9 million in 2013 [3]. Nguyen et al., 2019 reported that among this amount, only about 1-2 % was recycled [1]. Hussin et al., 2013 concluded that Vietnam was a developing country with an unprecedented construction boom with a lack of CDW management [4]. The CDW in Vietnam is mainly used for landfill and bricks (Nguyen et al. 2019) and very limited use for recycling [1]. Cuong et al., 2019 carried out tests on waste masonry collected from a CDW landfill site in Hanoi. These materials were crushed and graded in the laboratory to prepare graded recycled aggregate (GRA) for unbound road subbase however the application has not been implemented yet [5].

There are a number of reasons for these applications, but the main reasons are lacks of Government management, encouragement policies and sustainable technologies for recycling. Recently, Prime Minister just approved Decision No. 491/QĐ-TTg dated May 7, 2018 the Adjusted National Strategy on Integrated Management of Solid Waste up to 2025, with a Vision toward 2050 following that sets the specific target that up to the year 2025, 90% of total construction solid waste generated in urban areas is collected and treated, in which 60% is reused or recycled to products and recycled materials by appropriate technologies [6]. Together with that MOC introduced Circular No. 08/2017/TT-BXD which also specifies the responsibilities of the People’s Committees of provinces/cities and Departments of Construction of provinces/cities with respect to CDW management [7].

The business model was considered when a local company in Hanoi joined to demolish 4 building from 4-7 stories using the mobile crushing machines. However, it was difficult to use these materials and the main reason are:

- Lack of Vietnamese standards for quality control and acceptance for recycled CDW materials
- Lack of Price references in which the CDW materials to be accounted for project’s cost estimation and payment.
- Lack of Demolition Guideline so that they and control the quality of CDW
- Lack of advanced technologies so that recycled materials could be accepted and to add added values for these materials for commercial purposes.

While the natural resources such as sand, aggregates are over exploited, the Vietnam’s government is implementing strict management for these natural material uses such as Degrees 33/2017/NĐ-CP [8] and 23/2020/NĐ-CP [9] to regulate the natural resource exploitation thus these virgin materials became very expensive and not enough for construction demand. Thus, recycling CDW becomes a very urgent task to ease the tension on material supply for construction industry as well as to reduce the negative environment impacts of untreated and unmanaged CDW on society. To solve these issues, a number of management and policies for CDW has been implemented worldwide. Japan introduced the Construction Material Recycling Law enacted in 2000 (MOE, 2000) [10]; Hong Kong introduced Construction Waste Disposal Charging Scheme in 2005 (Hao et al., 2008) [11]. The
Construction & Demolition Waste Management Protocol (EU, 2016) [12] and Guidelines for the waste audits before demolition and renovation works of buildings; EU Construction and Demolition Waste Management (EU, 2018) [13] were introduced in Europe in 2016 and 2018. These laws and regulations have significantly supported to increase recycling rate and technologies of the regions. In order to support the Government’s management policies and well as to promote sustainable technologies for CDW recycling, the JST-JICA SATREPS project [14] between Vietnam and Japan institutional links was newly implemented. The research is to support:

- (1) to establish Standard, Guidelines necessary for the environmentally sound CDW management and quality standards for recycled materials produced from CDW.
- (2) to develop new technologies utilizing recycled materials produced from CDW.

This paper will introduce the results of some Management policies as well as Technologies for recycling CDW in Vietnam for sustainable development. This research is the preparation for introducing the circle economy for CDW in Vietnam.

2. Current situation of CDW management in Vietnam. and the new Standard and Guideline for CDW to be introduced.

2.1. Site survey for construction demolition work

The survey by interviewing the demolition companies was carried out in the two largest cities, Hanoi and Hochiminh, in Vietnam. There were 48 contractors joined the survey in which 29 were in Hanoi and 17 were in Hochiminh. The combination between indirect measurement method (SV group) and area-based calculation method (GRC group) were adopted for measuring the amount of CDW. Nghiem et al., 2019 [15] reported the typical 5 steps for demolition work carried out in Hanoi and Hochiminh which is shown in figure 1.

