



BUILDING MATERIAL SELECTION AND USE

An Environmental Guide

Prepared for WWF Environment and Disaster
Management Green Recovery Connect



TABLE OF CONTENTS

Introduction.....	3
Project Cycle and Materials.....	4
Environmental Guide to Selection of Common Building Materials	5
Material Life Cycle.....	15
Responsible Material Selection and Use: Key Concepts	16
Additional Resources	17
References	18

ACRONYMS

ABC	Aggregate Base Concrete
ACI	American Concrete Institute
BRE	Building Research Establishment
CBO	Community-based Organization
CGI	Corrugated Galvanized Iron
CSEB	Compressed Stabilized Earth Block
GESI	Gender Equality and Social Inclusion
HSE	Health and Safety Executive
NGO	Nongovernmental Organization

© 2016 WWF. All rights reserved by World Wildlife Fund, Inc.

Reproduction of this publication for educational and other noncommercial purposes is authorized without prior permission of the copyright holder. However, WWF Inc. does request advance written notification and appropriate acknowledgment. WWF Inc. does not require payment for the noncommercial use of this published work and in no way intends to diminish use of WWF research and findings by means of copyright. Reproduction or other use of photographs and maps that appear in this publication is prohibited.

Cover photo credit:

© WWF-Indonesia / Fazedah Nasution

Published by:

World Wildlife Fund
1250 24th Street NW
Washington, DC 20037

envirodm@wwfus.org
www.envirodm.org

Acknowledgements:



EDM

This environmental guide is made possible by the World Wildlife Fund Environment and Disaster Management program. This guide was initially developed for use in Nepal with WWF Nepal and the Hario Ban Program. Additional country-level versions are under development.

Authors

Dr. Missaka Hettiarachchi
Senior Fellow, World Wildlife Fund

Charith Fonseka
Lecturer, University of Moratuwa

Anita Van Breda
Senior Director, Environment and Disaster Management, World Wildlife Fund

Jennifer Pepson Elwood
Senior Program Officer, Environment and Disaster Management, World Wildlife Fund

INTRODUCTION

Increasing populations, rising urbanization, economic expansion, and the emergence of new industrial centers are among the driving factors of increasing demand for construction material around the world. Reconstruction needs after major disasters only compound this issue. Exponential increases of material extraction, processing and disposal can cause significant environmental and social impacts such as erosion, deforestation, landslides, and floods; deprive communities of essential livelihood resources; and put people, infrastructure, and ecosystems at greater risk of future disasters.

Practical guidelines for responsible material selection and use for government agencies, nongovernmental organizations (NGOs) and the private sector are rare. This guide aims to fill a gap and provide guidance on better practices for government agencies, private sector companies, NGOs, and community-based organizations (CBOs) for environmentally responsible selection, sourcing, use and disposal of construction material.

A number of construction materials are available in different regions of the world. If selected and used in an environmentally responsible manner along with the employment of responsible construction technology and practices, future construction needs can be met while creating a resilient built environment.

AIM

The aim of this document is to provide a general guideline for engineers, architects, project managers, and technicians in construction projects to select, source (or procure), and use specific building materials in an environmentally responsible manner. It is assumed that the user has a basic knowledge about building materials and the construction process, but it is not necessary to have advanced technical training to use this tool.

The guide provides information on environmental better practices related to design, planning, storage, use, and disposal for common building materials as well as key environmental costs and benefits. The guide also introduces the user to some useful overall concepts for environmentally responsible selection and use of building materials throughout a construction project and material life cycles.

This guide provides only general environmental information for each material; the actual process of material selection and use requires careful professional judgment in each individual case.

PROJECT CYCLE AND MATERIALS

Material-related decisions in construction projects are not made at one given time. Different issues are addressed in material selection, sourcing, procuring, storage, use and disposal and emerge at different stages of the project cycle. Figure 1 displays the typical building material-related decisions that need to be made and environmental issues at different stages of the project cycle.

For example, material selection can substantially impact the cost of construction and project management. This decision has to be made at the beginning of the inception stage even before the detailed designs are done—e.g., bricks versus rammed earth walls. More detailed issues such as using water-based paints instead of solvent-based paints, can be addressed later in the design stage or construction stage. Disposal of waste material is an issue that arises in the construction stage, but the reuse or disposal methods and sites should be identified well in advance of commencing construction.

