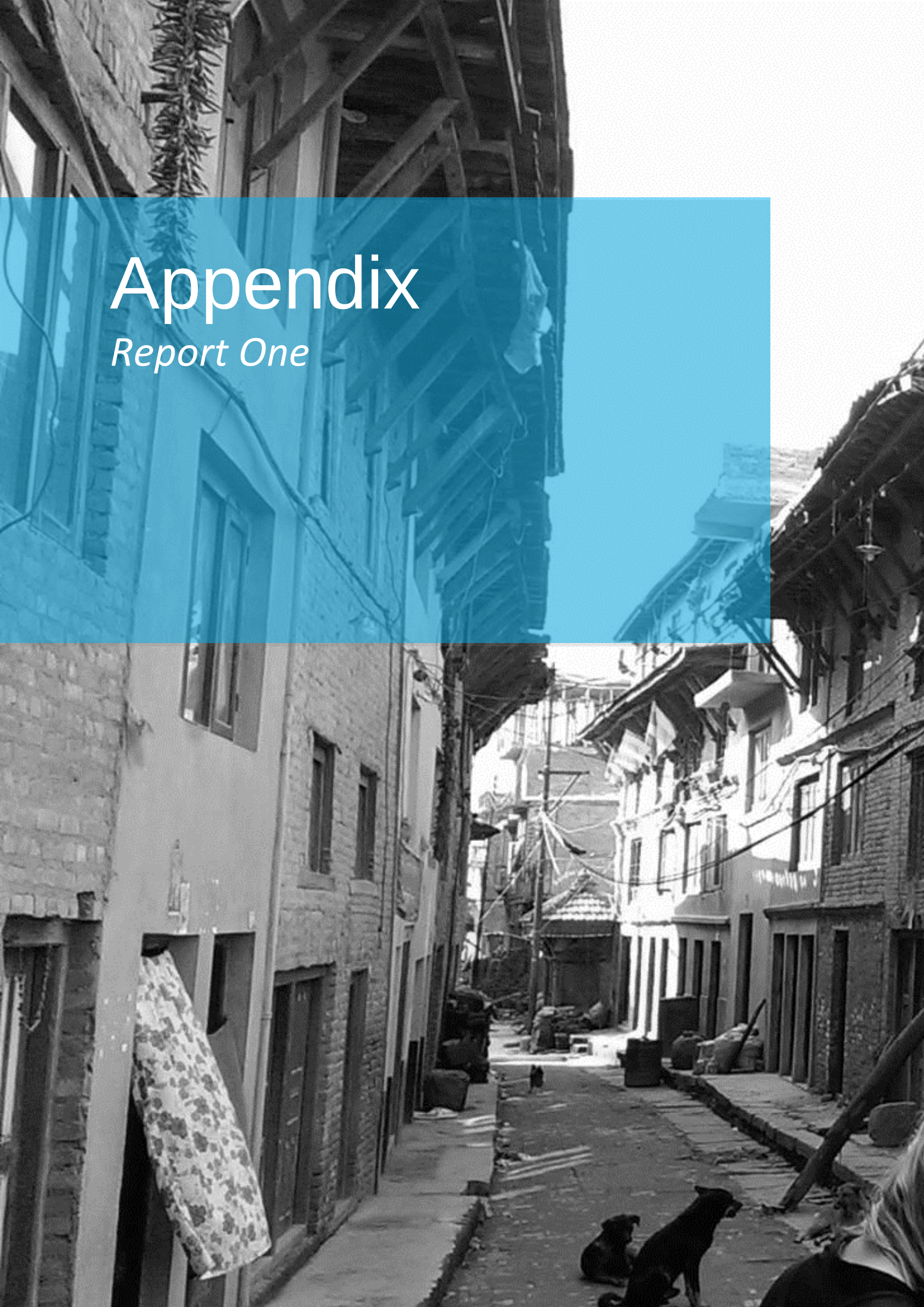


Appendix

Report One

Appendix Report 1

Appendix 1.A.

The values given in this appendix are only applicable for report one. This means that in other kind of situations the values can differ.

Appendix 1.A.1. – Commonly used building methods in earthquake affected area Nepal

In this section commonly used building methods in earthquake-affected area Nepal are highlighted, this section includes traditional masonry buildings to reinforced concrete frame structures. Criteria are developed to check if the already used building methods are suited for earthquake safe construction.

Low strength (stone) masonry

Introduction			
This building style is mostly found on foothills, hills and mountains in the rural and remote areas of Nepal {Parajuli, Bothara, & Upadhyay, 2015}. The buildings typically consist of river stone foundations, load bearing stone walls, timber window frames, and varying roof/flooring systems. The walls are composed of two layers of mountain stone and the space between is frequently filled with mud, small stones and pieces of rubble {Bothara & Brzev}.			
Category	**Description**		**Value**
Technical			
Building components	Typical elements are foundations, load bearing stone walls, timber window frames, and varying roof/flooring systems. The heavy building method demands a sufficient foundation on a firm base {DUDBC, 1994). The walls are composed of two walls and space between is frequently filled with mud, small stones and pieces of rubble {Bothara & Brzev}. The load bearing walls usually have above average redundancy but the weakness of the mortar has a negative effect on this. This building type is included in the BC with thumb rules and limitations.	***Redundancy***	2
		Building code	4
Seismic Performance Standard	Buildings are mostly regular in plan and elevation (no cantilevers/ overhang). Load bearing stone masonry walls provide the lateral load resisting system. This building method has a high seismic vulnerability due to the following factors: High inertia loads due to heavy weight of stones. Lack of structural integrity out of plane collapse, in-plane shear cracking delamination of wall walls (two layer without proper bonding in between), failure due to irregular stone shapes {Bothara & Brzev}.	***Performance***	1
Improved Seismic Performance	The structural Integrity and seismic resistance can be strengthened by means of vertical and horizontal reinforcement (timber, bamboo, reinforced concrete). Stiff diaphragms such as concrete slabs are favoured above flexible diaphragms. The out-of-plane capacity can be improved by adding of wall meshes (experimental techniques).	***Possible***	2
Sensitivity to surface	Soil slopes of 20° maximum (1:3, Vertical: Horizontal) are stable suitable for construction. In case of proper retaining walls, steeper slopes are allowed {DUDBC, 1994}. Typically it is found on sloping terrain.	***Performance***	3
Climate	With respect to daylight entrance, the size of wall openings is limited (15-25% of the wall). Thick stone walls can have favourable thermal mass and insulation properties.	***Openings (ventilation and sunlight)***	3
		Thermal	*3*

	The stones can keep the moisture out. The mortar (or lack of mortar, dry stacking) influences the wind and rain proofing of this building methods. The walls can be plastered, to increase the wind proofing.		
Life span	Stone masonry structures can be highly durable with long lifespan due to the non-deteriorating character of stones, when not exposed to extreme events(force majeure)	***Lifespan***	5
Maintenance	The stone walls require little maintenance, additional timber elements or bamboo elements do need regular maintenance. The performance of maintenance can be difficult due to the replacement of stones or additional elements covered by heavy stones. The building is accessible during most types of smaller maintenance.	***Reliability***	3
		Maintainability	3
		Availability	2
Complexity	This construction type is incorporated in the building code (Nepal National Building code NBC 203: 1994 Low strength masonry). The know-how is mainly passed on informally {Parajuli, Bothara, & Upadhyay, 2015}, and skills vary per person. House-owners are mostly part of the construction team, often they are helped by local artisans/ masons. It is learnable in short time but expertise comes with the years.	***Ease of learning***	3
Resources			
Material	The walls are built with river stones or boulder stones. A classification can be made between random rubble stone, semi-dressed stone, and dressed stone {Bothara & Brzev}. Random stones are irregular shaped, randomly placed stones whereas coursed and dressed stones are cut to regular (rectangular) shapes and placed regularly. More rectangular shapes of stones are favoured with respect to structural performance. In most areas, the stones are held together with the locally available mud mortar. Where no mud of sufficient bonding quality is available the stones are dry-stacked. Building which stand near roads more frequently have cement mortar as bonding. Mud mortar is relatively weak. It can be beneficial if small cracks occur in the mud mortar, dissipating energy through frictional sliding. The stones and mud are locally available throughout the year, also from the debris of the collapsed houses. Availability and reliability of timber for seismic bands and timber framing is low due to anti-deforestation programs and prices are high due to permits.	*Quality*	5
		Availability	5
		Reliability	5
Labour	Masonry is labour-intensive, not suitable for mechanization or prefabrication. The stone masonry buildings are mostly built by a construction team including a mason and usually the owner himself. The owner can therefore contribute to the provision of labour. However, not so much masons are familiar with the proper reinforcement techniques. Mason-training programs are therefore being set-up by several organisations.	*Experience*	5
		Intensity	4
Time	Stone masonry is not a fast assembled construction method. It requires the collection or alteration of rocks fit for building and the drying of Mortar.	*Technical period*	3
Feasibility			
Price Label	The ranking is based on price indications and reference countries	*Ranking*	5
Local economy	Stone masonry involves local materials (boulders stones and mud mortar). Since the method is familiar with local builder's builders and masons it stimulates the local economy.	*Use of local resources*	5
National economy	Stones and masonry skills does not have to be imported from other countries. Stones are mined near the construction site in most cases, or transported from a near location. Cash flow remains within Nepal and is beneficial for the economy.	*Use of national resources*	4
Social / cultural			
Social/ cultural	The walls can be plastered or finishing can be applied to allow the appropriate social/ cultural aesthetics. For example the thick wall allows the placement of niches for religious attributes. Also different shapes of the building are possible.	*Adaptability*	2

Architectural embedding	Stone masonry is a commonly used building practice and is embedded in local building traditional and architectural identity.	*Embedding*	5
Functional			
Building height	Low-strength masonry buildings which are conform to building code NBC 203: 1994: maximum allowed to have up to two storeys with an additional attic floor. {Nepal building code, 1994}	*Amount of storeys*	2
Expandability	The building can be vertically expanded but the building code limits the amount of storeys. Therefor expansion is only possible at a one storey building.	*Possibilities*	1
Workspace	According to the Nepalese building code should the combined width of wall openings not exceed 25% of the total wall length, based on a two storey building.	*Opportunity*	2
Protection	Rain can wash away mud mortar, wind can penetrate through crevices in low strength masonry wall. Safety is provided with locks, bars and insect screens, but can be easily removed.	*Elements*	2
		Safety	3
Utilities	The structure is not able to withstand vertical loads and is for that reason not able to bear loads on the roof. Utilities are only available on ground level or externally.	*Possibilities*	2
Sustainable			
Recyclable	The stones which are held by mud mortar can be recycled / reused on large scale. They can be re-used for new buildings, walls, road fill-up etc., or be recycled into smaller material like aggregates for instance. Mud mortar is reusable as new mud mortar by adding water.	*Re-usable*	5
		Recyclable	5
Environmental	The building construction has a low CO2 footprint and impact on the environment. Only large amounts of stone mining can create an 'ugly' landscape.	*Impact*	4
		Sustainable	3
Images			

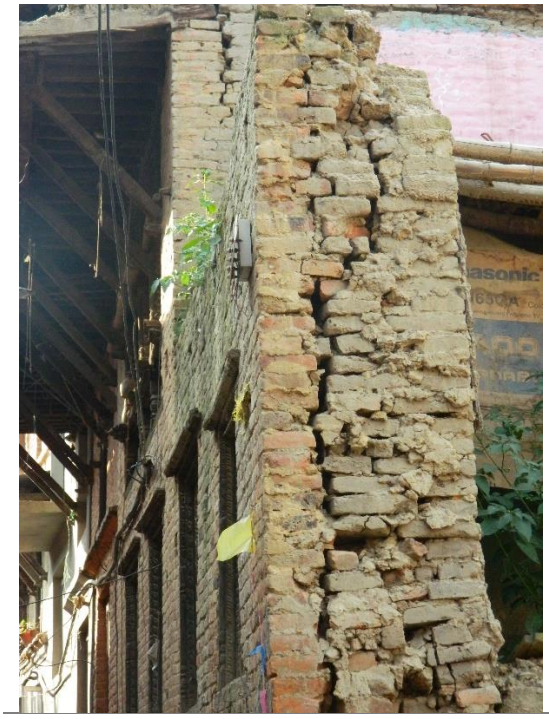
Low strength (brick) masonry

Introduction
This building style is very common in old villages and towns of the Kathmandu valley. The buildings typically consist of river stone foundations, a combination of burned brick on the outer wall and sun dried brick masonry on the inner wall, the brick masonry is often held together with mud mortar. The space between is frequently filled with mud, small stones and pieces of rubble. The average low strength brick masonry house has a basic rectangular design. Within this category the traditional Newari building style can be classified.

Category	Description		Value
Technical			
Building components	Typical elements are foundations, load bearing brick masonry walls, timber window frames, and varying roof/flooring systems. The heavy building method demands a sufficient foundation on a firm base {DUDBC, 1994). The walls are composed of two walls, one baked, one sun dried brick. The space between is frequently filled with mud, small stones and pieces of rubble {Bothara & Brzev}. The load bearing walls usually have above average redundancy but the weakness of the mortar has a negative effect on this. This building type is included in the BC with thumb rules and limitations.	*Redundancy*	2
		Building code	4
Seismic Performance Standard	Buildings are mostly regular in plan and elevation (few cantilevers/ overhang). Load bearing brick masonry walls provide the lateral load resisting system. Lighter structures will induce less seismic loads, and therefore less damage. Hence the wall thickness should be as thin as possible, with a minimum of 300 mm. The type and quality of the bond within the wall units contribute most to the integrity and strength of the walls. All the bricks units should be properly laid in order to provide sufficient integrity {DUDBC, 1994). High seismic vulnerability due to high inertia loads due to heavy weight of bricks. Buildings lack adequate connections between building elements (for example side and front facade, floors and walls).	*Performance*	2
Improved Seismic Performance	The structural Integrity and seismic resistance can be strengthened by means of vertical and horizontal reinforcement (timber, bamboo, reinforced concrete). Stiff diaphragms such as concrete slabs are favoured above flexible diaphragms. The out-of-plane capacity can be improved by adding of wall meshes (experimental techniques).	*Possible*	3
Building on a slope	Soil slopes of 20° maximum (1:3, Vertical: Horizontal) are stable suitable for construction. In case of proper retaining walls, steeper slopes are allowed {DUDBC, 1994}.	*Performance*	3
Climate	Ability for making openings with respect to daylight entrance, the size of wall openings is limited (15-25% of the wall). Traditional masonry is not humidity-proof the ground floor is therefore exposed to the atmosphere. The wall can be plastered, but this is not considered good practice.	*Openings (ventilation and sunlight)*	3
		Thermal	*2*
Life span	Brick masonry structures can have a long lifespan when maintained and not exposed to extreme events (force majeure)	*Lifespan*	5
Maintenance	Timber elements are vulnerable to rotting when exposed to moisture; therefore need regular checking and maintenance. The maintainability is good due to the fact that structural elements are reachable without much trouble and maintenance does not necessarily require workmanship. The building is available during most structural maintenance.	*Reliability*	2
		Maintainability	3
Complexit	This construction type is incorporated in the building code (Nepal National	*Ease of*	3

y	Building code NBC 203: 1994 Low strength masonry). The know-how is mainly passed on informally {Parajuli, Bothara, & Upadhyay, 2015}, and skills vary per person. House-owners are mostly part of the construction team, often they are helped by local artisans/ masons. It is learnable in short time but expertise comes with the years.	*learning*	
Resources			
Material	The building stands on a foundation of river stones, sometimes until a meter or so to keep the moisture out. The wall build up is mostly done by sun-dried bricks on the inside of the buildings, and baked bricks on the outside. The availability of both sun dried as baked brick is high respectively due to local production and production in Nepali brick kilns. The reliability of availability is different for both sun dried as baked brick, as sun dried bricks are not producible in the monsoon season due to heavy rainfall. Whereas baked bricks are producible all year through. However in the current situation of Nepal the baked brick have become scarce.	*Quality*	3
		Availability	4
		Reliability	4
Labour	Masonry is labour-intensive, not suitable for mechanization or prefabrication. The brick masonry buildings are mostly built by a construction team including a mason and usually the owner himself. The owner can therefore contribute to the provision of labour. However, not so much masons are familiar with the proper reinforcement techniques. Mason-training programs are therefore being set-up by several organisations.	*Experience*	5
		Intensity	4
Time	Brick masonry is not a fast assembled construction method. Construction speed is dependent on the drying time of mud mortar before being able to apply the next layer.	*Technical period*	3
Feasibility			
Price label	The ranking is based on price indications and reference countries	*Ranking*	5
Local economy	This building method can be executed with local materials, by local masons benefitting the local economy. Low strength masonry uses sun dried bricks or a combination of sun dried and burnt bricks, which all are fabricated locally. Masonry is a well-known profession, frequently seen locally.	*Use of local resources*	4
National economy	There are many brick kilns in the Kathmandu valley producing fire-burnt bricks from the local clay, however due to the large demand, bricks might be imported from India. Sun dried bricks however are produced nationally. In general the cash flow remains within Nepal to build low strength masonry.	*Use of national resources*	4
Social / cultural			
Social/ cultural	The walls can be plastered or finishing can be applied to allow the appropriate social/ cultural aesthetics. For example the thick wall allows the placement of niches for religious attributes. Also different shapes of the building are possible.	*Adaptability*	2
Architectural embedding	Brick masonry is a commonly used building practice and is embedded in local building traditional and architectural identity.	*Embedding*	5
Functional			
Building height	Low-strength masonry buildings which are conform to building code NBC 203: 1994: maximum allowed to have up to two storeys with an additional attic floor. {Nepal building code, 1994}	*Amount of storeys*	2
Expandability	The building can be vertically expanded but the building code limits the amount of storeys. Therefor expansion is only possible at a one storey building.	*Possibilities*	2
Workspace	According to the Nepalese building code should the combined width of wall openings not exceed 25% of the total wall length, based on a two storey building.	*Opportunity*	2

Protection	Rain can wash away mud mortar, wind can penetrate through crevices in low strength masonry wall. Safety is provided with locks, bars and insect screens, but can be easily removed.	*Elements*	2
		Safety	3
Utilities	The structure is not able to withstand vertical loads and is for that reason not able to bear loads on the roof. Utilities are only available on ground level or externally.	*Possibilities*	2
Sustainable			
Recyclable	Due to the mud mortar the bricks are not damaged as they would have with cement mortar. Parts of the bricks can be re-used or recycled for road fill-up for instance.	*Re-usable*	4
		Recyclable	4
Environmental	The brick kilns for fire burnt bricks however cause smog and climate pollution. However the low-strength masonry buildings also use sun dried bricks which do not have a negative impact on the environment.	*Impact*	4
		Sustainable	3
Images			



Stone masonry in cement mortar

Introduction
This building style is similar to stone masonry and mostly found in the more mountainous parts of Nepal. The houses consists of stacked mountain stones held together by cement instead of mud mortar.

Category	Description		Value
Technical			
Building components	Typical elements are sturdy foundations, load bearing stone masonry walls, held together by cement, timber window frames, and varying roof/flooring systems. Some buildings have applied horizontal bands at sill, lintel and floor level. The heavy building method demands a sufficient foundation on a firm base {DUDBC, 1994). The load bearing walls usually have above average redundancy. This building type is included in the BC.	*Redundancy*	3
		Building code	5
Seismic Performance Standard	The materials used, the quality of the mortar and workmanship, and the pattern in which the units are assembled can significantly affect the durability of the overall masonry construction. Sufficient bonding between mortar and stones is needed to resist shear cracking. Seismic performance is influenced by the bond between mortar and stone connection, the connection between building elements such as walls, corners and junctions, and between walls and floors, roofs {D'ayala}. Very low or no tensile strength is mostly the cause of shear failure of wall elements in the case of stone masonry. Combined with the irregular shape of stones, further destabilizes the wall by their movements. (NSET, 1994)	*Performance*	3
Improved Seismic Performance	The structural integrity and seismic resistance can be strengthened by means of vertical and horizontal reinforcement (timber, bamboo, reinforced concrete). Stiff diaphragms such as concrete slabs are favoured above flexible diaphragms and light roofs systems are preferred.	*Possible*	4
Slope sensitivity	Soil slopes of 20° maximum (1:3, Vertical : Horizontal) are stable suitable for construction. In case of proper retaining walls, steeper slopes are allowed {DUDBC, 1994}.	*Performance*	3
Climate	Wall openings should be as small and as centrally located as practicable, the limits on opening size are: total width of openings should be less than 0,3 of the total width of the wall. Openings should preferably be at the same level, for the continuation of lintels. Ventilators shall be 450x450mm or smaller {DUDBC, 1994}	*Openings (ventilation and sunlight)*	3
		Thermal	4
Life span	Masonry structures held together with lime mortar can be highly durable, with an extremely high potential lifespan of more than 500 years, if well-constructed and maintained and if not damaged or destructed by force majeure events {J.Morton, 1990}. On the other hand the functional lifespan is presumed to be shorter.	*Lifespan*	4
Maintenance	The stone walls need limited maintenance when constructed in the right manner only regular check for cracks is needed. Timber elements are vulnerable to rotting due to moisture; therefore need regular checking and maintenance. The maintainability is good due to the fact that structural elements are reachable with some effort and maintenance does not necessarily require	*Reliability*	3

	workmanship. The building is available during limited structural maintenance. The cement bonding increases the difficulty due to the effort required to remove specific stones.	*Maintainability*	2
Complexity	This construction type is incorporated in the building code (Nepal National Building code NBC 109 : 1994 Unreinforced masonry); the codes specify substantial constraints on unreinforced masonry construction to improve seismic resistance {DÁyala}. The skill to build unreinforced stone masonry houses is limited, the addition of reinforcement makes the building method more complex.	*Ease of learning*	3
	Resources		
Material	The stones are mostly coursed and dressed into rectangular shapes. The bonding material cement is executed as 1:6 cement sand mortar. Mortars are subject to greater variation, but the basic materials used in mortar mixes are sand, water, and one or more of the bonding agents, mud, clay, or cement, depending on local availability. The proportion of bonding agent's to sand determines the compressive and bonding strength of the mortar {D'ayala}.	*Quality*	4
		Availability	5
Labour	Masonry is labour-intensive and not suitable for mechanization or prefabrication. Nepal has a lot of experience with masonry.	*Experience*	5
		Intensity	3
Time	Stone masonry is not a fast assembled construction method. Limited layers of stones can be placed, cement mortar needs to dry before next layer. Many slaps and lintels need to be constructed for the building to be earthquake safe.	*Technical period*	3
	Feasibility		
Price Label	The ranking is based on price indications and reference countries	*Ranking*	4
Local economy	This building method can be executed with local materials, by local masons. Stones are mined locally. Cement is produced locally within the Kathmandu Valley, however in cases is imported from India.	*Use of local resources*	4
National economy	The stones are locally produced and the quality of Nepalese cement is sufficient, in the case of improved seismic performance cement can also be imported. Importing would lead to some cash flow leaving Nepal.	*Use of national resources*	4
	Social / cultural		
Social/ cultural	The walls can be plastered or finishing can be applied to allow the appropriate social/ cultural aesthetics. The use of clean mountain stone as exterior is often seen in the cultural history of Nepal. For example the thick wall allows the placement of niches for religious attributes. Also different divisions of spaces and shapes of the building are easily possible.	*Adaptability*	3
Architectural embedding	Stone masonry is a commonly used building practice and is embedded in local building traditional and architectural identity.	*Embedding*	5
	Functional		
Building height	Building codes for load-bearing masonry (NBC 202:1994) limit stone masonry houses with cement mortar to two storeys with an additional attic floor. {Nepal building code, 1994}	*Amount of storeys*	2
Expandability	The building can be vertically expanded but the building code limits the amount of storeys. Therefor expansion is only possible at a one storey building. However storeys are added informally, sometimes with heavy materials, adding vertical load. This is not considered a good practice for the structural performance of the buildings.	*Possibilities*	3
Workspace	According to the Nepalese building code should the combined width of wall openings not exceed 25% of the total wall length, based on a two storey	*Opportunity*	3

	building.		
Protection	Rain cannot wash away cement mortar and the crevices in the masonry wall are filled with cement mortar and cannot be penetrated by wind. Safety is provided with locks, bars and insect screens.	*Elements*	4
		Safety	3
Utilities	If constructed in the right manner, the building method is able to withstand gravitational forces. For this reason the utilities are possible beyond ground level.	*Possibilities*	3
	Sustainable		
Recyclable	Mountain stones are re-usable if their shape is still intact. Damaged stones can be used for building retaining walls or road fill-up for instance. Cement mortar is useless after demolition.	*Re-usable*	4
		Recyclable	3
Environmental	Same description as 'low strength stone masonry' however due to the cement mortar there is a bigger impact on the environment.	*Impact*	4
		Sustainable	4
	Images		

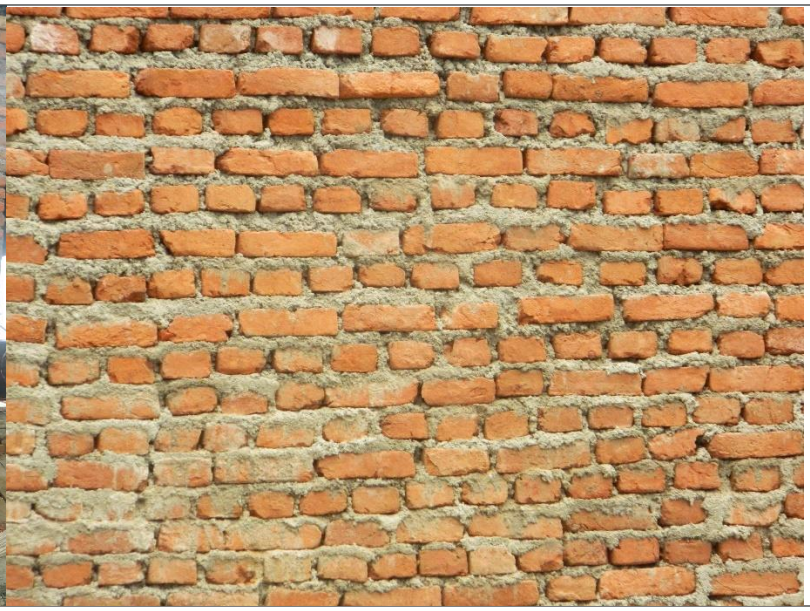
Brick masonry in cement mortar

Introduction
This building style is similar to brick masonry and mostly found the villages and towns of the Kathmandu Valley. The brick masonry is held together with cement instead of mud mortar to construct load bearing walls. The walls usually exist out of multiple layers of brick.

Category	Description		Value
Technical			
Building components	Typical elements are foundations, load bearing brick walls, timber window frames, and varying roof/flooring systems. The walls are composed of two walls and space between is frequently filled with mud, small stones and pieces of rubble {Bothara & Brzev}. The load bearing walls usually have above average redundancy. This building type is included in the BC.	*Redundancy*	3
		Building code	5
Seismic Performance Standard	The materials used, the quality of the mortar and workmanship, and the pattern in which the units are assembled can significantly affect the durability of the overall masonry construction. Sufficient bonding between mortar and bricks is needed to resist shear cracking (D'Ayala). Seismic performance is influenced by the bond between mortar and bricks connection between wall connection between building elements (connections between walls, corners and junctions, and between walls and floors, roofs) {D'ayala}	*Performance*	3
Improved Seismic Performance	The structural integrity and seismic resistance can be strengthened by means of vertical and horizontal reinforcement (timber, bamboo, reinforced concrete). Refer to chapter on masonry reinforcement. Stiff diaphragms such as concrete slabs are favoured above flexible diaphragms and light roofs systems are preferred.	*Possible*	4
Slope sensitivity	Soil slopes of 20° maximum (1:3, Vertical: Horizontal) are stable suitable for construction. In case of proper retaining walls, steeper slopes are allowed {DUDBC, 1994}.	*Performance*	3
Climate	Wall openings should be as small and as centrally located as practicable, the limits on opening size are: total width of openings should be less than 0,3 of the total width of the wall. Openings should preferably be at the same level, for the continuation of lintels. Ventilators shall be 450x450mm or smaller {DUDBC, 1994} Use of brick masonry can increase the thermal mass of a building and its fire resistance.	*Openings (ventilation and sunlight)*	4
		Thermal	4
Life span	Masonry structures held together with lime mortar can be highly durable, with an extremely high potential lifespan of more than 500 years, if well-constructed and maintained and if not damaged or destructed by force majeure events {J.Morton, 1990}. On the other hand the functional lifespan is presumed to be shorter.	*Lifespan*	4
Maintenance	The stone walls need limited maintenance when constructed in the right manner only regular check for cracks is needed. Timber elements are vulnerable to rotting due to moisture; therefore need regular checking and maintenance. The maintainability is good due to the fact that structural elements are reachable	*Reliability*	3

	with some effort and maintenance does not necessarily require workmanship. The building is available during limited structural maintenance. The cement bonding increases the difficulty due to the effort required to remove specific bricks.	*Maintainability*	2
Complexity	This construction type is incorporated in the building code (Nepal National Building code NBC 109: 1994 Unreinforced masonry); the codes specify substantial constraints on unreinforced masonry construction to improve seismic resistance {DÁyala}.	*Ease of learning*	3
	Resources		
Material	Building blocks bricks. Bricks are mainly of sufficient quality, having a crushing strength of above 7.5 N/mm2 (NSET, 2009). The bonding material cement is executed as 1:6 cement sand mortar. The major factors influencing the strength of the bricks are the purity of the clay and the firing temperature. Mortars are subject to greater variation, but the basic materials used in mortar mixes are sand, water, and one or more of the bonding agents, mud, clay, or cement, depending on local availability. The proportion of bonding agent/s to sand determines the compressive and bonding strength of the mortar. {D'ayala} The bricks are made of local clay, good quality clay is available seen the fact that the Kathmandu valley used to be a lake. Over-burnt, Under-burnt and deformed bricks are not suitable for good construction. The availability of baked brick is high due to local production and the reliability of availability is high given that baked bricks are producible all year through.	*Quality* *Availability* *Reliability*	3 3 3
Labour	Masonry is labour-intensive, not suitable for mechanization or prefabrication. Nepal has a lot of experienced with masonry.	*Experience* *Intensity*	5 4
Time	Brick masonry is not a fast assembled construction method. Limited layers of bricks can be placed, cement mortar needs to dry before next layer.	*Technical period*	3
	Feasibility		
Price Lable	The ranking is based on price indications and reference countries	*Ranking*	4
Local economy	Brick and cement are not local since they have to come from outside the 50 km range. Labour however is local.	*Use of local resources*	3
National economy	There are many brick kilns in the Kathmandu valley producing fire-burnt bricks from the local clay, however due to the large demand, cement might be imported from India.	*Use of national resources*	3
	Social / cultural		
Social/ cultural	The walls can be plastered or finishing can be applied to allow the appropriate social/ cultural aesthetics. The walls can be plastered or finishing can be applied to allow the appropriate social/ cultural aesthetics. The use of clean bricks as exterior is often seen in the cultural history of Nepal. For example the thick wall allows the placement of niches for religious attributes. Also different divisions of spaces and shapes of the building are easily possible.	*Adaptability*	4
Architectural embedding	Brick masonry is a commonly used building practice and is embedded in local building traditional and architectural identity.	*Embedding*	5
	Functional		
Building height	Building codes for load-bearing masonry (NBC 202:1994) limits fired brick masonry to three storeys high. {Nepal building code, 1994}	*Amount of storeys*	3
Expandability	Building can be vertically expanded but the building code limits the amount of storeys. Expansion is possible when the maximum building height is not reached. Storey can be easily expanded by proceeding on the existing structure. Often	*Possibilities*	3

	storeys are added informally, sometimes with heavy materials, adding vertical load. This is not considered a good practice for the structural performance of the buildings.		
Workspace	According to the Nepalese building code should the combined width of wall openings not exceed 25% of the total wall length, based on a two storey building.	*Opportunity*	3
Protection	Rain cannot wash away cement mortar and the crevices in the masonry wall are filled with cement mortar and cannot be penetrated by wind. Safety is provided with locks, bars and insect screens.	*Elements*	4
		Safety	4
Utilities	If constructed in the right manner, the building method is able to withstand gravitational forces. For this reason the utilities are possible beyond ground level.	*Possibilities*	4
Sustainable			
Recyclable	Bricks with cement mortar are not easily re-usable, the cement mortar needs to be removed before the bricks can be re-used, and this is not always possible. According to Nepalese building code: Masonry units that have been previously used should not be re-used in brickwork or brickwork construction unless they have been thoroughly cleaned and shown to conform to the Nepal Standard Brick Masonry NS: 1/2035.	*Re-usable*	2
		Recyclable	2
Environmental	The brick kilns for fire burnt bricks contribute to the smog and pollution of the Kathmandu Valley.	*Impact*	3
		Sustainable	4
Reference			
This traditional building style is mostly found in the urban areas of the Kathmandu Valley. In the old city cores of Kathmandu, Lalitpur and Bhaktapur, but also in urban heritage towns such as Bungamati and Sankhu. Many traditional brick buildings collapsed due to the 2015 earthquake. The buildings were vulnerable to earthquakes since many are quite old and ill-maintained.			
The structural integrity is threatened when existing houses are divided amongst sons. Building of additional storeys (and additional load) due to family expansion also negatively affects the structure's performance. Floors are not considered to be rigid diaphragms: often constructed of wooden logs, topped with wooden chips and a relatively heavy layer of mud. These floors do not comply with modern wishes. Floor heights (2.20 to 2.50) are also too low for modern demands.			
Some buildings are equipped with a Dalan frame, a double timber frame within the wall structure, masonry only being the outer shell {D'Ayala & Bajracharya, 2015}. Horizontal timber bands can be applied to tie the masonry leaves together. In good construction practice, one can find closely spacing of timber floor joists. The joints are connected to the walls by means of timber pegs, which ensure a uniform redistribution of horizontal loads and ensure integrity between building elements. {D'Ayala & Bajracharya, 2015}.			
Originally self-built structures, nowadays repair and building of this traditional style will be executed by a contractor. Knowledge on this building method was locally widespread available, but will get lost with the up rise of concrete structures. Rebuilding in this method can contribute to the preservation of living heritage and local identity. Integration with modern techniques, new ways to treat timber can enhance its seismic strength.			