![Demolition workflow in Vietnam](image)

**Figure 1.** Demolition workflow in Vietnam.

This is the typical process that is being held in Vietnam. In this process, reinforced steel is separated from CDW at site for selling as value material. The rest of materials include concrete, brick, wood, plastic, gypsum, etc are mixed and transported to the sites by trucks. There is no guideline to instruct contractors how to separate CDW and each contractor carries the job based on its own experience. There is no official Guideline for Construction Demolition Work yet. The CDW material at various sizes and no separation as shown in figure 2 is transported directly to the sites for dumped illegally.
Since the CDW with no technics for separation and technologies for crushing and recycling this this material is mainly used for landfill and partially for bricks. The value for these uses is low thus it is difficult to attract the CDW recycling business therefore it is not sustainable and hard to reduce the amount of this waste.

2.2. Method to measure to quantify the amount of generated CDW

The quantify the amount of CDW generated from the surveyed buildings, the following equation was proposed.

\[ G_{CDW} = G_{CC-CB} + G_S + G_A \] \hspace{1cm} [ton/m^2] \hspace{1cm} (1)

Where:

- \( G_{CC-CB} \): Generated amount of Crushed concrete – crushed brick (CC–CB)
- \( G_S \): Mass of steel and other valued metals which were separated from CDW for selling as value materials.
- \( G_A \): Aluminium generated from the structure and is measured as following equation:

\[ G_A = \frac{m_A}{GFA} \] \hspace{1cm} [kg/m^2] \hspace{1cm} (5)

\( m_A \): mass of aluminium generated from CDW.

The generated amount of Crushed concrete – crushed brick (CC–CB) and determined as following:

\[ G_{CC-CB} = \frac{m_{CC-CB}}{GFA} \] \hspace{1cm} [kg/m^2] \hspace{1cm} (2)

Where:

- \( m_{CC-CB} \): The total bulk volume of CC–CB after being crushed to separate reinforcing steel be \( V \), this volume is then treated in two ways:
  - A major portion is transported to landfills, denoted as \( V_1 \); and
  - Another portion is employed as backfilling material on site, denoted as \( V_2 \).

Volume \( V_1 \) is determined by recording the number and type of transport trucks and is used for calculating the generation rate of CC–CB as it is the portion of CDW that is discarded hence exerts pressure on the environment.

Convert volume \( V_1 \) into mass by multiplying it with the bulk density of CC–CB, \( \rho_{CC-CB} = 830 kg/m^3 \) (Máli, 2013) [17].

The generation rate of steel is measured as following:

\[ G_S = \frac{m_s}{GFA} \] \hspace{1cm} [kg/m^2] \hspace{1cm} (4)

Where:

- \( m_s \): mass of steel and other valued metals which were separated from CDW for selling as value materials.

The following equation is used for calculating the generation rate of CC–CB as it is the portion of CDW that is discarded hence exerts pressure on the environment.

\[ m_{CC-CB} = V_1 \times \rho_{CC-CB} \] \hspace{1cm} (3)
This area-based calculation method in conjunction with daily site visit provided an important method to measure the amount of CDW generated from surveyed buildings. This equation is therefore important for future estimation of the demolished buildings.

Related regulations for CDW
Vietnamese Government is implementing regulations on CDW in order to manage the illegal dumping as well as protect the environment. Nguyen et al., 2018 reported the lists of related laws and regulation in Vietnam for CDW [16] which is shown in the following table 2.

Table 2. Vietnamese legal document relevant to CDW management.

