UNHCR The UN Refugee Agency | Technical Support Section

Community Infrastructure Catalogue

with sustainability assessments

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Co-convened by
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Introduction

Infrastructure is a critical component of the support provided by UNHCR in refugee settlements. Various types of infrastructure support the provision of shelter and services for displaced people and host communities. Community infrastructure encompases a diverse range of simple, small-scale infrastructure that is often an essential componement of camp envrironments. The simplicity and scale of community infrastructure promotes cost-effective service delivery and supports sustainability by relying on materials and techniques that enable community engagement in infrastructure construction and maintenance.

This Community Infrastructure Catalogue from the UNHCR Technical Support Section presents a range of examples of community infrastructure commonly used in camp settings. The presentation of community infrastructure designs includes basic environmental impact assessments, comparative assessments, bills of quantities, drawings and specifications to support decision-making and implementation in relation to camp infrastructure.

The designs presented are drawn from operations and publications of UNHCR and partner organisations. Variations and alternatives are provided for a range of forms of community infrastructure, taking into account different conditions across UNHCR operations and reflecting priorities defined by the UNHCR Shelter Community of Practice.

Water Tank	**Reinforced Concrete**	**A1**
Water Tank	**Brick**	**A2**
Water Tank	**Ferrocement**	**A3**
Tapstand	**Reinforced Concrete**	**B1**
Tapstand	**Gravel**	**B2**
Tapstand	**Timber Pallet**	**B3**
Drain Channel	**Concrete**	**C1**
Drain Channel	**Precast Concrete**	**C2**
Drain Channel	**Brick Masonry**	**C3**
Drain Channel	**Bamboo**	**C4**
Road	**Concrete**	**D1**
Road	**Brick**	**D2**
Road	**Asphalt**	**D3**
Culvert	**Brick Masonry**	**E1**
Culvert	**Stone**	**E2**
Culvert	**Precast Concrete**	**E3**
Retaining Wall	**Reinforced Concrete**	**F1**
Retaining Wall	**Stone Masonry**	**F2**
Retaining Wall	**Stone Gabion**	**F3**
Retaining Wall	**Bio-stabilised Slope**	**F4**
Laundry Pad	**Reinforced Concrete**	**G1**


Image courtesy Md. Sultan Mahmud, UNHCR

Information and Assessment Criteria

For each piece of infrastructure addressed in this catalogue, information is provided to support decision-making with regard to the suitability of the design.

Introduction text provides a brief overview of the design, identifying the function of the infrastructure, the source of the design, comparable material options, and critical considerations for successful construction. A list of pros and cons to assist with decision-making in regard to different material and construction options.

Scorecard provides a generic rating of the infrastructure design in relation to three criteria: Affordability, Performance and Environmental Sustainability. For each of the criteria, a generic (*rule of thumb*) rating is provided, noting that accurate assessments for affordability, performance and environmental sustainability depend upon specific contextual conditions. Generic assessments compare each design with the other material options provided in this catalogue.

> ***Affordability*** takes into account costs of initial construction and ongoing maintenance in relation to the capacity (extent of service) of the design-material option.
>
> ***Performance*** takes into account the service/output capacity of each design and its capacity for continued operation over time (durability).
>
> ***Environmental sustainability*** takes into account embodied CO2-equivalent and the reuse potential of materials used in the design in comparison with other material options provided in this catalogue.

Drawings provided are suitable for construction purposes. The drawings are available in .pdf and .dwg format to enable adaptation and use in field operations.

Bills of quantities (BOQs) provided list all material and components required for construction. Given large variations in costs in different locations, cost estimates are not provided. BOQs are available in .pdf and .xlsx formats in standard layouts that include fields for unit costs and total item costs to enable adaptation and use in field operations.

Environmental impacts are described in relation to three criteria: material weight, embodied CO2 equivalent, and embodied water. For linear infrastructure such as drains, roads and retaining walls, environmental impacts per metre are considered. For each of the criteria, a generic assessment is provided, noting that accurate assessments for embodied CO2 equivalent, and embodied water depend upon specific details such as project location and supply chains (inc. production processes and transport distances). Calculations for material weight, embodied CO2 equivalent and embodied water were supported by the UNHCR Shelter Sustainability Assessment Tool.

> ***Material weight*** provides information about relative quantities of materials and material-use efficiency.
>
> ***Embodied CO2 equivalent (eCO2-e)*** disaggregates production and transportation-related eCO2-e. *Production-related eCO2-e* calculations are based on material weights and material eCO2-e coefficients from the ICE (versions 2.0 and 3.0) databases. *Transportation-related eCO2-e* calculations generalise transport distances using an equation that estimates transport distance assuming material production and use in a country with a land area equivalent to that of Kenya and transportation via medium load truck. This rough calculation is limited for any particular location, though addresses transport-related eCO2-e in a consistent manner enabling comparison of different material options.
>
> ***Embodied water*** calculations are based on material weights and material embodied H2O coefficients from the EPIC database (2019). Generic coefficients provide a general assessment of embodied H2O, while accurate assessments depend upon context and process-specific conditions.

Specifications outline general requirements for construction, including site-related requirements, material standards, and construction standards. Specifications are available in .pdf and .doc format to enable adaptation and use in field operations.

A1 Water Tank **Reinforced Concrete**

Context

Water supply and water tanks are important components of WASH assistance. Water tanks may be constructed in a variety of capacities (sizes) and shapes, with a range of material options that vary in cost, durability, complexity, and construction time.

This design for a reinforced concrete water tank is drawn from the UNHCR Standardized WASH Design Guidelines for Refugee Settings (D-301/2016a). In this catalogue, the design is presented alongside comparable brick masonry and ferrocement construction options. The design presented here is for a 50m3 (i.e., 50,000 litre) capacity tank, however smaller tank capacities - such as 30m3 or 10m3 – may be built with dimension adjustments (and corresponding adjustments to the BOQ). The presented design is rectangular, however cylindrical tank variations are achievable using the same construction details, noting that cylindrical tanks provide greater material efficiency though may be entail greater complexity for construction (particularly with formwork for concreting).

Reinforced concrete is a common long-term water supply solution. Reinforced concrete construction is relatively complex in comparison with brick masonry and ferrocement options, yet skills and materials for reinforced concrete construction are widely available. Reinforced concrete construction typically requires engagement of a construction contractor/ company, nevertheless local communities may be involved in providing labour for construction.

Several matters are critical to ensuring the structural integrity and proper functioning of the reinforced concrete water tank. Local engineering expertise should be engaged to verify and modify the design to structural footings/foundations to take into account local geological (soil) conditions and local construction norms. Concrete should be mixed, poured and cured in accordance with the material specifications to ensure structural integrity and avoid cracking. Cement mortars used for plastering and waterproofing should be mixed and applied in accordance with material specifications for ensure water tightness of the tank.

PROS	CONS
Strength and durability of reinforced concrete reduce maintenance requirements Flexibility regarding size and shape enables adaptation to site and capacity requirements Common availability of materials and skills for construction and maintenance	Relatively high initial construction costs Reinforced concrete construction requires involvement of a construction contractor/company Limited reuse or modification potential

Affordability
(considering initial and operating costs)

Performance
(considering capacity and durability)

Environmental sustainability
(considering e-CO2-eq and reuse potential)

(Relatve affordability, performance and environmental impact may vary with with prevailing conditions)


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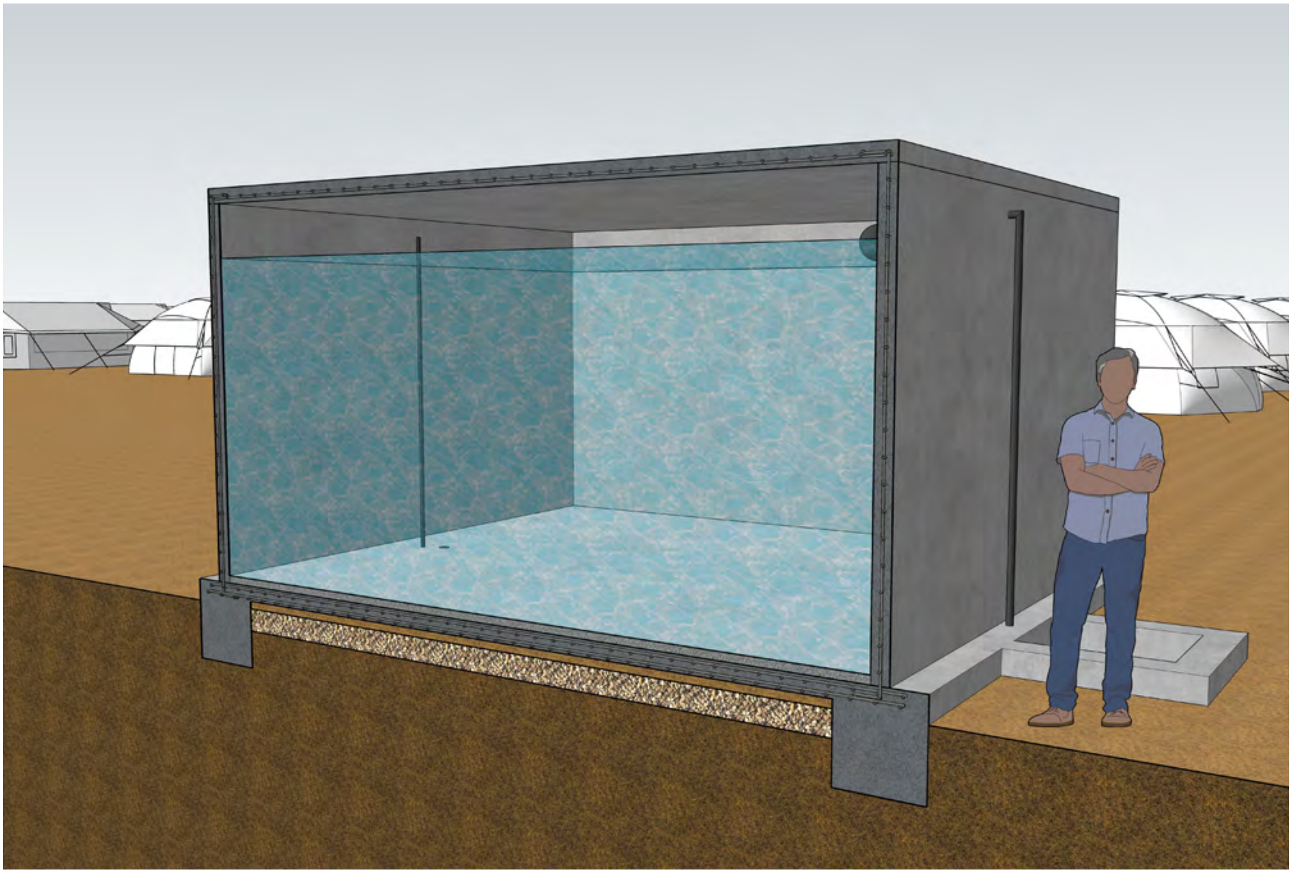

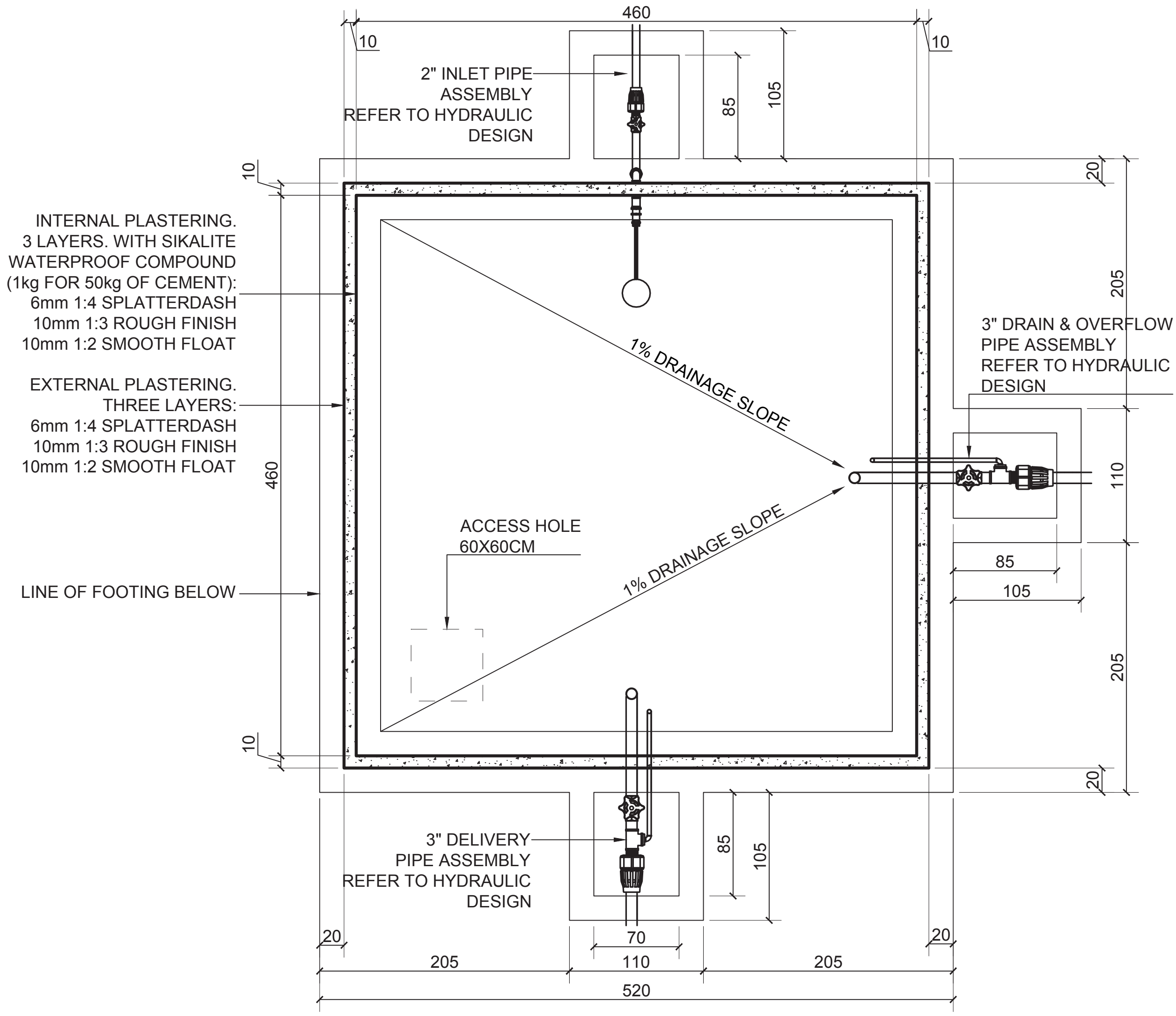

NOTES

1. Refer to *UNHCR, 2016. Tools and Guidance for Refugee Settings - D312-2016a,* for step-by-step construction instructions
2. Refer to Specification for material descriptions.
3. Structural design to be verified by local engineer for compliance with local conditions and norms
4. Ensure the correct water content of mixed concrete - slump test should yield < $\frac{1}{4}$ height reduction.
5. Slabs to be cast in a single pour. All concrete works to be vibrated or well rodded.
6. Ensure all poured concrete is kept damp and out of direct sunlight for at least 7 days while curing.
7. Refer to hydraulic design for pipe assemblies. Valve boxes should be sized according to inlet and outlet arrangements.

DWG NO.	TITLE	DRAWN BY	UNITS
A1-1	**Reinforced Concrete water tank, 50m3** Plan	**AU**	**CM**
		CHECKED BY **RN**	SHEET **1 of 2**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:50**	DATE **31.08.2023**

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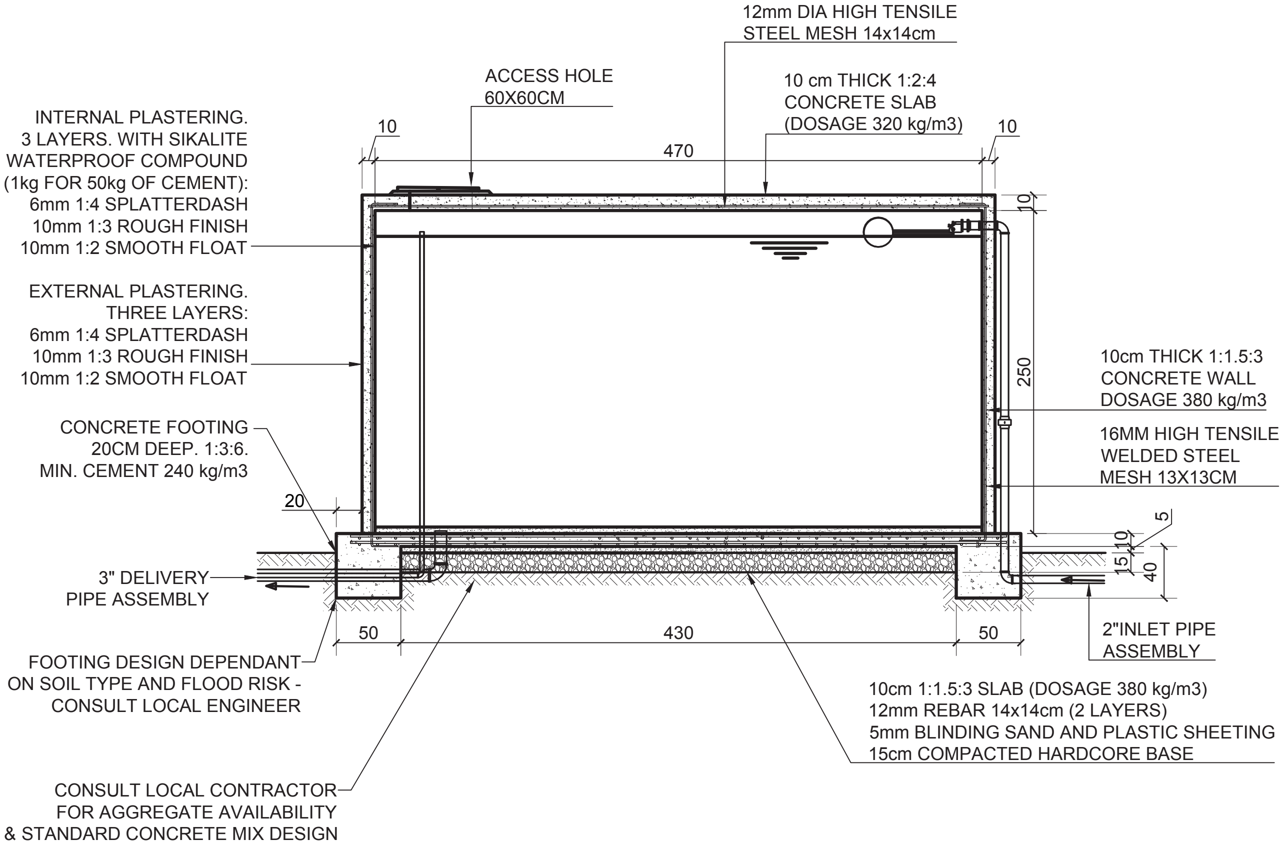

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2. Refer to Specification for material descriptions.
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4. Ensure the correct water content of mixed concrete - slump test should yield < $\frac{1}{4}$ height reduction.
5. Slabs to be cast in a single pour. All concrete works to be vibrated or well rodded.
6. Ensure all poured concrete is kept damp and out of direct sunlight for at least 7 days while curing.
7. Refer to hydraulic design for pipe assemblies. Valve boxes should be sized according to inlet and outlet arrangements.

DWG NO.	TITLE	DRAWN BY	UNITS
A1-2	**Reinforced Concrete water tank, 50m3** Section	**AU**	**CM**
		CHECKED BY **RN**	SHEET **2 of 2**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:50**	DATE **31.08.2023**

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Technical Support Section
Community Infrastructure Catalogue

Bill of Quantities

Ref	Item description	Unit	Quantity
1	Wooden Stakes (65cm x 5cm x 5cm)	pce	46
2	Wooden Planks (4m x 20cm x 2.5cm)	pce	150
3	Wooden Posts (4m x 5cm x 5cm)	pce	67
4	Wooden Beams (4m x 5cm x 2.5cm)	pce	12
5	Nails (6cm Galvanized)	kg	6
6	Nails (8cm Galvanized)	kg	2
7	High Tensile Steel Weld-Mesh Ø12mm 14cm x 14cm	m2	52
8	High Tensile Steel Weld-Mesh Ø16mm 13cm x 13cm	m2	67
9	High Tensile Steel Weld-Mesh Ø12mm 14cm x 14cm	m2	26
10	Tying Wire Ø 1mm	kg	0.5
11	Plastic Sheeting	m2	30
12	Metallic Valve Box Covers (70cm x 70cm x 2mm)	pce	4
13	Coarse Sand	m3	12
14	Coarse Gravel (12mm – 25mm)	m3	12.9
15	Cement (50kg sacks)	sacks	113
16	Compacted Hardcore Sub-Base	m3	4.6
17	Inlet Pipe Assembly	pce	1
18	Outlet Pipe Assembly	pce	1
19	Drain Pipe Assembly	pce	1

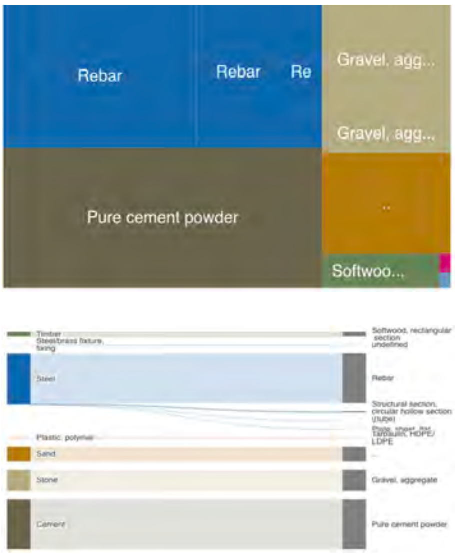
Environmental Impacts

Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

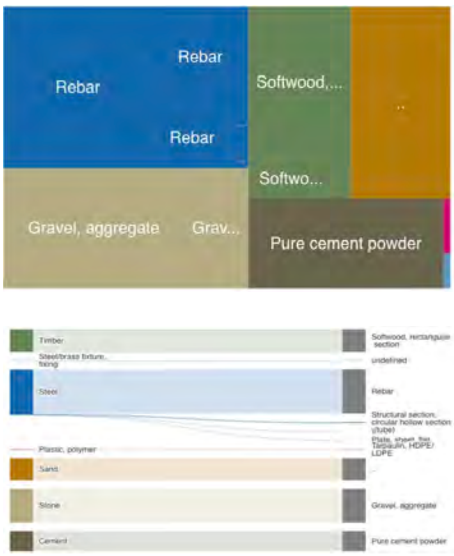
	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Timber	1940,42	504,51	203,74	708,25	49 791,24
Steel/brass fixture, fixing	8	29,6	0,84	30,44	620,8
Steel	2 689,94	7 800,42	282,44	8 082,87	99 800,34
Plastic, polymer	5,7	36,48	0,6	37,08	980,4
Sand	26 880	188,16	2 123,52	2 311,68	48 384
Stone	39 200	274,4	3 096,8	3 371,2	74 480
Cement	5 650	7 345	593,25	7 938,25	44 070
Total	76 374,06	16 178,57	6 301,2	22 479,77	318 126,78

Material weight (kg) [1]

Embodied carbon (kgCO2e) [2]



Embodied water (L) [5]



1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

2 Embodied carbon dioxide equivalent - expressed as kg.eCO2e - reflects the amount of various greenhouse gases associated with the production and use of the material. The metric converts other gases to the equivalent amount of CO2 with the same global warming potential.

3 Production embodied carbon reflects the component of eCO2e associated with material production. While embodied carbon from production differs with factors such as prevailing energy sources, a simplified calculation here uses coefficients derived from global averages.

4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

5 Embodied water reflects the amount of tap water used in production of the material. While embodied water depends on specific production processes, a simplified calculation here uses coefficients derived from global averages.

Specification

1 GENERAL

1.1 SCOPE

This specification is to be read in conjunction with the Drawings and Bill of Quantities (BOQ). In the event of any discrepancy, the Specification and Bill of Quantities takes precedence over Drawings.

1.2 LOCAL REGULATIONS AND STANDARDS

Work shall comply with local regulations and local construction standards. Discrepancies between designs and with regulations or standards shall be addressed before work commences.

Structural designs shall be reviewed by a local Engineer to confirm adequacy in relation to local regulations, construction practices, and site conditions.

2 SITE

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SET-OUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

2.4 SOAKAGE PITS

Sizing of soakage pits, trenches and drain fields depend local site soil infiltration rates and the quantity of wastewater that is expected. Soakage pit dimensions should be determined by on-site soil infiltration tests, considering soil types and infiltration rates noted below.

	Infiltration rate (litres/m2/day)	
	clean water	wastewater
Sand	720-2400	33-50
Sandy loam	480-720	24
Silt loam	240-480	18
Clay loam	120-240	8
Clay	24-120	Unsuitable

Source: Davis & Lambert (2002) Engineering in Emergencies, 2nd edition. Practical Action Publishing: Warwickshire

Water collection and usage points should be equipped with adequately designed soakage systems located at least 30 metres away from groundwater sources. A soakage pit base must be at least 1.5m above the highest average groundwater table level.

2.5 PREVENTION OF SURFACE OR GROUNDWATER CONTAMINATION

Location and construction of water supply related infrastructure must avoid contamination of surface water and groundwater sources. Risks are generally low and related to contamination from water treatment chemicals, water treatment by-products and contamination from wastewater.

3 MATERIALS

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%.

A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free from oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 CEMENT

Ordinary portland cement must be used before the expiry date. Cement should be kept dry and stored at least 15cm above ground to avoid ground moisture. Expired or damaged cement may be indicated by excessive grittiness or lumps of set cement.

3.5 CEMENT PLASTER

Cement plaster shall comprise ordinary portland cement, sand and water as specified herein. A cement:sand ratio of 1:4 shall be used unless otherwise noted. Cement plasters shall be applied to a minimum thickness of 1cm unless otherwise noted. After application, plastered surfaces shall be cured (kept moist) for a minimum of 7 days.

Waterproof cement plasters for interior and exterior surfaces of water tank shall comprise 3 layers: 1) 6mm, 1:4, spatter-dash, 2) 10mm, 1:3, rough finish, 3) 10mm, 1:2, smooth float. Each layer shall be applied before the base layer is cured, with the base layer wetted and scratched to ensure proper bonding. Waterproof plasters should be mixed with a waterproofing compound (Sikalite or equivalent) at the dosage specified by the compound manufacturer.

3.6 CEMENT MORTAR

Cement mortar shall comprise Portland cement, sand and water as specified herein. A cement:sand ratio of 1:6 shall be used unless otherwise noted. Cement mortar in brick masonry and stone masonry shall be applied to a minimum thickness of 6-10mm unless otherwise noted. After laying, mortar within brick and stone masonry shall be cured (kept moist) for a minimum of 10 days.

3.7 CONCRETE

3.7.1 *Formwork*

Formwork for in-situ poured shall be straight and true with adequate bracing to avoid deformation under the load of poured concrete. Formwork may be constructed of plywood, sawn timber or steel according to local standards and concrete finish (appearance) requirements. Ensure adequate chamfer – around 2cm – at external corners.

Ensure that formwork construction enables removal without damage to concrete. To minimise adhesion of concrete, wet surfaces of formwork that will come in contact with concrete and apply a wash of limewash, linseed oil or soapy water.

3.7.2 *Concrete mix*

Concrete shall comprise Portland cement, sand, aggregate, and water as specified herein.

For general structural purposes, a cement:sand:aggregate mix of 1:2:4 (with a minimum cement dosage of 320kg/m3) shall be used unless otherwise noted. For water retaining structures (reservoir walls and bases) a cement:sand:aggregate mix of 1:1.5:3 shall be used unless otherwise noted (1:2:4 is not waterproof) (with a minimum cement dosage of 380kg/m3). For mass concrete applications a cement:sand:aggregate mix of 1:3:6 shall be used unless otherwise noted.

For hand mixing, additional cement should be added in accordance with the table below.

Mix	Cement		Sand (m3)	Aggregate (m3)
	Machine mix (kg)	Hand mix (kg)		
1 : 1.5: 3	370	380	0.42	0.84
1 : 2 : 4	290	300	0.45	0.90
1 : 3 : 6	190	200	0.46	0.92

Source: Khanna, P.N. (1982) Indian Civil Engineers Handbook, 8th ed. Engineers Publishers: New Delhi

Ensure that concrete mixtures are not over watered – a bucket slump test of mixed concrete should yield less than ¼ reduction in the slump height.

3.7.3 *Concrete pouring*

Each concrete element – e.g., each concrete slab, each section of footing or parapet - shall be cast in a single pour.

3.7.4 *Concrete rodding and curing*

Cast concrete should be immediately covered with fabric, plastic sheet, straw, cement bags, sacking or leaves to keep the concrete moist and cool during the curing period. All concrete should be well vibrated or rodded to remove air voids. The concrete shall be cured with frequent watering at least twice daily for at least 10 days before use.

3.7.5 *Concrete finishing*

Provide a minimum of 1% fall to water collection and drainage surfaces. Provide a rough, non-slip finish to trafficable concrete surfaces, e.g., by brushing the surface during curing.

3.8 STEEL REINFORCEMENT

Reinforcement bars shall be free from rust and of the correct type and size for concrete construction work (typically a characteristic yield stress of at least 210 N/mm^2). Steel reinforcement should be placed as per the designs (typically 7/8 of the slab or wall thickness) to ensure the bars function correctly in tension. All bars should have at least 12mm concrete cover.

Image courtesy Md. Sultan Mahmud, UNHCR

A2 Water Tank **Brick Masonry**

Context

Water tanks are important components of WASH assistance. Water tanks may be constructed in a variety of capacities (sizes) and shapes, with a range of material options that vary in cost, durability, complexity, and construction time.

This design for a brick masonry walled water tank is drawn from the *UN Habitat Pakistan Guidelines for Community Infrastructure (2012)*. In this catalogue, the design is presented alongside comparable reinforced concrete and ferrocement construction options. The design presented here is for a 50m3 (i.e., 50,000 litre) capacity tank, however smaller tank capacities - such as 30m3 or 10m3 – may be built with dimension adjustments (and corresponding adjustments to the BOQ). The presented design is rectangular, however cylindrical tank variations are achievable using the same construction details.

Brick masonry construction is common in many places, ensuring that the skills and equipment required for construction are widely available. The design here requires specialist skills for brick laying and reinforced concrete construction, nevertheless local communities may be involved in providing labour for construction.

Local engineering expertise should be engaged to verify and modify the design to structural footings/ foundations to take into account local geological (soil) conditions and local construction norms. Brick laying should be undertaken with due care to ensure courses are straight and plum. Layed brickwork should be kept moist and covered (i.e., cured) for at least 10 days. Concrete should be mixed, poured and cured in accordance with the material specifications to ensure structural integrity and avoid cracking. Cement mortars used for plastering and waterproofing should be mixed and applied in accordance with material specifications for ensure water tightness of the tank.

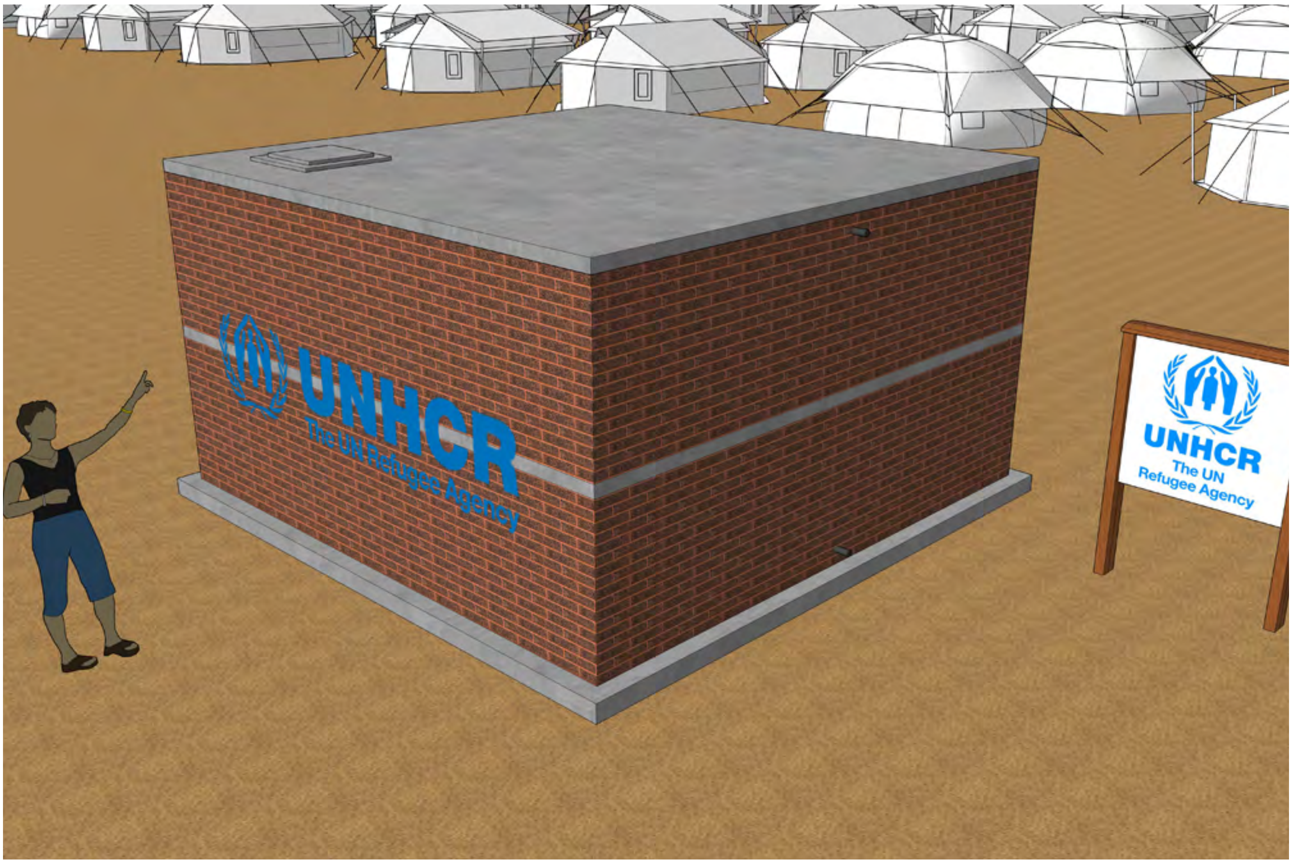
PROS	CONS
Flexibility regarding size and shape enables adaptation to site and capacity requirements Common availability of materials and skills for construction and maintenance Strength and durability of brick masonry reduces maintenance requirements	Relatively long construction time Brick masonry construction requires skilled labour, reducing scope for community involvement Limited reuse or modification/adaptation potential

Affordability
(considering initial and operating costs)

Performance
(considering capacity and durability)

Environmental sustainability
(considering e-CO2-eq and reuse potential)

(Relatve affordability, performance and environmental impact will vary with prevailing conditions)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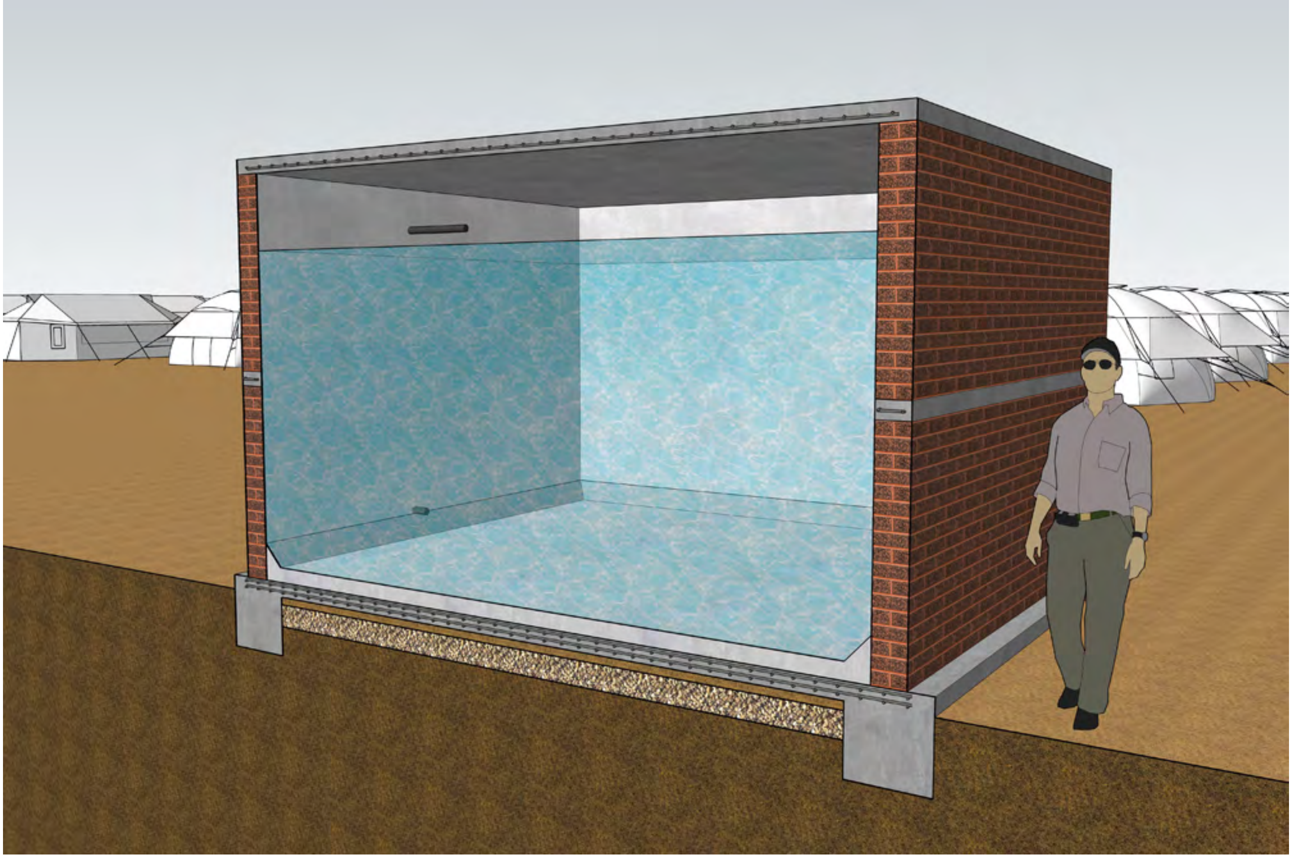
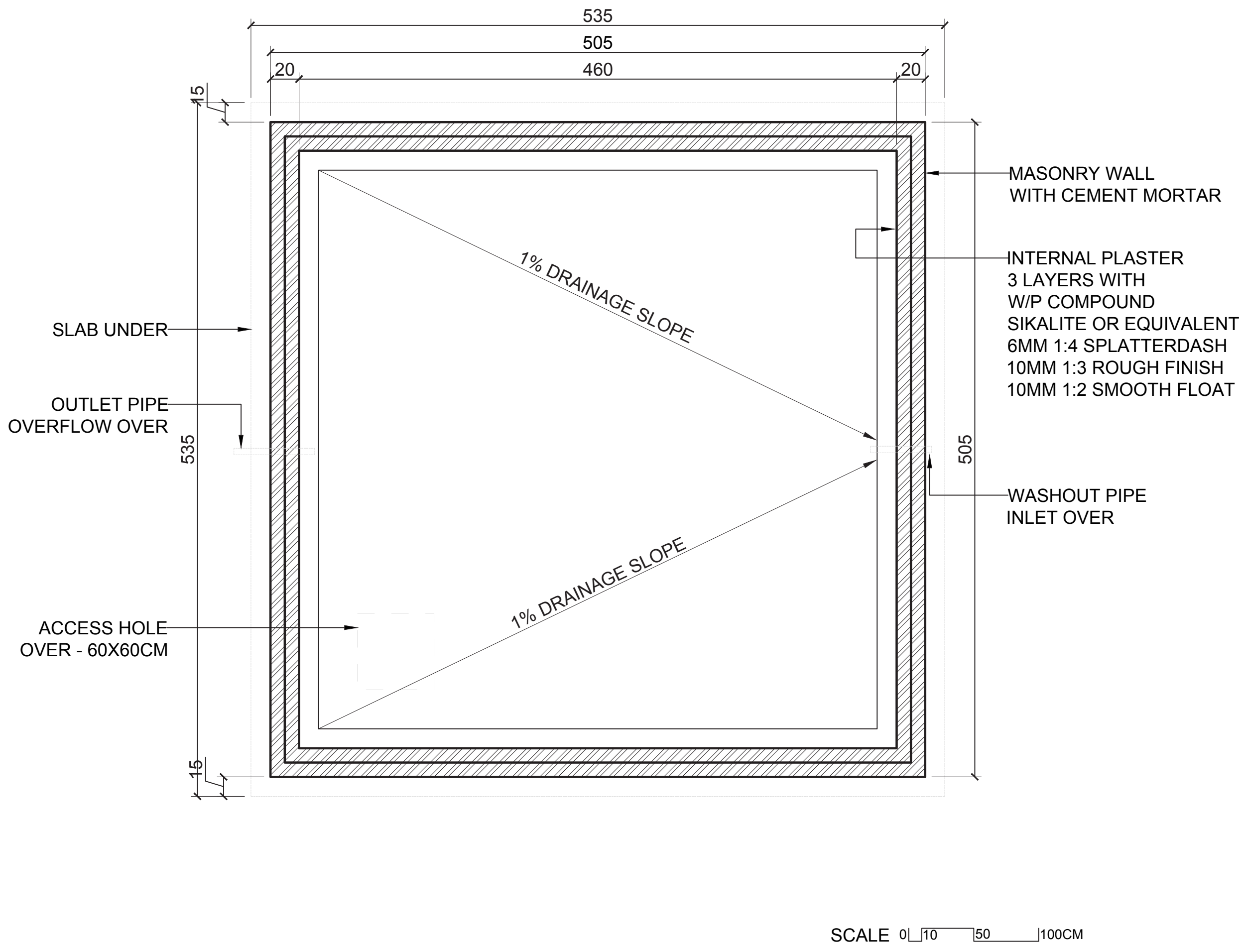
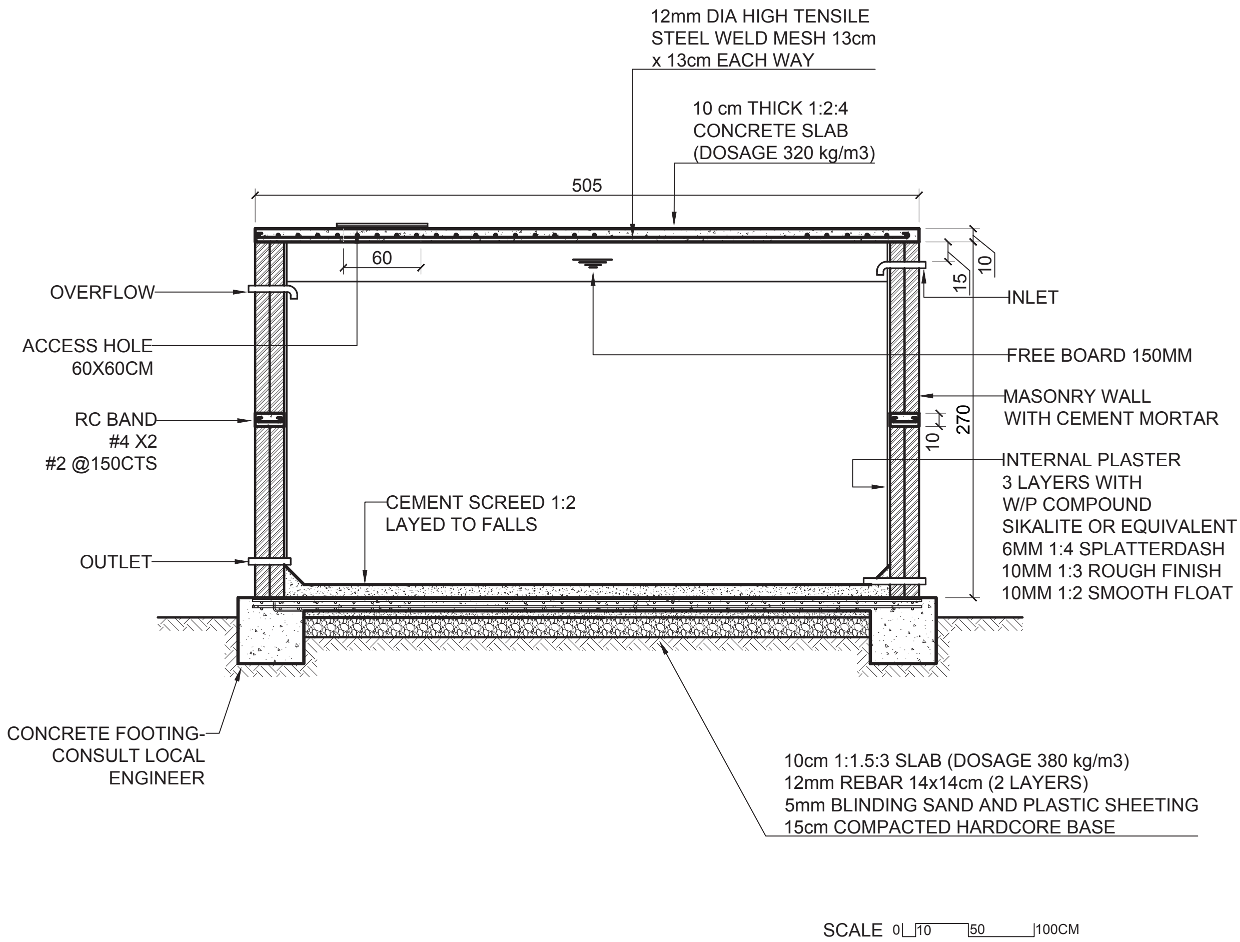




NOTES

1. Refer to Specification for material descriptions.
2. Structural design to be verified by local engineer for compliance with local conditions and norms
3. Ensure the correct water content of mixed concrete - slump test should yield < $\frac{1}{4}$ height reduction.
4. Slabs to be cast in a single pour. All concrete works to be vibrated or well rodded.
5. Ensure all poured concrete is kept damp and out of direct sunlight for at least 7 days while curing.
6. Refer to hydraulic design for pipe assemblies. Valve boxes should be sized according to inlet and outlet arrangements.