Hollow concrete brick masonry

Introduction
Hollow concrete blocks are used around the Kathmandu Valley and are popular in certain areas {Habitat Nepal}. The blocks are designed to have hollow compartments inside in order to reduce cost, the addition of these air pockets also makes the blocks fire resistant provides insulation. {Hornbostel, 1991} The blocks are held together by cement mortar and allow for incorporation of rebar and cement in the air pockets for additional strength.

Category	Description		Value
Technical			
Building components	Typical elements are foundations, load bearing hollow concrete brick walls and varying roof/flooring systems. The load bearing walls usually have above average redundancy. The bricks are available in numerous rectangular dimensions and specially shaped corner blocks. The cement bricks are bound together with mortar and the cavities in the bricks can be used for filling with rebar and concrete for extra strength. This building type is included in the BC.	*Redundancy*	4
		Building code	5
Seismic Performance Standard	Structurally each concrete block wall behaves as shear wall, reducing the vulnerability of the structure. Due to the uniform distribution of reinforcement in both vertical and horizontal directions increased tensile resistance and ductile behaviour of the elements. (Ecologic, n.d.) Shake Table testing of the Indian University proved that the seismic resistance of a hollow concrete brick wall is less than a brick masonry wall (Ahmad, 2013)	*Performance*	3
Improved Seismic Performance	The structural Integrity and seismic resistance can be strengthened by means of vertical and horizontal reinforcement (timber, bamboo, reinforced concrete). Stiff diaphragms such as concrete slabs are favored above flexible diaphragms. Hollow blocks can be reinforced with steel to increase their seismic performance. {Global Shelter Cluster, 2014}	*Possible*	4
Building on a slope	The base of a hollow concrete brick structured needs to be flat to distribute the loads in vertical and horizontal directions. In case of proper retaining walls, steeper slopes are allowed {DUDBC, 1994}.	*Performance*	3
Climate	Similar openings to brick masonry can be managed. Hollow concrete provides thermal and sound insulation: the air pockets in the hollow blocks keeps the house cool in the summer and warm in the winter. (Ahmad, 2013) Although several households are very unhappy with their experience of the thermal performance of hollow concrete block construction (Hiçyılmaz, Bothara, & Stephenson , 2012).	*Openings (ventilation and sunlight)*	3
		Thermal	*4*
Life span	A lifespan of 20+ years can be managed {Global Shelter Cluster, 2014}	*Lifespan*	3
Maintenance	The amount and cost of maintenance of hollow concrete brick masonry is less than brick masonry because of efflorescence in brick masonry wall. (Ahmad, 2013) When plastered the CHB walls don't absorb much moisture decreasing the need for maintenance. {Global Shelter Cluster}	*Reliability*	4
		Maintainability	2
		Availability	3
Complexity	Hollow concrete bricks are already used in Nepal, the blocks are locally produced and the method of masonry is similar to brick masonry.	*Ease of learning*	3
Resources			
Material	Waste products like fly ash can be used in the production process of hollow concrete bricks. The masonry with blocks consumes less mortar than traditional masonry styles because of the limited volume of the joints. The blocks can be	*Quality*	4
		Availability	4

	filled with concrete and steel rods for reinforcement. The availability of these materials is high and comparable to the availability of concrete, which can be considered high due to local cement factories in Nepal and the large availability of cement in India and China. The reliability can be very good when road conditions and political situations are good, but during monsoon season many roads are damaged and limit the flow of products coming from India and China.	*Reliability*	4
Labour	Only semi-skilled labour is required for the construction with hollow concrete bricks and often the constructions built with hollow cement blocks are of simple nature, also reducing the labour required.	*Experience*	4
		Intensity	4
Time	The production and construction of concrete blocks is faster compared to brick masonry buildings. Let alone by the less amount of actions needed to finish construction.	*Technical period*	4
	Feasibility		
Price label	The ranking is based on price indications and reference countries	*Ranking*	4
Local economy	Because only semi-skilled labour is required for construction with hollow concrete bricks, a large part of the work force can be utilised. The bricks can also be locally produced and are not bound to a location, the cement however comes from outside the 50 km range.	*Use of local resources*	3
National economy	For the production of hollow concrete bricks cement and sand is necessary these product are nationally produced in Nepal. Cement is also often imported from India, therefore some cash flow is leaving Nepal.	*Use of national resources*	3
	Social / cultural		
Social/ cultural	Buildings constructed with hollow concrete bricks are bound to the dimensions of the bricks, the walls can be plastered to allow the appropriate social/cultural aesthetics. The walls do not allow the placement of niches for religious attributes.	*Adaptability*	4
Architectural embedding	Hollow concrete bricks are used as a building method in Nepal, however not very widely spread. Masonry structure is seen as embedded in the local building tradition.	*Embedding*	3
	Functional		
Building height	Unreinforced hollow concrete bricks are comparable with traditional brick masonry buildings. (Koski, 1992) and (Nepal building code, 1994) Building codes for load-bearing masonry (NBC 202:1994) limits fired brick masonry to three storeys high. {Nepal building code, 1994} Reinforced hollow concrete brick buildings are suited for tall buildings, examples of 10 plus story buildings are seen in the USA.	*Amount of storeys*	3
Expandability	Unreinforced hollow concrete bricks are easy to expand if the structural strength of the building is not compromised. When the structure is reinforced this expansion is seen as more difficult. Since the building method is not included in the building code but performs similar to brick masonry, the expendability also seen as similar.	*Possibilities*	3
Workspace	According to the Nepalese building code should the combined width of wall openings not exceed 25% of the total wall length, based on a two storey building.	*Opportunity*	3
Protection	Rain cannot wash away cement mortar and the crevices in the masonry wall are filled with cement mortar and cannot be penetrated by wind. Safety is provided with locks, bars and insect screens.	*Elements*	4
		Safety	4
Utilities	If constructed in the right manner, the building method is able to withstand gravitational forces. For this reason the utilities are possible beyond ground level.	*Possibilities*	4
	Sustainable		
Recyclable	Hollow concrete bricks are placed with cement mortar and especially with	*Re-usable*	4

	reinforcement hardly recyclable. It is however re-usable for retaining walls, road fill-up etc.	*Recyclable*	2
Environmental	Hollow concrete bricks can be made with fly ash, a waste material and part replacement of cement. (Ahmad, 2013) Without waste material concrete has an impact on the environment.	*Impact*	3
		Sustainable	3

Images

Reinforced Cement Concrete Frames

Introduction
This building type can be found widespread in urban and semi-urban areas of Nepal, and is one of the most emerging building methods {Marhatta, Bothara, Magar, & Chapagain}. An important distinction can be made between engineered and non-engineered (informally constructed) concrete frames. The main structural system is a moment-resisting reinforced cement concrete skeletal frame of cast-in-place concrete beams and columns with masonry infill walls. Infill is mostly solid clay bricks, infill with stone masonry is also seen in informal structures.

Category	Description		Value
Technical			
Building components	The main structural system is a moment-resisting reinforced concrete (RC) skeletal frame of cast-in-place concrete beams and columns with masonry infill walls. Infill is mostly solid clay bricks, infill with stone masonry is also seen in informal structures. The walls can be painted and plastered. Floor and roof slabs are mostly cast-in-place concrete slabs. Roof and floor diaphragms are considered to be stiff and rigid, able to distribute lateral forces. When RCC is performed with the minimum amount of columns they don't offer much redundancy, however increasing the amount of columns and adding shear walls has a positive influence on redundancy. RCC frames are incorporated in the building code.	*Redundancy*	3
		Building code	5
Seismic Performance Standard	For non-engineered structures the frame is usually designed for gravity loads only {Marhatta, Bothara, Magar, & Chapagain}. For engineered structures the monolithic beam-column connections. The lateral load system is officially the concrete frame, in reality combined action with the brick masonry infill walls - resembling a shear wall structure. The infill walls actually have to take quite a portion of the lateral load. Class C	*Performance*	3
Improved Seismic Performance	Seismic performance can be considerably improved by good construction practice, adequate detailing and sufficient reinforcement. The addition of shear walls is found to significantly reduce lateral displacement.	*Possible*	5
Building on a slope	Building on slopes is not advised with a reinforced concrete construction due to column failures. During an earthquake the columns in a cross section move by the same amount in a horizontal direction. This causes for columns of different lengths to attract different horizontal forces, resulting in different stresses being exerted on different column lengths.{SUJIT KUMAR et al.} This can be compensated by several advanced methods or by construction of braces or a plane foundation with retaining walls.	*Performance*	4
Climate	Window openings are quite flexible due to the frame construction. The frame however must be designed on lateral load. Often it is only for gravitational loads and then the structure is also dependent on the masonry infill; decreasing flexibility of window openings. Insulation and acoustic properties depend mostly on type of infill. When bricks see brick masonry	*Openings (ventilation and sunlight)*	5
		Thermal	*3*
Life span	Life span of RC frame construction is lower than masonry building methods. Estimated lifespans are 30-100 years	*Lifespan*	4
Maintenance	RCC frame building require little maintenance, because the structural elements consist of and are protected by the concrete. However when the concrete is damaged or is in need of maintenance the work requires workmanship and	*Reliability*	5
		Maintainability	2

	much resources such as concrete injections, rebar replacements, poor quality or limited cover could result in corrosion of the reinforcement. The accessibility of the construction is good due to open spaces and the supporting elements being limited to the columns and floors.		
Complexity	Reinforced concrete frame with masonry infill is addressed in the national building code. Design and construction expertise is limited available due to a lack of engineers. Engineers are (if at all) involved for drawings and permits and structural design, construction monitoring and quality control. Non-engineered building practice forms a risk, since RC frame construction requires sufficient level of 'technology, expertise, and workmanship, particularly in the field during construction' (Yakut).	*Ease of learning*	2
	Resources		
Material	The concrete is made of a mixture of sand, cement and water. (Mixtures combined with waste products are also possible.) The concrete is strengthened by steel reinforcement. The infill walls are often made of baked bricks, although block and stone infills are also seen. In rural villages, combinations of stone and brick infill can be found. Availability of concrete can be considered high due to local cement factories in Nepal and the large availability of cement in India and China. The reliability can be very good when road conditions and political situations are good, but during monsoon season many roads are damaged and limit the flow of products coming from India and China. The availability of steel rods for rebar is good due to much local production.	*Quality* *Availability* *Reliability*	5 4 4
Labour	Building with Reinforced Concrete Frames is a labour intensive building method due to the specificity of activities such as correctly making the cement or the placement of casts. The placement of rebar is considered to be one of the most labour intensive activities seeing that the typical unit rate costs is more expensive than other structural elements (Jarkas, 2012)	*Experience* *Intensity*	4 3
Time	According to a study performed for the British Association of Reinforcements the construction speed when working with reinforced concrete is relatively fast (http://uk-bar.org/frame_costs.htm). The construction time can be even faster than other methods such as steel and prefab when taking into account lead times and procurement. The construction speeds can be optimized when performed by an experienced team building in a systematic manner with extreme examples such as the Burj Khalifa with 160+ floors within 6 years.	*Technical period*	3
	Feasibility		
Price label	The ranking is based on price indications and reference countries	*Ranking*	3
Local economy	Brick and cement are not local since they have to come from outside the 50 km range. Labour however is local. Wall infill can be done with a local product.	*Use of local resources*	3
National economy	Most materials are available in Nepal, however large quantities are imported from India. Especially for RCC large amounts of cement is required, as well as for the concrete as for the mortar.	*Use of national resources*	2
	Social / cultural		
Social/ cultural	RCC is a method that can be altered in many different ways allowing for the use of almost any desired exterior and interior. In Bhaktapur (historic settlement) that was damaged by the earthquake RCC frames are used to rebuild the historic centre by applying traditional exterior elements as if it were built in a traditional building style.	*Adaptability*	5
Architectural embedding	RCC has been used for some decades in Nepal, mostly used in the bigger cities and urban outskirts that have quickly developed due to economic growth. It is a method that is known to most people living in larger settlements of Nepal and the characteristics of this methods are widely known. It depends largely how the structures are finished. That shows that a lot of different kind of appearances are possible with this method.	*Embedding*	3

Functional			
Building height	If well-constructed and designed, this building type is internationally suitable for low-rise and high-rise when constructed in the appropriate manner. There is not limitation in the building height according to the Nepalese building code. It is recommended to have a maximum height of three stories. (DUDBC, 1994)	*Amount of storeys*	5
Expandability	This building method is extendable, future extension should be taken in to account during a earlier construction phase by leaving out reinforcement bars at the main columns. If not the expendability is experienced as difficult.	*Possibilities*	5
Workspace	The frame structure should be able to withstand all the loads with the frame column structure. This offers flexibility for the incorporation for space for shops and workspaces.	*Opportunity*	5
Protection	Rain cannot wash away cement mortar and the crevices in the masonry infill walls are filled with cement mortar and cannot be penetrated by wind. Safety is provided with locks, bars and insect screens.	*Elements*	4
		Safety	4
Utilities	Utilities are possible at any level of the building, structure is designed to withstand loads at the rooftop.	*Possibilities*	5
Sustainable			
Recyclable	The building method does not have the opportunity to re-use material. If collapsed, the debris of concrete frame structures is hard to remove and mostly unable to reuse. Specialized equipment is needed to remove the debris, in Kathmandu experts and equipment from other countries had to be called for. From interviews it became clear that regular people and small organisations such as schools do not have the means or knowledge to remove RCC debris on their own.	*Re-usable*	2
		Recyclable	2
Environmental	Environmental impact is dependent on the production of construction materials, the construction itself, the life cycle and the demolition of a construction. The production of materials used for concrete has relatively low impact due to the natural availability of the materials however some chemicals are needed in the process. Construction with concrete needs relatively much transport and machinery resulting in more impact.{Struble, L., & Godfrey, J. (2004, May)} Activities relted to repairs of RCC constructions can increase the environmental impact associated with this building method. Hossain, K. and Gencturk, B. (2014) And the demolition of Reinforced Concrete requires brute force and the use of machinery. According to a study done by Struble, L., & Godfrey, J. (2004, May) the use of concrete has less environmental impact than the use of steel.	*Impact*	3
		Sustainable	5
Images			
			

Timber construction

Introduction
Common Nepali building practise in areas where trees are abundant. Often constructed in stud wall frame or wood frame construction, with either concrete or stone foundations. Walls are built out of vertical timber elements and are stiffened by plywood or gypsum board sheathing. The roofs are often executed out of timber joists or prefab timber trusses {Arnold}.

Category	Description		Value
Technical			
Building components	Key-building components are: usually concrete (reinforced concrete stip-footing foundations), sometimes stone foundations. Walls are built out of vertical timber elements (rectangular cross-sections), and are covered (stiffened) by plywood/ gypsum board sheathing. An alternative seen in Japan is bracing of the timber wall with diagonal members. Floor are made with joists, covered with plywood or OSB, Roofs are executed out of timber joists or prefab timber trusses {Arnold}.	*Strength*	
		Redundancy	3
		Non-structural elements	1
		Building code	5
Seismic Performance Standard	The seismic performance is relatively high {Arnold} in case of sufficient material- and construction quality. The lateral load-bearing system if formed by plywood/ OSB panels nailed to the vertical member which act as shear walls. Also diagonal timber braces can be applied. Structures have satisfactory redundancy due to the typically large number of walls and nailed connections {Arnold}. Seismic deficiencies are inadequate connections to foundation causing the building to move of the foundation, inadequate shear resistance, lacking of bracing, inadequate Joints without mechanical fasteners, lack of proper maintenance {Arnold}	*Performance*	4
Improved Seismic Performance	The seismic performance can be enhanced by application of the adequate finishing; the non-load bearing walls can provide significant dissipation of energy when they are damaged {Arnold}.	*Possible*	5
Building on a slope	Timber structures can be built on slopes, however the vertical forces need to be distributed in a correct manner. A way to achieve this is the use of braces or by constructing a level foundation on which the main structure can be placed.	*Performance*	5
Climate	Location of window openings is very flexible due to the timber braced frame. In a timber construction the infill of walls can be of any desired material, often it is seen that infill consists of rocks. The rock walls are lighter with respect to stone masonry structures, therefore they have lesser thermal mass and insulation properties.	*Openings (ventilation and sunlight)*	5
		Thermal	*3*
Life span	The life span of timber is subjected to the amount of maintenance and the kind of wood used. With the use of the right wood and properly maintained the life span could reach to 80 years.	*Lifespan*	4
Maintenance	Timber is highly subject to maintenance, it requires regular maintenance to prevent the structural elements from rotting requiring maintenance every 3 to 5 years. Maintenance can be done by the owners themselves if they have the knowhow and it does not require much resources. The availability of the structure during maintenance is good except when concerning the maintenance of roof or floor elements.	*Reliability*	3
		Maintainability	5
		Availability	3
Complexity	This construction type is incorporated in the building code (Nepal National Building code NBC 112: 1994 Timber). The know-how is mainly passed on informally {Parajuli, Bothara, & Upadhyay, 2015}, and skills vary per person. House-owners are mostly part of the construction team, often they are helped by local artisans/	*Ease of learning*	3

	masons. It is learnable in short time but expertise comes with the years.		
	Resources		
Material	For structural elements such as beams, columns, bands etc. hardwood, such as the locally available Sal wood, should be used (not soft-wood) (DUDBC, 1994). Timber should be adequately treated to prevent decay. The availability and reliability of proper timber for seismic bands and timber framing is low due to anti-deforestation programs and prices are high due to transportation costs.	*Quality*	5
		Availability	2
		Reliability	4
Labour	Timber is locally known as a building material, there are special carpenters who are able to build with timber frames and connections. Due to the fact that timber is relatively light weight it can be done with few people, however the processing of wood for a timber frame can be time costly requiring a small team of 5 - 10 people.	*Experience*	5
		Intensity	3
Time	Timber construction is a 'dry' construction method and can therefore quickly be assembled and executed.	*Technical period*	4
	Feasibility		
Price label	The ranking is based on price indications and reference countries	*Ranking*	1
Local economy	Timber might be imported from other parts of the country, however might give an impulse to local carpenters	*Use of local resources*	3
National economy	In large scale, timber should probably be imported	*Use of national resources*	3
	Social / cultural		
Social/ cultural	Wood is used for decades in Nepal for finishing and decoration of the houses and temples. Therefore it has the ability to meet the social and cultural requirements of Nepali housing in terms of social status or ethnic identity.	*Adaptability*	4
Architectural embedding	Wood is already used in the construction sector in Nepal for decades. Therefore it is possible to blend in with surrounding, be embedded in traditional building or considered acceptable.	*Embedding*	4
	Functional		
Building height	The maximum building height of timber buildings is not described in the Nepalese building code. Typically and internationally wood frame structures are 3 storeys high. This height is taken in to consideration for the Nepalese situation.	*Amount of storeys*	2
Expandability	Since the maximum building height is not limited by the building code and the effort for extending a timber frame structure is low, the expandability is high.	*Possibilities*	4
Workspace	Timber frame structures can create a large over span which can be used as openings for workspace. Timber elements longer than four meters are costly and therefore not recommended in construction	*Opportunity*	4
Protection	Timber elements provide shelter against rain and wind but are not fully protective against the elements because they can be penetrated by wind and rain. Safety is provided with locks, bars and insect screens.	*Elements*	3
		Safety	3
Utilities	If constructed in the right manner, the building method is able to withstand gravitational forces. For this reason the utilities are possible beyond ground level.	*Possibilities*	3
	Sustainable		
Recyclable	When properly maintained the material is highly re-usable. In case of damage it is also recyclable as firewood for instance.	*Re-usable*	5
		Recyclable	4
Environmental	Timber is a renewable material, which also provides temporary storing of CO2. In a controlled way large amounts of timber can be used.	*Impact*	4

	Sustainable	4

Images

Appendix 1.A.2. – Reference building methods

Criteria of the reference building methods in more rich earthquake-prone areas like Santiago, Los Angeles and Tokyo the added expense in the building sector to make a building earthquake safe has become normal. Due to reinforced concrete, strong steel structures and innovative techniques like shock absorbers buildings are withstanding greater tensions due to earthquakes. Also strict building codes, which are also strictly followed thousands of lives were saved during previous earthquakes, such as a quake with a magnitude of 8,8 hit Chile in February 2010, and japan 9.0 earthquake in march 2011.

It is important for Nepal to use cheap and innovative methods that are used in earthquake-prone areas around the world. In this paragraph various building methods will be elaborated on the criteria of geography (mountains, plat land etc.) and income. As reference countries Chili, Pakistan, Haiti, North India, Japan, Rest of Nepal, Peru, Indonesia are chose.

Adobe

Introduction
This building method is common for low-income rural populations. The Adobe building method uses building materials such as earth, un stabilized mud-like blocks or sun-dried bricks. This building method is one of the earliest building methods in the world, dating back to 8000B.C. {Houben and Guillard 1994}. The typical building consists of a strip footing foundation, adobe material walls and floors spanned with wood joists. The roof is usually clad with clay tiles or corrugated sheet metal. {Blondet & Villa Garcia}

Category	Description		Value
Technical			
Building components	Adobe buildings exist of (strip-footing) foundations, load-bearing walls and varying floor- and roof systems. The heavy structures demands a firm soil as a base and concrete or stone foundation. The sun dried adobe blocks are used for both walls and roofs. The thickness of walls is limited by the thickness to height ratio of 1:8 by building codes 204:1994. Floors are mostly spanned with wood joists (or locally found tree trunks). The roof is clad with corrugated sheet metal clay tiles {Blondet & Villa Garcia}. The roofs can also be adobe domes or cylindrical. The load bearing walls usually have average redundancy and is comparable to low strength brick masonry. This building method is in the building code with thumb rules and limitations on design.	*Strength* *Redundancy* *Building code*	 **2** 4
Seismic Performance Standard	Traditional adobe buildings perform poor seismic behaviour, causing loss in lives and property. The earthen walls are the main seismic resistant elements; traditional structures do not have additional systems to restrain lateral loads The heavy walls generate high seismic forces. The low-strength and brittle wall experience severe cracking under seismic loads. Further seismic vulnerability is caused by insufficient connection between building elements (roof, wall separation of walls disintegration of walls."	*Performance*	**1**
Improved Seismic Performance	The seismic performance can be significantly improved with reinforcement of the walls. Vertical wooden posts and horizontal wooden elements embedded in walls are the expected key earthquake resistant elements in these buildings. There are success stories of Adobe with geomesh for more (EERI)"	*Possible*	2
Building on a slope	Soil slopes of 20° maximum (1:3, Vertical: Horizontal) are stable suitable for construction. In case of proper retaining walls, steeper slopes are allowed {DUDBC, 1994}.	*Performance*	2
Climate	The window openings should be limited and well-spaced. The length between openings is limited to 1.2 m by the building code. The thick wall (0, 25 - 0, 8 m) provides thermal mass and excellent insulation and acoustic properties. The thickness of the wall will vary per climatic region {Blondet & Villa Garcia}. Walls are vulnerable to moisture; 'damp rising from the ground, penetration of rainwater into the wall from a leaking roof and splashing of water during rain', as stated in building code 204:1994. Measures should be adopted to protect the mud/ earthen walls.	*Openings (ventilation and sunlight)* *Thermal*	**2** *4*
Life span	Lifespan of Adobe structures can be very long when maintained correctly and sufficiently and when not exposed to extreme events (force majeure).	*Lifespan*	4
Maintenance	For some building a 2-inch straw reinforced mud cover protects the wall against the weather. Every 4 to 6 years this layer has to be replaced. The structural elements require often periodic maintenance. The performance of maintenance is very easy and do not require workmanship and little to no resources. The availability of the structure during maintenance is similar to low strength brick masonry.	*Reliability* *Maintainability* *Availability*	2 4 2

Complexity	The simple construction method is mostly self-made, simple. This method is typically non-engineered. {Blondet & Villa Garcia}	*Ease of learning*	3
	Resources		
Material	Adobe is a building material made of earth, sun-dried blocks. The wall strength dependent on the local soil quality. The right proportion of clay is essential for the performance of adobe blocks; enough is needed to bond the dry earth material, whereas excessive clay amount can cause cracking due to shrinkage while drying {Blondet & Villa Garcia}.	*Quality*	4
	When the right proportion of clay is available this can be a low-cost, readily available construction material.	*Availability*	5
		Reliability	5
Labour	Good workmanship has a large influence on the strength of adobe masonry. Nepal is very experienced with this method. In the last years this method is not used much anymore in the cities. But the knowledge of this building method is still available. Adobe can be built with a small team but the overall building time can be time consuming due to the drying time of the bricks and the mud.	*Experience*	5
		Intensity	4
Time	Adobe is a time consuming construction method. As described in the box above it can be time consuming due to the drying time of each brick and mortar.	*Technical period*	3
	Feasibility		
Price label	The ranking is based on price indications and reference countries	*Ranking*	5
Local economy	Construction practice can be performed by local builders/ masons. Materials to make adobe are locally available (sand, mud, clay etc.,)	*Use of local resources*	5
National economy	Cash flow to build adobe houses remains in Nepal, since material, labour and knowledge is available.	*Use of national resources*	4
	Social / cultural		
Social/ cultural	Social status of being an unsophisticated lower quality building method in Nepal {Toppa}. However, the method is used in Iran by both poor and wealthy families {Blondet & Villa Garcia}.	*Adaptability*	2
Architectural embedding	Adobe was already widely used in the building sector in Nepal before the earthquake. A lot of these structures did not survive the earthquake. Before it prevailed many mountainous, rural regions and even sometimes in sub urban areas.	*Embedding*	5
	Functional		
Building height	Buildings are typically one story (3m high), but are seen to be built 3 storeys high in mountainous regions {Blondet & Villa Garcia}. The buildings in conformity with the code 204:1994 may not exceed 1 storey with an additional attic floor, the corresponding acceptable storey height is between 1.8 - 2.5 meters. {Building Code} According to the world housing net the maximum safe number of storeys is considered to be one storey.	*Amount of storeys*	1
Expandability	Since the building code limits the building height vertical expansion is also limited.	*Possibilities*	1
Workspace	Opening size and locations are controlled by the building code, limiting the opportunity for workspace, restaurants and shops. Floor to floor height is maximized to 2.5 m by the building code (204:1994).	*Opportunity*	2
Protection	Adobe structures provide shelter against rain and wind but are not fully protective against the elements because they can be penetrated by wind and rain. Safety is provided with locks, bars and insect screens.	*Elements*	2
		Safety	3

Utilities	If constructed in the right manner, the building method is able to withstand gravitational forces. For this reason the utilities are possible beyond ground level.	*Possibilities*	2
	Sustainable		
Recyclable	Made of mud, earth or clay, adobe constructions are highly recyclable. Wall elements however will not be re-used.	*Re-usable*	1
		Recyclable	5
Environmental	Low environmental impact, no requirement of additional energy resources. All materials are local and natural	*Impact*	5
		Sustainable	3

	Reference
Iran	Iran has a large amount of dwellings built with adobe and is hit multiple times with devastating earthquakes. In the 2003 Bam earthquake, over 40.000 people died; in 1990, over 40.000 people dead. Many people were killed in adobe structures due the heavy roof that collapsed (http://db.world-housing.net/building/104, 10/8/2015).
	Images

Dhajji Dewari

Introduction
Traditional building method in the western Himalayas, mostly found in both Pakistan and India. Similar building methods can be found in parts of Europe and Central America {Hicyilmaz, Bothara & Stephenson, 2014}. It is largely adopted as a rebuilding method after the 2005 Kashmir earthquake. The building method exists of an extensively braced timber frame filled with either stone or brick masonry held together with mud mortar. The method is generally laid on shallow foundations stone masonry {Hicyilmaz, Bothara & Stephenson, 2014}. Flooring is done with timber beams which span wall to wall, timber floor boards on top of the beams are overlain with a layer of clay/ mud. Roof are either flat, timber logs with a mud layer pitched timber constructions with metal roof sheeting.

Category	Description		Value
Technical			
Building components	The method is generally laid on shallow foundations stone masonry {Hicyilmaz, Bothara & Stephenson, 2014}. Flooring is done with timber beams which span wall to wall, timber floor boards on top of the beams are overlain with a layer of clay/ mud. Roof are either flat, timber logs with a mud layer or pitched timber constructions with metal roof sheeting. Walls consist of a timber frame construction with many braces and infill with irregular shaped rocks. The redundancy is good due to the frame construction and the many braces that distribute the loads evenly. This construction method is not in the building code but acceptable according to general structural principles.	*Strength*	
		Redundancy	5
		Non-structural elements	3
		Building code	3
Seismic Performance Standard	Timber framing combined with the masonry infill provides the main lateral load resisting system. The timber framing acts as a stable confinement, and contributes to the limitation of out-of-plane demands on masonry infill (Hicyilmaz, Bothara & Stephenson, 2012). The low-strength mud allows yielding at relatively small lateral loads, and provides energy dissipation by means of friction between infill pieces.	*Performance*	3
Improved Seismic Performance	Building method is validated by state of the art engineering analysis {Hicyilmaz, 2011}, and is considered to provide satisfactory earthquake resistance, having more ductility than confined masonry.	*Possible*	4
Building on a slope	Dhajji Dewari structures are typically built on flat terrain {Hicyilmaz, Bothara & Stephenson, 2014}. This can be accounted to the braces that have to connect to a horizontal surface or optimal load distribution.	*Performance*	3
Climate	Location of window openings is quite flexible due to the timber braced frame however window sizes are limited when wanting to maintain the positive effect of the timber bracings.	*Openings (ventilation and sunlight)*	3
	Walls are lighter with respect to stone masonry structures, therefore also less thermal mass and insulation properties."	*Thermal*	*3*
Life span	The timber elements are vulnerable to deterioration however with sufficient maintenance and construction this can be a durable construction method {Hicyilmaz, Bothara & Stephenson, 2014}.	*Lifespan*	4
Maintenance	Due to the large use of timber, maintenance demand is quite high. Lack of maintenance can undermine inherent seismic resistance and general structural safety. The execution of maintenance is relatively easy due to the ease of reaching structural elements. The maintenance does not necessarily require workmanship and some resources due to the many timber elements. The availability of the structure during maintenance is good due to the high redundancy of structural elements.	*Reliability*	3
		Maintainability	3
		Availability	2

Complexity	This method is not common or familiar in the affected area of Nepal (2015). However in India the method is known by local builders, included in the building code and regarded as a straightforward construction technology, easy to build from local materials {Hicyilmaz, 2011}. Making transferring of knowledge from Indian builders to Nepali builders realistic and possible.	*Ease of learning*	2
	Resources		
Material	Materials used are timber for the framing, stone or brick masonry infill and local mud mortar. Materials for infill are locally available in rural and mountainous regions. The feasibility of the building method is largely dependent on the availability and affordability of wood, which is limited by Nepali anti-deforestation programs.	*Quality*	5
		Availability	3
		Reliability	4
Labour	The construction with Dhajji Dewari is commonly used in South Asia (http://www.world-housing.net/tutorials/other/dhajji-dewari). However this method is not very common in Nepal. Therefore construction workers are not used to this building method.	*Experience*	2
		Intensity	3
Time	For the rebuilding after the 2005 Kashmir earthquake, Dhajji Dewari was selected for its speed {Hicyilmaz, Bothara & Stephenson, 2014}. It can be build relatively quick but only with experienced construction workers.	*Technical period*	3
	Feasibility		
Price label	The ranking is based on price indications and reference countries	*Ranking*	3
Local economy	Material for Dhajji Dewari is available (timber to some level, stone). Local carpenters and masons however would need some training, which needs to be imported	*Use of local resources*	4
National economy	If sufficient timber is available, all materials could be provided locally. However on large scale construction timber needs to be imported, which leads to some cash flow leaving Nepal.	*Use of national resources*	3
	Social / cultural		
Social/ cultural	The walls can be plastered or finishing can be applied to allow the appropriate social/ cultural aesthetics. The thick wall allows for example the placement of niches for religious attributes, although the Dhajji Dewari walls are more slender than stone masonry.	*Adaptability*	4
Architectural embedding	This building type is widely found in Pakistan and India. The building has strong reference/ remembrance to stone masonry, prevailing many mountainous and rural regions.	*Embedding*	3
	Functional		
Building height	The maximum building height of timber buildings is not described in the Nepalese building code. Typically and internationally wood frame structures are 3 storeys high. This height is taken in to consideration for the Nepalese situation.	*Amount of storeys*	3
Expandability	Since the maximum building height is not limited by the building code and the effort for extending a timber frame structure is low, the expandability is high.	*Possibilities*	2
Workspace	The building method is considered to have more availability and flexibility for openings for open due to its timber framework.	*Opportunity*	2
Protection	Wind can penetrate through crevices in low strength masonry wall. Safety is provided with locks, bars and insect screens, but can be easily removed.	*Elements*	3
		Safety	3
Utilities	If constructed in the right manner, the building method is able to withstand gravitational forces. For this reason the utilities are possible beyond ground level.	*Possibilities*	3
	Sustainable		
Recyclable	The stones which are held by mud mortar can be re-used. The mortar itself is	*Re-usable*	5

	recyclable into new mortar.	*Recyclable*	5
Environmental	The building construction has a low footprint. Stone and timber are natural and local materials. Although the amount of used wood should be monitored to prevent deforestation.	*Impact*	4
		Sustainable	4

Reference	
North-Pakistan	This building method performed relatively well in the earthquake of October 2005 (magnitude 7.6) in North Pakistan.

