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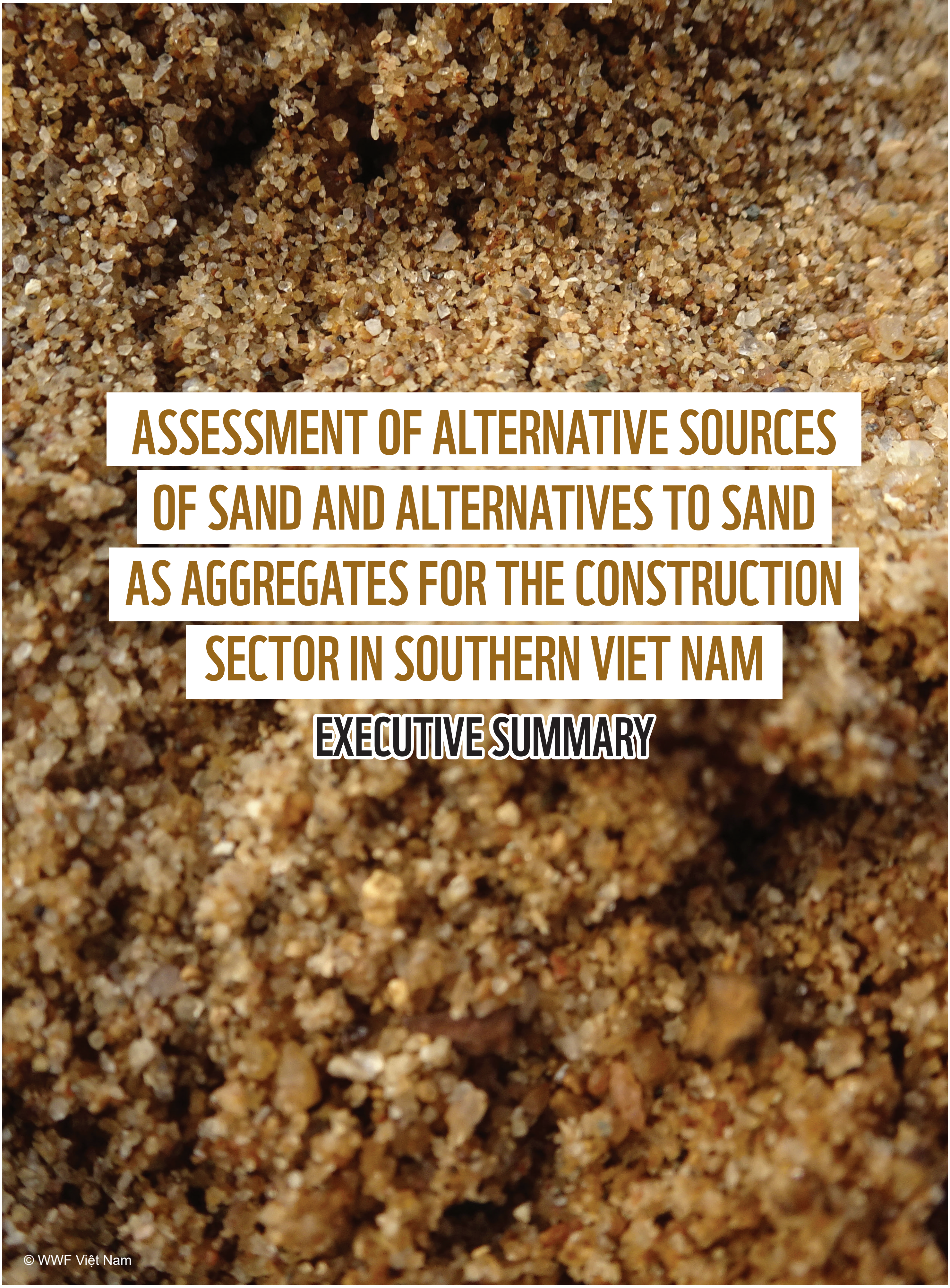


ASSESSMENT OF ALTERNATIVE SOURCES OF SAND AND ALTERNATIVES TO SAND AS AGGREGATES FOR THE CONSTRUCTION SECTOR IN SOUTHERN VIET NAM

EXECUTIVE SUMMARY

This report has been commissioned by the World Wide Fund for Nature (WWF) for the project Drifting Sands: Mitigating the impacts of climate change in the Mekong Delta through public and private sector engagement in the sand industry with financial support from the International Climate Initiative (IKI) - BMU, Germany. The project aims to mitigate the impacts of climate change in the Mekong Delta through public and private sector engagement in the sand industry by: establishing a delta-wide sand-budget to improve understanding of sand stocks and flows in the delta; promoting public awareness of unsustainable sand exploitation; promoting dialogue in the construction sector on the risks of sand sourcing and possible alternatives; and supporting the improvement of policies and practices in relation to sand management.