DWG NO. A2-1	TITLE **Brick Masonry Water Tank, 50m3** Plan	DRAWN BY **AU**	UNITS **CM**	UNHCR The UN Refugee Agency
		CHECKED BY **RN**	SHEET **1 of 2**	**Technical Support Section** Community Infrastructure Catalogue
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:50**	DATE **31.08.2023**	



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DWG NO.	TITLE	DRAWN BY	UNITS
A2-2	**Brick Masonry Water Tank, 50m3** Section	**AU**	**CM**
		CHECKED BY **RN**	SHEET **2 of 2**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:50**	DATE **31.08.2023**

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Technical Support Section
Community Infrastructure Catalogue

Bill of Quantities

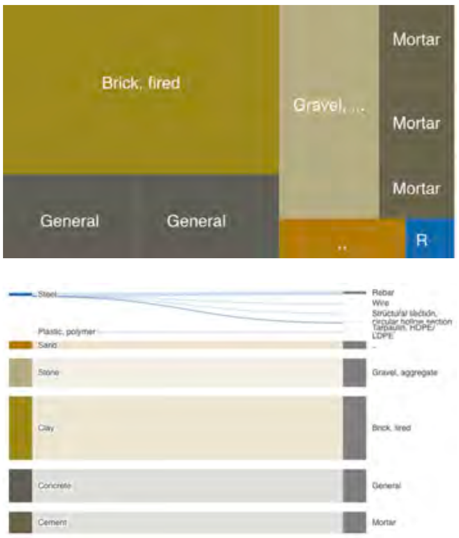
Ref	Item description	Unit	Quantity
1	Fired clay brick masonry (with cement mortar 1:4)	m3	12
2	Concrete (1:2:4) for ground slab	m3	2.9
3	Concrete (1:2:4) for roof slab	m3	2.6
4	Concrete (1:2:4) for ring beam	m3	0.5
5	High Tensile Steel Weld-Mesh Ø12mm 14cm x 14cm	m2	52
6	High Tensile Steel Weld-Mesh Ø12mm 14cm x 14cm	m2	26
7	Reinforcement bar for ring beam - 10mm	m	67
8	Cement mortar (1:2) for external plaster - 25mm thick	m3	2
9	Cement mortar (1:2) for internal plaster - 25mm thick - with waterproofing compound (Sikalite or equivalent)	m3	1.25
10	Cement mortar floor screed laid to falls	m3	1.5
11	Tying Wire Ø 1mm	kg	0.3
12	Plastic Sheeting	m2	20
13	Metallic Valve Box Covers (70cm x 70cm x 2mm)	pce	4
14	Coarse Sand	m3	1.3
15	Compacted Hardcore Sub-Base	m3	4.6
16	Inlet Pipe Assembly	pce	1
17	Outlet Pipe Assembly	pce	1
18	Drain Pipe Assembly	pce	1

Environmental Impacts

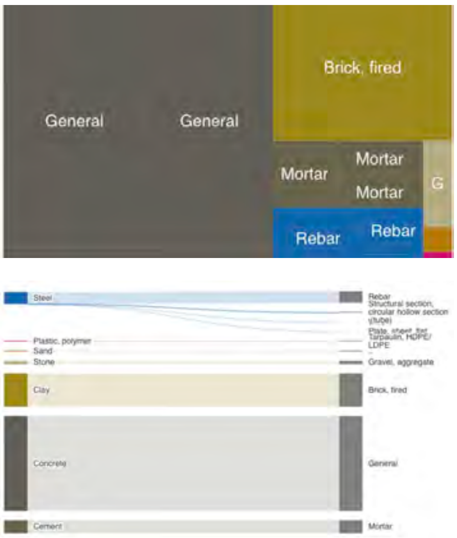
Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

	Material weight (kg) [1]	Embodied Carbon (kg) [2] Production [3]	Transportation [4]	Total	Embodied water (L) [5]
Steel	1100,52	3191,26	115,55	3306,82	40 831,38
Plastic, polymer	28,5	182,4	2,99	185,39	4902
Sand	2912	20,38	230,05	250,43	5241,6
Stone	10304	72,13	814,02	886,14	19577,6
Clay	23040	7372,8	1820,16	9192,96	41472
Concrete	12000	24924	1260	26184	768
Cement	7837,5	2743,13	822,94	3566,06	28998,75
Total	57222,52	38506,1	5065,71	43571,81	141791,33

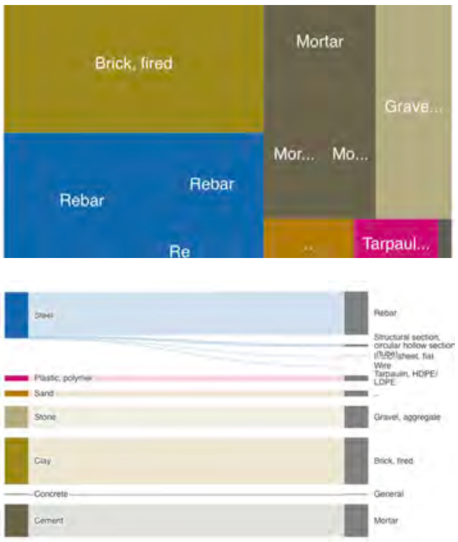
Material weight (kg) [1]



Embodied carbon (kgCO2e) [2]



Embodied water (L) [5]



1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

2 Embodied carbon dioxide equivalent - expressed as kg.eCO2e - reflects the amount of various greenhouse gases associated with the production and use of the material. The metric converts other gases to the equivalent amount of CO2 with the same global warming potential.

3 Production embodied carbon reflects the component of eCO2e associated with material production. While embodied carbon from production differs with factors such as prevailing energy sources, a simplified calculation here uses coefficients derived from global averages.

4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

5 Embodied water reflects the amount of tap water used in production of the material. While embodied water depends on specific production processes, a simplified calculation here uses coefficients derived from global averages.

Specification

1 **GENERAL**

1.1 SCOPE

This specification is to be read in conjunction with the Drawings and Bill of Quantities (BOQ). In the event of any discrepancy, the Specification and Bill of Quantities takes precedence over Drawings.

1.2 LOCAL REGULATIONS AND STANDARDS

Work shall comply with local regulations and local construction standards. Discrepancies between designs and with regulations or standards shall be addressed before work commences.

Structural designs shall be reviewed by a local Engineer to confirm adequacy in relation to local regulations, construction practices, and site conditions.

2 **SITE**

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SET-OUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

2.4 SOAKAGE PITS

Sizing of soakage pits, trenches and drain fields depend local site soil infiltration rates and the quantity of wastewater that is expected. Soakage pit dimensions should be determined by on-site soil infiltration tests, considering soil types and infiltration rates noted below.

	Infiltration rate (litres/m2/day)	
	clean water	wastewater
Sand	720-2400	33-50
Sandy loam	480-720	24
Silt loam	240-480	18
Clay loam	120-240	8
Clay	24-120	Unsuitable

Source: Davis & Lambert (2002) Engineering in Emergencies, 2nd edition. Practical Action Publishing: Warwickshire

Water collection and usage points should be equipped with adequately designed soakage systems located at least 30 metres away from groundwater sources. A soakage pit base must be at least 1.5m above the highest average groundwater table level.

2.5 PREVENTION OF SURFACE OR GROUNDWATER CONTAMINATION

Location and construction of water supply related infrastructure must avoid contamination of surface water and groundwater sources. Risks are generally low and related to contamination from water treatment chemicals, water treatment by-products and contamination from wastewater.

3 MATERIALS

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%.

A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free of oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 CEMENT

Ordinary portland cement must be used before the expiry date. Cement should be kept dry and stored at least 15cm above ground to avoid ground moisture. Expired or damaged cement may be indicated by excessive grittiness or lumps of set cement.

3.5 CEMENT PLASTER

Cement plaster shall comprise ordinary portland cement, sand and water as specified herein. A cement:sand ratio of 1:4 shall be used unless otherwise noted. Cement plasters shall be applied to a minimum thickness of 1cm unless otherwise noted. After application, plastered surfaces shall be cured (kept moist) for a minimum of 7 days.

Waterproof cement plasters for interior and exterior surfaces of water tank shall comprise 3 layers: 1) 6mm, 1:4, spatter-dash, 2) 10mm, 1:3, rough finish, 3) 10mm, 1:2, smooth float. Each layer shall be applied before the base layer is cured, with the base layer wetted and scratched to ensure proper bonding. Waterproof plasters should be mixed with a waterproofing compound (Sikalite or equivalent) at the dosage specified by the compound manufacturer.

3.6 CEMENT MORTAR

Cement mortar shall comprise Portland cement, sand and water as specified herein. A cement:sand ratio of 1:6 shall be used unless otherwise noted. Cement mortar in brick masonry and stone masonry shall be applied to a minimum thickness of 6-10mm unless otherwise noted. After laying, mortar within brick and stone masonry shall be cured (kept moist) for a minimum of 10 days.

3.7 CONCRETE

3.7.1 *Formwork*

Formwork for in-situ poured shall be straight and true with adequate bracing to avoid deformation under the load of poured concrete. Formwork may be constructed of plywood, sawn timber or steel according to local standards and concrete finish (appearance) requirements. Ensure adequate chamfer – around 2cm – at external corners.

Ensure that formwork construction enables removal without damage to concrete. To minimise adhesion of concrete, wet surfaces of formwork that will come in contact with concrete and apply a wash of limewash, linseed oil or soapy water.

3.7.2 *Concrete mix*

Concrete shall comprise Portland cement, sand, aggregate, and water as specified herein.

For general structural purposes, a cement:sand:aggregate mix of 1:2:4 (with a minimum cement dosage of 320kg/m3) shall be used unless otherwise noted. For water retaining structures (reservoir walls and bases) a cement:sand:aggregate mix of 1:1.5:3 shall be used unless otherwise noted (1:2:4 is not waterproof) (with a minimum cement dosage of 380kg/m3). For mass concrete applications a cement:sand:aggregate mix of 1:3:6 shall be used unless otherwise noted.

For hand mixing, additional cement should be added in accordance with the table below.

Mix	Cement		Sand	Aggregate
	Machine mix (kg)	Hand mix (kg)	(m3)	(m3)
1 : 1.5 : 3	370	380	0.42	0.84
1 : 2 : 4	290	300	0.45	0.90
1 : 3 : 6	190	200	0.46	0.92

Source: Khanna, P.N. (1982) Indian Civil Engineers Handbook, 8th ed. Engineers Publishers: New Delhi

Ensure that concrete mixtures are not over watered – a bucket slump test of mixed concrete should yield less than ¼ reduction in the slump height.

3.7.3 *Concrete pouring*

Each concrete element – e.g., each concrete slab, each section of footing or parapet - shall be cast in a single pour.

3.7.4 *Concrete rodding and curing*

Cast concrete should be immediately covered with fabric, plastic sheet, straw, cement bags, sacking or leaves to keep the concrete moist and cool during the curing period. All concrete should be well vibrated or rodded to remove air voids. The concrete shall be cured with frequent watering at least twice daily for at least 10 days before use.

3.7.5 *Concrete finishing*

Provide a minimum of 1% fall to water collection and drainage surfaces. Provide a rough, non-slip finish to trafficable concrete surfaces, e.g., by brushing the surface during curing.

3.8 STEEL REINFORCEMENT

Reinforcement bars shall be free from rust and of the correct type and size for concrete construction work (typically a characteristic yield stress of at least 210 N/mm^2). Steel reinforcement should be placed as per the designs (typically 7/8 of the slab or wall thickness) to ensure the bars function correctly in tension. All bars should have at least 12mm concrete cover.

3.9 BRICK MASONRY

Bricks should be made from clay free of stone or other organic or inorganic impurities. Bricks shall be of a standard, consistent size that conforms with local standards, and shall have plane rectangular faces and right-angled edges. Bricks should be of sufficient strength, with a minimum crushing strength of 125kg/cm2, or to not break when dropped from a height of 1m. Bricks should be fired sufficiently such that, when immersed in water, a brick shall not absorb water more that 20% of its dry weight.

Bricks shall be soaked in water for a minimum of 15 minutes prior to laying in cement mortar.

Bricks shall be laid in horizontal courses, with brickwork laid in a single day not exceeding 1m height to avoid excessive pressure on newly laid lower courses.

Cement mortar joints should be 6-10mm. A cement : sand mix of 1:6 should be used for masonry mortar unless otherwise noted. Brickwork shall be covered with plastic sheeting or textile and kept wet (cured) for minimum 10 days after laying.

Image courtesy Md. Sultan Mahmud, UNHCR

A3 Water Tank **Ferrocement**

Context

Water tanks are important components of WASH assistance. Water tanks may be constructed in a variety of capacities/sizes and shapes, with a range of options that vary in cost, durability, and construction time. This design for a ferrocement water tank is drawn from the publication *Large Ferro-cement Water Tank – Design parameters and construction details (UNHCR, 2006).*

The design is presented alongside comparable reinforced concrete and brick masonry construction options. The design presented here is for a 50m3 (i.e., 50,000 litre) capacity tank, however smaller tank capacities may be built with dimension adjustments and corresponding adjustments to the BOQ. Ferrocement is not common and may not be familiar to local construction companies and communities.

Step-by-step construction instructions are available in the publication *Large Ferro-cement Water Tank – Design parameters and construction details.*

Local engineering expertise should be engaged to verify and modify the design of structural footings/foundations to take into account local geological/soil conditions and local construction norms. Concrete and cement plaster construction should be undertaken in accordance with material specifications. Concrete should be mixed, poured and cured in accordance with the material specifications to ensure structural integrity and avoid cracking. Cement mortars used for plastering and waterproofing should be mixed and applied in accordance with material specifications for ensure water tightness of the tank.

PROS	CONS
Rapid construction time Efficient use of materials, potentially reducing costs and reliance on local supply chains	Relatively low durability of thin shell construction that may be easily damaged Limited reuse or modification/adaptation potential

Affordability
(considering initial and operating costs)

Performance
(considering capacity and durability)

Environmental sustainability
(considering e-CO2-eq and reuse potential)

(Relatve affordability, performance and environmental impact will vary with prevailing conditions)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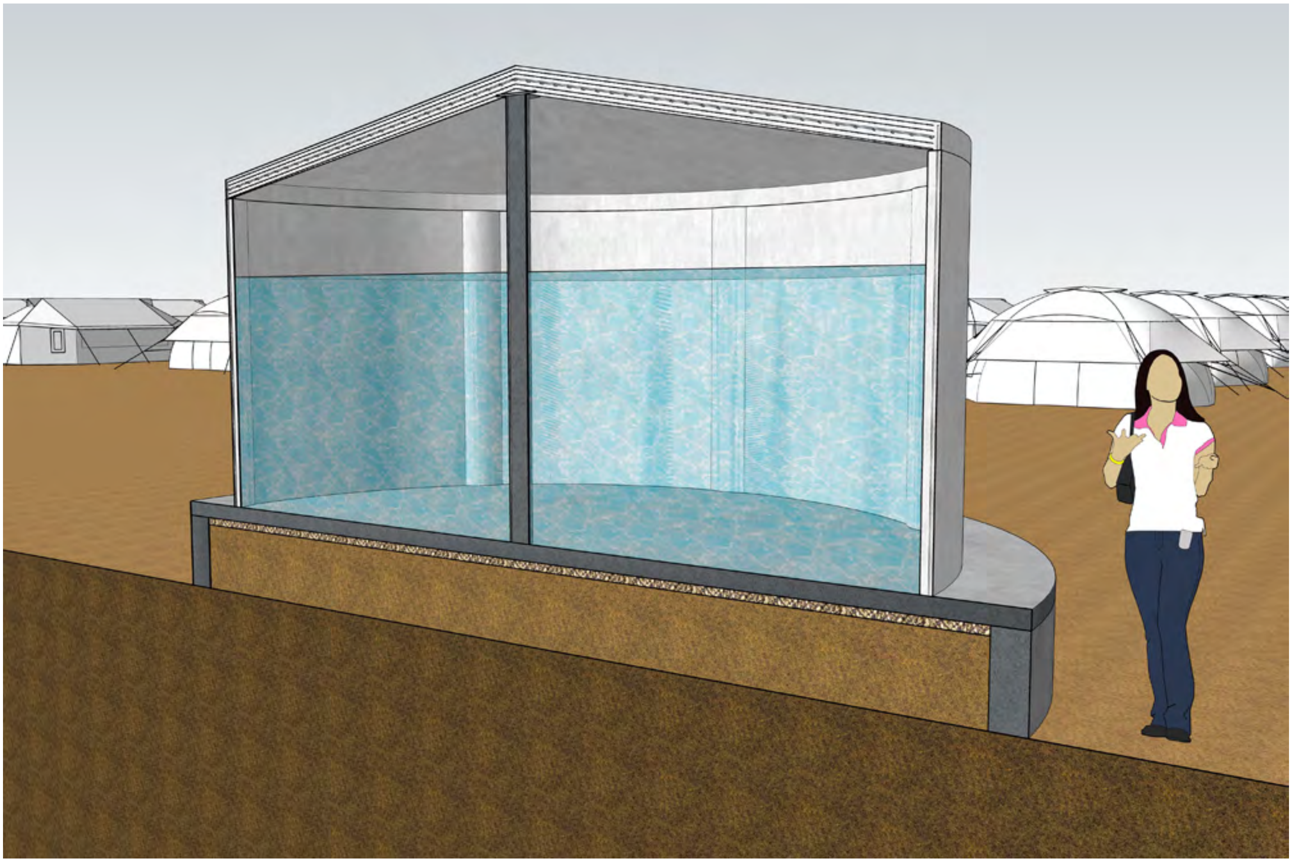
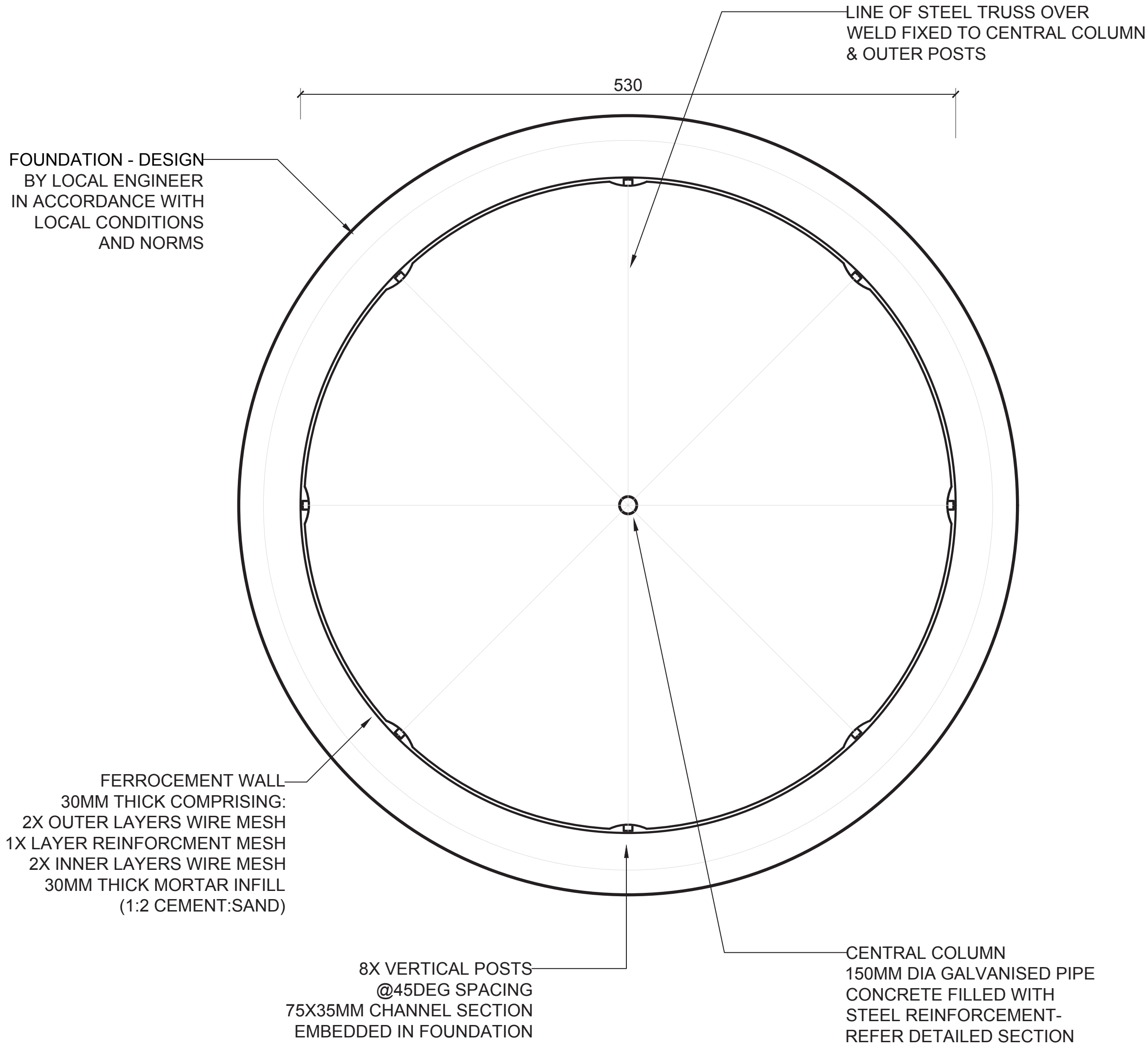




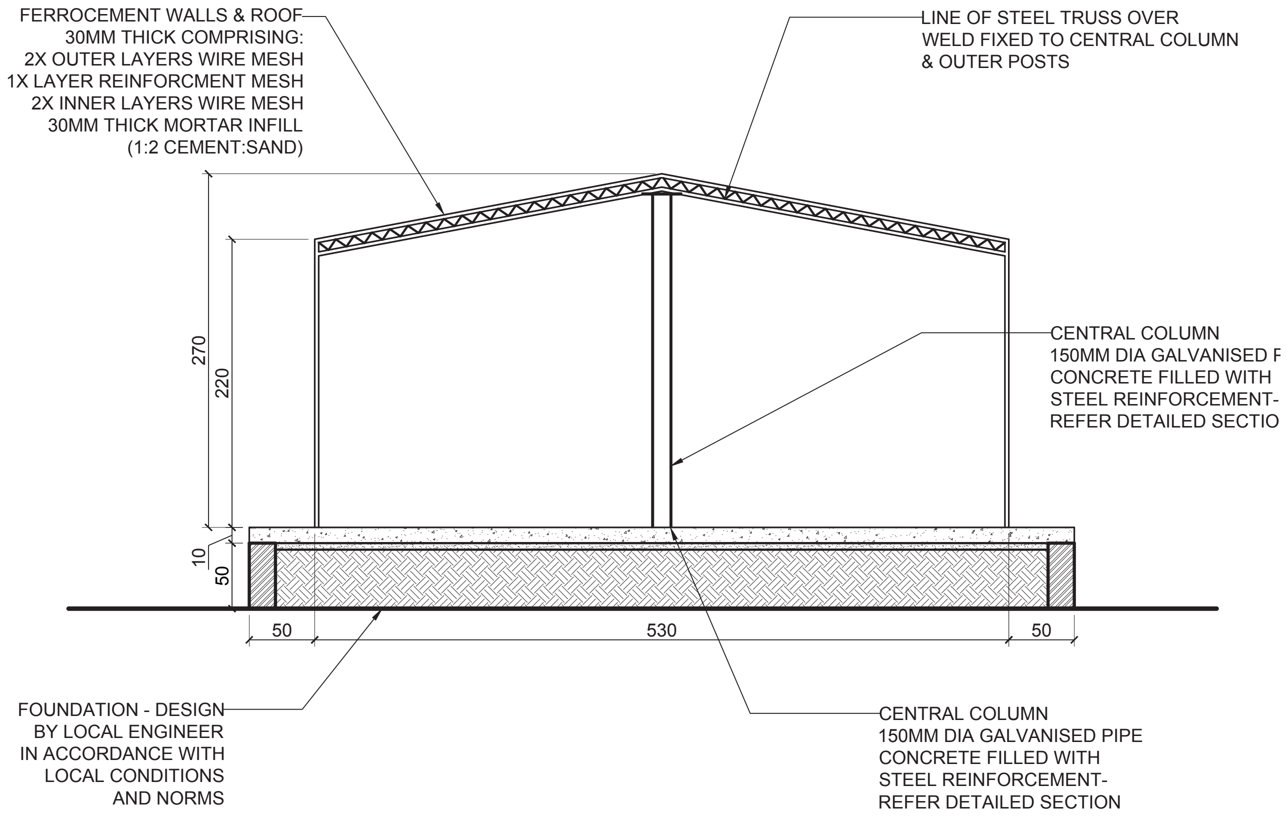
NOTES

1. Refer to *UNHCR, 2006. Large Ferro-Cement Water Tank Design Parameters and Construction Details* for step-by-step construciton instructions.
2. Refer to Specification for material descriptions.
3. Structural design to be verified by local engineer for compliance with local conditions and norms
4. Ensure the correct water content of mixed concrete - slump test should yield < $\frac{1}{4}$ height reduction.
5. Slabs to be cast in a single pour. All concrete works to be vibrated or well rodded.
6. Ensure all poured concrete is kept damp and out of direct sunlight for at least 7 days while curing.
7. Refer to hydraulic design for pipe assemblies. Valve boxes should be sized according to inlet and outlet arrangements.

DWG NO.	TITLE	DRAWN BY	UNITS
A3-1	**Ferrocement water tank, 50m3** Plan	**AU**	**CM**
		CHECKED BY **RN**	SHEET **1 of 2**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:50**	DATE **31.08.2023**

UNHCR The UN Refugee Agency

Technical Support Section
Community Infrastructure Catalogue



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DWG NO.	TITLE	DRAWN BY	UNITS
A3-2	**Ferrocement water tank, 50m3** Section	**AU**	**CM**
		CHECKED BY **RN**	SHEET **2of 2**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:50**	DATE **31.08.2023**

UNHCR The UN Refugee Agency
Technical Support Section
Community Infrastructure Catalogue

Bill of Quantities

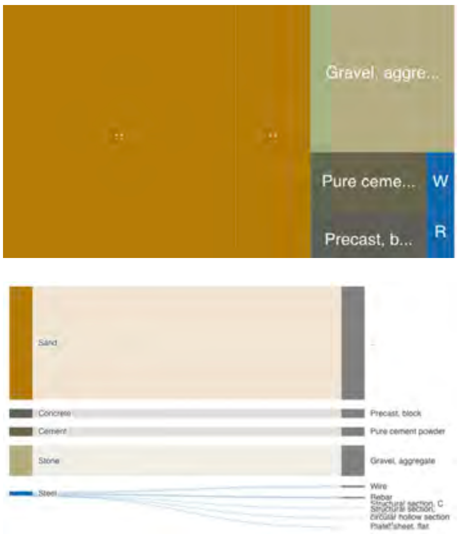
Ref	Item description	Unit	Quantity
1	Course sand (for foundation)	m3	14
2	Concrete blocks for foundation perimeter (400 x 200 x 200)	pce	150
3	Cement	kg	3300
4	Fine sand (for concrete and mortar)	m3	4.5
5	Aggregate (for concrete)	m3	5
6	Reinforcement bar - 6mm	m	170
7	Reinforcement bar - 9mm	m	1460
8	Steel channel sections - 3m x 75mm x 37.5mm	pce	6
9	Wire mesh - 1mm dia. In 20 x 20mm grid	m2	125
10	Galvanised pipe - 2.7m x 150mm dia	pce	1
11	Steel plate	m2	0.1
	Refer to *Large Ferro-cement Water Tank – Design parameters and construction details (UNHCR, 2006)* for a reinforcement bending schedule.		

Environmental Impacts

Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Sand	41440	290,08	3273,76	3563,84	74592
Concrete	3240	777,6	340,2	1117,8	11988
Cement	3300	4290	346,5	4636,5	25740
Stone	11200	78,4	884,8	963,2	21280
Steel	1574,58	3934,28	165,33	4099,61	64104,84
Total	60754,58	9370,36	5010,59	14380,95	197704,84

Material weight (kg) [1]



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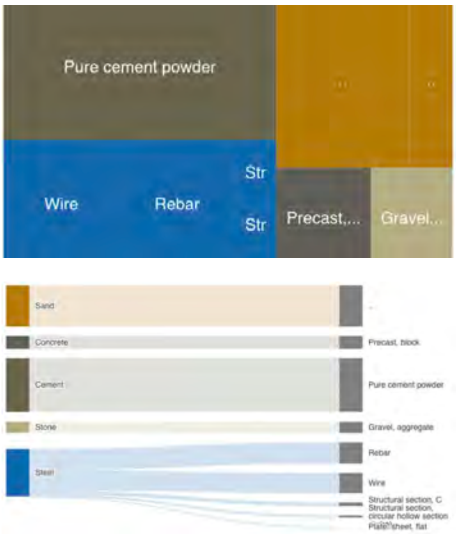
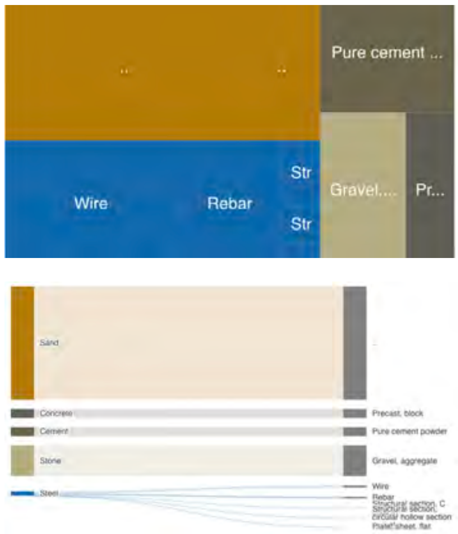


Embodied water (L) [5]



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Sizing of soakage pits, trenches and drain fields depends local site soil infiltration rates and the quantity of wastewater that is expected. Soakage pit dimensions should be determined by on-site soil infiltration tests, considering soil types and infiltration rates noted below.

	Infiltration rate (litres/m2/day)	
	clean water	wastewater
Sand	720-2400	33-50
Sandy loam	480-720	24
Silt loam	240-480	18
Clay loam	120-240	8
Clay	24-120	Unsuitable

Source: Davis & Lambert (2002) Engineering in Emergencies, 2nd edition. Practical Action Publishing: Warwickshire

Water collection and usage points should be equipped with adequately designed soakage systems located at least 30 metres away from groundwater sources. A soakage pit base must be at least 1.5m above the highest average groundwater table level.

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Location and construction of water supply related infrastructure must avoid contamination of surface water and groundwater sources. Risks are generally low and related to contamination from water treatment chemicals, water treatment by-products and contamination from wastewater.

3 MATERIALS

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%.

A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

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Water used for construction should be non-saline, and free of oils, acids, alkalies and from impurities including soil/mud and organic matter.

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Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

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Ordinary portland cement must be used before the expiry date. Cement should be kept dry and stored at least 15cm above ground to avoid ground moisture. Expired or damaged cement may be indicated by excessive grittiness or lumps of set cement.

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3.6 CEMENT MORTAR

Cement mortar shall comprise Portland cement, sand and water as specified herein. A cement:sand ratio of 1:6 shall be used unless otherwise noted. Cement mortar in brick masonry and stone masonry shall be applied to a minimum thickness of 6-10mm unless otherwise noted. After laying, mortar within brick and stone masonry shall be cured (kept moist) for a minimum of 10 days.

3.7 CONCRETE

3.7.1 *Formwork*

Formwork for in-situ poured shall be straight and true with adequate bracing to avoid deformation under the load of poured concrete. Formwork may be constructed of plywood, sawn timber or steel according to local standards and concrete finish (appearance) requirements. Ensure adequate chamfer – around 2cm – at external corners.

Ensure that formwork construction enables removal without damage to concrete. To minimise adhesion of concrete, wet surfaces of formwork that will come in contact with concrete and apply a wash of limewash, linseed oil or soapy water.

3.7.2 *Concrete mix*

Concrete shall comprise Portland cement, sand, aggregate, and water as specified herein.

For general structural purposes, a cement:sand:aggregate mix of 1:2:4 (with a minimum cement dosage of 320kg/m3) shall be used unless otherwise noted. For water retaining structures (reservoir walls and bases) a cement:sand:aggregate mix of 1:1.5:3 shall be used unless otherwise noted (1:2:4 is not waterproof) (with a minimum cement dosage of 380kg/m3). For mass concrete applications a cement:sand:aggregate mix of 1:3:6 shall be used unless otherwise noted.

For hand mixing, additional cement should be added in accordance with the table below.

Mix	Cement		Sand (m3)	Aggregate (m3)
	Machine mix (kg)	Hand mix (kg)		
1 : 1.5 : 3	370	380	0.42	0.84
1 : 2 : 4	290	300	0.45	0.90
1 : 3 : 6	190	200	0.46	0.92

Source: Khanna, P.N. (1982) Indian Civil Engineers Handbook, 8th ed. Engineers Publishers: New Delhi

Ensure that concrete mixtures are not over watered – a bucket slump test of mixed concrete should yield less than ¼ reduction in the slump height.

3.7.3 *Concrete pouring*

Each concrete element – e.g., each concrete slab, each section of footing or parapet - shall be cast in a single pour.

3.7.4 *Concrete rodding and curing*

Cast concrete should be immediately covered with fabric, plastic sheet, straw, cement bags, sacking or leaves to keep the concrete moist and cool during the curing period. All concrete should be well vibrated or rodded to remove air voids. The concrete shall be cured with frequent watering at least twice daily for at least 10 days before use.

3.7.5 *Concrete finishing*

Provide a minimum 1% fall to water collection and drainage surfaces. Provide a rough, non-slip finish to trafficable concrete surfaces, e.g., by brushing the surface during curing.

3.8 STEEL REINFORCEMENT

Reinforcement bars shall be free from rust and of the correct type and size for concrete construction work (typically a characteristic yield stress of at least 210 N/mm^2). Steel reinforcement should be placed as per the designs (typically 7/8 of the slab or wall thickness) to ensure the bars function correctly in tension. All bars should have at least 12mm concrete cover.

3.9 FERRO-CEMENT WIRE MESH

Galvanised wire mesh for ferro-cement should be 0.50-1.00mm diameter with a mesh spacing of 10-20mm. Wire should be galvanised and supplied free of rust, oil or other impurities that may reduce adhesion with cement plaster.

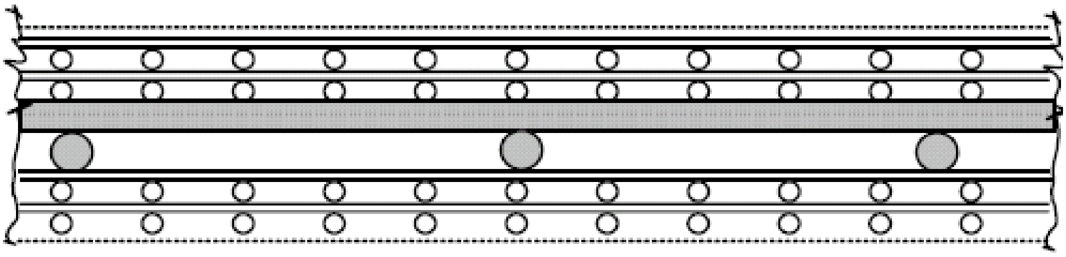


Fig. 1. Detail section of wire mesh and steel reinforcement configuration for ferro-cement

3.10 BRICK MASONRY

Bricks should be made from clay free of stone or other organic or inorganic impurities. Bricks shall be of a standard, consistent size that conforms with local standards, and shall have plane rectangular faces and right-angled edges. Bricks should be of sufficient strength, with a minimum crushing strength of 125kg/cm2, or to not break when dropped from a height of 1m. Bricks should be fired sufficiently such that, when immersed in water, a brick shall not absorb water more that 20% of its dry weight.

Bricks shall be soaked in water for minimum 15 minutes prior to laying in cement mortar.

Bricks shall be laid in horizontal courses, with brickwork laid in a single day not exceeding 1m height to avoid excessive pressure on newly laid lower courses.

Cement mortar joints should be 6-10mm. A cement : sand mix of 1:6 should be used for masonry mortar unless otherwise noted. Brickwork shall be covered with plastic sheeting or textile and kept wet (cured) for minimum 10 days after laying.

3.11 STONE MASONRY

Stone masonry shall be laid in horizontal courses, with stones laid in a single day not exceeding 1m height to avoid excessive pressure on newly laid lower courses. Stones shall be laid by hand as close as possible with broadest side downwards. Joints and gaps between stones shall be filled with smaller stones.

Cement mortar joints should be 6-10mm. A cement : sand mix of 1:6 should be used for masonry mortar unless otherwise noted. Finished masonry shall be covered with plastic sheeting or textile and kept wet (cured) for minimum 10 days after laying.

B1 Tapstand **Reinforced Concrete**

Context

Tap stands support communal water supply through centralised distribution points. Along with hygienic potable and wastewater management, accessibility and durability in wet conditions are important considerations in tap stand design. Timing of assembly or construction is a further critical consideration in emergency situations.

This design for an emergency tap stand featuring a reinforced concrete apron is drawn from the *UNHCR Standardized WASH Design Guidelines for Refugee Settings (D-301/2015a).* The tap stand has an apron area of 5.7m2, accommodates six taps, and provides drainage to a soakage pit. The design in presented here alongside alternative designs featuring gravel (B2) and timber pallet (B3) aprons.

Reinforced concrete is a common solution for wet aprons, providing a durable, accessible surface that facilitates access and drainage. Reinforced concrete construction is relatively complex in comparison with gravel and timber pallet options, yet skills and materials for reinforced concrete construction are widely available. Reinforced concrete construction typically requires engagement of a construction contractor/company. The publication *UNHCR Standardized WASH Design Guidelines for Refugee Settings (D-301/2015a)* includes step-by-step instructions that could enable community-led construction with some technical support.

To ensuring the structural integrity and proper functioning of the reinforced concrete apron, concrete should be mixed, poured and cured in accordance with the material specifications to ensure structural integrity and avoid cracking. Cement mortars used for plastering and levelling to falls should be mixed and applied in accordance with material specifications.

PROS	CONS
Strength and durability of apron surface and associated maintenance requirements	Relatively high initial construction costs
Flexibility regarding size and shape enables adaptation to site and capacity requirements	Skills for reinforced concrete construction typically requires involvement of a construction contractor
Common availability of materials and skills for construction and maintenance	Limited reuse or modification/adaptation potential

Affordability
(considering initial and operating costs)

Performance
(considering capacity and durability)

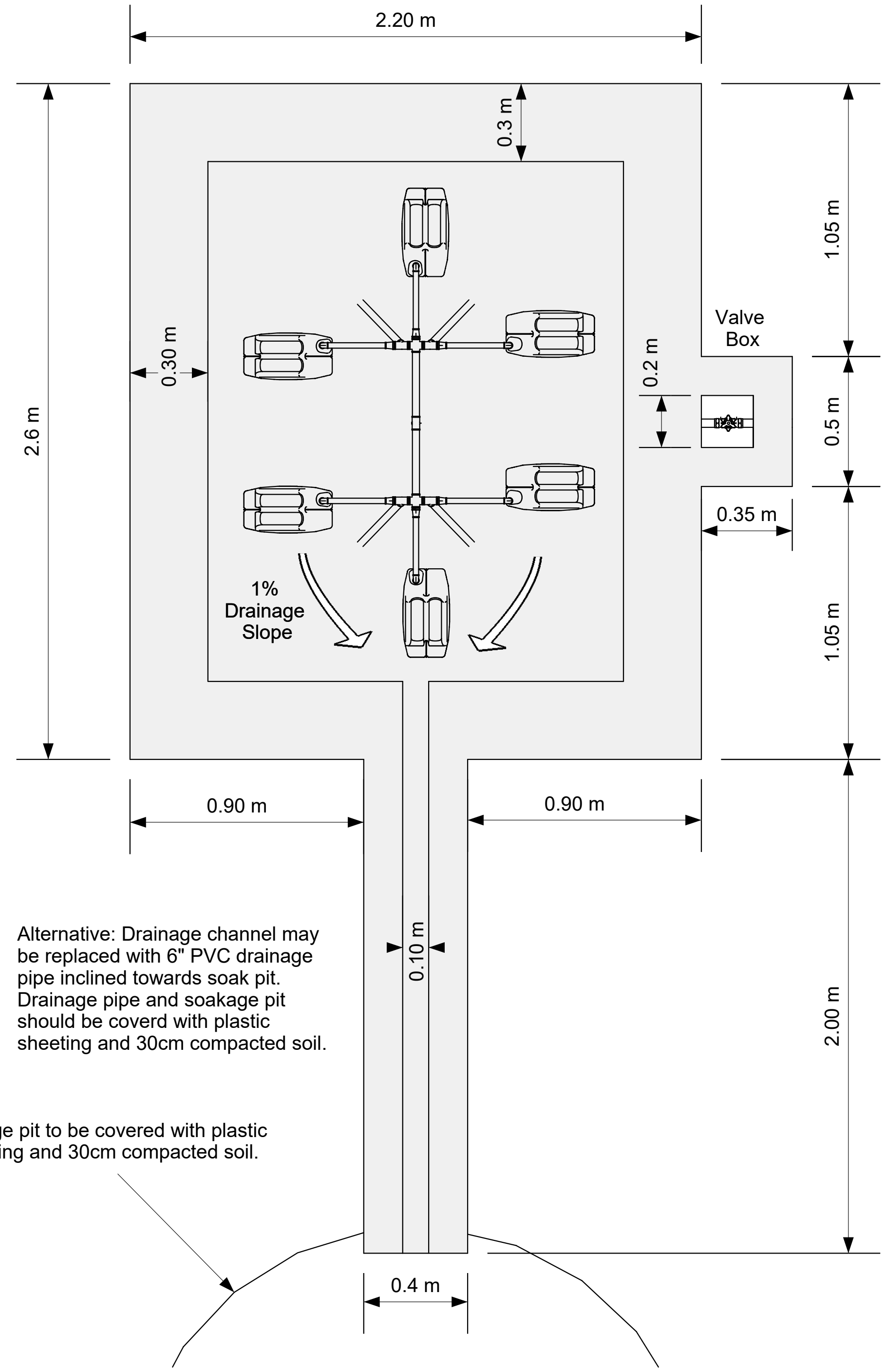
Environmental sustainability
(considering e-CO2-eq and reuse potential)

(Relatve affordability, performance and environmental impact will vary with prevailing conditions)

Bill of Quantities

Ref	Item description	Unit	Quantity
1	High Tensile Steel Weld-Mesh Ø6mm 20cm x 20cm	m2	10
2	Plastic Sheeting	m2	10
3	Coarse Sand	m3	0.9
4	Coarse Gravel (12mm – 25mm)	m3	1.5
5	Cement (50kg sacks)	sacks	10
6	Compacted Hardcore Sub-Base	m3	1.5
7	Complete Tapstand Assembly (Tapstand, 6x taps, elbow, pipe)	pce	1

General Layout



NOTES

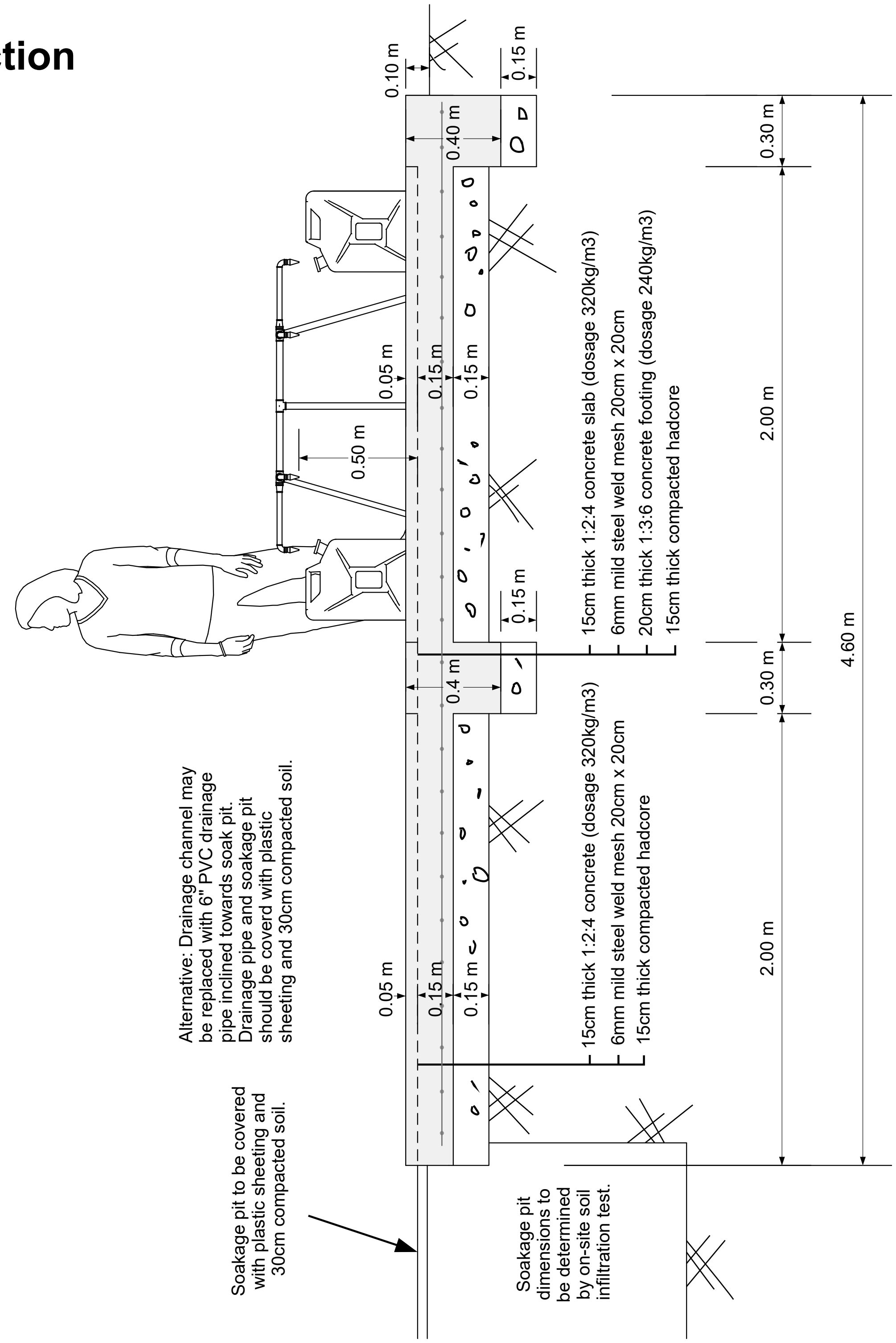
1. Tapstand to be positioned centrally with tap spouts exactly 50cm above concrete surface.
2. Concrete surface to be finished with non-slip (lightly brushed) surface with 1% slope to soakage pit.
3. Soakage pit dimensions to be determined by on-site soil infiltration test (see Appendix 20 of Engineering in Emergencies. Alternatively refer to the table of typical soil infiltration rates on page 213 of the UNHCR WASH Manual).

D-301

TITLE **Post Emergency Tapstand** General Layout	**DRAWN BY** B. Harvey - 11/10/15	**UNITS** metres
	APPROVED BY M. Burt - 15/11/15	**SHEET** 1 of 2
PROJECT Project Name, Country	**SCALE** 1:30	**DATE PUBLISHED** 15/11/15

UNHCR The UN Refugee Agency

Section



NOTES
1. Mass concrete footings 1:3:6 (min 240kg/m3 cement dosage). Slab concrete 1:2:4 (min 320kg/m3 cement dosage).
2. 15cm compacted hardcore layer to be covered with 1mm sand blinding before pouring concrete.
3. Slab reinforcement to consist of high tensile mild steel 6mm weld mesh 20cm x 20cm positioned 3cm above compacted hardcore.