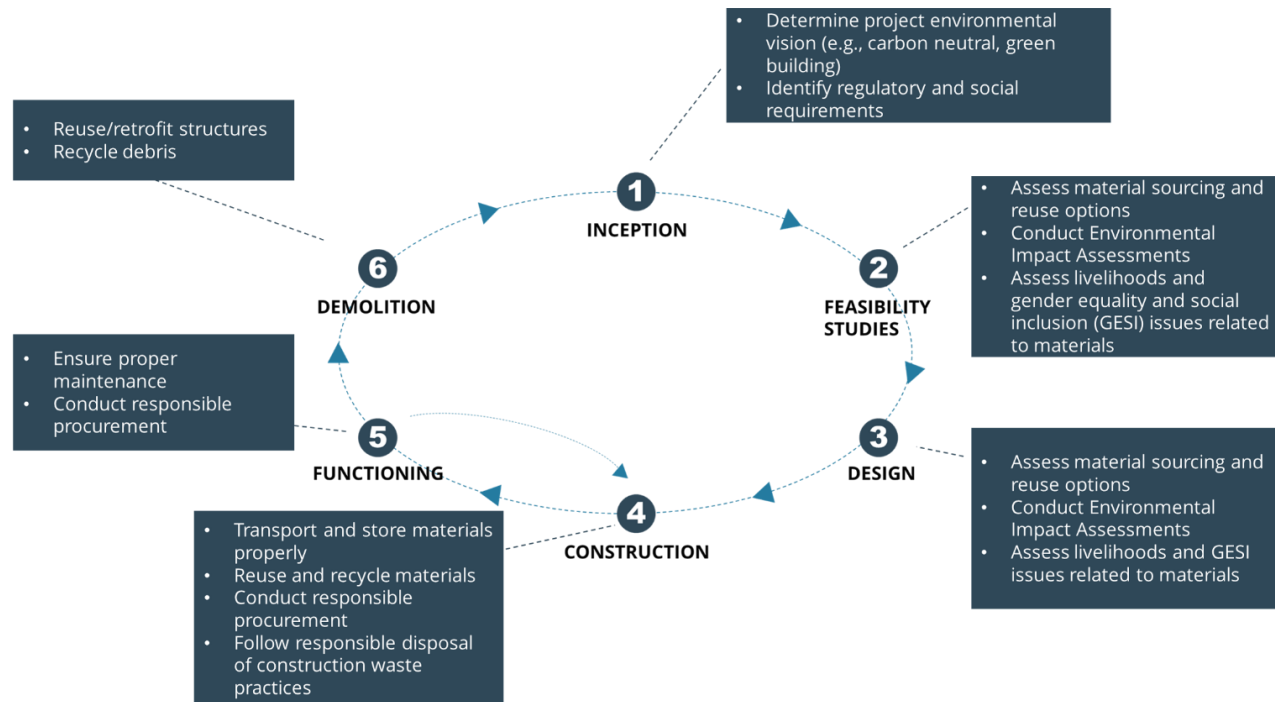


FIGURE 1. CONSTRUCTION PROJECT CYCLE AND MATERIAL-RELATED INTERVENTION POINTS

ENVIRONMENTAL GUIDE TO SELECTION OF COMMON BUILDING MATERIALS

No.	Material	Types of Use [special technical remarks]	Environmental Costs / Benefits		Management & Alternatives			Key Resources
			Environmental impacts	Environmental benefits	Potential material alternatives	Environmental Better practices (Design/Planning)	Environmental Better practices (Storage/Use/Disposal)	
A. General Construction Material								
A1	River sand	Concrete, Cement Mortar, Plaster (as a bedding material), Asphalt	<p>Extraction Erodes channel bed and banks, increases channel slope, and leads to changes in channel morphology. These impacts may cause:</p> <ul style="list-style-type: none"> • undercutting and collapse of river banks • loss of adjacent land and/or structures • upstream erosion • downstream erosion • downstream changes in patterns of deposition • destruction of riverine habitats <p>Transport Transport using large trucks affects rural roads and may cause noise and air pollution.</p> <p>Production/Treatment None</p> <p>Toxicity None</p>	None	Manufactured sand (crushed rock/gravel), Sea sand, Crushed rubble (debris), Fly ash/bottom ash, Recycled building and quarry dust	<ul style="list-style-type: none"> • Use alternatives to concrete/mortar, e.g., stabilized earth walls (refer to section B) • Use premixed concrete instead of in-situ mixing • Use prefabricated concrete items • Optimize concrete mix design (don't over-specify) (BRE mix design, ACI method of concrete mix design) • Use standardized bricks to minimize mortar and plaster 	<p>Storage Store in a manner free from contamination by other site materials, for example, by providing containment with proper base and curb. Protect from rain and other water sources.</p> <p>Use Adhere to the building specifications mixing mortar and concrete and building. Overuse of the material will not add additional strength, and will cause waste. Mix in small adequate batches to minimize waste. Do not mix more fresh concrete/mortar than you will use in a two-hour period.</p> <p>Disposal Never dispose of washout cement, sand, cement mortar, or concrete in environment. They can be</p> <ul style="list-style-type: none"> • reused on-site/off-site for construction purposes (e.g., filling), • safely transported to a construction material recycling facility, or • safely transported to a sanitary landfill 	[10] [20] [27] [34] [37] [38]

A2	River gravel/ boulders	Concrete, Random rubble masonry, Aggregate base concrete (ABC), Road base, Manufacturing sand, Asphalt	<p>Extraction Same as A1</p> <p>Transport Transport using large trucks affects rural roads and may cause noise and air pollution.</p> <p>Production/Treatment Process often involves crushing into uniform sizes or fines (sand). Crushing plants cause noise, air pollution, silting of water bodies/wetlands etc.</p> <p>Toxicity None</p>	None	Crushed rock, Crushed rubble (debris)	<ul style="list-style-type: none"> Plan and design construction to minimize waste Use alternatives to concrete/ mortar, e.g., stabilized earth walls Use premixed concrete instead of in-situ mixing Use prefabricated concrete items 	<p>Storage Locate stockpiles to provide safe access for withdrawing material.</p> <p>Use Refer to A1</p> <p>Disposal Refer to A1</p>	Refer to A1
A3	Quarried rock	Concrete, Random rubble masonry, Aggregate base concrete (ABC), Road base, Manufactured sand, Asphalt	<p>Extraction Extraction from quarries involves blasting. Quarries cause noise, dust, air pollution, habitat destruction and vibration if not properly managed. Unplanned rock quarrying can cause landslides and hydro-geological impacts. Without planning and protection blasting causes occupational hazards.</p> <p>Transport Transport using large trucks affects rural roads and may cause noise and air pollution.</p> <p>Production/Treatment Process often involves crushing into uniform sizes or fines (sand). Crushing plants cause noise, air pollution, silting of water bodies/wetlands etc.</p> <p>Toxicity None</p>	None	Crushed concrete, Broken brick (for certain uses only)	<ul style="list-style-type: none"> Use optimum mix design to minimize the quantity of quarried rock used Select a quarry site close to the construction site to minimize distance of transportation Consider mixing with recycled material (crushed concrete or broken brick) in design 	<p>Storage Locate stockpiles to provide safe access for withdrawing material and ensure minimum spill and waste.</p> <p>Use Refer to A1</p> <p>Disposal Refer to A1</p>	Refer to A1

A4	Cement	<p>Concrete, Mortar, Plaster, Stabilized earth construction/ blocks</p> <p><i>[consistent quality, predictable structural strength]</i></p>	<p>Extraction Uses limestone and other minerals extracted from quarries or mines in manufacturing, which can cause severe mining impacts.</p> <p>Transport Transport using large trucks affects rural roads and may cause noise and air pollution.</p> <p>Production/Treatment Produces greenhouse gases both, directly through the production of carbon dioxide when calcium carbonate is heated (producing lime and carbon dioxide), and indirectly through the use of energy, particularly if the energy is sourced from fossil fuels.</p> <p>Toxicity None</p>	None	Lime mortar, Other cement-derived material (not suitable for concrete)	<ul style="list-style-type: none"> • Use alternatives to concrete/mortar, e.g., stabilized earth walls • Use premixed concrete instead of in-situ mixing • Use prefabricated concrete items • Optimize concrete mix design (don't over-specify) • Use standardized bricks to minimize mortar and plaster • Use precast concrete designs for construction; precast concrete can be designed to optimize (lessen) the amount of concrete used in a structure or element 	<p>Storage Store cement in a building that is dry, leak-proof, and as moisture proof as possible. There should be a minimum number of windows in the storage building. Stack the cement bags off the floor on wooden planks in such a way, so that bags are about 150 mm to 200 mm above the floor.</p> <p>Use Use quantities as specified in the optimum mix design. Avoid wastage by calculating adequate hauling times when purchasing premixed concrete and use retarders in case of long hauls. Do not mix more fresh concrete or cement than you will use in a two-hour period. Also refer to A1</p> <p>Disposal Refer to A1 Never dispose of cement slurry or washout in streams or street drains. Never dispose of empty cement bags in the environment. Instead, dispose of them in a sanitary landfill.</p>	Refer to A1 [2]
----	--------	---	--	------	--	---	--	-----------------