The present study captures the findings of the research project “SAND!” funded by the German Federal Ministry for Education and Research (BMBF).

LIST OF ABBREVIATIONS

CDW	Construction and demolition waste
EAF	Electric arc furnace slag
GBFS	Granulated blast furnace slag
ISO	International Organization for Standardization
LCA	Life-cycle analysis
M-Sand	Manufactured (or crushed) sand
RHA	Rice-husk ash
SBA	Sugarcane bagasse ash
WWF	World Wide Fund for Nature

1. INTRODUCTION

Scope and goal of this report: The present report provides an overview of primary and secondary raw materials that are structurally suitable substitutes for river sand and do not pose substantive environmental risks to people and nature when used as a building material. It covers sand applications in building, road and landfill construction.

The study intends **to inform the political and technical debate** on the introduction of **alternative building materials** in Vietnam.

Method: The research is based on a **review of the scientific literature** on primary and secondary raw materials for use as aggregates in the construction sector. A L**ife Cycle Assessment** (LCA, following ISO 14040/14043) was then carried out for three exemplary applications to understand the different materials' environmental footprint, namely in i) Non- reinforced concrete (C25/30), ii) Road subbase layers, iii) Landfill capping layers.

Background: The construction sector in South-East Asia is booming due to urbanisation, industrialisation, economic and population growth. The high demand for construction materials puts pressure on natural resources; specifically, the demand for sand by far exceeds the stocks that would be sustainably exploitable. Sand is one of the world's most consumed natural resources after water (Gavriletea, 2017). It forms the unrecognised building block of economies due to its ubiquitous and versatile application in various sectors. The construction industry is the major consumer of sand, in civil engineering and deep construction as well as in landfill and road construction. Sand can be acquired cheaply and easily, thus making it the largest mined and traded resource by volume.

Across the region, substantive overextraction of sand over the past decades has caused widespread environmental degradation and (macro-)economic losses, including riverbank and riverbed erosion with ensuing losses of farmland and houses, the lowering of groundwater tables contributing to the salinisation of groundwater near the coast, as well as the destruction of freshwater habitat impacting the reproduction of fish (Padmalal and Maya, 2014c).

In the Vietnamese Mekong Delta, extraction rates now by far exceed the natural replenishment capacity of the Mekong River. Especially along the Mekong's main branches, the consequences have become increasingly apparent, exposing millions of riparians to riverbank erosion, saltwater intrusion and higher tidal amplitudes. The Mekong Delta loses around 500 hectares of land every year due to subsidence, and due to this hundreds of families lose their houses and fields (Worldbank, 2021). The situation has led to a four- or five-fold increase in building- sand prices. Several provincial construction departments have already announced that public construction projects have become more expensive and been delayed due to the lack of sand.

2. KEY FINDINGS AND RECOMMENDATIONS

2.1 KEY FINDINGS

Primary raw materials: Of the primary raw materials investigated in this study, only **crushed or manufactured sand (M-Sand)** is both suitable as a substitute for river sand and available in sufficient quantities, with a comparatively limited environmental footprint across the impact categories studied here. M-Sand **is already deployed at an industrial scale**, the technical norms and regulations are in place, and its technical suitability is fairly well understood and proven. Sea sand was excluded from the analysis due to its substantive environmental footprint. While there might also be other primary raw materials available in principle, they are not available in sufficient quantities or cannot be mined in a sustainable manner in the Mekong Delta.

Secondary raw materials: As the study reveals, there is also a range of secondary (i.e., recycled) raw materials structurally suitable to substitute river sand fully or partially in various applications in the construction sector that are not yet used widely or at all (see Table 1).