Rammed earth

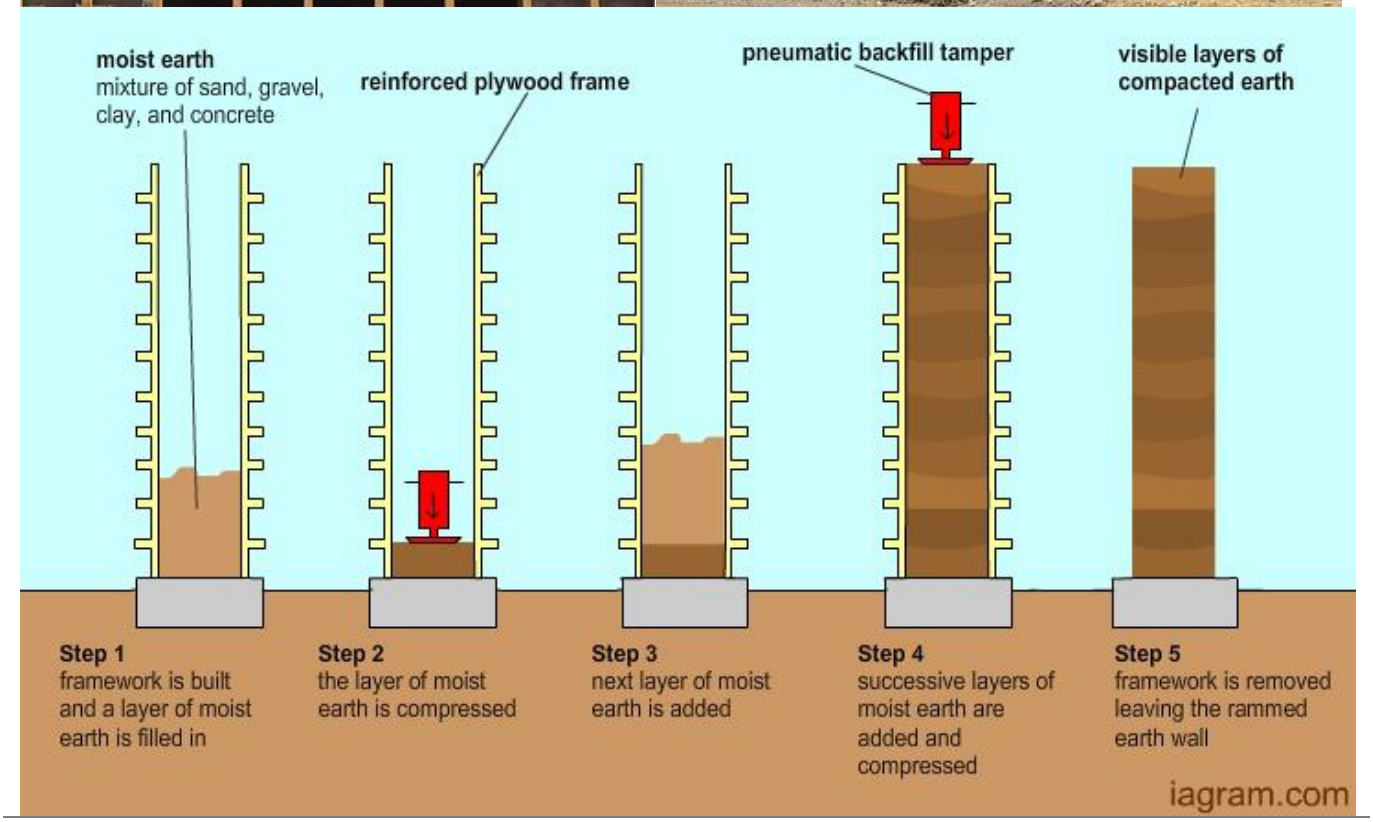
Introduction
This ancient technique is mostly used for residential purposes in many different countries. Also in Nepal it is used in many places ranging from the Terai (plains) to the Himalayas. Rammed earth is the in-situ ramming of moist soil into a placed mold (Sassu & Ngoma, 2015) to make foundations, floors and walls. Rammed earth is gaining renewed interest, due to its usage of sustainable and locally available building material. The roofs are mostly made of timber or bamboo structure (pitched) and clad with corrugated iron sheets.

Category	**Description**		**Value**
	Technical		
Building components	Rammed earth buildings exist of sturdy stone or concrete foundations, load-bearing rammed earth walls and varying floor- and roof systems. The heavy structures demands a firm soil as a base and concrete or stone foundation. Wall height is approximately 2.5 m and wall thickness ranges from 0.20 to 0.30 m. Floors are mostly spanned with wood joists (or locally found tree trunks). Roofs are mostly made of timber or bamboo structure (pitched) and clad with corrugated iron sheets. The load bearing walls usually have average redundancy and is comparable to low strength brick masonry and adobe. This building method is in the building code with thumb rules and limitations on design.	*Redundancy*	**3**
		Building code	3
Seismic Performance Standard	The load bearing system consists of rammed earth walls. The strength of the wall is low and depends on compacting and quality of soil. The structures generally have little lateral load bearing capacity.	*Performance*	**2**
Improved Seismic Performance	The seismic performance can be significantly improved with reinforcement of the walls. Vertical wooden posts and horizontal wooden elements embedded in walls are the expected key earthquake resistant elements in these buildings. Another way of increasing the strength is the use of stabilized rammed earth method which incorporates the use of concrete to bond the rammed earth.	*Possible*	3
Building on a slope	Requires levelling of sloping terrain, is never seen on sloped terrain (Sassu & Ngoma, 2014).	*Performance*	1
Climate	The window openings should be limited and well-spaced. Walls can have good thermal properties due to thickness of the walls resulting in good thermal mass. The walls are susceptible for water damage if not well protected requiring an overhanging roof overhang or other protective measures to protect it from the rain/ moisture.	*Openings (ventilation and sunlight)*	**2**
		Thermal	*4*
Life span	Rammed earth structures are considered durable with lifespan considered to be over 100 years {http://www.forgreenies.com/rammed-earth-houses} and some promoters even claiming that the structures can maintain their integrity for over 1000 years. {http://www.rammedearth.info/rammed-earth-FAQ.htm}	*Lifespan*	4
Maintenance	Once a wall is rammed and sealed it requires little to no maintenance for a period between 10 to 20 years. Performing maintenance is considered to be easy because it only requires resealing of the rammed earth wall. This can be done with little to no workmanship and some resources. The availability of the structure is low during maintenance due to the average redundancy.	*Reliability*	2
		Maintainability	5
		Availability	2
Complexity	The building method requires many experience (THD, 2015), and the quality is dependent on consistent workmanship.	*Ease of learning*	2
	Resources		

Material	The technique makes use of locally available clay, sand, gravel and some cement. The wall strength dependent on the local soil quality and the compacting effort. The method can be considered low-cost with readily available construction materials that are available during the dryer periods in the year. Limiting the possibility to construct in the monsoon season.	*Quality*	5
		Availability	4
		Reliability	4
Labour	The technique requires in-situ ramming and is considered labour intensive if there is no machinery available (powered tampers).	*Experience*	3
		Intensity	2
Time	Speed of construction depends on how fast the ramming can be done, if machinery is available the ramming can be done much quicker. Construction time for a simple house is considered 2 weeks for the wall construction 1 week for the roof.	*Technical period*	4
Feasibility			
Price label	The ranking is based on price indications and reference countries	*Ranking*	5
Local economy	External training and mentoring is needed to perform this technique with local builders	*Use of local resources*	4
National economy	Since rammed earth makes mainly use of materials like sand, mud and clay cash flow is not leaving Nepal.	*Use of national resources*	4
Social / cultural			
Social/ cultural	Social status of being an unsophisticated lower quality building method {Toppa}, perceived as a old-fashioned building method with respect to concrete. The use of rammed earth can have quite the same appearance as adobe which is commonly known in Nepal.	*Adaptability*	2
Architectural embedding	Rammed earth can look quite similar to adobe. Both make use of the earth/clay that is available nearby the construction site. Adobe was already widely used in the building sector in Nepal before the earthquake. A lot of these structures did not survive the earthquake. Before it prevailed in many mountainous, rural regions and even sometimes in sub urban areas.	*Embedding*	2
Functional			
Building height	The buildings in conformity with the code 204:1994 may not exceed 1 storey with an additional attic floor, the corresponding acceptable storey height is between 1.8 - 2.5 meters. {Building Code} According to the world housing net the maximum safe number of storeys is considered to be one storey.	*Amount of storeys*	1
Expandability	Since the building code limits the building height vertical expansion is also limited.	*Possibilities*	1
Workspace	Opening size and locations are controlled by the building code, limiting the opportunity for workspace, restaurants and shops. Floor to floor height is maximized to 2.5 m by the building code (204:1994).	*Opportunity*	2
Protection	Soil structures provide shelter against rain and wind but are not fully protective against the elements because they can be penetrated by wind and rain. Safety is provided with locks, bars and insect screens.	*Elements*	2
		Safety	3
Utilities	If constructed in the right manner, the building method is able to withstand gravitational forces. For this reason the utilities are possible beyond ground level.	*Possibilities*	2
Sustainable			
Recyclable	Made of mud, earth or clay, are highly recyclable. However wall elements of rammed earth cannot be re-used	*Re-usable*	1
		Recyclable	5
Environmen	Low environmental impact, no requirement of additional energy resources. All used	*Impact*	5

tal	materials are local and natural.	*Sustainable*	3

Reference	
Project: Abari	The firm Abari is experimenting with rammed earth structures combined with bamboo roofs in Nepal.



Steel

Introduction
Structural steel was predominately used for industrial and agricultural structures and found it's up rise in the second world war. {http://www.ncibuildingsystems.com/careers/campus/mbi_history.html} After the war the use of steel as a construction material for buildings, bridges and other structures was widely accepted and accessible due to its cost-efficiency. Nowadays steel is not only used for complex structures but also for regular housing projects in seismically active areas, such as Japan where the use of steel in building housing is subsidized.

Category	**Description**		Value
Technical			
Building components	Steel construction with shear walls or steel braces, often combined with a reinforced concrete foundation. The basic structure is consisting of steel braced frame with reinforcements to make the constructing resistant to lateral and transversal loads. Up to 5 storeys cross braces or shear walls are used. Over 5 storeys reinforced concrete slips or jump formed wall are commonly used {10/5/2015, http://db.world-housing.net/building/3#tabs-4}.	*Strength*	
		Redundancy	3
		Non-structural elements	3
		Building code	5
Seismic Performance Standard	Seismic performance of structural steel constructions can be considered very good due to a number of desirable attributes. It is relatively lightweight, while providing great strength. Steel has a high ductility which is a favourable trait during an earthquake.	*Performance*	5
Improved Seismic Performance	The performance during an earthquake can be increased by use of special moment resisting frames and different types of braces such the V-brace, inverted V-brace, X-brace, and two storied X-brace etc. A combination of the properties of steel and the possibilities to enhance the frame make steel frame buildings a good construction type for seismically active areas.{lecture by Michael D Engelhardt Michael D. Engelhardt University of Texas at Austin, Design of Seismic Design of SeismicResistant Steel Building Structures}	*Possible*	5
Building on a slope	Steel structures can be built on slopes, however the vertical forces need to be distributed in a correct manner. A way to achieve this is by using bracings and constructing a level foundation on which the main structure can be placed. {http://web.mit.edu/cron/Backup/project/zalewski/layouts/slopes01d.pdf}	*Performance*	5
Climate	Openings in exterior walls can easily be made due to the openness of steel frames, only limited by possible placement of braces. The interior climate of a steel structure can be easily regulated depending on the choices for interior and exterior wall covering and choice of insulating layers. A disadvantage of steel construction frames is the ability of steel to conduct heat, having possible negative effects on the interior climate.	*Openings (ventilation and sunlight)*	5
		Thermal	*3*
Life span	Steel structures can have a very long lifespan (exceeding 100 years) when maintained properly.	*Lifespan*	4
Maintena	Steel structures have some disadvantages when it comes to maintenance. Steel is	*Reliability*	3

nce	vulnerable to corrosion when exposed to oxygen, water and humidity, to prevent corrosion periodic painting is needed. Another issue that needs periodic maintenance is the fire protective coating that ensures the structural integrity of steel during a fire. The amount of maintenance and the consequences of not performing maintenance are both large. The maintainability of steel is relatively easy when it comes to treating the steel with a protective layer, however the maintenance that requires welding does require more workmanship and resources. The availability of the structure during maintenance is good and comparable to the RCC frame.	*Maintainability*	2
Complexity	The complexity of constructing with steel is that it requires knowledge on correctly connecting the frame and braces. Bad detailing, due a lack of knowledge among the construction workers can result in unsafe structures. Building with steel requires special tools and the knowledge on properly handling these tools.	*Ease of learning*	3
	Resources		
Material	The main materials needed are steel beams with the correct quality marks, cement for the construction of a foundation, welding materials and the materials of choice for flooring, interior and exterior covering. The availability of materials under normal circumstances is good, a threat to the availability is the political situation with neighbouring countries seeing that the beams need to be imported. Another factor playing a role is the conditions of the roads, especially after monsoon season when these can get swiped away by landslides. Steel is a material that is produced and readily available in Nepal, however this only concerns the production of steel rods and rebar. Very little to no producers offer structural steel beams requiring the import of steel beams for construction purposes. {http://www.fncci.org/members/page1.php?op=pageload&file=search_result&type=am&am_catid=18}	*Quality* *Availability* *Reliability*	5 3 3
Labour	The labour intensity of building with steel is relatively low. A small team of workers 4 to 10 can erect a steel frame for housing. However skilled labour is needed for welding and construction with steel. Right now steel buildings are not very popular in Nepal.	*Experience* *Intensity*	2 3
Time	The construction time for a small house built with steel is dependent on the amount of workers, varying between 2 to 6 months making it a relatively quick building method. { http://www.steelconstruction.info/Residential_and_mixed-use_buildings}	*Technical period*	4
	Feasibility		
Price label	The ranking is based on price indications and reference countries	*Ranking*	1
Local economy	Steel is not a local product, non-structural elements however can be done with local material.	*Use of local resources*	3
National economy	On national scale the economy will not necessarily benefit given that the main product needs to be imported.	*Use of national resources*	1
	Social / cultural		
Social/ cultural	Steel frames allow for many shapes and forms, the materials to fill the frame can be adapted to the owner's preferences allowing for high adaptability. The materials usable for the infilling can be the same as known to the local people.	*Adaptability*	5
Architectural embeddding	Unfamiliar from traditional point of view, however in the urban villages more and more examples of steel frame buildings are seen. Although not always correctly implemented.	*Embeddding*	3
	Functional		
Building height	Steel is not limited by the Nepalese building code in its building height. Internationally steel is used as a building material for high rise structures.	*Amount of storeys*	5
Expandability	Steel frames are easily expandable when accounted for in the design, extra steel frame elements can be welded on the existing structure	*Possibilities*	5

Workspace	Steel frame constructions also work with columns and beams, therefore large spans can be made, the incorporation of space for shops and workspaces is relatively easy.	*Opportunity*	5
Protection	Rain cannot wash away cement mortar and the crevices in the masonry infill walls are filled with cement mortar and cannot be penetreated by wind. Safety is provided with locks, bars and insect screens.	*Elements*	4
		Safety	4
Utilities	Utilities are possible at any level of the building, structure is designed to withstand loads at the rooftop.	*Possibilities*	5
Sustainable			
Recyclable	The steel used for the frames is reusable when not damaged and otherwise recyclable by melting. The materials used for filling the frame can be chosen by the owner and can also be both recyclable and reusable.	*Re-usable*	4
		Recyclable	5
Environmental	Steel is an environmentally beneficial product, allowing for easy recycling and reusing. The construction speed is quicker than traditional labour intensive materials reducing local impact. {http://www.steelconstruction.info/} Compared with concrete it has less associated energy usage due to less mass needing to be transported, less formwork etc. However steel building has more heavy metal emissions due to welding, treatment of steal etc. {Guggemos, A. and Horvath, A. (2005)}	*Impact*	3
		Sustainable	5

Reference	
Project: japan	Steel structures are dominant in the construction industry in Japan, especially in Japan after WWII steel structures increased enormously. At present it in Japan it accounts for 40 percent of the total amount of building in a year, while wood and concrete are only responsible for 20 percent. This is unique in the world. The reason behind this is the strong support of the government after the Meiji restoration. The idea behind this is that Japan needed a material that should be used to resist the impact of severe earthquakes. Although steel is more expensive to build with than concrete and timber it has been sustained by the nation's wealth of Japan. However these cost can be a problem for Nepal (2009, Earthquake-Resistant Engineering of Steel Structures, Hitoshi Kuwamura, Stock Management for Sustainable Urban Regeneration, Volume 4 of the series cSUR-UT Series: Library for Sustainable Urban Regeneration pp 133-156).
Chile	In Chile there was no severe damage in the serious earthquakes of 1960 with a magnitude of 9.5 with these steel constructions (10/5/2015, http://db.world-housing.net/building/3#tabs-4).

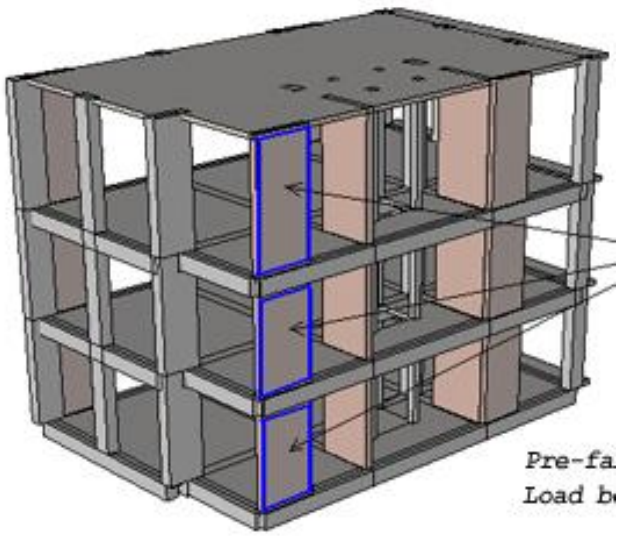
Concrete in-situ shear wall

Introduction
Buildings made with cast-in-situ reinforced concrete walls have been practiced since 1960. This type can be widely found in urban regions of seismic hazard areas such as Canada, Chile, Romania, Turkey, Columbia and the republics of the former soviet Union {Moroni}. Shear walls are usually placed along both length and width of buildings, they carry earthquake loads downwards to the foundation. Shear walls can be executed in several ways such as, all shear wall, tunnel or limited shear wall.

Category	Description		Value
Technical			
Building components	RCC construction with shear walls, often combined with a reinforced concrete strip or mat foundation. The basic structure is consisting of RCC frame with reinforced concrete load-bearing walls (varying from 140 mm to 500 mm) to make the constructing resistant to lateral and transversal loads. Floors are reinforced concrete slabs and less often precast hollow-core slabs {Moroni}. The redundancy is good due to the use of shear walls. Incorporated in the building code	*Strength* *Redundancy* *Building code*	 4 5
Seismic Performance Standard	Main lateral load bearing elements are the reinforced shear walls, providing resistance to both gravity and horizontal loads. These shear walls need to be provided in the two principle directions. The seismic resistance is considered adequate, due to very good performance in previous earthquakes in Chile, Turkey {Moroni}. The principle of a shear wall is similar to confined masonry, the walls work to distribute the seismic loads, reinforced concrete shear walls are graded as more seismic resistant than confined masonry. (Build change, n.d.) Seismic vulnerability can be caused by inadequate construction quality, inadequate amount and detailing of wall reinforcement, soft story mechanisms, reduced wall density- torsional effects.	*Performance*	5
Improved Seismic Performance	Seismic performance can be improved by good construction practice and detailing. Strategic placement of shear walls, providing the largest arm to withstand torsional forces.	*Possible*	5
Building on a slope	Building on slopes is not advised with a reinforced concrete construction due to column failures. During an earthquake the columns in a cross section move by the same amount in a horizontal direction. This causes for columns of different lengths to attract different horizontal forces, resulting in different stresses being exerted on different column lengths.{SUJIT KUMAR et al.} This can be compensated by several advanced methods or by construction of a plane foundation.	*Performance*	4
Climate	Window openings are quite flexible due to the frame construction. The frame however must be designed on lateral load. Often it is only for gravitational loads and then the structure is also dependent on the masonry infill; decreasing flexibility of window openings. It is not recommended to have openings in shear walls, openings can be provided but their size must be small to ensure the least interruption to force flow through the walls. (IITK, n.d.) Insulation and acoustic properties depend mostly on type of infill. When bricks see brick masonry	*Openings (ventilation and sunlight)* *Thermal*	4 *3*
Life span	When constructed in the right manner reinforced concrete walls have a long life span. Life span of RC frame construction is lower than masonry building methods. Estimated lifespans are 30-100 years	*Lifespan*	4
Maintenance	RCC shear wall buildings require little maintenance, because the structural elements consist of and are protected by the concrete. However when the	*Reliability* *Maintainabil*	5 2

	concrete is damaged or is in need of maintenance the work requires workmanship and much resources such as concrete injections, rebar replacements.	*ity*	
Complexity	Uncommon in settlement typology B, C, D, E. In the city core (A) cast in-situ concrete walls are used. The technique is used in the hydropower industry, therefore the technique is present. Cast in-situ walls are also seen in houses constructed on the downhill side of the road. The wall is the boundary between house and the hill. Non-engineered building practice forms a risk, since RC frame construction requires sufficient level of 'technology, expertise, and workmanship, particularly in the field during construction' (Yakut).	*Ease of learning*	2
	Resources		
Material	The concrete is made of a mixture of sand, cement and water. The concrete is strengthened by steel reinforcement. The infill walls are often made of baked bricks, although block and stone infills are also seen. In rural villages, combinations of stone and brick infill can be found. Availability of concrete can be considered high due to local cement factories in Nepal and the large availability of cement in India and China. The reliability can be very good when road conditions and political situations are good, but during monsoon season many roads are damaged and limit the flow of products coming from India and China. The availability of steel rods for rebar is good due to much local production.	*Quality*	5
		Availability	4
		Reliability	4
Labour	The place of the walls in the structure combined with the amount of rebar in the wall make the building method labour intensive. But there are less connection to be made compared to a RCC frame building. The building method can be done with local labour but proper training and supervision is needed.	*Experience*	3
		Intensity	2
Time	Speed of construction: completion of approximately one floor/week. The application of tunnel-form construction can significantly speed up the pace, by casting the walls and slabs (in an upside down "U"-shape) in a single operation. (moroni, n.d.). The solidification time of concrete is one of the main factors that takes time.	*Technical period*	3
	Feasibility		
Price label	The ranking is based on price indications and reference countries	*Ranking*	2
Local economy	Cement is not local since they have to come from outside the 50 km range. Labour however is local. Wall infill can be done with a local product.	*Use of local resources*	2
National economy	Most materials are available in Nepal, however large quantities are imported from India. Especially for RCC large amounts of cement is required, as well as for the concrete as for the mortar.	*Use of national resources*	2
	Social / cultural		
Social/ cultural	Concrete buildings are widely seen in Nepal for the last few decades. Adaptions such as painting, plastering and decorations are possible to allow the appropriate social/cultural aesthetics. This can be quite similar to reinforced concrete structures.	*Adaptability*	5
Architectural embedding	The building method is used in the more urban areas of Nepal, but also here the usage is limited. In the more remote areas the shear wall is more used as a wall as a retaining wall, than to increase the strength of the building. Apart from this shear walls are not really architectural embedded in Nepal, although it has a lot of the same characteristics as reinforced concrete.	*Embedding*	3
	Functional		
Building height	If well-constructed and designed, this building type is internationally suitable for low-rise and high-rise when constructed in the appropriate manner. There is not limitation in the building height according to the Nepalese building code. This	*Amount of storeys*	5

	construction type is used for medium- to high-rise: 4 to 35 storeys high {moroni}.		
Expandability	This building method is extendable, future extension should be taken in to account during a earlier construction phase by leaving out reinforcement bars at the main columns. If not the expendability is experienced as difficult. The expandability is more difficult than with RCC frames	*Possibilities*	3
Workspace	In general, these walls are continuous throughout the building height; however, some walls are discontinued at the street front or basement level to allow for commercial or parking spaces. {Moroni}	*Opportunity*	4
Protection	Rain cannot wash away cement mortar and the crevices in the masonry infill walls are filled with cement mortar and cannot be penetrated by wind. Safety is provided with locks, bars and insect screens.	*Elements*	4
		Safety	4
Utilities	Utilities are possible at any level of the building, structure is designed to withstand loads at the rooftop.	*Possibilities*	4
	Sustainable		
Recyclable	The building method does not have the opportunity to re-use material. If collapsed, the debris of concrete frame structures is hard to remove and mostly unable to reuse. Specialized equipment is needed to remove the debris, in Kathmandu experts and equipment from other countries had to be called for. From interviews it became clear that regular people and small organisations such as schools do not have the means or knowledge to remove RCC debris on their own.	*Re-usable*	2
		Recyclable	2
Environmental	The environmental impact is similar to the RCC frame building method.	*Impact*	3
		Sustainable	5
	Reference		
Project	Projects in Chile, Kyrgyzstan, Canada and Taiwan.		
	Images		



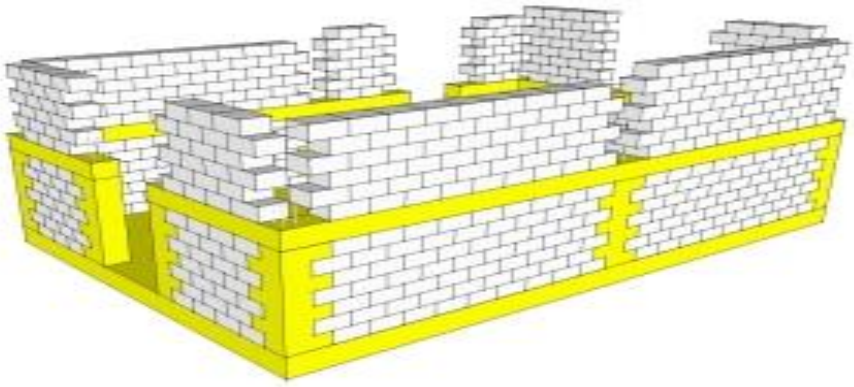
Confined masonry

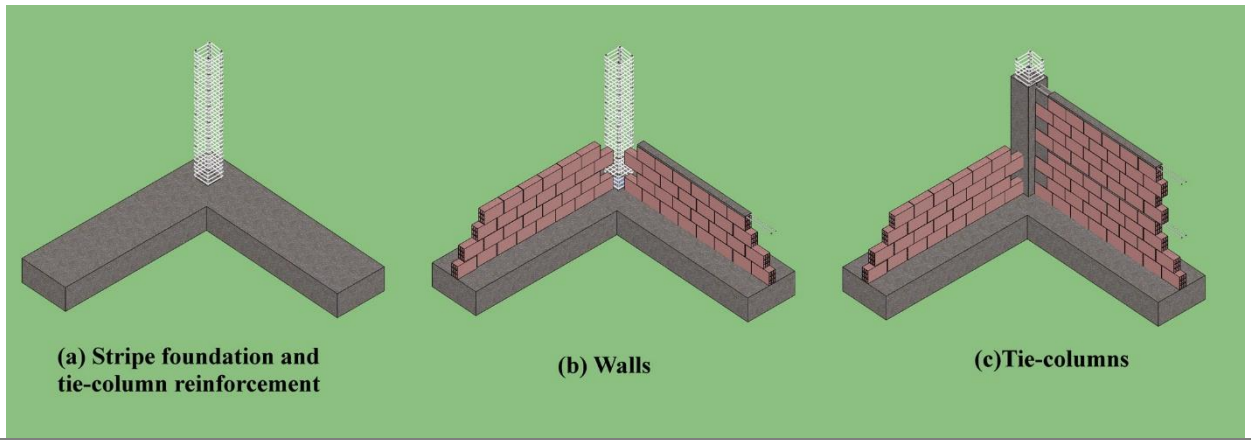
Introduction
This building type is found in urban and rural areas highly seismic areas, for example Chile. This type is practiced in most countries since the last 30-35 years, the building method gets its strength from tie-columns which are cast-in-place after the masonry wall construction has been completed. Tie-columns and tie-beams work as ties that provide reinforcement to the structure. Reinforcement steel is needed to provide this tie function between the columns and beams. {Rodriquez}.

Category	Description		Value
Technical			
Building components	RCC construction with brick masonry shear walls, often combined with a reinforced concrete strip or mat foundation. The basic structure is consisting of unreinforced masonry load-bearing walls strengthened by a confinement with reinforced concrete tie-columns and -beams, mostly cast-in-place concrete floors and roofs. Also timber roofs are seen, combined with the RC tie-beams. The walls can be consist of several types of building block. The redundancy is good due to the use of shear walls. The method is incorporated in the Building Code	*Strength* *Redundancy* *Building code*	 **4** 5
Seismic Performance Standard	The seismic behaviour is considered satisfactory, if it is well constructed and if materials are used with sufficient quality {Rodriquez}. In the confined masonry method the walls work as load bearing walls and not only as infills, with this are the walls able to withstand horizontal loads. When the wall is able to withstand load it works as a shear wall which is proven to work during earthquakes. (build change, n.d.) The seismic performance of confined masonry is total depend on the quality of the workmanship. The columns, beams and walls should be bond in the right way. Vulnerability is increased when structures are built without adequate roof-to-wall connection or without adequate wall-to-wall connections.	*Performance*	**4**
Improved Seismic Performance	Seismic performance can be improved by adding concrete reinforced bands on different height within a storey and by using load bearing shear walls as inner walls, providing the largest arm to withstand torsional forces.	*Possible*	5
Building on a slope	A confined masonry wall should be able to withstand a serious earthquake, this is the same effect as the wall tilted at an angle of 20.5 degrees. Building on slopes is not advised with a reinforced concrete construction due to column failures. During an earthquake the columns in a cross section move by the same amount in a horizontal direction. This causes for columns of different lengths to attract different horizontal forces, resulting in different stresses being exerted on different column lengths. {SUJIT KUMAR et al.}	*Performance*	3
Climate	Window openings are limited due to the brick masonry load bearing walls. The integrity of the structure is dependent on the masonry infill, decreasing flexibility in possibilities for window openings. It is not recommended to have openings in the confined walls, openings can be provided but their size must be small to ensure the least interruption to force flow through the walls. Use of brick masonry can increase the thermal mass of a building and its fire resistance.	*Openings (ventilation and sunlight)* *Thermal*	**2** *4*
Life span	The life span of a confined masonry building is similar to a RCC frame building, estimated lifespans are 30-100 years	*Lifespan*	4
Mainten	The building does not require much maintenance, the maintenance that is	*Reliability*	4

ance	done does not necessarily require workmanship and can be done by the owner, there is little or no maintenance done to the exterior wall. (world housing encyclopaedia, 2010). For more structural maintenance, masons or more experienced workers are needed.	*Maintainability* *Availability*	2 3
Complexity	First the brick walls are constructed stand-alone, after these are finished the concrete columns combine the walls into a building. This method increases the complexity since the stand-alone walls need to be constructed aligned to the columns. Especially the connection of the beams with the columns requires quality workmanship since this is critical to the construction. The building method requires skilled masons. (build change, n.d.)	*Ease of learning*	2
	Resources		
Material	Brick: In confined masonry the brick wall works with the columns and ties to increase the strength of the building. Therefore the bricks need to be baked to withstand the load bearing capacity. Bricks are mainly of sufficient quality, having a crushing strength of above 7.5 N/mm2 (NSET, 2009). The stones are mostly coursed and dressed into rectangular shapes. The bonding material cement is executed as 1:6 cement sand mortar. The availability of baked brick is high due to local production and the reliability of availability is high given that baked bricks are producible all year through. Concrete: The concrete is made of a mixture of water, cement and sand (1:2:3). The concrete is strengthened by steel reinforcement. Availability of concrete can be considered high due to local cement factories in Nepal and the large availability of cement in India and China. The reliability can be very good when road conditions and political situations are good, but during monsoon season many roads are damaged and limit the flow of products coming from India and China. The availability of steel rods for rebar is good due to much local production.	*Quality* *Availability* *Reliability*	3 3 3
Labour	The higher complexity in the building method requires for the skilled masons, these masons are less available and higher paid. If the skilled masons are not available training is required to ensure the quality of the structure.	*Experience* *Intensity*	3 3
Time	The construction time is similar to RCC frame with brick masonry infill.	*Technical period*	3
	Feasibility		
Price label	The ranking is based on price indications and reference countries	*Ranking*	3
Local economy	Local masons are able to work with the building method, since it is similar. Bricks are transported mainly from Kathmandu and surroundings.	*Use of local resources*	3
National economy	The national brick and concrete sector benefit from the construction of confined masonry. However cement is frequently imported from India.	*Use of national resources*	3
	Social / cultural		
Social/ cultural	The walls can be plastered or finishing can be applied to allow the appropriate social/ cultural aesthetics. For example the thick wall allows the placement of niches for religious attributes.	*Adaptability*	4
Architectural embedding	Brick masonry is a commonly used building practice and is embedded in local building traditional and architectural identity. Combined with the increasingly embedded concrete building method.	*Embedding*	4
	Functional		
Building height	Confined masonry is typically seen as a building method for low-rise construction (2 to 4 storeys) In Mexico, up to 7 stories are seen, where the first two floors are strengthened with RC shear walls. (Rodriquez) Concluding: When properly designed and constructed up to seven storeys is reachable.	*Amount of storeys*	5

Expandability	This building method is extendable, future extension should be taken in to account during an earlier construction phase by leaving out reinforcement bars at the main columns. If not the expendability is experienced as difficult.	*Possibilities*	5
Workspace	The load bearing strength is distributed through the walls, therefore there is open space and opportunity for workspace. The correct positioning of the load bearing wall is essential to guarantee enough workspace.	*Opportunity*	3
Protection	Rain cannot wash away cement mortar and the crevices in the masonry infill walls are filled with cement mortar and cannot be penetrated by wind. Safety is provided with locks, bars and insect screens.	*Elements*	4
		Safety	4
Utilities	Utilities are possible at any level of the building, structure is designed to withstand loads at the rooftop.	*Possibilities*	4
	Sustainable		
Recyclable	For confined masonry it is not able to recycle the materials after construction. Removing cement mortar in general causes the bricks to break or crack. In the building method only recycled bricks that are able to withstand a crushing strength of 7, 5 N/mm2 are allowed. (NSET, 2009)	*Re-usable*	2
		Recyclable	2
Environmental	The environmental impact is similar to the RCC frame building method.	*Impact*	3
		Sustainable	5
	Reference		
Project	Projects in Mexico, (Tena-Colunga, 2010)		





Bamboo

Introduction

Bamboo is found in several forms in the construction practice in Nepal {Pokhrel}. It can be used as building material in combination with other materials. Floor or roof systems, or as an reinforcement for methods such as adobe or stone. Bamboo can be used practically for the majority of the housing components (walls, floors, roof, doors, windows, and stairs) but in practise is most common in the Terai region as building method and only as scaffolding in other parts of Nepal.