B. Wall Material

B1	Burnt bricks	Walls, Columns, Foundations, Floor paving	<p>Extraction Mining of surface clays, shales and some fire clays occurs in open pits with power equipment; then the mixtures require transport to plant storage areas.</p> <p>Transport Transport using large trucks affects rural roads and may cause noise and air pollution.</p> <p>Production/Treatment Brick firing is an energy-intensive process. The brick industry is therefore one of the largest consumers of coal and, hence, is also a significant air polluter. Air pollution and the use of good-quality agricultural soil are the major environmental concerns related to the use of bricks. Brick kilns may emit toxic fumes (suspended particulate matter, carbon monoxides, and oxides of</p>	None	Cement blocks, Stabilized earth blocks, Stabilized earth walls, Straw clay walls, Bamboo/timber reinforced earth walls, Prefabricated wall panels	<ul style="list-style-type: none"> • Produce bricks on-site (e.g., stabilized earth blocks) • Encourage reuse of bricks from demolished buildings • Use standardized, quality-controlled bricks for construction • Reduce wastage by accurately estimating brick requirement • Use standard lengths and optimal wall thicknesses in design to minimize brick waste 	<p>Storage Properly package/load bricks during transport and store in a dry place in suitable stack heights.</p> <p>Use Not significant</p> <p>Disposal Reuse bricks/blocks for on-site/off-site construction purposes (e.g., filling, paving) or safely transport to a construction material recycling facility. Never dispose of bricks/blocks in streams, wetlands, coastal areas or agricultural lands.</p>	[7] [10] [34] [38]
----	--------------	---	--	------	---	---	--	-----------------------------

			<p>sulphur—SOx) that are harmful to eyes, lungs, and throat.</p> <p>Toxicity None</p>					
B2	Cement blocks	Walls	<p>Extraction Requires cement, quarried and mined material (e.g., sand, rock chips, and gravel). (see A1, A2, A3, and A4)</p> <p>Transport Transport using large trucks affects rural roads and may cause noise and air pollution.</p> <p>Production/Treatment Manufacturing uses power or manually operated pressure molds. Casting yards can cause dust, noise and silt problems.</p> <p>Toxicity None</p>	<ul style="list-style-type: none"> No firewood demand Minimal air pollution 	Stabilized earth blocks, Stabilized earth walls, Straw clay walls, Bamboo/timber reinforced earth walls, Prefabricated wall panels	<ul style="list-style-type: none"> Use standardized and good quality blocks for construction Use accurate estimates to purchase blocks—this will minimize wastage Produce concrete blocks on-site Use standard lengths and optimal wall thicknesses in design to minimize brick waste 	<p>Storage Refer to B1</p> <p>Use Not significant</p> <p>Disposal Refer to B1</p>	Refer to B1 [11]
B3	Stabilized earth blocks/ CSEB	Walls <i>[not suitable for high-moisture environments or load-bearing walls]</i>	<p>Extraction Requires soil with small amounts of sand and cement. Soil extraction can cause habitat destruction and landslides, and can pollute water bodies and alter hydrology.</p> <p>Transport Transport using large trucks affects rural roads and may cause noise and air pollution.</p> <p>Production/Treatment Manufacturing uses power or manually operated pressure molds. Casting yards can cause dust, noise and silt problems.</p> <p>Toxicity None</p>	<ul style="list-style-type: none"> No fire wood demand No air pollution Minimal demand for quarried material 	Stabilized earth walls, Straw clay walls, Bamboo/timber reinforced earth walls, Prefabricated wall panels	<ul style="list-style-type: none"> Design the building to match available block dimensions Produce CSEB on-site with proper quality control, this will reduce the cost of transportation and production 	<p>Storage Refer to B1</p> <p>Use Not significant</p> <p>Disposal Refer to B1</p>	Refer to B1 [3] [6] [26]
B4	Earth walls (stabilized earth, clay-straw, rammed earth, bamboo reinforced earth)	Walls <i>[not suitable for high-moisture environments or load-bearing walls]</i>	<p>Extraction Requires soil with small amounts of sand and cement. Soil extraction can cause habitat destruction and landslides, and pollute water bodies and alter hydrology.</p> <p>Transport Transport requirement is minimal.</p> <p>Production/Treatment Fabricating is in-situ using wooden or steel formwork and soil/clay.</p> <p>Toxicity None</p>	<ul style="list-style-type: none"> No fire wood demand No air pollution No demand for quarried material Minimal transport requirement 	Straw clay walls, Bamboo/timber-reinforced earth walls, Prefabricated wall panels	<ul style="list-style-type: none"> Match available steel or wood formwork dimensions with the structural dimensions of the building Reduce construction time with proper planning Use only in areas where earth can be extracted without causing hazards or environmental impacts Use standard lengths and optimal wall thicknesses 	<p>Storage Store soil in a dry, enclosed space.</p> <p>Use Use optimum mix proportions and only mix in small and adequate batches.</p> <p>Disposal Never dispose of demolished wall material in streams, wetlands or coastal areas. Reuse demolished walls material for on-site/off-site construction.</p>	[21]

C1	Forest timber	Roof structure, Beams, Columns, Door and window frames, Decks, Floor paving, Roof tiles, Wall panels, Formwork	<p>Extraction Extraction can cause forest destruction, landslides, land degradation, and habitat destruction, and can increase flood risk.</p> <p>Transport Transport of logs can further damage forests and rural roads.</p> <p>Production/Treatment Processing takes place in timber mills. Mills that are poorly managed cause solid-waste pollution, and noise and air pollution.</p> <p>Toxicity Requires treatment for pest control. Using toxic chemicals for treatment causes environmental and health hazards.</p>	<ul style="list-style-type: none"> • A renewable resource, if well managed 	Farmed timber, Plywood, Fiber boards, Bamboo	<ul style="list-style-type: none"> • Do not over design/over specify— where possible, conduct proper structural design for timber buildings and calculate the timber need accordingly • Minimize cutoffs • Treat timber properly for long-term durability • Minimize the use of timber for formwork and use reusable modular formwork instead 	<p>Storage Store timber as close as practicable to your site. Properly store in a covered dry place, with proper stack heights. Allow air circulation and support well to avoid sagging. Keep it away from moisture as much as possible.</p> <p>Use Schedule timber delivery in-line with the phase of the project when it will be required to prevent unnecessary exposure of timber to the elements. Take extra care when handling to ensure that products are not spoiled while being moved. Use protection when handling and cutting chemically treated timber.</p> <p>Disposal Encourage timber reuse (e.g., door and window frames, roof members). Never dispose of timber in streams, wetlands, or coastal areas. Chemically treated timber cutoffs should be considered a hazardous material; never use as firewood.</p>	<p>[17] [19] [22] [28] [31]</p>
C2	Farmed timber	Roof structure, Beams, Columns, Door and window frames, Decks, Floor paving, Roof tiles, Wall panels, Formwork	Same as C1	<ul style="list-style-type: none"> • Minimal impact on natural forests • Over-extraction can be managed 	Plywood, Fiber boards, Bamboo	<ul style="list-style-type: none"> • Refer to C1 	Refer to C1	Refer to C1 [8]
C3	Plywood/ laminated panels, Chip boards, Fiber boards	Wall panels, Floor panels, Formwork, Partition walls, <i>[only suitable for temporary use in external work]</i>	<p>Extraction Extraction can cause forest destruction, landslides, land degradation, and habitat destruction, and can increase flood risk.</p> <p>Transport Transport of logs can further damage forests and rural roads.</p> <p>Production/Treatment Manufacturing uses timber-mill by-products or farmed soft wood and chemical binders. It takes place in large factories with energy-intensive</p>	<ul style="list-style-type: none"> • Minimal impact on natural forests • Uses timber mill by-products • Ability to be preformed into efficient sizes and thicknesses 	Woven bamboo panels	<ul style="list-style-type: none"> • Refer to C1 • Design to use standard panel sizes (minimize cutoffs) 	<p>Storage Refer to C1</p> <p>Use Refer to C1</p> <p>Disposal Refer to C1</p>	Refer C1