The **most promising materials** in terms of **structural suitability, environmental footprint and estimated quantities available** currently or in the mid-term **include**:

- **Demolition and construction waste (CDW)**
- **Rice-husk ash**
- **Sugarcane bagasse ash**
- **Fly ash**

Recycled D&C waste will be important in the mid-term, based on the experience of other countries like Germany and Belgium, though significant volume streams can only be expected from 2050.

Most **secondary raw materials** have in common that the **quantities** available are **(locally) limited**, and in some cases, processing (e.g., addition of admixtures or treatment at a controlled temperature) may be required before they can be used to substitute sand. Nevertheless, in light of the current vast gap between sand demand and supply, **these materials merit** a more precise **assessment of quantities available**, an **analysis of their economic viability**, the establishment of **technological processing capacities, as required, as well as the development of technical norms and regulation.**

These findings suggest that **the legislator and actors from the construction sector should collaborate to bring promising substitute building materials to market and promote their widespread use.**

2.2 RECOMMENDATIONS

Much remains to be done to promote the market maturity and deployment at scale of the above-mentioned substitute aggregates, from improving data availability over research to setting financial and policy incentives.

The following recommendations address policy-makers as well as businesses and associations from the construction-sector:

Improving data availability

- **Develop more accurate estimates** of long-term **demand for and (sustainable) supplies of construction materials including sand** through evidence-based methods: To carry out planning for responsible mining and production of construction materials, an accurate estimation of the long-term supply and demand for these materials has to be made.

- **Further develop nationally and regionally specific life cycle inventory data for the construction sector.** Life Cycle Analysis (LCA) helps assess the negative impacts of inputs and outputs within a given value chain on long-term sustainability. It thus helps manufacturers reduce the impact of their products, policymakers to improve the policy framework and consumers in making sustainable consumption choices. Much of the data needed to assess the life cycle impacts of construction materials in Vietnam is not yet available.

Bolstering knowledge and capacities

- **Step up funding for Research and Development on substitute building materials,** particularly also for landfill construction in light of its high sand demand

- **Strengthen capacities in the public and private sectors** on the environmental footprint of building materials as well as on secondary raw materials. Provincial and local authorities as well as actors from the construction sector need to be aware of both the environmental impacts of sand mining and the alternatives available to actively support the transition.

Refining the policy framework

- **Leverage policy for the promotion of alternative (secondary) resources.** Under Decree 09/2021/ND-CP on the management of building materials and the Strategy for the Development of Building Materials in Vietnam for the period 2021–2030 with a vision until 2050, the Government of Viet Nam has set itself ambitious targets for the shift towards more sustainable building materials. More specific targets and policy interventions will now be needed to promote a deployment at scale of the most promising alternative aggregates in the construction sector.

Promoting norm development and sustainable production

- **Develop technical and quality norms for substitute building aggregates,** aligned with international standards and with support from the private sector. In particular, norms for use in landfill construction are needed, in light of the latter's substantive aggregate demand. Given these are secondary raw materials, lessons learned e.g. on how to define an "end of waste status" may be gleaned from relevant regulations, such as the German Circular Economy Law.

- **Foster a shift towards low-carbon energy provision for production and low-carbon modes of transport** and an optimisation of transportation routes/distances, as the carbon footprint associated with the production and transportation of construction materials constitutes a major aspect of their total environmental impact.

OVERVIEW OF ALTERNATIVE MATERIALS TO RIVER SAND, INDICATIVE REPLACEMENT RATES AND QUANTITIES AVAILABLE

Note: It is to be noted that the robustness of the findings may differ depending on the number of studies found. See full report for details.

Use in construction sector up Raw to x%* material	Conventional concrete	Self-compacting concrete	High-strength concrete	Bricks	Paving blocks, pavement, concrete blocks	Mortar	Landfill capping layer	Road sub-base layer	Est. quantity available (p.a.)	Processing requirements
M-Sand	100%	100%	100%	100%	100%	100%	100%	100%	~1.9 mt (D100 HCMC)	Mining, grinding
Rice-husk ash	30%	25%p	n.i.**	30%	n.i.	n.i.	50–60%	n.i.	~3 mt/a (country)	Burning at controlled temperature
Sugarcane bagasse ash	20–30%	20%	n.i.	n.i.	n.i.	~30%	n.i.	n.i.	~1.08 mt/a (country)	
Copper slag	50%	40–50%	40%						29.000t	addition of nano-silica beyond 40%
(Granulat- ed) blast furnace sl.	40–60%	~40%				25-75%	(15-20% as liner)	100%	~3.45 mt/a blast furnace slag (country, 2017)	Potent. addition of superplasticiser
Coal bottom ash	30-50%			30%	100%				min. 235,000 t/a (country, 2015)	
Coal fly ash (class F)	50%	30-40%	n.i.	30%	20-30%	60–70%	50–80%	n.i.	min. 822,500 t/a (country, 2015)	Capturing in the chimney
Foundry slag	25%	25%								
Foundry sand	20–30%	30%						50–100%		
Foundry ash										