Category	Description		Value
	Technical		
Building components	Key building elements are: (individual column footings) foundation, vertical bamboo culm members set in concrete footing, varying wall infill, varying floor systems, bamboo rafters or truss, purlins. Wall infill could be executed as a grid of split bamboo/ weaving bamboo strips plastered with cement, clay or mud. The redundancy is average to good when more columns are used for the structural frame.	*Strength*	
		Redundancy	3
		Building code	3
Seismic Performance Standard	Bamboo has a very high strength-to-weight ratio {Lakkad, 1981}. This is favourable for earthquake construction. Its compressive strength outperforms wood, brick and concrete, and peers with steel in tensile strength (Rottke, 2002). Designs are made in America which are earthquake-resistant and verified.	*Performance*	3
Improved Seismic Performance	The seismic performance can be enhanced by application of the adequate finishing; the non-load bearing walls can provide significant dissipation of energy when they are damaged {Arnold}.	*Possible*	4
Building on a slope	Bamboo structures are similar to timber structures and can be built on slopes, however the vertical forces need to be distributed in a correct manner. A way to achieve this is the use of braces or by constructing a level foundation on which the main structure can be placed.	*Performance*	5
Climate	The light bamboo frame structure allows for flexible location of window openings due to the framed construction. In a bamboo construction the infill of walls can be of many desired material, often it is seen that infill consists of boards or bamboo sheets. The walls are light and have lesser thermal mass and insulation properties.	*Openings (ventilation and sunlight)*	5
		Thermal	*2*
Life span	Bamboo structures are extremely susceptible to moisture and decay by insects, significantly limiting its life span. Protection can be provided by means of roof overhangs, drainage gutters, raised footings. There are also several ways to treat the bamboo. Treatment and design of bamboo construction largely influences the life span. The lifespan of natural bamboo is maximum 36 months, the development on treatment methods is ongoing but since the results are not visible yet the natural lifespan is considered. (National building code of India, 2005)	*Lifespan*	1
Maintenance	Bamboo has high maintenance and treatment requirements The firm Abari has developed a promising method for bamboo treatment (Abari)	*Reliability*	1
		Maintainability	4
Complexity	Bamboo is widely used in Nepal as scaffolding and it is therefore an important material in the construction industry of Nepal. International standards for bamboo as a construction material and Nepal national building codes for Bamboo are lacking.	*Ease of learing*	3
	Resources		

Material	Matured bamboo should be used with a minimum of 3 years old. Bamboo needs to be treated properly, otherwise the material is highly vulnerable to decay by fungus and termite attacks. The natural building material does not come in a uniform shape, size or age. Processing into building panels would evade disadvantages such as uniformity and vulnerability to decay. Bamboo is one of the fastest growing plant species, and it grows on poor soil. It matures within 3 years. Bamboo is widely available in the southern part of Nepal {Habitat for Humanity, 2007}.	*Quality*	5
		Availability	5
		Reliability	4
Labour	Due to the trait that bamboo is a light weight material it can easily be executed by a small team of people (5-10). The cutting of the bamboo can be done by one person and the carrying to location by 2 or 3 depending on the size. The experience required to build with bamboo is available in most parts of Nepal as scaffolding and simple constructions are built with bamboo.	*Experience*	4
		Intensity	3
Time	Bamboo construction allows for quick assembly due to its light weight and assembly with simple tools.	*Technical period*	5
	Feasibility		
Price label	The ranking is based on price indications and reference countries	*Ranking*	5
Local economy	Promotion of bamboo construction could stimulate bamboo farming and thereby the local economy. Farmers and agricultural land is commonly seen in the area.	*Use of local resources*	5
National economy	Bamboo is a locally available building material in Nepal. Cash flow of bamboo harvest will remain in Nepal.	*Use of national resources*	4
	Social / cultural		
Social/ cultural	Bamboo has a poor status perception as a long term building solution {Pokhrel}, it is seen as a material to be used for temporary structures and scaffolding. This perception is considered to differ per area (rural, urban areas).	*Adaptability*	2
Architectural embedding	Whole buildings can be constructed with bamboo, however also only the structural elements can be built with bamboo. The exterior can be adjusted to local demands. In the south of Nepal (Terai) a lot of bamboo dwellings do exist. In the north bamboo is less commonly used in the construction sector	*Embedding*	4
	Functional		
Building height	Bamboo is not included in the Nepalese building code, typically Bamboo houses are 1 to two storeys high.	*Amount of storeys*	3
Expandability	For this case the maximum storey height of two storeys is taken in to consideration. Due to this limited storey height vertical expansion options are not high.	*Possibilities*	4
Workspace	Using bamboo for truss structures allows sufficient light-weight spans to create open space for workspace	*Opportunity*	4
Protection	Bamboo elements provide shelter against rain and wind but are not fully protective against the elements because they can be penetrated by wind and rain. Safety is provided with locks, bars and insect screens.	*Elements*	2
		Safety	3
Utilities	If constructed in the right manner, the building method is able to withstand gravitational forces. For this reason the utilities are possible beyond ground level.	*Possibilities*	2
	Sustainable		
Recyclable	Natural material of bamboo has a high rate of recyclability, and can be easily	*Re-*	4

	disassembled for re-use due to its tied joints.	*usable*	
		Recyclable	3
Environmental	Environmentally friendly building material: bamboo is one of the fastest growing species - growth rates ranging from 30 cm to 100 cm per day. Use of bamboo provides temporary storage of CO2. Use of bamboo will help lowering deforestation.	*Impact*	5
		Sustainable	3

Reference

Appendix 1.A.3. – New building methods

New building methods can be profitable for rebuilding Nepal back better. These are quite new methods that are not widely used right now but may have a potential for rebuilding the country. In this paragraph a selection is made of different building methods that are tested on the following criteria: quick building time, easy, costs, prefab, lightweight, earthquake resistance and local building materials. Different meeting with builders and factories were planned to discuss their options. Moreover different meetings of Shelter Cluster and the DUBDC (Department of Urban Development and Building Constructions) were attended to see the different methods that are used and proposed right now for the rebuilding of Nepal. Below this paragraph will elaborate various methods which the authors selected with the criteria described above.

Earthbags

Introduction
The use of piled sandbags for the creation of walls is a technique that has been used for decades in flood protection and by the military in creating strong barriers. However the application of using sturdy bags filled with local materials for use in the construction sector is fairly new. {http://www.earthbagbuilding.com/} In building with earthbags different kind of methods are developed such as regular earthbags, super earthbags, hyper earthbags and sandsbags. Earthbags have been used in many countries to develop cheap and easy to construct houses. They can incorporate barbed wire and/or rebar for the strengthening of weak spots.

Category	Description		Value
	Technical		
Building components	Gravel filled bags or nets that are wider than the bag walls are used for foundation purposes. Earth filled bags are used as load bearing walls, window frames and non-structural walls held together with barbed wire to prevent shifting of bags and rebar for strengthening weak spots. Concrete lintels over doors and windows and a concrete bonding beam can be used for extra safety. An alternative is the use of frames which can be filled with the earthbags, reducing the need for concrete. The exterior of the structure should be covered. {earthbag structures} The redundancy of the structure is comparable to masonry structures and is considered average. The earthbags structures are not incorporated in the Building Code and are doubtable to fit general structural principles	*Strength*	
		Redundancy	**3**
		Non-structural elements	
		Building code	2
Seismic Performance Standard	Owen Geiger has claimed that more than 50 Earth Bag structures in Nepal have survived the earthquakes of 2015. {buildsimple} Although inertial loads are high.	*Performance*	**2**
Improved Seismic Performance	Filling the earthbags with Adobe is called Super adobe this method has been proven to resist earthquakes with 8 on the Richter scale {http://windriche.com/superadobe/advantages_and_disadvantages_of_earthbag_construction.htm}. Several types of vertical and horizontal reinforcement methods are possible.	*Possible*	2
Building on a slope	Earthbag buildings are substantially heavier than bricks thus require a sturdy soil to be built on. The bags require a flat surface to be built on for good distribution of forces.	*Performance*	2
Climate	Earthbags allow for the making of openings of different sizes however with limitations, the sizes of openings can be compared to that of low strength brick masonry structures.	*Openings (ventilation and sunlight)*	**2**
	Protection against external elements is done by covering the structure in plaster creating a layer that is resistant against rain and solar exposure. Earth Bag have similar thermal qualities as structures made of mud/ earth, which generally have good thermal capacity. In very cold climates ensuring internal climate can be done by adding insulating layers in the earthbags or against the interior of a wall.	*Thermal*	*4*
Life span	Different sources claim different life spans, the fact that earthbags are only used recently make it difficult to give exact numbers on the lifespan. Logically it can be derived from the determination rate of the poly bags that it can vary from decades to a century	*Lifespan*	3
Maintenance	Earth Bag structures are low maintenance, since there are no hidden structural members, the main structural components are made of earth and the interior is done as desired allowing for replacement when needed. The only difficulty is when rebar is used to connect bags vertically.	*Reliability*	4
		Maintainability	5
		Availability	2

Complexity	Building with earthbags is relatively easy, except for some crucial guidelines which have to be followed. E.g. placement of bag, manner of sealing bag, manner of placing rebar/barbed wire, testing bags etc. The presence of one or multiple experts is required to ensure the structural elements. Unskilled workers can be used for stacking and preparing the bags. The buildings can be made with little to no electrical or advanced tools, decreasing complexity.	*Ease of learning*	4
	Resources		
Material	"Poly bags (strong, new or unexposed to sunlight), bags in can used in different shapes and sized, such as long bags, small bags or tube bags. Barbed wire for bounding the bags, Rebar for strengthening the weak points such as corners, Earth, crushed rock, moist soil, clay or similar filling, Plaster, mud or different material for exterior covering, Roofing can be done in a multitude of ways including traditional. Optional: cement for extra bonding seems between bags, steel, bamboo, wood or other material usable for making frame," The availability and reliability of these materials is high because many are locally available, the poly bags can be imported from manufacturers in China. {http://chinawovenbag.com/}	*Quality*	5
		Availability	5
		Reliability	5
Labour	The labour intensity of Earth Bag structures is low, work includes filling bags with soil, placement of bags, connecting the bags, plastering the structure. The disadvantage to building with Earth Bags is the physical strain caused by the weight of the bags especially above a certain height. The experience with building with earthbags is not very much present in Nepal.	*Experience*	3
		Intensity	4
Time	When performed by 2 unskilled labourers a small Earth Bag house can be constructed in 6 weeks, however final building time is very dependent on amount of people working, amount of experience, complexity of the structure and size of the structure (book earthbags).	*Technical period*	3
	Feasibility		
Price label	The ranking is based on price indications and reference countries	*Ranking*	5
Local economy	Sand is a local product, only the bags need to be produced for the large scale usage.	*Use of local resources*	4
National economy	Sand is a national product and bags can be produced in Nepal as well, cash flow is not leaving the country.	*Use of national resources*	4
	Social / cultural		
Social/ cultural	Earth Bag structures can be made in many forms and shapes, for the finishing it can be plastered or covered by other materials according to desire. {earthbagbuilding}	*Adaptability*	3
Architectural embedding	Unfamiliar from traditional point of view, however multiple parties are busy with projects throughout Nepal. Earthbags are used for making retaining walls e.g. garden walls and shelters.	*Embedding*	2
	Functional		
Building height	Earthbags are not included in the Nepalese building code as a building method. Typically earthbag structures are seen as one storey buildings.	*Amount of storeys*	1
Expandability	Expanding a structure made from Earth Bags can only be done in a horizontal direction by building against the existing structure. Creating passages from existing to new construction is not advised to maintain structural integrity of the building.	*Possibilities*	1
Workspace	Given that Earth Bag structures can be made in many desired shapes and seized the opportunity to create space for shops and workspaces is relatively easy, however the building method does not provide the ability to create large openings to have a connection with the external infrastructure	*Opportunity*	2
Protection	Earthbags provide shelter against rain and wind but are not fully protective against the elements because they can be penetrated by wind and rain. Safety is provided with locks, bars and insect screens.	*Elements*	3
		Safety	3
Utilities	Only utilities at ground level are possible.	*Possibiliti*	3

		es	
Sustainable			
Recyclable	The materials used in an Earth Bag structure are mostly recyclable. The plastic of the bags can be recycled, the filling can be reused in the creation of a new building, the barbed wire and rebar can be reused when fixed with little or no concrete.	*Re-usable*	5
		Recyclable	5
Environmental	The environmental impact of constructing with earthbags is relatively small given that most of the building materials is obtained from the direct environment (excavation of soil or rock). Bags however are made out of polyester.	*Impact*	4
		Sustainable	3

Reference

"Haiti: http://earthbagstructures.com/projects/johnson.htm Iran/ Mexico/ California: http://www.earthbagbuilding.com/projects/sandbagshelters.htm South Africa: http://www.house-of-sand.com/building-with-sandbags USA/ Colombia/ Mexico http://www.inspirationgreen.com/earthbag-construction.html http://windriche.com/superadobe/advantages_and_disadvantages_of_earthbag_construction.htm http://earthbagstructures.com/ http://buildsimple.org/

Interlocking bricks

Introduction
Interlocking bricks are bricks that form a connection with each other without necessarily the addition of mortar. The blocks are shaped with projecting parts, which fit exactly into depressions in the blocks placed above, such that they are automatically aligned horizontally and vertically which makes bricklaying possible without special masonry skills. The row interlocking bricks directly on the foundation is done with cement and must be completely straight. On top of that bricks can be laid down. In the end the holes can be filled up with cement and steel barns for reinforcement. Interlocking bricks can be made locally and consist of a mixture of cement and soil.

Category	Description		Value
Technical			
Building components	Typical elements are foundations, load bearing brick walls, timber window frames, and varying roof/flooring systems. The length of each Interlocking Brick is exactly double its width in order to achieve accurate alignment. For the construction of a building there is choice of bricks which can be used for different elements such as Walls, Window Frame, Concrete Joists, Concrete Floor Pans or Stringers, Treads for staircases and Tiles for Roofing (http://www.unicef.org/education/files/Interlocking_Earth_Bricks_technology.pdf). The interlocking brick allows for average redundancy comparable to brick masonry. The method is not incorporated in the building code but is acceptable according to structural principles	*Strength* *Redundancy* *Building code*	 **3** 4
Seismic Performance Standard	The seismic performance of interlocking bricks is not proven however the shape of the bricks can be seen as an effective level of bonding to create mechanical interlocking and resist shear-cracking (D'Ayala, n.d.)	*Performance*	**4**
Improved Seismic Performance	Insertion of concrete with steel reinforcement through the holes of the blocks provide reinforcement to the building, increasing the wind and earthquake resistance.	*Possible*	4
Building on a slope	The foundation of a interlocking brick building needs to be completely level, therefore the method is not suited to build on a slope without the addition of a stable and levelling foundation.	*Performance*	1
Climate	The building method is offers flexibility for openings however some limitations are applicable comparable to brick masonry. Even though the blocks are placed with the right precision, the joints are not entirely resistant to wind, rain and therefore heat penetration. Plastering is needed to provide protection against the elements. The use of certain ingredients in the creation of the interlocking brick can add to the increase of thermal mass and its fire resistance.	*Opening* *Thermal*	**3** *3*
Life span	Interlocking bricks can be highly durable, with a long lifespan.	*Lifespan*	5
Maintenance	Bricks with the correct ratio of cement are not vulnerable to rotting or breaking, therefore the need for maintenance is limited. However when the bricks are made more of adobe type of material the need for maintenance increases. For the different use of materials refer to the corresponding comparable building method. The maintainability of interlocking brick is comparable to low strength brick or stone masonry and considered to be relatively easily maintainable	*Reliability* *Maintainability*	4 2
Complexity	This method is already used in Nepal. Nevertheless it is not widely known and therefore not a lot of knowledge is available among the local masons however the use of interlocking bricks is claimed to be relatively easy when supervised by an expert.	*Ease of learning*	4

Resources			
Material	Based on raw materials there are various types of bricks: - Soil-cement bricks (cement-to-soil ratio is depending on the soil quality, lies between 1:6 and 1:10) - Concrete bricks (typically mixed in Cement-to-sand-to-gravel 1:5:3) - Rice Husk Ash - cement bricks (cement-to-RHA lies around 1:4) - Clay cement bricks. To improve the strength of a building reinforcement steel and cement mortar can be used. The flexibility of materials usable for making interlocking bricks makes the availability and reliability of materials very good. Soil and clay are readily available in many places and cement can be bought from local producers or be imported from India or China with the latter being less reliable due to dependence on political situation and road conditions.	*Quality*	4
		availability	4
		Reliability	5
Labour	Designed to reduce the need for skilled labour and maximize the use of the unskilled labour force. Certain amount of training is required to ensure that walls are properly aligned and no gaps are left. Training needed in the production of blocks, mix proportions and moisture content. Also in producing uniform sized blocks	*Experience*	3
		Intensity	4
Time	According to the Habitech Center Interlocking bricks have the ability to utilise a large workforce and the advantage of sequential actions shortens the construction time.	*Technical period*	4
Feasibility			
Price Lable	The ranking is based on price indications and reference countries	*Ranking*	4
Local economy	When the brick producing machine is available the bricks can be produced by local labourers, also local labour can be used in the placement of the blocks. However local skilled masons and carpenters are not used when building with this building method, which might have negative effects for them.	*Use of local resources*	3
National economy	The production of cement and steel reinforcement is guaranteed, although it is less than constructing a RCC frame building.	*Use of national resources*	3
Social / cultural			
Social/ cultural	There are not much alterations possible in the architecture of a interlocking brick building, although the walls can be plastered to allow the appropriate social/cultural aesthetics.	*Adaptability*	3
Architectural embedding	Interlocking bricks are not commonly used as a building method and is therefore not embedded in the local building tradition. However the appearance of an interlocking brick building can be compared with brick buildings and depends on the finishing.	*Embedding*	3
Functional			
Building height	Interlocking bricks are suited for two or more storey buildings, with as a rule of thumb that the height of the wall does not exceed 20 times its thickness. Interlocking bricks are not included in the Nepalese building code and therefore not limited in their height. In this case the building height is considered to be two storeys with an attic.	*Amount of storeys*	2
Expandability	When the construction is finished it is not possible to create additional openings for horizontal expandability. Vertical expandability depends on the wall thickness of the structure, but is possible when the interlocking ability of the top bricks is still intact.	*Possibilities*	3
Workspace	The same layout as a brick masonry building can be achieved when building with interlocking bricks	*Opportunity*	3
Protection	Rain cannot wash away cement mortar and the crevices in the masonry wall are filled with cement mortar and cannot be penetrated by wind. Safety is provided with locks, bars and insect screens.	*Elements*	3
		Safety	4
Utilities	If constructed in the right manner, the building method is able to withstand gravitational forces. For this reason the utilities are possible beyond ground level.	*Possibilities*	3
Sustainable			

Recyclable	The blocks are placed without mortar, when their shape is still intact they are re-usable. The blocks which are reinforced by reinforcement steel and cement are not re-usable.	*Re-usable*	4
		Recyclable	2
Environmental	When the location has proper soil conditions the building can be made with local and natural materials, with the addition of cement for the base.	*Impact*	4
		Sustainable	4

Reference

"NepalThis method is already fewly used in Nepal. A typical three-room house can be built in two weeks because the bricks self-align, and can cost up to 40 per cent less than a conventional brick-cement house. (http://www.nepalitimes.com/blogs/thebrief/2015/05/26/the-building-blocks-of-reconstruction/, 10/8/2015) ThailandInterlocking bricks has been used for post-tsunami reconstruction in Thailand in 2008 and after Cyclone Nargis ravaged Burma in 2010 to build more than 1,000 homes, schools, health clinics. (http://www.nepalitimes.com/blogs/thebrief/2015/05/26/the-building-blocks-of-reconstruction/, 10/8/2015) 56 houses and one community house were build in the of Baan Nam Khem Vilage in the Phang-nga Province is build with interlocking ricks.Each plot size is 120 sq. m. and the house size of two storey is 74 sq. m.. The cost per sq. m. was US 100 dollar and it took 10 months to complete (http://www.unicef.org/education/files/Interlocking_Earth_Bricks_technology.pdf, 10/08/2015)."

Prefab-framed in-situ concrete

Introduction
Prefab-sandwich concrete panels are currently not used in Nepal but is used in countries with similar conditions. The frame exists of a simple construction made of hollow steel wire/ Styrofoam panels which should be filled with concrete, the method allows for the use of rebar and other strengthening. To be able to construct these houses in Nepal a new factory and office need to be realized that works by importing styrene fluid for the creation of foam panels. The steel wire is the same as used in car tires and therefore a material that should be locally present. For harder to reach areas a mobile production system can be attached to a truck. The interior and exterior walls can be finished in any way, giving the opportunity to safeguard the Nepali architecture and culture.

Category	Description		Value
Technical			
Building components	Modules have a width of 1200 mm, and can be 12 meter long. However the normal length is one floor height (ca 3 m). The thickness of the wall depends on the required strength (seismic risk) and insulation (national climate), in total 55 different variations are possible. Facades, load bearing walls, interior walls, floors and the roof can be built with this system. The average weight of each element before concrete is poured in is around 30 to 35 kg per panel. The interior and exterior walls can be finished in any way, giving the opportunity to safeguard the Nepali architecture and culture.	*Strength*	
		Redundancy	5
		Non-structural elements	5
		Building code	4
Seismic Performance Standard	Calculation of the University of Leuven have shown that the building method is resistant to earthquakes, also the structures built with this method have performed in earthquake prone countries over the years. (Sismouk, n.d.)	*Performance*	5
Improved Seismic Performance	The structural Integrity and seismic resistance can be strengthened by means of vertical and horizontal reinforcement (timber, bamboo, reinforced concrete). Stiff diaphragms such as concrete slabs are favoured above flexible diaphragms. The out-of-plane capacity can be improved by adding of wall meshes (experimental techniques).	*Possible*	5
Building on a slope	Monolith structure, freedom in making a variety of forms	*Performance*	3
Climate	Openings can be easily included in the building method, the width of the openings is limited due to the structural integrity of the building. The building method provides insulation against temperatures, this insulation can be improved with the addition of the wall finish.	*Openings (ventilation and sunlight)*	4
		Thermal	*4*
Life span	Prefab-sandwich concrete frames structures can be highly durable, with a long potential useful lifespan.	*Lifespan*	4
Maintenance	The infill panels are filled with concrete and do not require much maintenance. The exterior walls do require maintenance. However when maintenance is needed it requires workmanship or even specialized expertise and resources.	*Reliability*	5
		Maintainability	2
Complexity	The method is not used in Nepal right now, however masons are used to work with concrete. All materials, except the styrene fluids are well known. For the fabrication of the panels a local factory is needed, as well as training for the placement of the panels.	*Ease of learning*	4
Resources			

Material	This method makes use of prefab panels that are filled with concrete that can be reinforced with rebar. These panels consist of Styrofoam that is hold together with steel wire. Steel-wire: to give form to the panels and create the monolith system Styrofoam: insulates the panels, creates the hollow space to pour concrete Concrete: to fill up all panels, floors etc. Reinforced steel: could be added in the panels while pouring concrete in case of building in high seismic areas. Wood: window frames, doors etc. The availability of materials can	*Quality*	3
		Availability	3
		Reliability	3
Labour	Since the method is not familiar in Nepal the local work force needs to be trained in working with the new building method.	*Experience*	2
		Intensity	3
Time	The method is designed to be quick and flexible, because of the high repetition possibilities and the presence of infill panels the method could reduce the construction time. But because all the panels are filled with concrete there is a required waiting time between the pouring of each section.	*Technical period*	3
	Feasibility		
Price Label	The ranking is based on price indications and reference countries. The price is dependent on large scale production. When producing in large numbers (800.000 m2/ year) the depreciation of the investment can become less than 1 euro {SISMO}.	*Ranking*	2
Local economy	Locals will be trained to work with the building method. Skilled masons and carpenters are not used when building with this building method. Also large amounts of cement will probably lead to an increase of import from India.	*Use of local resources*	2
National economy	The placement of a factory will create jobs and income for the national economy. It might also create exportable knowledge.	*Use of national resources*	5
	Social / cultural		
Social/ cultural	There are not much alterations possible in the architecture the building method. On the exterior walls all possible finishes are possible to allow the appropriate social/cultural aesthetics. The wall do not allow the placement of niches for religious attributes.	*Adaptability*	5
Architectural embedding	The building method is not commonly used as a building method and is therefore not embedded in the local building tradition.	*Embedding*	1
	Functional		
Building height	The building method is not included in the Nepalese building code. For the construction of houses typically 3 to 4 storied buildings are seen.	*Amount of storeys*	5
Expandability	The building method is not designed to be extendable, but an effort can be made to design the construction extendable, as well horizontal as vertical,	*Possibilities*	3
Workspace	In the design large openings can be included when extra measures are taken into consideration. These extra measures are mainly strengthening by adding extra rebar.	*Opportunity*	4
Protection	The protection depends on the infill walls, for this case brick infill walls are taken into consideration.	*Elements*	5
		Safety	4
Utilities	If constructed in the right manner, the building method is able to withstand gravitational forces. For this reason the utilities are possible beyond ground level.	*Possibilities*	3
	Sustainable		
Recyclable	Since the building method is poured in concrete it is not recyclable, but some recycled materials can be used for the infill of the panels	*Re-usable*	1
		Recyclable	2
Environmental	The production process is non-polluting and reduces jobsite waste, the insulating quality reduces energy consumption. (Sismouk, n.d.) Production of concrete has some impact on the environment.	*Impact*	4
		Sustainable	5
	Reference		
Project	Coralform has experience with building SISMO houses in seismic active regions such as Europe (France, Spain, Portugal, Italy, Switzerland, Turkey), Asia (South Korea) and		

the Middle East (Iraq)	
	

Single Panel Walling System

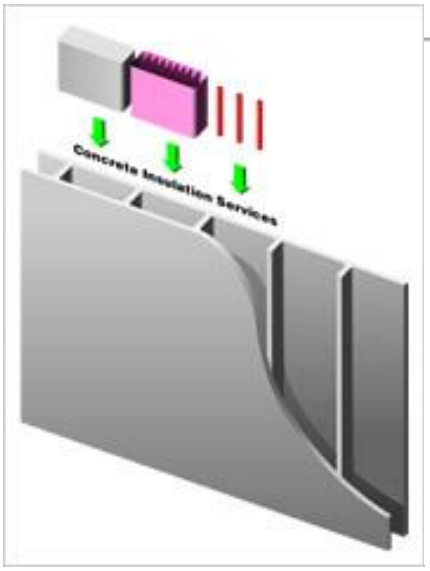
Introduction
Rapid Building Systems make use of Gypsum plaster products that are present in debris in the building and construction industry. The panel serves both as the internal and external wall and eliminates the need for bricks, blocks, timber wall frames. The panels are load bearing and can be used in single, double, or multi storey construction. RapidWall is mainly used in India and China, the two countries in which between Nepal is landlocked. Also both surrounding countries have RapidWall factories (2009, RapidWall, presentation UN-Habitat).

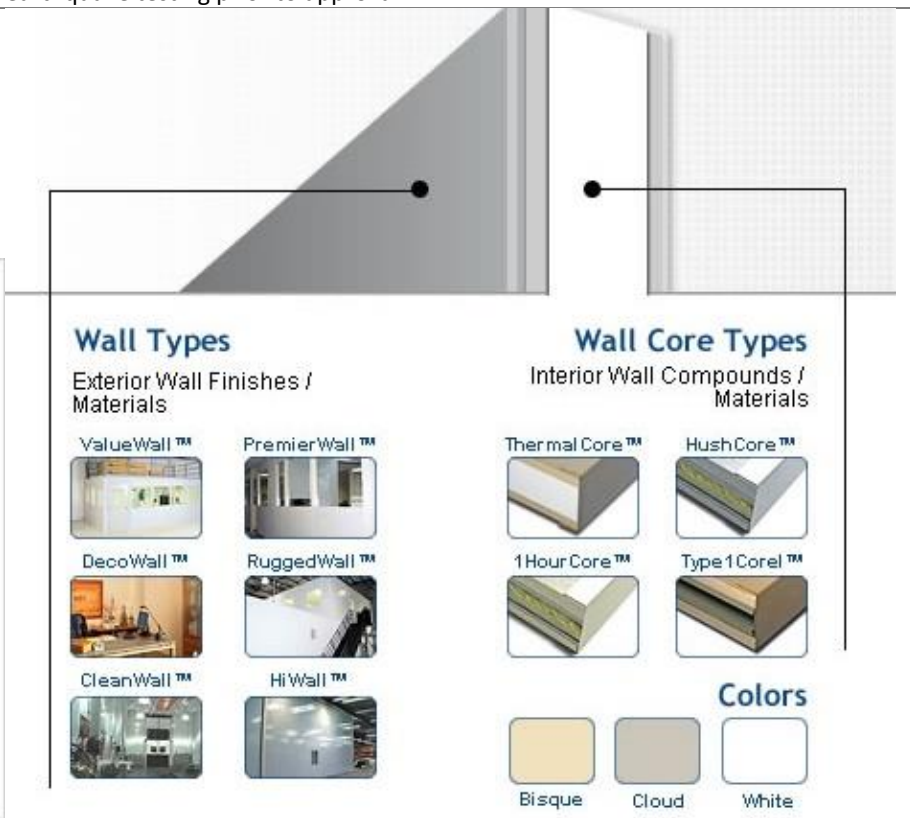
Category	Description		Value
Technical			
Building components	The panels are 12 by 3 metre and 120mm thick. The panel serves both as the internal and external wall and eliminates the need for bricks, blocks, timber wall frames. The panels are load bearing and can be used in single, double, or multi storey construction. This is a representation of a RapidWall panel. In the cavities different building services can be put such as plumbing, electrical, isolation or concrete for increasing the load bearing (2009, RapidWall, presentation UN-Habitat). Light weight (44kg/m2). Pre-fabricated (12m X 3m X 124mm)	*Strength*	4
		Redundancy	5
		Non-structural elements	-
		Building code	4
Seismic Performance Standard	Rapidwall underwent earthquake testing and achieved a maximum peak ground acceleration of 0.36g's and as a result Rapidwall was rated for the equivalent of a magnitude 7 earthquake on the Richter scale. A 12 m x 3 m x 120 mm reinforced concrete wall panel weighs over 10 tonnes. A similarly sized Rapidwall panel weighs only 1.5 tonnes. This means the Rapidwall panels are very light which can be a positive aspect for seismic performance.	*Performance*	4
Improved Seismic Performance	The voids in Rapidwall panels can be used to add concrete with steel bars for load bearing capacity.	*Possible*	5
Building on a slope	The prefab panels require a good flat foundation for optimal distribution of forces.	*Performance*	2
Climate	Openings in exterior walls can easily be made when incorporated in the design, only limited by possible placement of extra rebar. The interior climate of the structure can be easily regulated depending on the choices for interior and exterior wall filling for insulating layers.	*Openings (ventilation and sunlight)*	3
		Thermal	*4*
Life span	Unknown	*Lifespan*	3
Maintenance	The panels do not require much maintenance but when maintenance is needed it requires workmanship and some resources. This can be more depending on the finishing of the exterior wall.	*Reliability*	5
		Maintainability	2
Complexity	The method is not used in Nepal right now, however it is quite an easy building method. The panels are delivered as prefab panels at the building site.	*Ease of learning*	4
Resources			
Material	Rapidwall panels are made of gypsum plaster and fibreglass. The prefab panels can be imported from either India or China with good availability however the reliability is	*Quality*	3

	susceptible to uncertainty due to road conditions and political situation. At only 44 kg per square metre, a single B-double truck can transport over 570 square metres of Rapidwall compared to 125 square metres of 120 mm thick precast concrete hollow blockwork.	*Availability*	4
		Reliability	4
Labour	Since the method is not familiar in Nepal the local work force needs to be trained in working with the new building method. In the Rapidwall plant manufacturing rate of 108 m2 /hr for a three table plant. At the building site a installation rate (two man crew) up to 45 m2 /hr is possible (rapidwall construction manual, 2014)	*Experience*	2
		Intensity	3
Time	The method is designed to be quick and flexible, because of the high repetition possibilities and the presence of infill panels the method could reduce the construction time.	*Technical period*	5
	Feasibility		
Price Label	The ranking is based on price indications and reference countries	*Ranking*	3
Local economy	Local labourers need training to perform this construction method, also skilled masons and carpenters are not used. Local material are in general not used	*Use of local resources*	2
National economy	The placement of a factory will create jobs and income for the national economy. However right now the factory of panels are located in India and China, meaning that money will also flows to these factories. However the final idea of this building system is that it will start a plant in the country for which it is producing.	*Use of national resources*	2
	Social / cultural		
Social/ cultural	The finishing of Rapidwall is equivalent to precast concrete, in-situ concrete. Adaptions such as painting, plastering and decorations are possible to allow the appropriate social/cultural aesthetics.	*Adaptability*	4
Architectural embedding	The building method is not commonly used as a building method and is therefore not embedded in the local building tradition.	*Embedding*	2
	Functional		
Building height	Unreinforced structures used as load bearings wall can go up to three storeys. Reinforced site-filled concrete structures with sufficient axial strength can support buildings up to 15 storeys.	*Amount of storeys*	5
Expandability	The building method comes in prefab elements, therefore the expandability is limited.	*Possibilities*	2
Workspace	In the design large openings can be included when extra measures are taken into consideration. These extra measures are mainly strengthening by adding extra rebar.	*Opportunity*	4
Protection	Rain and wind cannot penetrate the concrete shell. Safety is provided with locks, bars and insect screens.	*Elements*	5
		Safety	4
Utilities	Utilities are possible at any level of the building, structure is designed to withstand loads at the rooftop.	*Possibilities*	5
	Sustainable		
Recyclable	Rapidwall claims to be 100% recyclable and manufactured from natural and/or waste raw materials (PDF Document Rapidwall® The world's most environmentally friendly, versatile and cost effective prefabricated walling system).	*Re-usable*	2
		Recyclable	5
Environmental	Is made of waste and/or raw material. However at the moment the panels should be imported from India or China.	*Impact*	4
		Sustaina	4

ble

Reference	
Project	In China, where clay brick production has been outlawed, Rapidwall has been selected as one of the preferred building materials. A plant in Jianan was constructed in 2002 and underwent significant earthquake testing prior to approval.