			<p>processes. Processing results in air pollution. (see C1)</p> <p>Toxicity Using binding material and treatment chemicals in manufacturing can cause environmental and health hazards.</p>					
D. Roofing Material								
D1	Asbestos cement sheets	<p>Roofing, Sheltering, Ceilings</p> <p><i>[banned in many countries due to health hazards]</i></p>	<p>Extraction Requires conventional mining practices to bring underground asbestos deposits and ore to the surface.</p> <p>Transport Transport of logs can further damage forests and rural roads.</p> <p>Production/Treatment Involves complicated processes that include mining and separating.</p> <p>Toxicity Extremely hazardous to human health.</p>	None	Clay roof tiles, Thatching material, Aluminum sheets, Plastic roofing sheets, CGI sheets	<ul style="list-style-type: none"> Do not recommend for any new construction 	<p>Storage Do not receive, store, distribute, or dispatch asbestos products from any place of work unless they are suitably sealed and labelled.</p> <p>Use Strictly follow health and safety guidelines in removal.</p> <p>Disposal Strictly follow health and safety guidelines in removal and disposal, as it is an extremely hazardous material.</p>	[25] [32]
D2	Clay roof tiles	<p>Roof sheltering</p> <p><i>[provide high level of thermal comfort]</i></p>	<p>Extraction Requires clay, and clay mining causes habitat destruction, pollutes water bodies, and alters hydrology.</p> <p>Transport Transport can damage rural roads.</p> <p>Production/Treatment Manufacturing uses wood-fired kilns, but the process is more managed than is brick-making. Kilns can cause severe air pollution due to improper quality control.</p> <p>Toxicity None</p>	None	Plastic/fiber glass roofing sheets, Thatching material	<ul style="list-style-type: none"> Minimize use in areas with widespread clay mining impacts Minimize roof area in design Encourage reuse from old buildings Procure proper estimates to minimize wastage 	<p>Storage Store in a dry place in suitable stack heights and use proper packaging and loading/ unloading in transport.</p> <p>Use Not significant</p> <p>Disposal Refer to B1</p>	[9] [14]
D3	Corrugated Galvanized Iron (CGI) sheets	<p>Roof sheltering, Wall panels</p> <p><i>[low thermal comfort, low durability in corrosive environments, use for wall panels suitable only in temporary installations]</i></p>	<p>Extraction Manufacturing process requires large quantities of steel, zinc and other metals. May contribute to mining impacts.</p> <p>Transport Transport can damage rural roads.</p> <p>Production/Treatment Manufacturing takes place in large-scale factories using energy-intensive processes. Factories can cause severe air and water pollution, if poorly managed. Manufacturing processes may release toxic heavy metals.</p>	None	Clay roof tiles, Aluminum sheets, Plastic/reinforced plastic roofing sheets, Thatching material	<ul style="list-style-type: none"> Use optimum design calculations to minimize cut wastes Use certified products and avoid using in corrosive environments Avoid contact with ground or high levels of moisture if using for wall panels Encourage reuse of un-corroded sheets from old buildings 	<p>Storage Store in a dry place in suitable stack heights and use proper packaging and loading/ unloading procedures in transport.</p> <p>Use Not significant</p> <p>Disposal Never dispose of CGI in the environment; it can be easily sold as scrap metal.</p>	[33]

			<p>Toxicity None</p>					
D4	Thatching material	<p>Roof sheltering</p> <p><i>[low durability, only usable in certain types of roof designs]</i></p>	<p>Extraction Natural or farmed vegetation (e.g., palm leaves, reed, grasses) is used in harvesting. Without proper management, it may have impacts on forests and natural vegetation.</p> <p>Transport Transport can damage rural roads.</p> <p>Production/Treatment Households or small-scale industries process material. Material needs seasoning and may cause water pollution if not properly managed.</p> <p>Toxicity None</p>	<ul style="list-style-type: none"> No requirement for quarried material or clay No firewood or energy requirement Can support indigenous livelihoods and knowledge 	Clay roof tiles	<ul style="list-style-type: none"> Use local knowledge where possible Use basic building designs Support local livelihoods and industries Consider fire risk in planning and design since thatch is combustible 	<p>Storage Store in a dry place in suitable stack heights and order at correct time to avoid wastage.</p> <p>Use Use local thatching material that can be obtained without environmental damage.</p> <p>Disposal Does not harm the environment since it is biodegradable. However, avoid disposing of large quantities in streams, estuaries and coastal areas.</p>	[29]
D5	Aluminum sheets	<p>Roof sheltering, Wall panels</p> <p><i>[use for wall panels suitable only in temporary installations]</i></p>	<p>Extraction Manufacturing process requires large quantities of aluminum and other metals. May contribute to mining impacts.</p> <p>Transport Transport can damage rural roads.</p> <p>Production/Treatment Manufacturing takes place in large-scale factories using energy-intensive processes. Factories can cause severe air and water pollution, if poorly managed.</p> <p>Toxicity None</p>	None	Plastic/fiber-reinforced plastic roofing sheets, Clay tiles, Thatching material	<ul style="list-style-type: none"> Refer to D3 Corrosion resistance makes aluminum sheets more environmentally appropriate in corrosive environments 	<p>Storage Refer to D3</p> <p>Use Not significant</p> <p>Disposal Refer to D3</p>	[1] [30]
D6	Plastic/ fiber-reinforced plastic roofing sheets	<p>Roof sheltering, Wall panels</p> <p><i>[use for wall panels suitable only in temporary installations]</i></p>	<p>Extraction None</p> <p>Transport Transport can damage rural roads.</p> <p>Production/Treatment Manufacturing takes place in medium-to-large-scale factories using energy-intensive processes. Factories can cause severe air and water pollution if poorly managed.</p> <p>Toxicity May cause health hazards because of the use of some harmful organic compounds and fibers in reinforced plastic sheets.</p>	<ul style="list-style-type: none"> Reduce environmental damage by using natural fibers and safe petroleum by-products in manufacturing 	Thatching material	<ul style="list-style-type: none"> Encourage the use of natural fibers (e.g., coir) in fiber reinforced plastic sheets Design to optimum criteria to minimize wastage Also refer to D3 	<p>Storage Refer to D3</p> <p>Use Use protection when cutting the sheets as dust and fumes may cause health hazards.</p> <p>Disposal Never dispose of in the environment; only dispose of in a sanitary landfill. Encourage reuse of material.</p>	[16] [18]
E. Finishing Material								
E1	Ceramic tiles	<p>Floor tiling, Wall tiling</p>	<p>Extraction Requires clay, and clay mining causes habitat destruction, pollutes water bodies, alters hydrology.</p>	None	Terracotta tiles, Cement tiles, Vinyl tiles,	<ul style="list-style-type: none"> Use optimal design (use only where necessary, limit aesthetic use) 	<p>Storage Requires proper transport and handling.</p>	Refer to B1 [15]

