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Research Paper

# Study on the Use of Construction and Demolition Waste for Road Base or Subbase Pavement Construction in Hanoi

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ABSTRACT

Reuse or recycling of construction and demolition waste (CDW) has become an inevitable trend in the world. Currently, the amount of CDW generated in Hanoi is estimated at more than 4,000 tons per day, of which only about 30% has been controlled and recycled. The CDW comes from many different sources such as construction, repair, renovation, demolition of houses, residential buildings, public buildings, transportation infrastructure works, etc... The CDW commonly comprises soil, bricks, mortar and concrete, and has been reused in many applications around the world. In Vietnam, there are also some research programs set up for reutilizing the material, however, has not been concretely applied in practice. In order to consider the applicability of CDW in road construction, an experimental program was conducted using CDW as the aggregate for the cement treated grain material base layer in road pavement structure. The weight ratios of cement used in the mixture were 4%, 5%, 6%, 7% and 8%. The test results showed that the main mechanical properties of compressive strength, split tensile strength and elastic modulus of the mixture, increased proportionally with the cement content in the mixture.

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## 1 Introduction

Solid municipal waste is one of the most important issues that need to be managed and treated. In that, the construction and demolition waste (CDW), although not causing serious consequences for environmental pollution, however the CDW dumping landfills usually occupy a large development space, and generate bad viewpoints which negatively affect the urban landscape.

According to statistics in 2009, the United States and Japan emitted 325 and 77 million tons of CDW, respectively. The amount from European countries in 2016 was 924 million tons. China, the country that produces and uses the greatest amount of concrete for developing the world's largest infrastructure, emitted 2.36 billion tons in 2018. Facing the negative impacts, and also identifying great potential of CDW for the construction industry, many countries have embarked on research and

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development programs to recycle or reutilize the CDW. As a result, in developed countries, the level of recycling is very high by applying restricted policies. In Switzerland, about 80% of construction materials are recycled. In the Netherlands, burying concrete is banned and the recycling rate of concrete is near 100% [1, 2].

Hanoi is the capital city and second GDP contribution of Vietnam. The dynamic development of the economy and the urban infrastructure construction systems in recent years lead to a large demand of construction materials, and also a large volume of CDW generation. Currently, the amount of CDW generated in Hanoi is estimated at more than 4,000 tons per day, of which only about 30% has been controlled and recycled.

## 2 Characteristics of CDW in Hanoi

The CDW comes from many different sources such as construction, repair, renovation, demolition of houses, residential buildings, public buildings, transportation infrastructure works, etc... In general, CDW can be classified into three types based on its domain con-tent and generating sources.


***Fig. 1 – CDW management at landfills in Hanoi [3]***

Type 1. Soil. Generating from the foundation excavation for construction works such as houses, buildings, or cutting roadbed segments. For this type of CDW, there are two options for reuse: (1) For soil satisfying the technical standards, it can be used for constructions with high technical requirements such as fill material for road embankment; (2) For poor quality soil, it can be used as levelling material.

Type 2. Broken concrete, broken brick, mortar, stone existing in different sizes. This is the product of the demolished works such as houses, service building, transport and other urban facilities that need to be reconstructed, renovated or cleared for other land-use purposes. For this type of CDW, the current solutions include: (1) dumping in landfill; or (2) partially utilized as lining layers for building foundation; (3) filling for building construction site; (4) fill material for roadway embankment in low technical requirements projects. The characteristics of this material are heterogeneity, irregular size, fragmentation and difficulty in processing, so it is rarely used for high quality elements such as pavement.

Type 3. The waste from the road pavement. This type of CDW is generated from road pavement demolition. The existing pavement structures of urban streets which do not satisfy the operational technical requirement have to be removed before replaced by a new structure since streets strictly maintain the pavement level in accordance with urban master plans. This type of material consists of old concrete, old crushed aggregate, asphalt, or bituminous treated pavement layer... The main features of this type of CDW is that it has a large volume, fairly uniform in size. However, except the concrete pavement slabs can be recycled, this type of CDW is often poor quality, and requires special technologies for reprocessing before reused.