D-301

TITLE **Post Emergency Tapstand** General Layout	**DRAWN BY** B. Harvey - 11/10/15	**UNITS** metres
PROJECT Project Name, Country	**APPROVED BY** M. Burt - 15/11/15	**SHEET** 2 of 2
	SCALE 1:30	**DATE PUBLISHED** 15/11/15

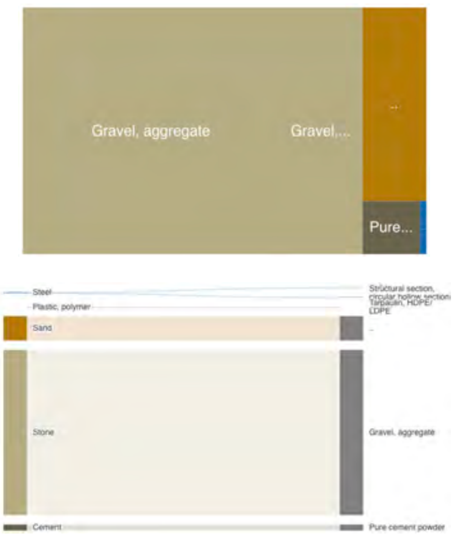
UNHCR The UN Refugee Agency

Environmental Impacts

Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

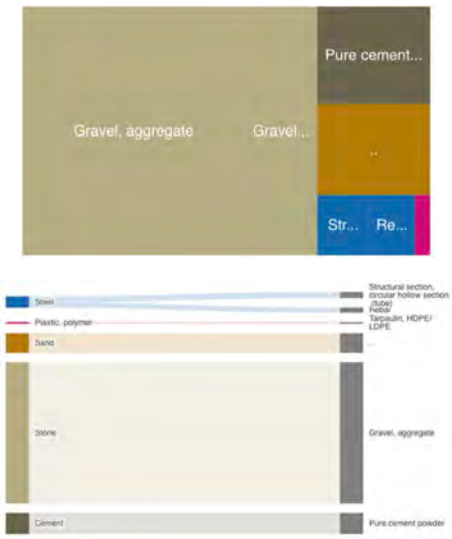
	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Steel	56,4	163,56	5,92	169,48	2 092,44
Plastic, polymer	1,9	12,16	0,2	12,36	326,8
Sand	2 016	14,11	159,26	173,38	3 628,8
Stone	13 664	95,65	1079,46	1175,1	25 961,6
Cement	500	650	52,5	702,5	3 900
Total	16 238,3	935,48	1297,34	2 232,82	35 909,64

Material weight (kg) [1]



Embodied carbon (kgCO2e) [2]

Embodied water (L) [5]



1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

2 Embodied carbon dioxide equivalent - expressed as kg.eCO2e - reflects the amount of various greenhouse gases associated with the production and use of the material. The metric converts other gases to the equivalent amount of CO2 with the same global warming potential.

3 Production embodied carbon reflects the component of eCO2e associated with material production. While embodied carbon from production differs with factors such as prevailing energy sources, a simplified calculation here uses coefficients derived from global averages.

4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

5 Embodied water reflects the amount of tap water used in production of the material. While embodied water depends on specific production processes, a simplified calculation here uses coefficients derived from global averages.

Specification

1 **GENERAL**

1.1 SCOPE

This specification is to be read in conjunction with the Drawings and Bill of Quantities (BOQ). In the event of any discrepancy, the Specification and Bill of Quantities takes precedence over Drawings.

1.2 LOCAL REGULATIONS AND STANDARDS

Work shall comply with local regulations and local construction standards. Discrepancies between designs and with regulations or standards shall be addressed before work commences.

Structural designs shall be reviewed by a local Engineer to confirm adequacy in relation to local regulations, construction practices, and site conditions.

2 **SITE**

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SET-OUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

2.4 SOAKAGE PITS

Sizing of soakage pits, trenches and drain fields depends local site soil infiltration rates and the quantity of wastewater that is expected. Soakage pit dimensions should be determined by on-site soil infiltration tests, considering soil types and infiltration rates noted below.

	Infiltration rate (litres/m2/day)	
	clean water	wastewater
Sand	720-2400	33-50
Sandy loam	480-720	24
Silt loam	240-480	18
Clay loam	120-240	8
Clay	24-120	Unsuitable

Source: Davis & Lambert (2002) Engineering in Emergencies, 2nd edition. Practical Action Publishing: Warwickshire

Water collection and usage points should be equipped with adequately designed soakage systems located at least 30 metres away from groundwater sources. A soakage pit base must be at least 1.5m above the highest average groundwater table level.

2.5 PREVENTION OF SURFACE OR GROUNDWATER CONTAMINATION

Location and construction of water supply related infrastructure must avoid contamination of surface water and groundwater sources. Risks are generally low and related to contamination from water treatment chemicals, water treatment by-products and contamination from wastewater.

3 MATERIALS

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%.

A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 CEMENT

Ordinary portland cement must be used before the expiry date. Cement should be kept dry and stored at least 15cm above ground to avoid ground moisture. Expired or damaged cement may be indicated by excessive grittiness or lumps of set cement.

3.5 CEMENT PLASTER

Cement plaster shall comprise ordinary portland cement, sand and water as specified herein. A cement:sand ratio of 1:4 shall be used unless otherwise noted. Cement plasters shall be applied to a minimum thickness of 1cm unless otherwise noted. After application, plastered surfaces shall be cured (kept moist) for a minimum of 7 days.

Waterproof cement plasters for interior and exterior surfaces of water tank shall comprise 3 layers: 1) 6mm, 1:4, spatter-dash, 2) 10mm, 1:3, rough finish, 3) 10mm, 1:2, smooth float. Each layer shall be applied before the base layer is cured, with the base layer wetted and scratched to ensure proper bonding. Waterproof plasters should be mixed with a waterproofing compound (Sikalite or equivalent) at the dosage specified by the compound manufacturer.

3.6 CEMENT MORTAR

Cement mortar shall comprise Portland cement, sand and water as specified herein. A cement:sand ratio of 1:6 shall be used unless otherwise noted. Cement mortar in brick masonry and stone masonry shall be applied to a minimum thickness of 6-10mm unless otherwise noted. After laying, mortar within brick and stone masonry shall be cured (kept moist) for a minimum of 10 days.

3.7 CONCRETE

3.7.1 *Formwork*

Formwork for in-situ poured shall be straight and true with adequate bracing to avoid deformation under the load of poured concrete. Formwork may be constructed of plywood, sawn timber or steel according to local standards and concrete finish (appearance) requirements. Ensure adequate chamfer – around 2cm – at external corners.

Ensure that formwork construction enables removal without damage to concrete. To minimise adhesion of concrete, wet surfaces of formwork that will come in contact with concrete and apply a wash of limewash, linseed oil or soapy water.

3.7.2 *Concrete mix*

Concrete shall comprise Portland cement, sand, aggregate, and water as specified herein.

For general structural purposes, a cement:sand:aggregate mix of 1:2:4 (with a minimum cement dosage of 320kg/m3) shall be used unless otherwise noted. For water retaining structures (reservoir walls and bases) a cement:sand:aggregate mix of 1:1.5:3 shall be used unless otherwise noted (1:2:4 is not waterproof) (with a minimum cement dosage of 380kg/m3). For mass concrete applications a cement:sand:aggregate mix of 1:3:6 shall be used unless otherwise noted.

For hand mixing, additional cement should be added in accordance with the table below.

Mix	Cement		Sand (m3)	Aggregate (m3)
	Machine mix (kg)	Hand mix (kg)		
1 : 1.5 : 3	370	380	0.42	0.84
1 : 2 : 4	290	300	0.45	0.90
1 : 3 : 6	190	200	0.46	0.92

Source: Khanna, P.N. (1982) Indian Civil Engineers Handbook, 8th ed. Engineers Publishers: New Delhi

Ensure that concrete mixtures are not over watered – a bucket slump test of mixed concrete should yield less than ¼ reduction in the slump height.

3.7.3 *Concrete pouring*

Each concrete element – e.g., each concrete slab, each section of footing or parapet - shall be cast in a single pour.

3.7.4 *Concrete rodding and curing*

Cast concrete should be immediately covered with fabric, plastic sheet, straw, cement bags, sacking or leaves to keep the concrete moist and cool during the curing period. All concrete should be well vibrated or rodded to remove air voids. The concrete shall be cured with frequent watering at least twice daily for at least 10 days before use.

3.7.5 *Concrete finishing*

Provide a minimum 1% fall to water collection and drainage surfaces. Provide a rough, non-slip finish to trafficable concrete surfaces, e.g., by brushing the surface during curing.

3.8 STEEL REINFORCEMENT

Reinforcement bars shall be free from rust and of the correct type and size for concrete construction work (typically a characteristic yield stress of at least 210 N/mm^2). Steel reinforcement should be placed as per the designs (typically 7/8 of the slab or wall thickness) to ensure the bars function correctly in tension. All bars should have at least 12mm concrete cover.

B2 Tapstand **Gravel**

Context

Tap stands support communal water supply through centralised distribution points. Along with hygienic potable and wastewater management, accessibility and durability in wet conditions are important considerations in tap stand design. Timing of assembly or construction is a further critical consideration in emergency situations.

This design for an emergency tap stand featuring a drained gravel apron is drawn from the *UNHCR Standardized WASH Design Guidelines for Refugee Settings (D-301/2015a).* The tap stand has an apron area of 5.7m2, accommodates six taps of a standard UNHCR tapstand assembly, and provides drainage to a soakage pit. The design in presented here alongside alternative designs featuring reinforced concrete (B1) and timber pallet (B3) aprons.

Gravel provides an expedient solution for a tapstand apron, considering the relatively quick construction time and low cost. Gravel laid in accordance with this design provides a well-drained surface. However, gravel provides a less stable surface compared to reinforced concrete. Gravel also requires more maintenance, specifically in the regular replenishment of gravel to maintain a sufficiently thick layer to provide a drained upper surface.

The publication *UNHCR Standardized WASH Design Guidelines for Refugee Settings (D-301/2015a)* includes step-by-step instructions that could enable community-led construction with some technical support.

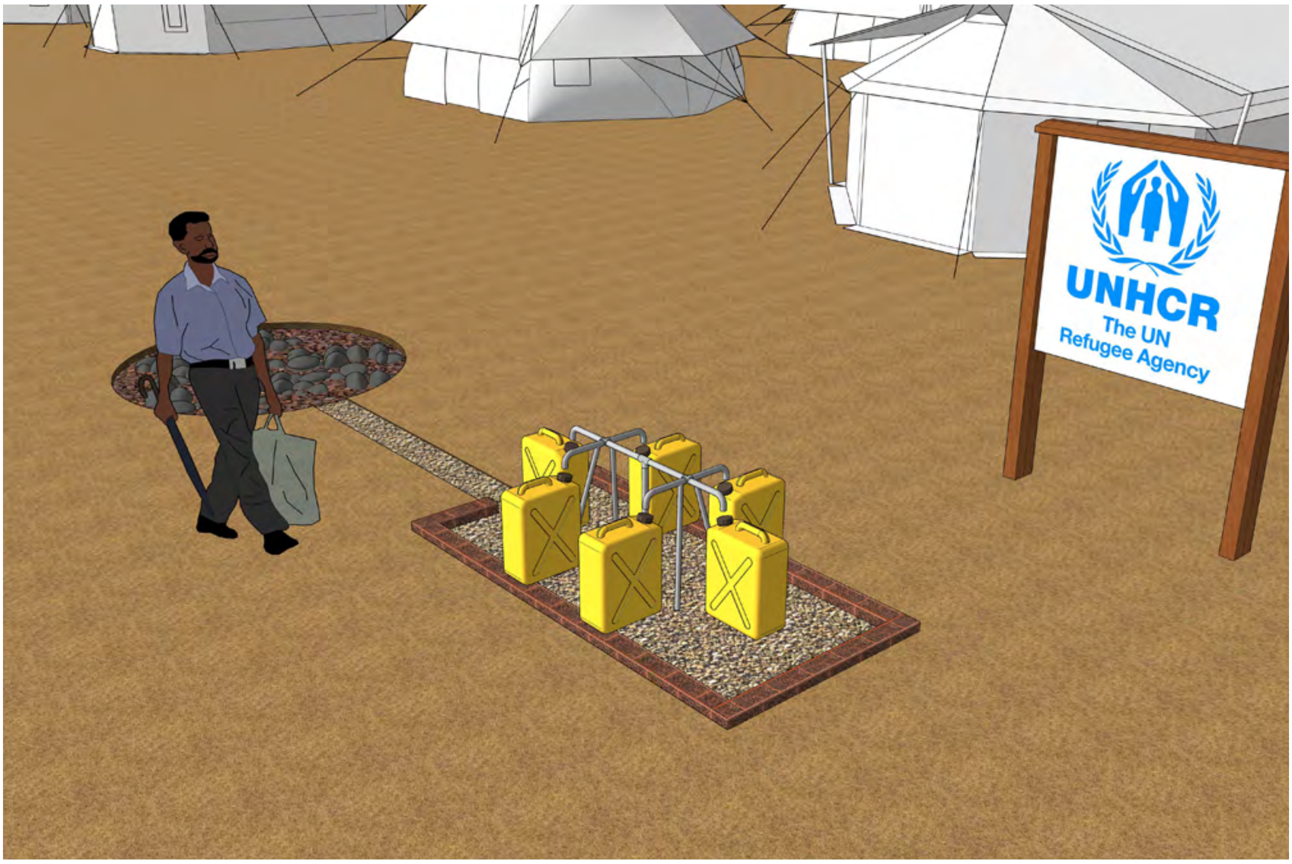
PROS	CONS
Relatively low inital cost Flexibility regarding size and shape enables adaptation to site and capacity requirements Basic construction techniques enable community-led construction	Limited durability and regular maintenance required to replenish gravel apron Gravel apron can hinder accessibility and functionality

Affordability
(considering initial and operating costs)

Performance
(considering capacity and durability)

Environmental sustainability
(considering e-CO2-eq and reuse potential)

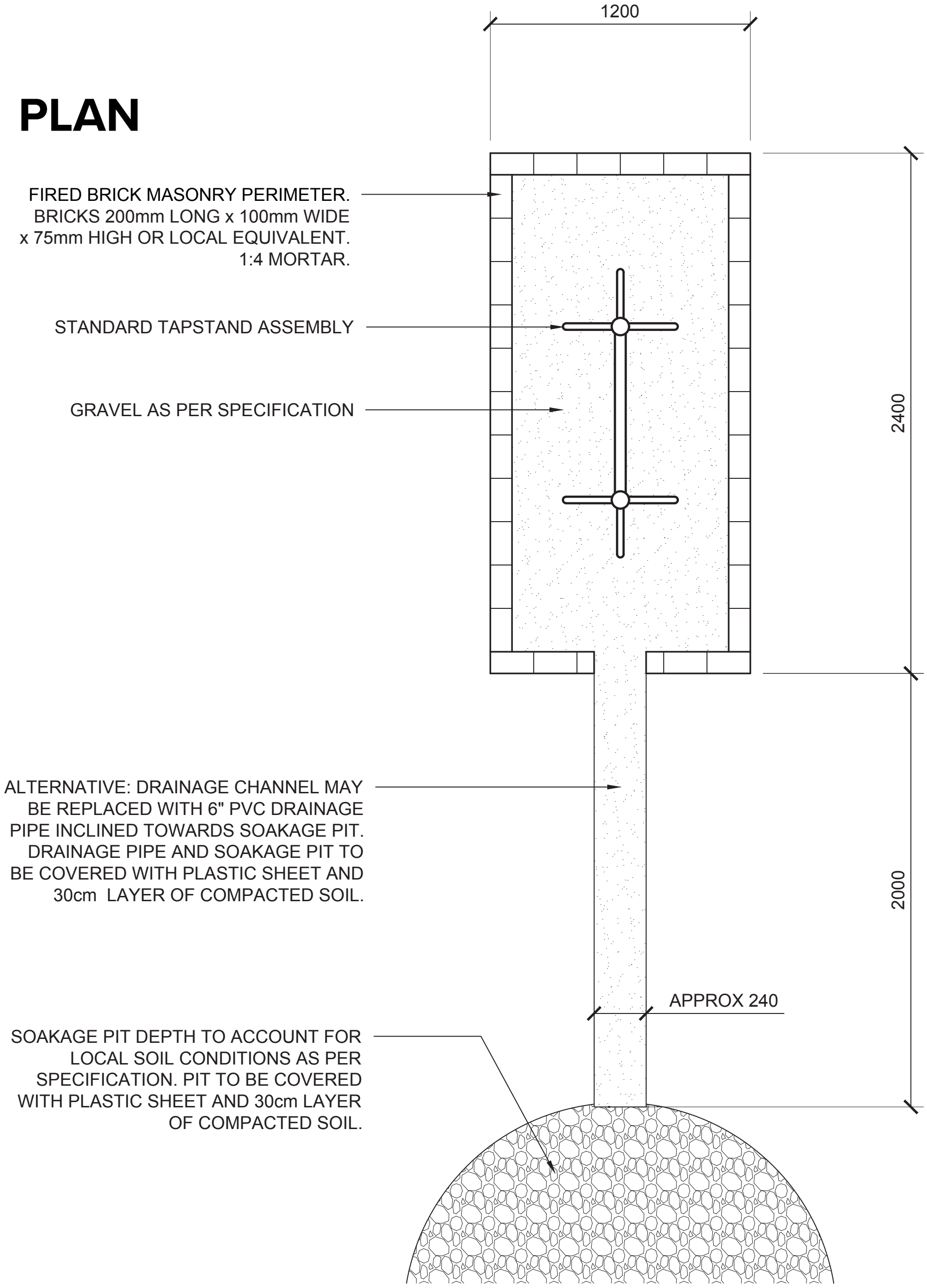
(Relatve affordability, performance and environmental impact will vary with prevailing conditions)



Bill of Quantities

Ref	Item description	Unit	Quantity
1	Bricks - 20cm x 10cm x 7cm (or similar)	pce	40
2	Plastic Sheeting	m2	2
3	Coarse Gravel (12mm – 25mm)	m3	1.5
4	Complete Tapstand Assembly (Tapstand, 6x taps, elbow, pipe)	pce	1

PLAN



NOTES

-TAPSTAND TO BE POSITIONED CENTRALLY WITH TAP SPOUTS 50cm ABOVE GRAVEL SURFACE
- SOAKAGE PIT DIMENSIONS TO BE DETERMINED BY ON-SITE SOIL INFILTRATION TESTS - REFER TO SPEC.
-REFER TO SPECIFICATION FOR MATERIAL DESCRIPTIONS
-DIMENSIONS ARE NOMINAL AND MAY BE ADJUSTED TO SUIT LOCAL CONDITIONS AND REQUIREMENTS

DWG NO.	TITLE	DRAWN BY	UNITS
B2-2	**Emergency Tapstand - Gravel** Plan	**AU**	**CM**
		CHECKED BY **RN**	SHEET **2of 2**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:30**	DATE **31.08.2023**

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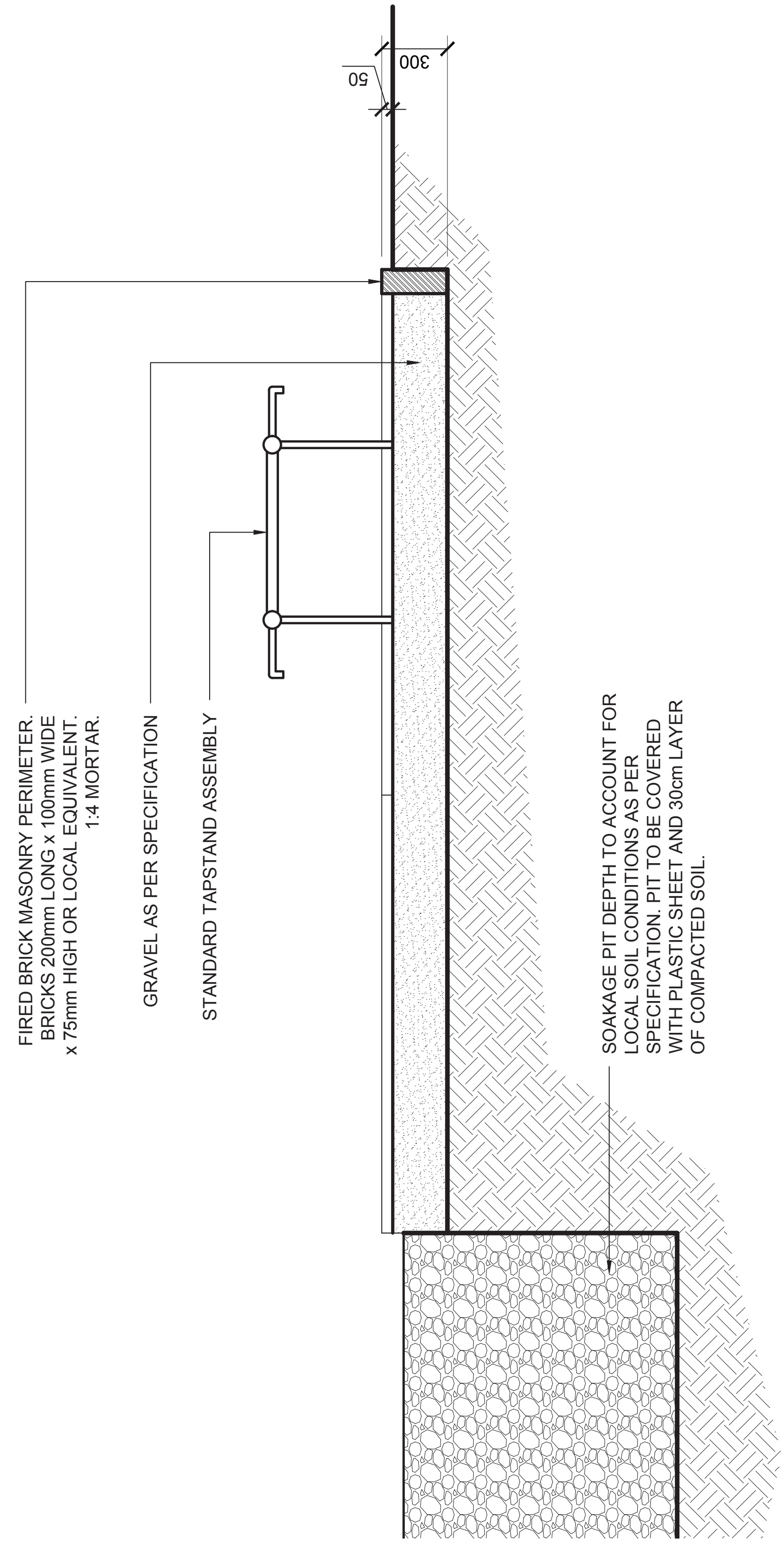

NOTES

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DWG NO.	TITLE	DRAWN BY	UNITS
B2-2	**Emergency Tapstand - Gravel** Plan	**AU**	**CM**
		CHECKED BY **RN**	SHEET **2of 2**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:30**	DATE **31.08.2023**

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Technical Support Section
Community Infrastructure Catalogue

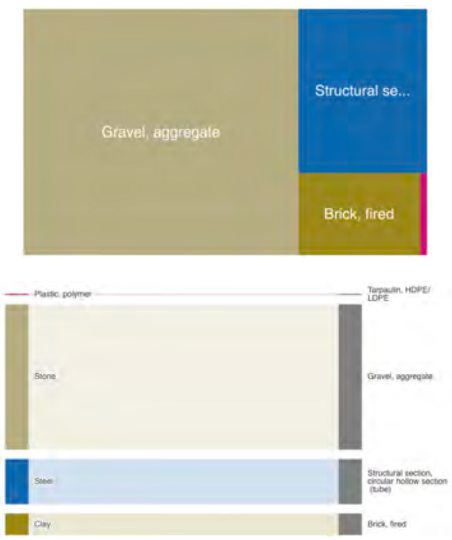
Environmental Impacts

Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Plastic, polymer	0,38	2,43	0,04	2,47	65,36
Stone	3 360	23,52	265,44	288,96	6 384
Steel	30	87	3,15	90,15	1113
Clay	107,52	34,41	8,49	42,9	193,54
Total	3 497,9	147,36	277,12	424,48	7 755,9

Material weight (kg) [1]

Embodied carbon (kgCO2e) [2]



Embodied water (L) [5]

1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

2 Embodied carbon dioxide equivalent - expressed as kg.eCO2e - reflects the amount of various greenhouse gases associated with the production and use of the material. The metric converts other gases to the equivalent amount of CO2 with the same global warming potential.

3 Production embodied carbon reflects the component of eCO2e associated with material production. While embodied carbon from production differs with factors such as prevailing energy sources, a simplified calculation here uses coefficients derived from global averages.

4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

5 Embodied water reflects the amount of tap water used in production of the material. While embodied water depends on specific production processes, a simplified calculation here uses coefficients derived from global averages.

Specification

1 **GENERAL**

1.1 SCOPE

This specification is to be read in conjunction with the Drawings and Bill of Quantities (BOQ). In the event of any discrepancy, the Specification and Bill of Quantities takes precedence over Drawings.

1.2 LOCAL REGULATIONS AND STANDARDS

Work shall comply with local regulations and local construction standards. Discrepancies between designs and with regulations or standards shall be addressed before work commences.

Structural designs shall be reviewed by a local Engineer to confirm adequacy in relation to local regulations, construction practices, and site conditions.

2 **SITE**

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SET-OUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

2.4 SOAKAGE PITS

Sizing of soakage pits, trenches and drain fields depends on local site soil infiltration rates and the quantity of wastewater that is expected. Soakage pit dimensions should be determined by on-site soil infiltration tests, considering soil types and infiltration rates noted below.

	Infiltration rate (litres/m2/day)	
	clean water	wastewater
Sand	720-2400	33-50
Sandy loam	480-720	24
Silt loam	240-480	18
Clay loam	120-240	8
Clay	24-120	Unsuitable

Source: Davis & Lambert (2002) Engineering in Emergencies, 2nd edition. Practical Action Publishing: Warwickshire

Water collection and usage points should be equipped with adequately designed soakage systems located at least 30 metres away from groundwater sources. A soakage pit base must be at least 1.5m above the highest average groundwater table level.

2.5 PREVENTION OF SURFACE OR GROUNDWATER CONTAMINATION

Location and construction of water supply related infrastructure must avoid contamination of surface water and groundwater sources. Risks are generally low and related to contamination from water treatment chemicals, water treatment by-products and contamination from wastewater.

3 MATERIALS

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%.

A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free from oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 BRICK MASONRY

Bricks should be made from clay free of stone or other organic or inorganic impurities. Bricks shall be of a standard, consistent size that conforms with local standards, and shall have plane rectangular faces and right-angled edges. Bricks should be of sufficient strength, with a minimum crushing strength of 125kg/cm2, or to not break when dropped from a height of 1m. Bricks should be fired sufficiently such that, when immersed in water, a brick shall not absorb water more that 20% of its dry weight.

Bricks shall be soaked in water for minimum 15 minutes prior to laying in cement mortar.

Bricks shall be laid in horizontal courses, with brickwork laid in a single day not exceeding 1m height to avoid excessive pressure on newly laid lower courses.

Cement mortar joints should be 6-10mm. A cement : sand mix of 1:6 should be used for masonry mortar unless otherwise noted. Brickwork shall be covered with plastic sheeting or textile and kept wet (cured) for minimum 10 days after laying.

Image courtesy Md. Sultan Mahmud, UNHCR

B3 Tapstand **Timber Palette**

Context

Tapstands support communal water supply through centralised distribution points. Along with hygienic potable and wastewater management, accessibility and durability in wet conditions are important considerations in tap stand design. Timing of assembly or construction is a further critical consideration in emergency situations.

This design for an emergency tap stand featuring an apron made form reused timber shipping palettes is drawn from the *UNHCR Standardized WASH Design Guidelines for Refugee Settings (D-301/2015a).* The tap stand has an apron area of 3m2, accommodates six taps of a standard UNHCR tapstand assembly, and provides drainage to a soakage pit. The design in presented here alongside alternative designs featuring reinforced concrete (B1) and gravel (B2) aprons.

Timber palettes provide an expedient solution for a tapstand apron, considering the quick construction time and low cost. Considering the limited durability of timber in wet conditions, this design serves as a short-term solution in emergency situations. Palettes provide a well-drained surface. However, the inconsistent surface provided by timber palettes may be inconvenient and hinder access to taps.

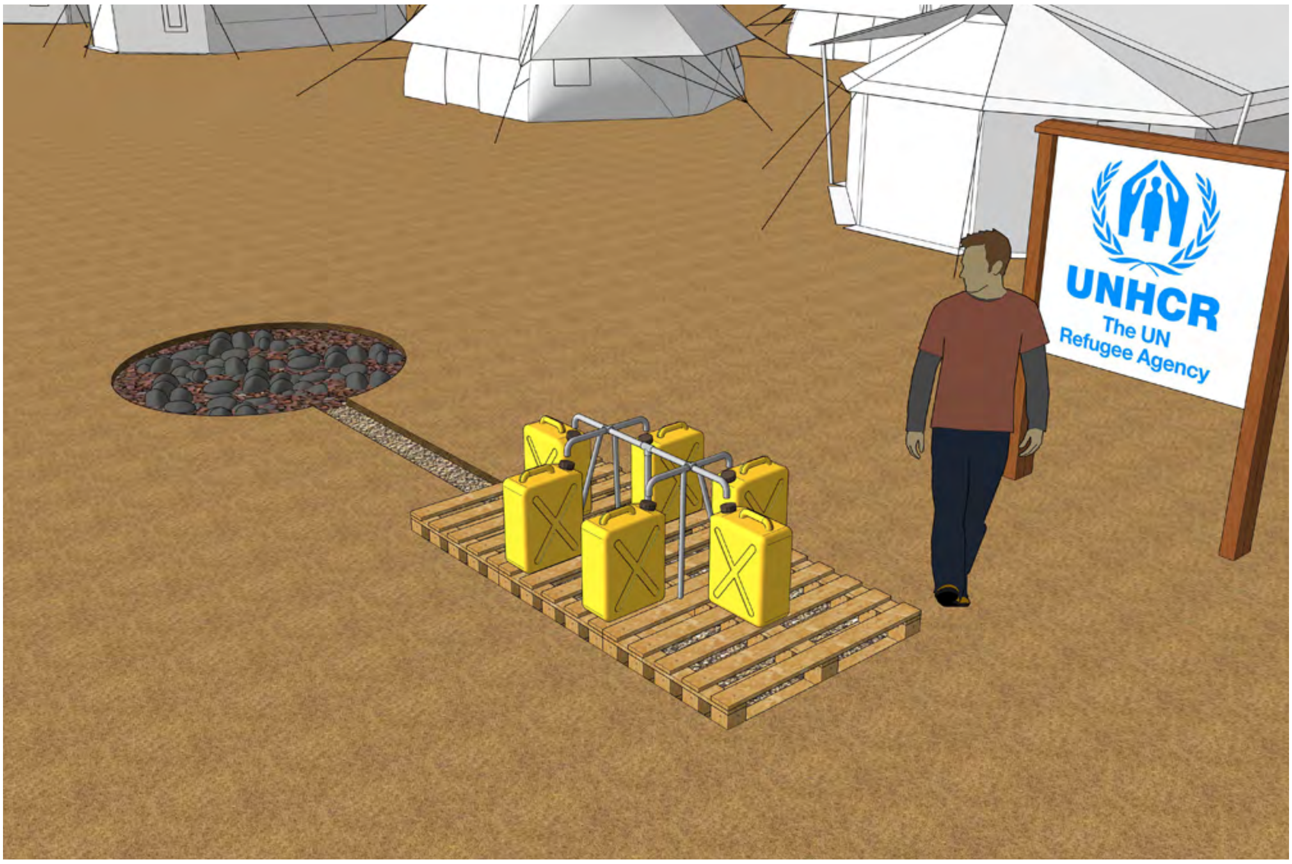
PROS	CONS
Relatively low inital cost Rapid construction time Basic construction techniques enable community-led construction	Limited durability and regular maintenance required to maintain palette position and stability. Timber palette apron can hinder accessibility and functionality Limited flexibility regarding size and shape due to standard timber palette sizing

Affordability
(considering initial and operating costs)

Performance
(considering capacity and durability)

Environmental sustainability
(considering e-CO2-eq and reuse potential)

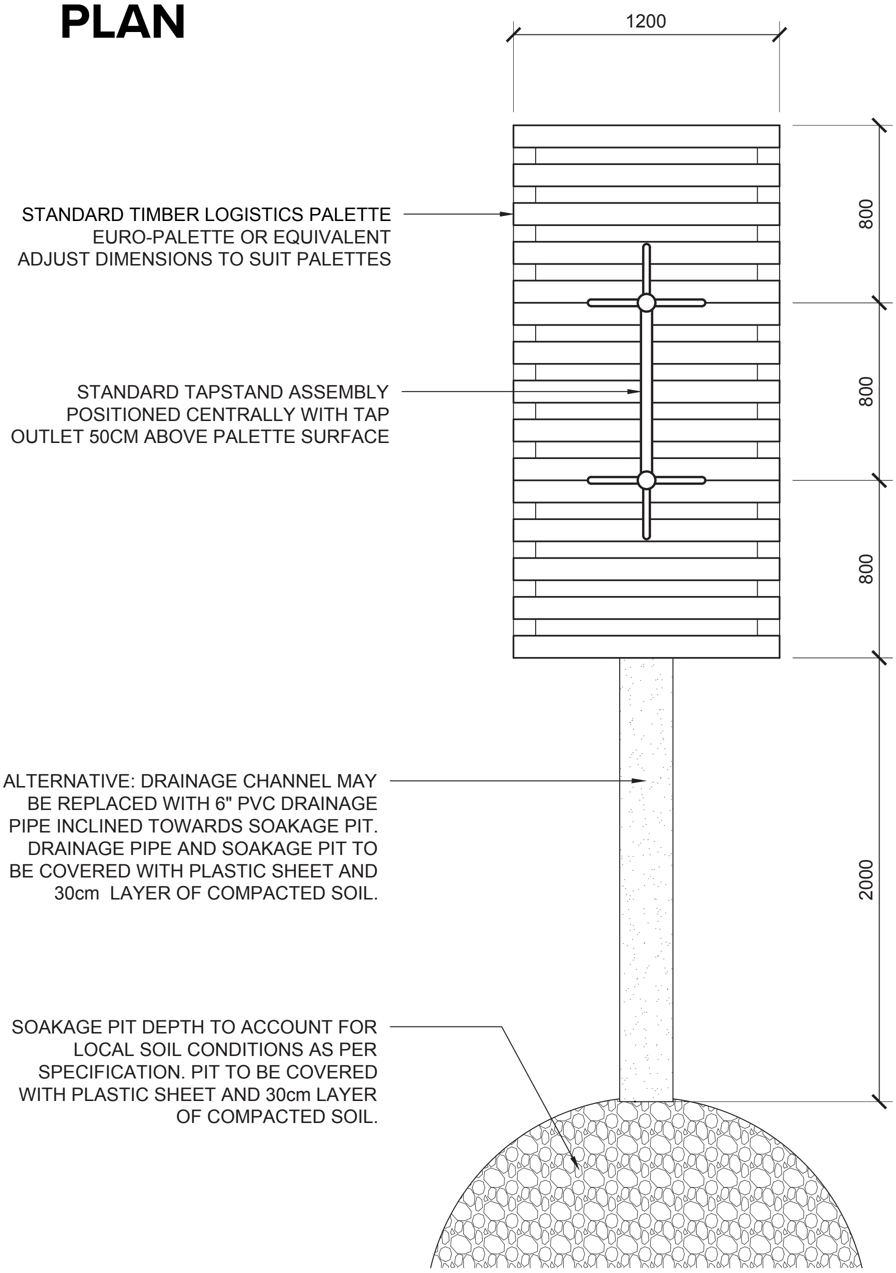
(Relatve affordability, performance and environmental impact will vary with prevailing conditions)



Bill of Quantities

Ref	Item description	Unit	Quantity
1	Timber palette - approx. 1.2m x 0.8m ((euro palette or equivalent)	pce	3
2	Plastic Sheeting	m2	3
4	Coarse Gravel (12mm – 25mm)	m3	0.75
7	Complete Tapstand Assembly (Tapstand, 6x taps, elbow, pipe)	pce	1

PLAN



NOTES

-TAPSTAND TO BE POSITIONED CENTRALLY WITH TAP SPOUTS 50cm ABOVE GRAVEL SURFACE
- SOAKAGE PIT DIMENSIONS TO BE DETERMINED BY ON-SITE SOIL INFILTRATION TESTS - REFER TO SPEC.
-REFER TO SPECIFICATION FOR MATERIAL DESCRIPTIONS
-DIMENSIONS ARE NOMINAL AND MAY BE ADJUSTED TO SUIT LOCAL CONDITIONS AND REQUIREMENTS

DWG NO.	TITLE	DRAWN BY	UNITS
B3-1	**Emergency Tapstand - Timber Palette** Plan	**AU**	**CM**
		CHECKED BY **RN**	SHEET **1 of 2**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:30**	DATE **31.08.2023**

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Technical Support Section
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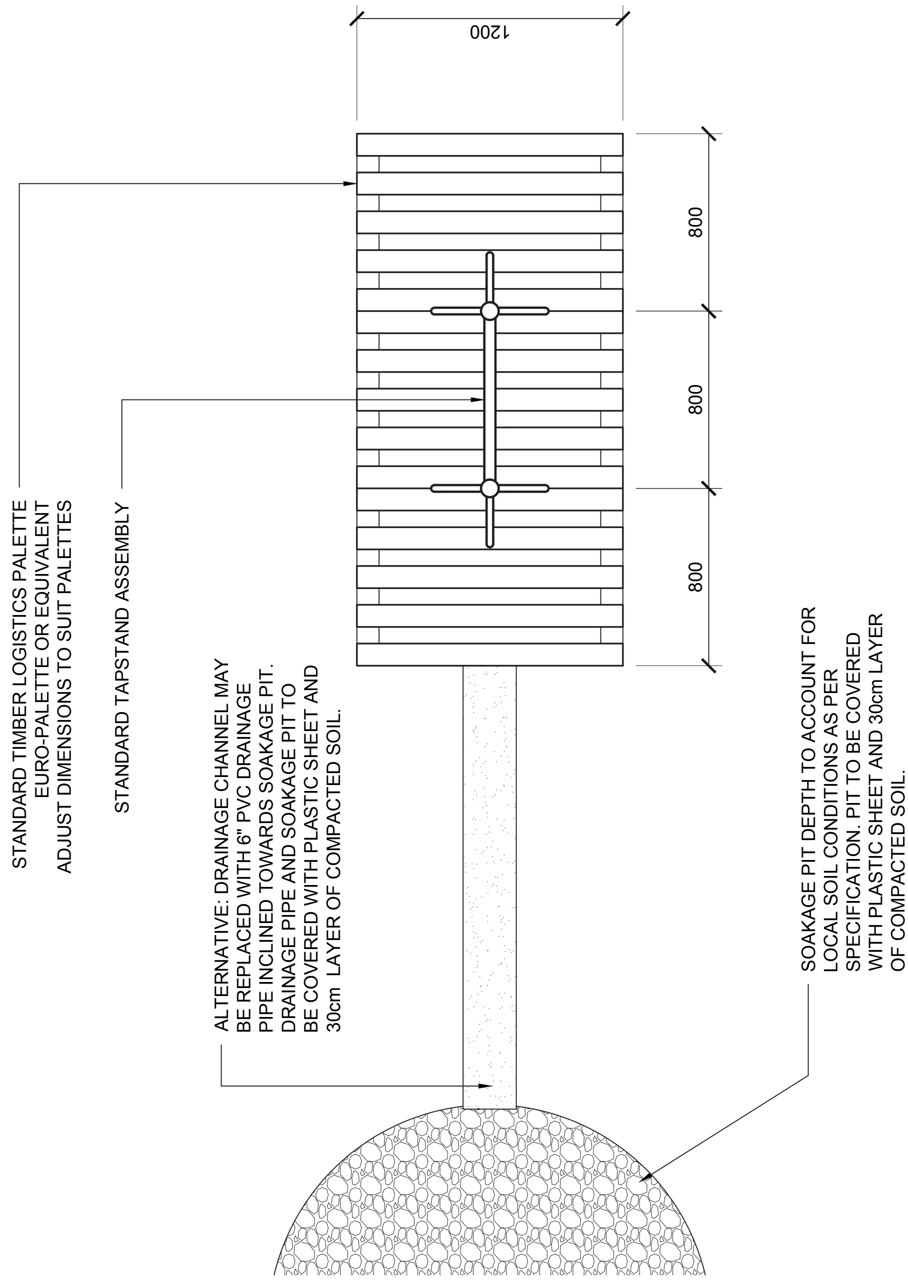

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DWG NO.	TITLE	DRAWN BY	UNITS
B3-2	**Emergency Tapstand - Timber Palette** Section	**AU**	**CM**
		CHECKED BY **RN**	SHEET **2 of 2**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:30**	DATE **31.08.2023**

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Technical Support Section
Community Infrastructure Catalogue

Environmental Impacts

Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Plastic, polymer	0,38	2,43	0,04	2,47	65,36
Stone	3360	23,52	265,44	288,96	6 384
Steel	30	87	3,15	90,15	1113
Timber	29,38	7,64	3,08	10,72	753,79
Total	3 419,76	120,59	271,71	392,3	8 316,15

Material weight (kg) [1]

Embodied carbon (kgCO2e) [2]

Embodied water (L) [5]

1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

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4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

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Specification

1 GENERAL

1.1 SCOPE

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2 SITE

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SET-OUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

2.4 SOAKAGE PITS

Sizing of soakage pits, trenches and drain fields depends local site soil infiltration rates and the quantity of wastewater that is expected. Soakage pit dimensions should be determined by on-site soil infiltration tests, considering soil types and infiltration rates noted below.

	Infiltration rate (litres/m2/day)	
	clean water	wastewater
Sand	720-2400	33-50
Sandy loam	480-720	24
Silt loam	240-480	18
Clay loam	120-240	8
Clay	24-120	Unsuitable

Source: Davis & Lambert (2002) Engineering in Emergencies, 2nd edition. Practical Action Publishing: Warwickshire

Water collection and usage points should be equipped with adequately designed soakage systems located at least 30 metres away from groundwater sources. A soakage pit base must be at least 1.5m above the highest average groundwater table level.

2.5 PREVENTION OF SURFACE OR GROUNDWATER CONTAMINATION

Location and construction of water supply related infrastructure must avoid contamination of surface water and groundwater sources. Risks are generally low and related to contamination from water treatment chemicals, water treatment by-products and contamination from wastewater.

3 MATERIALS

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%.

A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free from oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 TIMBER PALETTES

Timber palettes shall be supplied undamaged and of consistent dimensions.


Image courtesy Md. Sultan Mahmud, UNHCR

Context

Drainage network design in camp settings should consider flood risk, drainage capacity, water retention, and surface erosion. Drainage networks should comprise primary, secondary and tertiary drains that will vary in dimensions (capacity) and construction type. A wide range of drain types are available (e.g., concrete, brick masonry, etc.). Selection of a drainage type should take into account drainage capacity requirements, local construction methods, cost, timing, local participation and other issues.

This design for a concrete drain is drawn from the UN Habitat Guidelines for Community Infrastructure (2012). In this catalogue, the design is presented alongside precast concrete, brick masonry, and bamboo-based options. The concrete drain design is based on standard construction methods in Pakistan. The concrete drain design presented here is for a drain 45cm wide x 45cm deep (depth varies to suit falls). The design enables adjustment of the drain up to 1m wide (requiring associated adjustments to the drawings and Bill of Quantities herein) to suit local drainage requirements.

The non-reinforced concrete design presented herein may be achieved in most situations where concrete construction is common, suggesting the availability of the required skills and materials. In general, concrete construction will require engagement of a construction contractor/company. However, concrete construction may also be achieved by assisted communities with consistent technical support and supervision.

Several matters are critical to ensuring the structural integrity and proper functioning of the concrete drain. Local engineering expertise should be engaged to verify and modify the design to structural footings/foundations to take into account local geological (soil) conditions and local construction norms. Concrete should be mixed, poured and cured in accordance with the material specifications to ensure structural integrity and avoid cracking.

PROS	CONS
Flexibility of dimensions and capacity enables adaptation to local requirements and terrain Strength and durability of concrete construction Widespread availability of skills and materials for concrete construction	Relatively high initial construction cost Skilled labour requirements limit potential for community involvement

Affordability
(considering initial and operating costs)

Performance
(considering capacity and durability)

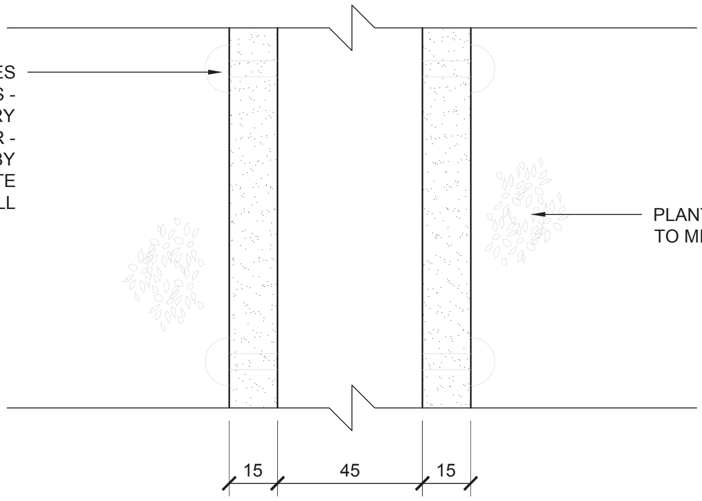
Environmental sustainability
(considering e-CO2-eq and reuse potential)

(Relatve affordability, performance and environmental impact will vary with prevailing conditions)

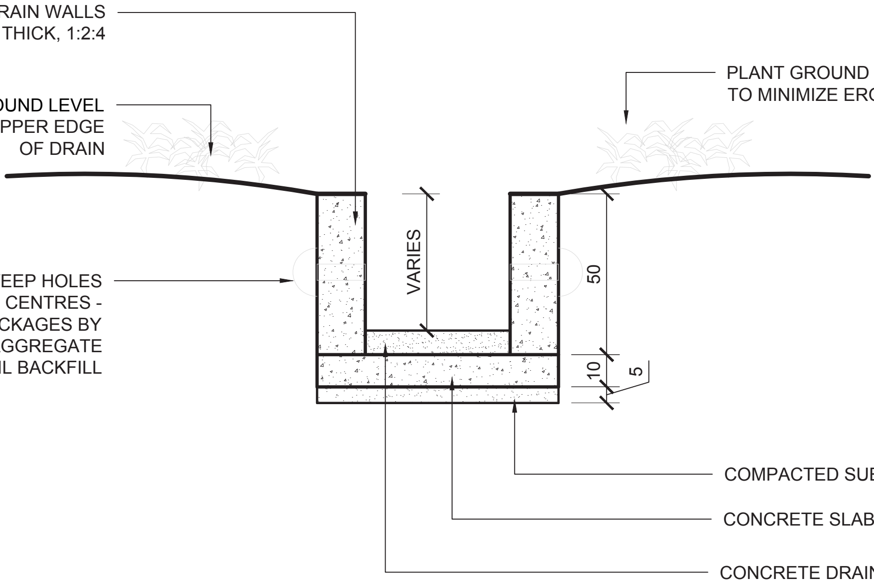
Bill of Quantities

Ref	Item description	Unit	Quantity
	(per 1m length of drain)		
1	Concrete for drain walls and slab base - 1:2:4	m3	0.22
2	Concrete for graded drain base - 1:3:6	m3	0.035
3	Gravel for compacted sub-base and weep-hole backing	m3	0.06
4	Excavation		

PLAN



SECTION



DWG NO.	TITLE	DRAWN BY	UNITS
C1-1	**Drainage channel - Concrete** Plan & Section	**AU**	**CM**
		CHECKED BY **RN**	SHEET **1 of 1**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:20**	DATE **31.08.2023**

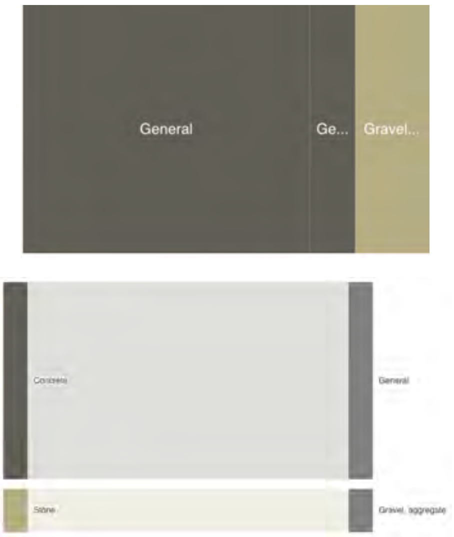
UNHCR The UN Refugee Agency
Technical Support Section
Community Infrastructure Catalogue

Environmental Impacts (per meter)

Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Concrete	510	1059,27	53,55	1112,82	32,64
Stone	112	0,78	8,85	9,63	212,8
Total	622	1060,05	62,4	1122,45	245,44

Material weight (kg) [1]



Embodied carbon (kgCO2e) [2]

Embodied water (L) [5]

1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

2 Embodied carbon dioxide equivalent - expressed as kg.eCO2e - reflects the amount of various greenhouse gases associated with the production and use of the material. The metric converts other gases to the equivalent amount of CO2 with the same global warming potential.