			<p>Transport Transport can damage rural roads.</p> <p>Production/Treatment Manufacturing takes place in large industrial kilns. It is highly energy intensive, and if not properly managed, factories can cause air and water pollution.</p> <p>Toxicity Glazing may use toxic compounds.</p>		Polymer composite tiles	<ul style="list-style-type: none"> Use standard sizes and shapes to minimize cutoffs 	<p>Store in safe, dry place in proper stack heights.</p> <p>Use Use protection when cutting.</p> <p>Disposal Refer to B1</p>	
E2	Parquet	Floor paving	<p>Extraction Manufacturing uses timber. (see C1)</p> <p>Transport See C1</p> <p>Production/Treatment See C1</p> <p>Toxicity See C1</p>	None	Ceramic tiles, Terracotta tiles, Cement tiles, Vinyl tiles, Polymer composite tiles	<ul style="list-style-type: none"> Limit foot traffic on finished wood flooring. Complete wood flooring toward the end of the construction project. Use optimal design (use only where necessary, limit aesthetic use). Use standard sizes and shapes to minimize cutoffs 	<p>Storage Refer to C1 and C3</p> <p>Use Refer to C1 and C3</p> <p>Disposal Refer to C1 and C3</p>	Refer to C1 and C3 [23]
E3	Lime mortar/ lime putty	Plastering, Filler, Paint	<p>Extraction Manufacturing uses limestone or coral. Coral extraction causes serious environmental damage. Mining small outcrops of limestone may also have significant environmental impacts.</p> <p>Transport Transport can damage rural roads.</p> <p>Production/Treatment Requires kilning to produce usable non-hydraulic or hydraulic lime. The kilning process (especially small-scale) causes air pollution.</p> <p>Toxicity None</p>	None	Cement mortar, Chemical fillers	<ul style="list-style-type: none"> Do not use lime made from coral or illegally mined limestone Minimize the use of lime from small-scale producers with wood-fired kilns Mix only required amounts to minimize waste 	<p>Storage Refer to A4</p> <p>Use Refer to A4</p> <p>Disposal Refer to A4</p>	Refer to A4 [5] [36]
E4	Chemical fillers	Filler	<p>Extraction Requires mined and quarried material. See A3</p> <p>Transport See A3</p> <p>Production/Treatment Manufacturing takes place in large-scale factories and can cause air and water pollution if not properly managed.</p> <p>Toxicity Production may use toxic compounds that can cause environmental and health hazards.</p>	<ul style="list-style-type: none"> Reduce the demand for lime produced in harmful small-scale industries 	None	<ul style="list-style-type: none"> Refer to the Material Safety Data Sheets before design or purchase Avoid toxic fillers unless absolutely necessary and educate the craftsman about safe use and disposal Do not over-specify 	<p>Storage Store the properly closed containers (airtight) in safe places.</p> <p>Use Finish the walls smoothly before application and apply in optimum thicknesses (do not over-specify). Mix only required amounts to minimize waste. Strictly follow Health and Safety Executive (HSE) guidelines when working with chemical fillers.</p> <p>Disposal Never dispose of hardened filler or their containers in the environment. Instead, dispose of them in a sanitary</p>	[24] [38]

							or hazardous waste disposal facility (for toxic fillers).	
E5	General emulsion or enamel paint	Painting	<p>Extraction Requires a variety of base chemicals in addition to mined and quarried material.</p> <p>Transport Transport can damage rural roads.</p> <p>Production/Treatment Manufacturing takes place in large-scale factories and can cause air and water pollution if not properly managed.</p> <p>Toxicity Enamel paint uses solvents. Some solvents may be harmful to human health and the environment.</p>	None	Water based paints, Natural pigments	<ul style="list-style-type: none"> Refer to the Material Safety Data Sheets before design or purchase Avoid toxic paints unless necessary, and educate the craftsperson about safe use and disposal Specify only the required number of coats of paint Limit the use of solvents and educate the craftsperson about safe use and disposal of solvents 	<p>Storage Store the properly closed containers (airtight) in safe places.</p> <p>Use Use protection when mixing and applying paints.</p> <p>Disposal Never dispose of hardened fillers or their containers in the environment; instead dispose of them in a sanitary or hazardous waste disposal facility (for toxic paints or solvents).</p>	[13] [39]
E6	Epoxy paints/ solvent based paints/ anticorrosive paints/ strong adhesives/ paint remover	Painting, Metal protection (as adhesives) <i>[generally expensive and used only for specific purposes]</i>	<p>Extraction Requires a variety of base chemicals in addition to mined and quarried material.</p> <p>Transport Transport can damage rural roads.</p> <p>Production/Treatment Manufacturing takes place in large-scale factories that can cause air and water pollution if not properly managed. Production processes of some of these chemicals may be extremely damaging to the environment and human health.</p> <p>Toxicity May release heavy metals and harmful organic compounds into the environment.</p>	None	None	<ul style="list-style-type: none"> Use certified products only Use only where it is absolutely necessary and avoid if possible Specify only if essential for the strength or durability of the building—not for ease of construction Refer to E5 	<p>Storage Store the properly closed containers (airtight), in a safe, secured place—away from fire and flooding hazards.</p> <p>Use Should be handled only by trained crafts persons, using protective equipment and strictly following Health and Safety Executive (HSE) guidelines in mixing and use.</p> <p>Disposal Treat strictly as hazardous waste in disposal of excess material and containers.</p>	Refer E5
E7	Termite treatment chemicals	Chemical treatment to eradicate termites (applied to soil around the perimeter and the subfloor of a building)	<p>Extraction Requires a variety of chemicals.</p> <p>Transport Transport can damage rural roads.</p> <p>Production/Treatment Large-scale factories produce.</p> <p>Toxicity Production process may release heavy metals and toxic organic compounds into the environment. Industrial accidents may cause serious hazards to humans and the environment.</p>	None	Use of ground electrocution, Integrated pest management	<ul style="list-style-type: none"> Use only if it is necessary and avoid if possible Only use certified products Try to use integrated pest management methods to get rid of pests 	<p>Storage Store the properly closed chemical containers (airtight), in a safe, secured place—away from fire and flooding hazards.</p> <p>Use Only use in specified dosages and with trained and certified persons. Use protective equipment and strictly follow Health and Safety Executive (HSE) guidelines in mixing and use.</p> <p>Disposal Treat strictly as hazardous waste in disposal of excess material and containers.</p>	[17] [35]
E8	Glass	Window panes	<p>Extraction Requires quarried and mined material in production.</p>	<ul style="list-style-type: none"> Glass is a fully recyclable 	Plastic polycarbonate	<ul style="list-style-type: none"> Use standard sizes and minimize cutoffs 	<p>Storage Transport, handle, and store with care in proper stack height to avoid</p>	[12]