| S/N | Type of document and Name of document | Year of approval |
|-----|--------------------------------------|------------------|
| 1   | Law on Construction                   | 2014             |
| 2   | Law on Environmental Protection      | 2014             |
| 3   | Law on Urban Planning                | 2009             |
| 4   | Law on Public Investment             | 2014             |
| 5   | Decree No. 59/2007/ND-CP on Solid Waste Management | 2007 |
| 6   | Decree No. 12/2009/ND-CP on Management of Investment Projects on the Construction of Works | 2009 |
| 7   | Decree No. 38/2015/ND-CP on the Management of Waste and Discarded Materials | 2015 |
| 8   | Decree No. 59/2015/ND-CP on Construction Project Management | 2015 |
| 9   | Circular No. 29/1999/QD-BXD on Promulgating the Regulations of Environmental Protection Applied for the Construction Sector | 1999 |
| 10  | Circular No. 10/2000/TT-BXD on Guiding the Elaboration of Reports on the Assessment of Environmental Impacts for Construction Planning Projects | 2000 |
| 11  | Circular No. 01/2011/TT-BXD on Guiding the Strategic Environmental Assessment in Construction and Urban Plans | 2011 |
| 12  | Circular No. 08/2017/TT-BXD on Regulation on Construction Solid Waste Management | 2017 |
| 13  | Joint Circular No. 01/2001/TTLT-BKHCNMTBXD on Guiding the Regulations on Environmental Protection for the Selection of Location for, and the Construction and Operation of Solid Waste Burial Sites | 2001 |
| 14  | TCVN 6705: 2009 Ordinary Solid Waste – Classification | 2009 |
| 15  | TCVN 6706: 2009 Hazardous Solid Waste – Classification | 2009 |
| 16  | TCVN 6707: 2009 Prevention and Warning Signs for Hazardous Waste | 2009 |
| 17  | TCVN 6696: 2009 Requirements for Environmental Protection for Sanitary Landfills | 2009 |

Among these regulations, the Circular No.08/2017/TT-BXD dated May 16, 2017 of the Minister of Ministry of Construction on Construction Solid Waste Management enacted in 2017. The new circular consists of the definition of terms (Chapter I, Article 2), general regulations on CDW management including separation, storage, collection, transportation, reuse and recycling, and disposal (Chapters II & III), and responsibility of stakeholders such as generator, treatment owners, investor, provincial people’s committee (PCs), Department of Construction (DOC), and so on (Chapter IV). The new
Circular introduces firstly a reporting system of CDW in Vietnam, i.e., construction companies, treatment companies, and landfill sites report CDW management plan and treatment data to competent agencies such as PCs and DOC. Furthermore, DOC has to develop and manage database on CDW management in provinces/cities and report Ministry of Construction annually. The new Circular has just become effective, however, it can be expected that responsible stakeholders will face many difficulties due to lack of experience and technical skills. Furthermore, it is still the Circular thus it is not mandatory for all DOC to follow. Many companies had no information about the new Circular as interviewed in the survey or found it difficult to comply due to the lack of demolition guidance, experience and not having enough knowledge and technology to recycle CDW. Thus, it is essential to develop these legal tools to support the implementation of this Circular as well to support private sectors to enter this business scheme.

3. New Standard and Guideline for CDW to be introduced.
The Circular No.08/2017/TT-BXD also instructs on how the CDW to be reused or recycled and some typical content is mentioned as following:
- CDW reused have to meet technical standards in accordance with regulations and laws
- Recycled CDW are specified in Clause 1 Article 11
- Recyclable CDW should be collected and transported to CDW treatment facilities

However, currently there is no Technical Standard for acceptance of reused and recycled CDW in Vietnam thus in order to promote the recycling of CDW in Vietnam, the JST-JICA SATREPS project between Japan and Vietnam implementing by National University of Civil Engineering (NUCE) and Saitama University are proposing the following tasks: (1) to establish guidelines necessary for the environmentally sound CDW management and quality standards for recycled materials produced from CDW; (2) to develop new technologies utilizing recycled materials produced from CDW; and (3) to propose strategic business models designed to promote the CDW recycling in Vietnam and examine their effectiveness and feasibility through on-site pilot projects. The final goal of this project is to contribute to the achievement of a CDW recycling rate of 60%, which meets the Vietnam national strategy for management of solid waste up to the year of 2025, through the application of developed technologies and business models to practical recycling business.

In order to instruct demolition contractors, the Guideline for CDW Demolition Work and Separation was proposed by the SATREPS Project and accepted by MOC, Vietnam. This guideline is scheduled to be accepted end of 2021. This guideline aims to introduce how to demolish; separate; store and treat the CDW at site and at the recycling facilities. This will significantly help the local administration for management and the contractors know how to carry out their jobs properly.

To promote the application of recycled CDW, a Vietnamese standard (TCVN) was proposed by the SATREPS Project and accepted by MOC, Vietnam in 2019. The proposed TCVN: Specifications - Test methods for recycled graded aggregate from Construction Demolition Waste using for Base and Subbase of Urban Roads. The TCVN is expected to enact in 2020. This standard will support the output of the recycled materials. With the test methods and specification for testing and acceptance, the materials now could be tested and used in actual projects.