3 Production embodied carbon reflects the component of eCO2e associated with material production. While embodied carbon from production differs with factors such as prevailing energy sources, a simplified calculation here uses coefficients derived from global averages.

4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

5 Embodied water reflects the amount of tap water used in production of the material. While embodied water depends on specific production processes, a simplified calculation here uses coefficients derived from global averages.

Specification

1 GENERAL

1.1 SCOPE

This specification is to be read in conjunction with the Drawings and Bill of Quantities (BOQ). In the event of any discrepancy, the Specification and Bill of Quantities takes precedence over Drawings.

1.2 LOCAL REGULATIONS AND STANDARDS

Work shall comply with local regulations and local construction standards. Discrepancies between designs and with regulations or standards shall be addressed before work commences.

Structural designs shall be reviewed by a local Engineer to confirm adequacy in relation to local regulations, construction practices, and site conditions.

2 SITE

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SET-OUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

3 MATERIALS

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%.

A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free from oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 CEMENT

Ordinary portland cement must be used before the expiry date. Cement should be kept dry and stored at least 15cm above ground to avoid ground moisture. Expired or damaged cement may be indicated by excessive grittiness or lumps of set cement.

3.5 CONCRETE

3.5.1 *Formwork*

Formwork for in-situ poured shall be straight and true with adequate bracing to avoid deformation under the load of poured concrete. Formwork may be constructed of plywood, sawn timber or steel according to local standards and concrete finish (appearance) requirements. Ensure adequate chamfer – around 2cm – at external corners.

Ensure that formwork construction enables removal without damage to concrete. To minimise adhesion of concrete, wet surfaces of formwork that will come in contact with concrete and apply a wash of limewash, linseed oil or soapy water.

3.5.2 *Concrete mix*

Concrete shall comprise Portland cement, sand, aggregate, and water as specified herein.

For general structural purposes, a cement:sand:aggregate mix of 1:2:4 (with a minimum cement dosage of 320kg/m3) shall be used unless otherwise noted. For water retaining structures (reservoir walls and bases) a cement:sand:aggregate mix of 1:1.5:3 shall be used unless otherwise noted (1:2:4 is not waterproof) (with a minimum cement dosage of 380kg/m3). For mass concrete applications a cement:sand:aggregate mix of 1:3:6 shall be used unless otherwise noted.

For hand mixing, additional cement should be added in accordance with the table below.

Mix	Cement		Sand (m3)	Aggregate (m3)
	Machine mix (kg)	Hand mix (kg)		
1 : 1.5 : 3	370	380	0.42	0.84
1 : 2 : 4	290	300	0.45	0.90
1 : 3 : 6	190	200	0.46	0.92

Source: Khanna, P.N. (1982) Indian Civil Engineers Handbook, 8th ed. Engineers Publishers: New Delhi

Ensure that concrete mixtures are not over watered – a bucket slump test of mixed concrete should yield less than ¼ reduction in the slump height.

3.5.3 *Concrete pouring*

Each concrete element – e.g., each concrete slab, each section of footing or parapet - shall be cast in a single pour.

3.5.4 *Concrete rodding and curing*

Cast concrete should be immediately covered with fabric, plastic sheet, straw, cement bags, sacking or leaves to keep the concrete moist and cool during the curing period. All concrete should be well vibrated or rodded to remove air voids. The concrete shall be cured with frequent watering at least twice daily for at least 10 days before use.

3.5.5 *Concrete finishing*

Provide a minimum 1% fall to water collection and drainage surfaces. Provide a rough, non-slip finish to trafficable concrete surfaces, e.g., by brushing the surface during curing.

C2 Drainage Channel **Precast Concrete**

Context

Drainage network design in camp settings should consider flood risk, drainage capacity, water retention, and surface erosion. Drainage networks should comprise primary, secondary and tertiary drains that will vary in dimensions (capacity) and construction type. A wide range of drain types are available (e.g., concrete, brick masonry, etc.). Selection of a drainage type should take into account drainage capacity requirements, local construction methods, cost, timing, local participation and other issues.

This design for a precast concrete V-shaped drain is drawn from the ICSG Site Improvement Catalogue (2021) published by IOM, UNHCR and WFP in relation to camps in Cox Bazaar district, Bangladesh. In this catalogue, the design is presented alongside concrete, brick masonry, and bamboo-based options. The concrete drain design is based on standard construction methods in Pakistan. The concrete drain design presented here is for rectangular precast panels 60cm long x 30cm wide x 7.5cm deep. Other drain dimensions may be achieved with the same design using different panel sizes. The weight on precast panels is a critical consideration in determining the panel and drain size.

The precast concrete design presented herein is simple to implement. The principle limiting factor is availability of precast panels, which may be purchased or produced locally. Local production of precast panels may be achieved using standard formwork and labour from local communities, with technical support and supervision. Concrete should be mixed, poured and cured in accordance with the material specifications to ensure structural integrity and avoid cracking. An area of sufficient size should be available for precast panel production to allow for curing and storage of panels.

PROS	CONS
Rapid construction time	Limited flexibility regarding dimensions and drainage capacity
Fabrication and assembly of precast concrete panels can enable local community involvement	Movement of precast panels may undermine functionality and durability of drain
High reuse potential of precast panels	
Relatively moderate initial construction cost	

Affordability
(considering initial and operating costs)

Performance
(considering capacity and durability)

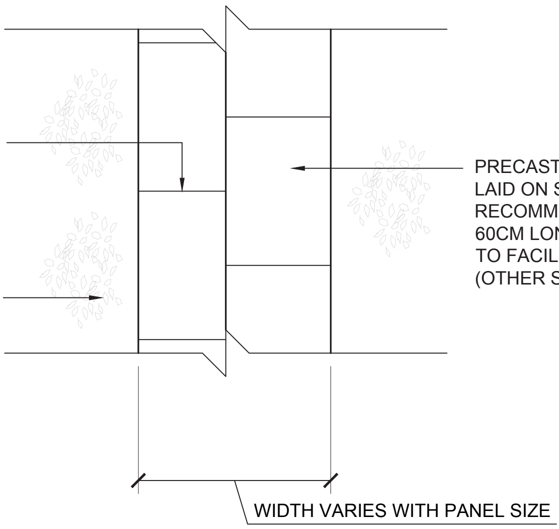
Environmental sustainability
(considering e-CO2-eq and reuse potential)

(Relatve affordability, performance and environmental impact will vary with prevailing conditions)

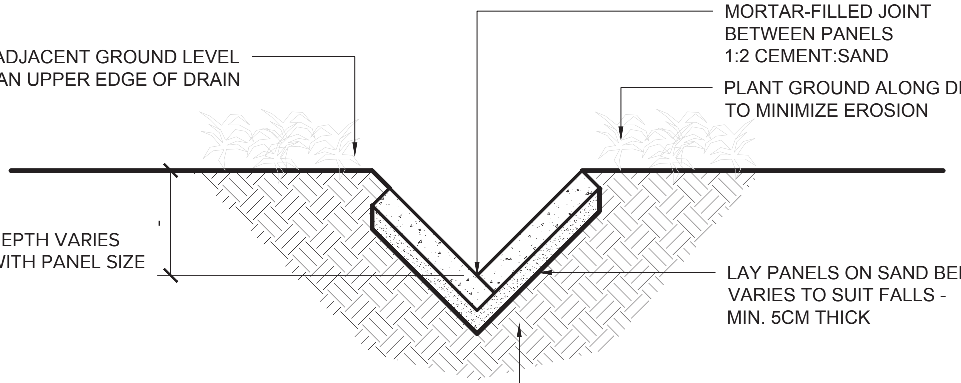
Bill of Quantities

Ref	Item description	Unit	Quantity
	(per 1m length of drain)		
1	Pre-cast concrete panels, 60cm L x 30cm W x 7.5cm T	pce	3.6
	or	m3	0.049
2	Sand (for base and panel joints)	m3	0.04

PLAN



SECTION



DWG NO.	TITLE	DRAWN BY	UNITS
C1-1	**Drainage channel - Precast concrete** Plan & Section	**AU**	**CM**
		CHECKED BY **RN**	SHEET **1 of 1**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:20**	DATE **31.08.2023**

UNHCR
The UN Refugee Agency
Technical Support Section
Community Infrastructure Catalogue

Environmental Impacts (per meter)

Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Concrete	107	25,68	11,24	36,92	395,9
Sand	90	0,63	7,11	7,74	162
Total	197	26,31	18,35	44,66	557,9

Material weight (kg) [1]

Embodied carbon (kgCO2e) [2]

Embodied water (L) [5]

1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

2 Embodied carbon dioxide equivalent - expressed as kg.eCO2e - reflects the amount of various greenhouse gases associated with the production and use of the material. The metric converts other gases to the equivalent amount of CO2 with the same global warming potential.

3 Production embodied carbon reflects the component of eCO2e associated with material production. While embodied carbon from production differs with factors such as prevailing energy sources, a simplified calculation here uses coefficients derived from global averages.

4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

5 Embodied water reflects the amount of tap water used in production of the material. While embodied water depends on specific production processes, a simplified calculation here uses coefficients derived from global averages.

Specification

1 **GENERAL**

1.1 SCOPE

This specification is to be read in conjunction with the Drawings and Bill of Quantities (BOQ). In the event of any discrepancy, the Specification and Bill of Quantities takes precedence over Drawings.

1.2 LOCAL REGULATIONS AND STANDARDS

Work shall comply with local regulations and local construction standards. Discrepancies between designs and with regulations or standards shall be addressed before work commences.

Structural designs shall be reviewed by a local Engineer to confirm adequacy in relation to local regulations, construction practices, and site conditions.

2 **SITE**

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SET-OUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

3 **MATERIALS**

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%.

A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free from oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 CEMENT

Ordinary portland cement must be used before the expiry date. Cement should be kept dry and stored at least 15cm above ground to avoid ground moisture. Expired or damaged cement may be indicated by excessive grittiness or lumps of set cement.

3.5 PRECAST CONCRETE

Precast concrete shall comprise Portland cement, sand, aggregate, and water as specified herein. Precast concrete units shall be cast using formwork that consistently provides uniform dimensions. For general structural purposes, a cement:sand:aggregate mix of 1:2:4 (with a minimum cement dosage of 320kg/m3) shall be used unless otherwise noted.

Image courtesy Md. Sultan Mahmud, UNHCR

Image courtesy Md. Sultan Mahmud, UNHCR

C3 Drainage Channel **Brick Masonry**

Context

Drainage network design in camp settings should consider flood risk, drainage capacity, water retention, and surface erosion. Drainage networks should comprise primary, secondary and tertiary drains that will vary in dimensions (capacity) and construction type. A wide range of drain types are available (e.g., concrete, brick masonry, etc.). Selection of a drainage type should take into account drainage capacity requirements, local construction methods, cost, timing, local participation and other issues.

This design for a brick masonry drain is drawn from the UN Habitat *Guidelines for Community Infrastructure* (2012). In this catalogue, the design is presented alongside precast concrete, concrete, and bamboo-based options. The brick masonry drain design is based on standard construction methods in Pakistan. The concrete drain design presented here is for a drain 45cm wide x 45cm deep (depth varies to suit falls). The design enables adjustment of the drain up to 1m wide (requiring associated adjustments to the drawings and Bill of Quantities herein) to suit local drainage requirements.

The brick masonry design presented herein may be achieved in most situations where brick construction is common, suggesting the availability of the required skills and materials. Brick masonry and concrete construction will require engagement of specialist tradesmen. Attention should be given to supply chains for bricks, noting that the involvement of indentured and child labour in brick production has been identified in some countries.

Several matters are critical to ensuring the structural integrity and proper brick masonry construction. Local engineering expertise should be engaged to verify and modify the design to structural footings/ foundations to take into account local geological (soil) conditions and local construction norms. Concrete should be mixed, poured and cured in accordance with the material specifications to ensure structural integrity and avoid cracking. Fired bricks should be checked to ensure they meet strength and quality requirements described in the specification.

PROS	CONS
Strength and durability of brick masonry reduces maintenance requirements Flexibility regarding size and shape enables adaptation to site and capacity requirements Common availability of materials and skills for construction and maintenance	Relatively high initial construction costs Relatively slow construction time Reinforced concrete construction requires skilled labour, limiting potential community involvment

Affordability
(considering initial and operating costs)

Performance
(considering capacity and durability)

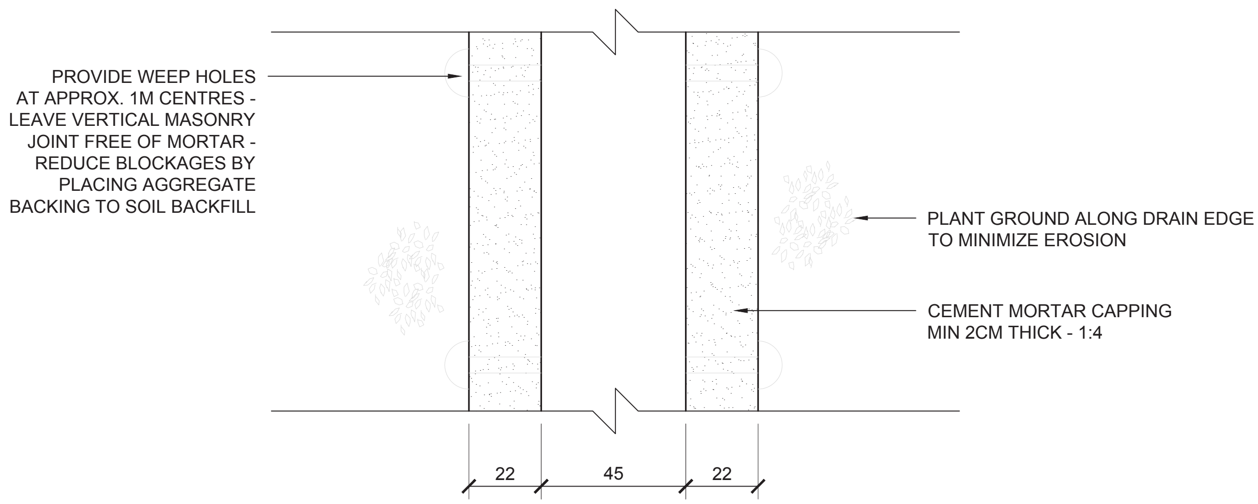
Environmental sustainability
(considering e-CO2-eq and reuse potential)

(Relatve affordability, performance and environmental impact will vary with prevailing conditions)

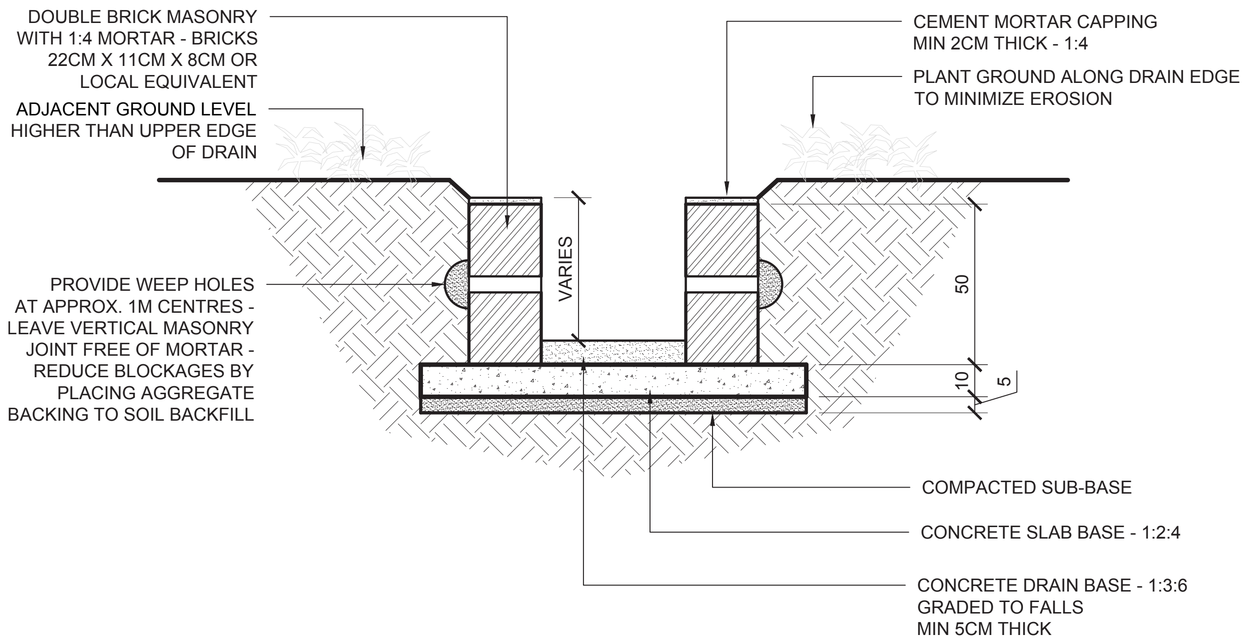
Bill of Quantities

Ref	Item description	Unit	Quantity
	(per 1m length of drain)		
1	Fired clay bricks - 22cm x 11cm x 8cm or similar	pce	110
	or	*m3*	*0.22*
2	Mortar - 1:2 (cement:sand) for masonry and capping	m3	0.04
3	Concrete for graded drain base - 1:3:6	m3	0.035
4	Concrete for slab base - 1:2:4	m3	0.1
5	Gravel for compacted sub-base and weep-hole backing	m3	0.05

PLAN



SECTION



DWG NO.	TITLE	DRAWN BY	UNITS
C2-1	**Drainage channel - Brick + concrete** Plan & Section	**AU**	**CM**
		CHECKED BY **RN**	SHEET **1 of 1**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:20**	DATE **31.08.2023**

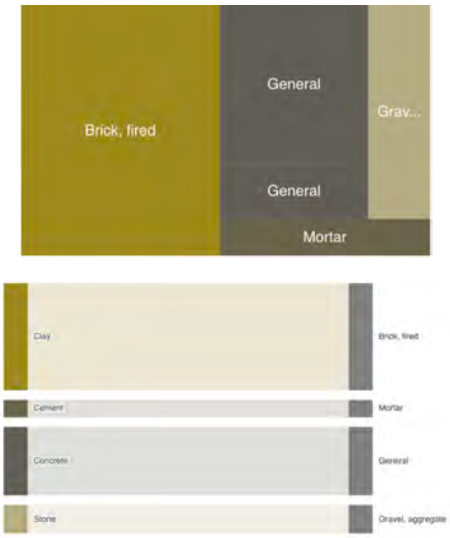
UNHCR The UN Refugee Agency
Technical Support Section
Community Infrastructure Catalogue

Environmental Impacts (per meter)

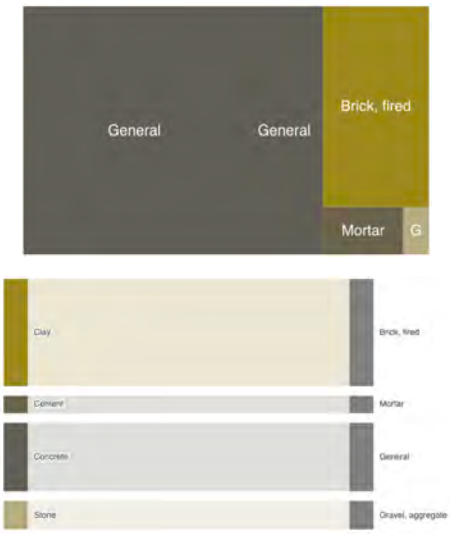
Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Clay	422,4	135,17	33,37	168,54	760,32
Cement	66	23,1	6,93	30,03	244,2
Concrete	270	560,79	28,35	589,14	17,28
Stone	112	0,78	8,85	9,63	212,8
Total	870,4	719,84	77,5	797,34	1234,6

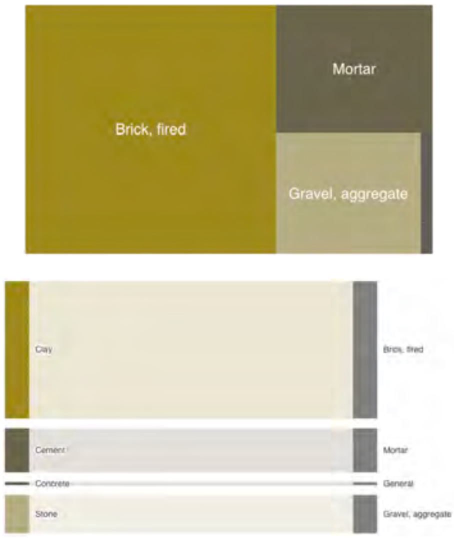
Material weight (kg) [1]



Embodied carbon (kgCO2e) [2]



Embodied water (L) [5]



1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

2 Embodied carbon dioxide equivalent - expressed as kg.eCO2e - reflects the amount of various greenhouse gases associated with the production and use of the material. The metric converts other gases to the equivalent amount of CO2 with the same global warming potential.

3 Production embodied carbon reflects the component of eCO2e associated with material production. While embodied carbon from production differs with factors such as prevailing energy sources, a simplified calculation here uses coefficients derived from global averages.

4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

5 Embodied water reflects the amount of tap water used in production of the material. While embodied water depends on specific production processes, a simplified calculation here uses coefficients derived from global averages.

Specification

1 GENERAL

1.1 SCOPE

This specification is to be read in conjunction with the Drawings and Bill of Quantities (BOQ). In the event of any discrepancy, the Specification and Bill of Quantities takes precedence over Drawings.

1.2 LOCAL REGULATIONS AND STANDARDS

Work shall comply with local regulations and local construction standards. Discrepancies between designs and with regulations or standards shall be addressed before work commences.

Structural designs shall be reviewed by a local Engineer to confirm adequacy in relation to local regulations, construction practices, and site conditions.

2 SITE

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SET-OUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

3 MATERIALS

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%.

A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free from oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 CEMENT

Ordinary portland cement must be used before the expiry date. Cement should be kept dry and stored at least 15cm above ground to avoid ground moisture. Expired or damaged cement may be indicated by excessive grittiness or lumps of set cement.

3.5 CEMENT MORTAR

Cement mortar shall comprise Portland cement, sand and water as specified herein. A cement:sand ratio of 1:6 shall be used unless otherwise noted. Cement mortar in brick masonry and stone masonry shall be applied to a minimum thickness of 6-10mm unless otherwise noted. After laying, mortar within brick and stone masonry shall be cured (kept moist) for a minimum of 10 days.

3.6 CONCRETE

3.6.1 *Formwork*

Formwork for in-situ poured shall be straight and true with adequate bracing to avoid deformation under the load of poured concrete. Formwork may be constructed of plywood, sawn timber or steel according to local standards and concrete finish (appearance) requirements. Ensure adequate chamfer – around 2cm – at external corners.

Ensure that formwork construction enables removal without damage to concrete. To minimise adhesion of concrete, wet surfaces of formwork that will come in contact with concrete and apply a wash of limewash, linseed oil or soapy water.

3.6.2 *Concrete mix*

Concrete shall comprise Portland cement, sand, aggregate, and water as specified herein.

For general structural purposes, a cement:sand:aggregate mix of 1:2:4 (with a minimum cement dosage of 320kg/m3) shall be used unless otherwise noted. For water retaining structures (reservoir walls and bases) a cement:sand:aggregate mix of 1:1.5:3 shall be used unless otherwise noted (1:2:4 is not waterproof) (with a minimum cement dosage of 380kg/m3). For mass concrete applications a cement:sand:aggregate mix of 1:3:6 shall be used unless otherwise noted.

For hand mixing, additional cement should be added in accordance with the table below.

Mix	Cement		Sand	Aggregate
	Machine mix (kg)	Hand mix (kg)	(m3)	(m3)
1 : 1.5 : 3	370	380	0.42	0.84
1 : 2 : 4	290	300	0.45	0.90
1 : 3 : 6	190	200	0.46	0.92

Source: Khanna, P.N. (1982) Indian Civil Engineers Handbook, 8th ed. Engineers Publishers: New Delhi

Ensure that concrete mixtures are not over watered – a bucket slump test of mixed concrete should yield less than ¼ reduction in the slump height.

3.6.3 *Concrete pouring*

Each concrete element – e.g., each concrete slab, each section of footing or parapet - shall be cast in a single pour.

3.6.4 *Concrete rodding and curing*

Cast concrete should be immediately covered with fabric, plastic sheet, straw, cement bags, sacking or leaves to keep the concrete moist and cool during the curing period. All concrete should be well vibrated or rodded to remove air voids. The concrete shall be cured with frequent watering at least twice daily for at least 10 days before use.

3.6.5 *Concrete finishing*

Provide a minimum 1% fall to water collection and drainage surfaces. Provide a rough, non-slip finish to trafficable concrete surfaces, e.g., by brushing the surface during curing.

3.7 BRICK MASONRY

Bricks should be made from clay free of stone or other organic or inorganic impurities. Bricks shall be of a standard, consistent size that conforms with local standards, and shall have plane rectangular faces and right-angled edges. Bricks should be of sufficient strength, with a minimum crushing strength of 125kg/cm2, or to not break when dropped from a height of 1m. Bricks should be fired sufficiently such that, when immersed in water, a brick shall not absorb water more that 20% of its dry weight.

Bricks shall be soaked in water for minimum 15 minutes prior to laying in cement mortar.

Bricks shall be laid in horizontal courses, with brickwork laid in a single day not exceeding 1m height to avoid excessive pressure on newly laid lower courses.

Cement mortar joints should be 6-10mm. A cement : sand mix of 1:6 should be used for masonry mortar unless otherwise noted. Brickwork shall be covered with plastic sheeting or textile and kept wet (cured) for minimum 10 days after laying.


Image courtesy Md. Sultan Mahmud, UNHCR

C4 Drainage Channel **Bamboo**

Context

Drainage network design in camp settings should consider flood risk, drainage capacity, water retention, and surface erosion. Drainage networks should comprise primary, secondary and tertiary drains that will vary in dimensions (capacity) and construction type. A wide range of drain types are available (e.g., concrete, brick masonry, etc.). Selection of a drainage type should take into account drainage capacity requirements, local construction methods, cost, timing, local participation and other issues.

This design for a drain with bamboo matting walls bamboo pole structure is drawn from the ISCG Site Improvement Catalogue (2021) published by IOM, UNHCR and WFP in relation to camps in Cox Bazaar district, Bangladesh. In this catalogue, the design is presented alongside poured concrete, precast concrete, and brick masonry.

The drain design is based on local practices and materials in Bangladesh. The availability of materials specified, particularly bamboo basha bera matting, should be confirmed when considering implementation of the design. The design is suitable for tertiary/household drains. The design is presented here with optional inclusion of plastic sheeting or cement mortar at the base, improving durability and water flow though reducing the permeability of the drain base.

PROS	CONS
Rapid construction Relatively low construction cost Use of locally-available materials (in bamboo-growing zones) Basic skill requirements can facilitate community involvement	Bamboo materials available in tropical zones only Relatively low durability requiring regular maintenance

(Relatve affordability, performance and environmental impact will vary with prevailing conditions)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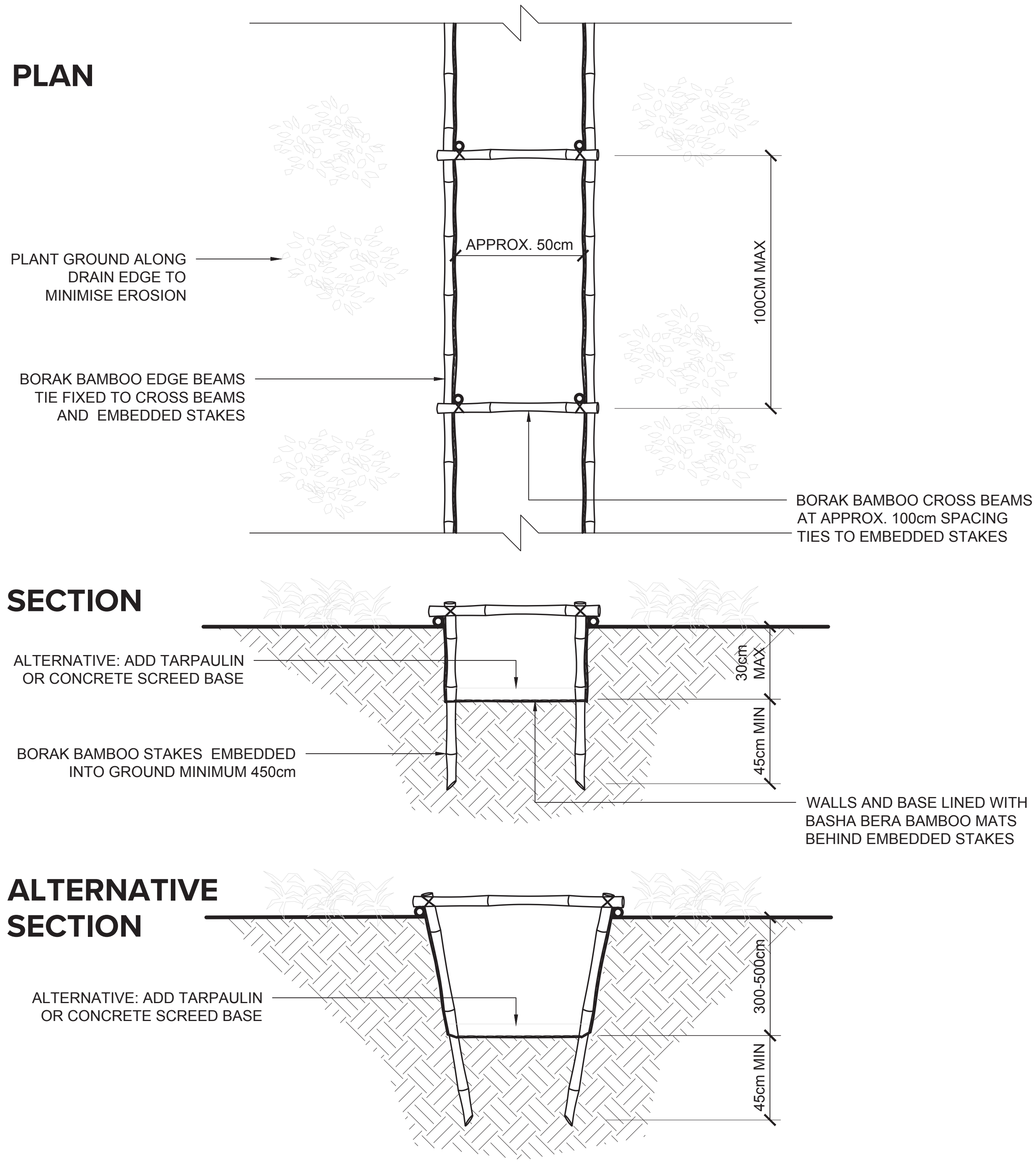

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C3-1	**Drainage channel - Bamboo** Plan & Section	CHECKED BY **RN**	SHEET **1 of 1**	
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:20**	DATE **31.08.2023**	**Technical Support Section** Community Infrastructure Catalogue

Bill of Quantities

Ref	Item description	Unit	Quantity
	(per 1m length of drain)		
1	Bamboo for stakes and cross beams - 4cm DIA (approx)	m	2.25
2	Bamboo for edge beams - 4cm DIA (approx)	m	2
3	Bamboo mats (Basha Bera)	m2	1.10
4	Natural fibre rope for tying bamboo	m	2
5	Tarpaulin base (otional)	m2	0.6
6	Cement screed base - 1:3 (optional)	m3	0.03

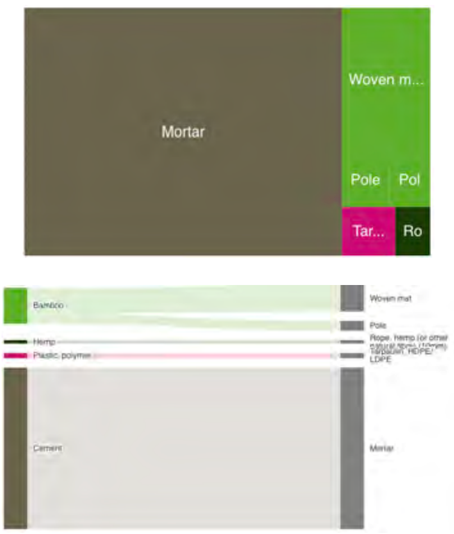
Environmental Impacts (per meter)

Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Bamboo	13,74	3,57	1,44	5,01	352,53
Hemp	0,11	0,48	0,01	0,49	2,09
Plastic, polymer	0,11	0,73	0,01	0,74	19,61
Cement	49,5	17,33	5,2	22,52	183,15
Total	63,46	22,1	6,66	28,77	557,38

Material weight (kg) [1]

Embodied carbon (kgCO2e) [2]



Embodied water (L) [5]

1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

2 Embodied carbon dioxide equivalent - expressed as kg.eCO2e - reflects the amount of various greenhouse gases associated with the production and use of the material. The metric converts other gases to the equivalent amount of CO2 with the same global warming potential.

3 Production embodied carbon reflects the component of eCO2e associated with material production. While embodied carbon from production differs with factors such as prevailing energy sources, a simplified calculation here uses coefficients derived from global averages.

4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

5 Embodied water reflects the amount of tap water used in production of the material. While embodied water depends on specific production processes, a simplified calculation here uses coefficients derived from global averages.

Specification

1 **GENERAL**

1.1 SCOPE

This specification is to be read in conjunction with the Drawings and Bill of Quantities (BOQ). In the event of any discrepancy, the Specification and Bill of Quantities takes precedence over Drawings.

1.2 LOCAL REGULATIONS AND STANDARDS

Work shall comply with local regulations and local construction standards. Discrepancies between designs and with regulations or standards shall be addressed before work commences.

Structural designs shall be reviewed by a local Engineer to confirm adequacy in relation to local regulations, construction practices, and site conditions.

2 **SITE**

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SET-OUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

3 **MATERIALS**

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%.

A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free from from oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 CEMENT

Ordinary portland cement must be used before the expiry date. Cement should be kept dry and stored at least 15cm above ground to avoid ground moisture. Expired or damaged cement may be indicated by excessive grittiness or lumps of set cement.

3.5 CEMENT PLASTER

Cement plaster shall comprise ordinary portland cement, sand and water as specified herein. A cement:sand ratio of 1:4 shall be used unless otherwise noted. Cement plasters shall be applied to a minimum thickness of 1cm unless otherwise noted. After application, plastered surfaces shall be cured (kept moist) for a minimum of 7 days.

3.6 CEMENT MORTAR

Cement mortar shall comprise Portland cement, sand and water as specified herein. A cement:sand ratio of 1:6 shall be used unless otherwise noted. Cement mortar in brick masonry and stone masonry shall be applied to a minimum thickness of 6-10mm unless otherwise noted. After laying, mortar within brick and stone masonry shall be cured (kept moist) for a minimum of 10 days.

3.7 BAMBOO

Bamboo for structural use should be 3-5 years old, harvested in the dry season and should be cut above the first node. Select fresh and light greyish green coloured bamboo that is almost fully grown.

Bamboo should generally be not less than 40mm in diameter. Bamboo should be cut using a sharp saw to avoid damage. Ensure there are no cracks in bamboo poles.

Image courtesy Md. Sultan Mahmud, UNHCR

D1 Road **Concrete**

Context

Road design in camp settings should take into account local geological (soil) conditions, anticipated loadings (e.g., passenger vehicles, loaded trucks), local construction methods, timing and cost. Road designs will vary in materials and dimensions, including the thickness of various surface and sub-surface layers.

This design for a concrete road is drawn from the UN Habitat Guidelines for Community Infrastructure (2012). In this catalogue, the design is presented alongside brick and asphalt options. The concrete drain design is based on standard construction methods in Pakistan. The concrete road design is presented herein with adjacent concrete drainage channels, which may be adjusted or omitted to suit local requirements. The design is for a road 2.4m wide, which may be adjusted (requiring associated adjustments to the drawings and Bill of Quantities herein) to suit local requirements.

The non-reinforced concrete design presented herein may be achieved in most situations where concrete construction is common, suggesting the availability of the required skills and materials. In general, concrete construction will require engagement of a construction contractor/company. However, concrete construction may also be achieved by assisted communities with consistent technical support and supervision.

Several matters are critical to ensuring the structural integrity and proper functioning of the concrete drain. Local engineering expertise should be engaged to verify and modify the design to structural footings/foundations to take into account local geological (soil) conditions and local construction norms. Concrete should be mixed, poured and cured in accordance with the material specifications to ensure structural integrity and avoid cracking. Sufficient grading (angle) of the finished road surface should be ensured for surface drainage.

PROS	CONS
High strength of concrete supports heavy loads High durability limits maintenance requirements Flexibility of dimensions enables adaptability to local terrain and capacity requirements	Relatively high initial construction costs

(Relatve affordability, performance and environmental impact will vary with prevailing conditions)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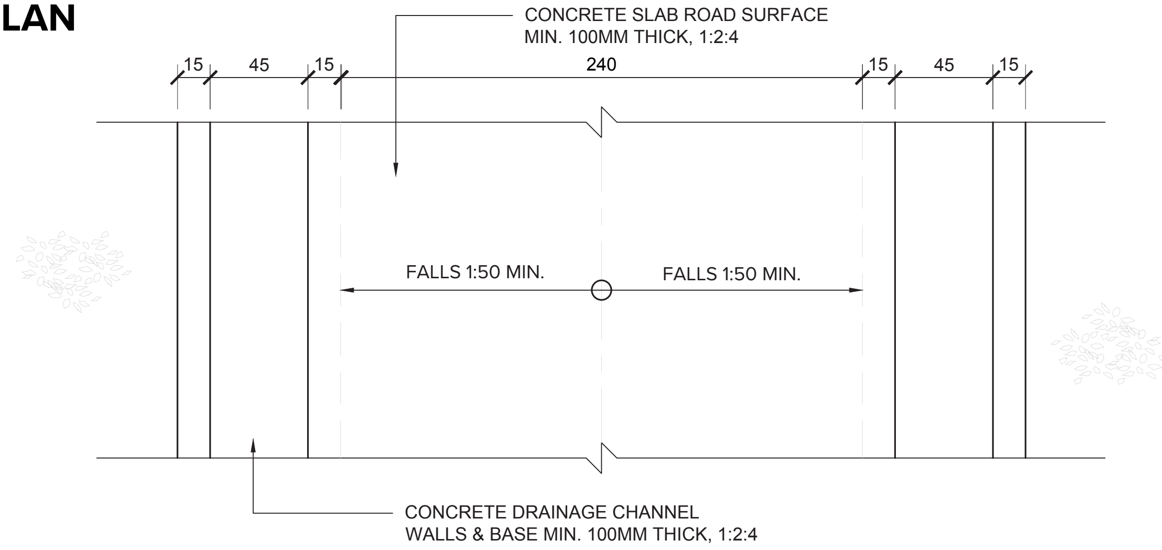
PLAN



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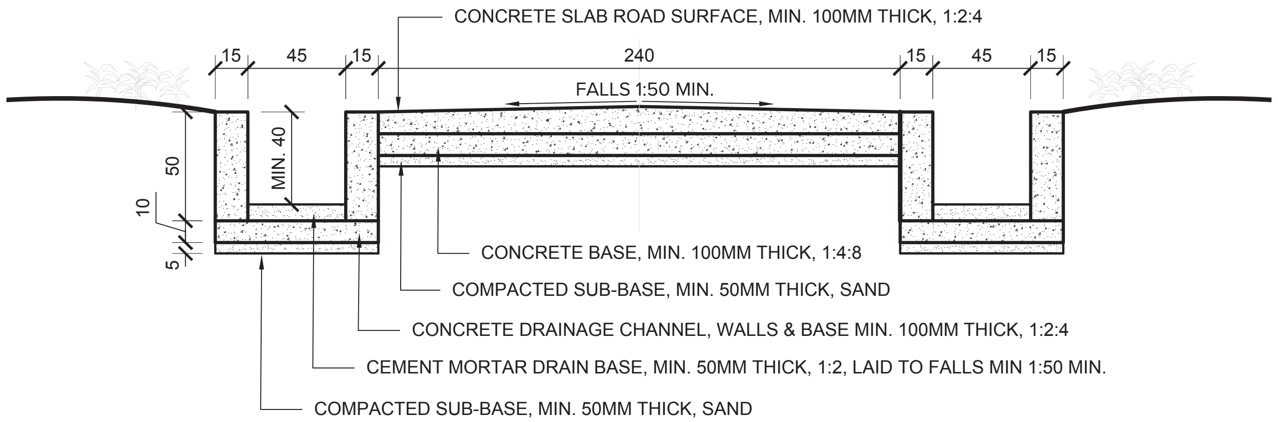

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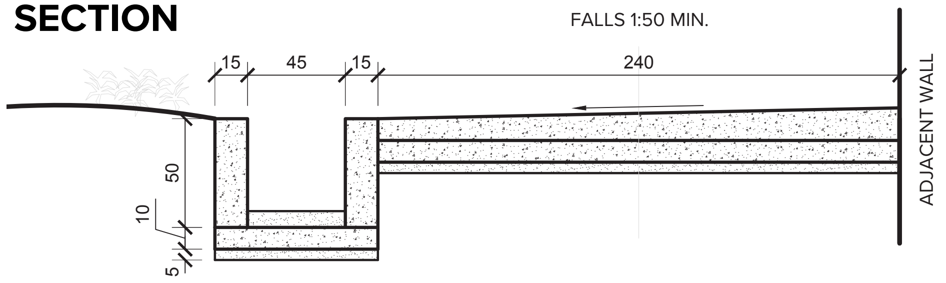

DWG NO.	TITLE	DRAWN BY	UNITS
D1-1	**Road - Concrete** Plan & Section	**AU**	**CM**
		CHECKED BY **RN**	SHEET **1 of 1**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:30**	DATE **31.08.2023**

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Community Infrastructure Catalogue

Bill of Quantities

Ref	Item description	Unit	Quantity
	(per 1m length of road)		
1	Concrete for road surface - 1:2:4	m3	0.30
2	Concrete for road base - 1:4:8	m3	0.24
3	Sand for road compacted sub-base	m3	0.12
4	Excavation for road	m3	0.60
5	Concrete for drainage channel 1 - 1:2:4	m3	0.023
6	Cement mortar for drainage channel 1 - 1:2	m3	0.04
7	Sand for drainage channel 1 sub-base	m3	0.04
8	Excavation for drainage channel 1	m3	0.5
9	Concrete for drainage channel 2 - 1:2:4	m3	0.023
10	Cement mortar for drainage channel 2 - 1:2	m3	0.04
11	Sand for drainage channel 2 sub-base	m3	0.04
12	Excavation for drainage channel 2	m3	0.5

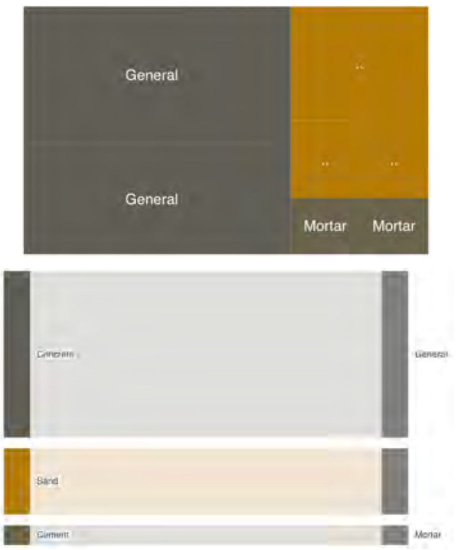
D1 Road **Concrete**

Environmental Impacts (per meter)

Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Concrete	1126	2338,7	118,23	2456,93	72,06
Sand	448	3,14	35,39	38,53	806,4
Cement	132	46,2	13,86	60,06	488,4
Total	1706	2388,04	167,48	2555,52	1366,86

Material weight (kg) [1]



Embodied carbon (kgCO2e) [2]

Embodied water (L) [5]

1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

2 Embodied carbon dioxide equivalent - expressed as kg.eCO2e - reflects the amount of various greenhouse gases associated with the production and use of the material. The metric converts other gases to the equivalent amount of CO2 with the same global warming potential.

3 Production embodied carbon reflects the component of eCO2e associated with material production. While embodied carbon from production differs with factors such as prevailing energy sources, a simplified calculation here uses coefficients derived from global averages.

4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

5 Embodied water reflects the amount of tap water used in production of the material. While embodied water depends on specific production processes, a simplified calculation here uses coefficients derived from global averages.

Specification

1 GENERAL

1.1 SCOPE

This specification is to be read in conjunction with the Drawings and Bill of Quantities (BOQ). In the event of any discrepancy, the Specification and Bill of Quantities takes precedence over Drawings.

1.2 LOCAL REGULATIONS AND STANDARDS

Work shall comply with local regulations and local construction standards. Discrepancies between designs and with regulations or standards shall be addressed before work commences.

Structural designs shall be reviewed by a local Engineer to confirm adequacy in relation to local regulations, construction practices, and site conditions.

2 SITE

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SET-OUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

3 MATERIALS

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%. A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free from oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 CEMENT

Ordinary portland cement must be used before the expiry date. Cement should be kept dry and stored at least 15cm above ground to avoid ground moisture. Expired or damaged cement may be indicated by excessive grittiness or lumps of set cement.

3.5 CONCRETE

3.5.1 *Formwork*

Formwork for in-situ poured shall be straight and true with adequate bracing to avoid deformation under the load of poured concrete. Formwork may be constructed of plywood, sawn timber or steel according to local standards and concrete finish (appearance) requirements. Ensure adequate chamfer – around 2cm – at external corners.

Ensure that formwork construction enables removal without damage to concrete. To minimise adhesion of concrete, wet surfaces of formwork that will come in contact with concrete and apply a wash of limewash, linseed oil or soapy water.

3.5.2 *Concrete mix*

Concrete shall comprise Portland cement, sand, aggregate, and water as specified herein.

For general structural purposes, a cement:sand:aggregate mix of 1:2:4 (with a minimum cement dosage of 320kg/m3) shall be used unless otherwise noted. For water retaining structures (reservoir walls and bases) a cement:sand:aggregate mix of 1:1.5:3 shall be used unless otherwise noted (1:2:4 is not waterproof) (with a minimum cement dosage of 380kg/m3). For mass concrete applications a cement:sand:aggregate mix of 1:3:6 shall be used unless otherwise noted.