Sử dụng trong lĩnh vực xây dựng, vât liệu thô lên đến x%*	Bê tông thông thường	Bê tông tự lèn	Bê tông cường độ cao	Gạch	Gạch lát nền, mặt đường, khối bê tông	Vữa	Lớp phủ bãi chôn lấp	Lớp móng dưới đường	Số lượng ước tính có sẵn (p.a.)	Yêu cầu xử lý
CDW: Crushed concrete	Cf. TCVN 7570:2006 “Aggregates for concrete and mortar: Speci-fications” and TVCN 9205:2012 “Crushed sand for concrete and mortar”					See left, con-crete	50-100%	100%	~ 6.3 mt/ a CDW (country	
CDW: Brick waste							50–100%		~ 1.07 mt/a (country)	
Quarry dust	50%		20%	100%	30%					
Dredging mater										
Glass waste	10–20%	5–15%			70%	20%	100%			
Rubber waste	7,5–25%		30%		12,5%					Pavements, floors, concrete highways, tunnels with NaOH 25%

** up to x% of sand substitutable with the respective material according to recent scientific research (see full report for references and details).*

*** no indication*

3. PRIMARY AND SECONDARY RAW MATERIALS SUITABLE

3.1 STRUCTURAL SUITABILITY

Primary raw materials alternative to river sand include natural sand stocks in sand pits and sea sand as well as natural rock for crushed sand production.

Sea sand has been ruled out from this investigation in light of the high environmental damage associated with its extraction (Dybas 2020). Also, sea sand needs washing prior to being usable for concrete production, which implies an additional environmental impact and brings up the cost.

Crushed or manufactured sand is already deployed at an industrial scale. Its structural suitability for concrete production depends on the type of rock: While magmatic and metamorphic rocks (e.g. marble, granodiorite, basalt) are suitable, amphibolite, broken bricks and clinker are not, as they decrease stability. An **estimate of the quantities of suitable rock** for M-Sand production based on lithological maps (Commission of the Geological Map of the World) **suggests 3.498, 947.284 and 6.436.988 million** tons of practically exploitable material **within a 30, 100 and 200 km diameter of Ho Chi Minh City**, respectively. This represents 50% of the stocks available, considering that a full exploitation is neither technologically feasible nor economically viable or ecologically justifiable. Better-informed analysis is required, however, taking into account current land-use and land-use restrictions, such as for protected areas and spiritual sites.

Potential **secondary raw materials** include **agricultural wastes**, namely rice husk ash (RHA) and sugarcane bagasse ash (SBA), **industrial metallurgical** and **mineral wastes**, namely copper slag, blast furnace slag, coal ash waste, coal bottom ash and coal fly ash as well as foundry slag and foundry ash, **construction and demolition wastes** (CDW), namely crushed concrete and brick waste, and **other wastes**, including granite and marble quarry dust, dredging materials, glass and rubber waste. Here, only those materials that hold promise both regarding their technical suitability and the quantities available are listed (for further detail, see full report).

Of these, **CDW, RHA and SBA** are the **most promising in terms of structural suitability**, notably for a partial substitution of sand in concrete production, **as well as quantities available.** While copper slag, BFS and bottom/fly ash allow for a higher admixture rate than do rice husk ash (RHA) and sugarcane bagasse ash (SBA), they are available in lower quantities.

For RHA and SBA, extensive research has shown that admixture of up to 20–30% to different types of concrete typically improves the latter's strength (cf. full report, chapter 5.3)1. It should be noted that the suitability of both materials depends on the processing, in that the residues - rice husk and sugarcane bagasse – need to be burned at a controlled temperature. Countrywide, about 72% of the rice husk is currently burned for energy production. How many incinerators are equipped with a temperature control remains to be ascertained.