Light Weight Steel Profile Building Systems

Introduction			
This method is currently not widely used in Nepal but has been used in many disaster struck countries for rapid rebuilding. The building method makes use of steel plate rolls which can be bended into profiles on location, the profiles are easily connected by bolts and nuts, the walls can be filled in with any type of material from local to styrofoam.			
Category	**Description**		Value
Technical			
Building components	Light weight steel construction with steel braces are often combined with a reinforced concrete foundation. The basic structure is consisting of a lightweight steel braced frame that creates resistance to lateral and transversal loads. The main structure is made of steel profiles that are pressed by a machine on location. The main structure walls and floors can be filled in with any kind of material desired by the owner. The building method is not incorporated in the building code but the structural principles are accepted internationally thus incorporation can be a quick process.	*Strength* *Redundancy* *Building code*	 5 3
Seismic Performance Standard	The Steel frame building systems claim to be earthquake resistant due to their lightweight construction while providing great strength. Steel has a high ductility which is a favorable trait during an earthquake allowing for the building to withstand lateral and transversal loads.	*Performance*	4
Improved Seismic Performance	The performance during an earthquake can be increased by use of special moment resisting frames and different types of braces such the V-brace, inverted V-brace, X-brace, two storied X-brace etc. A combination of the properties of steel and the possibilities to enhance the frame make steel frame buildings a good construction type for seismically active areas.{lecture by Michael D Engelhardt Michael D. Engelhardt University of Texas at Austin, Design of Seismic Design of SeismicResistant Steel Building Structures} However light weight steel profile building systems often already have many braces, the improvement during seismic activity is marginal.	*Possible*	5
Building on a slope	All references are built on level ground or concrete foundations	*Performance*	3
Climate	Openings in exterior walls are only limited by possible placement of braces. Protection against external elements can be done by any kind of exterior covering material such as wood, bricks, mud or clay. Regulating of internal climate can be done by using materials with good thermal properties, a material that is advocated by promoters of the steel profile building systems is styrofoam panels.	*Openings (ventilation and sunlight)* *Thermal*	4 *3*
Life span	According to manufacturers the lifespan is “long” and they offer a 50 year warranty on the steel frame	*Lifespan*	4
Maintenance	The steel frame requires little maintenance, maintenance of this building type would be dependent of the choice of the frame filling materials. The execution of maintenance would be a relatively easy task requiring little workmanship and some resources.	*Reliability* *Maintainability*	5 3

Complexity	Building with steel profile building systems is relatively easy. The designer of the house programmes the steel pressing machine to produce the frame components and provides the drawings with coded components. Trained workers assemble the frame by connecting the joints with nuts and bolts. The infilling of the house can be done as desired by the owner and only requires experts when using complex filling materials. The method is easily teachable to workers and requires the presence of a trainng center which can train workers but also train trainers.	*Ease of learing*	4
	Resources		
Material	The resources required for light weight steel profile buildings are rolls of steel plating, material for frame filling, roofing material, exterior covering material and mortars. The availability of required materials is good given that much of the steel products and wall infill can be locally produced or is importable. The reliability can be less good due to dependence on road conditions and political situation for the import of steel.	*Quality*	4
		Availibility	3
		Reliability	3
Labor	The labour intensity of steel profile building systems is low, work includes feeding the machine with steel, putting the frame components in place, bolting the components together and placing of interior, exterior and roof filling. The frame components are lightweight and easy to lift by a construction worker.	*Experience*	3
		Intensity	4
Time	A house for a family can be constructed in 6 days by a team of trained workers. {http://www.veerhuis.eu/portfolio/cite-soleil/}	*Technical period*	5
	Feasibility		
Price Lable	The ranking is based on price indications and reference countries	*Ranking*	2
Local economy	Steel bending machine can be bought and used for local production, however requires training. Wall infill can be done with local materials.	*Use of local recources*	3
National economy	Light weight steel needs to be imported, togheter with machinery.It can create a new sector, with new jobs. Investments are maid in Nepal. Possibility to export knowledge.	*Use of national recources*	5
	Social / cultural		
Social/ cultural	Steel profile building systems allow for many shapes and forms, the materials to fill the frame can be adapted to the owners preferences allowing for high adaptability. The materials usable for infiling can be the same as known to the local people.	*Adaptability*	5
Architectural embedding	Unfamiliar from traditional point of view, however multiple parties are busy with projects throughout Nepal.	*Embedding*	3
	Functional		
Building height	The building method is not included in the building code, for this case light pile construction around 2 to 3 storeys is taken into consideration.	*Amount of storeys*	2
Expandability	The typical structures built with steel profile building systems do not allow for expansion after construction, however the design of these buildings is very adaptable and possibilities for expandable houses might easily be designed.	*Possibilities*	4
Workspace	Given that steel profile building systems allow for structures to be made in many desired shapes and sized the creation of space for shops and workspaces is relatively easy	*Opportunity*	4
Protection	The protection depends on the infill walls, for this case brick infill walls are taken into consideration.	*Elements*	4
		Safety	3
Utilities	If constructed in the right manner, the building method is able to	*Possibilities*	2

	withstand gravitational forces. For this reason the utilities are possible beyond ground level.		
Sustainable			
Recyclable	The steel used for the frames is reusable when not damaged and otherwise recyclable. the materials used for filling the frame can be chosen by the owner and can also be both recyclable and reusable.	*Re-usable*	3
		Recycable	5
Environmental	According to the manufacturers the building system reduces the emissions of CO2 depended on the insulation materials. The materials save natural resources(such as water, sand, wood, cement) compared to most traditional building styles, when damaged or destroyed the buildings generate less solid waste, due to good climate control improvement of health and safety can be achieved.	*Impact*	4
		Sustainable	4
Images			

Appendix 1.B. - Damage assessment

The basic factors of seismic vulnerability are mentioned with their associated damage patterns.

0: Building location	
Vulnerability factors	**Associated damage**
Pounding of adjacent buildings - No gap provided between the building and the adjacent building - The gap is filled with rigid material (concrete/ brick) or is made rigid by using rigid materials	Damage due to pounding of an adjacent building
Building site (steep slope, land slide risk)	Movement of whole building due to liquefaction, landslide or sliding of foundation
A. Global strength, stiffness, stability and ductility	
Vulnerability factors	**Associated damage**
Weak- or no application of seismic-resisting elements	Total or partial building collapse
Unfavorable choice of material and detailing	
B. Building configuration and mass distribution	
Vulnerability factors	**Associated damage**
Building mass distribution (compliance center of mass/ inertia?) - Mass concentration - Mass asymmetry	Local cracks or failure due to high stress concentrations Collapse or partial failure due to torsional forces Collapse/ implosion of a weak or soft story
Building configuration: regularity in plan - Re-entrant corners - Irregular geometry - Irregular distribution of lateral load resisting elements (frames/ shear walls)	
Building configuration: regularity in elevation - Cantilever - Set-back or stepped elevation - Weak story, change in strength (change in structural components) - Soft story, change in stiffness (ground floor open for commercial purposes)	
Distribution of live loads - such as large water-tanks or swimming pools on the roof	
C. Load path	
Vulnerability factors	**Associated damage**
Continuity of load path • Are there masonry walls in cantilevers • Are there masonry walls which do not continue to the foundation • Are there any columns starting from a beam	
Interconnection of members	Separation of connecting walls
Lack of stiff diaphragms	
Redundancy • Is there a single bay in one or both directions?	Total building collapse
D. Building components	
Vulnerability factors	**Associated damage**
Condition of materials • Deterioration of concrete • Corrosion of reinforcement	•

• Deterioration of wood	
Weak building members	
Brittle building members	• Opening of existing cracks of other defects • Crushing and 'X' pattern of walls between openings • Crushing of infill walls • Delamination of wall wythes • Out-of-plane or in-plane wall failure
Amount and location of window openings	
E. Non-structural elements	
Vulnerability factors	**Associated damage**
Falling hazard of non-structural elements	Shearing of chimneys and towers
Weak / brittle non-structural elements	Collapse of internal non-structural walls
Insufficiently connected non-structural elements	

Zone A: Urban core (Kathmandu center)

Characteristic building methods:

- RCC frame buildings
- Brick masonry buildings / some traditional brick masonry
- Historical heritage sites

RC-frame buildings

Many vulnerable factors are seen with respect to discontinuous load paths (cantilevers), lack of redundancy and bad quality of construction and detailing.

Vulnerable factor	Potential reason
Discontinuous load paths (cantilevers)	Creating more surface area on the rented plot
Weak/soft storeys	Commercial use of ground floor in the form of open storefronts, work places and restaurants at the street side
Lack of redundancy slender frame structures	Having own plot is favored above apartment buildings, resulting in slender buildings
Low quality RC- construction and detailing	Lack of skilled engineers and building code inspectors

Brick masonry and traditional brick masonry buildings

Most of the severe damage caused in the urban core can be found in the old masonry structures. Many of these older buildings were built in the traditional Newari style (timber decorations). Newer brick masonry buildings are made with sober timber window frames and sometimes concrete slabs as flooring. Many vulnerable factors are seen with respect to lack of maintenance and lack of coherency between building elements.

Vulnerable factor	Potential reason
Thick and heavy walls, high inertia loads	To provide sufficient insulation and strength
Later addition of storeys and vertical load	Expansion of family, need for more space
Lack of maintenance	Trouble and effort of regular maintenance

RC-frame buildings (masonry infill)

Location	Urban core: Thamel, Kathmandu
Building method	RCC frame masonry infill, 5 storeys
Vulnerability factors	B. Building configuration Soft story (shop front) C. Load path Discontinuous load path • Masonry wall on cantilever • First floor cantilever on extended slab
Damage / observation	X

Location	Urban core: Thamel, Kathmandu
Building method	RCC frame masonry infill, 9 storeys
Vulnerability factors	C. Load path Discontinuous load path • Masonry wall on cantilever Redundancy • Single bay in one direction
Damage / observation	X

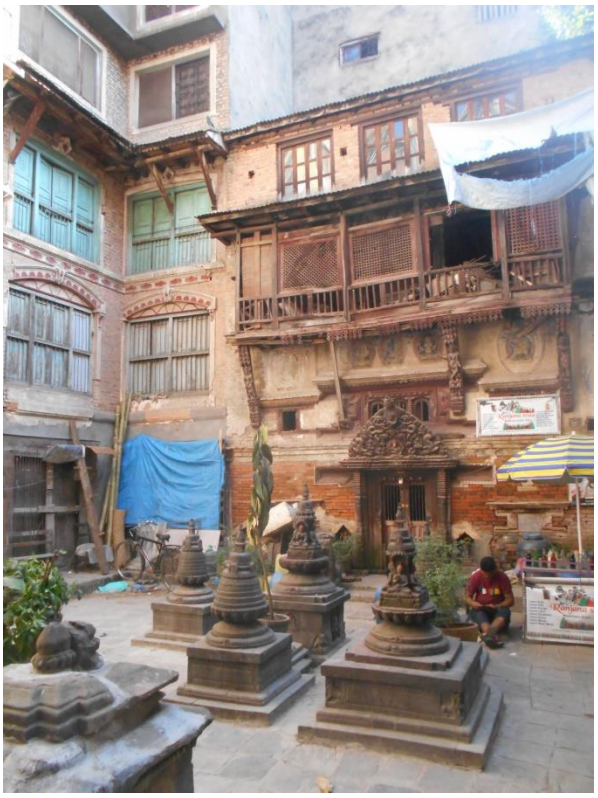
Location	Urban core: Thamel, Kathmandu
Building method	RCC frame masonry infill, plastered, 8 storeys
Vulnerability factors	Redundancy • One bay in one direction Configuration • Very slender in transverse direction
Damage / observation	X

Location	Urban core: Thamel, Kathmandu
Building method	RCC frame masonry infill, plastered, 7 storeys
Vulnerability factors	C. Load path Discontinuous load path • Masonry wall on cantilever
Damage / observation	Temporary strutting necessary to provide stability

Location	Urban core: Thamel, Kathmandu
Building method	RCC frame masonry infill, plastered, 4 storeys
Vulnerability factors	Soft/ weak story • Sudden change of stiffness • Parking garage without infill walls at ground story Building configuration • L-shaped
Damage / observation	X

Brick masonry

Location	Urban core: Thamel, Kathmandu
Building method	Brick masonry, timber window frames and vertical timber posts >2nd floor
Vulnerability factors	C. Discontinuous load path • Masonry wall on cantilever • Timber cantilever
Damage / observation	X



Location	Urban core: Thamel, Kathmandu
Building method	Brick Masonry, traditional Newari style
Vulnerability factors	D. Building components • Condition of materials (maintenance)
Damage / observation	Deterioration and damage of timber balustrade and timber frames

Location	Urban core: Patan, Lalitpur
Building method	Traditional brick masonry (Newari), 3 storeys
Vulnerability factors	D. Building components • Condition of materials (maintenance)
Damage / observation	Instability: temporary strutting to prevent collapse

Location	Urban core: Kathmandu, near Bagmati river
Building method	Traditional brick masonry, 2,5 storeys
Vulnerability factors	B. Building configuration • Length/ width ratio Long unsupported masonry wall
Damage / observation	Partial collapse of the building

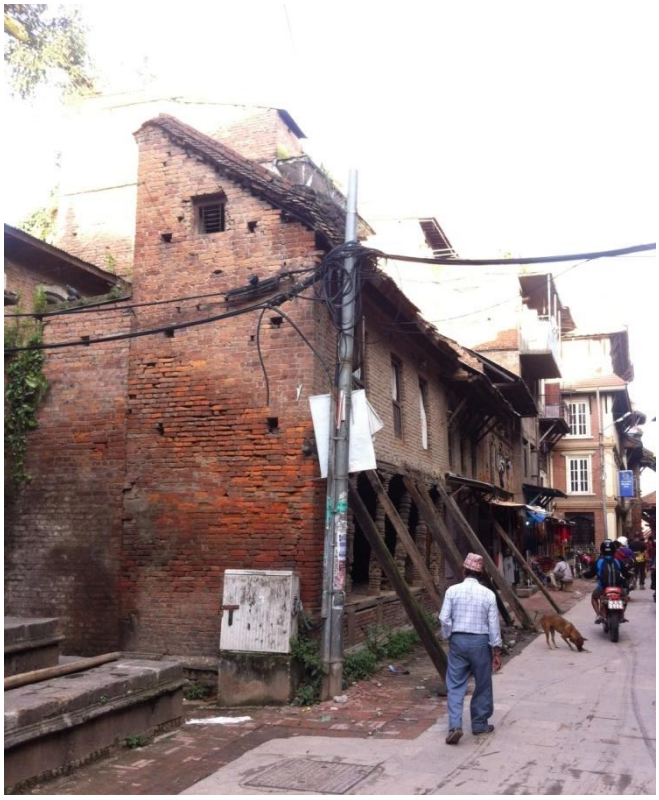
Location	Urban core: Kathmandu, near Bagmati river
Building method	Traditional brick masonry (Newari), 2,5 storeys
Vulnerability factors	B. Building configuration • Length/ width ratio • Too long unsupported masonry wall D. Building components • Lack of coherence in brick bonding
Damage / observation	Partial collapse of the building

Location	Urban core: Patan, Kathmandu
Building method	Traditional brick masonry (Newari), 3 storeys
Vulnerability factors	B. Mass distribution Heavy floors causing horizontal thrust force D. Building components Condition of materials (maintenance)
Damage / observation	Instability: temporary strutting to prevent collapse Outward bulging of exterior wall

Location	Urban core: Patan, Kathmandu
Building method	Traditional brick masonry (Newari), 3 storeys
Vulnerability factors	B. Load path Lack of Interconnection of side and front wall D. Building components Placement of window openings
Damage / observation	Vertical tear above door lintel Vertical tear in front wall, near the side wall

Location	Urban core: Patan, Kathmandu
Building method	Traditional brick masonry (Newari), 3 storeys
Vulnerability factors	x
Damage / observation	Temporary strutting to prevent collapse

Location	Urban core: Patan, Kathmandu
Building method	Traditional brick masonry (Newari), 3 storeys
Vulnerability factors	D. Load path Insufficient connection/ ties between walls
Damage / observation	Outward building of the exterior wall / corner Vertical tear at building corner Temporary strutting to prevent collapse



Location	Urban core: Patan, Kathmandu
Building method	Traditional brick masonry (Newari), 3 storeys
Vulnerability factors	B. Mass distribution Floor causing horizontal thrust forces D. Building components Deterioration of building materials (timber)
Damage / observation	Temporary diagonal strutting to prevent collapse Outward bulging of the exterior wall

Zone B: Urban village (Outside ring road)

Characteristic building methods:

- Concrete frame buildings
- Brick masonry buildings
- Corrugated sheet shelters

The outskirts are characterized by an urban sprawl of non-engineered buildings. Most problems are seen due to informal construction, discontinuous load paths, unfavorable configurations and building on slopes

Vulnerable factor	**Reason**
Non-engineered, informal building	Lack of skilled masons, engineers, building code inspectors
Building on slopes	Scarcity of plain building sites, building along roadside is favorable
Soft/ weak storeys	Commercial use of ground floor in the form of open storefronts, work places and restaurants at the street side

Location	Urban outskirts: Kathmandu
Building method	Brick masonry, 1 or 2 storeys
Vulnerability factors	Informal/ non-engineered building Bad construction quality
Damage / observation	X

Location	Urban outskirts: Kathmandu
Building method	RCC frame buildings with masonry infill, plastered, 6 storeys
Vulnerability factors	B. Building configuration L-shaped plan • Torsional forces • High stress concentrations in re-entrant corner
Damage / observation	X

Location	Urban outskirts: Kathmandu
Building method	RCC frame buildings with masonry infill, 3 to 4 storeys
Vulnerability factors	0. Site Building on a slope, unequal height of columns / foundation B. Building configuration Soft story, no infill walls
Damage / observation	X

Location	Urban outskirts: Kathmandu
Building method	RCC frame buildings with masonry infill, 3 to 4 storeys
Vulnerability factors	0. Site Building on a slope, unequal height of columns
Damage / observation	X

Zone C: Urban historical settlements

Characteristic building methods:

- Traditional building methods (for example Newari)
- Unreinforced brick masonry
- Rc-frame construction with masonry infill
- Non-engineered

These settlements are characterized by clusters of traditional brick masonry buildings (Newari style) and newer RC-frame buildings. Many traditional buildings have collapsed or are severely damaged. The main reason is bad maintenance of timber elements and inadequate connections between building elements. The relatively newer concrete buildings have performed better during this quake, also due to their smaller age. But also these buildings form a threat in future quakes due to discontinuous load paths, weak storeys and low quality of construction and detailing.

Traditional brick masonry

Vulnerable factor	**Reason**
Thick and heavy building walls, high inertia loads	To provide sufficient insulation and strength
Later addition of storeys and vertical load	Expansion of family, need for more space
Lack of maintenance	Trouble and effort of regular maintenance
Soft/ weak storeys	Commercial use of ground floor in the form of open storefronts, work places and restaurants at the street side
Discontinuous load paths (cantilevers)	Creating more surface area on the rented plot

RC-construction

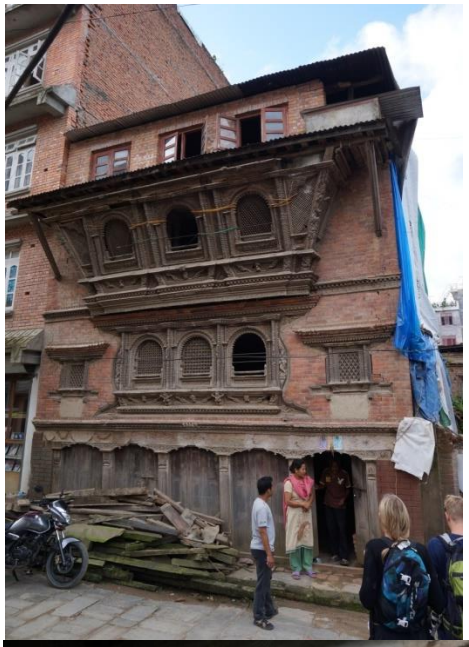
Vulnerable factor	**Reason**
Discontinuous load paths (cantilevers)	Creating more surface area on the rented plot
Weak storeys	locating shops, work places and restaurants with at the street
Low quality RC construction and detailing	Lack of skilled engineers and building code inspectors

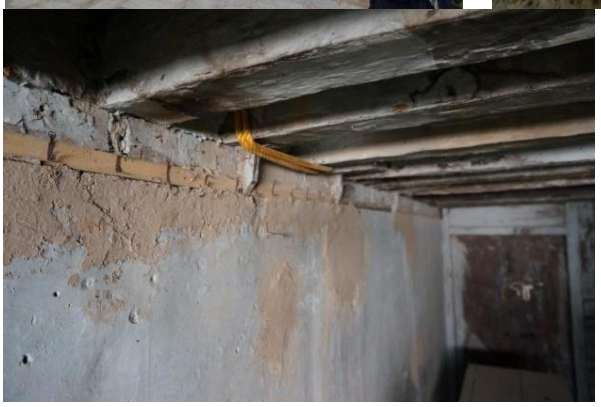
Preliminary rebuilding activities

Location	Urban heritage settlement: Sankhu
Building method	Temporary rebuilding, one story high brick masonry with mud mortar and timer poles

Location	Urban core: Sankhu
Building method	Temporary rebuilding, one story high brick masonry with mud mortar

Traditional brick masonry (Newari)





Location	Urban heritage: Sankhu
Building method	Traditional brick masonry Newari
Vulnerability factors	B. Mass distribution - Heavy overhanging window units D. Building components - Deterioration of timber elements
Damage / observation	D. Building components - Collapse of side wall - Diagonal tears in masonry - Decay of timber elements

Location	Urban heritage: Kirtipur
Building method	Brick masonry, 3 storeys
Vulnerability factors	0. Building placement Lack of seismic gap, risk of pounding of adjacent buildings
Damage / observation	Tear at junction of two buildings

Location	Urban heritage: Kirtipur
Building method	Brick masonry, 3 +1 storeys
Vulnerability factors	B.Building and construction materials Heavy incremental additional storey, addition of vertical load
Damage / observation	X

Brick masonry

Location	Urban heritage: Sankhu
Building method	Combination of brick masonry and RCC frame
Vulnerability factors	A. Too many storeys for brick masonry building
Damage / observation	Building is tilting over causing secondary moments

Location	Urban heritage: Sankhu
Building method	Brick masonry
Vulnerability factors	A. too many storeys for unreinforced masonry building B. Building configuration Vertical irregularity; set back building Incremental building
Damage / observation	Diagonal tear in masonry ground floor (in-plane) Vertical tear under window lintel Diagonal tears in corner peers

Location	Urban heritage: Sankhu
Building method	Brick masonry
Vulnerability factors	E. Non-structural elements Bad construction practice of overhang/ balcony Slab is filled with bricks as cheaper infill alternative of concrete
Damage / observation	Damage and partial collapse of cantilever

Location	Urban heritage: Kirtipur
Building method	Brick masonry, 4 storeys
Vulnerability factors	A. Building materials and construction Exposed wall infill of sun-dried bricks (vulnerable to moisture B. Building configuration Vertical irregularity C. load path Masonry wall standing on cantilever Cantilever balcony on thin concrete slab

Damage / observation	X (whole town not that damaged by earthquake)

Location	Urban heritage: Sankhu
Building method	Brick masonry, 3 storeys
Vulnerability factors	D. load path Insufficient corner connections and corner ties
Damage / observation	Large vertical tear at corner junction of walls

RC-frame construction with masonry infill walls

Location	Urban heritage: Sankhu
Building method	RC frame construction, brick masonry infill, 4 storeys
Vulnerability factors	A. Low quality construction and concrete detailing - Non optimal spacing of stirrups - Too little concrete cover - Insufficient ties of concrete stirrups
Damage / observation	X-tears in masonry infill walls (in-plain failure) Bursting out of masonry walls Tears in plasterwork Splitting of concrete, expose of reinforcement

Location	Urban heritage: Kirtipur
Building method	RC frame, masonry infill, 2 storeys
Vulnerability factors	B.Mass distribution Distribution of live loads, heavy water tanks on slender cantilever slab
Damage / observation	X

Zone D: Rural village

Characteristic building methods:

- Concrete frame buildings
- Stone masonry houses
- Brick masonry
- Corrugated sheet temporary shelters

In these settlements vulnerabilities are seen in construction quality and building configuration; soft/weak storeys, and discontinuous load paths in the form of cantilevers.

Vulnerable factor	**Reason**
Building on a slope	Building along the road is favorable for commercial reasons Lack of flat building plots in hilly/ mountainous areas
A. Building construction and materials	Lack of skilled builders and code inspectors
B. Building configuration Soft/ weak storeys	Commercial use of the ground floor

Location	Rural village: ribbon development, Dhunce
Building method	RCC frame, masonry infill plastered, 3 storeys
Vulnerability factors	0. Building site • Building on a slope
Damage / observation	X

Location	Rural village: ribbon development, Dunche
Building method	RCC frame, masonry infill, 5 storeys
Vulnerability factors	0. Building site • Building on a slope (downhill) D. Building components • One layer masonry infill, lateral forces
Damage / observation	X

Location	Rural village: ribbon development, Dunche
Building method	RCC frame, masonry infill, 5 storeys
Vulnerability factors	0. Building site • Building on/ near a slope (uphill)
Damage / observation	X

< Location	Rural village: ribbon development, Dunche
Building method	RCC frame, masonry infill, 5 storeys
Vulnerability factors	0. Building site • Building on a slope (downhill) D. Building components • One layer masonry infill, lateral forces
Damage / observation	X

Location /	Rural village: ribbon development, Dunche
Building method	RCC frame, masonry infill, 5 storeys
Vulnerability factors	B. Building configuration Building extensions on non-engineered RCC structure
Damage / observation	X

Location	Rural (mountain) village:Chisapani
Building method	RCC frame, masonry infill, plastered, 4 storeys
Vulnerability factors	Building configuration: • Weak/ soft story
Damage / observation	Failure of columns ground floor Collapse of building

Location	Rural (mountain) village:Chisapani
Building method	RCC frame, masonry infille, plastered, 4 storeys
Vulnerability factors	0.Building site Building on a slope A.Building construction and material use Stiff masonry infill with respect to concrete columns
Damage / observation	Bursting out of masonry infill wall

Location	Rural (mountain) village
Building method	RCC frame, masonry infill, plastered, 2 storeys
Vulnerability factors	X
Damage / observation	Diagonal tears near window openings Vertical tear near change in stiffness of elevation

Location	Rural (mountain) village
Building method	Stone masonry, plastered, x storeys
Vulnerability factors	A. Building construction and materials
Damage / observation	Tiered / diagonal cracks X-cracks between windows

Zone E: Remote village (mountain villages)

Characteristic building methods:

- Rubble stone houses
- Rubble stone with timber elements

Remote settlements are threatened by site hazards such as land- (mud) and rock-slides. Risks are higher during Monsoon season when the rains decrease the ground stability, and for building slopes which have little vegetation holding the ground together with its roots. The majority of buildings is made of rubble stone masonry. These buildings are highly vulnerable to earthquakes due to heavy material, irregular stones and lack of coherency between building elements.