For hand mixing, additional cement should be added in accordance with the table below.

Mix	Cement		Sand	Aggregate
	Machine mix (kg)	Hand mix (kg)	(m3)	(m3)
1 : 1.5 : 3	370	380	0.42	0.84
1 : 2 : 4	290	300	0.45	0.90
1 : 3 : 6	190	200	0.46	0.92

Source: Khanna, P.N. (1982) Indian Civil Engineers Handbook, 8th ed. Engineers Publishers: New Delhi

Ensure that concrete mixtures are not over watered – a bucket slump test of mixed concrete should yield less than ¼ reduction in the slump height.

3.5.3 *Concrete pouring*

Each concrete element – e.g., each concrete slab, each section of footing or parapet - shall be cast in a single pour.

3.5.4 *Concrete rodding and curing*

Cast concrete should be immediately covered with fabric, plastic sheet, straw, cement bags, sacking or leaves to keep the concrete moist and cool during the curing period. All concrete should be well vibrated or rodded to remove air voids. The concrete shall be cured with frequent watering at least twice daily for at least 10 days before use.

3.5.5 *Concrete finishing*

Provide a minimum 1% fall to water collection and drainage surfaces. Provide a rough, non-slip finish to trafficable concrete surfaces, e.g., by brushing the surface during curing.

3.6 STEEL REINFORCEMENT

Reinforcement bars shall be free from rust and of the correct type and size for concrete construction work (typically a characteristic yield stress of at least 210 N/mm^2). Steel reinforcement should be placed as per the designs (typically 7/8 of the slab or wall thickness) to ensure the bars function correctly in tension. All bars should have at least 12mm concrete cover.

Image courtesy Md. Sultan Mahmud, UNHCR

Image courtesy Md. Sultan Mahmud, UNHCR

D2 Road **Brick**

Context

Road design in camp settings should take into account local geological (soil) conditions, anticipated loadings (e.g., passenger vehicles, loaded trucks), local construction methods, timing and cost. Road designs will vary in materials and dimensions, including the thickness of various surface and sub-surface layers.

This design for a fired clay brick road is drawn from the UN Habitat Guidelines for Community Infrastructure (2012). In this catalogue, the design is presented alongside concrete and asphalt options. The fired brick design is based on standard construction methods in Pakistan. The brick road surface is suitable for low to moderate vehicle loads, for relatively flat gradients, and for areas with low rainfall. For heavy truck access, steeper gradients and areas of moderate or high rainfall, consider concrete or asphalt road surfaces.

The brick road design is presented herein with adjacent brick drainage channels, which may be adjusted or omitted to suit local requirements. The design is for a road 2.4m wide, which may be adjusted (requiring associated adjustments to the drawings and Bill of Quantities herein) to suit local requirements.

The fired brick surfaced road presented herein may be achieved in most situations where brick construction is common, suggesting the availability of the required skills and materials. In general, brick construction will require engagement of specialist tradesmen. However, assisted communities may be engaged in the construction with consistent technical support and supervision.

Several matters are critical to ensuring the structural integrity and proper functioning of the concrete drain. Local engineering expertise should be engaged to verify and modify the design to structural footings/ foundations to take into account local geological (soil) conditions and local construction norms. Fired bricks should be checked to ensure they meet strength and quality requirements described in the specification. Attention should be given to supply chains for bricks, noting that the involvement of indentured and child labour in brick production has been identified in some countries.

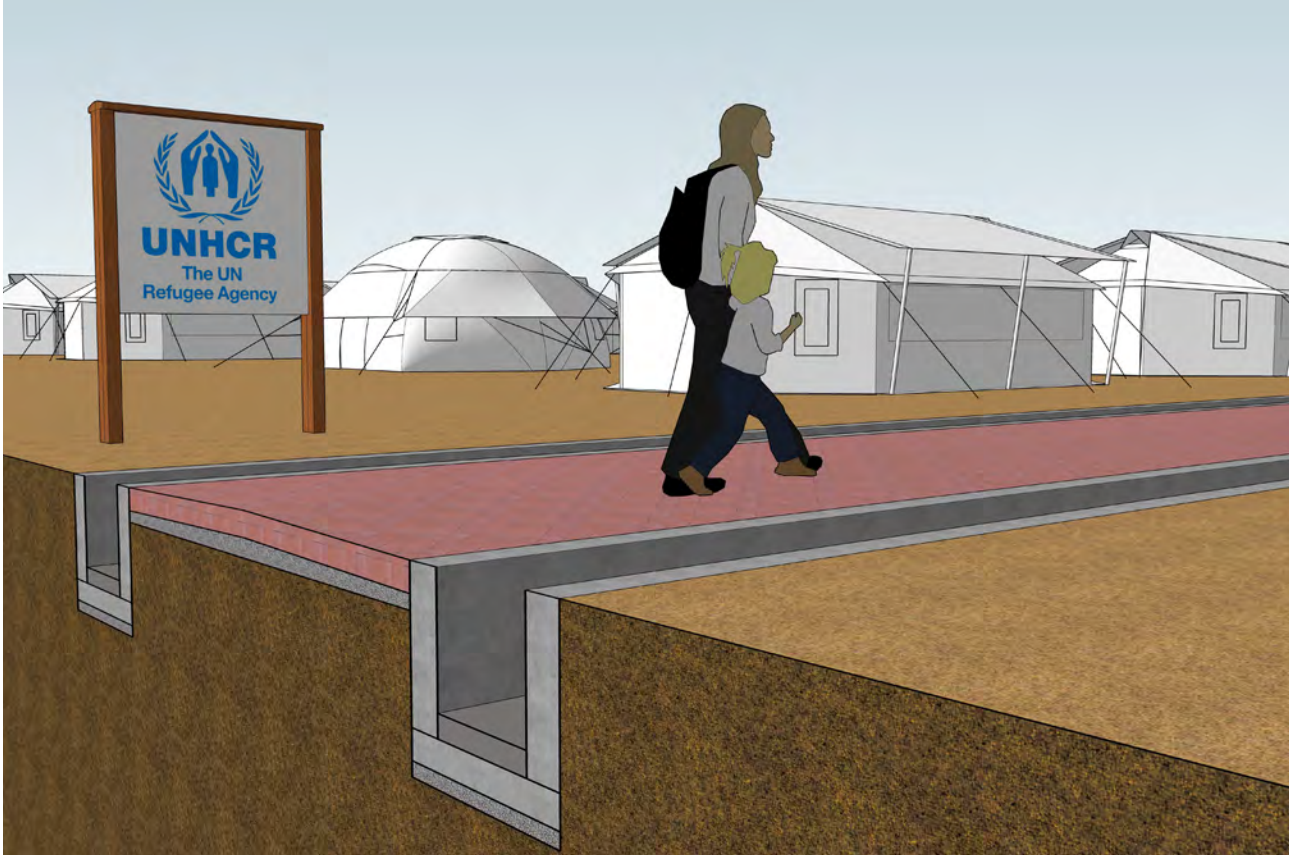
PROS	CONS
Relatively rapid construction time	Not suitable for steep terrain
Supports moderate vehicle loads	High maintenance requirements
Relatively low initial construction cost	Not suitable for heavy vehicle loads

Affordability
(considering initial and operating costs)

Performance
(considering capacity and durability)

Environmental sustainability
(considering e-CO2-eq and reuse potential)

(Relatve affordability, performance and environmental impact will vary with prevailing conditions)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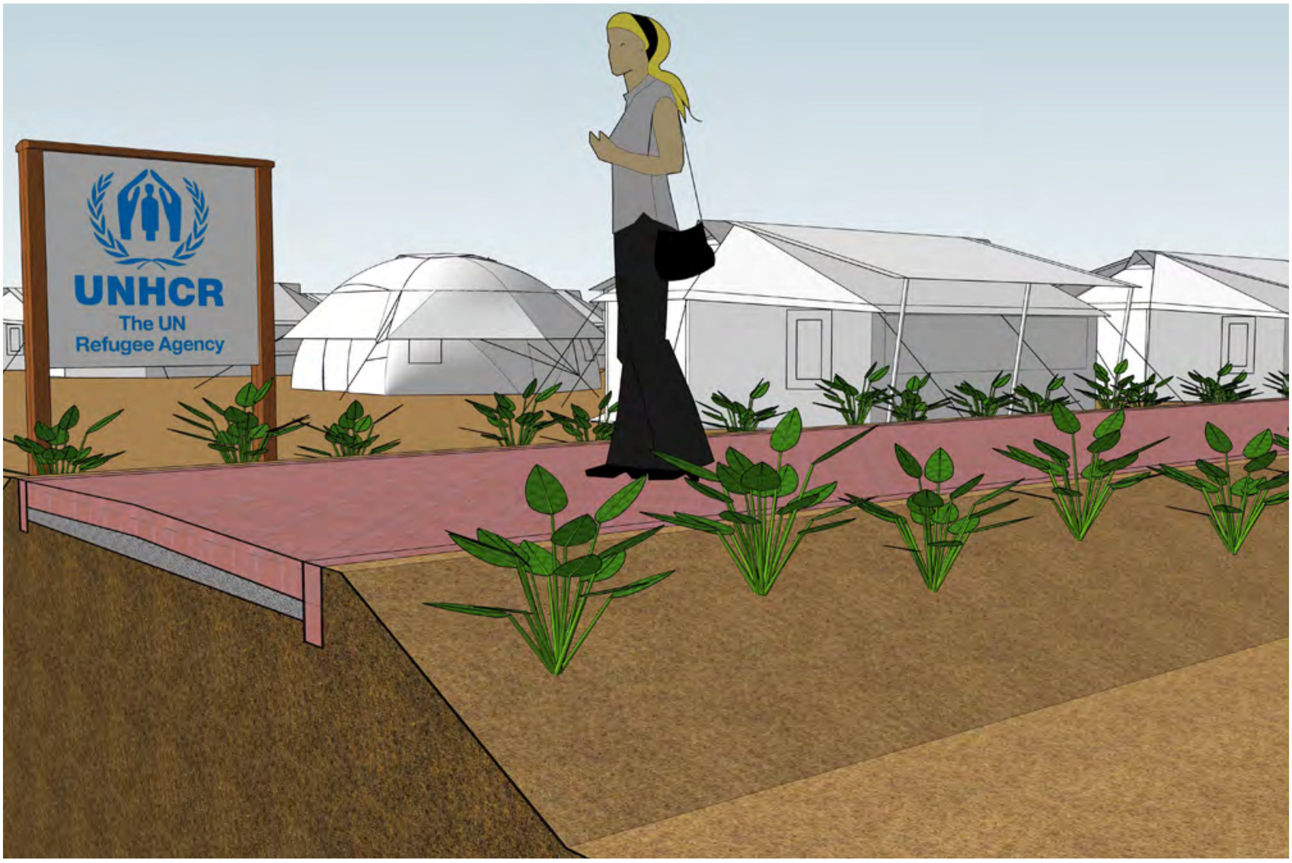
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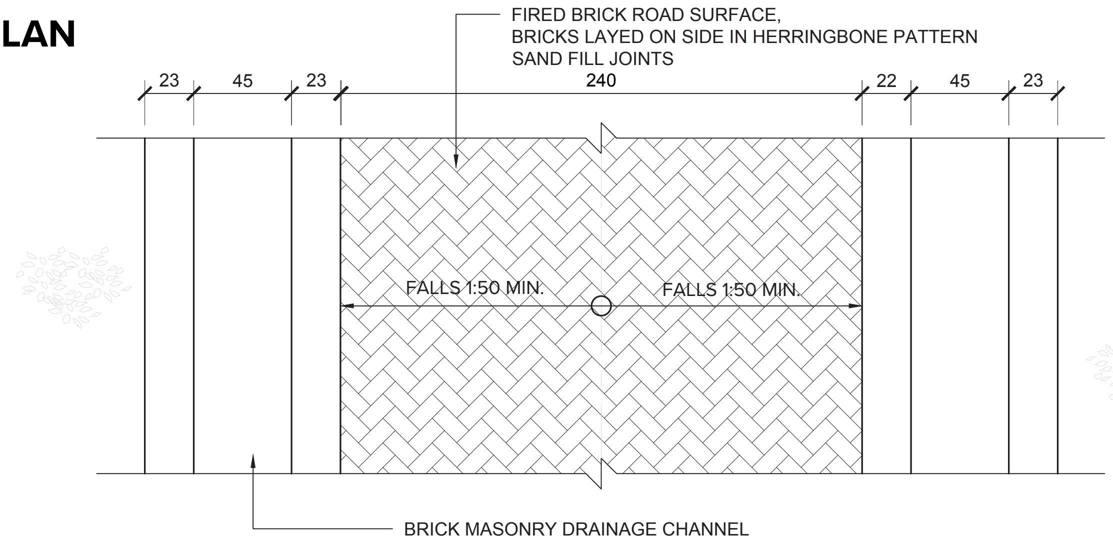
PLAN



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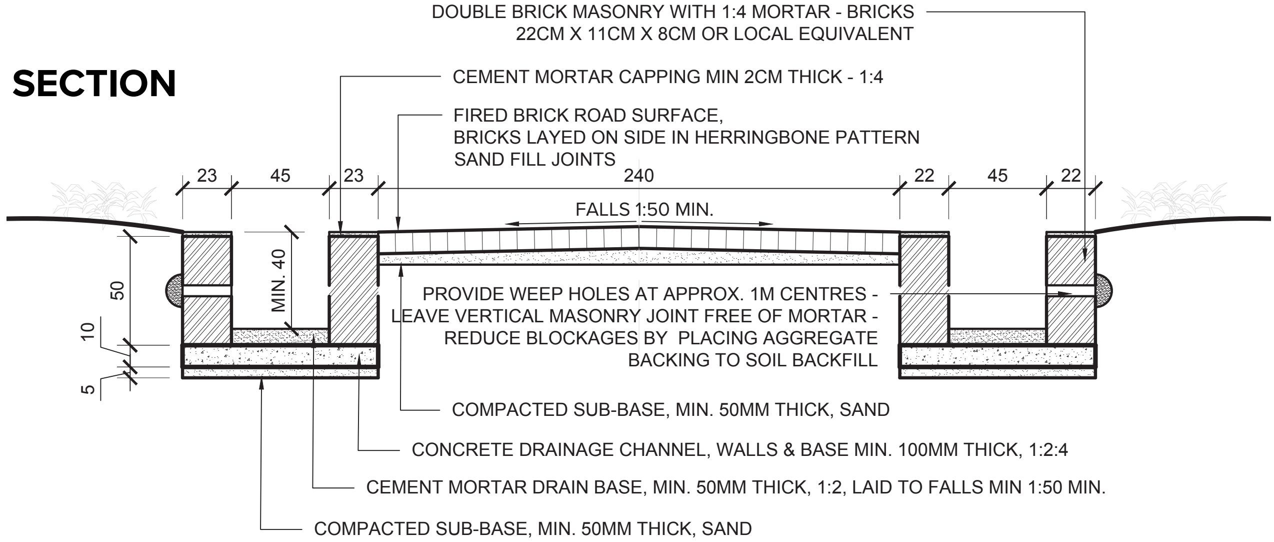

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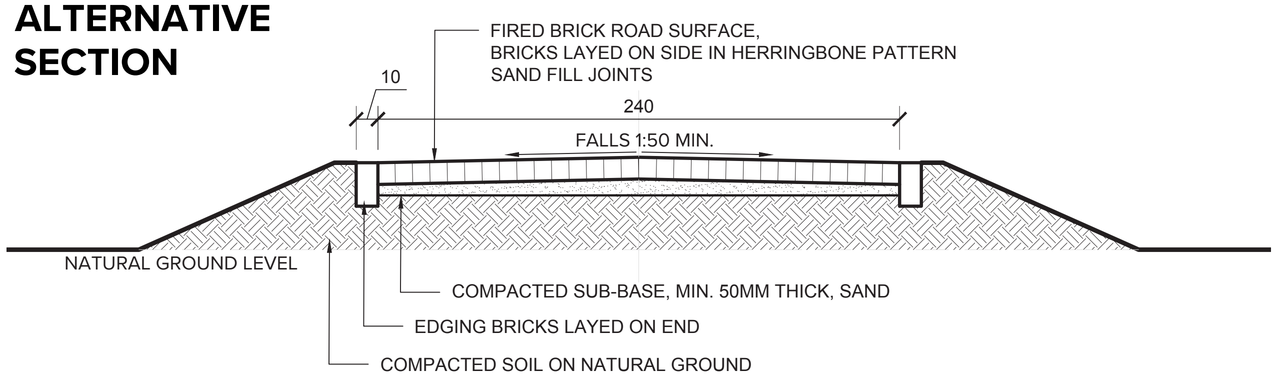


DWG NO.	TITLE	DRAWN BY	UNITS
D2-1	**Road - Brick** Plan & Section	**AU**	**CM**
		CHECKED BY **RN**	SHEET **1 of 1**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:30**	DATE **31.08.2023**

UNHCR The UN Refugee Agency
Technical Support Section
Community Infrastructure Catalogue

Bill of Quantities

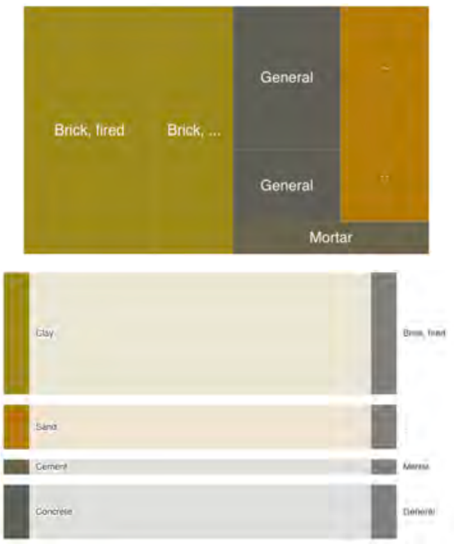
Ref	Item description	Unit	Quantity
	(per 1m length of road)		
	Option 1		
1.1	Brick for road surface - fired clay, 22 x 11 x 8cm or local equivalent	m3	0.26
	or	No	140
1.2	Sand for road compacted sub-base	m3	0.12
1.3	Brick for drainage channels - 22cm x 11cm x 8cm or local equivalent	pce	220
	or	*m3*	0.44
1.4	Mortar - 1:4 (cement:sand) for masonry and capping	m3	0.08
1.5	Concrete for graded drain base - 1:3:6	m3	0.07
1.6	Concrete for slab base - 1:2:4	m3	0.2
1.7	Sand for drain compacted sub-base	m3	0.10
1.8	Excavation	m3	0.7
	Option 2		
2.1	Brick for road surface - fired clay, 22 x 11 x 8cm or local equivalent	m3	0.30
	or	No	165
2.2	Sand for road compacted sub-base	m3	0.12
2.3	Excavation for road	m3	0.20

Environmental Impacts (per meter)

Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Clay	1344	430,08	106,18	536,26	2 419,2
Sand	492,8	3,45	38,93	42,38	887,04
Cement	165	57,75	17,33	75,07	610,5
Concrete	600	1246,2	63	1309,2	38,4
Total	2 601,8	1737,48	225,43	1962,91	3 955,14

Material weight (kg) [1]



Embodied carbon (kgCO2e) [2]

Embodied water (L) [5]

1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

2 Embodied carbon dioxide equivalent - expressed as kg.eCO2e - reflects the amount of various greenhouse gases associated with the production and use of the material. The metric converts other gases to the equivalent amount of CO2 with the same global warming potential.

3 Production embodied carbon reflects the component of eCO2e associated with material production. While embodied carbon from production differs with factors such as prevailing energy sources, a simplified calculation here uses coefficients derived from global averages.

4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

5 Embodied water reflects the amount of tap water used in production of the material. While embodied water depends on specific production processes, a simplified calculation here uses coefficients derived from global averages.

Specification

1 GENERAL

1.1 SCOPE

This specification is to be read in conjunction with the Drawings and Bill of Quantities (BOQ). In the event of any discrepancy, the Specification and Bill of Quantities takes precedence over Drawings.

1.2 LOCAL REGULATIONS AND STANDARDS

Work shall comply with local regulations and local construction standards. Discrepancies between designs and with regulations or standards shall be addressed before work commences.

Structural designs shall be reviewed by a local Engineer to confirm adequacy in relation to local regulations, construction practices, and site conditions.

2 SITE

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SET-OUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

3 MATERIALS

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%.

A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free from oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 CEMENT

Ordinary portland cement must be used before the expiry date. Cement should be kept dry and stored at least 15cm above ground to avoid ground moisture. Expired or damaged cement may be indicated by excessive grittiness or lumps of set cement.

3.5 CEMENT MORTAR

Cement mortar shall comprise Portland cement, sand and water as specified herein. A cement:sand ratio of 1:6 shall be used unless otherwise noted. Cement mortar in brick masonry and stone masonry shall be applied to a minimum thickness of 6-10mm unless otherwise noted. After laying, mortar within brick and stone masonry shall be cured (kept moist) for a minimum of 10 days.

3.6 CONCRETE

3.6.1 *Formwork*

Formwork for in-situ poured shall be straight and true with adequate bracing to avoid deformation under the load of poured concrete. Formwork may be constructed of plywood, sawn timber or steel according to local standards and concrete finish (appearance) requirements. Ensure adequate chamfer – around 2cm – at external corners.

Ensure that formwork construction enables removal without damage to concrete. To minimise adhesion of concrete, wet surfaces of formwork that will come in contact with concrete and apply a wash of limewash, linseed oil or soapy water.

3.6.2 *Concrete mix*

Concrete shall comprise Portland cement, sand, aggregate, and water as specified herein.

For general structural purposes, a cement:sand:aggregate mix of 1:2:4 (with a minimum cement dosage of 320kg/m3) shall be used unless otherwise noted. For water retaining structures (reservoir walls and bases) a cement:sand:aggregate mix of 1:1.5:3 shall be used unless otherwise noted (1:2:4 is not waterproof) (with a minimum cement dosage of 380kg/m3). For mass concrete applications a cement:sand:aggregate mix of 1:3:6 shall be used unless otherwise noted.

For hand mixing, additional cement should be added in accordance with the table below.

Mix	Cement		Sand (m3)	Aggregate (m3)
	Machine mix (kg)	Hand mix (kg)		
1 : 1.5 : 3	370	380	0.42	0.84
1 : 2 : 4	290	300	0.45	0.90
1 : 3 : 6	190	200	0.46	0.92

Source: Khanna, P.N. (1982) Indian Civil Engineers Handbook, 8th ed. Engineers Publishers: New Delhi

Ensure that concrete mixtures are not over watered – a bucket slump test of mixed concrete should yield less than ¼ reduction in the slump height.

3.6.3 *Concrete pouring*

Each concrete element – e.g., each concrete slab, each section of footing or parapet - shall be cast in a single pour.

3.6.4 *Concrete rodding and curing*

Cast concrete should be immediately covered with fabric, plastic sheet, straw, cement bags, sacking or leaves to keep the concrete moist and cool during the curing period. All concrete should be well vibrated or rodded to remove air voids. The concrete shall be cured with frequent watering at least twice daily for at least 10 days before use.

3.6.5 *Concrete finishing*

Provide a minimum 1% fall to water collection and drainage surfaces. Provide a rough, non-slip finish to trafficable concrete surfaces, e.g., by brushing the surface during curing.

3.7 BRICK MASONRY

Bricks should be made from clay free of stone or other organic or inorganic impurities. Bricks shall be of a standard, consistent size that conforms with local standards, and shall have plane rectangular faces and right-angled edges. Bricks should be of sufficient strength, with a minimum crushing strength of 125kg/cm2, or to not break when dropped from a height of 1m. Bricks should be fired sufficiently such that, when immersed in water, a brick shall not absorb water more that 20% of its dry weight.

Bricks shall be soaked in water for minimum 15 minutes prior to laying in cement mortar.

Bricks shall be laid in horizontal courses, with brickwork laid in a single day not exceeding 1m height to avoid excessive pressure on newly laid lower courses.

Cement mortar joints should be 6-10mm. A cement : sand mix of 1:6 should be used for masonry mortar unless otherwise noted. Brickwork shall be covered with plastic sheeting or textile and kept wet (cured) for minimum 10 days after laying.

Soling stones should be packed by hand as close as possible with broadest side downwards and length across the road width. Joints should be staggered. Gaps between stones should be filled with smaller sones, well driven in to make tight packing and complete the filling of all interstices.

Road Asphalt

Context

Road design in camp settings should take into account local geological (soil) conditions, anticipated loadings (e.g., passenger vehicles, loaded trucks), local construction methods, timing and cost. Road designs will vary in materials and dimensions, including the thickness of various surface and sub-surface layers.

This design for as asphalt surfaced road is drawn from the UN Habitat Guidelines for Community Infrastructure (2012). In this catalogue, the design is presented alongside concrete and brick options. The asphalt and base in this design is suitable for low and medium vehicle loads. For heavy truck access adjustments to the depths of sub-base, stone soling and asphalt layers should be made in consultation with a structural engineer.

The asphalt surfaced road presented herein may be achieved in most situations where asphalt roads are common, suggesting the availability of the required skills and materials. In general, stone soling and asphalt surfacing requires specialist skills and equipment. The premixing of asphalt may be achieved on-site (rather than at premix batching plants), however attention should be given to on-site production of premixed asphalt, noting that heating and mixing processes can generate substantial waste and pollution. The final compaction of asphalt surfaces typically requires specialist machinery.

Several matters are critical to ensuring the structural integrity of the finished road. Local engineering expertise should be engaged to verify and modify the design to structural footings/foundations to take into account local geological conditions. Stone soling should be done with proper care to ensure stones are well-placed to provide a stable base to distribute loads. Premixing of asphalt should ensure that all aggregate is coated with bitumen, though that excessive bitumen is not added, which undermines the strength of the finished road surface.

PROS	CONS
Relatively rapid construction time Supports heavy vehicle loads Low maintenance requirements Flexibility of dimensions enables adaptation to local terrain and capacity requirements	Asphalt surfacing and stone soling requires specialist equipment and skilled labour Skilled labour and equipment requirements may entail relatively high construction costs

Affordability
(considering initial and operating costs)

Performance
(considering capacity and durability)

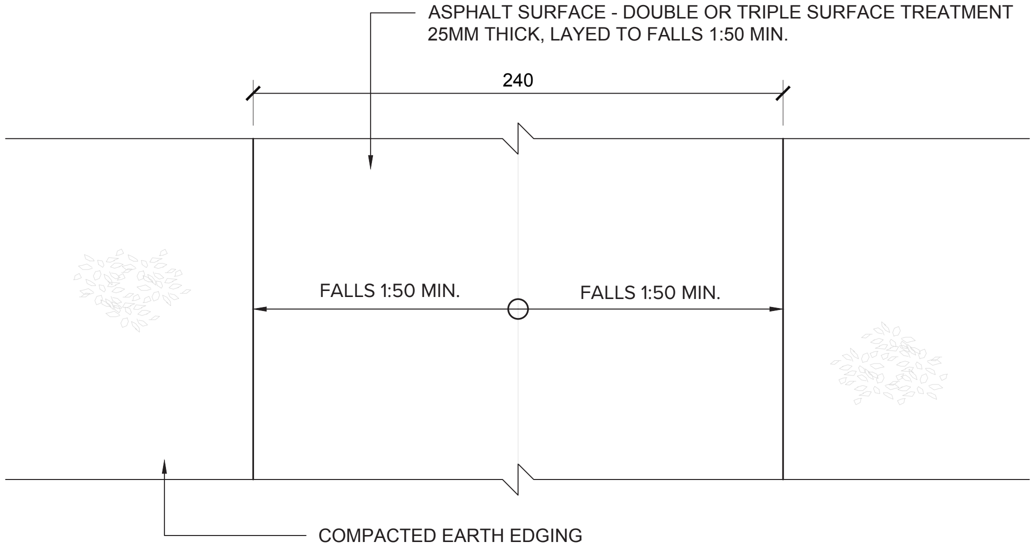
Environmental sustainability
(considering e-CO2-eq and reuse potential)

(Relatve affordability, performance and environmental impact will vary with prevailing conditions)

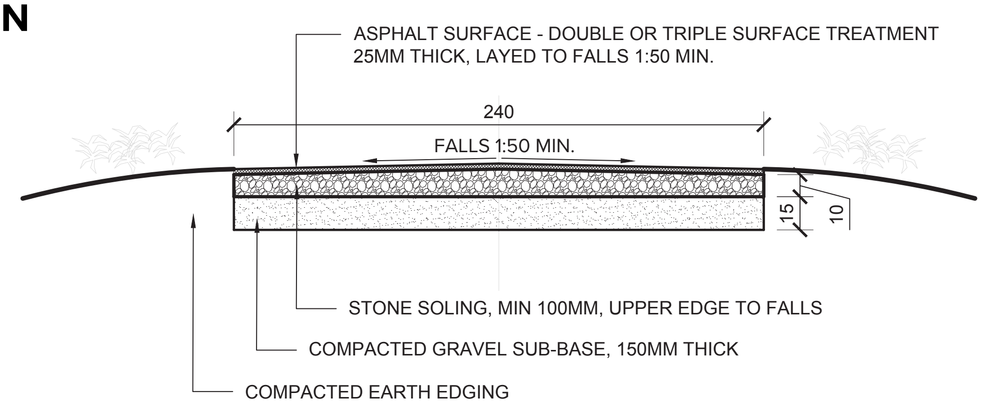
Bill of Quantities

Ref	Item description	Unit	Quantity
	(per 1m length of road)		
1	Asphalt surface - double or triple surface treatment - 25mm thick	m3	0.06
2	Stone soling (close packed stone base) - 5-10cm DIA	m3	0.24
3	Gravel for compacted sub-base	m3	0.36
4	Excavation	m3	0.70

PLAN



SECTION



DWG NO.	TITLE	DRAWN BY	UNITS
D3-1	**Road - Asphalt** Plan & Section	**AU**	**CM**
		CHECKED BY **RN**	SHEET **1 of 1**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:30**	DATE **31.08.2023**

UNHCR The UN Refugee Agency
Technical Support Section
Community Infrastructure Catalogue

Environmental Impacts (per meter)

Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Bitumen	60	12	6,3	18,3	174
Stone	1497,6	60,25	118,31	178,56	2 845,44
Total	1557,6	72,25	124,61	196,86	3 019,44

Material weight (kg) [1]

Embodied carbon (kgCO2e) [2]

Embodied water (L) [5]

1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

2 Embodied carbon dioxide equivalent - expressed as kg.eCO2e - reflects the amount of various greenhouse gases associated with the production and use of the material. The metric converts other gases to the equivalent amount of CO2 with the same global warming potential.

3 Production embodied carbon reflects the component of eCO2e associated with material production. While embodied carbon from production differs with factors such as prevailing energy sources, a simplified calculation here uses coefficients derived from global averages.

4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

5 Embodied water reflects the amount of tap water used in production of the material. While embodied water depends on specific production processes, a simplified calculation here uses coefficients derived from global averages.

Specification

1 GENERAL

1.1 SCOPE

This specification is to be read in conjunction with the Drawings and Bill of Quantities (BOQ). In the event of any discrepancy, the Specification and Bill of Quantities takes precedence over Drawings.

1.2 LOCAL REGULATIONS AND STANDARDS

Work shall comply with local regulations and local construction standards. Discrepancies between designs and with regulations or standards shall be addressed before work commences.

Structural designs shall be reviewed by a local Engineer to confirm adequacy in relation to local regulations, construction practices, and site conditions.

2 SITE

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SET-OUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

3 MATERIALS

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%.

A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free from oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 STONE SOLING

Stone soling shall use stones of 10-20cm and not less than 10cm in any dimension. The height shall equal the height of the soling course with a tolerance of 25mm. The depth of stone soling courses shall be 15cm unless otherwise noted.

Soling stones should be packed by hand as close as possible with broadest side downwards and length across the road width. Joints should be staggered. Gaps between stones should be filled with smaller sones, well driven in to make tight packing and complete the filling of all interstices.

3.5 ASPHALT

Hard, angular aggregates shall be used for pre-mixed asphalt. The maximum size of aggregate should not exceed ¾ of the thickness of the consolidated and compacted surface layer.

Sufficient binder should be used to thoroughly coat each piece of aggregate. However, only just-sufficient a quantity of bituminous binder should be used, noting that excess binder acts as a lubricant that encourages sliding movement rather than binding of aggregates.

Pre-mixing is preferred. However, on-site hand mixing may be done using drums, noting that hand mixing in a drum can be used to mix 2m3 of aggregate per drum per day. Larger outputs and better coating of aggregate can be achieved in hot weather and when aggregates are exposed to the sun. Pre-mixed asphalt shall be laid in a thicker layer and consolidated to around 25mm thick layer unless otherwise noted.

E1 Culvert **Brick Masonry**

Context

Culverts provide road access over drainage and irrigation channels and natural water courses. This design for a brick masonry culvert is drawn from the UN Habitat Guidelines for Community Infrastructure (2012). In this catalogue, the design is presented alongside stone masonry and precast concrete pipe options. The brick masonry drain design is based on standard construction methods in Pakistan.

The brick masonry culvert design presented here is for a span 1.8m wide x 1.8m deep. The design enables adjustment of the drain up to 2.5m deep (requiring associated adjustments to the drawings and Bill of Quantities herein) to suit local drainage requirements. Any adjustments should be made in consultation with a structural engineer.

The brick masonry design presented herein may be achieved in most situations where brick construction is common, suggesting the availability of the required skills and materials. Brick masonry and concrete construction will require engagement of a construction contractor/company. Attention should be given to supply chains for bricks, noting that the involvement of indentured and child labour in brick production has been identified in some countries.

Several matters are critical to ensuring the structural integrity of the brick masonry culvert. Local engineering expertise should be engaged to verify and modify the design to structural footings/ foundations to take into account local geological conditions and local construction norms. Concrete should be mixed, poured and cured in accordance with the material specifications to ensure structural integrity and avoid cracking. Fired bricks should be checked to ensure they meet strength and quality requirements described in the specification. To ensure adequate strength, concrete and brick masonry should be cured for a minimum of 10 days in accordance with the specification.

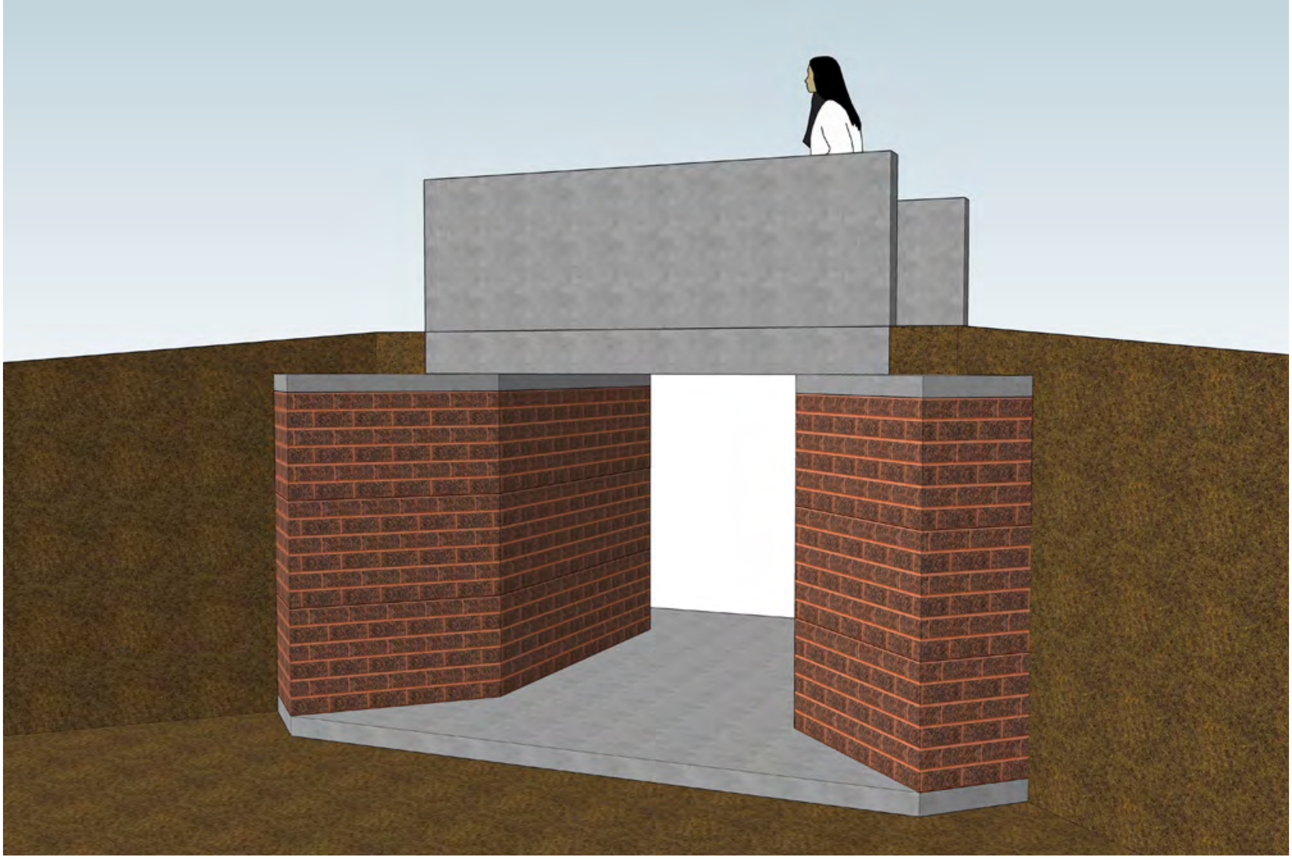
PROS	CONS
Strength and durability of reinforced concrete and brick masonry construction Flexibility of masonry and concrete construction enables adaptation to local terrain and load requirements	Relatively high initial construction cost Relatively slow construction time

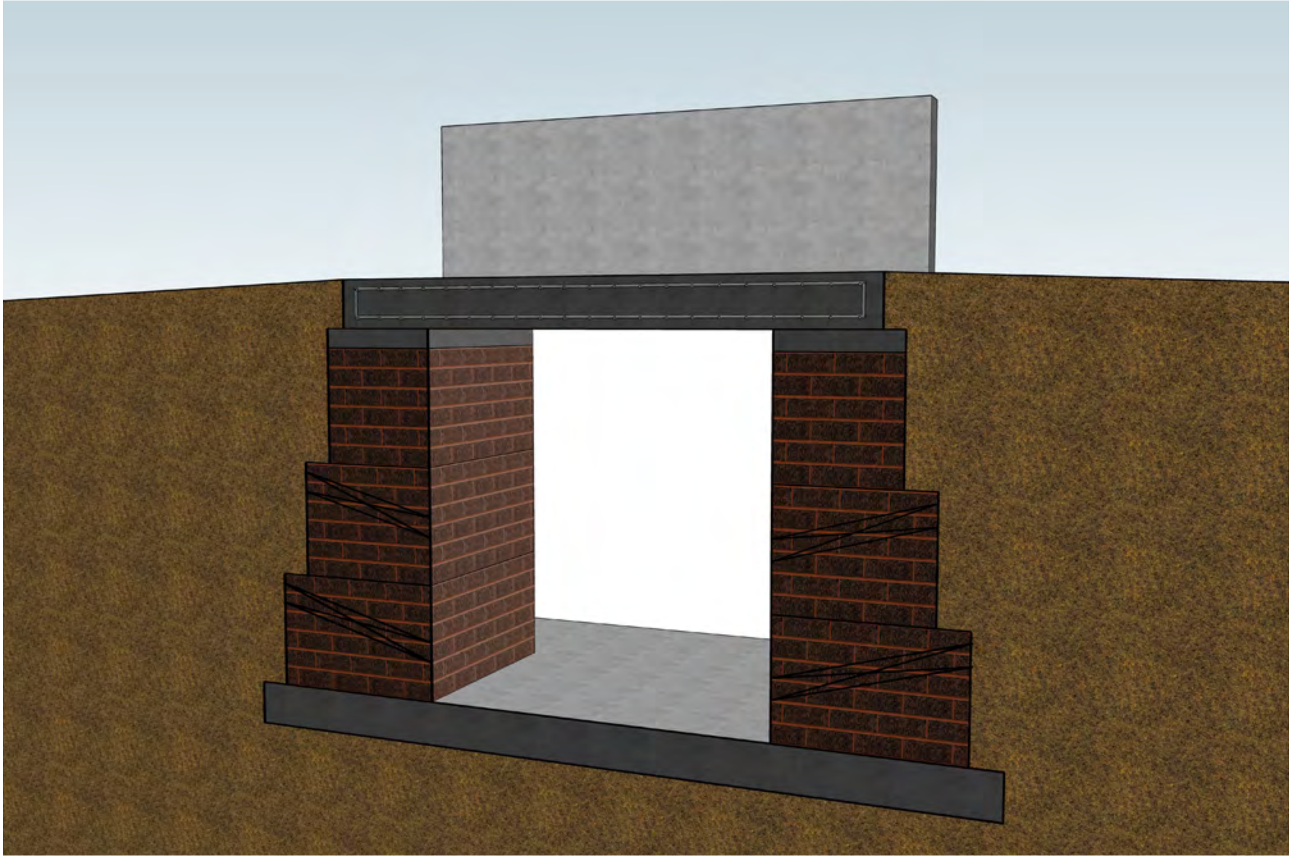
Affordability
(considering initial and operating costs)

Performance
(considering capacity and durability)

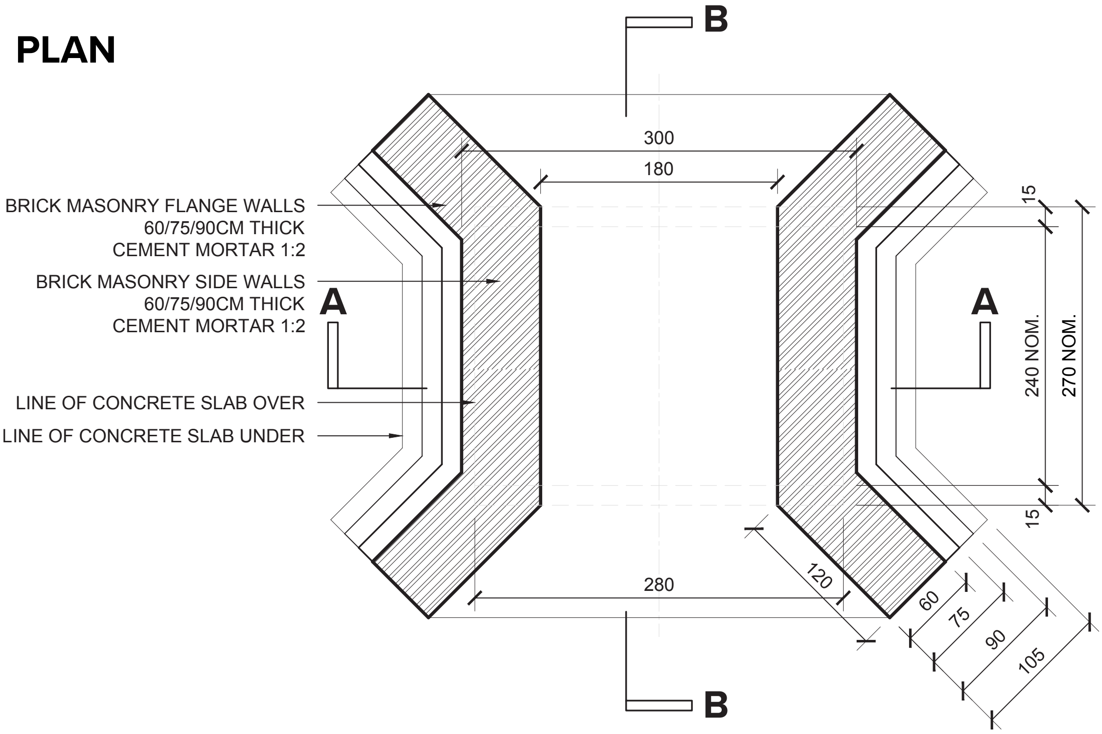
Environmental sustainability
(considering e-CO2-eq and reuse potential)

(Relatve affordability, performance and environmental impact will vary with prevailing conditions)

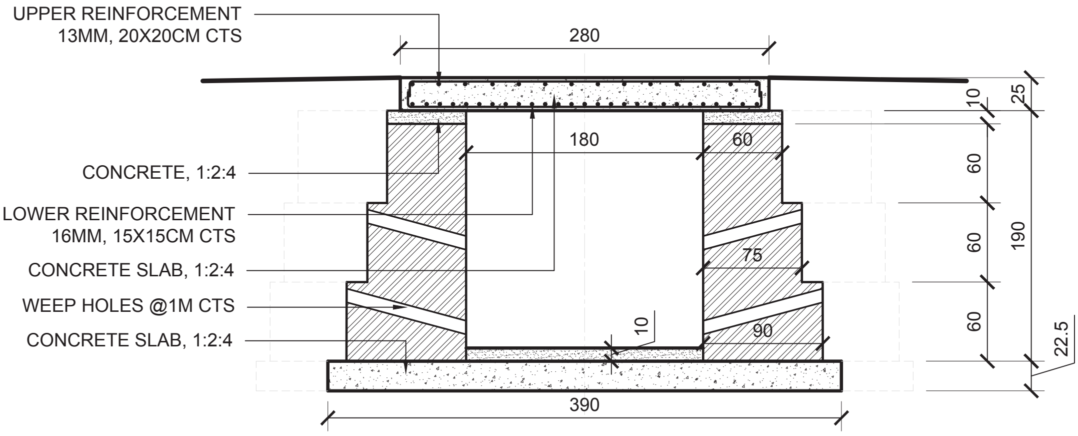




PLAN



CROSS SECTION AA



NOTES
1. Refer to Specification for material descriptions.
2. Structural design to be verified by local engineer for compliance with local conditions and norms
3. Ensure the correct water content of mixed concrete - slump test should yield < 1/4 height reduction.
4. Slabs to be cast in a single pour. All concrete works to be vibrated or well rodded.
5. Ensure all poured concrete is kept damp and out of direct sunlight for at least 7 days while curing.
6. Span and height dimensions nominal - adjust to suit site conditions and requirements.

DWG NO.	TITLE	DRAWN BY	UNITS
E1-1	**Culvert - Brick Masonry** Plan & Cross Section	**AU**	**CM**
		CHECKED BY **RN**	SHEET **1 of 2**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:50**	DATE **31.08.2023**

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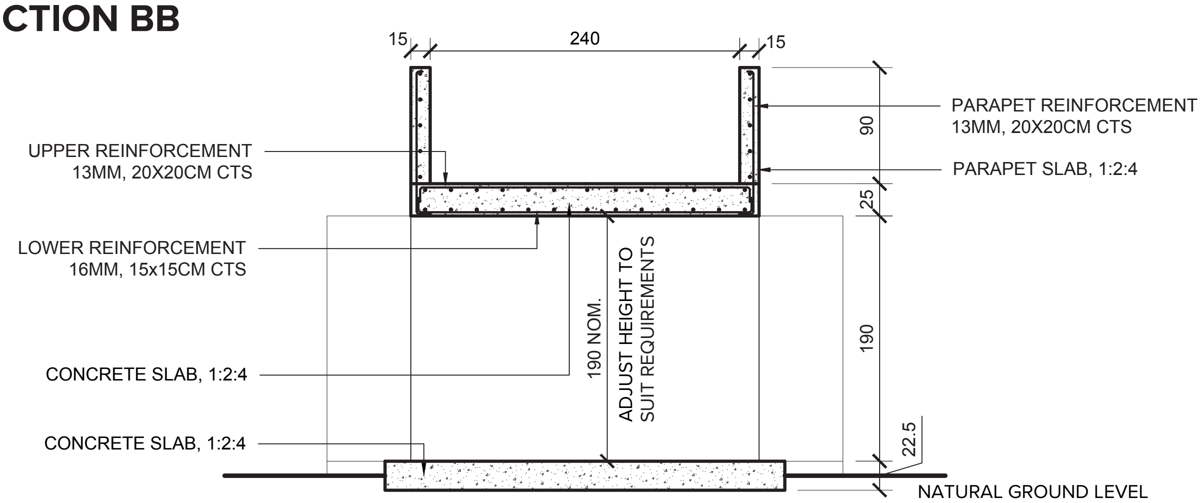
LONG SECTION BB



NOTES
1. Refer to Specification for material descriptions.
2. Structural design to be verified by local engineer for compliance with local conditions and norms
3. Ensure the correct water content of mixed concrete - slump test should yield < 1/4 height reduction.
4. Slabs to be cast in a single pour. All concrete works to be vibrated or well rodded.
5. Ensure all poured concrete is kept damp and out of direct sunlight for at least 7 days while curing.
6. Span and height dimensions nominal - adjust to suit site conditions and requirements.