Fly ash. At least 60% of production lines use thermal power fly ash or other industrial waste to replace clay materials in the production of clinker. The use of over 30% fly ash or coal bottom ash as an additive in cement production is recommended. In light of Vietnam's commitments to phase out fossil fuel combustion, both fly ash and bottom ash should be regarded as an intermediate resource the stocks of which will decrease in the mid-term, which can, however, be used until other suitable material flows such as C&D waste have increased.

Copper slag is similar to natural sand regarding its physical properties and enhances the mechanical properties of all grades of concrete when used to substitute 40–50% of sand; the addition of nano-silica has been shown to allow for higher substitution rates. It is also suitable for a range of uses in geotechnical applications. As the annually produced quantity is estimated only at around 29,000 t (based on 2015 data on copper production), the material should predominantly be used in applications where few other materials are suitable.

Further industrial and mining wastes are promising regarding their technical suitability, however, the quantities currently available are limited, so their economic viability has to be well understood before bringing them to market.

3.2 ENVIRONMENTAL SUSTAINABILITY

For three applications in the construction sector which require large amounts of sand, different sets of substitute building materials were compared with river sand by conducting a Lifecycle Analysis (see full report, chapter 6) of their environmental footprint regarding: 1) global warming,

2) stratospheric ozone, 3) emission of fine particulate matter, 4) ozone formation, 5) terrestrial acidification, 6) freshwater eutrophication, 7) marine eutrophication, 8) land use, 9) mineral resource consumption, 10) fossil resource scarcity and 11) water consumption.

The three applications include i) road sub-base layers, ii) landfill capping and iii) non-reinforced concrete C25/30. A fourth LCA was carried out for non-reinforced C25/30 concrete using ashes to partially replace cement (see chapter 6).

Road subbase-layer: Four out of the five alternative materials assessed featured a better environmental performance than river sand, with **CDW** and **fly ash** yielding the best results. All five materials could substitute river sand in full (100%) in terms of their structural suitability.

Landfill capping: The LCA analysis for the landfill capping layers utilising various alternative combinations highlighted that in the avoidance scenario, the combination using glass waste and brick waste had a better environmental footprint across the four main impact categories GWP, mineral resource, land use and water consumption. The greatest footprint contribution of the materials derived from the transportation processes, thus, sourcing of materials closer to the site or using low emission transport alternatives needs to be considered.

1. *In a lab test series preceding the LCA on non-reinforced concrete, five different ashes were used to partially substitute cement, with crushed quartz replacing sand as aggregate. In mixes replacing 10%, 20% and 30% of cement respectively, however, compressive strength tests yielded that only mixes with up to 10% of coarse ash and two types of blast furnace ash were equivalent in strength to C25/30. Concrete mixes with the other types of ash – rice-husk ash and filter ash – and/or with higher substitution rates displayed a lower compressive strength.*

Non-reinforced concrete C25/30 using different aggregates: The LCA yielded that C25/30 concrete containing granite sand featured the lowest impact of all five aggregates investigated regarding Global Warming Potential, particulate matter, ozone formation, terrestrial acidification, freshwater eutrophication, marine eutrophication, mineral resource use and fossil resource scarcity. Basalt sand and round as well as flaky quartz sands still exhibit a lower average environmental footprint than marble sand, though differences were partly marginal.

Non-reinforced concrete C25/30 using ashes to substitute cement: A fourth LCA was performed for concrete cubes made of two concrete mixes with coarse ash and blast furnace ash substituting 10% of Portland cement. With much of the global warming potential of concrete production arising from process emissions due to cement usage rather than from energy consumption, replacing cement is the biggest lever to reduce concrete's significant carbon footprint. The assessment revealed that the two alternative mixes reduced the concrete's environmental footprint by an average of 10% across all impact categories investigated except water consumption.