With these two new regulations, both administration and private sectors now have the common tools to carry out the demolition and application works of recycled CDW.

4. New technologies for CDW
The CDW recycling business model is considered very new in Vietnam and there is no successful case up to date for this area. According to Master Plan of Solid Waste Management of Hanoi up to 2030 and vision to 2050, the city will have 18 solid waste treatment sites. According to (National Current Environment Situation Report, 2016), CDW in Hanoi is buried in deep natural or manmade ponds. Until 2015, Hanoi has several CDW sites:
- Van Noi site with total area of 7.5 ha and receives 800 to 1000 Tons of CDW per day.
- Nguyen Khe site with receives 100 Tons/day of CDW.
- Vinh Quynh site with an area of 4.9 ha and receives 600 Tons/day of CDW.
- Song Phuong – Hoai Duc site with an area of 3 ha and receives 300 Tons/day.
- Dan Phuong site with an area of 4.6 ha and receives about 300 tons/day of CDW.

However, municipal solid waste and CDW are now sometimes mixed together thus it makes it difficult to sort and manage. Furthermore, some sites already reached to full capacity of filling thus most of the sites are inactive now. In order to overcome the situation, Hanoi has tried to promote some methods and one of them is to attract private sectors to invest in this solid waste treatment. One of the proposals at the new site at Duc Tu, Dong Anh district with an area of 7.1 ha and capacity of recycling for 1,000 Tons/day of CDW and 1,000 m³/day of sludge treatment was accepted for master plan. This facility was requested to apply advanced technologies to recycle solid waste.

To support the sustainable development in which attract the private sector to enter CDW recycling and generate profit for their growth, key technologies to add added values for recycling materials are very crucial. This technologies and profit will enable the sustainable development of recycling CDW. The SATREPS Project cooperated with the company which invested in this facility to design and carry out the pilot crushing machine and test at the site.

The pilot design and the actual crushing machine are shown in the figure 3&4.

![Figure 3. CDW recycling Pilot design at site](image1)

![Figure 4. CDW crushing machine at site.](image2)

The pilot crushing machine with the capacity of 40 Tons/hour is designed to produce recycled CDW. The local CDW was tested for mechanical properties as well as other applications. Some of the applications for these recycled aggregates are to produce permeable asphalt payment; concrete; base and subbase. These technologies could help to consume the large amount of CDW as well as make profit for business sectors.

### 5. Results and discussions

#### 5.1. Composition and specifications of recycled aggregates.

The crushing machine was operated and local CDW was used. The aggregate sizes were less than 5 mm; 5 – 10 mm and 10 – 20 mm. Depending on the location and the age of construction building the composition of the CDW is different.

The composition by weight of Hanoi’s CDW was shown in table 3 for reference.

| Composition       | Percentage (%) |
|-------------------|----------------|
| Brick             | 17             |
| Natural aggregate | 13             |
| Concrete          | 33             |
| Mortar            | 32             |
| Others            | 5              |

![Table 3. Composition of CDW by weight in Hanoi.](image3)
It is noticed in the composition of bricks in the CDW in Hanoi is pretty high (17%). It is due to the construction tradition in Vietnam back to 30 – 40 years ago when bricks were mainly used for building walls. Concrete and mortar contribute to 33% and 32% of the composition respectively and these are major components of the CDW. This agrees well with the 2016 National State of Environment Report (MONRE, 2017) [17].

The specification comparison between the Natural aggregates (NA) and Recycled Aggregates (RA) are shown in the table 4 for 5-10 mm size.

| No  | Specifications             | Unit          | Natural aggregate 5-10 mm | Recycled aggregate 5-10 mm |
|-----|---------------------------|---------------|---------------------------|---------------------------|
| 1   | Specific Gravity          | g/cm³         | 2.72                      | 2.65                      |
| 2   | Bulk density              | kg/m³         | 1360                      | 1310                      |
| 3   | Compacted Bulk density    | kg/m³         | 1660                      | 1430                      |
| 4   | Dry density               | g/cm³         | 2.62                      | 2.32                      |
| 5   | Saturated surface dry     | %             | 0.14                      | 6.85                      |
| 6   | The flat and elongated particle | %   | 1.4                       | 3.9                       |
| 7   | Contaminated material     | %             | 0.08                      | 0.86                      |

It could be seen that some important parameters such as specific density, bulk density of both types have quite similar values while others such as Saturated surface dry, the flat and elongated particle, the RA showed much higher value.