DWG NO.	TITLE	DRAWN BY	UNITS
E1-2	**Culvert - Brick Masonry** Long Section	**AU**	**CM**
		CHECKED BY **RN**	SHEET **2 of 2**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:50**	DATE **31.08.2023**

UNHCR The UN Refugee Agency
Technical Support Section
Community Infrastructure Catalogue

Bill of Quantities

Ref	Item description	Unit	Quantity
1	Concrete for reinforced concrete slab - 1:2:4	m3	1.90
2	Steel reinforcement for reinforced concrete slab - upper - 13mm	m	80.00
	or	kg	(84.00)
3	Steel reinforcement for reinforced concrete slab - lower - 16mm	m	108.00
	or	kg	(170.60)
4	Concrete for parapet walls - 1:2:4	m3	0.38
5	Steel reinforcement for parapet walls - 13mm	m	30.30
	or	kg	(31.82)
6	Concrete for masonry capping - 1:2:4	m3	0.06
7	Brick for brick masonry	m3	9.80
	or	No	(4900)
8	Cement mortar for brick masonry - 1:2	m3	2.95
9	Concrete for concrete slab base - 1:2:4	m3	3.75
10	Excavation	m3	4.00
	(Adjust quantities to suit dimension (height, width) adjustments)		

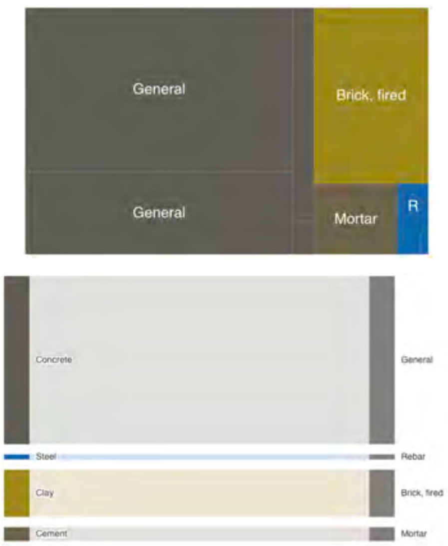
Environmental Impacts

Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

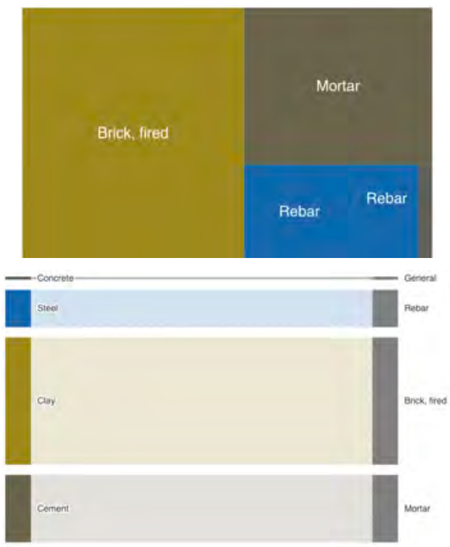
	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Concrete	12 180	25 297,86	1278,9	26 576,76	779,52
Steel	268,7	779,22	28,21	807,43	9 968,65
Clay	18 816	6 021,12	1486,46	7 507,58	33 868,8
Cement	4 867,5	1703,63	511,09	2 214,71	18 009,75
Total	36 132,2	33 801,83	3 304,66	37 106,49	62 626,72

Material weight (kg) [1]

Embodied carbon (kgCO2e) [2]



Embodied water (L) [5]



1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

2 Embodied carbon dioxide equivalent - expressed as kg.eCO2e - reflects the amount of various greenhouse gases associated with the production and use of the material. The metric converts other gases to the equivalent amount of CO2 with the same global warming potential.

3 Production embodied carbon reflects the component of eCO2e associated with material production. While embodied carbon from production differs with factors such as prevailing energy sources, a simplified calculation here uses coefficients derived from global averages.

4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

5 Embodied water reflects the amount of tap water used in production of the material. While embodied water depends on specific production processes, a simplified calculation here uses coefficients derived from global averages.

Specification

1 GENERAL

1.1 SCOPE

This specification is to be read in conjunction with the Drawings and Bill of Quantities (BOQ). In the event of any discrepancy, the Specification and Bill of Quantities takes precedence over Drawings.

1.2 LOCAL REGULATIONS AND STANDARDS

Work shall comply with local regulations and local construction standards. Discrepancies between designs and with regulations or standards shall be addressed before work commences.

Structural designs shall be reviewed by a local Engineer to confirm adequacy in relation to local regulations, construction practices, and site conditions.

2 SITE

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SET-OUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

2.4 PREVENTION OF SURFACE OR GROUNDWATER CONTAMINATION

Location and construction of water supply related infrastructure must avoid contamination of surface water and groundwater sources. Risks are generally low and related to contamination from water treatment chemicals, water treatment by-products and contamination from wastewater.

3 MATERIALS

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%.

A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free from oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 CEMENT

Ordinary portland cement must be used before the expiry date. Cement should be kept dry and stored at least 15cm above ground to avoid ground moisture. Expired or damaged cement may be indicated by excessive grittiness or lumps of set cement.

3.5 CEMENT MORTAR

Cement mortar shall comprise Portland cement, sand and water as specified herein. A cement:sand ratio of 1:6 shall be used unless otherwise noted. Cement mortar in brick masonry and stone masonry shall be applied to a minimum thickness of 6-10mm unless otherwise noted. After laying, mortar within brick and stone masonry shall be cured (kept moist) for a minimum of 10 days.

3.6 CONCRETE

3.6.1 *Formwork*

Formwork for in-situ poured shall be straight and true with adequate bracing to avoid deformation under the load of poured concrete. Formwork may be constructed of plywood, sawn timber or steel according to local standards and concrete finish (appearance) requirements. Ensure adequate chamfer – around 2cm – at external corners.

Ensure that formwork construction enables removal without damage to concrete. To minimise adhesion of concrete, wet surfaces of formwork that will come in contact with concrete and apply a wash of limewash, linseed oil or soapy water.

3.6.2 *Concrete mix*

Concrete shall comprise Portland cement, sand, aggregate, and water as specified herein.

For general structural purposes, a cement:sand:aggregate mix of 1:2:4 (with a minimum cement dosage of 320kg/m3) shall be used unless otherwise noted. For water retaining structures (reservoir walls and bases) a cement:sand:aggregate mix of 1:1.5:3 shall be used unless otherwise noted (1:2:4 is not waterproof) (with a minimum cement dosage of 380kg/m3). For mass concrete applications a cement:sand:aggregate mix of 1:3:6 shall be used unless otherwise noted.

For hand mixing, additional cement should be added in accordance with the table below.

Mix	Cement		Sand (m3)	Aggregate (m3)
	Machine mix (kg)	Hand mix (kg)		
1 : 1.5 : 3	370	380	0.42	0.84
1 : 2 : 4	290	300	0.45	0.90
1 : 3 : 6	190	200	0.46	0.92

Source: Khanna, P.N. (1982) Indian Civil Engineers Handbook, 8th ed. Engineers Publishers: New Delhi

Ensure that concrete mixtures are not over watered – a bucket slump test of mixed concrete should yield less than ¼ reduction in the slump height.

3.6.3 *Concrete pouring*

Each concrete element – e.g., each concrete slab, each section of footing or parapet - shall be cast in a single pour.

3.6.4 *Concrete rodding and curing*

Cast concrete should be immediately covered with fabric, plastic sheet, straw, cement bags, sacking or leaves to keep the concrete moist and cool during the curing period. All concrete should be well vibrated or rodded to remove air voids. The concrete shall be cured with frequent watering at least twice daily for at least 10 days before use.

3.6.5 *Concrete finishing*

Provide a minimum 1% fall to water collection and drainage surfaces. Provide a rough, non-slip finish to trafficable concrete surfaces, e.g., by brushing the surface during curing.

3.7 STEEL REINFORCEMENT

Reinforcement bars shall be free from rust and of the correct type and size for concrete construction work (typically a characteristic yield stress of at least 210 N/mm^2). Steel reinforcement should be placed as per the designs (typically 7/8 of the slab or wall thickness) to ensure the bars function correctly in tension. All bars should have at least 12mm concrete cover.

3.8 BRICK MASONRY

Bricks should be made from clay free of stone or other organic or inorganic impurities. Bricks shall be of a standard, consistent size that conforms with local standards, and shall have plane rectangular faces and right-angled edges. Bricks should be of sufficient strength, with a minimum crushing strength of 125kg/cm2, or to not break when dropped from a height of 1m. Bricks should be fired sufficiently such that, when immersed in water, a brick shall not absorb water more that 20% of its dry weight.

Bricks shall be soaked in water for minimum 15 minutes prior to laying in cement mortar.

Bricks shall be laid in horizontal courses, with brickwork laid in a single day not exceeding 1m height to avoid excessive pressure on newly laid lower courses.

Cement mortar joints should be 6-10mm. A cement : sand mix of 1:6 should be used for masonry mortar unless otherwise noted. Brickwork shall be covered with plastic sheeting or textile and kept wet (cured) for minimum 10 days after laying.

Image courtesy Md. Sultan Mahmud, UNHCR

Context

Culverts provide road access over drainage and irrigation channels and natural water courses. This design for a brick masonry culvert is drawn from the UN Habitat Guidelines for Community Infrastructure (2012). In this catalogue, the design is presented alongside brick masonry and precast concrete pipe options. The stone masonry culvert design replicated the brick masonry culvert design, providing material options for the same culvert design.

The culvert is for a span 1.8m wide x 1.8m deep. The design enables adjustment of the drain up to 2.5m deep (requiring associated adjustments to the drawings and Bill of Quantities herein) to suit local drainage requirements. Any adjustments should be made in consultation with a structural engineer.

The stone masonry design presented herein may be achieved in most situations where stone construction is common, suggesting the availability of the required skills and materials. In general, stone masonry and concrete construction will require engagement of a construction contractor/company.

Several matters are critical to ensuring the structural integrity of the stone masonry culvert. Local engineering expertise should be engaged to verify and modify the design to structural footings/ foundations to take into account local geological conditions and local construction norms. Concrete should be mixed, poured and cured in accordance with the material specifications to ensure structural integrity and avoid cracking. Stone masonry should be cured in accordance with specifications.

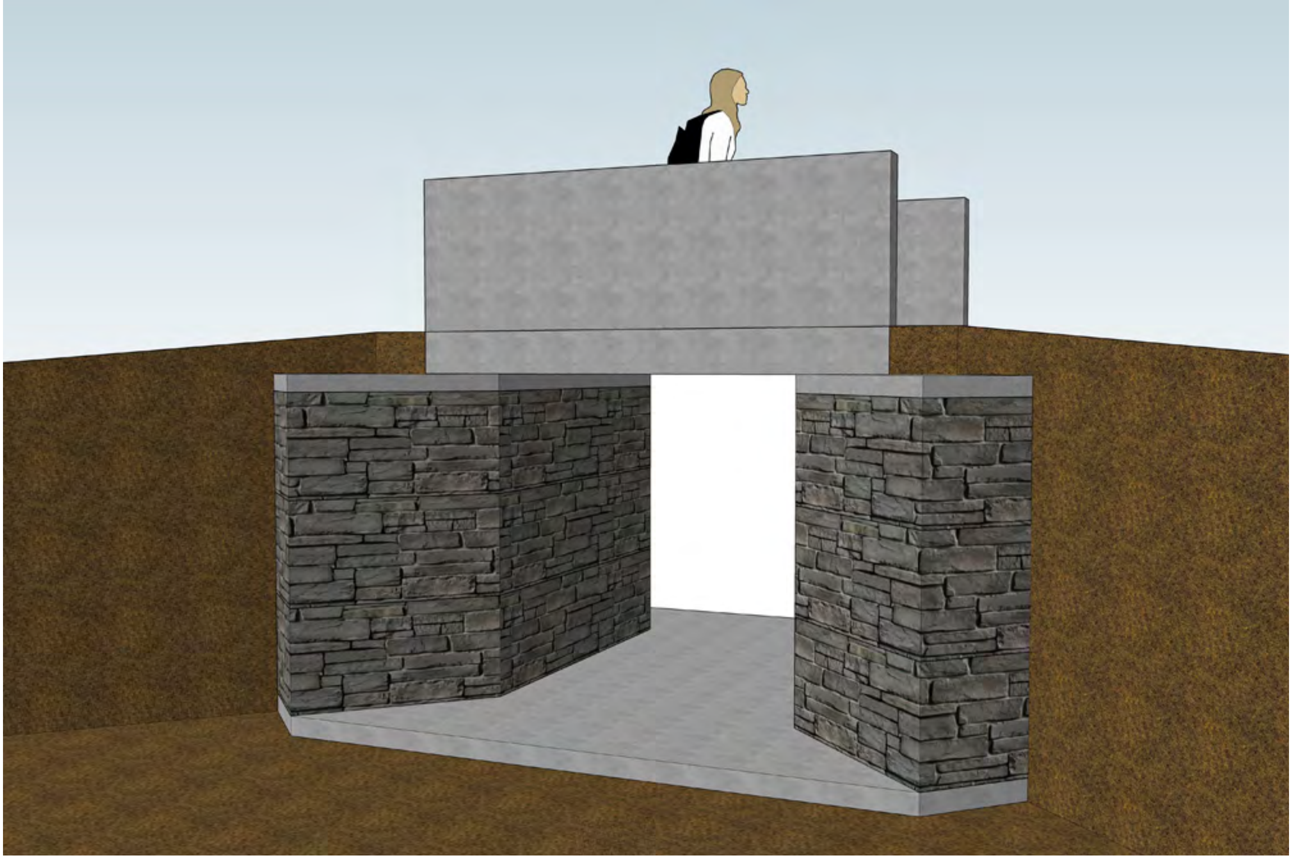
PROS	CONS
Strength and durability of reinforced concrete and stone masonry construction Flexibility of masonry and concrete construction enables adaptation to local terrain and load requirements	Relatively high initial construction cost Relatively slow construction time

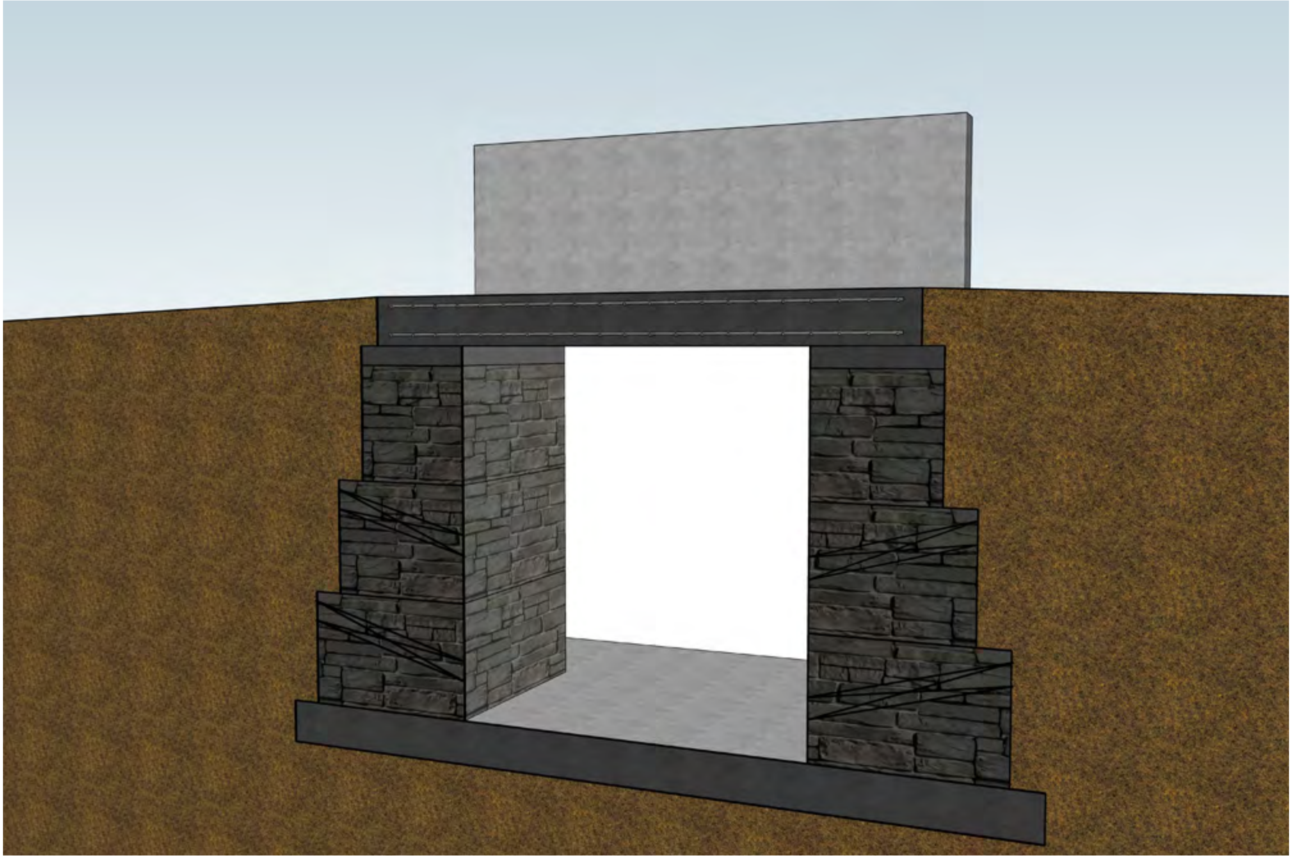
Affordability
(considering initial and operating costs)

Performance
(considering capacity and durability)

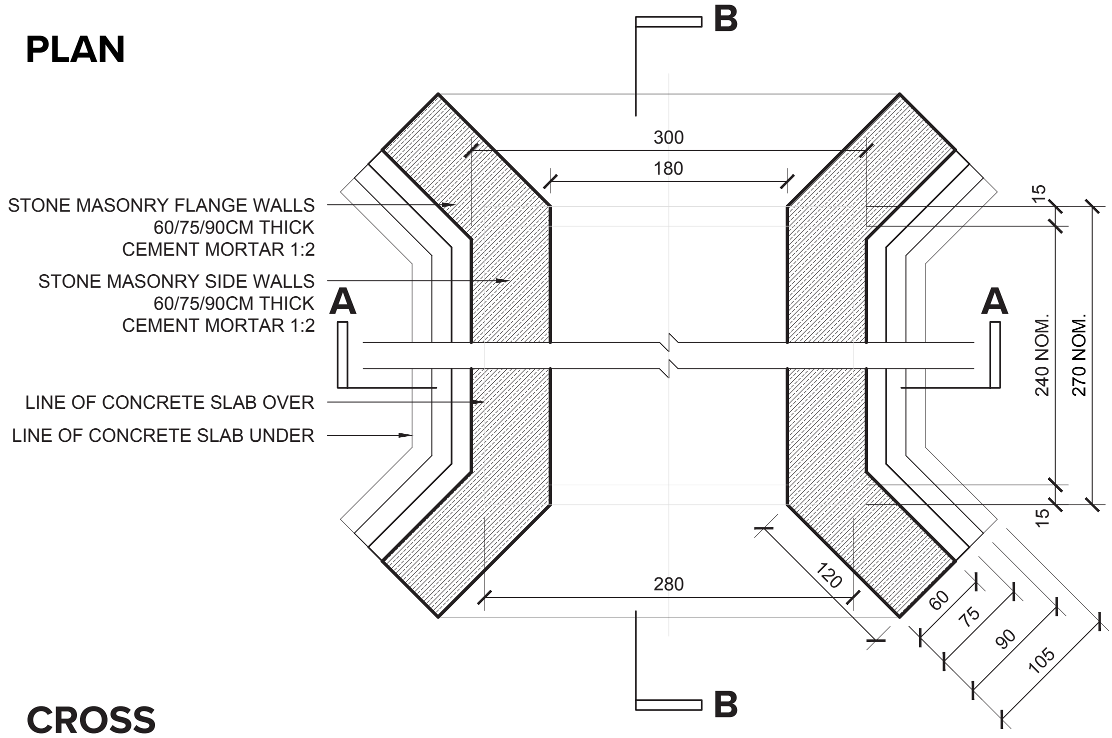
Environmental sustainability
(considering e-CO_2-eq and reuse potential)

(Relatve affordability, performance and environmental impact will vary with prevailing conditions)

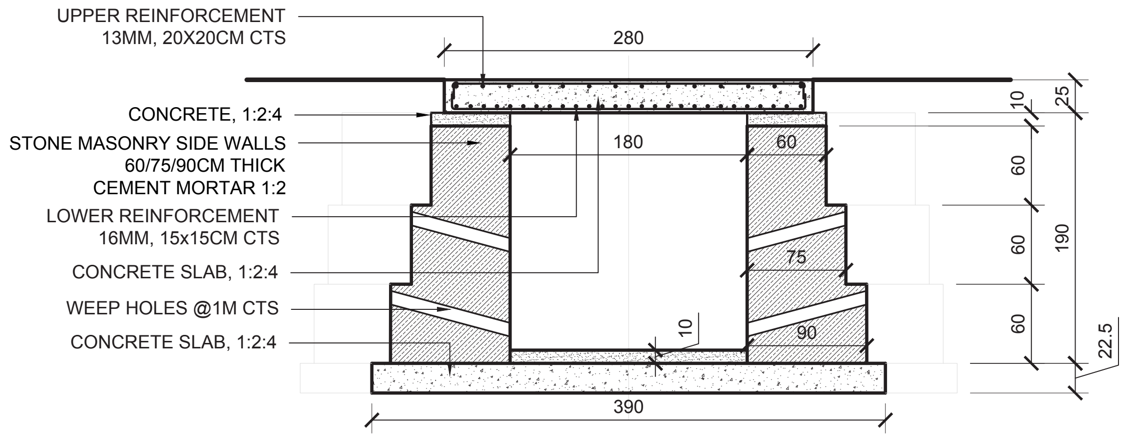




PLAN



CROSS SECTION AA



NOTES
1. Refer to Specification for material descriptions.
2. Structural design to be verified by local engineer for compliance with local conditions and norms
3. Ensure the correct water content of mixed concrete - slump test should yield < 1/4 height reduction.
4. Slabs to be cast in a single pour. All concrete works to be vibrated or well rodded.
5. Ensure all poured concrete is kept damp and out of direct sunlight for at least 7 days while curing.
6. Span and height dimensions nominal - adjust to suit site conditions and requirements.

DWG NO.	TITLE	DRAWN BY	UNITS
E2-1	**Culvert - Stone Masonry** Plan & Cross Section	**AU**	**CM**
		CHECKED BY **RN**	SHEET **1 of 2**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:50**	DATE **31.08.2023**

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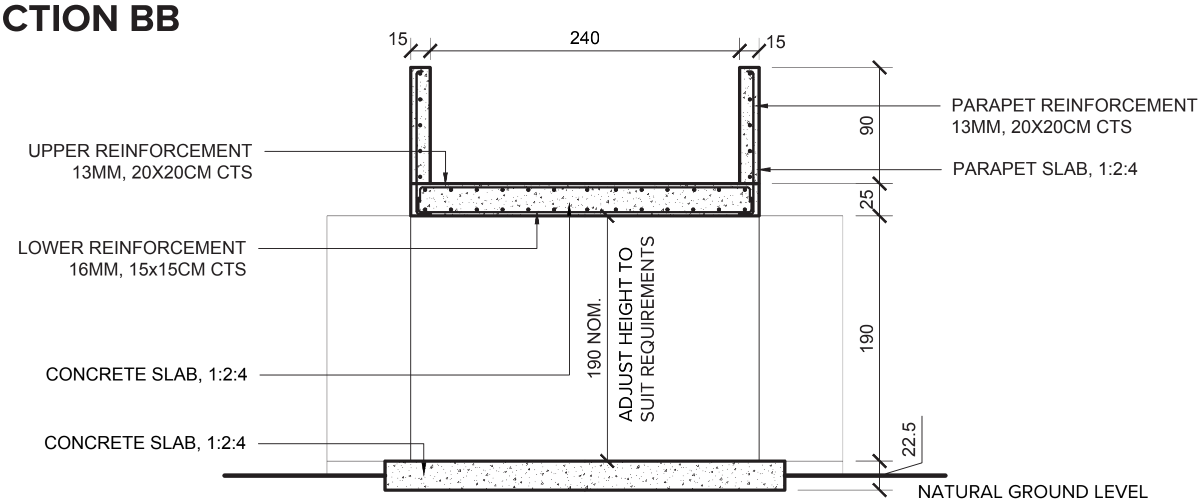
LONG SECTION BB



NOTES
1. Refer to Specification for material descriptions.
2. Structural design to be verified by local engineer for compliance with local conditions and norms
3. Ensure the correct water content of mixed concrete - slump test should yield < 1/4 height reduction.
4. Slabs to be cast in a single pour. All concrete works to be vibrated or well rodded.
5. Ensure all poured concrete is kept damp and out of direct sunlight for at least 7 days while curing.
6. Span and height dimensions nominal - adjust to suit site conditions and requirements.

DWG NO.	TITLE	DRAWN BY	UNITS
E2-2	**Culvert - Stone Masonry** Long Section	**AU**	**CM**
		CHECKED BY **RN**	SHEET **2 of 2**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:50**	DATE **31.08.2023**

UNHCR The UN Refugee Agency
Technical Support Section
Community Infrastructure Catalogue

Bill of Quantities

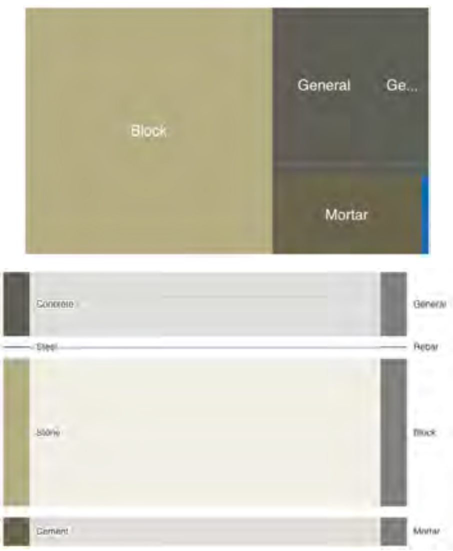
Ref	Item description	Unit	Quantity
1	Concrete for reinforced concrete slab - 1:2:4	m3	1.90
2	Steel reinforcement for reinforced concrete slab - upper - 13mm	m	80.00
	or	kg	(84.00)
3	Steel reinforcement for reinforced concrete slab - lower - 16mm	m	108.00
	or	kg	(170.60)
4	Concrete for parapet walls - 1:2:4	m3	0.38
5	Steel reinforcement for parapet walls - 13mm	m	30.30
	or	kg	(31.82)
6	Concrete for masonry capping - 1:2:4	m3	0.06
7	Stone for stone masonry	m3	9.80
8	Cement mortar for stone masonry - 1:2	m3	3.30
9	Concrete for concrete slab base - 1:2:4	m3	3.75
10	Excavation	m3	4.00
	(Adjust quantities to suit dimension (height, width) adjustments)		

Environmental Impacts

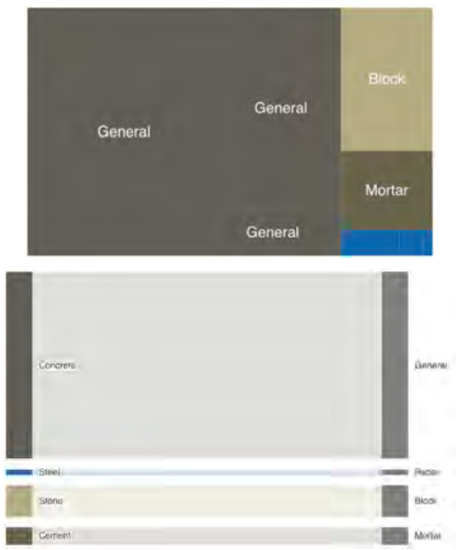
Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Concrete	12 180	25 297,86	1278,9	26 576,76	779,52
Steel	268,7	779,22	28,21	807,43	9 968,65
Stone	28 224	2 229,7	2 229,7	4 459,39	53 625,6
Cement	5 445	1905,75	571,73	2 477,48	20 146,5
Total	46 117,7	30 212,53	4 108,53	34 321,06	84 520,27

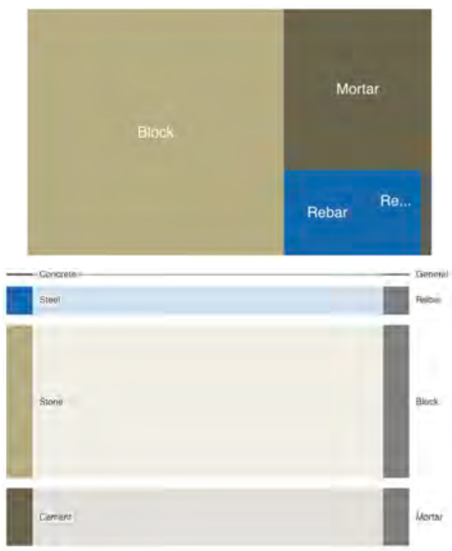
Material weight (kg) [1]



Embodied carbon (kgCO2e) [2]



Embodied water (L) [5]



1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

2 Embodied carbon dioxide equivalent - expressed as kg.eCO2e - reflects the amount of various greenhouse gases associated with the production and use of the material. The metric converts other gases to the equivalent amount of CO2 with the same global warming potential.

3 Production embodied carbon reflects the component of eCO2e associated with material production. While embodied carbon from production differs with factors such as prevailing energy sources, a simplified calculation here uses coefficients derived from global averages.

4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

5 Embodied water reflects the amount of tap water used in production of the material. While embodied water depends on specific production processes, a simplified calculation here uses coefficients derived from global averages.

Specification

1 **GENERAL**

1.1 SCOPE

This specification is to be read in conjunction with the Drawings and Bill of Quantities (BOQ). In the event of any discrepancy, the Specification and Bill of Quantities takes precedence over Drawings.

1.2 LOCAL REGULATIONS AND STANDARDS

Work shall comply with local regulations and local construction standards. Discrepancies between designs and with regulations or standards shall be addressed before work commences.

Structural designs shall be reviewed by a local Engineer to confirm adequacy in relation to local regulations, construction practices, and site conditions.

2 **SITE**

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SET-OUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

2.4 PREVENTION OF SURFACE OR GROUNDWATER CONTAMINATION

Location and construction of water supply related infrastructure must avoid contamination of surface water and groundwater sources. Risks are generally low and related to contamination from water treatment chemicals, water treatment by-products and contamination from wastewater.

3 **MATERIALS**

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%.

A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free from oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 CEMENT

Ordinary portland cement must be used before the expiry date. Cement should be kept dry and stored at least 15cm above ground to avoid ground moisture. Expired or damaged cement may be indicated by excessive grittiness or lumps of set cement.

3.5 CEMENT MORTAR

Cement mortar shall comprise Portland cement, sand and water as specified herein. A cement:sand ratio of 1:6 shall be used unless otherwise noted. Cement mortar in brick masonry and stone masonry shall be applied to a minimum thickness of 6-10mm unless otherwise noted. After laying, mortar within brick and stone masonry shall be cured (kept moist) for a minimum of 10 days.

3.6 CONCRETE

3.6.1 *Formwork*

Formwork for in-situ poured shall be straight and true with adequate bracing to avoid deformation under the load of poured concrete. Formwork may be constructed of plywood, sawn timber or steel according to local standards and concrete finish (appearance) requirements. Ensure adequate chamfer – around 2cm – at external corners.

Ensure that formwork construction enables removal without damage to concrete. To minimise adhesion of concrete, wet surfaces of formwork that will come in contact with concrete and apply a wash of limewash, linseed oil or soapy water.

3.6.2 *Concrete mix*

Concrete shall comprise Portland cement, sand, aggregate, and water as specified herein.

For general structural purposes, a cement:sand:aggregate mix of 1:2:4 (with a minimum cement dosage of 320kg/m3) shall be used unless otherwise noted. For water retaining structures (reservoir walls and bases) a cement:sand:aggregate mix of 1:1.5:3 shall be used unless otherwise noted (1:2:4 is not waterproof) (with a minimum cement dosage of 380kg/m3). For mass concrete applications a cement:sand:aggregate mix of 1:3:6 shall be used unless otherwise noted.

For hand mixing, additional cement should be added in accordance with the table below.

Mix	Cement		Sand	Aggregate
	Machine mix (kg)	Hand mix (kg)	(m3)	(m3)
1 : 1.5 : 3	370	380	0.42	0.84
1 : 2 : 4	290	300	0.45	0.90
1 : 3 : 6	190	200	0.46	0.92

Source: Khanna, P.N. (1982) Indian Civil Engineers Handbook, 8th ed. Engineers Publishers: New Delhi

Ensure that concrete mixtures are not over watered – a bucket slump test of mixed concrete should yield less than ¼ reduction in the slump height.

3.6.3 *Concrete pouring*

Each concrete element – e.g., each concrete slab, each section of footing or parapet - shall be cast in a single pour.

3.6.4 *Concrete rodding and curing*

Cast concrete should be immediately covered with fabric, plastic sheet, straw, cement bags, sacking or leaves to keep the concrete moist and cool during the curing period. All concrete should be well vibrated or rodded to remove air voids. The concrete shall be cured with frequent watering at least twice daily for at least 10 days before use.

3.6.5 *Concrete finishing*

Provide a minimum 1% fall to water collection and drainage surfaces. Provide a rough, non-slip finish to trafficable concrete surfaces, e.g., by brushing the surface during curing.

3.7 STEEL REINFORCEMENT

Reinforcement bars shall be free from rust and of the correct type and size for concrete construction work (typically a characteristic yield stress of at least 210 N/mm^2). Steel reinforcement should be placed as per the designs (typically 7/8 of the slab or wall thickness) to ensure the bars function correctly in tension. All bars should have at least 12mm concrete cover.

3.8 STONE MASONRY

Stone masonry shall be laid in horizontal courses, with stones laid in a single day not exceeding 1m height to avoid excessive pressure on newly laid lower courses. Stones shall be laid by hand as close as possible with broadest side downwards. Joints and gaps between stones shall be filled with smaller stones.

Cement mortar joints should be 6-10mm. A cement : sand mix of 1:6 should be used for masonry mortar unless otherwise noted. Finished masonry shall be covered with plastic sheeting or textile

Image courtesy Md. Sultan Mahmud, UNHCR

Context

Culverts provide road access over drainage and irrigation channels and natural water courses. This design for a brick masonry culvert is drawn from the UN Habitat Guidelines for Community Infrastructure (2012). In this catalogue, the design is presented alongside brick and stone masonry options.

Two dimension options are presented here: 1) a span 2m wide x 0.8m deep, and 2) a span of 1m wide and 0.8m deep. The design enables adjustment of the culvert depth (requiring associated adjustments to the drawings and Bill of Quantities herein) to suit local drainage requirements. Any adjustments should be made in consultation with a structural engineer.

The precast concrete design presented herein is simple to implement. The principle limiting factor is availability of precast panels pipes, which, in general, will be purchased from local producers (compared to simpler precast elements such as panels, which may be produced by local communities with adequate technical support).

Several matters are critical to ensuring the structural integrity of the precast concrete culvert. Local engineering expertise should be engaged to verify and modify the design to structural footings/ foundations to take into account local geological conditions and local construction norms. Concrete should be mixed, poured and cured in accordance with the material specifications to ensure structural integrity and avoid cracking.

PROS	CONS
Relatively rapid construction time Simple construction methods can engage local communities	Limited flexibility of precast pipes limits adaptability to local terrain and capacity requirements Precast concrete pipes may require off-site fabrication

Affordability
(considering initial and operating costs)

Performance
(considering capacity and durability)

Environmental sustainability
(considering e-CO2-eq and reuse potential)

(Relatve affordability, performance and environmental impact will vary with prevailing conditions)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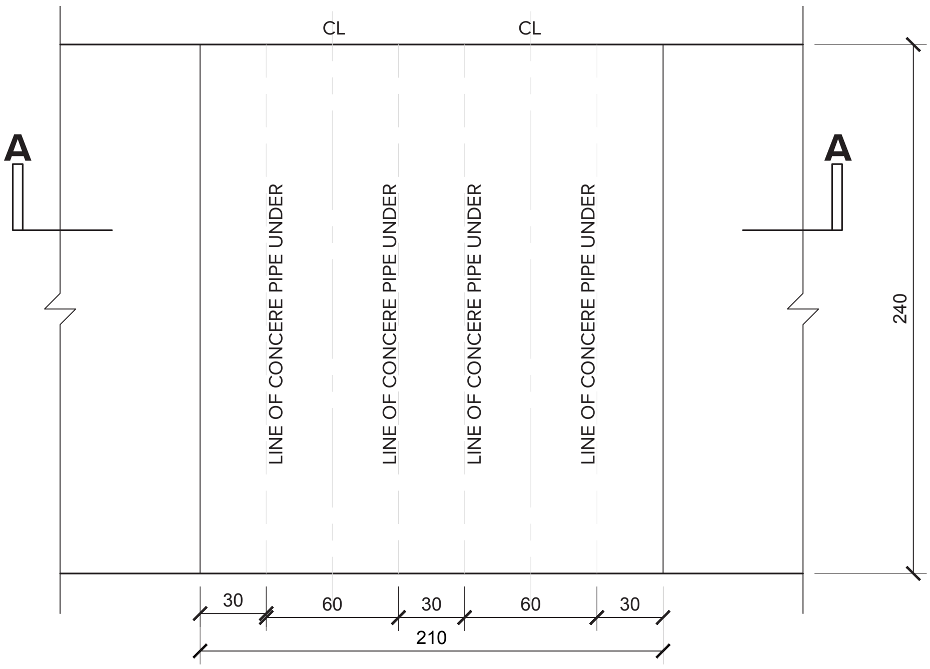
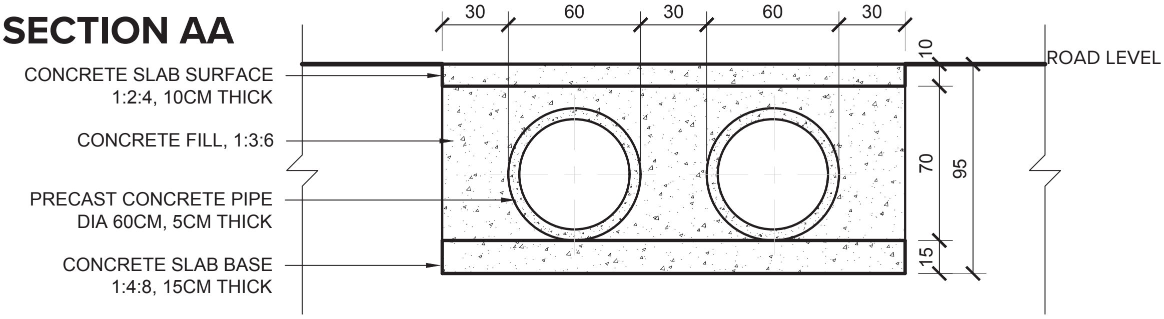
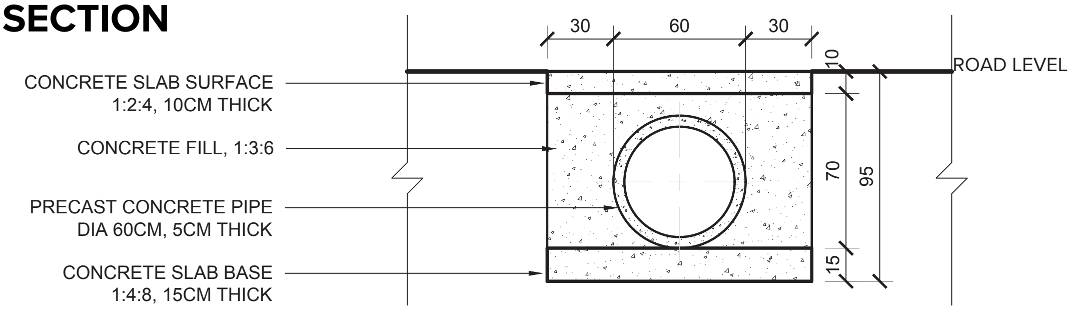
PLAN



CROSS SECTION AA



ALTERNATIVE SECTION



NOTES
1. Refer to Specification for material descriptions.
2. Structural design to be verified by local engineer for compliance with local conditions and norms
3. Ensure the correct water content of mixed concrete - slump test should yield < 1/4 height reduction.
4. Slabs to be cast in a single pour. All concrete works to be vibrated or well rodded.
5. Ensure all poured concrete is kept damp and out of direct sunlight for at least 7 days while curing.
6. Span and height dimensions nominal - adjust to suit site conditions and requirements.

DWG NO.	TITLE	DRAWN BY	UNITS
E3-1	**Culvert - Concrete Pipe** Plan & Cross Section	**AU**	**CM**
		CHECKED BY **RN**	SHEET **1 of 1**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:30**	DATE **31.08.2023**

UNHCR The UN Refugee Agency
Technical Support Section
Community Infrastructure Catalogue

Bill of Quantities

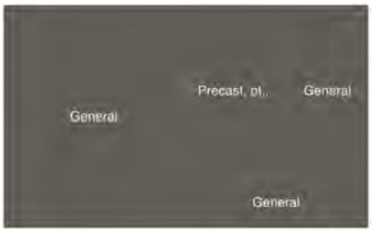
Ref	Item description	Unit	Quantity
	Option 1		
1.1	Concrete for concrete slab surface - 1:2:4	m3	0.51
1.2	Precast concrete pipe - 60cm dia, 5cm thick (or equivalent)	m	4.80
1.3	Concrete for lean concrete fill - 1:3:6	m3	2.20
1.4	Concrete for concrete slab base - 1:4:8	m3	0.77
1.5	Excavation	m3	5.00
	Option 2		
2.1	Concrete for concrete slab surface - 1:2:4	m3	0.30
2.2	Precast concrete pipe - 60cm dia, 5cm thick (or equivalent)	m	2.40
2.3	Concrete for lean concrete fill - 1:3:6	m3	1.35
2.4	Concrete for concrete slab base - 1:4:8	m3	0.44
2.5	Excavation	m3	2.80
	(Adjust quantities to suit dimension (height, width) adjustments)		

Environmental Impacts

Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Concrete	8 896	14 920,56	934,08	15 854,64	7 608,64
Total	8 896	14 920,56	934,08	15 854,64	7 608,64

Material weight (kg) [1]



Embodied carbon (kgCO2e) [2]

Embodied water (L) [5]

1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

2 Embodied carbon dioxide equivalent - expressed as kg.eCO2e - reflects the amount of various greenhouse gases associated with the production and use of the material. The metric converts other gases to the equivalent amount of CO2 with the same global warming potential.

3 Production embodied carbon reflects the component of eCO2e associated with material production. While embodied carbon from production differs with factors such as prevailing energy sources, a simplified calculation here uses coefficients derived from global averages.

4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

5 Embodied water reflects the amount of tap water used in production of the material. While embodied water depends on specific production processes, a simplified calculation here uses coefficients derived from global averages.

Specification

1 **GENERAL**

1.1 SCOPE

This specification is to be read in conjunction with the Drawings and Bill of Quantities (BOQ). In the event of any discrepancy, the Specification and Bill of Quantities takes precedence over Drawings.

1.2 LOCAL REGULATIONS AND STANDARDS

Work shall comply with local regulations and local construction standards. Discrepancies between designs and with regulations or standards shall be addressed before work commences.

Structural designs shall be reviewed by a local Engineer to confirm adequacy in relation to local regulations, construction practices, and site conditions.

2 **SITE**

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SET-OUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

3 **MATERIALS**

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%. A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free from oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 CEMENT

Ordinary portland cement must be used before the expiry date. Cement should be kept dry and stored at least 15cm above ground to avoid ground moisture. Expired or damaged cement may be indicated by excessive grittiness or lumps of set cement.

3.5 CONCRETE

3.5.1 *Formwork*

Formwork for in-situ poured shall be straight and true with adequate bracing to avoid deformation under the load of poured concrete. Formwork may be constructed of plywood, sawn timber or steel according to local standards and concrete finish (appearance) requirements. Ensure adequate chamfer – around 2cm – at external corners.

Ensure that formwork construction enables removal without damage to concrete. To minimise adhesion of concrete, wet surfaces of formwork that will come in contact with concrete and apply a wash of limewash, linseed oil or soapy water.

3.5.2 *Concrete mix*

Concrete shall comprise Portland cement, sand, aggregate, and water as specified herein.

For general structural purposes, a cement:sand:aggregate mix of 1:2:4 (with a minimum cement dosage of 320kg/m3) shall be used unless otherwise noted. For water retaining structures (reservoir walls and bases) a cement:sand:aggregate mix of 1:1.5:3 shall be used unless otherwise noted (1:2:4 is not waterproof) (with a minimum cement dosage of 380kg/m3). For mass concrete applications a cement:sand:aggregate mix of 1:3:6 shall be used unless otherwise noted.

For hand mixing, additional cement should be added in accordance with the table below.

Mix	Cement		Sand	Aggregate
	Machine mix (kg)	Hand mix (kg)	(m3)	(m3)
1 : 1.5 : 3	370	380	0.42	0.84
1 : 2 : 4	290	300	0.45	0.90
1 : 3 : 6	190	200	0.46	0.92

Source: Khanna, P.N. (1982) Indian Civil Engineers Handbook, 8th ed. Engineers Publishers: New Delhi

Ensure that concrete mixtures are not over watered – a bucket slump test of mixed concrete should yield less than ¼ reduction in the slump height.

3.5.3 *Concrete pouring*

Each concrete element – e.g., each concrete slab, each section of footing or parapet - shall be cast in a single pour.

3.5.4 *Concrete rodding and curing*

Cast concrete should be immediately covered with fabric, plastic sheet, straw, cement bags, sacking or leaves to keep the concrete moist and cool during the curing period. All concrete should be well vibrated or rodded to remove air voids. The concrete shall be cured with frequent watering at least twice daily for at least 10 days before use.

3.5.5 *Concrete finishing*

Provide a minimum 1% fall to water collection and drainage surfaces. Provide a rough, non-slip finish to trafficable concrete surfaces, e.g., by brushing the surface during curing.

3.6 PRECAST CONCRETE

Precast concrete shall comprise Portland cement, sand, aggregate, and water as specified herein. Precast concrete units shall be cast using formwork that consistently provides uniform dimensions. For general structural purposes, a cement:sand:aggregate mix of 1:2:4 (with a minimum cement dosage of 320kg/m3) shall be used unless otherwise noted.