According to estimates of the Ministry of Construction, in average, the composition of CDW at landfills of Hanoi includes 23% of concrete, 31% of brick, 36% of gravel, soil and sand, 5% of steel or metal, 4% of wood and plastic, and about 1% of the others. In addition, according to the survey report of SATREPS, the proportion of concrete components in the city's large construction waste landfills accounts for a large proportion: Thanh Tri 39.6%; VinhQuynh landfills 53.8% [4, 5].

Generally, the three types of CDW mentioned above do not have high homogeneity, there are many sizes in the direction of the material's size expansion. Experimental results show that after removing some of the oversized species, the remaining material has a fairly dispersed composition, some of which contain little fine-grained components and vice versa.

Due to the nature of waste and poor classification, there are many different types of materials, making it difficult to use since the material has lost its original properties. The solution for utilization is that CDW will be screened to remove unsuitable content, processing to make a relatively uniform aggregate, and then use cement as stabilizer for bonding the CDW aggregate. In the next part of the paper, we would like to present the laboratory study about the performance of cement treated construction and demolition waste (denoted as CTCDW) as a material for the use in road base or subbase construction in the Hanoi area.

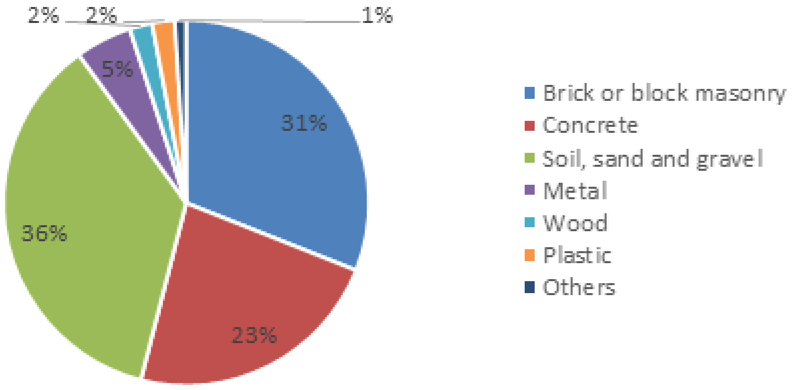



***Fig. 2 – Composition of CDW of Hanoi***

## 3 Experimental Program

In order to conduct the initial evaluation on the ability to use CDW for pavement structural layers, conduct an experimental program is formulated as follows:

(1) Screening and processing the CDW to select the suitable composition for use in road base pavement.

(2) Select the ratio of Portland cement as stabilizer for CDW and estimate the corresponding optimum moisture content.

(3) Testing the basic mechanical and physical properties of CTCDW for evaluation.

**Table 1 – Content of CTCDW.**

| Sample Denote | Aggregate Composition (wt.%) | |
|---|---|---|
| | CDW | PCB40 |
| SP1 | 96 | 4 |
| SP2 | 95 | 5 |
| SP3 | 94 | 6 |
| SP4 | 93 | 7 |
| SP5 | 92 | 8 |

## 4 Material

### *4.1 Coarse Aggregate CDW*

The content of CDW collected from landfills in Hanoi includes many types of construction materials, in which mainly are demolition concrete from buildings, pavement or other constructions, mortar, brick and residual stone, gravel, sand from construction sites. Randomized volume of CDW was taken to check basic physical properties, which is shown in Table 2.

### *4.2 Portland Cement*

Portland cement is used as treatment material for CDW. The purpose is to improve the stability, durability and strength of the original aggregate. The Portland cement PC30 Nghi Son was used based on the comparison of physical and chemical properties with specification limits in TCVN 2682:1999 [6]. The physical properties of cement presented in Table 2.