Vulnerable factors	**Reason**
C.Load path Lack of seismic elements	Scarcity and high prices of timber
	Difficult transportability and high prices of cement and reinforcement
Dry stacked stones without bonding	No adequate mud-mortar available
High inertia loads due to heavy stones	Stones are locally available, and thick walls provide insulation
Irregular stones	Cutting irregular stones to regular shapes is labor-intensive and costly

Site hazard: landslides and rockslides

Risk	Mud-, landslide

Risk	Dislocation of trees

Risk	Rock avalanche

Stone masonry

Location	Remote village: Goisakunda
Building method	Stone masonry, dry stacked, 1 story
Vulnerability factors	0. Building site • Building on a slope C. Load path • Integrity of building elements Lack of (horizontal) seismic ties D. Building components • High inertia loads due to stones • No bonding between building blocks • Irregular shape of stones causes stress concentrations
Damage / observation	Collapse of head walls

Location	Remote village: Goisakunda
Building method	Stone masonry, cement mortar, 1 story
Vulnerability factors	C. Load path • Integrity of building elements (lack of seismic ties) Lack of horizontal seismic bands (lintel) • Load path above window opening D. Building components • High inertia loads – heavy stones
Damage / observation	Collapse of head wall/ pitched roof

Location	Remote village: Goisakunda
Building method	Stone masonry, cement mortar, 1 story
Vulnerability factors	C. Load path • Integrity of building elements (lack of seismic ties) Lack of horizontal seismic bands (lintel) • Load path above window opening D. Building components • High inertia loads – heavy stones
Damage / observation	Vertical tear above weak spot (window opening) Diagonal tear Collapse of head wall/ pitched roof

Location	Remote village: Goisakunda
Building method	Stone masonry, timber planks interior, dry stacked, 1 story
Vulnerability factors	D. Building components • High inertia loads – heavy stones • No bonding (mortar) of stones
Damage / observation	Stones have fallen outwards, timber interior structures is still standing

Appendix 1.C. - Solution Space

ID	Aspect	Sub-aspect	Requirement	Requirement Value Qualitative
			Technical	
TE-1011	Structural Building Components	**Strength**	Loading types and loads withstandable by construction	Construction should minimally be able to withstand the constant and variable loads as given by the Building Code
TE-1012	Structural Building Components	**Redundancy**	Presence of redundancy regarding structural elements	Structure should atleast allow some redundant elements to relieve structure´s dependency on a single structural element in its imagined form.
TE-1013	Structural Building Components	**Non-structural elements**	Placement and amount of non structural elements	Non-structural elements should not diminish the inherent properties of structural elements or general safety
TE-1014	Structural Building Components	**Regulated safety**	Level of safety needed in regular usage of building according to buildingcode	If building type is mentioned in the building code then compliance with minimal requirements as stated in most recent version of the Nepali Building Code If not mentioned in building code then according to general structural principles
TE-1020	Seismic Performance	**General seismic performance**	Structure should be able to withstand seismic activity	Combination of aspects TE-1021 - TE-1025 determine the performance during seismic activity, the structure should at least be considered categorie C according to the Worldhousing.net classification
TE-1021	Seismic Performance	**Seismic elements**	Application of seismic elements	Combination of seismic elements must resist lateral loads
TE-1022	Seismic Performance	**Diaphragms**	Degree of stiffness of diaphragms	Must allow for diaphragms that can provide ensure a uniform redistribution of lateral loads amongst structural elements
TE-1023	Seismic Performance	**Mass distribution**	Manner in which mass is distributed within the structure	Mass of the structure should be distributed as evenly and low as possible within the structure
TE-1024	Seismic Performance	**Load**	Amount of continuity within loadpath of structural elements	Continuity in structural elements must be guarenteed
TE-1025	Seismic Performance	**Building plan**	Structure should consist of or should be partitionable into symetrical shapes	The construction method should offer possibilities to make a symetrical floor plan
TE-1026	Seismic Performance	**Possibility to increase seismic performance**	Seismic Performance	Possibility of adding realistic improvements for Nepal to increase performance of aspects TE-1021 - TE-1025. The structure should at least be considered categorie D according to the Worldhousing.net classification
TE-1041	Climate	**Openings (ventilation & sunlight penetration)**	Controle of interior climate and level of humidity inside structure Adaptation of exterior wall openings to regulate penetration	

			of sunlight into building	
TE-1042	Climate	**Thermal capacity**	Regulation of temperature in different seasons needed to ensure acceptable living conditions with respect to heat transmission	
TE-1051	Construction	**Lifespan building**	Lifespan of building method when maintained correctly	Minimum lifespan should be around 50 years or equal to at least two generations
TE-1061	Maintenance	**Reliability**	Amount of maintenance required to maintain standard living conditions and safety given the lifespan	Structure should at most require maintenance every 3-5 years
TE-1062	Maintenance	**Maintainability**	Technical and physical ease of performing maintenance on a structure	Structure should not require extensive and very specialized workmanship and much resources
TE-1063	Maintenance	**Availability**	Availability of the structure during maintenance	
TE-1071	Construction	**Complexity**	Ease of learning to correctly implement technique required for building method	The complexity of the construction should at most be so complicated to require some years of training
Resources				
RE-2011	Material	**Initial quality**	Acceptable quality of a material in its initial state	Used materials require latest NS, IS or other similar approved standard quality certificate. If used material is adapted, innovative, recycled or not provided with mark it may also be used given that the characteristics are tested to be equivalent or higher than the Standards given by the Nepal National Building Code.
RE-2012	Material	**Processing quality**	Building materials should be transportable to building site with minimum damage given transportation conditions	
RE-2013	Material	**Availability**	Availability of a material when abstracted from the environment in large quantity	Available quantity of building material needs to be just enough to construct the required amount of houses of case village
RE-2014	Material	**Reliability**	Material reliable to be available in all situations	Material needed for construction should be available during all situations and seasons but may be susceptible to uncertainty regarding availability
RE-2021	Labour	**Labour experience**	Level of task experience of workers required for construction	The construction should at most require some experts for correct execution of building
RE-2022	Labour	**Construction intensity**	Amount of workers needed at one time to construct a building type	A building method should not be limited by the of workers it requires for safe and qualitative execution
RE-2031	Time	**Construction time**	Technical construction period needed to build one layer	The construction of a technique should at most take up the duration of a Nepalese construction season, which is limited by the monsoon period and harvesting period resulting in a maximum building time of 1-3

				months per storey.
Feasibility				
FE-3011	Financial	**Investment**	Total investment costs	The construction method should maximally allow for the construction (of a livable partition) of a house that is within budget of target group including loans, funds from government and charity funds
FE-3021	Economic	**Local**	Beneficial for local economy	Construction should at least use some local resources resulting in at least a small benefit for the local economy
FE-3022	Economic	**National**	National benefit	Construction should atleast add some welfare into Nepalese economy by the use of a mixed local / import cashflow
Social-Cultural				
SO-4011	Social	**Status**	Ability to meet the social and cultural requirements of Nepali housing in terms of social status or ethnic identity	
SO-4031	Social	**Architectural identity**	Ability to meet the architectural needs	
SO-4021	Cultural	**Religious**	Space to accommodate religious attributes	
Functional				
FU-5011	Building	**Stories**	Height of the building meets the function requirement of the owner	
FU-5012	Building	**Expandability**	Structure has to offer the possibility for expansion after completion of construction while fitting the technical requirements.	
FU-5013	Building	**Flexibility**	Structure has to offer flexibility in usage of rooms and partitioning of the living area	Rooms should be changable with the use of some resources.
FU-5021	Working	**Workspace**	Structure has to be able to provide a workspace for profession related activities such as workshop, restaurant, shop, animal stal	
FU-5031	Protection	**Rainwater**	Structure has to provide shelter against monsoon rain with a maximum of acceptable leakage	
FU-5032	Protection	**Wind**	Structure has to provide shelter against winds	
FU-5033	Protection	**Solar intensity**	Structure has to provide shelter against solar intensity	
FU-5034	Protection	**Social Safety**	Minimum level of personal safety needed in building	

FU-5041	Facilities	**Utilities**	Structure has to be able to accommodate the connection of utilities such as gas, water, electricity	
FU-5042	Facilities	**External infrastructure**	Construction should accommodate a connection with direct environment	
Sustainability				
SU-6011	Life cycle	**Reusability**	Extent to which used materials are fit to be re-used after demolition	Material do not have to be re-usable after the demolition/end of functional period
SU-6012	Life cycle	**Recyclability**	Number of cycles a material can be re-used	There are not restrictions on the recyclability of used materials.
SU-6021	Environment	**Impact**	Damage done to nature by construction	There are no restrictions on damage to the environment however should be avoided where possible
SU-6022	Environment	**Sustainability**	Extent to which the houses can be self sustainable	

Appendix 1.D. – Contacts made in Nepal

Organisation	Person	Description	Contact	What did we discuss	Minutes available	Extra information
Government						
Nepalese Consul General to the Netherlands	C.F. (Cas) de Stoppelaar Nepalese Consul General to the Netherlands.	Cas' experience in Nepal started when he founded Summit Nepal Trekking in 1974, followed by Summit Hotel in 1990. In 1996 he was appointed Consul General of the Consulate of Nepal to the Netherlands. In his tenure, Cas built a large professional network in Nepal, as he connected people and companies between the Netherlands and Nepal. Cas is an experienced investor in Nepal.	Email: mail@casdestoppelaar.nl Email: consulgeneral@nepal.nl	Cas de Stoppelaar helped us with setting up Shock Safe Nepal and was with Team One in Nepal for the first two weeks.	No	Initiator of Shock Safe Nepal
DUDBC (Department of Urban Development and Building Construction)	()	Organizing large scale projects to rebuild Nepal. However besides the earthquake situation they also have other interests on urban developments and constructions.	Email: info@dudbc.gov.np	We joined several meetings and presentations of the DUDBC about rebuilding Nepal. (Technical workshop)	Yes	()
National Planning Commission (NPC)	()	The NPC is the advisory body of the Nepalese Government for national vision, planning and policy development. After the earthquakes they were assigned to perform the Post Disaster Needs Assessment (PDNA), in which the damage and needs are inventoried.	()	Used the PDNA's made by the NPC.	No	()
Special Envoy of the Prime Minister	Shesh Ghale	Shesh Ghale, president of the NRNA (Non-Resident Nepali Association), has been appointed as Nepal's special envoy to raise necessary funds for rehabilitation and reconstruction efforts {Republica}. The government appointed him as the Special Envoy to collect funds, since the PDNA pointed out $6,6 billion is required to	()	()	No	We became in contact via Cas de Stoppelaar. The NRNA is planning to rebuild thousands of houses. Very interesting to

		rebuild Nepal.				share knowledge. Sunir Pandey is interested to keep updated about our progress.
	Sunir Pandey Coordinator Secretariat of the Special Envoy		Email: +9779851190489 Website: mitgroupfoundation.org	Had a fruitful discussing about rebuilding Nepal and the political situation right now.	Yes	
Universities and knowledge institutes						
Kathmandu University	Prachand Man Pradhan, Ph.D.	Head of Department (Acting) & Professor (Asst.) Department of Civil & Geomatics Engineering, School of Engineering	prachand@ku.edu.np Kathmandu University Telephone: +977-11-661399 Ext.1105 (Office) Fax:+977-11-661443 Cell:+977-9851049174	He is willing to sign a MOU with the TU Delft and is prepared to guide future SSN Teams	Yes	Is willing to sign a MOU with TU Delft
Tribhuvan University	Madan Gopal Shrestha	President Friends of Sankhu (NGO in Nepal) Chairperson: Nepal Seve Micro-finance Bank Associate professor : Tribhuvan University, Padmakanya Multiple Collage	Nepal, Kathmandu, Sankhu, Pukhulachhi-06 Phone no: 977-01-4450007 / +9779851066177 Email: fosyb@ntc.net.np website: www.fos.org.np Facebook: https://www.facebook.com/friendssankhu	We had a site visit in Sankhu. Madan showed us around and explained about what was going on there.	No	They have a lot of information about Sankhu. Damage assessments, maps, etc..
Delft University of Technology	Binod Prasad Koirala, M.Sc.	Nepales Phd at TU Delft	Mail: b.p.koirala@tudelft.nl	Binod Prasad Koirala explained the situation in Nepal after the earthquake	Yes	()
Delft University of Technology (Academic Board of Shock Safe Nepal)	ir drs Jules Verlaan Construction Management and Engineering CITG - opleidingsdirecteur CME Sectie Integraal	This is the academic board of Shock Safe Nepal.	Phone: 06 54 721 269 Email: j.g.verlaan@tudelft.nl	()	Yes	()

	Ontwerp & Beheer					
	Ir. H.R. (Roel) Schipper BCC coordinator		Email: H.R.Schipper@tudelft.nl			
	Prof.dr.ir. A.R.M. (Rogier) Wolfert Grading Professor					
	Dr.ir. M.G.C. (Marian) Bosch-Rekveldt Internship coordinator					
	Dr.ir. G.A. (Sander) van Nederveen IDM coordinator					
KU Leuven	Annelies Part-time employee at the KU Leuven	The KU Leuven was working together with the UN-Habitat.	()	We discussed our project and asked for their vision.	Yes	()
	Stefanie Part-time employee at the KU Leuven		Email: stefaniedens@gmail.com Phone [be] +32 497 75 21 09 Phone [npl] +977 981 031 61 08 Skype: stefanie.dens		Yes	()
Smart Shelter Research	Martijn Schildkamp	Martijn Schildkamp is the founder and owner of Smart Shelter Foundation. He has build schools and buildings for many years all over the world and is busy with a platform for building methods.	Email: info@smartshelterfoundation.org	He gave us a training about 'non-engineered' earthquake proof construction in Nepal.	Yes	()
NSET (National Society for Earthquake Technology-	Surya Narayan Shrestha Deputy Executive Director	The NSET is a non-governmental institute founded in 1998 with the vision to realize earthquake safe communities in Nepal by 2020. The institute constitutes professionals belonging to various technical	Karya Binayak Municipality, Bhaisepati Residential Area, Lalitpur GPO Box: 13775, Kathmandu, Nepal		No	We would have a meeting with Surya in Nepal but instead we had a meeting with

Nepal)		and social aspects of earthquake disaster management.	Mobile: +977-98511 03625 Tel: +977-1-5591000, 5593000, 5592522 Fax: +977-1-5592692, 5592693 Email: sshrestha@nset.org.np, shresthasn@gmail.com URL: www.nset.org.np			Hima and Kumar.
	Hima Shrestha (M.Sc. Structural Engineering) Director, EERT Division		hshrestha@nset.org.np, hima.shrestha@gmail.com (977-1) 5591000 Ext 205	We discussed the roll of NSET. NSET has a lot of knowledge about earthquake technology in Nepal. However is not a department of the government and mostly paid by US-AID. We discussed what Shock Safe Nepal could contribute to the knowledge right now.	Yes	()
	Dev Kumar Maharjan Structural Engineer		Email: dmaharjan@nset.org.np Phone: (977-1) 5591000 Phone: 9849531851			()
Companies						
Arcadis (Shelter Program)	Bert Smolders Shelter Program Manager	Arcadis and UN-Habitat set up the Shelter Program in 2010. Over sixty missions, trainings and other Shelter activities have been organized in Asia, Africa and Middle America. Over 500 ARCADIS experts from a range of disciplines have been actively engaged in the program by sharing their knowledge, expertise and providing capacity-building support skills to help bring the UN-Habitat mission forward.	Email: bert.smolders@arcadis.nl Phone: 0627060436	We had a very interesting meeting with UN-Habitat and Arcadis to discuss the possibilities of Shock Safe Nepal	Yes	()
Abari	Sagar Chitrakar Architect at Abari	Abari is a company that is specialized in building with rammed earth and bamboo.	Facebook	We discussed the different options of rammed earth and bamboo	NO	Became friends with Sagar and Tenzing. They have a lot of knowledge of
	Tenzing Yangcean Tamang Architect at Abari		Facebook			

						rammed earth and bamboo construction in Nepal
Veerhuis	Albert Veerman CEO	Albert Veerman is the CEO and founder of Veerhuis Bouwsystemen that is building with steel profiling and styrofoam all over the world.	Email: a.veerman@veerhuis.eu Phone: 00310299324243	Had two meetings with Albert. He joined the first meeting of the Shock Safe Nepal project to give his vision about rebuilding Nepal.	Yes	()
Sismo / Coralform	Nico van Veen Directeur Coralform Nederland	Sismo / Coralform is a quick and easy prefab building method that is much used in India and China	Email: info@coralform.nl Phone: 0638250293	We discussed the Sismo system and its possibilities for Nepal.	Yes	Nico is very interested in building in Nepal. Contacts are via the Nepalese Consulate in Amsterdam
ECONOMIC "Building Generations"	Ronald Cozijn	Ronald Cozijn has much experience with building solutions in foreign countries like Nepal.	r.cozijn@economichousing.nl	Ronald Cozijn helped us with selecting new building methods.	No	()
Rapidwall	Via Ronald Cozijn	()	Via Ronald Cozijn	()	No	()
Finish Profiles	Prasan Chawla	Nepalese Steel profiling building company.	Email: prasan315@gmail.com	Discussed the possibilities of steel profiling building methods in Nepal.		()
NGO and similar organisations						
UN-Habitat	Padma Sunder Joshi Habitat Programme Manger for Nepal	This United Nations programme works towards a better urban future, by promoting sustainable human settlements development and achieving shelter for all. Already before the earthquakes UN-Habitat was running 7 projects between 2008 and 2013 with a budget of $7.074.204 {www.unhabitat.org/nepal/}.	UN House, Pulchowk	We had a very interesting meeting with UN-Habitat and Arcadis to discuss the possibilities of Shock Safe Nepal	Yes	
Global Shelter Cluster (GSC)	Siobhan Kennedy Technical Coordinator	The GSC is a platform with 35 regular partners, of which UN-Habitat is one of them. On global level GSC works on	Email: tech2.nepal@sheltercluster.org |skype:	We discussed the current situation in Nepal with respect to all the NGO's	Yes	

		technical capacity and system-wide preparedness in order to respond to humanitarian emergencies, they support country-level shelter clusters. They collect, analyse and share best practices and lessons learned via their website. Shelter Cluster is trying to coordinate	siobhan.kennedy3 Phone:(+977) 9818414269 | www.sheltercluster.org |	and different organisations that are currently active in Nepal.		
Nepalese organisation in The Netherlands						
NRNA (Non-Resident Nepali Association) (Also See Shesh Ghale)	Fanindra Panta	President NRNA International Coordination Council Representative of The Netherlands The NRNA carries out various activities to serve the interests of Nepali Diaspora as its constituents in the following areas 1. Organizes global and regional conferences and interaction programs for itfos stakeholders. 2. Facilitates strong networking among the NRNs, resident Nepalis and Nepali organizations worldwide. 3. Liaise with the National Coordination Councils, Nepali associations abroad, government and international organizations. 4. Acts as a forum for the promotion and protection of the interests of the NRN community both in Nepal and abroad.	Email: panta_basil@hotmail.com	Fanindra Panta gave us a lot of valuable inside information about Nepal and contacts in Nepal.	()	
Nepal Samaj Nederland	Ram Budhathoki President	NSN is the first Nepalese association which aims to promote Nepalese culture, language and tradition among the Nepalese and others in the Dutch society. NSN also works to support the integration and strengthen the bonds between Dutch and Nepalese.	Email: rbudhathoki@delft.nl Phone: (0031)620145700	Ram Budhathoki gave us a lot of valuable inside information about Nepal and contacts in Nepal.	No	
Consulate of Nepal	C.F. (Cas) de Stoppelaar	Cas' experience in Nepal started when he founded Summit Nepal Trekking in 1974, ,	mail@casdestoppelaar.nl consulgeneral@nepal.nl	Cas de Stoppelaar helped us with setting up Shock	No	Initiator of Shock Safe Nepal

		followed by Summit Hotel in 1990. In 1996 he was appointed Consul General of the Consulate of Nepal to the Netherlands. In his tenure, Cas built a large professional network in Nepal, as he connected people and companies between the Netherlands and Nepal. Cas is an experienced investor in Nepal.		Safe Nepal and was with Team One in Nepal for the first two weeks.	
More relevant people					
Students	Anatta Shrestacharya	Graduated students who worked as volunteer for the UN Habitat programme in Bungamati.	Email: shranatta@gmail.com Phone: 9843376419	It was very helpful to discuss our project with them. They obviously know Nepal very well and also know what is happening in the reconstruction of Nepal.	No
	Anil Maharjan		Email: anil.maharjan@unhabitat.org.np Phone: 9803875040		No
	Kusma Thapa		Facebook		No
Friends of Sankhu and Associate professor at Tribhuvan University	Madan Gopal Shrestha President Friends of Sankhu (NGO in Nepal) Chairperson: Nepal Seve Micro-finance Bank Associate professor : Tribhuvan University, Padmakanya Multiple Collage	()	Nepal, Kathmandu, Sankhu, Pukhulachhi-06 Phone: 977-01-4450007 / +9779851066177 Email: fosyb@ntc.net.np website: www.fos.org.np Facebook: https://www.facebook.com/friendssankhu		No
One to Watch	Willem Grimminck Director (CEO)	One to Watch builds together with Nepalese entrepreneurs and impact investors from around the world. Successful companies in Nepal.	Via Cas de Stoppelaar.	Willem has a great experience in Nepal that was very usefull for advice in our project.	No
Home	Sanchit	Sanchit has much experience in Nepal with	Via Cas de Stoppelaar.	Sanchit told us alot about	

Makers		big building processes.		how big construction projects take place in Nepal	
Drafting Factory	Jolein Feteris	The Drafting factory is a technical drawing company who employs 45 people, such as architectural students.	Via Cas de Stoppelaar.	We worked for five weeks on the drawing factory. It was very fruitful to work surrounded with alot of Nepalese architectural students and architects. They helped us out with an survey and questions about the building environment in Nepal.	No
Bagmati Project	Kanak Dixit Cas de Stoppelaar Anuk	The Bagmati River Project (Bagmati) is busy to redevelop the banks of the Bagmati river in Nepal.	Via Cas de Stoppelaar	It was good to see how different project try to preserve the architectural history of Nepal.	No

Appendix 1.E. – Minutes of conversations

All the minutes of the conversations can be find in the google drive of Shock Save Nepal, future teams therefore have easy access to this information. The minutes of conversation in the Netherlands can all be found online. Some of the minutes of conversations that are referred to in this report are selected for this appendix.

UN-Habitat / Arcadis / KU Leuven

Date:	7-9-2015		
Location:	UN-Habitat, Kathmandu		
Secretary:	Coen Spelt		
Present SSN-team:	Allard de Stoppelaar		
	Arjan Oosterhof		
	Baris Can Düzgün		
	Coen Spelt		
	Emilie van Wijnbergen		
Interviewed party:	Bert Smolders	-	Arcadis / urban planning
	Radbout	-	Arcadis / construction manual
	Nienke	-	Arcadis / urban planning
	Padma Sunder Joshi	-	UNhabitat Programme manager
	Anil Maharjan	-	UNhabitat Engineer
	Anatta Shrestacharya	-	Nepali volunteer
	Anil	-	Nepali Volunteer
	Stephanie Dens	-	KULeuven / urban planning
	Annelies de Nijs	-	KULeuven / urban planning

Introduction about ShockSafeNepal

Allard gave a small introduction about the ShockSafeNepal project with the opportunity for Arcadis and UNhabitat to give their opinion. Especially Padma Sunder Joshi shared his knowledge and concerns about the situation in Nepal.

The building categories in Nepal can be divided in 3 types of buildings:

1. Concrete frame structure/RCC
    - The Nepalese have the illusion that this construction method is much stronger than brick buildings (because most of the brick buildings are collapsed).
    - The recent earthquake was not that strong in the Kathmandu valley: in the north it had a 8+, in the valley 7+ magnitude. A stronger earthquake would have resulted in a much bigger devastation.
    - The Nepali are comparing old buildings with new buildings, many concrete buildings are not engineered, not maintained and older than the concrete buildings.
    - 90% of the houses are owner build, they have not enough construction knowledge: slim Columns, combined with thick beams, quality of cement, sand, to much water because that makes it easier to mix but decreases strength and ability to bond.
    - In the north/western part of Kathmandu more concrete structures were collapsed, buildings were tilted because of the clay soil conditions
    - A very important point is the condition of the structure before the earthquake.

- The main risk of constructing with concrete in the urban villages and rural areas is the lack of knowledge.

2. Traditional brick wood mud (especially in the Kathmandu valley
    - The brick building is mostly seen in clusters of houses. The father divides his property among his sons vertically. They start building higher and higher.
    - A lot of buildings mistakes: The floors of original building is made with wooden floors, they heightened the building by adding an additional floor with a concrete roof and floor.
    - No damp profile course, emission of damps affect the ground floor, this is been fixed with plaster, which is not a good technique.
    - Much of the old buildings collapsed due to bad maintenance, not by bad constructions.
    - The tallest temple of Baktapur, 5 tiers high, has not collapsed during the earthquakes. We should try to learn out of these techniques. (wooden skeleton inside brick structure.

3 Stone masonry

Dhulika many buildings survived (stone and mud mortar) Newar buildings. Many buildings collapsed because of missed horizontal load capability

Previous earthquake in Nepal

In 2011 on sept 18 an earthquake occurred in eastern part of Nepal: large number of traditional buildings collapsed. After this building improvements where designed, unfortunately this improvements where never implemented.

Introduction about Arcadis project / KULeuven project

In the Kathmandu valley there are 3 major towns. There are 53 satellite towns (for example Sankhu and Bungamati. Most of the urban area is neglected by the government and NGO's, that is why UNhabitat sees this as their responsibility.

UNhabitat asked Arcadis and KULeuven to help them with creating a master plan for the city Bungamati. The project looks at the lager picture and zooms in on Bungamati. The focus is not only on the construction of earthquake safe buildings but on all the aspects of the city. (waste water, utility of open spaces, etc) On of the main focuses of the reconstruction is to rebuild in a traditional way.

KUleuven:

- Framework to start fieldwork
- master plan strategy of which the cities will fit into.
- Mapping/understanding – set up systems in order to design
- Detailed assessment (mapping damage assessment)
- Deal with temporary shelters
- Determine priority projects

Arcadis

- Example strategy for all the other towns
- Sanitation (first measures)
- Urban planning
- Public space, no occupied by shelters (memorial park)
- Building back better (manual, training)
    - To much information
        - The traditional architecture of the Kathmandu valley (book)
    - Adjust out-dated information
    - Compress the right information on a couple of sheets
    - Locational training (get their output out in the open)

- Have not done training in Nepal yet
- People interested to meet:
  - Rohit Ranjitkar (Architect Summit Hotel)
    - Kathmandu vally
  - Rabindra puri

- Work on priority projects; focus because otherwise the projects will end up in the shelf. (Priority and how to finance)
- Priority projects are short term
- Visitors centre to get people to spent money in the area

Questions from UN-Habitat

Risk of using knowledge constructing with concrete in the mountains, (knowledge)
Compressed Stabilized earth blocks, we are trying to use it on the inside of buildings, (ambition green construction materials) Question of UN-Habitat, the usage of this earth blocks in the construction of buildings.
Clay bricks also help as climate control.
If our information is helpful for your project please use it.

- Damage assessment (buildings total collapsed, damaged)

Additional information

Details from the PDNA, government/world bank came up with an estimate.
800k houses are damaged; the average size of an house was 60m2, which costs 10k Rupees per 1m2. This is too expensive to rebuild.
- The new houses are 15m2, the government pays 200k Rupees to affected households.
NRA: national reconstruction authority decides about payment

Follow up after interview

- Sent an email with detailed needed information

Contact Radboud about the manual! Passed over to Anil Maharjan.

Bagmati Heritage Walkway

Date:	8 September 2015
Location:	Kathmandu
Present SSN-team:	Allard de Stoppelaar
	Arjan Oosterhof
	Baris Can Düzgün
	Coen Spelt
	Emilie van Wijnbergen
Present other:	Cas de Stoppelaar (Consul-General of Nepal to the NL)
	Kanak Dixit

Office meeting

95% of the river water in Kathmandu is contaminated sewer water.
Kathmandu is a river civilization and the culture is (/was) closely linked to the river.
Economical drive in combination with political chaos (lack of political stability) caused the river (banks) to be polluted.

Kathmandu is a former lake: good fertile soil -> rice production -> wealth -> competition between three kingdoms/ cities (stimulating art and architecture)

In Nepal, the old traditional culture is still alive.

→ it is important to save streetscapes
River banks have an holy and religious purpose (Buddhist and Hindu), where water and culture meet

The 'Bagmati Heritage Walkway' or 'Bagmati hangout' project revolves around the revival of a specific stretch of river bank between the Radha Krishna Mandir (temple) and thapathall bridge. They want to bring people to the river (especially the middle class).

They want to create a promenade connecting all cultural, religious elements along the river bank. The river banks can be a place for hangout, chess, morning walks, yoga.

They work in parallel with the municipality to create involvement/commitment
parallel: Kathmandu municipality is bureaucratic with lack of leadership

Since the Bagmati river is so polluted there is smell nuisance. However they claim the north bank of the river does not have this problem

look up their project on facebook: bagmati hangout

Kanak: "since the quake there is more interest for renovation (also as career), whereas in the past students were more interested in new building.

Site visit

trapezoidal bricks
Typical Newar bricks are not completely rectangular, but sloping down towards the inner facade. Cement (or mud mortar) is only used on the inner half of the bricks, giving it the 'dry stacked' look on the outside. These bricks are called Dachi appa.

Clay bricks
Soft slippery clay is brought from Kathmandu Lake. Lower origin of the clay lead to better quality. The clay is stored to dry for more than a year, so the moisture is absorbed. Finally, a rectangular shape is made and it is burned to a brick.

Plastic garbage
The riverbeds are littered with colored plastic bottles, bags and other artifacts. Dogs are wandering the banks looking for food. People are standing in the water looking for metals.

Religion/ tradition
A tilted carved stone is built/ sunken in the river banks. People on their deathbeds are put on the stone with their feet in the water. The river is believed to be connected to heaven, and this tradition would make it easier to go to heaven.
Wooden beams are lying on the banks for cremation of bodies. Two simple pavilions cover the cremation process. Afterwards, the ashes are put in the river.

Temples along the river
Many religious buildings, temples and shrines are located along the riverside. Historic public buildings are meant to temporarily house travelers visiting the shrines.

Openings of temples and shrines are inhabited by people looking for shelter. Plastic canvas are covering openings indicating the temporary shelter. Improvised tents made of plastic canvas are placed along the riverbanks.

Damaged masonry temples
The weight of the heavy bricks pushes the mortar outward.

Some traditional temples have timber framing. This has helped some shrines to withstand from collapsing completely. Batches of masonry exterior have fallen out.
The wooden lintels are heavily decorated. Wooden pecks are used to make screwless connections. A gap/ margin is left in the allow some movement during the quakes. This proves that a lot of knowledge is developed over the centuries to cope with quakes. Guide: "this will be lost moving to steel and concrete structures".

Moisture
Nepal lies in a humid climate, moisture is a problem. Therefore buildings need renovation in the form of replacing rotten wood, beam lintels, removing grass from roof (attract moisture). Replacing bulging/ tilting walls.

NSET

Date:	9-9-2015
Location:	UN-Habitat, Kathmandu
Secretary:	Emilie van Wijnbergen
Present SSN-team:	Allard de Stoppelaar
	Arjan Oosterhof
	Baris Can Düzgün
	Coen Spelt
	Emilie van Wijnbergen
Interviewed party:	Dev Kumar Maharjan, Structural engineer NSET
	Hima Shresha, Director EERT Divison NSET
Absent:	Surya Narayan Shrestha, Deputy Executive Director of NSET
Contact:	Mobile: +977-98511 03625
	Tel: +977-1-5591000, 5593000, 5592522
	Fax: +977-1-5592692, 5592693
	e-mail: sshrestha@nset.org.np, shresthasn@gmail.com

Background information:
Documents on research gate
https://www.researchgate.net/profile/Surya_Shrestha4

About NSET

The Nepalese people, living in a country of high seismic hazard, have faced the consequences of many earthquakes including those of Great Earthquakes. Therefore, in order to reduce the impacts of future earthquakes; to raise awareness amongst the people on the possibilities of earthquake disaster reduction; to contribute to the development of science and technology related to earthquake disaster mitigation and implementation of earthquake resistant measures in construction; and to fulfil the necessity of a national, professional, non-governmental scientific organization, Nepalese professionals belonging to various technical as well as social aspects of earthquake disaster management decided to constitute the National Society for Earthquake Technology-Nepal. In order to gain a legal status to this national level organization, the founders of this Society unanimously adopted its Constitution.

Questions for NSET
What is the role of NSET? NSET/ UN Habitat / Shelter cluster
The NSET is responsible for:

- Policy of guidelines
- Research on type of structures
- Implementation of knowledge
- Making communities aware of risks, transferring knowledge

All actions and programs of NSET are done through the government. The building codes are made by the DUDBC (Department of Urban Development and Building Construction), concepts and technical support is prepared by NSET. NSET is mainly funded by USAID (for 80%). Government is not funding the organisation.

PDNA report (Post Disaster Needs Assessment) is made by the National Planning committee. This is a global report: assessing damage for example in categories: collapsed, damaged. Economic loss is considered, the condition of the country is assessed via hired professionals from the Worldbank. NSET performs more detailed damage assessment, classification of levels and information of damage levels. NSET is trying to improve fragility curve by doing detailed damage assessment. (damage assessments are not yet published)

Do you have a good overview of what others are doing?

We don't have a concrete idea on what others are doing. We are members of shelter cluster. Surya is one of the main bodies in the reconstruction authority national committee.

DUDBC (Department of Urban Development and Building Construction) - has the best overview. They have made prototype building designs according to the building codes.

Government website: National information center provides general reports

Can you tell us something on how the reconstruction is organized?

Most of the buildings are non-engineered buildings which means there is no involvement of engineers. Instead: petty contractors/ masons/ informal builders.

Therefore the NSET has a training program for the district / community people/ mason builders.

A house owner training on how the buildings can be made safe.

Programs: NSET is working in 30 municipalities. They are working on effective building code implementation and providing awareness programs for engineers, contractors. These awareness programs are necessary because people are not aware of the possible risks and the necessary requirements. However, awareness has increased since the past earthquake.

The building codes are only checked in municipalities, not in VDC (Village Development Committee). However the areas of municipalities are extending. For example, recently (after the earthquake) Bungamati has become part of the municipality.

→ find map of VDCs and municipalities (NSET has it?)

VDCs have no technical capacity to check building plans/ construction processes for compliance to building codes, due to lack of engineers. A training program is planned for them. Implementation is the main problem. Each municipality should have at least one civil engineer. Therefore we (NSET) have to enlarge capacity: provide training to engineers and masons.

3 level of certificates: foundation level, second level plinth, completion certificate

Completion. Need electricity and water system

IS there another way to get electricity? \

Only if you have permit for building

Permit for 3 stories, but build 4 stories but now the municipality is stricter.

Do you think the government will keep strict?

It has been 4 months, 1 or 2 months scared. They were ready to remove stories

Now that fear is lower.

- In what way Nepal construction firms have to comply to the NSET codes?
- Since the NSET is an NGO what is there power / influence

Is NSET making building codes? Or government

The building codes were set up in 1994 with help of a New Zealand team and US, and members of NSET.
DUDBC director team leader

There are 4 levels of building code: ABCD

- A: international state of art
- B: professional engineered buildings
- C: mandatory rules of thumb - predesigned building - up to 3 story building 1000 sq feet, span less than 4,5 m, 12 by 12 inch pillar size, 8 number of rebar's with diagonal, grid lines concrete frame/ masonry, also detailing, bans
- D: low-strength masonry building, guideline mud-mortar buildings 2 stories +.. floor

Sanchit (Home Makers)

Date:	9-9-2015		
Location:	Summit Hotel		
Secretary:	Emilie van Wijnbergen		
Present SSN-team:	Allard de Stoppelaar		
	Arjan Oosterhof		
	Baris Can Düzgün		
	Coen Spelt		
	Emilie van Wijnbergen		
	(Cas de Stoppelaar	-	Consul-General of Nepal to the NL)
Interviewed party:	Sanchit	-	Home Makers

Preparation:

- What is your role in the construction sector?

- How does the Nepali/Kathmandu construction sector work in general? Difference in- and outside KTM? Market change before/after earthquake? (price per m2, housing market, material scarcity, cost price, labour etc), what are information sources?
  Is there a difference in logistics?

- How is money distributed for the rebuilding?

- How big is the practical influence of organizations such as UN Habitat, NSET, Shelter cluster

- How is the materials quality and the balance between import (China/India) and Nepali?
- Are there technical changes due to the earthquake?
  Do you notice changes in procedure?

- What are the procedures regarding permits and building codes? And how is the actual practice?

- What do you think of traditional building methods? Compared to ‘modern’ materials such as concrete/ concrete blocks?

- What do the Nepali demand in housing regarding the earthquake?
  in remote areas/ urban outskirts and town center

- **What do you think of traditional building methods? Compared to ‘modern’ materials such as concrete/ concrete blocks?**

Brick as main building material

Sanchit starts explaining the general problems of the building industry. Brick is a heavy building material, not the best choice in terms of safety. However it is the main building material in Nepal, is still being used.
The government is promoting lighter structures, for example light partition walls. Change is hard on people, since they (trust?) are accustomed to brick. A lot of products are coming from other countries, but people find it difficult to accept these.

- **What are the procedures regarding permits and building codes? And how is the actual practice?**

Building codes

The government sets up the laws with input of NGO’s.
After the earthquakes the government handles the building codes/ permits very strict. Before building, the Kathmandu municipality checks if there are drawings, and if the codes have to be followed are followed? . One needs a certificate to start building, a certificate to show the foundations are done correctly, a certificate when the plint is done(until 1e floor) half way certificate and a completion certificate. This last one enables the building to receive electricity and water.
Deviate from the codes delivers high risk: an employee from the government can come by to inspect. If the buildings do not comply, you can’t apply for facilities such as water and electricity.
The new building codes are driving up the costs of building – in all sectors of the building industry. For example: roads are required to be bigger (for two fire engines to pass). Therefore people could lose parts of their plot.
Laws are the same for building types – applied to private individuals /private homes. Applied certified drawings for municipality are necessary to build.

Foundation

The new building codes subscribe that above 6 floors building foundations have to have piling and not rafting. Piling foundation is more expensive than rafting.