Image courtesy Md. Sultan Mahmud, UNHCR

F1 Retaining Wall **Reinforced Concrete**

Context

Retaining walls enable the modification of steep terrain to provide level ground for safe use. Retaining walls resist significant loads from soil and below-ground water. Moreover, the failure of retaining walls presents grave safety risks from falling material and landslides. Hence care must be taken to ensure adequate retaining wall structural and drainage design.

The reinforced concrete retaining wall design is presented here alongside comparable stone masonry and stone gabion options. This design for a reinforced concrete retaining wall includes two height options: 1m high and 2m high. These heights and other dimensions may be adjusted to suit local conditions, noting that the design and any modifications should be verified by a local structural engineer to take into account local geological and hydrological conditions and local construction standards.

Reinforced concrete construction is relatively complex in comparison with brick masonry and ferrocement options, yet skills and materials for reinforced concrete construction are widely available. Reinforced concrete construction typically requires engagement of a construction contractor/ company, nevertheless local communities may be involved in providing labour for construction.

Several matters are critical to ensuring the structural integrity and proper functioning of the reinforced concrete retaining wall. Concrete should be mixed and poured in accordance with the material specifications to ensure structural integrity and avoid cracking. Steel should be placed in accordance with the drawings with adequate concrete cover. Poured concrete should be cured in accordance with the specifications to ensure adequate strength. Adequate drainage through weepholes and backfill should take into account local geological and hydrological conditions.

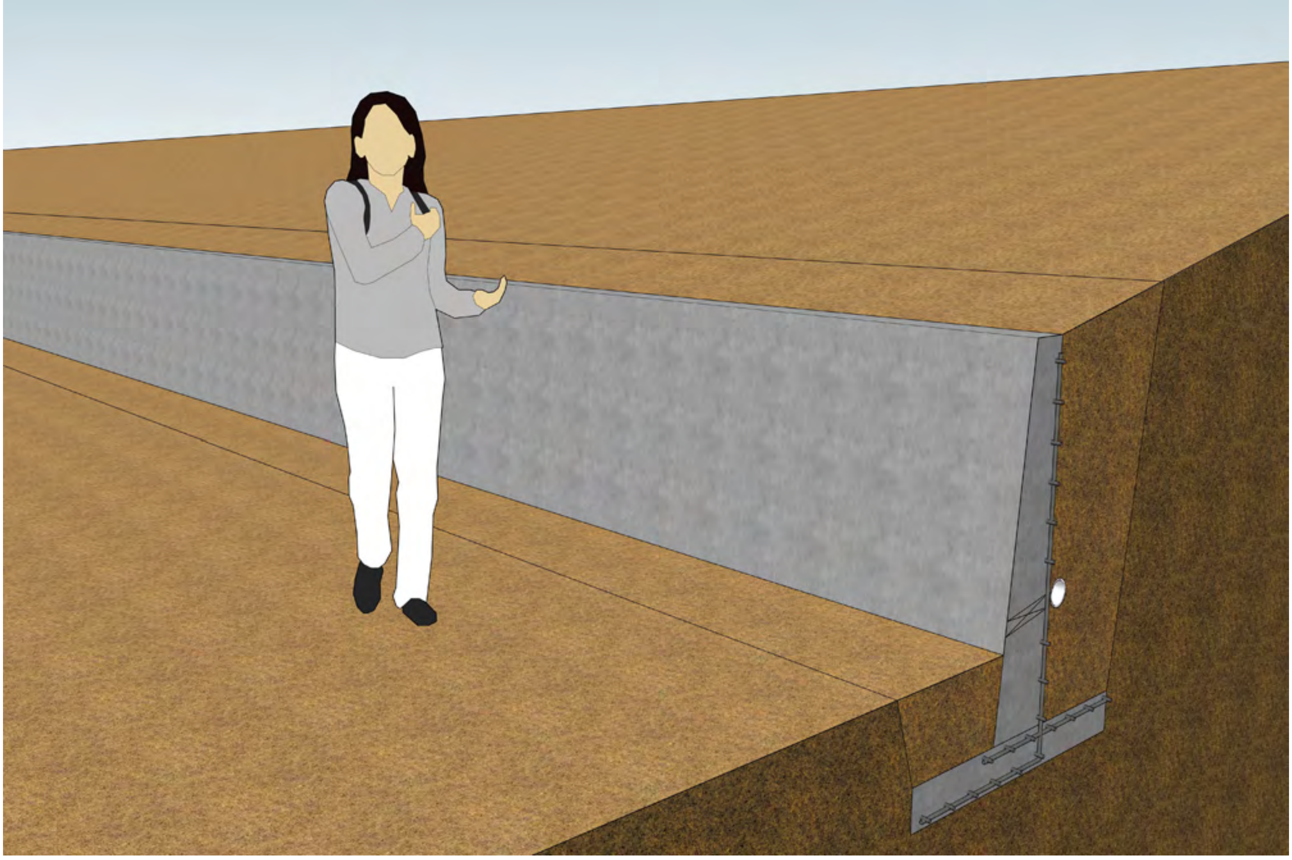
PROS	CONS
Strength and durability of reinforced concrete construction Flexibility of concrete construction enables adaptation to local terrain	High initial construction cost Long initial construction time Skilled labour requirements limit potential for involvment of local communities

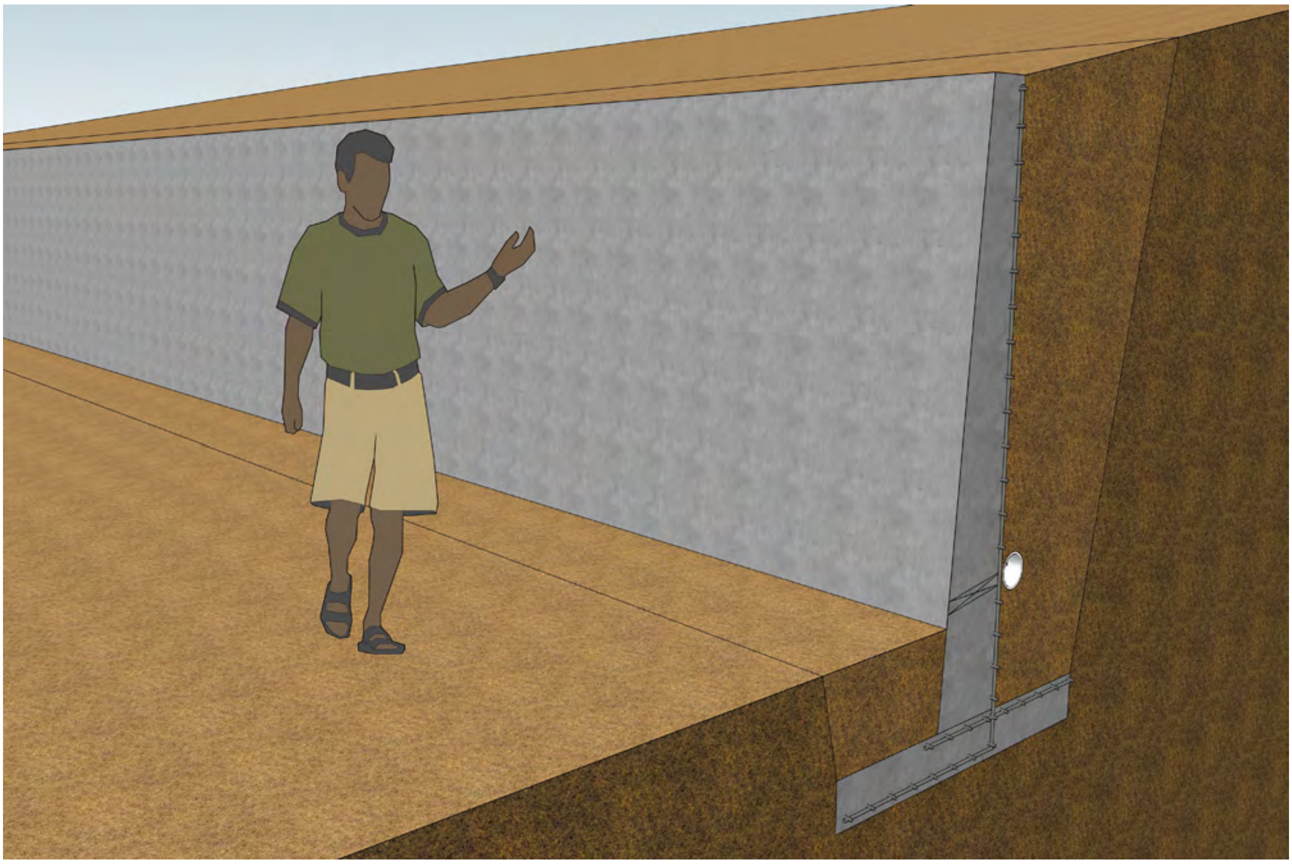
Affordability
(considering initial and operating costs)

Performance
(considering capacity and durability)

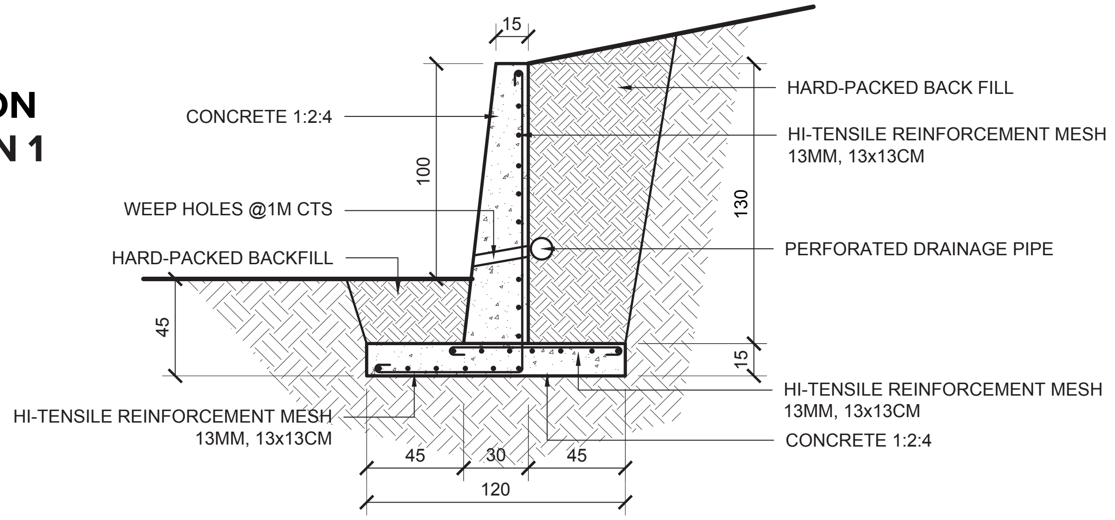
Environmental sustainability
(considering e-CO2-eq and reuse potential)

(Relatve affordability, performance and environmental impact will vary with prevailing conditions)

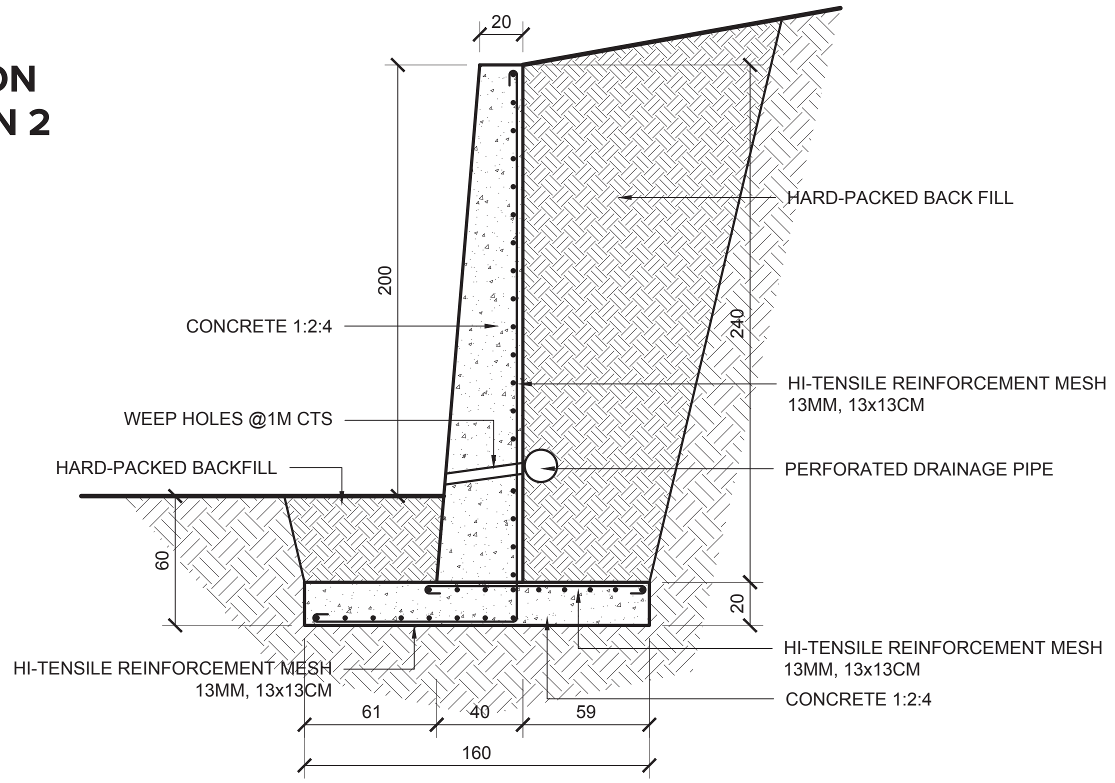




SECTION OPTION 1



SECTION OPTION 2



NOTES

1. Refer to Specification for material descriptions.
2. Structural design to be verified by local engineer for compliance with local conditions and norms
3. Ensure the correct water content of mixed concrete - slump test should yield < $\frac{1}{4}$ height reduction.
4. Slabs to be cast in a single pour. All concrete works to be vibrated or well rodded.
5. Ensure all poured concrete is kept damp and out of direct sunlight for at least 7 days while curing.

DWG NO.	TITLE	DRAWN BY	UNITS
F1-1	**Retaining Wall - Reinforced concrete** -	**AU**	**CM**
		CHECKED BY **RN**	SHEET **1 of 1**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:30**	DATE **31.08.2023**

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Technical Support Section
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Bill of Quantities

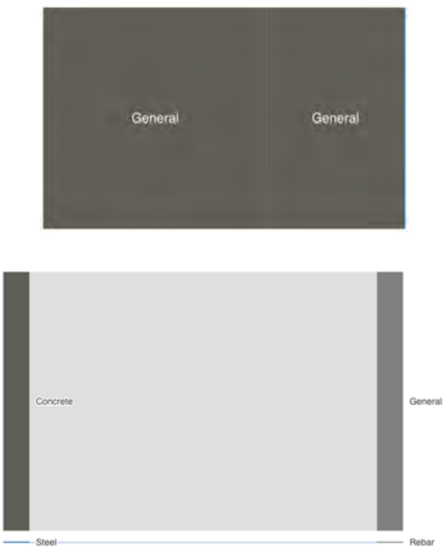
Ref	Item description	Unit	Quantity
	Quantities per m length of retaining wall		
	Option 1 - 1m high		
1.1	Concrete for reinforced concrete wall - 1:2:4	m3	2.95
1.2	Steel reinforcement for reinforced concrete wall - 13mm, high tensile	m	22.20
	or	kg	(23.30)
1.3	Concrete for reinforced concrete base - 1:2:4	m3	1.80
1.4	Steel reinforcement for reinforced concrete base - 13mm, high tensil	m	25.00
	or	kg	(26.25)
1.5	Excavation	m3	1.60
	Option 2 - 2m high		
2.1	Concrete for reinforced concrete wall - 1:2:4	m3	7.20
2.2	Steel reinforcement for reinforced concrete wall - 13mm, high tensile	m	40.00
	or	kg	(42.00)
2.3	Concrete for reinforced concrete base - 1:2:4	m3	3.20
2.4	Steel reinforcement for reinforced concrete base - 13mm, high tensil	m	33.00
	or	kg	(35.00)
2.5	Excavation	m3	3.60
	(Adjust quantities to suit dimension (height, width) adjustments)		

Environmental Impacts (per meter)

Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

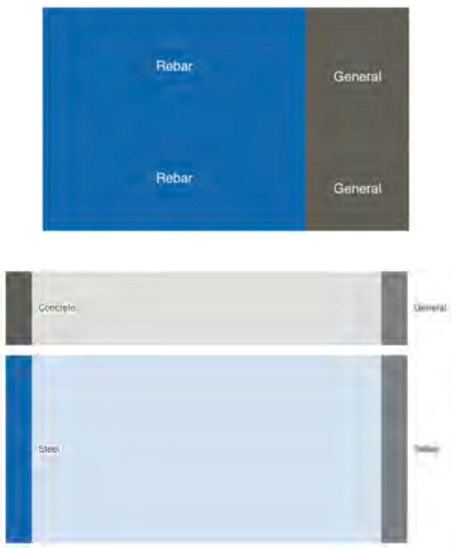
	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Concrete	9 500	19 731,5	997,5	20 729	608
Steel	41,96	121,69	4,41	126,09	1556,75
Total	9 541,96	19 853,19	1001,91	20 855,09	2164,75

Material weight (kg) [1]



Embodied carbon (kgCO2e) [2]

Embodied water (L) [5]



1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

2 Embodied carbon dioxide equivalent - expressed as kg.eCO2e - reflects the amount of various greenhouse gases associated with the production and use of the material. The metric converts other gases to the equivalent amount of CO2 with the same global warming potential.

3 Production embodied carbon reflects the component of eCO2e associated with material production. While embodied carbon from production differs with factors such as prevailing energy sources, a simplified calculation here uses coefficients derived from global averages.

4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

5 Embodied water reflects the amount of tap water used in production of the material. While embodied water depends on specific production processes, a simplified calculation here uses coefficients derived from global averages.

Specification

1 **GENERAL**

1.1 SCOPE

This specification is to be read in conjunction with the Drawings and Bill of Quantities (BOQ). In the event of any discrepancy, the Specification and Bill of Quantities takes precedence over Drawings.

1.2 LOCAL REGULATIONS AND STANDARDS

Work shall comply with local regulations and local construction standards. Discrepancies between designs and with regulations or standards shall be addressed before work commences.

Structural designs shall be reviewed by a local Engineer to confirm adequacy in relation to local regulations, construction practices, and site conditions.

2 **SITE**

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SETOUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

3 **MATERIALS**

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%. A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free from oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 CEMENT

Ordinary portland cement must be used before the expiry date. Cement should be kept dry and stored at least 15cm above ground to avoid ground moisture. Expired or damaged cement may be indicated by excessive grittiness or lumps of set cement.

3.5 CONCRETE

3.5.1 *Formwork*

Formwork for in-situ poured shall be straight and true with adequate bracing to avoid deformation under the load of poured concrete. Formwork may be constructed of plywood, sawn timber or steel according to local standards and concrete finish (appearance) requirements. Ensure adequate chamfer – around 2cm – at external corners.

Ensure that formwork construction enables removal without damage to concrete. To minimise adhesion of concrete, wet surfaces of formwork that will come in contact with concrete and apply a wash of limewash, linseed oil or soapy water.

3.5.2 *Concrete mix*

Concrete shall comprise Portland cement, sand, aggregate, and water as specified herein.

For general structural purposes, a cement:sand:aggregate mix of 1:2:4 (with a minimum cement dosage of 320kg/m3) shall be used unless otherwise noted. For water retaining structures (reservoir walls and bases) a cement:sand:aggregate mix of 1:1.5:3 shall be used unless otherwise noted (1:2:4 is not waterproof) (with a minimum cement dosage of 380kg/m3). For mass concrete applications a cement:sand:aggregate mix of 1:3:6 shall be used unless otherwise noted.

For hand mixing, additional cement should be added in accordance with the table below.

Mix	Cement		Sand (m3)	Aggregate (m3)
	Machine mix (kg)	Hand mix (kg)		
1 : 1.5 : 3	370	380	0.42	0.84
1 : 2 : 4	290	300	0.45	0.90
1 : 3 : 6	190	200	0.46	0.92

Source: Khanna, P.N. (1982) Indian Civil Engineers Handbook, 8th ed. Engineers Publishers: New Delhi

Ensure that concrete mixtures are not over watered – a bucket slump test of mixed concrete should yield less than ¼ reduction in the slump height.

3.5.3 *Concrete pouring*

Each concrete element – e.g., each concrete slab, each section of footing or parapet - shall be cast in a single pour.

3.5.4 *Concrete rodding and curing*

Cast concrete should be immediately covered with fabric, plastic sheet, straw, cement bags, sacking or leaves to keep the concrete moist and cool during the curing period. All concrete should be well vibrated or rodded to remove air voids. The concrete shall be cured with frequent watering at least twice daily for at least 10 days before use.

3.5.5 *Concrete finishing*

Provide a minimum 1% fall to water collection and drainage surfaces. Provide a rough, non-slip finish to trafficable concrete surfaces, e.g., by brushing the surface during curing.

3.6 STEEL REINFORCEMENT

Reinforcement bars shall be free from rust and of the correct type and size for concrete construction work (typically a characteristic yield stress of at least 210 N/mm^2). Steel reinforcement should be placed as per the designs (typically 7/8 of the slab or wall thickness) to ensure the bars function correctly in tension. All bars should have at least 12mm concrete cover.


Image courtesy Md. Sultan Mahmud, UNHCR

Context

Retaining walls enable the modification of steep terrain to provide level ground for safe use. Retaining walls resist significant loads from soil and below-ground water. Moreover, the failure of retaining walls presents grave safety risks from falling material and landslides. Hence care must be taken to ensure adequate retaining wall structural and drainage design.

The stone masonry retaining wall design is presented here alongside comparable reinforced concrete and stone gabion options. This design for a stone masonry retaining wall includes two form options - stepped and angled. The two options achieve the same 2.5m high functional outcome though provide flexibility to adapt to local construction norms.

The retaining wall height may be adjusted to suit local conditions, noting that the design and any modifications should be verified by a local structural engineer to take into account local geological and hydrological conditions and local construction standards.

The stone masonry design presented herein may be achieved in most situations where stone construction is common, suggesting the availability of the required skills and materials. In general, stone masonry and concrete construction will require engagement of a construction contractor/company. Nevertheless, local communities may be involved in providing labour for construction.

Several matters are critical to ensuring the structural integrity of the stone masonry culvert. Local engineering expertise should be engaged to verify and modify the design to structural footings/ foundations to take into account local geological conditions and local construction norms. Concrete should be mixed, poured and cured in accordance with the material specifications to ensure structural integrity and avoid cracking. Stone masonry should be cured in accordance with specifications.

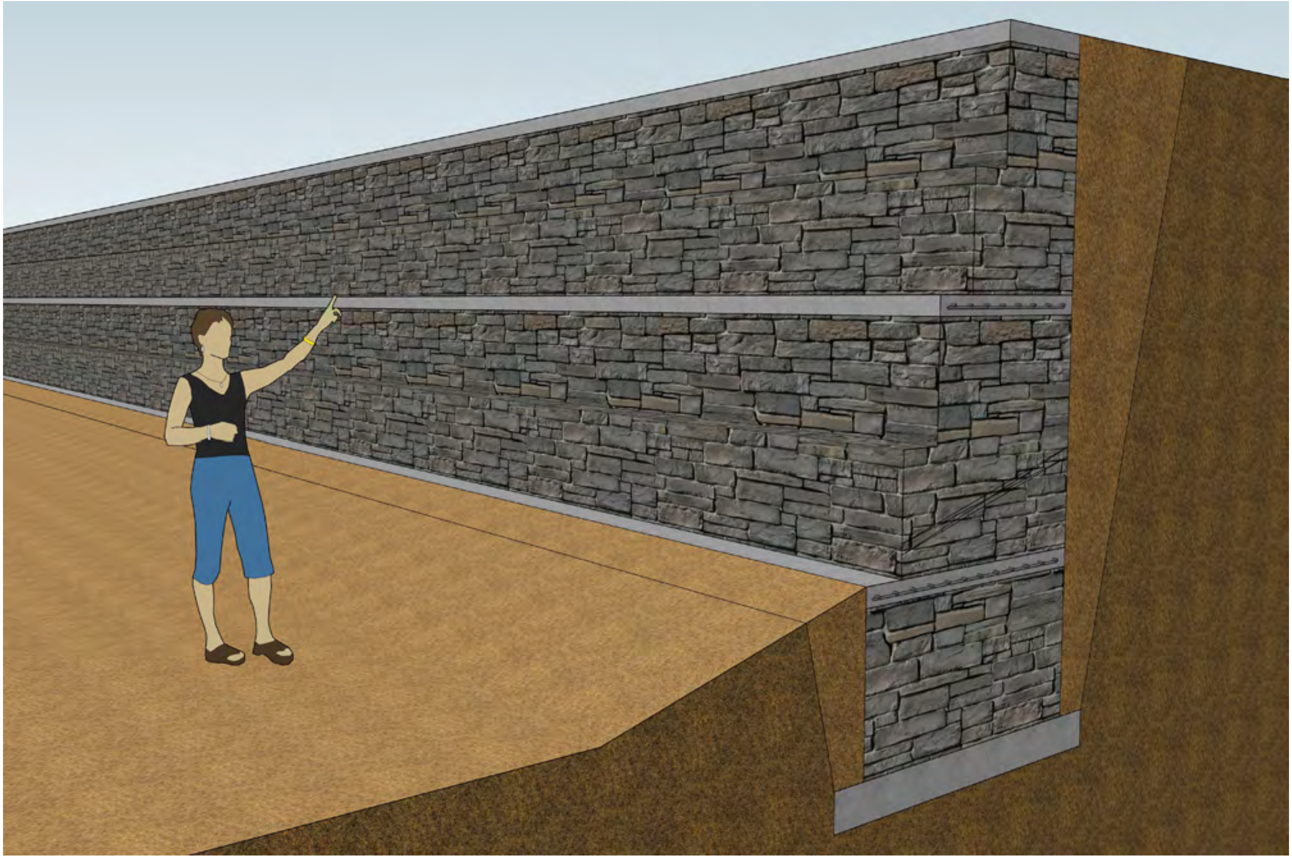
PROS	CONS
Strength and durability of stone masonry construction Flexibility of masonry construction enables adaptation to local terrain Widespread availability of materials and labour	Relatively slow initial construction Skilled labour requirements limit potential for involvment of local communities

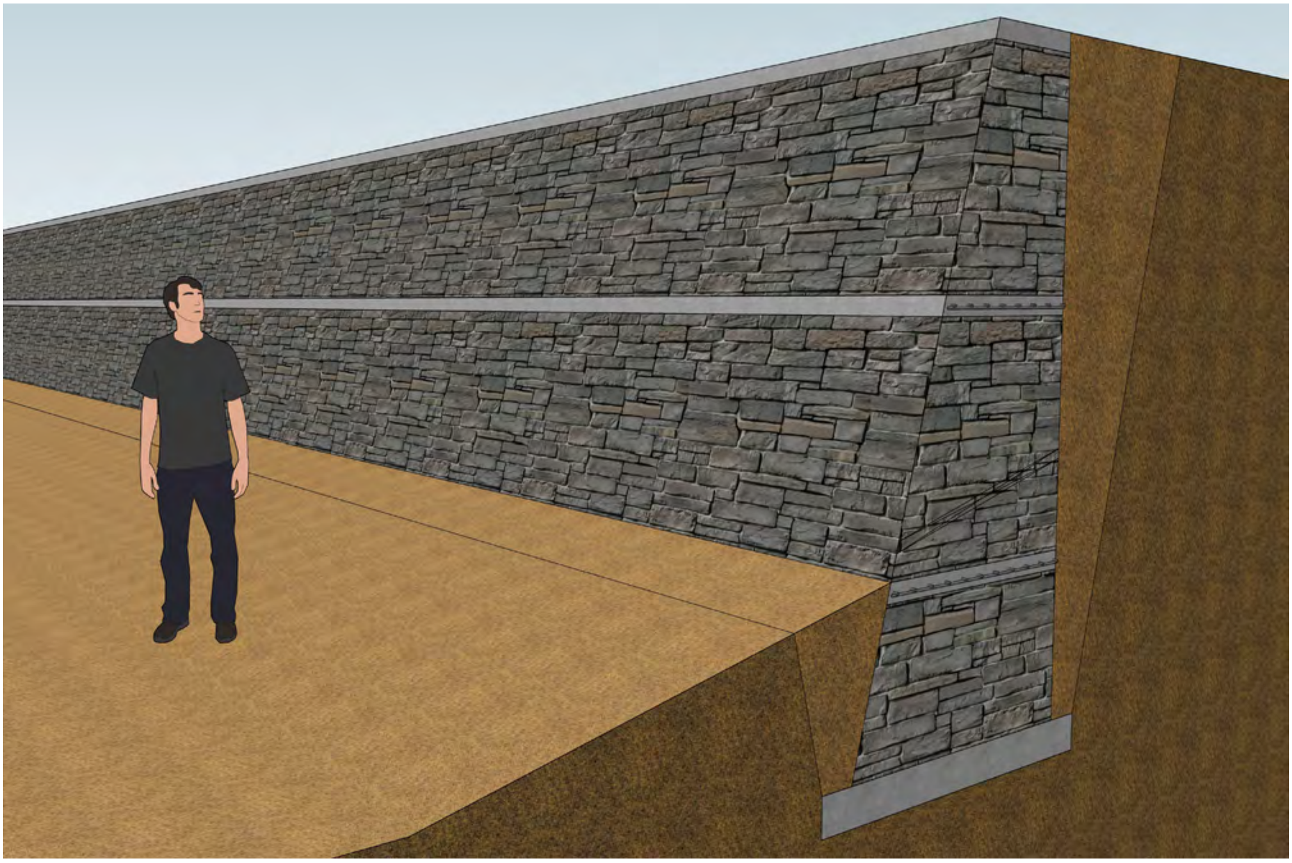
Affordability
(considering initial and operating costs)

Performance
(considering capacity and durability)

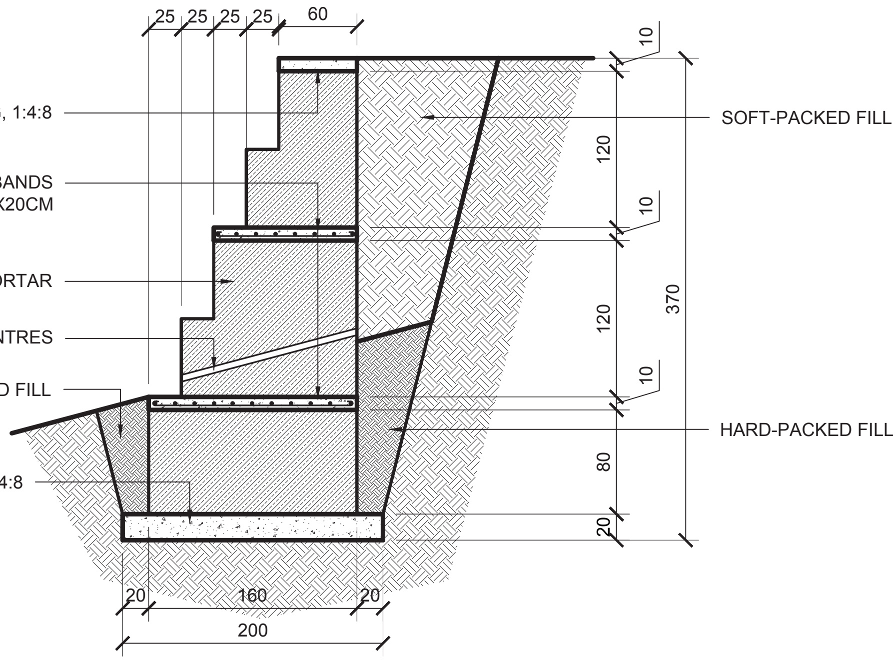
Environmental sustainability
(considering e-CO2-eq and reuse potential)

(Relatve affordability, performance and environmental impact will vary with prevailing conditions)

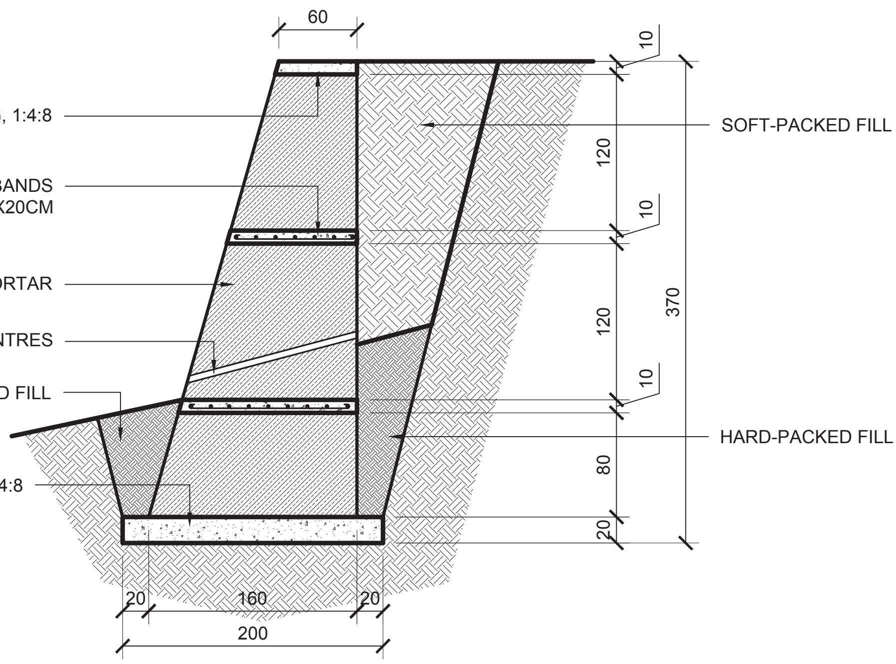




SECTION OPTION 1



SECTION OPTION 2



NOTES
1. Refer to Specification for material descriptions.
2. Structural design to be verified by local engineer for compliance with local conditions and norms
3. Ensure the correct water content of mixed concrete - slump test should yield < 1/4 height reduction.
4. Slabs to be cast in a single pour. All concrete works to be vibrated or well rodded.
5. Ensure all poured concrete is kept damp and out of direct sunlight for at least 7 days while curing.
6. Span and height dimensions nominal - adjust to suit site conditions and requirements.

DWG NO.	TITLE	DRAWN BY	UNITS
F2-1	**Retaining Wall - Stone Masonry** Option 1	**AU**	**CM**
		CHECKED BY **RN**	SHEET **1 of 2**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:50**	DATE **31.08.2023**

UNHCR The UN Refugee Agency
Technical Support Section
Community Infrastructure Catalogue

Bill of Quantities

Ref	Item description	Unit	Quantity
	Quantities per metre length of retaining wall		
	Option 1 - 2.6m high, stepped		
1.1	Concrete for capping - 1:4:8	m3	0.06
1.2	Concrete for reinforced concrete bands - 1:4:8	m3	0.27
1.3	Steel reinforcement for reinforced concrete bands - 13mm	m	35.80
	or	kg	(37.60)
1.4	Concrete for concrete base - 1:4:8	m3	0.40
1.5	Stone for stone masonry	m3	2.90
1.6	Cement mortar for stone masonry	m3	0.70
1.7	Excavation	m3	6.50
	Option 2 - 2.6m high, angled		
2.1	Concrete for capping - 1:4:8	m3	0.06
2.2	Concrete for reinforced concrete bands - 1:4:8	m3	0.24
2.3	Steel reinforcement for reinforced concrete bands - 13mm	m	31.00
	or	kg	(32.60)
2.4	Concrete for concrete base - 1:4:8	m3	0.40
2.5	Stone for stone masonry	m3	2.90
2.6	Cement mortar for stone masonry	m3	0.70
2.7	Excavation	m3	6.50
	(Adjust quantities to suit dimension (height, width) adjustments)		

Environmental Impacts (per meter)

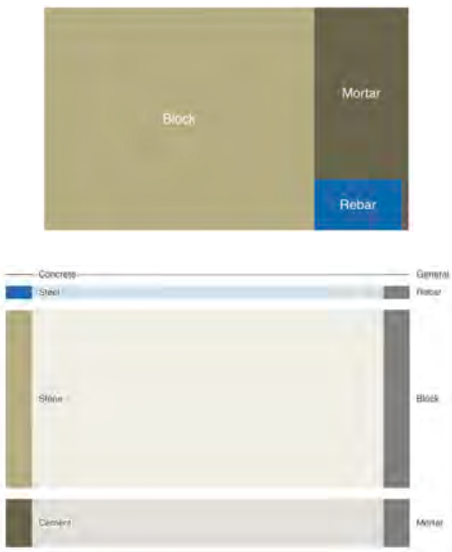
Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Concrete	1460	3 032,42	153,3	3 185,72	93,44
Steel	31,83	92,3	3,34	95,64	1180,75
Stone	8 352	659,81	559,81	1319,62	15 868,8
Cement	1155	404,25	121,27	525,53	4 273,5
Total	10 998,83	4 188,77	937,72	5 126,5	21416,49

Material weight (kg) [1]

Embodied carbon (kgCO2e) [2]

Embodied water (L) [5]



1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

2 Embodied carbon dioxide equivalent - expressed as kg.eCO2e - reflects the amount of various greenhouse gases associated with the production and use of the material. The metric converts other gases to the equivalent amount of CO2 with the same global warming potential.

3 Production embodied carbon reflects the component of eCO2e associated with material production. While embodied carbon from production differs with factors such as prevailing energy sources, a simplified calculation here uses coefficients derived from global averages.

4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

5 Embodied water reflects the amount of tap water used in production of the material. While embodied water depends on specific production processes, a simplified calculation here uses coefficients derived from global averages.

Specification

1 GENERAL

1.1 SCOPE

This specification is to be read in conjunction with the Drawings and Bill of Quantities (BOQ). In the event of any discrepancy, the Specification and Bill of Quantities takes precedence over Drawings.

1.2 LOCAL REGULATIONS AND STANDARDS

Work shall comply with local regulations and local construction standards. Discrepancies between designs and with regulations or standards shall be addressed before work commences.

Structural designs shall be reviewed by a local Engineer to confirm adequacy in relation to local regulations, construction practices, and site conditions.

2 SITE

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SET-OUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

3 MATERIALS

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%.

A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free from oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 CEMENT

Ordinary portland cement must be used before the expiry date. Cement should be kept dry and stored at least 15cm above ground to avoid ground moisture. Expired or damaged cement may be indicated by excessive grittiness or lumps of set cement.

3.5 CEMENT MORTAR

Cement mortar shall comprise Portland cement, sand and water as specified herein. A cement:sand ratio of 1:6 shall be used unless otherwise noted. Cement mortar in brick masonry and stone masonry shall be applied to a minimum thickness of 6-10mm unless otherwise noted. After laying, mortar within brick and stone masonry shall be cured (kept moist) for a minimum of 10 days.

3.6 CONCRETE

3.6.1 *Formwork*

Formwork for in-situ poured shall be straight and true with adequate bracing to avoid deformation under the load of poured concrete. Formwork may be constructed of plywood, sawn timber or steel according to local standards and concrete finish (appearance) requirements. Ensure adequate chamfer – around 2cm – at external corners.

Ensure that formwork construction enables removal without damage to concrete. To minimise adhesion of concrete, wet surfaces of formwork that will come in contact with concrete and apply a wash of limewash, linseed oil or soapy water.

3.6.2 *Concrete mix*

Concrete shall comprise Portland cement, sand, aggregate, and water as specified herein.

For general structural purposes, a cement:sand:aggregate mix of 1:2:4 (with a minimum cement dosage of 320kg/m3) shall be used unless otherwise noted. For water retaining structures (reservoir walls and bases) a cement:sand:aggregate mix of 1:1.5:3 shall be used unless otherwise noted (1:2:4 is not waterproof) (with a minimum cement dosage of 380kg/m3). For mass concrete applications a cement:sand:aggregate mix of 1:3:6 shall be used unless otherwise noted.

For hand mixing, additional cement should be added in accordance with the table below.

Mix	Cement		Sand (m3)	Aggregate (m3)
	Machine mix (kg)	Hand mix (kg)		
1 : 1.5 : 3	370	380	0.42	0.84
1 : 2 : 4	290	300	0.45	0.90
1 : 3 : 6	190	200	0.46	0.92

Source: Khanna, P.N. (1982) Indian Civil Engineers Handbook, 8th ed. Engineers Publishers: New Delhi

Ensure that concrete mixtures are not over watered – a bucket slump test of mixed concrete should yield less than ¼ reduction in the slump height.

3.6.3 *Concrete pouring*

Each concrete element – e.g., each concrete slab, each section of footing or parapet - shall be cast in a single pour.

3.6.4 *Concrete rodding and curing*

Cast concrete should be immediately covered with fabric, plastic sheet, straw, cement bags, sacking or leaves to keep the concrete moist and cool during the curing period. All concrete should be well vibrated or rodded to remove air voids. The concrete shall be cured with frequent watering at least twice daily for at least 10 days before use.

3.6.5 *Concrete finishing*

Provide a minimum 1% fall to water collection and drainage surfaces. Provide a rough, non-slip finish to trafficable concrete surfaces, e.g., by brushing the surface during curing.

3.7 STEEL REINFORCEMENT

Reinforcement bars shall be free from rust and of the correct type and size for concrete construction work (typically a characteristic yield stress of at least 210 N/mm^2). Steel reinforcement should be placed as per the designs (typically 7/8 of the slab or wall thickness) to ensure the bars function correctly in tension. All bars should have at least 12mm concrete cover.

3.8 STONE MASONRY

Stone masonry shall be laid in horizontal courses, with stones laid in a single day not exceeding 1m height to avoid excessive pressure on newly laid lower courses. Stones shall be laid by hand as close as possible with broadest side downwards. Joints and gaps between stones shall be filled with smaller stones.

Cement mortar joints should be 6-10mm. A cement : sand mix of 1:6 should be used for masonry mortar unless otherwise noted. Finished masonry shall be covered with plastic sheeting or textile and kept wet (cured) for minimum 10 days after laying.

F3 Retaining Wall **Stone Gabion**

Context

Retaining walls enable the modification of steep terrain to provide level ground for safe use. Retaining walls resist significant loads from soil and below-ground water. Moreover, the failure of retaining walls presents grave safety risks from falling material and landslides. Hence care must be taken to ensure adequate retaining wall structural and drainage design.

The stone masonry retaining wall design is presented here alongside comparable reinforced concrete and stone masonry options. This design for a stone masonry retaining wall includes two form options – stepping towards or away from the natural gradient. The two options achieve the same approximately 2m high functional outcome though provide flexibility to adapt to local spatial constraints and preferences.

Stone gabions provide a flexible retaining wall solution in that a higher retaining wall may be achieved with the addition of further stone-filled gabion cages. Ensure that additional levels are stepped adequately to ensure structural integrity. Any modifications should be verified by a local structural engineer to take into account local geological and hydrological conditions, in particular, ensuring the adequate loadbearing capacity of soil foundations.

In general, stone gabion construction enables significant involvement of local communities with adequate technical support and supervision.

Several matters are critical to ensuring the structural integrity of the stone gabion construction. The load-bearing capacity on soil foundations should be confirmed. Ensure that steel wire cages are of adequate strength in accordance with specifications. For gabion cages fabricated on-site, ensure steel mesh sheets are joined securely. Stones should be packed securely inside gabion cages to minimise lateral loading on wire cages.