			<p>Transport Transport can damage rural roads.</p> <p>Production/Treatment Results in mass combustion of fossil fuel. Emits sulphur dioxide (SO₂), and if unmanaged, it may cause water pollution.</p> <p>Toxicity Minimal</p>	material and is chemically inert		<ul style="list-style-type: none"> Use only the required thickness; however, thin plate glass is susceptible to easy breaking and waste of material 	<p>breakage and waste. Glass can be hazardous to children.</p> <p>Use Handle carefully, using proper equipment; broken glass can cause serious injury.</p> <p>Disposal Glass can be easily sold for recycling, and it should never be disposed of in the environment.</p>	
E9	Tarpaulin sheets	Shelter material and wall panels (in temporary structures), Weather proofing building sites	<p>Extraction Tarpaulin sheets are layered sheets that sandwich a polyester woven fabric base between plastic films. Crude oil is the main raw material used for production.</p> <p>Transport Transport can damage rural roads.</p> <p>Production/Treatment Emits greenhouse gasses during production. Untreated wastes from factories contain toxic chemicals and cause water pollution.</p> <p>Toxicity Chemicals contain toxic substances.</p>	None	Waterproof canvas, Thatching material	<ul style="list-style-type: none"> Properly tie and join the sheets to avoid tearing Use the whole sheet, do not cut Reuse old tarpaulin sheets 	<p>Storage Store in covered dry place, away from fire hazards.</p> <p>Use Should be handled carefully.</p> <p>Disposal Recycle where possible or since tarpaulin is a nonbiodegradable material, special care should be taken when disposing of it.</p>	[4] [18]

MATERIAL LIFE CYCLE

All materials come to the construction site through a process of extraction, transport, processing/manufacturing, packaging, and storage. Furthermore, the life of a material does not end after being used for construction; the structures are often demolished after a useful lifetime, and the materials are reused, recycled, repurposed, or disposed of. Some structures deteriorate with time, and the materials disintegrate into the environment. All these stages of the life cycle of a material may cause adverse environmental and social impacts.

Figure 2 displays the potential social and/or environmental impacts at different stages of a generic material life cycle.

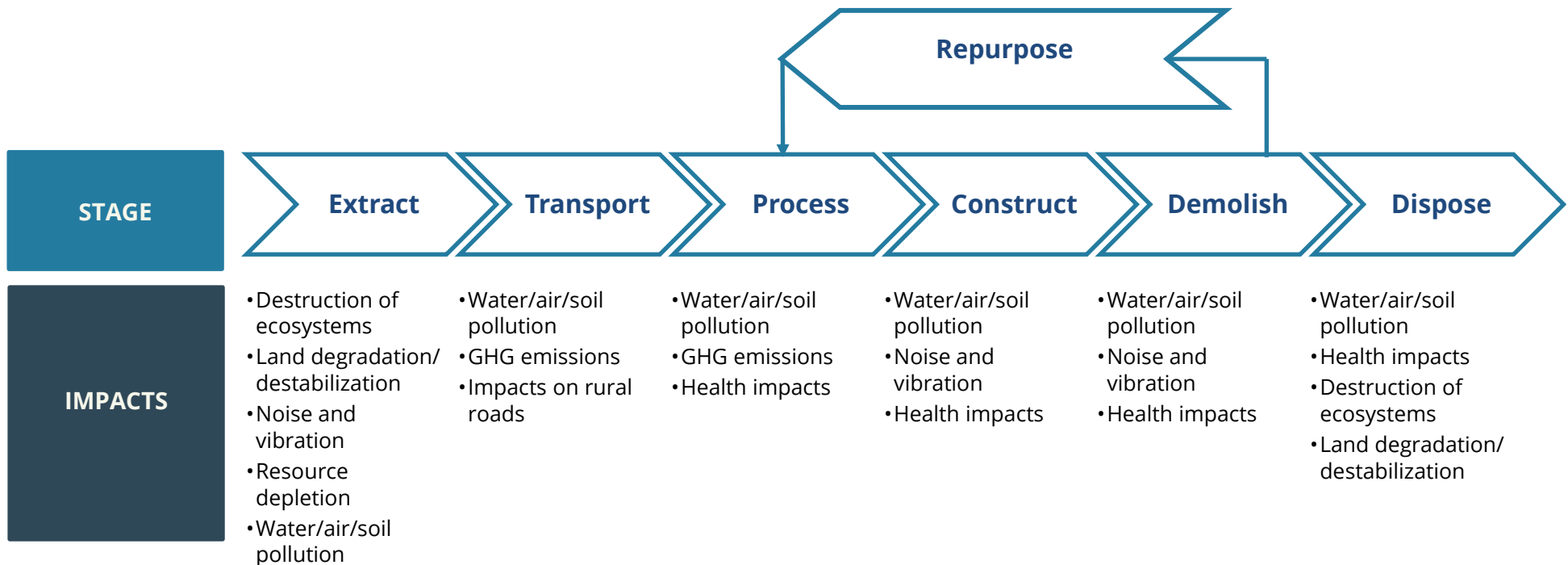


FIGURE 2. STAGES AND IMPACTS OF A MATERIAL'S LIFE CYCLE

RESPONSIBLE MATERIAL SELECTION AND USE: KEY CONCEPTS

1

Think through the whole supply chain. Environmental and social impacts from building materials can occur at any point in the supply chain, from sourcing raw materials, through processing and delivery to the site. This includes the social and environmental practices of manufacturers. For example, do working conditions at the processing plant meet responsible standards? Is the processing plant disposing of leftover material in an environmentally and socially responsible way?

The first criterion for an environmentally responsible material is the safety of the structure that will be built with it. “Not safe” is “not green.”