Municipalities

The implementation of building codes is done in villages which belong or are covered by the Kathmandu municipality. These villages have access to engineers who can perform checks or make drawings.
Villages which lie further away do not comply to the municipality (not yet), but to VDCs. Village development committees. Due to a lack of engineers, it is hard to follow/ check building codes. Remote villages are not in the municipality, and are not compliant to the code.
The Nepal population is approximately 30 million, fo which 10 million live in VdCs.

Construction sector

Labor has doubled in costs. The government is trying to stop workers leaving for other countries. By making other countries pay for working visa, they are trying to bring workers back.
Material costs, surprisingly not so much. Brick has gone op 300% . An explanation can be that there was no construction going on since the earthquake until now. Only since the past 2 weeks new certificates are issued.
The building codes subscribe certain factors allowing

- The percentage of building plot which may be used for the building

- The amount of floors

Both factors have influence on total possible revenue of the owner.
A lot of new buildings had no sceptic tanks for drainage. Now it is required to have one. (before sewer water was dumped in mother river Bagmati)
Do the same rules apply for new buildings and existing buildings?
For existing buildings and renovations, also the new laws should be compliant.
How realistic are these laws?/ new building codes
It depends on your risk appetite: do you want to lose a building over a permit?
Due to the building permit and limitations on number of stories or building area someone might lose 20 rooms. But the total price of the building is much higher.
This leads to a negative view on the government. Responsibility of the permits / deaths

Building codes

Do you think the codes are safe enough?
Given the country's limitations, the codes are plausible. It is now an 'ok' balance between the costs for safety and the human right to have a shelter or house
What are in your view the limitations of this country? (building sector)
The country is inflexible in materials use, we have no quarries. These kind of materials have to come from a third country, and the costs of transport are high.
The government can't discourage bricks because there is now no feasible/suitable alternative.
Are bricks inavoidable?
People just like bricks. Educated people have visited conferences about new materials..
But people stick to brick, is a difficult to break mindset

Finance

How is money distributed for the rebuilding?
Nepal is getting a lot of money. Where does it go?
The reconstruction budget is around 6.6 billion dollars. A reconstruction authority is identified, led by several ministerial people. Led by national planning commission (head of this body)
From the budget 300 health posts (mini hospitals/ clinics) are being built/ being upgraded. Focus lies on schools, public facilities, and infrastructure.
Housing is a touchy issue. Low-cost housing / low-income housing
It is not yet clear how this problem will be solved. Up till now only corrugated sheets are distributed.
If a people need to rebuild their house, they can apply for a subsidized interest loan from the bank. Himalayan bank can provide loans for housing. up to 2000 to 25000 for one or two years..
(normaly the interest is 12% .. now 5%). This is meant to be distributed on the hand of income.
However it is questionable if villagers are eligible for these loans. In remote towns there is little contact with the bank. Furthermore, they need collateral / onderpand which they generally do not have.
GTZ – German Aid Agency
Health posts are led by Germans. They provide drawings, plans and funding. The plans are handed to the government, put out to tender, bid.
Plans are better for public buildings than for housing. Funding for schools is much higher.
What are the average costs for normal building house?
220 roepies / square foot residential building
30 roepies /square foot

Funding – does it stay in Nepal?

If you come as NGO, they can use the money for nonprofit to build and sell
As a foreigner you cannot invest and sell … there are legal ways if you don't take profit
The legal advisor present is helping British people to do real estate .. and find loopholes so the profit can be used to expand the project.

Prime minister relief fund:
Shesh Ghale is building in Thamel. He is a special envoy for the prime minister, earthquake reconstruction. The plan is 10.000 houses.. but where? Which land? … far more complicated!
For foreigners it is hard to invest in real estate.
The laws are really strict direct after the earthquake. How will these last? risk of diminishing?!.....
Some laughter…

Special envoy for the Prime Minister

Date:	10-9-2015 (14:00)		
Location:	Summit Hotel		
Secretary:	Baris Can Düzgün		
Present SSN-team:	Allard de Stoppelaar		
	Arjan Oosterhof		
	Baris Can Düzgün		
	Coen Spelt		
	Emilie van Wijnbergen		
Interviewed party:	Sunir Pandey	-	Special envoy for the PM

Preparation:
What does the special envoy do?
What are the focus points of the special envoy?
Is it correct the government focusses mainly on rural areas?

How does large scale construction work on political level after the earthquake?

How does your organization work in general, where does the money come from?

Are there any conditions on spending the funds?

How does the plan of the NRNA for spending the (foreign 30mil euro) donations looks like.
10.000 houses / where / for who (rural/urban) / which construction method / which company?

Do you trust the collected funds will be spend in the right way or be spend in general?

What is your key advice to the PM? What do you think should happen/ is the best for Nepal?

Where do you gather your information for earthquake advice?

What is the plan? (Demolition, construction, what periods etc.)

What is the procedure for compensation affected families
2000e/family with collateral, accessible by a road.

Do you think there are any common grounds? Can you help us?

Actual meeting

Shesh Gale is the advisor of the PM regarding post-earthquake building, he is the "face" of the campaign. Sunir Pandey is his coordinator of Shesh Gale. The goal of the special envoy is to raise funds and connect donating people/countries to the Nepali government. The special envoy does not have influence on project content like; budget, location, technique etc. The connect people, however there are some issues why this is not working….

Founding of the special envoy: Government is looking for people who want to fund and built houses, schools etc. Because the government is 'busy' they've set up an authority (special envoy), but there is no real department with responsibility of rebuilding Nepal.

The special envoy is responsible for finding those parties who are interested in building and funding. They look for investors who want to do that via the government but that does not happen because people/countries do not trust the government and are therefore not willing to transfer the pledged money.

Sunir thinks the government should take the first step (setting up projects and a plan) and then other people will follow.

Shesh also set up MIT group foundation, focuses on education and health.

They have trouble collecting the pledged funds because no one trusts the government, people say they will help but they don't because of the lack of trust. A lot of countries like india promised funds, 4 billion in total, but because there is no trustworthy governmental body. There should be a commision with a CEO, then there is a trustworthy governmental body and they can start collect the pledged 4 billion. However politically it is difficult to establish this body. It was founded but only had 60 days of authority…. They want to establish this body for at least 5 years (rebuilding period) however both the parliament as the opposition both want the CEO position of this commision. Therefore this commision has not been founded yet…...

The plan is to divide the to be collected funds into four sectors:
housing (60% of the funds), infra (roads, hydro, phone lines etc, industry, tourism (?) (4th sector was not completely clear…)

The housing sector (60% of total) focusses mainly on rural area (but also some on urban). Majority will go to rural areas.

Building codes are for urban area, proper codes for rural are missing
Sankhu is rural, a lot of agriculture

This new commission should also make new building codes. NSET recommendations probably will not be adopted because they are US aid and not governmental. The government might use NSET's case studies. They are independent, Sunir was not that enthusiastic about them.

In patan, village: pilatsjee (fonetisch); is a plan for rebuilding, which is a good plan to use, Sunir will send this plan to us.

Financial plan of the government:
15.000 Rp. gift to families with damaged/broken house (already handed out to almost everyone, first help package)
185.000 rp. temporary housing - gift (comes later is in the budget)
1 mill rp. village house (loan amount)
1,5 mill city houses (loan amount)
1 or 2 percent loan

In 1988 the loan became a gift after the earthquake

At the moment the loan plan is absolutely not concrete, local administration units on site are necessary to organize the money flow. This however has 'no priority' because of the elections and constitution chaos.

PM relief fund is used for flying helicopters, general stuff the government needs to organize right after the earthquake. Anyone can put money in the fund, that however does not happen that much because trust is an issue…..

(He'll ask shesh to show us the Marriott Hotel)

1000 temporary houses for 30 mill dollar/rp ? NRNA project?
NRNA Rajesh Rana ed@nrn.org

Sunir will also link us to a Nepali guy (Rabindra Pari) who builds locally but earthquake resistant in Bhaktapur

Key advice of Sunir to the PM is to get a (working) policy in place, new building code for rural, how to get earthquake resistant techniques and materials to rural places.

DRR.portal gov.np it has statistics and maps, is online. (Coen already started analyzing its use)

http://drrportal.gov.np/

14 out of 31 regions that were hit were ' crisis hits' . A till C category. A is highest damaged in the north.

The temporary housing loan (185.000 rp.) might become too late, monsoon is already for couple of months…

1000 - 1500 people leave every day leave to malaysia qatar etc.

Rural people definitely depend on funds… otherwise they'll live in temporary housing for ever...
due to earthquake poverty raise from 20 something to 30 something percent

SSN will update the special envoy, they can contact us with the government for the coming teams.

Shelter Cluster Nepal: launch of Reconstruction and Recovery Committee

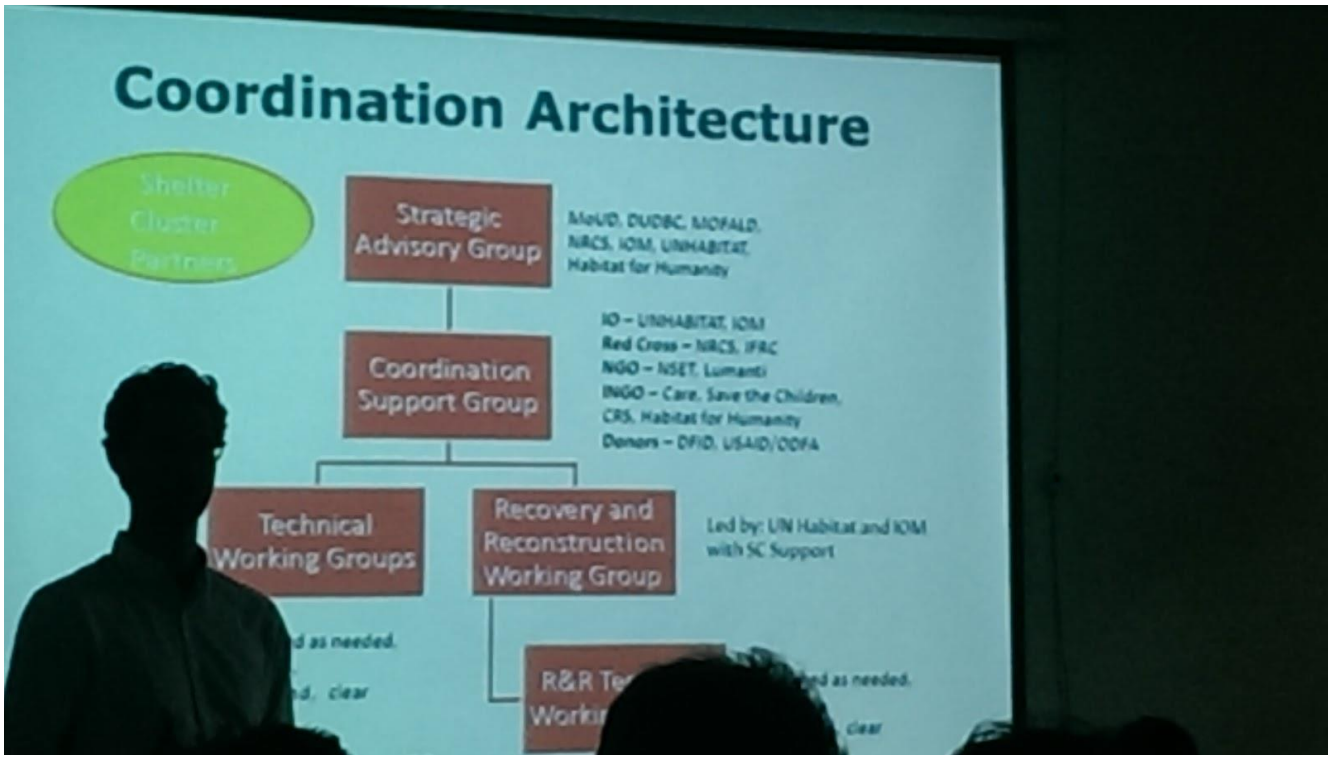
Date:	10-9-2015
Location:	Department of Urban Development Building Construction
Secretary:	Baris Can Düzgün
Present SSN-team:	Baris can Duzgun
	Emilie van Wijnbergen

Summary of event:

The Shelter Cluster Nepal group is a group that coordinates humanitarian efforts in disaster struck areas by performing a number of activities. The group in Nepal has 180 partnering organizations (NGO's etc.) that all have their own area of work where they perform certain types of relief work. The nature of the SCN is of such a form that initially it is very active in coordination and after a certain period/ achievement of goals they stay present in countries in a supporting role. The activities that have been performed by the SCN since the last earthquake are the following.

- coordination of efforts by government, NGO's and private,
- collecting important information,
- data analyses,
- gap analysis,
- information, education & communication materials,
- technical guidelines.

Now the efforts will be continued by two governmental groups; the strategic advisory group and the recovery and reconstruction group.



The Shelter Cluster is lead by the MoUD and DUDBC and they are co-lead by IFRC.

The newly formed Recovery and Reconstruction Working Group (R+R WG) is led by UN habitat and the International Organization for Migration (IOM), they are supported by the Shelter Cluster. Their objective is to provide a platform for coordination, strategic planning and technical guidance for agencies involved in longer term recovery and reconstruction, and to engage with the GoN, WB and other stakeholders to inform the wider housing reconstruction plan.

The workgroup will decide in the coming weeks how the money available through the government will be distributed among the affected people and what designs will be officially published by the DUDBC as model houses which are in accordance with the building code.

The ministry is looking for rural housing types/methods/materials that are earthquake safe.

The Vice President of the working group gives a short speech on his vision regarding the reconstruction. He mentions that the government is interested in rebuilding back better, with available and local materials, in a style that is fitting for Nepal and will perform good in an earthquake. He believes that the physical recovery will be the easiest compared to the social and economical reconstruction. He advises reconstructing parties to pay attention to their actions not to cause disharmony in a community. He warns that there are different groups within a community and only helping one will cause friction within the community. He also points out the economical side of reconstruction. A truck bringing bricks from KTM should use the opportunity to also bring back local products to KTM.

The meeting is closed off with a summary of the event and the announcement when the next closed meeting will be held.

Shelter Cluster

Date: 11-9-2015
Location: Summit Hotel, Lalitpur, Kupondole
Minutes secretary: Allard de Stoppelaar
Present SSN-team: Allard de Stoppelaar
Arjan Oosterhof
Baris Can Düzgün
Coen Spelt
Emilie van Wijnbergen
Interviewed party: Siobhan Kennedy (Shelter Cluster)
Questions:

- What is the role / function/ aim of shelter cluster?
- How is the organisation of Shelter Cluster set up?
- What is you opinion on the political promises (2k$)? What is your view on funding of the reconstruction?
- Difference in approach: classification of rural area/ urban outskirt/ urban Kathmandu
- What do you see as the biggest obstacles for rebuild?
- lack of knowledge and skilled masons?
- How good is your overview of the work done by NGO's and how can you ensure the level of quality they deliver
- Which building materials suitable for rebuilding?
- Research on traditional building methods?
- What could be an addition to the prototype housing of DUDBC?
- Which focus?
- traditional building methods, compliant to building code, good maintenance
- traditional building methods, strengthened with innovative additions 'geomesh'
- alternative buildings styles, local materials
- new building styles, not-local materials
- What is your view on maintenance of timber building elements of existing building styles? It seems as if rotting of timber elements due to bad maintenance if often a problem.
- What do you think about shelter/ transition / semi-permanent housing?
- Are there any gaps in the research?
- Niches in which students can perform valuable complementary research?
- Focus on a certain city/ village / area?
- Interested to function as a client? feedback organization?

Interview

How is the process going on with the national disaster committee? We heard from different sources that Nepal must have a committee and a good plan before getting their funds from most of the foreign countries like India, China, Japan etc.?

"The government will have a national disaster committee. But Nepal is political very complex. Political there is a lot discussion of who is going to be the chairman. Two persons who are fighting now to be the CEO. Just after the earthquake Nepal had a similar committee, but that was temporary for 60 days. This one will be more permanent but has to pass the parliament. We are still hopeful and thinking this will happen in a couple of days."

“However there is a plan but there has be still has to be damage reports. NSET has done PDA's but those are just estimates.”

What is the government promising right now for the people whose house has collapsed?

“The only thing is relatively clear that 2000 dollar will be available for new construction. It is not official. The one I can say is that is going pretty fast comparing to other post disaster companies. Shelter cluster is only talking technical assistants, because we don’t want to interfere in political movements. So with technical assistants we means things as information centres. Finally we want to give collective movement. This is for now the purpose of the cluster.”

In what time scope the reconstruction will be?

“First it was just quick response: just blankets, sheets and temporary housing (quite advance to low tech). Now they are preparing houses also for the winter. We start masons training etc. but we also have to update data before we start. We have 4 coordination offices in every region. The main aim of shelter is coordinate and to standardize. Shelter cluster is just trying to coordinate, every NGO is feeling free to join or not.”

We are also trying to find our role in this reconstruction process, we of course have some ideas but after telling our story what would be your advice?

“You should go to Sanku, similar as Bungamati but even more devastated. And you should tell NSET, because they are looking for someone over there.

Do you more about Dhulikhel?

“I don’t know much about it, but it is devastated. Would just go there and look around.”

On what should we focus, rural or urban?

“The government will right now focusing on rural. At the moment rural everything outside of Kathmandu valley. They are also announcing new municipality. So mostly they draw a line around a certain amount of housing. So sometimes it is not very urban at all. So it is a bit complicated to tell you what is urban and rural.”

On what is UN habitat focusing?

“UN habitat is more focusing on temporarily. They are now looking for technical assistance. I guess some rural and urban.”

“Most organizations are focusing on rural because it is easier. Target areas along Namche Bazar and Gorka are much tougher because those are very remote.. Helicopters was one way to get there but very expensive. Sherpa’s were used to get everything up. The fastest reconstruction is probably along those parts. Because people have limited expectations for help, so they don’t wait for it.”

Is culture an import aspect for rebuilding Nepal?

“There is a very important aspect on rebuilding the culture. It is very important for the close Newari groups. They are very proud on their heritage. Also some people even say that 100 years back were better in building than right now. Bhaktapur is very interesting in a sense that they think it is important to conserve the traditionally style. Government is even paying for 80 percent of the timber. Timber banding is quite important but the problem is treatment of the timber because it often rotten. In rural areas it is even harder to get access to treated timber.”

Not possible to treat timber yourself?

‘Well it is not often done at household level. The other question is if you promote only timber what is that going to do for the environment.”

Didn’t the government already provide some examples for designing housing, prototype housing?

*“*Yes but The designs are a little bit secondary, they fit the building codes. But not always fit the estitics.”

Moreover, one of the ideas is to build houses flexible for the future's, so that they are expendable, do you think this would work?

Well I don’t know exactly but you get only the funds when you build compliant to the codes. The aim of the subsidy is support the rebuilding. This way it also worked well after the Kashmir earthquake.

Are there also more innovative techniques in the building code, such as confined masonry?

“Not really, stone masonry with mud and stone with cement are popular but confined masonry is not very popular right now.”

“Another example right now is a gabion band. But the code can’t be updated every couple of weeks for every new method. However I think these techniques can be interesting. To look at other ways of banding. Access of timber is hard but cement is even harder. Even bamboo is talked about as banding material.”

Can this maybe be interesting for us, these techniques?

“Yes, this could be interesting, but a lot of experts that have looked into this. I will put you in contact to the gabion band people.”

“Nepal has a lot of very senior experts on stone masonry. Tentendera can be interesting for you he is experienced with this. So maybe it is better to continue the research rather than a new piece of research. Or maybe documenting the construction typologies. It is not typically research, but it can help for further research.”

“Another aspect that is interesting is that to document the high rise buildings, how they are repaired. Moreover research can be needed for replacement of steel, so maybe plastic instead of steel.”

Is there also a good overview of the research that is going on right now?

“Well no not really because research is less straight. So it is hard to have a good overview. We hope there is getting a better platform, such as the technical platforms. NSET is working on some of it. Surya has probably the best overview of the current situation in terms of research. I will ask Surya. NSET has contacts all over the world. Moreover the universities should have a good network.”

“If Padma Sunder Joshi (UN-Habitat Programme Manager) has something that you can do research, I would advise you this. Because he has a good network.”

Further comments of Siobhan:

- “One of fears for situations like Nepal is that temporally shelters are becoming permanent.”
- “The positive thing of earthquake is that is improving the construction sector.”
- “Retrofitting à Subsidy for retrofitting is lower than building completely new. The cost and level of technical stuff of big buildings are enormous.”
- “Recognize the value of culture - potential topic for research.”
- “Local building traditions represent rich sources of knowledge including hazard resistance.”
- “Understanding how people live, their cultural and social values and preferences, is critical to understanding how they will build their homes. “
- “Building codes were quite good but the application was not good. Just as in Ireland, so transfer knowledge.”
- “Traditionally you have two and half stories. Below was animals and stuff. People just repair what is left. So just put up a lot shelter on a half broken house.”
- “PO is the name that the government is using for everyone which is not government.”

KU Leuven

Date:	11-9-2015
Location:	Arts Bar, Lalitpur next to UN Habitat
Minutes secretary:	Allard de Stoppelaar
Present SSN-team:	Allard de Stoppelaar
	Arjan Oosterhof
	Baris can Duzgun
	Coen Spelt
	Emilie van Wijnbergen
Interviewed party:	Stefanie Dens
	Annelies de Nijs

Questions

1. Can you tell us something about your role in this project? and the role of your students
2. What is your opinion on building traditions and materials?
3. How can we perform research that is complementary to your project? Same village/ different village
4. Why did you choose this village to do the project?
5. Which building materials are suitable for rebuilding?
6. What do you see as the biggest obstacles for rebuild? lack of knowledge and skilled masons?
7. What is the political/ practical side of you project?
8. How will you get the funding? Or is this only a study project?
9. What do you think about shelter/ transition / semi-permanent housing?
10. Is your contact arcadis or unhabitat?
11. Where do you get your information from, do you believe it to be a reliable source?

Interview

Can you tell us something about your role in this project and the role of your students?

"We are from the urban planning department of the KU Leuven, post graduated. Students from all over the world.

"The idea is that students can use this project for their master thesis. Often a collective subject is chosen for a small group of students. We already had collaborations before with UN Habitat. They contacted us to make the framework for this Bungamati project. We linked the thesis of our students to this project. So we have a "double agenda."

How did you setup your project?

"The framework was already decided by UN-Habitat."

What is the role of Arcades in this project?

"Arcadis has an understanding with UN Habitat and this is called Shelter. Arcadis gives pro bono advice to UN-Habitat. This a non-profit department of Arcadis."

It seems that your project has similar focus points as Shock Safe Nepal, can we help each other?

“Due a lack time we couldn't finish some aspects of our projects. We are busy with the project ‘building back better’. We want to show people how you can achieve this. We would prefer doing his with a test case.”

Why did you choose for Bungamati?

“This came by a hotspot analyse by Arcadis. Arcadis wanted aspects like: historical quality, certain gradient of destruction and medium distance to Kathmandu so there is still a influence from the main capital. Also the community of Bungamati has also set up a relief committee by theirself. Moreover they are planning to put the village on a unesco heritage list.”

“In Bungamati there is still a lot of knowledge about the traditional building methods. There are craftsman who can still make the traditional joints. Those joints still have some space for movements in contrast of the concrete joints in the case of earthquakes. The concrete and brick structures have problematic joints.”

“Moreover we want to use Bungamati as an example for similar villages and cities. There are a lot of similarities between Bungamati and surrounding towns.”

What do you think about our project, do you have any tips regarding SSN after your stay here?

There are many different building technologies in different regions. Bungamati is looking for stakeholders, knowledge etc. but bungamati is not the only town out there. The UN-Habitat choose Bungamati and they want to go to donors for this project. However the UN will stay for a long time in Nepal so they may have also other opportunities for you. I would advise to go to Padma Sunder Joshi (Habitat Programme Manager for Nepal), he has got a big network.

We mapped building materials and a lot more such as collapsed buildings, new buildings etc. The social aspects, temporary shelters. For example the Danish shelters are build so good that we think they can last for at least for 20 years instead the 5 years that they are meant for. All this is very important for the masterplan.

Did your preparation helped you in Nepal?

“In Belgium we had a lot of preparation but actually after a couple of days we had to change everything. Of course we expected that.”

Do you know anything about the cash flows that are used to rebuild Nepal?

“Well, we don’t know much about this, UN Habitat is doing this part of our project. What is interesting is that there are a lot of coorparives of the local people. They all invest money in a local fund and that fund is giving out loans. We are seeing this is getting very popular. You of course have to realize alot of people are not familiair with banks or their loans. Also barter systems are popular. Moreover people lend ‘time’ to each other, they help to rebuild each other houses.”

Are people that you met open to new building techniques?

“We notice that people quickly believe in new techniques, they want to be modern. However there is also a lot of proud about their village. In the centre of bungamati they really wanted to rebuild a newari kind of house.”

Does your project also look into the reinforcement of existing houses?

“No, we do not have that knowledge. What we noticed that well maintained houses are still standing. People use land seed oil to maintain their house.”

Would people be interested in expandable housing?

“They already use this logic for concrete housing, you see all these steel barns sticking out the houses. It can be an option. Houses often get separated vertically when dividing it among children. They even put extra staircases and front doors in those houses, which of course is affecting the construction.”

Do you have any tips for us?

“Maybe you should focus on public buildings. It is very hard to choose who will get a private house and who will not. Not only hospitals or schools but buildings with a social character, buildings that mean something for the whole community. “

What is the future of this project, will somebody take over this project, be the owner of it?

“Well, that is still an uncertain. Upcoming monday we have an important presentation to all our stakeholders and we hope we will find the answer to that question!”

Moreover:

- KU Leuven did not receive the damage report of NSET.
- Use local people for translation, the interpretation of question however can be different. Be aware of this.
- The students of KU Leuven will stay until the 24th of september.
- Giving money lead to a ‘lazy’ economie. Try to avoid this.

Technical Workshop or Rural Housing

Organized by the National Planning Commission
Partner Ministries/ Agencies

September 12, 2015

SESSION 1
Brief of introduction Technical Working Committee (TWC) and Review Panel & Workshop objectives - Presentation, discussion and finalization of draft prototypes designs prepared.

- *Brief presentation of National Building Codes for Housing Construction by NBC representative*

The NBC is in the final phase of building code revision.
Major changes are limits to building height of 2,3 stories masonry.

- *Presentation of type designs by DUDBC*

Focus lies on rural areas. The DUDBC will publish 25 prototype housing designs.
The designs are technical and standard, compliant to the building code (via mandatory thumb rules).

Designs vary in material (stone masonry, brick masonry), in number of stories (1 or 2- 2,5), reinforcement band material (timber, concrete, bamboo), light roof materials.
Reinforced concrete can be used as band if it is accessible, or if people can afford it. Hardwood is too expensive, local (treated) softwood will be used.

Q:: Are you also taking into account stonesize? A mismatch in stone sizes can also cause collapse.
Q::
The drawings seem architectural, are there also any structural calculations?

1. It is feasible to apply hybrid systems, also systems such as Gabion band..
2. I do not understand why a T-shaped building is included?
3. The buildings seem to be designed for a hot climate; protecting from the sun. In colder areas the sun has to get into the building.

The DUDBC has made technical reliable non-specific designs. They deliberately do not focus on all cultures, just on basic things and technical aspects.

Q::
In the post-earthquake context,

1. Most of the people are poor, how will they be able to afford these houses?
2. How are they going to get technical support?

DUDBC is setting up a program to train trainers.

Q:: Why aren't you looking at new materials? These designs are not enough. More effort needs to be done to make the designs payable. Sustainable, but cost-effective.

Q:: some issues with the designs

1. Most of the rural houses are self-built, local artisans, local masons. Prevent disembarking local people in the process.

DUDBC: the prototypes are more a reference how to reconstruct than that they should be strictly followed.

2. Do the designs facilitate implemental growth? House building in Nepal is incremental; if one gets married or gets children can extra rooms be added?
3. In Pohara for example, a large number of people are wood carvers and work from the house. This is to first priority. Incorporate these things in design!
4. How many houses failed due to bad plans? More on mistakes in compromising construction practices. House owner is mainly concerned how much it will cost.
5. Guidance on siting is needed. Hill, slope, landslide areas. Construction and design comes afterward.

Q::

1. Only 1 of 25 is made with traditional mud mortar. No two story buildings. This amount should be more.
2. Is the idea that agencies will teach according to these designs?

Q::

1. Think more on culture/ livelihood. Beware of laying the path in the wrong direction.
2. Animals, agriculture is not so much considered.

Q:: It would be good to have designated engineers at villages for technical support.

Q:: The bands are driving up the costs. It is interesting to look at how many are needed.
Q:: It is necessary to support on choosing the building plot.

Private organisations

- *Abari*

Abari is working with rammed earth, combined with bamboo.
Choice of rammed earth is based on choice for local materials. Mud/ clay quality can be good in many regions of Kathmandu. Their building in Ghurka have withstood the earthquakes without a scratch. Mud is heterogenous, but when it has good consistency is it a good material!

Adobe blocks are combined with reinforcement. Wood = expensive, therefore bamboo and steel. Steel is cheaper, but one should choose what is appropriate for logistics.
Sometimes geomesh, or use of plastic mesh.
Process: ram the earth from 4 to 2 inch in its formwork.
Seismic tests are done on adobe/ rammed earth in Chile.
Bamboo is used for roof trusses, strong in tension along their fibre.
They have a problem with durability, but we have developed a process to push out the stark.
89% of the budget stimulates local economy. Houses cost only 15% more than regular house.

- *Hulas steel*

It is important to keep the costs low.
We focus on extendable housing if social situations change.

We chose to use pre-engineered steel trusses (low-cost) to stabilize the whole structure. The trusses are identical each section. C-type hot rolled sections. Building in modular units of 3x3 m.
Walls made of mud and bricks can be placed around the structure. People are ready for change.
Hulas steel buildings are like IKEA buildings, no training needed. One example house in every VDC.

- *CORD*

Our designs are intended for rural areas: build back better. Based on local circumstances.

Cement is a nightmare: storage, maintenance, mixing, logistics…

Two technologies:

1. CSEB technology: the stabilized earth block

Environmentally friendly, supporting local livelihood. A simple machine needed. Mix+compress manually. Result: really good bricks.

2. Stone masonry with GI wire based on traditional practice. (Galvanized wire).

Combine with mesh. Stone is there, mud is there, introduce one easy to introduce technology.

- *Habitat building technology*

Important to investigate challenges/ opportunities
modern/ traditional. -> technology based on traditional.

Choice for CSEB interlocking bricks, made from local resources.
The interlock bricks are created with a hand press / hydraulic machines.
report FEMA: numerical tests done on interlocking bricks.
The bricks lock like lego, reinforcement can be pulled through the holes at specific places. Design is made with separate toilet and animal shelter.

- *Presentation of type designs by JICA representative*

JICA does a proposal to make better mortar houses.
Also one proposal has a timber second floor.

- *Presentation by type designs by N-SET representative*

Basis and scope:

- rural cases
- tentative costs
- flexibility in lay-out
- phase wise construction
- compliant with NBC 203 code provisions

NSET reacts to concerns on the single bar in the corner- coming to the same conclusion.
For mud mortar the bar doesn't change the amount of safety, why spend money?
Solution → not to disturb the wall too much.
Materials → timber and steel
Double timber frame, not in the wall but around and on the inner corner.

Extra provisions for big earthquake: combine timber reinforcement with gabion wire mesh on the inside and outside.
For wall resistance is created by frictional sliding and energy dissipation. How can you enhance this frictional sliding?

Q:: People are not necessarily interested in the designs, but in what of the designs makes the building more earthquake safe. In the basic technical methodologies.

Q::

1. How will you get sand, cement and steel into rural areas where there is no road access?

2. 80% will be building own home, also plans for house owner training?
   will these technologies match the skills?
3. NSET: great corner posts and GI wire enhancements.

ANSWER: owner built means: owner helping a mason.

Bamboo is proposed in circular section: banding + vertical posts. Are there different ways to use bamboo / enhance longevity?

Q:: Might be interesting to be able to show what is earthquake safe, and what is earthquake resilient. Make a distinction what is safe and what is even safer.

Q:: Good job focusing on local materials and the process.
Approach should be: tell us what works best for you. 'In my village I think this will work.' Let people and local artisans choose.

Q:: Request for not only drawings, but real design calculations.

Session 2

Discussion on application of flexibility of prototype designs during construction

- Draw up guidelines for flexible application of prototype designs, construction materials, technologies;
- Draw up simple construction processes to be followed during construction

Surya Shresta pleas for flexibility in prototype designs.
→ allowing people to have their own designs.
Showing how it is possible, giving a range of options, taking into account primary conditions geological conditions, etc.

Proposal: stepwise requirement (of the codes) = Step 1 - Step 10
Horizontal band is the most important seismic element.

Set-up MR: minimum requirements. Guidelines/ rules of thumb.
Allow for flexible designs; people will take their own path.
Follow ten points and get a safer house.

- *Siobhan*

They are working on simplified guidance to people via illustrated posters.
People are already starting to rebuild, sheets should be made with specific messages.

Q:: How to ensure that people are using the same / right materials?

→ Confusion on self-build culture:
The building process is led by masons, but the house-owner helps by providing labor.
Guidelines are useful for mason+owner combinations.

Q:: How can you secure that trained trainers will not go work somewhere else?
ANSWER: you can't: therefore massive training is needed. massive scale to provide enough engineers.

Session 3

Endnote by R. Pokharel, Vice Chairman NPC

- It is good that many people are focussing on local materials.
- Request: Please provide us information on where you are working so we can coordinate this.
- It is important to include incremental growth in reconstruction strategies, due to changing social situations.
- Please don't forget elements such as animal sheds, these our part of the settlements
- Provide information on life span of proposed structures so people can make rational decisions on what to build.
- Conceptual designs are useful: people can use these designs based on a choice of local availability and local identity.
- Please keep in mind that the reconstruction task is acute and massive at the moment, but a lot of people will not be mason all their life once the demand starts to diminish.
  Combine the mason training with other trainings: like partial farmership. To provide an alternative when mason career is ending.
- We need to complete the trainings before the festivals. Otherwise people will already start rebuilding without proper training.