5.2. CDW recycling life and contributions of new management and technologies.

The Circular No.08/2017/TT-BXD was an important document from Government for the CDW management and recycling. However, it was difficult for contractors to comply with the new regulation due to lack of guidelines for demolition work and sorting, standards for testing and acceptance of recycled CDW, technologies for developing new products which used added values CDW recycling materials.

The SATREPS Project is developing a multiple task for different stages of the life circle of recycling CDW.

- New equation to estimate the amount of CDW generated from a building. This could help both owner and contractor to estimate the amount of waste and prepare for following tasks.
- Developing the guideline which is accepted by Ministry of Construction of Vietnam for demolition, sorting, transportation, treatment at facility, report and environment, safety issues.
- New standard (TCVN) for testing methods, acceptance of recycled CDW so that these materials could be used for actual projects.

These activities could support the implementation of Circular No.08/2017/TT-BXD as well as to help to meet the Adjusted National Strategy on Integrated Management of Solid Waste up to 2025, with a Vision toward 2050 following that sets the specific target that up to the year 2025, 90% of total construction solid waste generated in urban areas is collected and treated, in which 60% is reused or recycled to products and recycled materials by appropriate technologies.

The circle of CDW recycling and support from new management and technologies that SATREPS Project is contributing is shown in figure 5.
Figure 5. New management regulations and technologies support for CDW recycling business.

The main reason in Vietnam that the CDW rate is very low of 1-2% (Nguyen et al, 2019) [1] due to the fact this work has not produced enough profits for companies to enter and invest in this business. This system is designed to support the CDW recycling business in Vietnam. All of the parts that to are currently needed be strengthened in order to promote the business are being developed or have been filled by the SATREPS Project. This model is expected to open a new CDW recycling sector in Vietnam and help to save environment, reduce the air pollution caused by these solid wastes. CDW should not be considered as waste. It should be considered as resources that could be used to replace natural materials. This is the precious opportunity for recycling industry and these added value recycling materials will change the concept of construction society in Vietnam. With the urbanization rate in Vietnam is increasing and the new sustainable management and technologies are the key factors to reduce and manage this solid waste.

6. Conclusions

This study introduces the series of activities and results that are contributing for the CDW recycling industry in Vietnam. The recycling rate of CDW in Vietnam is still very low and no mandated regulations have been implemented to boost these activities from the Government. The recently introduced Circular No.08/2017/TT-BXD faces tough situations that no guidelines, standards and instructions for both contractors and local administration available for support this implementation process. This research carried out the interviews, site survey with contractors from two biggest cities in Vietnam: Hanoi and Hochiminh cities.

- From the results, it has proposed the Equation to estimate the amount of CDW generated from a building based on drawing and site estimation before the demolition. This could help owners and contractors for pre-construction preparation and application work with local government. The local administration also has a tool to estimate and accept the plan proposed by contractor which is now required by Circular No.08/2017/TT-BXD.

- Based on the review of current laws and demolition, transportation and treatment for CDW, this research is developing a new Guideline that help contractors know how to demolish, sort,
transport and treat CDW properly. This guideline will significantly help contractors to boost their work since most of them, based on the survey, are carrying out the demolition work based on their own experience and they are different from one to another.

- The new standard for specifications of testing methods and acceptance for CDW recycling materials are scheduled to be finalized. This research’s standard is the key for recycled materials to be justified and accepted for construction projects. Without this standard, both contractors and owners do not know whether these materials meet the requirements for using or not thus this is the way out for this industry.

- In order to promote this recycling industry, it is vital to attract contractors to join and invest in this business. Therefore, the recycling products must include the added values so that it could generate profits for companies and the added values materials will support for the sustainable development of this industry. The research introduced a pilot test as well as research on the application of these recycling materials. The materials will be used in various application such as permeable asphalt pavement, concrete, base and subbase and etc.

- The life circle of the CDW recycling business was designed which applied all the new results from equation, new guideline, new standards, new technologies for application of recycled materials and business model. This model that used new management and technologies will help for the sustainable development of the recycling industry in Vietnam.

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