2

Only support sound and legal sourcing of materials. In large-scale, post-disaster rebuilding, the demand for raw materials can quickly outstrip the supply of sustainably produced natural resources, such as clay for bricks, sand for cement, and wood for timber. For example, unsound excavation of clay or clear-felling of timber on steep hillsides to rebuild hundreds or thousands of houses increases the risk of landslides and topsoil erosion. Such environmental damage can increase risk and jeopardize the success of the overall recovery effort. Project managers should be aware of the sources of their building materials and make sure that they establish contract specifications for the use of sound and legally sourced materials. Using materials that have been credibly certified can be one strategy for ensuring that materials have been sourced sustainably. Material sourcing, processing, and use should be socially equitable. Any form of material sourcing that puts disproportionate burdens on women, children, differently abled or socially marginalized people is not sustainable. Furthermore, material sourcing should not disturb the established local livelihoods.

3

Design to use fewer materials and reduce waste. In designing structures such as houses, project managers should consider ways to effectively meet humanitarian needs with fewer materials. Reducing packaging materials and designing structures with standard material sizes can help prevent waste of materials during the transportation and construction phases. Designing structures and specifying materials for optimal design rather than either overengineering or creating rigid requirements can reduce material waste by allowing some flexibility in construction and in material options. For example, if one material or size is not available locally, another can be used in its place to achieve optimal design instead of importing additional materials to fit a very specific requirement. Following material-specific storing and handling guidelines also helps extend the shelf life of materials and ensures that materials are not damaged and will not need to be replaced.

4

Use local sources—where this can be done in an environmentally responsible way. Local procurement of materials can be a more environmentally sound strategy than the procurement of distant materials because of reduced carbon emissions from transportation and natural resource use in packaging. Give priority to materials selected or processed with traditional knowledge. When using local materials, however, project managers should make sure that extraction, processing, and use do not put people's health or environment at risk.

5

Use disaster debris as a reconstruction material. One of the most environmentally sustainable options for construction projects in a post-disaster setting is the reuse of building materials found in disaster debris. If using disaster debris, project managers must ensure that the debris meets applicable specifications for strength and safety.

6

Use materials with recycled content and recycle. Materials with recycled content are widely available. One example is cement produced with fly ash from coal-fired power plants. Project managers should consider using building materials with recycled content where practical to reduce demand on natural resources and lower the project's human and environmental impacts. Leftover material or material packaging should also be considered for reuse, repurposing, and/or recycling.

ADDITIONAL RESOURCES

1. Inter-Agency Standing Committee (IASC). *Debris as a Construction Material: The Environmental and Economic Benefits*.
2. United Nations Development Programme (UNDP). 2013. *Debris Management: The Door to Development*.
<http://www.ht.undp.org/content/dam/haiti/docs/reduction%20de%20la%20pauvrete/Debris%20-TOI%20EN%20Final%2020130718.pdf>
3. United Nations Environment Programme (UNEP). 2008. *After the Tsunami: Sustainable building guidelines for South-East Asia*. <http://www.unep.org/sbci/pdfs/After-Tsunami-Sustainable-building-guidelines.pdf>
4. UNDP. *Environmental Procurement Practice Guide*.
<http://www.ht.undp.org/content/dam/haiti/docs/reduction%20de%20la%20pauvrete/Debris%20-TOI%20EN%20Final%2020130718.pdf>
5. WWF-Nepal. *Beyond Investment: Developing sustainable green infrastructure in Nepal*. Hariyo Ban Program, WWF Nepal, Kathmandu, Nepal.
http://d2ouvy59p0dg6k.cloudfront.net/downloads/beyond_investment.pdf
6. WWF-US and American Red Cross. 2010. *Module 5: Materials and the Supply Chain, Green Recovery & Reconstruction: Training Toolkit for Humanitarian Aid (GRRT)*.
<http://envirodm.org/training/eng/green-guide-to-materials-and-the-supply-chain>



**VILLAGE WOMAN USING
MUD AND CLAY
TO FINISH CONSTRUCTING
HER HOUSE
IN CROSS RIVER STATE, NIGERIA**

REFERENCES

- Aluminum Association. "Guidelines for in-plant handling of aluminum plate, flat sheet and coil." Arlington, VA: The Aluminum Association, 2006. Accessed September 15, 2016. http://www.aluminum.org/sites/default/files/Guidelines_for_in_plant_handling_of_aluminum_plate_flat_sheet_and_coil.pdf
- Ambuja Foundations. "Environment Impact." Accessed September 15, 2016. <http://foundationsakc.com/process/environment-impact>
- AnyWay Solid Environmental Solutions Ltd. "Introduction to the Production of Compressed Stabilized Earth Block (CSEB)." AnyWay Solid Environmental Solutions, 2014. Accessed September 15, 2016. <http://www.anywaysolutions.com/wp-content/uploads/2010/08/introduction-to-the-production-of-CSEB-using-AnyWay-Soil-Block-last-updated-20121.pdf>
- Arbeitsgemeinschaft der Schweizerischen PVC Industrie (PVCH), PVCplus Kommunikations GmbH. *Everything About PVC From Manufacturing To Recycling*. Germany: PVCplus Kommunikations GmbH, 2012.
- Asociación Nacional de Fabricantes de Cales y Derivados de España (ANCADE) [Spanish National Association of Manufacturers of Lime and Lime Derivatives]. "Practical Guide to Lime Mortars." Accessed September 15, 2016. www.eula.eu/file/464/download?token=3WJ3Oqj1
- Auroville Earth Institute (AVEI). "Compressed Stabilized Earth Blocks." AVEI, 2013. Accessed September 15, 2016. http://www.earth-auroville.com/maintenance/uploaded_pics/cseb.pdf
- Building and Construction Authority (BCA). "Delivery, Handling & Storage." BCA, 2011. Accessed September 15, 2016. <https://www.bca.gov.sg/professionals/iquas/..%5Clquas%5Cgpgs%5CWEWall%5CWEWChpt4.pdf>
- Carsan, Sammy and Christine Holding. "Growing farm timber: practices, markets and policies." Kenya: World Agroforestry Centre, 2006. Accessed September 16, 2016. <http://www.worldagroforestry.org/downloads/Publications/PDFS/b14639.pdf>
- Chandrasekhar, S.R. "Development of Guidelines for Proportioning Calicut Tiled Timber Roof Structure." 1st ed. Sri Lanka: IESL, 1995.
- Civil Engineering and Development Department, Public Fill Committee. "Guidelines for Selective Demolition and On Site Sorting." 1st ed. Hong Kong: Civil Engineering and Development Department, 2004. Accessed September 15, 2016. http://www.cedd.gov.hk/eng/services/recycling/doc/sel_dem.pdf
- Concrete Block Association (CBA). "Aggregate Concrete Blocks: A Guide to Selection and Specification." UK: CBA, 2007. Accessed September 15, 2016. <http://www.thakeham.co.uk/images/upload/docum/Block%20Selector.pdf>
- Consulting Engineers Association of India (CEAI), Central Public Works Department (CPWD), and Indian Building Congress (IBC). *Guidelines on use of Glass in Buildings - Human Safety*. 2nd ed. Confederation of Construction Products and Services (CCPS), 2009.
- Government of India Ministry of Railways. *Comprehensive Guide on Painting for Buildings*. India: Centre for Advanced Maintenance Technology, 2007.
- Home Advancement. "The Basics of Clay Tile Roof Installation." Accessed September 15, 2016. <http://www.homeadvancement.com/roof/installation/clay-tile-roofing>
- Hong Kong Building Department. *Practice Note for Registered Contractors*. 3rd ed. Hong Kong: Buildings Department, 2013. Accessed September 16, 2016. <http://www.bd.gov.hk/english/documents/pnrc/Pnrc67.pdf>
- Inter-Agency Standing Committee (IASC) and Haiti Shelter Cluster. "Reuse, recycle and disposal of emergency plastic sheets." Accessed September 15, 2016. http://www.humanitarianlibrary.org/sites/default/files/plastic_sheeting_disposal_guidelines.pdf
- . "Selection and Safe Use of Chemical Wood Protection." IASC Haiti Shelter Cluster, 2010. Accessed September 15, 2016. <https://www.sheltercluster.org/sites/default/files/docs/Timber%20treatment%20Chemical%20safe%20use%20guidance%20note.pdf>
- International Federation of Red Cross and Red Crescent Societies (IFRC) and Oxfam International. *Plastic Sheeting: A Guide to the Specification and Use of Plastic Sheeting in Humanitarian Relief*. IFRC and Oxfam GB, 2007. Accessed September 16, 2016. www.ifrc.org/PageFiles/71111/D.03.a.01.Plastic%20Sheeting_Englis.pdf
- IFRC, UN Office for the Coordination of Humanitarian Affairs (UNOCHA) and CARE International. "A guide to the planning, use, procurement and logistics of timber as a construction material in humanitarian relief." 1st ed. IFRC, 2009. Accessed September 15, 2016. <http://reliefweb.int/sites/reliefweb.int/files/resources/D.03.c.01.%20Timber%20Guidelines-EN.pdf>