**Table 2 – Cement Properties**

| Indicators | Value (Average) | Specification limits |
|---|---|---|
| Compression strength (MPa) | | |
| 3-day | 30.8 | ≥ 18 |
| 7-day | 42.4 | |
| 28-day | 52.2 | ≥ 40 |
| Setting time | | |
| Initial setting time (min.) | 45 | ≥ 45 |
| Last setting time (min.) | 360 | ≤ 375 |
| Fineness | | |
| Remaining on sieve 0.09 (%) | 0.6 | 10 |
| Specific surface area (cm2/g) | 3877 | 2800 |
| SiO3 (%) | 2.1 | ≤ 3.5 |

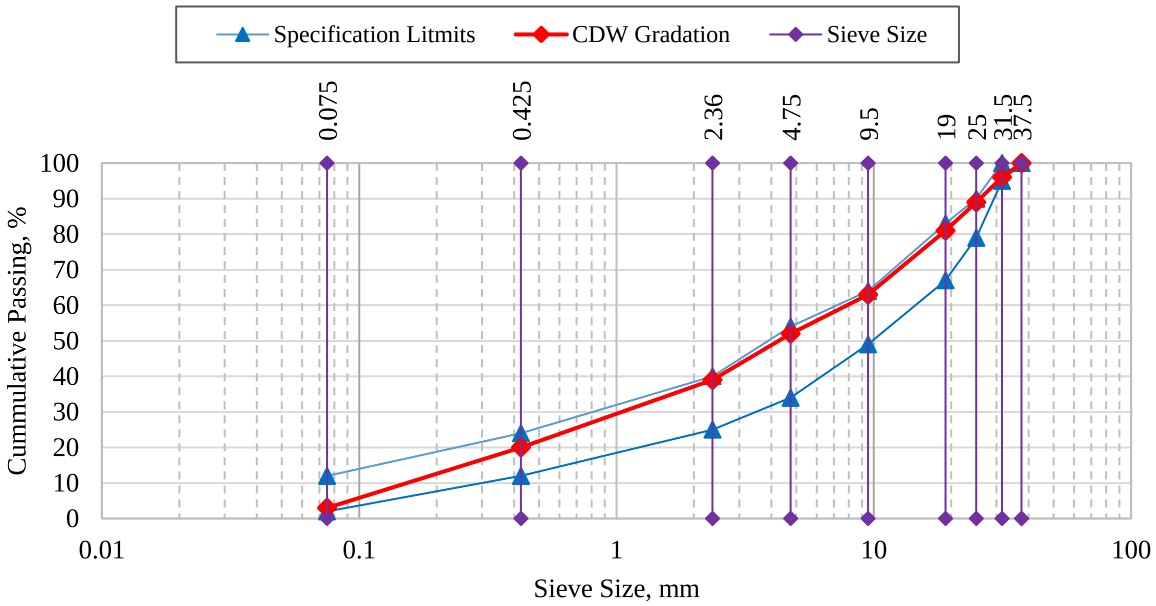



*Fig. 3 – Particle gradation curve of processed CDW*

**Table 3 – Sample Test Preparation**

| Test Indicators | Sample Size | Number of Samples | Test Standards |
|---|---|---|---|
| Compression | Cylinder D152.4, H101.6 | 3x5 | TCVN 3118:1993 |
| Split Tensile | Cylinder D152.4, H101.6 | 3x5 | TCVN 8862:2011 |
| Elastic Modulus | Cylinder D152.4, H101.6 | 3x5 | TCVN 9843:2013 |

### *4.3 Water*

Water used to mix into the CTCDW mixture aims to create conditions for the hydrationreaction of the cement. It also makes a suitable moisture for the compaction process. The water used in the sample preparation process is normal domestic tap water, satisfying the requirements for standard of water for concrete and mortar TCVN 4506:2012 [7].

## 5 Experimental Test

### *5.1 Particle Size Analysis*

The sieve analysis was conducted to test the grain size distribution of CDW aggregate. At first, the CDW collected from dumping landfills was screened to remove unsuitable components and treated for oversized particles. After processing, the treated CDW aggregate was analysed by sieve test to get the typical particle gradation, which is com-pared with the specification limits before the material was used for the other tests.

The particle gradation curve of CDW aggregate in Fig. 3 shows that the treated CDW particle distribution is in compliance with requirements for crushed stone gradation used for base of pavement shown in the current standards [8-10].

### *5.2 Compaction Test*

The compaction test was implemented to find out the optimum moisture content (O.M.C) corresponding to the maximum dry density of CTCDW mixture. The experimental process was conducted in accordance with guidance in current standard 22TCN 333:06 [11].