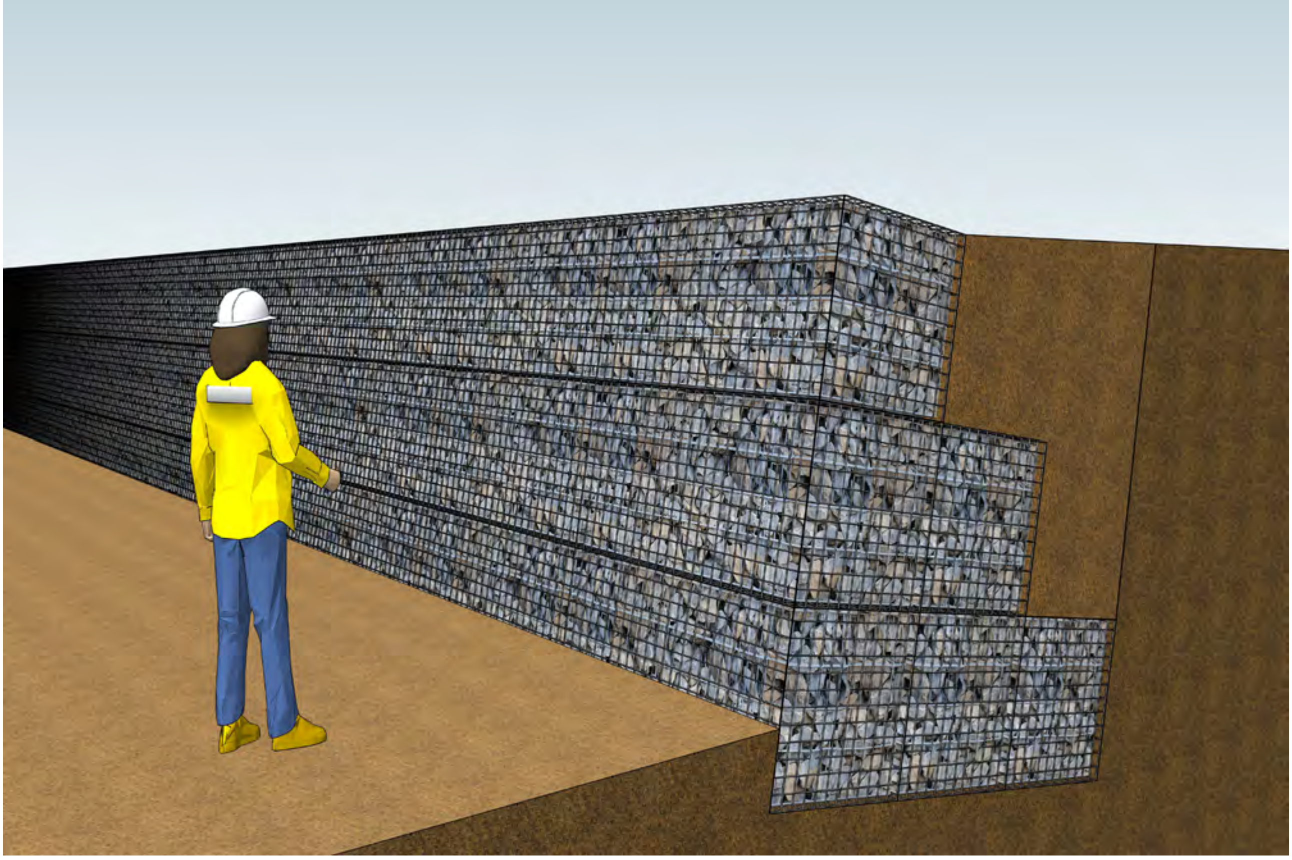
PROS	CONS
Basic skil requirements enable substantial local community involvement in construction Widespread availability of materials and labour Relatively low material costs	Wide base requirements entail inefficient use of land - not suitable for restricted areas Suitable wire mesh for gabion cages may not be widely available in some locations

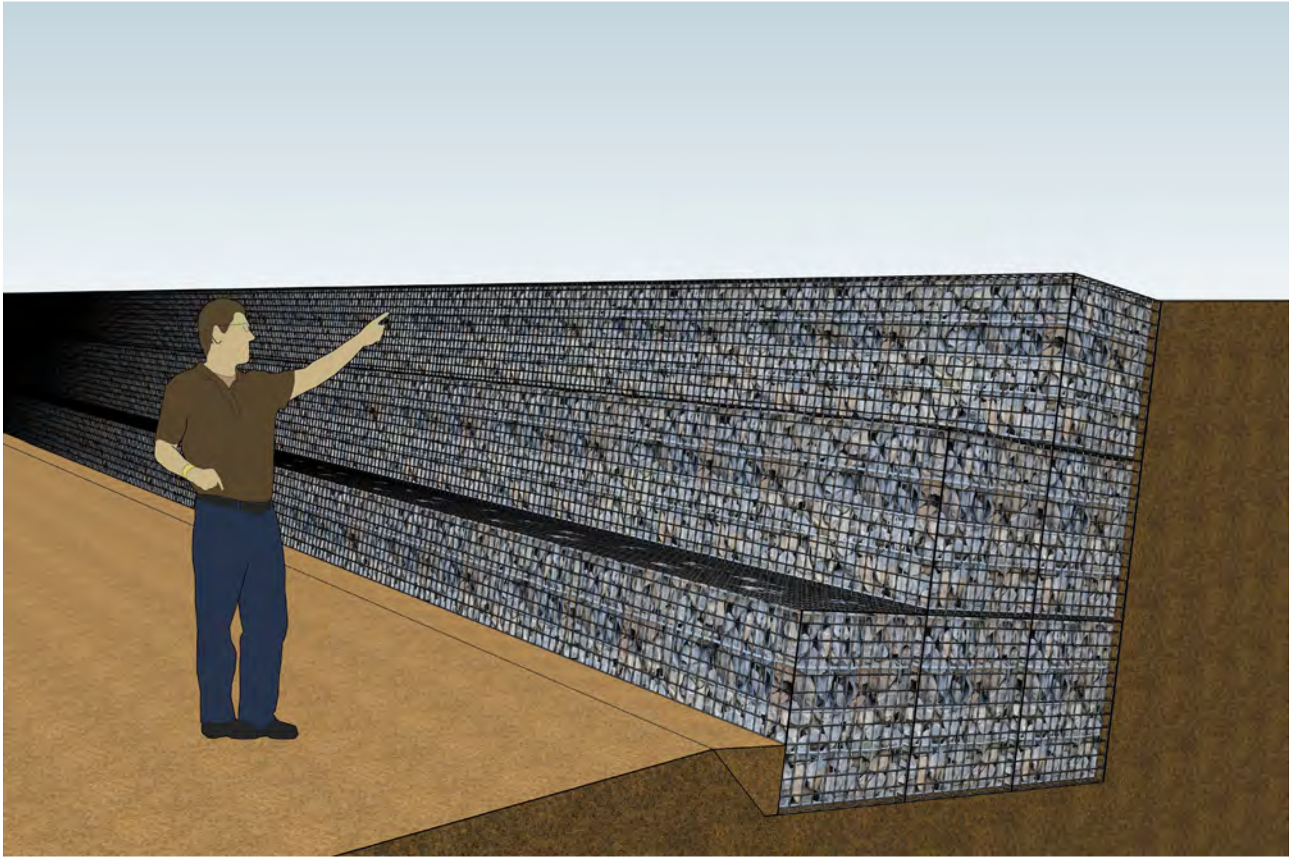
Affordability
(considering initial and operating costs)

Performance
(considering capacity and durability)

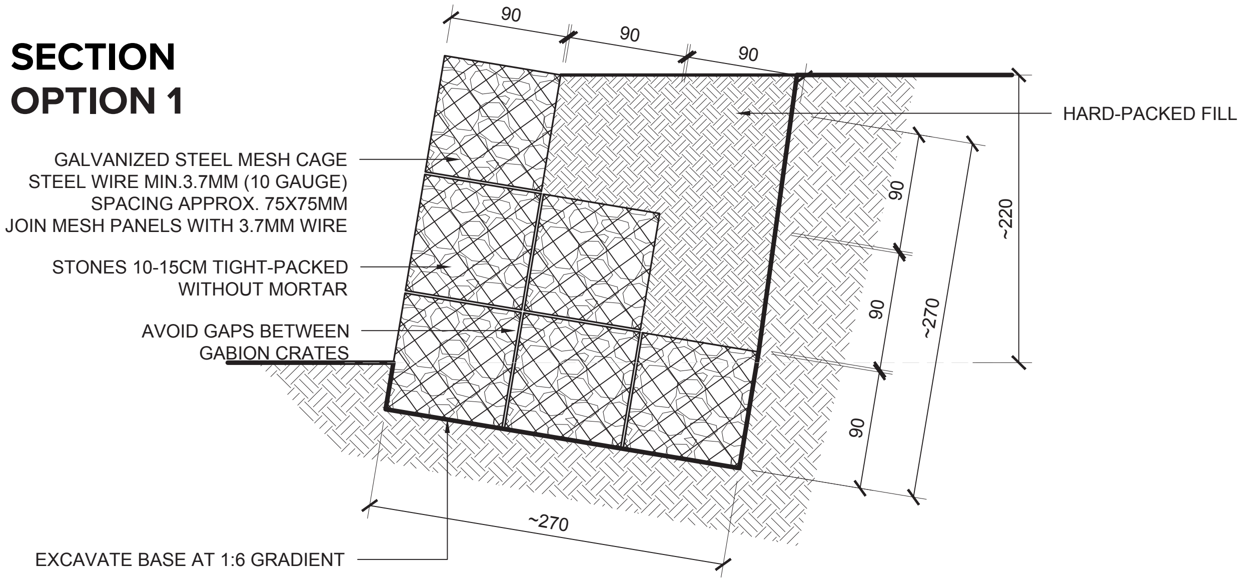
Environmental sustainability
(considering e-CO2-eq and reuse potential)

(Relatve affordability, performance and environmental impact will vary with prevailing conditions)

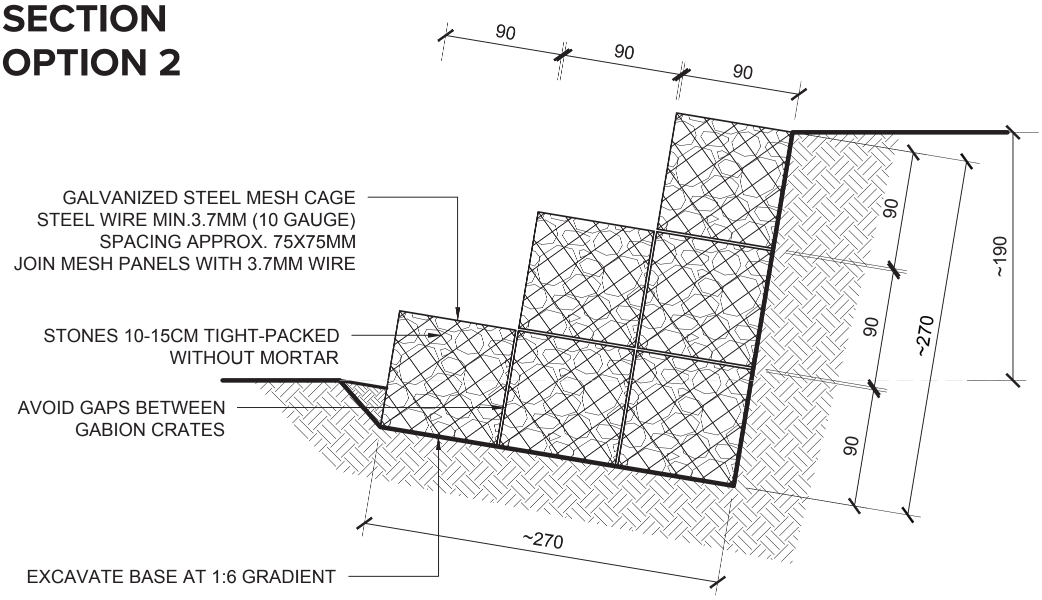




SECTION OPTION 1



SECTION OPTION 2



NOTES
1. Refer to Specification for material descriptions.
2. Structural design to be verified by local engineer for compliance with local conditions and norms
3. For locally-produced steel mesh, ensure adequate knotting (triple knotting)
4. Span and height dimensions nominal - adjust to suit site conditions and requirements.
5. Gabion crates nominal dimensions 90x180cm. Alternate dimensions may be used to facilitate local fabrication.

DWG NO.	TITLE	DRAWN BY	UNITS
F3-1	**Retaining Wall - Stone Gabion** -	**AU**	**CM**
		CHECKED BY **RN**	SHEET **1 of 1**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:50**	DATE **31.08.2023**

UNHCR The UN Refugee Agency
Technical Support Section
Community Infrastructure Catalogue

Bill of Quantities

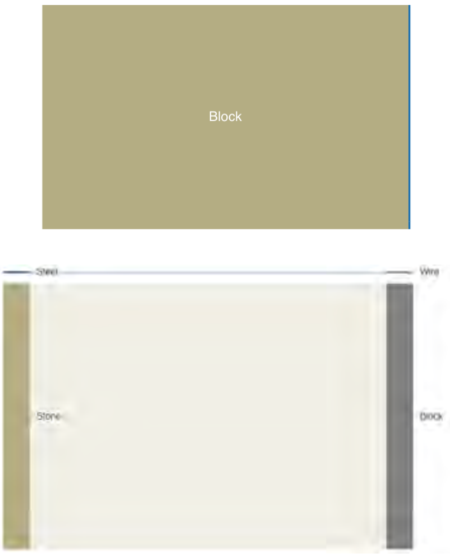
Ref	Item description	Unit	Quantity
	Quantities per metre length of retaining wall		
	Option 1 and Option 2		
1.1	Wire mesh for gabion cages - 3.7mm dia, 75 x 75mm spacing	m2	28
1.2	Wire for gabion mesh joints, 3.7mm dia	m	30.00
1.3	Stone for stone gabion fill - 10-15cm dia	m3	5.00
1.4	Excavation	m3	5.00
	(Adjust quantities to suit dimension (height, width) adjustments)		

Environmental Impacts (per meter)

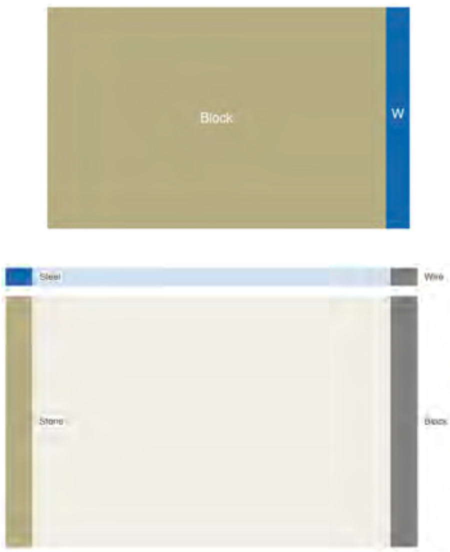
Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Steel	72,5	152,25	7,61	159,86	3 211,75
Stone	14 400	1137,6	1137,6	2 275,2	27 360
Total	14 472,5	1289,85	1145,21	2 435,06	30 571,75

Material weight (kg) [1]



Embodied carbon (kgCO2e) [2]



Embodied water (L) [5]

1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

2 Embodied carbon dioxide equivalent - expressed as kg.eCO2e - reflects the amount of various greenhouse gases associated with the production and use of the material. The metric converts other gases to the equivalent amount of CO2 with the same global warming potential.

3 Production embodied carbon reflects the component of eCO2e associated with material production. While embodied carbon from production differs with factors such as prevailing energy sources, a simplified calculation here uses coefficients derived from global averages.

4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

5 Embodied water reflects the amount of tap water used in production of the material. While embodied water depends on specific production processes, a simplified calculation here uses coefficients derived from global averages.

Specification

1 GENERAL

1.1 SCOPE

This specification is to be read in conjunction with the Drawings and Bill of Quantities (BOQ). In the event of any discrepancy, the Specification and Bill of Quantities takes precedence over Drawings.

1.2 LOCAL REGULATIONS AND STANDARDS

Work shall comply with local regulations and local construction standards. Discrepancies between designs and with regulations or standards shall be addressed before work commences.

Structural designs shall be reviewed by a local Engineer to confirm adequacy in relation to local regulations, construction practices, and site conditions.

2 SITE

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SET-OUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

3 MATERIALS

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%. A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free from oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 GABION CAGE WIRE MESH

Wire mesh cages for stone gabion walls shall be formed from welded hi-tensile wire mesh with minimum diameter of 3.7mm and minimum spacing of 75x75mm. A nominal cage size of 60x60x90cm may be adjusted to suit wire mesh and stone sizing and site constraints. Wire mesh panels to be joined using hi-tensile wire of minimum 3.7mm diameter, woven continuously through area adjacent mesh opening in connected panels.

3.5 STONE GABION

Gabions shall use stones of 10-20cm and not less than 10cm in any dimension. Gabion stones should be packed by hand as close as possible with broadest side downwards. Joints should be staggered. Gaps between stones should be filled with smaller stones to tightly pack all interstices.

Context

Bio-stabilisation of slopes may be used instead of retaining walls is situations of low or moderate gradients. In general, bio-stabilisation combines inert slope stabilisation (through walls/fences) with biological slope stabilisation through plant roots that bind the topsoil layer. Bio-stabilisation involves the insertion of live, woody plants into topsoil layers of slopes. Ensuing root growth reduces erosion and provides slope stability at steeper gradients.

A wide variety of bio-stabilisation techniques are available. Different techniques combine components of: 1) live, woody stems, 2) other branches for fence/ wall construction, and 3) geotextile. These different configurations of components are adapted to suit local conditions including the type of live, woody stems, the slope gradient, and local geological and hydrological conditions. The appropriate height and gradient of bio-stabilisation structures should be determined taking into account local conditions and requirements.

The principal limitation on use of bio-stabilisation is the availability of appropriate live, woody stems. A wide variety of plants may be used, including poplar, willow, cottonwood or similar. When considering use of bio-stabilisation of slopes, ensure adequate local availability of suitable species such that harvesting does not lead to deforestation or other negative impacts.

Two options for bio-stabilisation of slopes are presented herein: 1) tiered bio-stabilisation using fences, and 2) graded bio-stabilisation using hessian or geotextile sacks. Both options are widely applicable and may be adapted to a variety of local conditions subject to verification by a local civil engineer.

Characteristics and quantities of materials for biostabilisation of slopes depend upon local conditions and materials. Generic bills of quantities and specifications may be misleading and have thus been omitted from this catalogue.

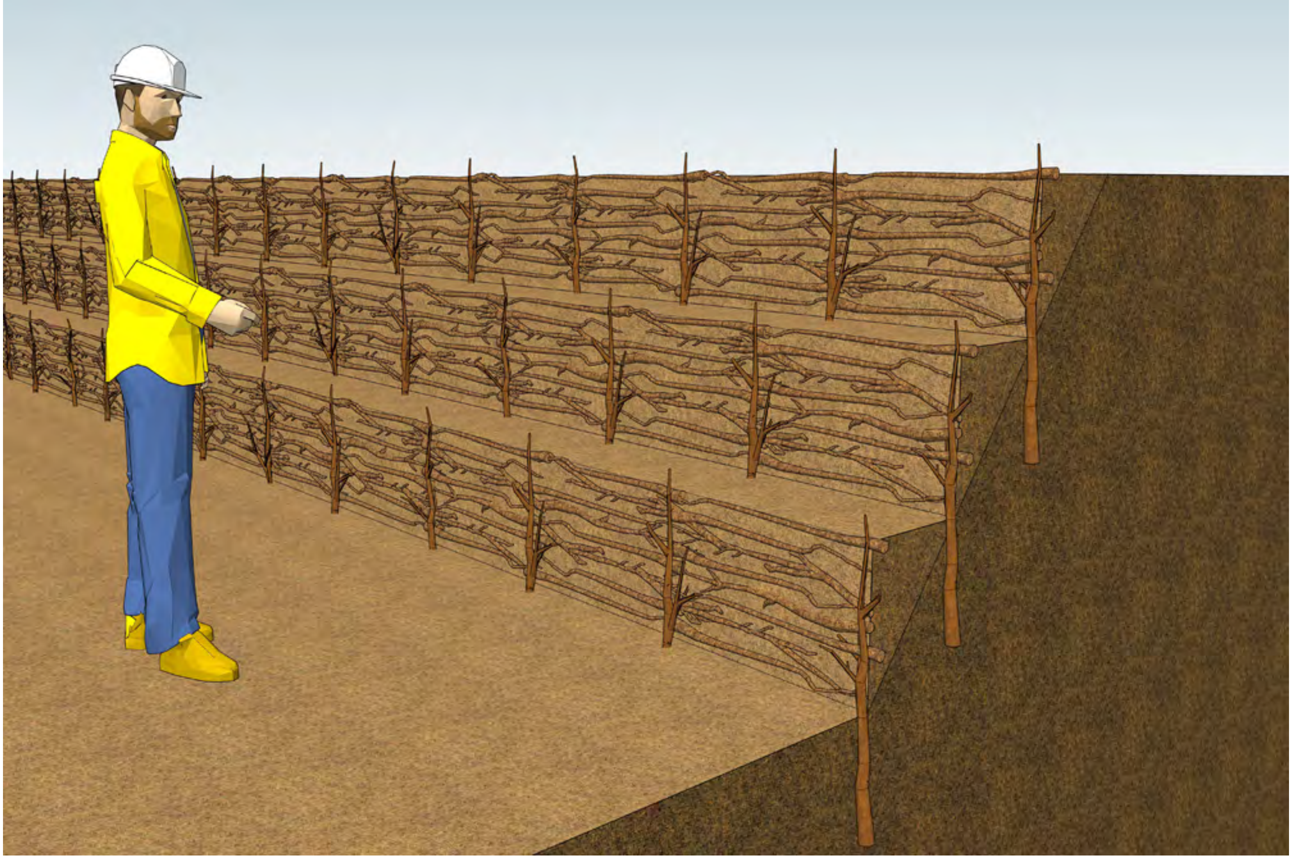
PROS	CONS
Very low environmental impact	Not suitable for steep gradients
Potential for use of locally-sourced materials	Requires sensitive adaptation to local soil conditions
Potential for extensive engagement of local communities	
Relatively low cost	

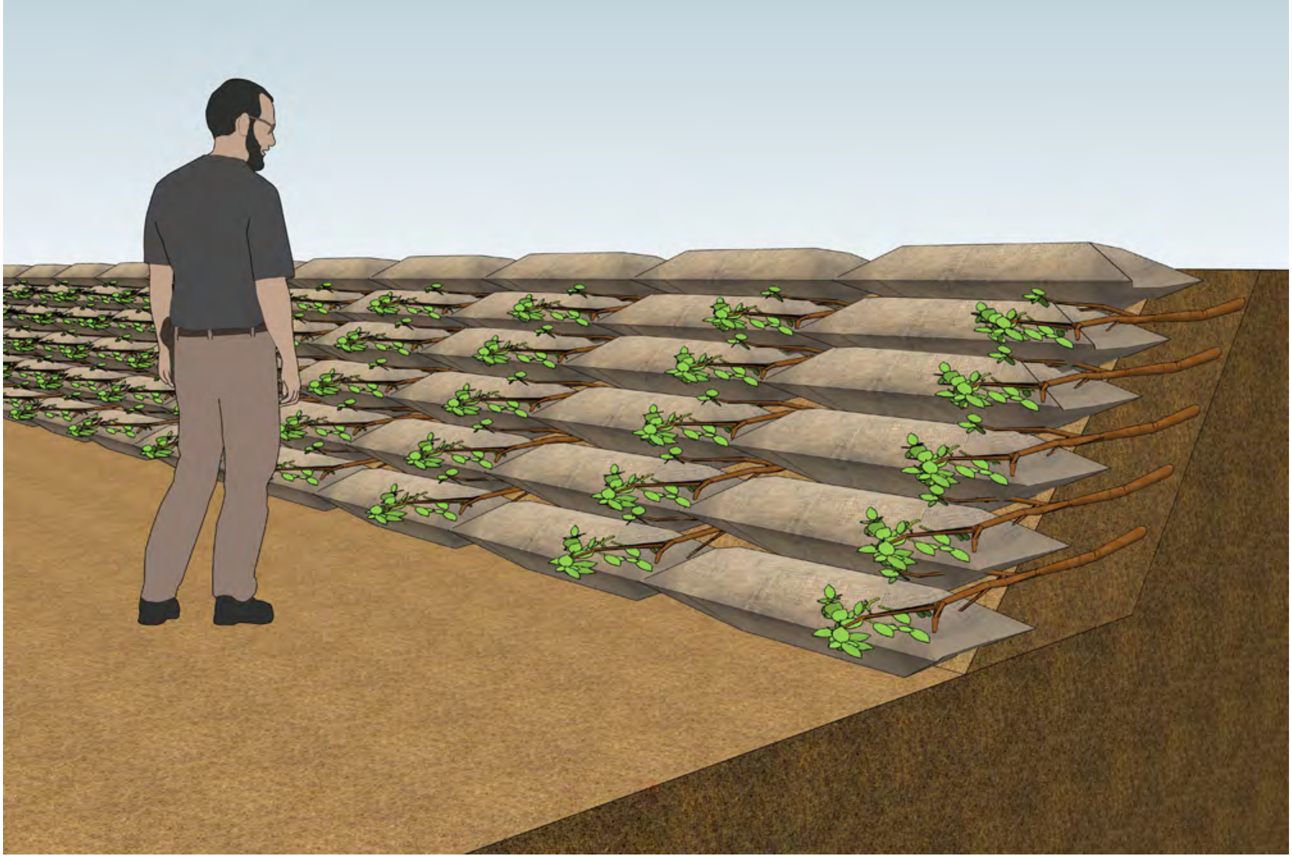
Affordability
(considering initial and operating costs)

Performance
(considering capacity and durability)

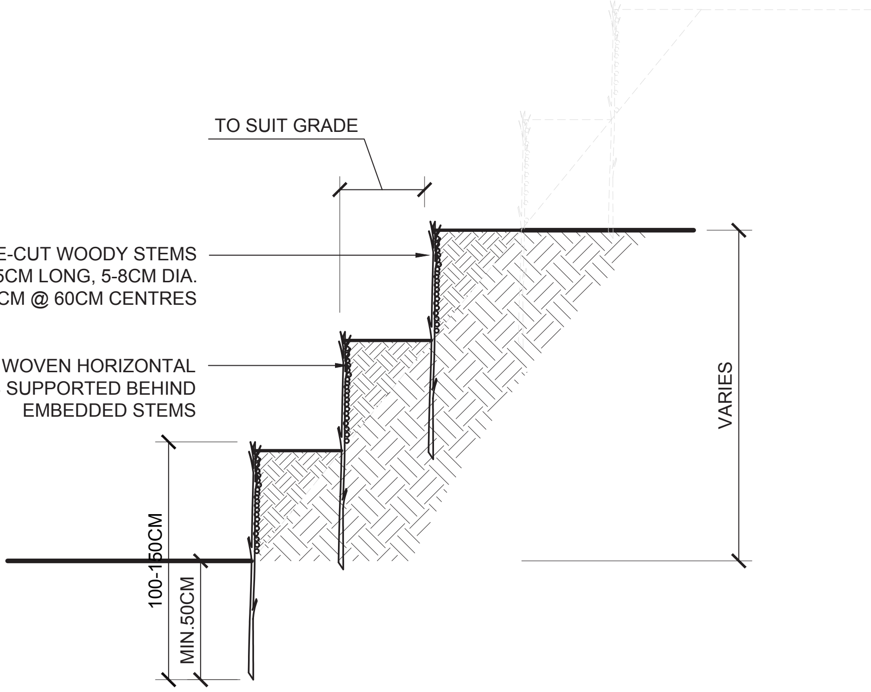
Environmental sustainability
(considering e-CO2-eq and reuse potential)

(Relatve affordability, performance and environmental impact will vary with prevailing conditions)





SECTION OPTION 1



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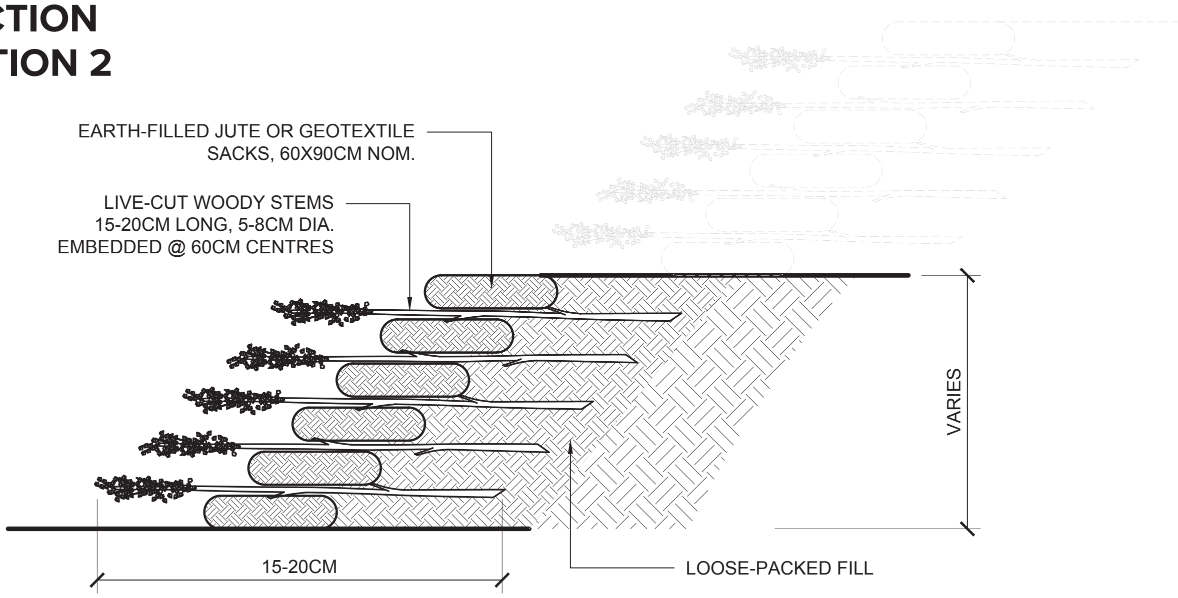

NOTES
1. Refer to Specification for material descriptions.
2. Woody stems to be live-cut - poplar, willow, cottonwood or similar (cutting during winter or autumn promotes root growth)
3. Span and height dimensions nominal - adjust to suit site conditions and requirements.
4. Use additional geo-textile fabric on fill surfaces to reduce surface erosion

DWG NO. F4-1	TITLE **Retaining Wall - Biostabilised** - PROJECT **Community Infrastructure Catalogue**	DRAWN BY **AU** CHECKED BY **RN** SCALE **1:30**	UNITS **CM** SHEET **1 of 1** DATE **31.08.2023**

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Image courtesy Md. Sultan Mahmud, UNHCR

Context

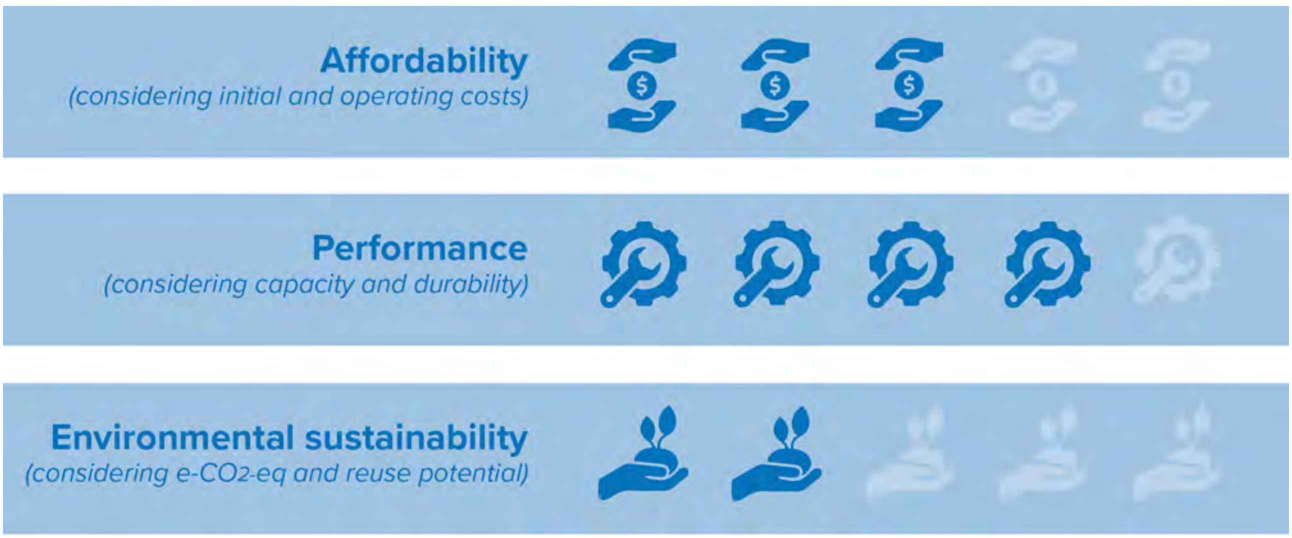
Laundry pads enable convenient clothes washing at centralised points to support efficient use of water and hygienic drainage that minimises risk of water contamination. Accessibility and durability in wet conditions are important considerations in laundry pad design.

This design for a laundry pad featuring a reinforced concrete apron is drawn from the UN Habitat *Guidelines for Community Infrastructure* (2012). The tap stand has an apron area of 7m2, accommodates eight wash points (stools), and provides drainage to a soakage pit.

Reinforced concrete is a common solution for wet aprons, providing a durable, accessible surface that facilitates access and drainage. Reinforced concrete construction is relatively complex, yet skills and materials for reinforced concrete construction are widely available. Reinforced concrete construction typically requires engagement of a construction contractor/company.

To ensure the structural integrity and proper functioning of the reinforced concrete apron, concrete should be mixed, poured and cured in accordance with the material specifications to ensure structural integrity and avoid cracking. Concrete should be laid to ensure adequate falls in accordance with the design.

PROS	CONS
Strength and durability of apron surface and associated maintenance requirements Flexibility regarding size and shape enables adaptation to site and capacity requirements Common availability of materials and skills for construction and maintenance	Relatively high initial construction costs Skills for reinforced concrete construction typically requires involvement of a construction contractor Limited reuse or modification/adaptation potential

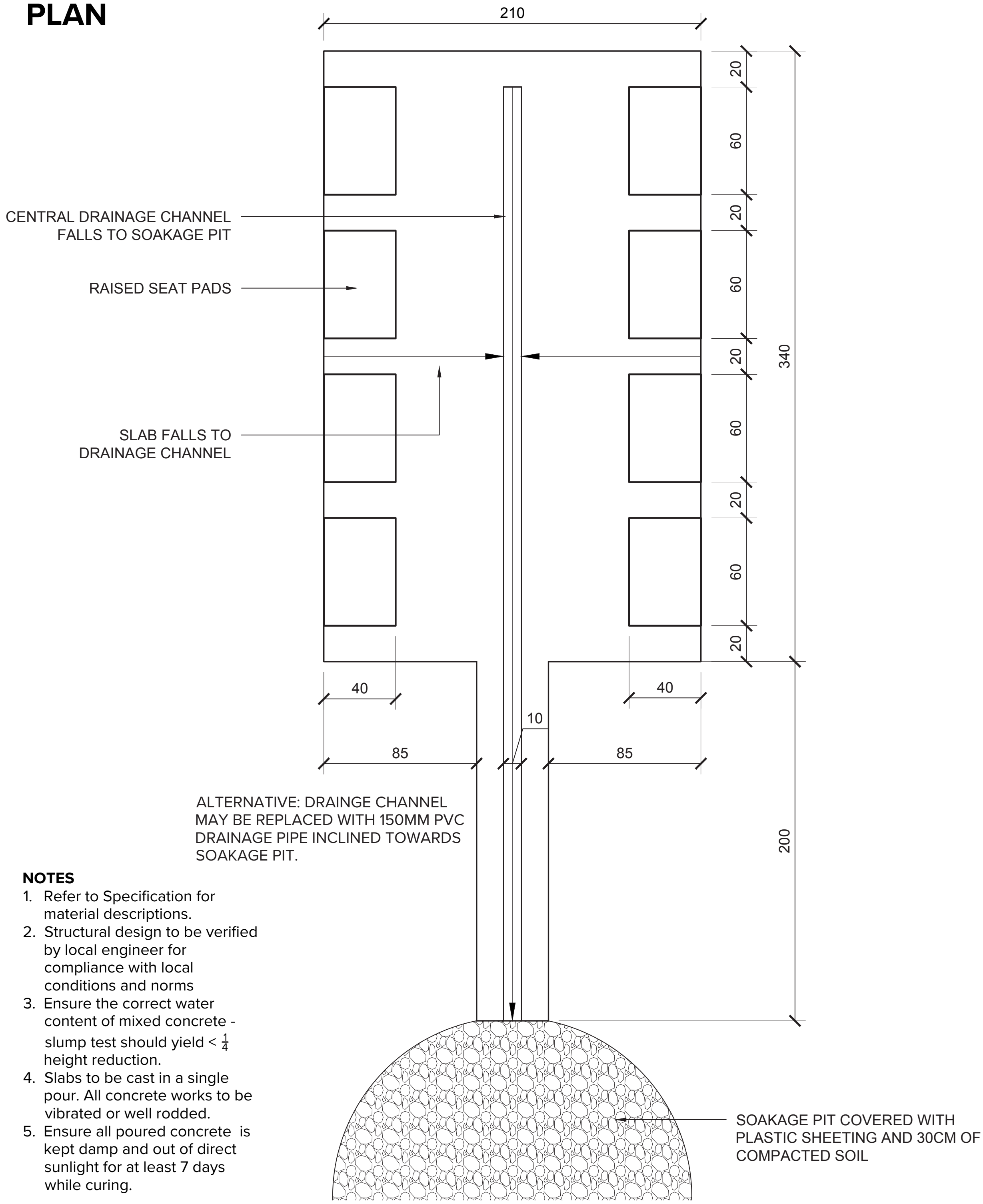


(Relatve affordability, performance and environmental impact will vary with prevailing conditions)

Bill of Quantities

Ref	Item description	Unit	Quantity
1	Concrete for reinforced concrete slab - 1:2:4	m3	9
2	Steel reinforcement for reinforced concrete slab - 6mm dia	m	82
	or	kg	(18.2)
3	Coarse Gravel (12mm – 25mm)	m3	1.9
4	Compacted Hardcore Sub-Base	m3	1.2

PLAN



NOTES
1. Refer to Specification for material descriptions.
2. Structural design to be verified by local engineer for compliance with local conditions and norms
3. Ensure the correct water content of mixed concrete - slump test should yield < $\frac{1}{4}$ height reduction.
4. Slabs to be cast in a single pour. All concrete works to be vibrated or well rodded.
5. Ensure all poured concrete is kept damp and out of direct sunlight for at least 7 days while curing.

DWG NO.	TITLE	DRAWN BY	UNITS
G1-2	**Laundry Pad - Reinforced concrete** Section	**AU**	**CM**
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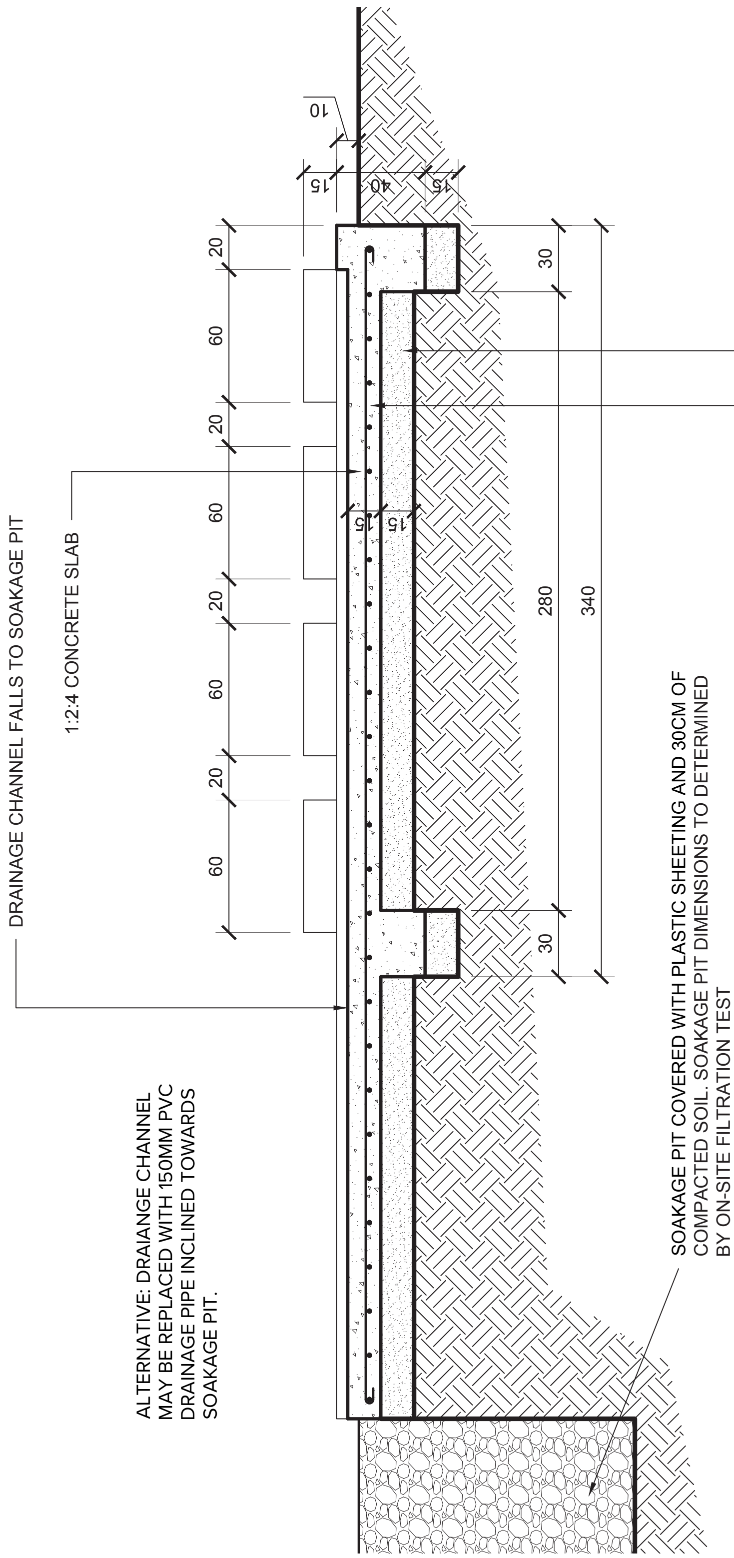

SECTION

NOTES

1. Refer to Specification for material descriptions.
2. Structural design to be verified by local engineer for compliance with local conditions and norms
3. Ensure the correct water content of mixed concrete - slump test should yield < $\frac{1}{4}$ height reduction.
4. Slabs to be cast in a single pour. All concrete works to be vibrated or well rodded.
5. Ensure all poured concrete is kept damp and out of direct sunlight for at least 7 days while curing.

DWG NO.	TITLE	DRAWN BY	UNITS
G1-2	**Laundry Pad - Reinforced concrete** Section	**AU**	**CM**
		CHECKED BY **RN**	SHEET **2 of 2**
	PROJECT **Community Infrastructure Catalogue**	SCALE **1:30**	DATE **31.08.2023**

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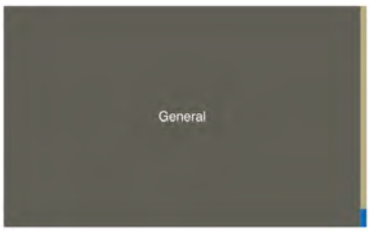
Environmental Impacts

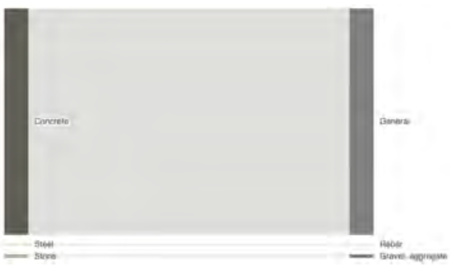
Based on assessments using the UNHCR Shelter Sustainability Assessment Tool

	Material weight (kg) [1]	Embodied Carbon (kg) [2]			Embodied water (L) [5]
		Production [3]	Transportation [4]	Total	
Concrete	18 000	37 386	1890	39 276	1152
Steel	18,04	52,32	1,89	54,21	669,28
Stone	6944	48,61	548,58	597,18	13 193,6
Total	24 962,04	37 486,92	2 440,47	39 927,39	15 014,88

Material weight (kg) [1]

Embodied carbon (kgCO2e) [2]





Embodied water (L) [5]

1 Each material in the BOQ is included in the assessment of environmental impacts. Material weights are presented to provide an overview of the amounts of each material used in the infrastructure.

2 Embodied carbon dioxide equivalent - expressed as kg.eCO2e - reflects the amount of various greenhouse gases associated with the production and use of the material. The metric converts other gases to the equivalent amount of CO2 with the same global warming potential.

3 Production embodied carbon reflects the component of eCO2e associated with material production. While embodied carbon from production differs with factors such as prevailing energy sources, a simplified calculation here uses coefficients derived from global averages.

4 Transportation embodied carbon reflects the component of eCO2e associated with material transportation from production site to the construction site. A simplified estimation here assumes production and use in the same country and a national land area equivalent to that of Kenya.

5 Embodied water reflects the amount of tap water used in production of the material. While embodied water depends on specific production processes, a simplified calculation here uses coefficients derived from global averages.

Specification

1 GENERAL

1.1 SCOPE

This specification is to be read in conjunction with the Drawings and Bill of Quantities (BOQ). In the event of any discrepancy, the Specification and Bill of Quantities takes precedence over Drawings.

1.2 LOCAL REGULATIONS AND STANDARDS

Work shall comply with local regulations and local construction standards. Discrepancies between designs and with regulations or standards shall be addressed before work commences.

Structural designs shall be reviewed by a local Engineer to confirm adequacy in relation to local regulations, construction practices, and site conditions.

2 SITE

2.1 SITE SELECTION

The site of works shall be selected to avoid risks of flooding, erosion, subsidence, exposure to high winds, contamination of ground water, and other avoidable risks.

2.2 SITE SET-OUT

The location of works shall be checked, set-out (marked) and approved before work commences.

2.3 SOIL CONDITIONS AND TESTING

Site soil conditions shall be assessed prior to commencement of works for suitability in relation to structural and hydraulic requirements.

2.4 SOAKAGE PITS

Sizing of soakage pits, trenches and drain fields depends on local site soil infiltration rates and the quantity of wastewater that is expected. Soakage pit dimensions should be determined by on-site soil infiltration tests, considering soil types and infiltration rates noted below.

	Infiltration rate (litres/m2/day)	
	clean water	wastewater
Sand	720-2400	33-50
Sandy loam	480-720	24
Silt loam	240-480	18
Clay loam	120-240	8
Clay	24-120	Unsuitable

Source: Davis & Lambert (2002) Engineering in Emergencies, 2nd edition. Practical Action Publishing: Warwickshire

Water collection and usage points should be equipped with adequately designed soakage systems located at least 30 metres away from groundwater sources. A soakage pit base must be at least 1.5m above the highest average groundwater table level.

2.5 PREVENTION OF SURFACE OR GROUNDWATER CONTAMINATION

Location and construction of water supply related infrastructure must avoid contamination of surface water and groundwater sources. Risks are generally low and related to contamination from water treatment chemicals, water treatment by-products and contamination from wastewater.

3 MATERIALS

3.1 SAND

Sand should be clean, sharp, angular (gritty to touch), clean and free from impurities. River or pit sand should be used rather than sea sand which contains salt and other impurities that affect structural applications. All sands should be washed before use to ensure a clay/silt content of no more than 6%.

A rough field test of sand may be carried out by rubbing a sample of sand between damp hands and noting the extent of discolouration from soil, dust or other impurities.

3.2 WATER

Water used for construction should be non-saline, and free from oils, acids, alkalies and from impurities including soil/mud and organic matter.

3.3 GRAVEL AND AGGREGATE

Gravel and aggregate for concrete and compacted sub-bases shall be clean and free from impurities including soil, dust, and organic material. Aggregates for concrete shall be 12-25mm to minimise crack propagation across load bearing concrete structures and to ensure an adequate covering of steel reinforcement.

3.4 CEMENT

Ordinary portland cement must be used before the expiry date. Cement should be kept dry and stored at least 15cm above ground to avoid ground moisture. Expired or damaged cement may be indicated by excessive grittiness or lumps of set cement.

3.5 CONCRETE

3.5.1 *Formwork*

Formwork for in-situ poured shall be straight and true with adequate bracing to avoid deformation under the load of poured concrete. Formwork may be constructed of plywood, sawn timber or steel according to local standards and concrete finish (appearance) requirements. Ensure adequate chamfer – around 2cm – at external corners.

Ensure that formwork construction enables removal without damage to concrete. To minimise adhesion of concrete, wet surfaces of formwork that will come in contact with concrete and apply a wash of limewash, linseed oil or soapy water.

3.5.2 *Concrete mix*

Concrete shall comprise Portland cement, sand, aggregate, and water as specified herein.

For general structural purposes, a cement:sand:aggregate mix of 1:2:4 (with a minimum cement dosage of 320kg/m3) shall be used unless otherwise noted. For water retaining structures (reservoir walls and bases) a cement:sand:aggregate mix of 1:1.5:3 shall be used unless otherwise noted (1:2:4 is not waterproof) (with a minimum cement dosage of 380kg/m3). For mass concrete applications a cement:sand:aggregate mix of 1:3:6 shall be used unless otherwise noted.

For hand mixing, additional cement should be added in accordance with the table below.

Mix	Cement Machine mix (kg)	Cement Hand mix (kg)	Sand (m3)	Aggregate (m3)
1 : 1.5 : 3	370	380	0.42	0.84
1 : 2 : 4	290	300	0.45	0.90
1 : 3 : 6	190	200	0.46	0.92

Source: Khanna, P.N. (1982) Indian Civil Engineers Handbook, 8th ed. Engineers Publishers: New Delhi

Ensure that concrete mixtures are not over watered – a bucket slump test of mixed concrete should yield less than ¼ reduction in the slump height.

3.5.3 *Concrete pouring*

Each concrete element – e.g., each concrete slab, each section of footing or parapet - shall be cast in a single pour.

3.5.4 *Concrete rodding and curing*

Cast concrete should be immediately covered with fabric, plastic sheet, straw, cement bags, sacking or leaves to keep the concrete moist and cool during the curing period. All concrete should be well vibrated or rodded to remove air voids. The concrete shall be cured with frequent watering at least twice daily for at least 10 days before use.

3.5.5 *Concrete finishing*

Provide a minimum 1% fall to water collection and drainage surfaces. Provide a rough, non-slip finish to trafficable concrete surfaces, e.g., by brushing the surface during curing.

3.6 STEEL REINFORCEMENT

Reinforcement bars shall be free from rust and of the correct type and size for concrete construction work (typically a characteristic yield stress of at least 210 N/mm^2). Steel reinforcement should be placed as per the designs (typically 7/8 of the slab or wall thickness) to ensure the bars function correctly in tension. All bars should have at least 12mm concrete cover.


Image courtesy Md. Sultan Mahmud, UNHCR

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