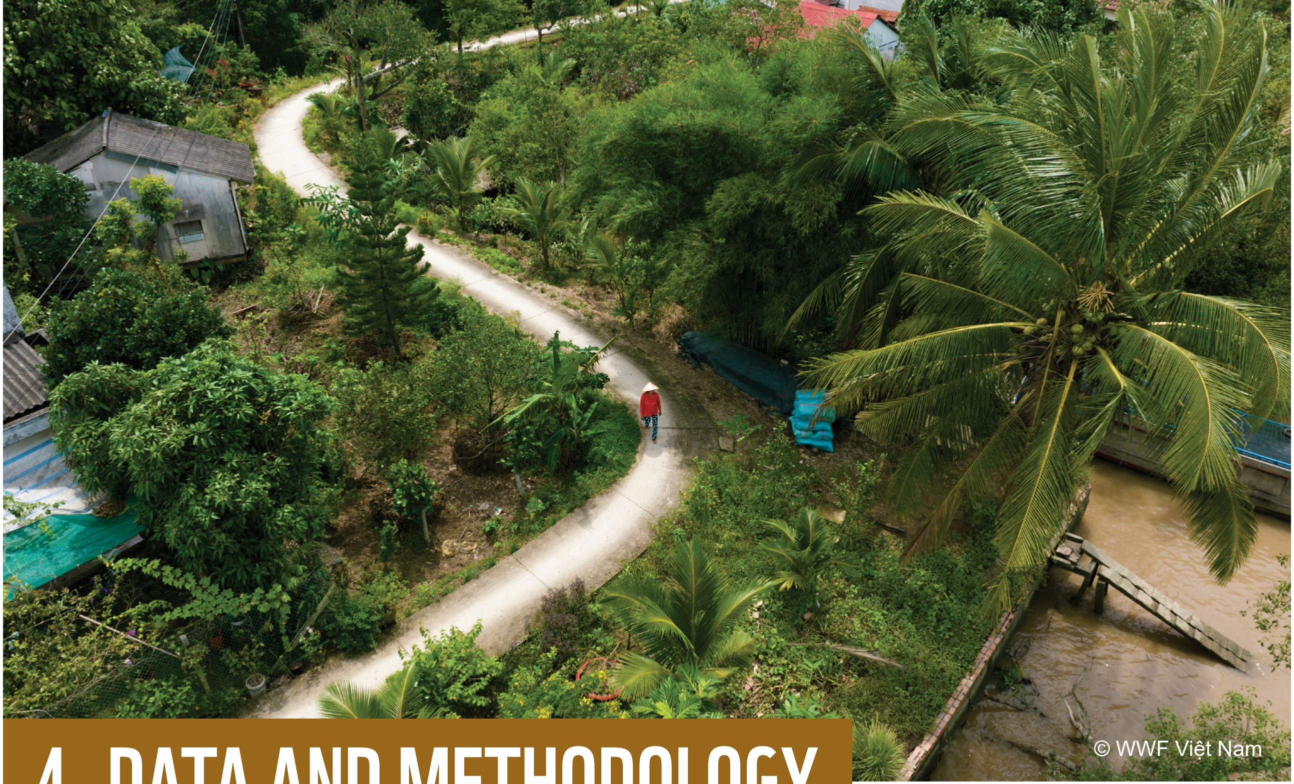
OVERALL LCA CONCLUSIONS

The scientific review reveals that a number of waste materials from industrial and agricultural waste can be used to satisfy the demand for aggregate in different applications (concrete, road subbase layer, landfill capping layers) in the construction sector, thereby alleviating pressure on natural river sand while also advancing a Circular/Green Economy.

The use of secondary raw materials as alternative fine aggregate construction materials provides significant environmental advantages:

- Reduced quantities of primary raw materials consumed;
- Reduced quantities of waste materials in landfills;
- An associated reduction of waste disposal and transport costs
- Generally, a better sustainability performance of secondary raw materials (e.g., brick waste, rice husk ash, fly ash and construction demolition waste) in various applications and across a range of environmental impact categories.

A key finding was the close correlation between the transport costs of building materials and their LCA performance, as transport distances greatly influence impact categories. Thus, there is scope for further decarbonising value chains if raw materials are sourced locally and energy provision is switched to 100% renewable energy sources. Note that biodiversity has not been included in the analysis and remains an important impact category to be investigated.



4. DATA AND METHODOLOGY

The present study assesses substitute building materials for the widely used river sand based on three important requirements: i) structural suitability, ii) the environmental footprint arising from the specific application in the construction sector, iii) quantities locally available in the Vietnamese Mekong Delta.