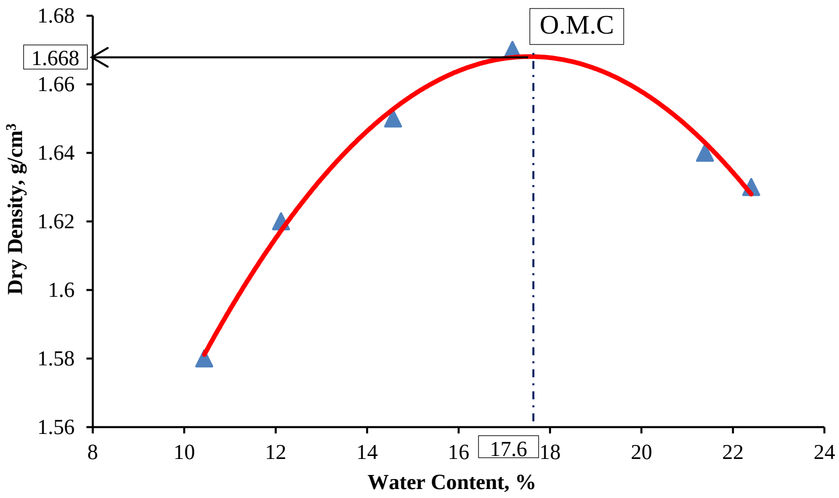



***Fig. 4 – The optimum moisture content of CDW aggregate***

The compaction test result shows that optimum moisture content is of 17.6 % and the maximum dry density of the CDW is of 1.668 g/cm3. The indicators will be referred for construction in practical application.

### *5.3 Compression strength test*

The compressive strength of CTCDW was measured according to TCVN 3118: 1993 [12]. The testing results shown in Fig. 5 indicate that the compressive strength steadily increases when Portland cement content in the mixture increases. The average compression strengths of CTCDW samples are 7.73, 8.69, 9.84, 11.79, 14.83 MPa, respectively, corresponding to cement ratios from 4, 5, 6, 7, 8 % wt.

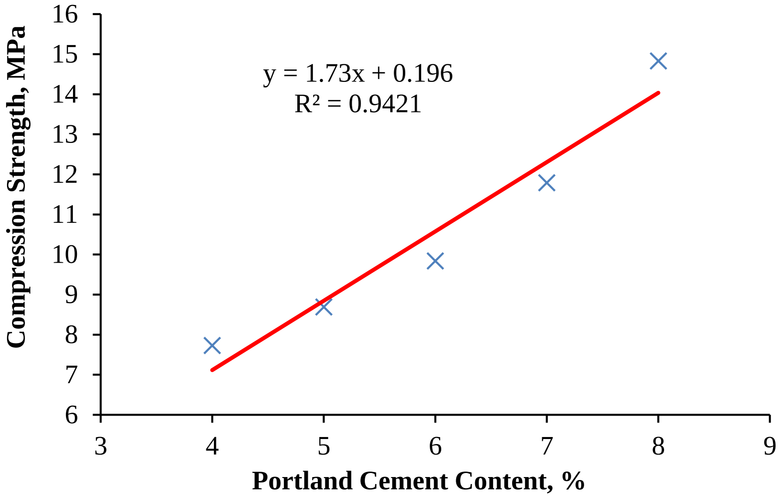



***Fig. 5 – Compressive strength of CTCDW***

The strong correlation between cement ratio and compression strength is represented by the correlation R-squared of 0.94.

### *5.4 Split Tensile Strength Test*

The split tensile test was employed to evaluate the tensile strength of the CTCDW according to the standard TCVN 8862:2011 [13] , and testing results present in Fig. 6.