20. International Finance Corporation (IFC) World Bank Group. *Environmental, Health, and Safety Guidelines for Construction Materials Extraction*. Washington, DC: World Bank, 2007. Accessed September 15, 2016. <http://www.ifc.org/wps/wcm/connect/d6bb0e80488551afa93cfb6a6515bb18/Final+-+Construction+Materials+Extraction.pdf?MOD=AJPERES>
21. Kandamby, T. and C. Jayasinghe. *Cement Stabilized Rammed Earth For Wall Junctions of Two Storey Houses*. University of Moratuwa, 2011. Accessed September 15, 2016. www.civil.mrt.ac.lk/conference/raghu/26.pdf
22. Miller, Frank, Taylor, Rodney, and George White. *Best Practices for Keeping Illegally Harvested Timber Out of Your Supply Chain*. 1st ed. WWF, 2006. Accessed September 16, 2016. <http://gftn.panda.org/?82060/Keep-it-legal-Best-Practices-for-Keeping-Illegally-Harvested-Timber-Out-of-Your-Supply-Chain-English-Chinese#>
23. National Wood Flooring Association (NWFA). *Wood Flooring Installation Guidelines and Methods*. 2nd ed. NWFA, 2012. Accessed September 16, 2016. http://www.midtnlumber.com/includes/resources/flooring/installation_guide.pdf
24. Occupational Safety and Health Branch Labour Department. "Guidance Notes on Health Hazards in Construction Work." Accessed September 15, 2016. <http://www.labour.gov.hk/eng/public/oh/OHB82.pdf>
25. Occupational Safety and Health Service (OSHS). "Guidelines for the Management and Removal of Asbestos." 2nd ed. Wellington: OSHS, 1999.
26. Perera, A.A.D.A.J. "Innovations, Applications and Standards of Compressed Stabilized Earth Blocks." University of Moratuwa, 2007. Accessed September 15, 2016. www.irbnet.de/daten/iconda/CIB15593.pdf
27. Portland Cement Association. "Recycled Aggregates." PCA, 2016. Accessed September 15, 2016. <http://www.cement.org/for-concrete-books-learning/concrete-technology/concrete-design-production/recycled-aggregates>
28. Practical Action. "Non Poisonous Timber Protection." United Kingdom: Practical Action, n.d. Accessed September 15, 2016. <http://practicalaction.org/media/preview/13104>
29. Pretoria Division of Building and Construction Technology. "A Guide to Good Thatching Practice." Pretoria: The Division of Building and Construction Technology, 1998.
30. Rathi, M.K. and Ajinkya K. Patil. "Use of Aluminium in Building Construction." Civil Engineering Portal. Accessed September 16, 2016. <http://www.engineeringcivil.com/use-of-aluminium-in-building-construction.html>
31. Rietz, Raymond C. *Storage of Lumber*. Washington, DC: U.S Department of Agriculture and Forestry, 1978. Accessed September 16, 2016. <http://www.esf.edu/wus/documents/StorageOfLumberFPL531.pdf>
32. Safe Work Australia. *How to Safely Remove Asbestos, Code of Practice*. NSW, 2011. Accessed September 16, 2016. http://www.safework.nsw.gov.au/_data/assets/pdf_file/0015/50082/how-to-safely-remove-asbestos-code-of-practice-3561.pdf
33. Shelter Cluster Nepal. "Corrugated Galvanised Iron (CGI) Specifications for Roofing." Accessed September 15, 2016. https://www.sheltercluster.org/sites/default/files/docs/cgi_specification_150708.pdf
34. State of California Department of Transportation. "Construction Site Best Management Practice (BMP) Field Manual and Troubleshooting Guide." Caltrans, 2003. Accessed September 15, 2016. http://www.dot.ca.gov/hq/construc/stormwater/BMP_Field_Master_FullSize_Final-Jan03.pdf
35. Termite Control by Do it yourself Pest Control. "Termite Chemical Treatments for Termite Control." Accessed September 16, 2016. <http://www.doityourselftermitecontrol.com/chemical-termite-treatments.html>
36. Traditional and Sustainable Building. *General Guidelines for Working with Lime Mortar and Limewash*. Traditional and Sustainable Building, 2007. Accessed September 16, 2016. http://www.johngreenwaltlee.com/battersea/battersea/2010_Daily_Logs/Entries/2010/8/10_Small_Mortar_Match_Tests_in_Place_files/Lime_Use_Guide-2.pdf
37. United Nations Environment Program (UNEP). "Sand, rarer than one thinks." UNEP Global Environmental Alert Services, March, 2014. Accessed September 15, 2016. http://www.unep.org/pdf/UNEP_GEAS_March_2014.pdf
38. United States Bureau of Reclamation (USBR). "Standards for Material Handling, Storage, and Disposal, Section 11." USBR, 2009. Accessed September 15, 2016. <http://www.usbr.gov/ssle/safety/RSHS/sec11.pdf>
39. US General Services Administration (GSA). *General Guidelines for Painting Exterior and Interior Surfaces*. Washington, DC: GSA, 2012. Accessed September 16, 2016. <http://www.gsa.gov/portal/content/112254>