The assessment is based on: i) a desk review to identify potential alternative sources or materials,

ii) a structured comparative sustainability assessment based on the Life-Cycle Analysis method. Of the materials identified as structurally suitable in the desk review, only those with a certain minimum mass flow were investigated further using the LCA method.

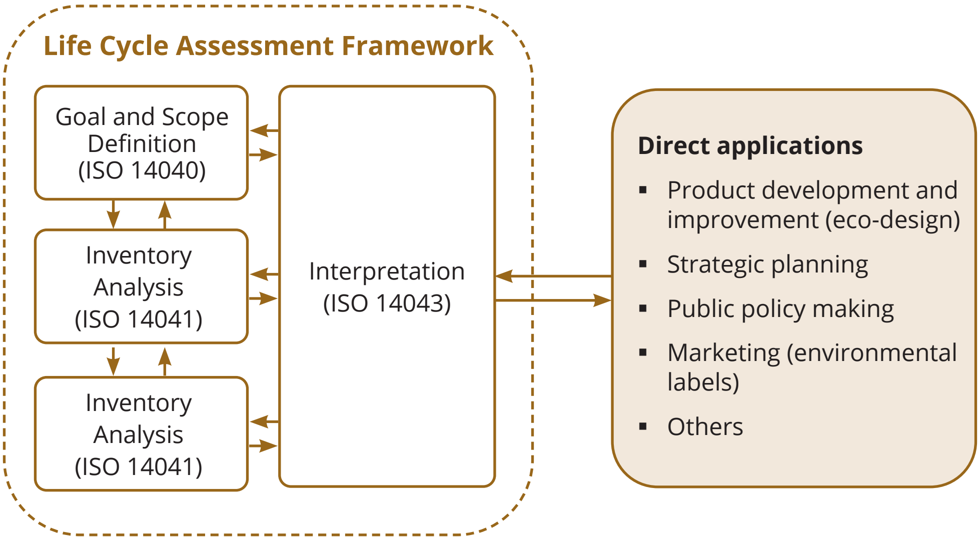
4.1 DESK REVIEW

The desk review involved: a review of i) the scientific literature published before/ between [month/ year], as well as of ii) relevant projects and online databases (esp. Viet Nam Biomass Atlas1) and iii) online/ remote data sources, followed by iv) an analysis and summary of the collected data.

4.2 STRUCTURED ASSESSMENT OF THE COMPARATIVE SUSTAINABILITY PERFORMANCE OF ALTERNATIVES USING LIFE-CYCLE ANALYSIS (ISO 14040/14043)

Life-cycle analysis is a widely used and recognised method to compare the environmental sustainability performance of alternative products or processes over their entire life-cycle[2]. A LCA typically consists of four stages, as defined by the ISO 14040-14043 standards:

2. *Nguồn: https://datacatalog.worldbank.org/search/dataset/0039043/Vietnam---Biomass-Atlas*
3. *Tại Việt Nam, phương pháp LCA được công nhận lần lượt là TVCN ISO 14040:2009, 14041:2011, ISO/TR 14047:2018 và ISO/TR 14048:2012.*



The LCAs undertaken here followed the **ISO 14040/14043** standards and utilised the **Ecoinvent** 3.6 database and the SimaPro 9.2 software. Three LCAs were carried out to compare five substitute materials (CDW, EAF, fly ash, GBF, M-Sand) and river sand in different applications in the construction sector:

- Road subbase layers using alternative and waste materials
- Landfill capping layers using alternative and waste materials
- Non-reinforced concrete C25/30 using different aggregates

A fourth LCA was undertaken using five different ashes to partially substitute cement in non- reinforced concrete of strength C25/30.

The system boundaries were set to include the production stage (extraction of natural aggregates, processing, waste processing and transport to site) or supply of the construction

materials (cradle-to-gate approach). The environmental impacts during the installation process and service life were deemed to be comparable to river sand.

The materials were compared regarding the following **environmental impact categories**: global warming potential; mineral resource scarcity; fossil resource scarcity; terrestrial acidification; freshwater eutrophication; marine eutrophication; fine particulate matter formation; stratospheric ozone depletion; ozone formation in terrestrial ecosystem; cumulative energy consumption.

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