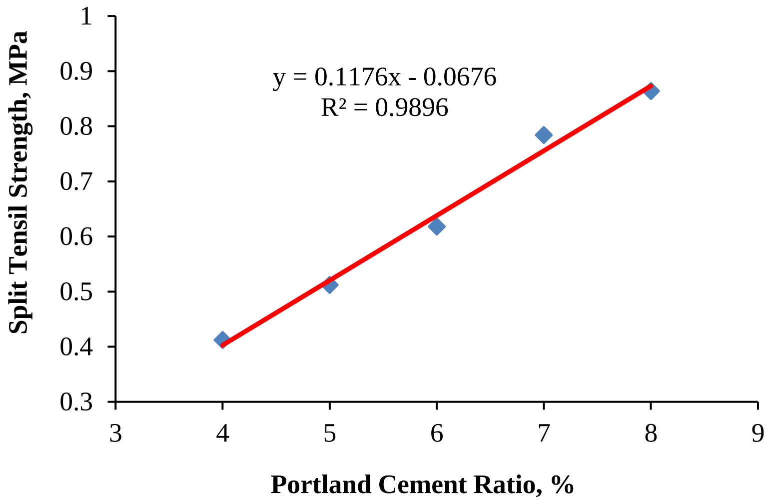



***Fig. 6 – Compressive strength of CTCDW***

Fig. 6. Split Tensile Strength of Portland Cement treated CDW Aggregate.

The values of split tensile of CTCDW are 0.41, 0.51, 0.62, 0.78, corresponding to cement ratios of 4, 5, 6, 7, 8 % wt. The high correlation between strength values and cement ratios is also represented by high correlation R-squared of 0.98.

### *5.5 Elastic Modulus Test*

The elastic modulus CTCDW was determined by method of static compressing cylindrical samples according to TCVN 9843:2013[14] . The testing results presented in Fig. 7 expressed a close linear relationship between CTCDW modulus of 359.2, 374.4, 391.8, 402.9, 420 MPa, corresponding to the cement ratios of 4, 5, 6, 7 and 8 wt. %, respective-ly, by the high correlation R-squared of 0.98.

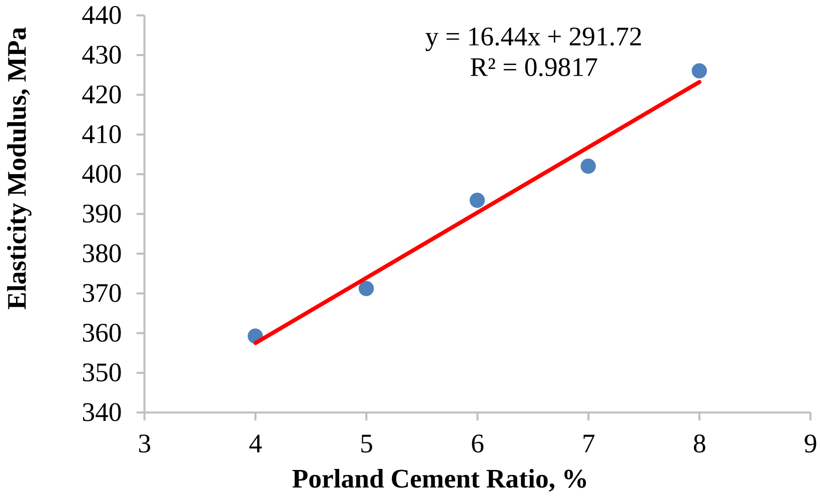
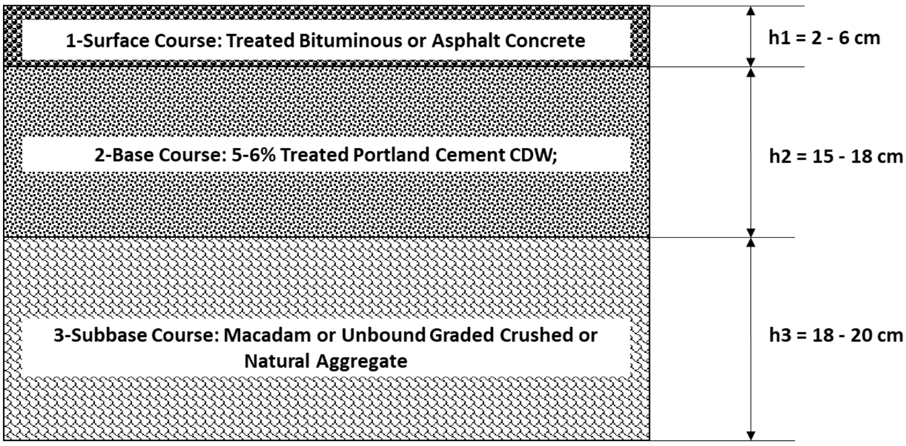
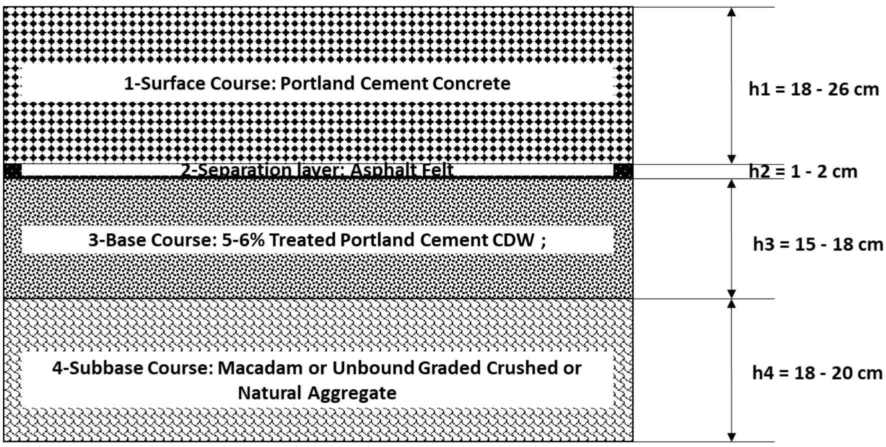



*Fig. 7 – Compressive strength of CTCDW*




(a) Bituminous pavement with CTCDW base




(b) Concrete pavement with CTCDW base

***Fig. 8 – Proposal of pavement structures using CDW as material for construction***

## 6 Evaluation the potential use of CDW for road construction

According to the limits regulated in specification[15] , the compression and split tensile strengths for the cement treated graded aggregate used for bases of road pavement structure have to be equal or greater than 4.0 MPa and 0.45 MPa, respectively, can be used as base layer of the pavement structure of expressway, highway category I, highway category II which having the surface course is asphalt concrete, cement concrete or bituminous surface treatment. For the other uses as base layer for other types of pavements, the compression and split tensile strength is equal or greater than 3.0 MPa and 0.35 MPa, respectively. Regarding the use of subbase layers, applied for all cases, the requirement for compression strength is not less than 1.5 MPa, and there is no limit value required for split tensile strength. The elastic modulus test results reveal that the CTCDW is equivalent to the upper range of cement or lime treated soil with highest quality, which varying from 300 MPa to 400 MPa, and lower partofcement treated crushed stone or cobblestone with broken surface, which is from 400 MPa to 500 MPa.

In the comparison to the regulations, the working capacity of CTCDW, represented by the common performance physical mechanical indicators, can satisfy the condition for use as base or subbase material of road pavement structures in almost all road categories. However, it is the result of screening and selection processes. Naturally, the CDW in Hanoi (or even other cities) is not homogenous material, represented in a wide variation of composition and particle size, depending on where the CDW collected and from which source it is generated.

Based on the experimental testing results and real condition of available CDW in Hanoi, it is recommended for use as a base layer of low traffic or rural road (Category IV-V). The typical pavement structures are suggested as shown in Fig. 5. In this common pavement prototype, the CTCDW in base layers replaced traditional materials. The layer thickness design will be calculated based on traffic volume, loading, subgrade and other related conditions.

## 7 Conclusion

The initial research results show that CTCDW can be completely used as material for base or subbase layers of road pavement structure, especially for low traffic or rural roads. In the context that Vietnam is promoting green and circular economic activities, the study becomes more meaningful since it boosts triple effects by recycling the waste, solving environmental problems and alternatives for depleting of aggregate.

For the use in higher road categories, it is necessary to conduct further studies on specific properties of CDW materials such as water absorption, corrosion, or the influence of water on the material strength, the durability and performance of the layer in pavement. On the supply side, the homogeneity of CDW composition could significantly improve the quality and broadening the application range of the material. Therefore, the innovative and advanced technologies for screening and classifying should be encouragingly applied at the initial stages in CDW management. On the other hand, to promote practical application, the consensus and cooperation of related stakeholders from central agencies to city governments, research institutions, scholars, experts and practitioners should be strongly coordinated and concretely shown by further studies, pilot projects, and allowable regulations in future.

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