Appendix

Report Two

Appendix Report Two

Appendix 2.A. General requirements ribbon development

Requirement ID	Aspect	Sub-aspect	Requirement	Requirement Value Qualitative	Source	Remarks
Technical						
TE-1011	Structural Building Components	**Strength**	Loading types and loads withstand by construction	Construction should minimally be able to withstand the constant and variable loads as given by the Building Code	Literature	Literature
TE-1012	Structural Building Components	**Redundancy**	Presence of redundancy regarding structural elements	Structure should at least allow some redundant elements to relieve structure´s dependency on a single structural element in its imagined form.	Literature	Fieldwork and literature
TE-1013	Structural Building Components	**Non-structural elements**	Placement and amount of non structural elements	Non-structural elements should not diminish the inherent properties of structural elements or general safety	Literature	Fieldwork
TE-1014	Structural Building Components	**Regulated safety**	Level of safety needed in regular usage of building according to building code	If building type is mentioned in the building code then compliance with minimal requirements as stated in most recent version of the Nepali Building Code If not mentioned in building code then according to general structural principles	Literature	
TE-1020	Seismic Performance	**General seismic performance**	Structure should be able to withstand seismic activity	Combination of seismic elements, diaphragms, mass distribution, load and building plan determine the performance during seismic activity, the structure should at least be considered category C according to the Worldhousing.net classification	Literature	
TE-1021	Seismic Performance	**Seismic elements**	Application of seismic elements	Combination of seismic elements must resist lateral loads	Literature	Literature
TE-1022	Seismic Performance	**Diaphragms**	Degree of stiffness of diaphragms	Must allow for diaphragms that can provide ensure a uniform redistribution of lateral loads amongst structural elements	Literature	
TE-1023	Seismic Performance	**Mass distribution**	Manner in which mass is distributed within the structure	Mass of the structure should be distributed as evenly and low as possible within the structure	Literature	

TE-1024	Seismic Performance	**Load**	Amount of continuity within load path of structural elements	Continuity in structural elements must be guaranteed	Literature	Fieldwork
TE-1025	Seismic Performance	**Building plan**	Structure should consist of or should be partition able into symmetrical shapes	The construction method should offer possibilities to make a symmetrical floor plan	Literature	Fieldwork
TE-1026	Seismic Performance	**Possibility to increase seismic performance**	Seismic Performance	Possibility of adding realistic improvements to the combination of seismic elements , diaphragms, mass distribution, load and building plan determine the performance during seismic activity. The structure should at least be considered category D according to the Worldhousing.net classification	Literature	
TE-1031	Construction	**Sensitivity to surface**	The needed type of foundation should not excessively increase technical difficulty	The building type should not require a perfectly accurate foundation	Literature Observation Interview	Field
TE-1041	Climate	**Openings (ventilation & sunlight penetration)**	Control of interior climate and level of humidity inside structure Adaptation of exterior wall openings to regulate penetration of sunlight into building	Structure must allow for ventilation of interior for comfort and regulate humidity to maintain quality of structure Structure should minimally allow for variations in size openings dependent on climate and solar orientation	Observation Interview	Fieldwork and literature
TE-1042	Climate	**Thermal capacity**	Regulation of temperature in different seasons needed to ensure acceptable living conditions with respect to heat transmission	Minimum able to regulate the temperatures to some degree, poor thermal performance is acceptable	Observation Interview	Fieldwork and literature
TE-1051	Construction	**Lifespan building**	Lifespan of building method when maintained correctly	Minimum lifespan should be around 50 years or equal to at least two generations	Observation Interview	Literature and fieldwork
TE-1061	Maintenance	**Reliability**	Amount of maintenance required to maintain standard living conditions and safety	Structure should at most require maintenance every 3-5 years	Observation	Fieldwork

			given the lifespan			
TE-1062	Maintenance	**Maintainability**	Technical and physical ease of performing maintenance on a structure	Structure should not require extensive and very specialised workmanship and much resources	Observation Literature	Fieldwork
TE-1063	Maintenance	**Availability**	Availability of the structure during maintenance	Should be available without major risk during maintenance except for very large maintenance	Observation	
TE-1071	Construction	**Complexity**	Ease of learning to correctly implement technique required for building method	The complexity of the construction should at most be so complicated to require some years of training	Observation Literature	Fieldwork
Resources						
RE-2011	Material	**Initial quality**	Acceptable quality of a material in its initial state	Used materials require latest NS IS or other similar approved standard quality certificate. If used material is adapted, innovative, recycled or not provided with mark it may also be used given that the characteristics are tested to be equivalent or higher than the Standards given by the Nepal National Building Code.	Literature Observation	Fieldwork
RE-2012	Material	**Processing quality**	Building materials should be transportable to building site with minimum damage given transportation conditions	Used material may be vulnerable but transportable without too many protective measures such that it can withstand rural roads without diminishing the inherent material properties	Literature Observation	Fieldwork
RE-2013	Material	**Availability**	Availability of a material when abstracted from the environment in large quantity	Available quantity of building material needs to be just enough to construct the required amount of houses of case village ~ enough material for max 100 houses	Observation	Fieldwork
RE-2014	Material	**Reliability**	Material reliable to be available in all situations	Material needed for construction should be available during all situations and seasons but may be susceptible to uncertainty regarding availability	Observation Interview	Fieldwork
RE-2021	Labour	**Labour experience**	Level of task experience of workers required for construction	The construction should at most require some experts for correct execution of building	Observation Interview	Fieldwork

RE-2022	Labour	**Construction intensity**	Amount of workers needed at one time to construct a building type	A building method should not be limited by the of workers it requires for safe and qualitative execution	Observation Literature	Fieldwork
RE-2031	Time	**Construction time**	Technical construction period needed to build one layer	The construction of a technique should at most take up the duration of a Nepalese construction season, which is limited by the monsoon period and harvesting period resulting in a maximum building time of 1-3 months per storey.	Observation Interview Literature	Fieldwork
Feasibility						
FE-3011	Financial	**Investment**	Total investment costs	The construction method should maximally allow for the construction (of a liveable partition) of a house that is within budget of target group including loans, funds from government and charity funds	Literature Interview	Fix amount - Fieldwork
FE-3021	Economic	**Local**	Beneficial for local economy	Construction should at least use some local resources resulting in at least a small benefit for the local economy. Local is considered to be within a 50 km radius around the case village	Observation	Fieldwork and literature
FE-3022	Economic	**National**	National benefit	Construction should at least add some welfare into Nepalese economy by the use of a mixed local / import cash flow	Literature	Literature
Social-Cultural						
SO-4011	Social	**Status**	Ability to meet the social and cultural requirements of Nepali housing in terms of social status or ethnic identity	Exterior should be adaptable in perspective with the already used resources in terms of costs and effort.	Interview Observation	Fieldwork
SO-4031	Social	**Architectural identity**	Ability to meet the architectural needs	Building method does not have to blend into surrounding but should be able to have small cultural historical element	Interview Observation	Fieldwork
SO-4021	Cultural	**Religious**	Space to accommodate religious attributes	No space for religious artefact or containing elements against beliefs of religion needed	Observation	Fieldwork
Functional						

FU-5011	Building	**Stories**	Height of the building meets the function requirement of the owner	Structure should minimum be able to handle 2 stories with an attic	Interview Observation	Fieldwork
FU-5012	Building	**Expandability**	Structure has to offer the possibility for expansion after completion of construction while fitting the technical requirements.	Vertical expansion should be possible after the use of some resources	Interview Observation	Fieldwork
FU-5013	Building	**Flexibility**	Structure has to offer flexibility in usage of rooms and partitioning of the living area	Rooms should be changeable with the use of some resources.	Interview Observation	Fieldwork or literature study
FU-5021	Working	**Workspace**	Structure has to be able to provide a workspace for profession related activities such as workshop, restaurant, shop, animal stable	Offer enough open room to facilitate the function of the building at street level	Interview Observation	Fieldwork and literature
FU-5031	Protection	**Rainwater**	Structure has to provide shelter against rain without leakage	Has to withstand the rainiest months in the monsoon (almost 400mm/month) with some leakage	Observation	Fieldwork and literature
FU-5032	Protection	**Wind**	Structure has to provide shelter against winds	Building should not collapse during storm winds but heavy damage is allowed	Literature	Literature
FU-5033	Protection	**Solar intensity**	Structure has to provide shelter against solar intensity	Building should be able to withstand much sun but is allowed to wither heavily due to intensive solar exposure	Observation	Fieldwork and literature
FU-5034	Protection	**Social Safety**	Minimum level of social safety needed in building	Plinth and windows should be lockable Windows should have decorative and protective bars Openings should allow insect screens	Observation	Fieldwork
FU-5041	Facilities	**Utilities**	Structure has to be able to accommodate the connection of utilities such as gas, water,	Building should at least allow for ground level tanked utilities	Observation	Fieldwork

			electricity			
FU-5042	Facilities	**External infrastructure**	Construction should accommodate a connection with direct environment	Connection to external infrastructure should provide space for private use	Observation	Fieldwork
Sustainability						
SU-6011	Life cycle	**Reusability**	Extent to which used materials are fit to be re-used after demolition	Material do not have to be re-usable after the demolition/end of functional period	Interview	Fieldwork
SU-6012	Life cycle	**Recyclability**	Number of cycles a material can be re-used	There are not restrictions on the recyclability of used materials.	Interview	Fieldwork
SU-6021	Environment	**Impact**	Damage done to nature by construction	There are no restrictions on damage to the environment however should be avoided where possible	Observation	Fieldwork and literature study
SU-6022	Environment	**Sustainability**	Extent to which the houses can be self sustainable	Structure should at least make the placement of temporary self-sustainable equipment possible	Interview	Fieldwork

Appendix 2.B. Explanation of values

Requirement ID	Aspect	Sub-aspect	Requirement	Requirement Value Qualitative	Explanation Scale
Technical					
TE-1012	Structural Building Components	**Redundancy**	Presence of redundancy regarding structural elements	Structure should at least allow some redundant elements to relieve structure´s dependency on a single structural element in its imagined form.	1= No redundancy, damage to part of structure causes collapse 2= Poor redundancy, damage to part of structure causes partial collapse 3= Average redundancy, damage to part of structure may cause collapse 4= Above average redundancy, damage to part of structure small chance of collapse 5= Good redundancy, damage to part of structure does not cause collapse
TE-1014	Structural Building Components	**Regulated safety**	Level of safety needed in regular usage of building according to building code	If building type is mentioned in the building code then compliance with minimal requirements as stated in most recent version of the Nepali Building Code If not mentioned in building code then according to general structural principles	1= Not in building code and not according to general structural principles 2= Not in building code and doubtable to fit general structural principles 3= Not in building code but acceptably according to structural principles 4= In building code with thumb rules and limitations on design 5= In building code and according to structural principles
TE-1020	Seismic Performance	**General seismic performance**	Structure should be able to withstand seismic activity	Combination of seismic elements, diaphragms, mass distribution, load and building plan determine the performance during seismic activity, the structure should at least be considered category C	1= Category A 2= Category B 3= Category C 4= Category D 5= Category E/F

				according to the Worldhousing.net classification	
TE-1026	Seismic Performance	**Possibility to increase seismic performance**	Seismic Performance	Possibility of adding realistic improvements to the combination of seismic elements , diaphragms, mass distribution, load and building plan determine the performance during seismic activity. The structure should at least be considered category D according to the Worldhousing.net classification	Category after improvement 1= Category A 2= Category B 3= Category C 4= Category D 5= Category E/F
TE-1031	Construction	**Sensitivity to surface**	The needed type of foundation should not excessively increase technical difficulty	The building type should not require a perfectly accurate foundation	1= High sensitive to building on a slope flat foundation needed 2= Above average sensitive to building on a slope 3= Average sensitive to building on a slope 4= Little sensitive to building on a slope 5= Not sensitive to building on a slope rough foundation sufficient
TE-1041	Climate	**Openings (ventilation & sunlight penetration)**	Control of interior climate and level of humidity inside structure Adaptation of exterior wall openings to regulate penetration of sunlight into building	Structure must allow for ventilation of interior for comfort and regulate humidity to maintain quality of structure Structure should minimally allow for variations in size openings dependent on climate and solar orientation	1= Openings can not be included in the walls 2= The method limits the possibilities on including openings in walls 3= The method offers possibilities to include 'sufficient' openings 4= Openings can easily and flexible included in the walls 5= Openings can be included in any size and on any locations
TE-1042	Climate	**Thermal capacity**	Regulation of temperature in different seasons needed to ensure acceptable living conditions with respect to heat transmission	Minimum able to regulate the temperatures to some degree, poor thermal performance is acceptable	1= Bad thermal performance during all seasons 2= Poor thermal performance during all seasons 3= Medium thermal

					performance during all seasons 4= Good thermal performance during all seasons 5= Excellent thermal performance
TE-1051	Construction	**Lifespan building**	Lifespan of building method when maintained correctly	Minimum lifespan should be around 50 years or equal to at least two generations	1= Temporary <5 years 2= More than temporary 5 - 15 years 3= 2 generations ~ 50 years 4= Long 50 - 100 years 5= Very long > 100 years
TE-1061	Maintenance	**Reliability**	Amount of maintenance required to maintain standard living conditions and safety given the lifespan	Structure should at most require maintenance every 3-5 years	1= Much periodic maintenance required / multiple per year 2= Often periodic maintenance required / each year 3= Periodic maintenance required / each 3- 5 years 4= Little maintenance required / each 5 - 10 years 5= No maintenance required / after 25 years
TE-1062	Maintenance	**Maintainability**	Technical and physical ease of performing maintenance on a structure	Structure should not require extensive and very specialised workmanship and much resources	1= Maintenance requires special expertise and much resources 2= Maintenance requires workmanship and much resources 3= Maintenance requires workmanship and resources 4= Maintenance does not necessarily require workmanship and some resources 5= Maintenance does not require workmanship en little to no resources
TE-1071	Construction	**Complexity**	Ease of learning to correctly implement technique required for building method	The complexity of the construction should at most be so complicated to require some years of training	1= Impossible to learn without many years of training 2= Learnable but with some years of training

					3= Learnable to some extent in short time and expert in some years 4= Learnable in short time, several weeks to months 5= Learnable and able to teach in short time
Resources					
RE-2011	Material	**Initial quality**	Acceptable quality of a material in its initial state	Used materials require latest NS, IS or other similar approved standard quality certificate. If used material is adapted, innovative, recycled or not provided with mark it may also be used given that the characteristics are tested to be equivalent or higher than the Standards given by the Nepal National Building Code.	1= No mark and no/bad test results 2= Mark but no/bad test results (possible fake mark) 3= No mark but acceptable test result 4= No mark but good test result 5= Mark and good test result
RE-2012	Material	**Processing quality**	Building materials should be transportable to building site with minimum damage given transportation conditions	Used material may be vulnerable but transportable without too many protective measures such that it can withstand rural roads without diminishing the inherent material properties	1= Materials are very vulnerable but transportable with extreme measures 2= Material is vulnerable but transportable with extra measures 3= Material is vulnerable but transportable without too much extra measures 4= Material is slightly vulnerable but transportable without any extra measures 5= Material is not vulnerable and easily transportable
RE-2013	Material	**Availability**	Availability of a material when abstracted from the environment in large quantity	Available quantity of building material needs to be just enough to construct the required amount of houses of case village ~ enough material for max 100 houses	1= Material is not available 2= Material is scarce/insufficient quantities 3= Available quantity is just acceptable 4= Material is plenty available

					5= Surplus of material
RE-2021	Labour	**Labour experience**	Level of task experience of workers required for construction	The construction should at most require some experts for correct execution of building	1= No experience/knowledge is available 2= Little experience/knowledge is available 3= Some experience/knowledge is available 4= Much experience/knowledge is available 5= Very much experience/knowledge is available
RE-2022	Labour	**Construction intensity**	Amount of workers needed at one time to construct a building type	A building method should not be limited by the of workers it requires for safe and qualitative execution	1= Large team required >15p 2= Medium team 10 - 15 people 3= Small team 5 - 10 people 4= Very small team 2-4 people 5= One or two persons
RE-2031	Time	**Construction time**	Technical construction period needed to build one layer	The construction of a technique should at most take up the duration of a Nepalese construction season, which is limited by the monsoon period and harvesting period resulting in a maximum building time of 1-3 months per storey.	1= > 6 months 2= 3- 6 months 3= 1-3 months 4= 1- 4 weeks 5= <1 week
Feasibility					
FE-3011	Financial	**Investment**	Total investment costs	The construction method should maximally allow for the construction (of a liveable partition) of a house that is within budget of target group including loans, funds from government and charity funds	The investment costs are interdependently ranked.
FE-3021	Economic	**Local**	Beneficial for local economy	Construction should at least use some local resources resulting in at least a small benefit for the local economy. Local is considered to be within a 50 km	1= No use of local resources 2= Some use of local resources 3= Mixed use of local resources and national resources 4= Mostly use of local resources

				radius around the case village	5= Only use of local resources
FE-3022	Economic	**National**	National benefit	Construction should at least add some welfare into Nepalese economy by the use of a mixed local / import cash flow	1 = Cash flow leaving Nepal, resources are mainly imported 2 = Mixed cash flow (local and import) 3 = Cash flow mainly staying in Nepal, resources are mainly national 4 = Cash flow staying, no import 5 = Making economic growth possible due to resource creation
Social-Cultural					
SO-4011	Social	**Status**	Ability to meet the social and cultural requirements of Nepali housing in terms of social status or ethnic identity	Exterior should be adaptable in perspective with the already used resources in terms of costs and effort.	1= Fixed exterior 2= 3= Exterior adaptable against some resources 4= 5= Exterior easily adaptable with little to no resources
SO-4031	Social	**Architectural identity**	Ability to meet the architectural needs	Building method does not have to blend into surrounding but should be able to have small cultural historical element	1= Contrasting in surroundings, not cultural historical 2= 3= Blends into surrounding except for some elements, known cultural historical 4= 5= Blends perfectly into surrounding, known and producible by locals
Functional					
FU-5011	Building	**Stories**	Height of the building meets the function requirement of the owner	Structure should minimum be able to handle 2 stories with an attic	1= Single story with attic 2= Can maximally handle 2 stories with attic 3= Can handle 2 to 4 stories 4= Can handle 4 to 5 stories 5= Can easily handle 5 or more

					stories
FU-5012	Building	**Expandability**	Structure has to offer the possibility for expansion after completion of construction while fitting the technical requirements.	Vertical expansion should be possible after the use of some resources	1= No expansion possible or allowed by regulation 2= Requires many alterations before expansion is possible 3= Requires some alterations before expansion is possible 4= Requires little alterations before expansion is possible 5= Expansion is directly possible
FU-5021	Working	**Workspace**	Structure has to be able to provide a workspace for profession related activities such as workshop, restaurant, shop, animal stall	Offer enough open room to facilitate the function of the building at street level	1= Does not offer open workplace 2= Offers little open workplace with much effort 3= Offers some open workspace with effort 4= Offers open workspace with little effort 5= Offers open workspace
FU-5030	Protection	**Elements**			
FU-5031	Protection	**Rainwater**	Structure has to provide shelter against rain without leakage	Has to withstand the rainiest months in the monsoon (almost 400mm/month) with some leakage	1= Building not suitable for rainy environment 2= Building suitable for mild rain 3= Building suitable for monsoon rains with heavy damage/ leakage 4= Building suitable for monsoon areas with light damage/leakage 5= Building suitable for monsoon areas without leakage
FU-5032	Protection	**Wind**	Structure has to provide shelter against winds	Building should not collapse during storm winds but heavy	1= Building not suitable for windy environment

				damage is allowed	2= Building can withstand mild wind 3= Building can withstand storm wind with heavy damage 4= Building can withstand storm wind with light damage 5= Building can withstand storm wind with no damage
FU-5033	Protection	**Solar intensity**	Structure has to provide shelter against solar intensity	Building should be able to withstand much sun but is allowed to wither heavily due to intensive solar exposure	1= Building not suitable for sunny environment 2= Building can withstand mild sun 3= Building can withstand much sun but withers heavily 4= Building can withstand much sun but withers 5= Building can withstand much sun without withering
FU-5034	Protection	**Social Safety**	Minimum level of social safety needed in building	Plinth and windows should be lockable Windows should have decorative and protective bars Openings should allow insect screens	1= Building has open elements or not lockable / no insect screens can be fitted 2= Building is closable and/or lockable but easily breakable 3= Building can be locked but can be broken into with some effort 4= Building can be locked and only be broken into with much effort 5= Building can be lockable and unbreakable and insect screens
FU-5041	Facilities	**Utilities**	Structure has to be able to accommodate the connection of utilities such as gas, water, electricity	Building should at least allow for ground level tanked utilities	1= No piping or tanks possible only central 2= Building allows for tanked on ground level 3= Building allows for tanked 4= Building allows for piping, tanked and central resources with some alterations 5= Building easily allows for use

					of piping, tanked resources and central resources
FU-5042	Facilities	**External infrastructure**	Construction should accommodate a connection with direct environment	Connection to external infrastructure should provide space for private use	1= No private space due to connection 2= Little private space due to connection 3= Some space due to connection 4= Much space for due to connection 5= Open en private space available
Sustainability					
SU-6011	Life cycle	**Reusability**	Extent to which used materials are fit to be re-used after demolition	Material do not have to be re-usable after the demolition/end of functional period	1= Material unusable after demolition/use 2= Little material usable after demolition/use with much resources required for retrieval 3= Some material usable after demolition/use with resources required for retrieval 4= Much material usable after demolition/use with some resources required for retrieval 5= Most materials usable after demolition/use or little to no resources required for retrieval
SU-6012	Life cycle	**Recyclability**	Number of cycles a material can be re-used	There are not restrictions on the recyclability of used materials.	1= Material not recyclable 2= Material recyclable for debris 3= Material recyclable for some other uses 4= Material recyclable for many other uses or many cycles 5= Material recyclable for same use, other use or many cycles
SU-6021	Environment	**Impact**	Damage done to nature by construction	There are no restrictions on damage to the environment however should be avoided where possible	1= Very devastating for nature 2= Devastating to nature 3= Damaging to nature 4= Some damage done to

					nature 5= Little to no damage done to nature
SU-6022	Environment	**Sustainability**	Extent to which the houses can be self sustainable	Structure should at least make the placement of temporary self-sustainable equipment possible	1= No sustainable resources possible 2= Temporary sustainability possible 3= Only solar sustainability possible 4= Small solar and water sustainability possible 5= Large solar and water sustainability

Appendix 2.C. Overview scores building methods

		Minimum values	Low strength (stone) masonry	Low strength (brick) masonry	Stone masonry in cement mortar	Brick masonry in cement mortar	Confined masonry	Hollow concrete brick masonry	Reinforced Cement Concrete Frames	Concrete in-situ shear wall	Timber construction	Adobe	Dhajji Dewari	Rammed earth	Steel	Bamboo	Earth bags	Interlocking bricks	Light Weight Steel Profile Building Systems	Prefab-framed in-situ concrete	Single Panel Walling System
Category		Minimum values																			
Technical																					
Building components	*Redundancy*	2	2	2	3	3	4	4	3	4	3	2	5	3	3	3	3	3	5	5	4
	Building code	3	4	4	5	5	5	5	5	5	5	4	3	3	5	3	2	4	3	4	4
Seismic Performance Standard	*Performance*	3	1	2	3	3	4	3	3	5	4	1	3	2	5	3	2	4	4	5	4
Improved Seismic Performance	*Possible*	4	2	3	4	4	5	4	5	5	5	2	4	3	5	4	2	4	5	5	5
Sensitivity to surface	*Foundation resources*	2	3	3	3	3	3	3	4	4	5	2	3	1	5	5	2	1	3	3	2
Climate	*Openings*	2	3	3	3	4	2	3	5	4	5	2	3	2	5	5	2	3	4	4	3
	Thermal	2	3	2	4	4	4	4	3	3	3	4	3	4	3	2	4	3	3	4	4
Life span	*Lifespan*	3	5	5	4	4	4	3	4	4	4	4	4	4	4	1	3	5	4	4	3
Maintenance	*Reliability*	3	3	2	3	3	4	4	5	5	3	2	3	2	3	1	4	4	5	5	5
	Maintainability	2	3	3	2	2	2	2	2	2	5	4	3	5	2	4	5	2	3	2	2
Complexity	*Ease of learning*	2	3	3	3	3	2	3	2	2	3	3	2	2	3	3	4	4	4	4	4
Resources																					
Material	*Quality*	3	5	3	4	3	3	4	5	5	5	4	5	5	5	5	5	4	4	3	3
	Availability	3	5	4	5	3	3	4	4	4	2	5	3	4	3	5	5	4	3	3	4

Labour	*Experience*	2	5	5	5	5	3	4	4	3	5	5	2	3	2	4	3	3	3	2	2
	Intensity	1	4	4	3	4	3	4	3	2	3	4	3	2	3	3	4	4	4	3	3
Time	*Technical period*	3	3	3	3	3	3	4	3	3	4	3	3	4	4	5	3	4	5	3	5
Feasibility																						
Price Label	*Ranking*	1	5	5	4	4	3	4	3	2	1	5	3	5	1	5	5	4	2	2	3
Local economy	*Use of local recourses*	2	5	4	4	3	3	3	3	2	3	5	4	4	3	5	4	3	3	2	2
National economy	*National benefit*	2	4	4	4	3	3	3	2	2	3	4	3	4	1	4	4	3	5	5	2
Social / cultural																						
Social/ cultural	*Adaptability*	2	2	2	3	4	4	4	5	5	4	2	4	2	5	2	3	3	5	5	4
Architectural embedding	*Embedding*	2	5	5	5	5	4	3	3	3	4	5	3	2	3	4	2	3	3	1	2
Functional																						
Building height	*Amount of storeys*	2	2	2	2	3	5	3	5	5	2	1	3	1	5	3	1	2	2	5	5
Expandability	*Possibilities*	3	1	2	3	3	5	3	5	3	4	1	2	1	5	4	1	3	4	3	2
Workspace	*Opportunity*	3	2	2	3	3	3	3	5	4	4	2	2	2	5	4	2	3	4	4	4
Protection	*Elements*	3	2	2	4	4	4	4	4	4	3	2	3	2	4	2	3	3	4	5	5
	Safety	3	3	3	3	4	4	4	4	4	3	3	3	3	4	3	3	4	3	4	4
Utilities	*Possibilities*	2	2	2	3	4	4	4	5	4	3	2	3	2	5	2	3	3	2	3	5
Sustainable																						
Recyclable	*Re-usability*	1	5	4	4	2	2	4	2	2	5	1	5	1	4	4	5	4	3	1	2
	Recyclability	1	5	4	3	2	2	2	2	2	4	5	5	5	5	3	5	2	5	2	5
Environmental	*Impact*	2	4	4	4	3	3	3	3	3	4	5	4	5	3	5	4	4	4	4	4
	Self-sustainable	2	3	3	4	4	5	3	5	5	4	3	4	3	5	3	3	4	4	5	4

Appendix 2.D. MCA Scenario

Appendix 2.D.1. MCA Baseline scenario

Weight (%)	Requirement Code	Sub-weight	Category	Unit	Values			Stone masonry in cement mortar			Brick masonry in cement mortar			Confined masonry			Hollow concrete brick masonry			Reinforced Cement Concrete Frames			Concrete in-situ shear wall		
					Solution space require-ment -1	min. value	max. value	Solution Space Value	Score (%)	Final Score (%)	Solution Space Value	Score (%)	Final Score (%)	Solution Space Value	Score (%)	Final Score (%)	Solution Space Value	Score (%)	Final Score (%)	Solution Space Value	Score (%)	Final Score (%)	Solution Space Value	Score (%)	Final Score (%)
										69%			**61%**			**67%**			**59%**			**71%**			**65%**
Technical										**11%**			**11%**			**17%**			**10%**			**16%**			**21%**
25%	TE-1020	30%	Seismic Performance Standard	Performance	2	3	5	3	33%	3%	3	33%	3%	4	67%	5%	3	33%	3%	3	33%	3%	5	100%	8%
	TE-1026	20%	Improved Seismic Performance	Possible	3	4	5	4	50%	3%	4	50%	3%	5	100%	5%	4	50%	3%	5	100%	5%	5	100%	5%
	TE-1031	20%	Foundation	Performance	1	1	5	3	50%	3%	3	50%	3%	3	50%	3%	3	50%	3%	4	75%	4%	4	75%	4%
	TE-1032	15%	Life span	Lifespan	2	3	5	4	67%	3%	4	67%	3%	4	67%	3%	3	33%	1%	4	67%	3%	4	67%	3%
	TE-1061-1062-1063	15%	Maintenance	Reliability	2	3	5	3	33%		3	33%		4	67%		4	67%		5	100%		5	100%	
				Maintainability	1	2	5	2	25%		2	25%		2	25%		2	25%		2	25%		2	25%	
				Final Score					29%	1%		29%	1%		46%	2%		46%	2%		63%	2%		63%	2%
Resources										**19%**			**13%**			**8%**			**13%**			**13%**			**11%**
19%	RE-2012-2013-RE-2021-2022	50%	Material	Availibility	2	2	5	5	100%	10%	3	33%	3%	3	33%	3%	4	67%	6%	4	67%	6%	4	67%	6%
		50%	Labor	Experience	1	2	5	5	100%	10%	5	100%	10%	3	50%	5%	4	75%	7%	4	75%	7%	3	50%	5%
Feasibility										**14%**			**13%**			**10%**			**13%**			**10%**			**6%**
15%	FE-3011	60%	Price Lable	Ranking	0	1	4	4	100%	9%	4	100%	9%	3	75%	7%	4	100%	9%	3	75%	7%	2	50%	5%
	FE-3021-3022	40%	Local economy	Use of local recources	1	2	4	4	100%		3	67%		3	67%		3	67%		3	67%		2	33%	
			National economy	National benefit	1	1	5	4	75%		3	50%		3	50%		3	50%		2	25%		2	25%	
				Final Score					88%	5%		58%	4%		58%	4%		58%	4%		46%	3%		29%	2%
Social / cultural										**10%**			**11%**			**10%**			**8%**			**10%**			**10%**
13%	SO-0203	100%	Social/ cultural	Adaptability	1	3	5	3	50%		4	75%		4	75%		4	75%		5	100%		5	100%	
			Architectural embedding	Embedding	1	1	5	5	100%		5	100%		4	75%		3	50%		3	50%		3	50%	
				Final Score					75%	10%		88%	11%		75%	10%		63%	8%		75%	10%		75%	10%
Functional										**5%**			**7%**			**16%**			**7%**			**16%**			**11%**
16%	FU-5011	50%	Building height	Amount of storeys	1	2	5	2	25%	2%	3	50%	4%	5	100%	8%	3	50%	4%	5	100%	8%	5	100%	8%
	FU-5012	50%	Expandability	Possibilities	2	2	5	3	33%	3%	3	33%	3%	5	100%	8%	3	33%	3%	5	100%	8%	3	33%	3%
Sustainable										**10%**			**6%**			**6%**			**8%**			**6%**			**6%**
12%	SU-6011-6012	50%	Recyclable	Re-usability	0	1	5	4	80%		2	40%		2	40%		4	80%		2	40%		2	40%	
				Recycability	0	2	5	3	60%		2	40%		2	40%		2	40%		2	40%		2	40%	
				Final Score					70%	4%		40%	2%		40%	2%		60%	4%		40%	2%		40%	2%
	SU-6021	50%	Environmental	Impact	1	3	4	4	100%	6%	3	67%	4%	3	67%	4%	3	67%	4%	3	67%	4%	3	67%	4%

Timber construction			Dhajji Dewari			Steel			Interlocking bricks			Light Weight Steel Profile Building Systems			Prefab-framed in-situ concrete			Single Panel Walling System		
Solution Space Value	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*
		64%			***52%***			***66%***			***57%***			***63%***			***53%***			***57%***
		20%			**12%**			**21%**			**13%**			**18%**			**19%**			**15%**
4	67%	5%	3	33%	3%	5	100%	8%	4	67%	5%	4	67%	5%	5	100%	8%	4	67%	5%
5	100%	5%	4	50%	3%	5	100%	5%	4	50%	3%	5	100%	5%	5	100%	5%	5	100%	5%
5	100%	5%	3	50%	3%	5	100%	5%	1	0%	0%	3	50%	3%	3	50%	3%	2	25%	1%
4	67%	3%	4	67%	3%	4	67%	3%	5	100%	4%	4	67%	3%	4	50%	2%	3	33%	1%
3	33%		3	33%		3	33%		4	67%		5	100%		5	100%		5	100%	
5	100%		3	50%		2	25%		2	25%		3	50%		2	0%		2	25%	
	67%	3%		42%	2%		29%	1%		46%	2%		75%	3%		50%	2%		63%	2%
		10%			**6%**			**6%**			**11%**			**8%**			**6%**			**9%**
2	0%	0%	3	33%	3%	3	33%	3%	4	67%	6%	3	33%	3%	3	33%	3%	4	67%	6%
5	100%	10%	2	25%	2%	2	25%	2%	3	50%	5%	3	50%	5%	2	25%	2%	2	25%	2%
		6%			**11%**			**4%**			**13%**			**10%**			**6%**			**9%**
1	25%	2%	3	75%	7%	1	25%	2%	4	100%	9%	2	50%	5%	2	33%	3%	3	75%	7%
3	67%		4	100%		3	67%		3	67%		3	67%		2	0%		2	33%	
3	50%		3	50%		1	0%		3	50%		5	100%		5	100%		2	25%	
	58%	4%		75%	5%		33%	2%		58%	4%		83%	5%		50%	3%		29%	2%
		10%			**8%**			**10%**			**7%**			**10%**			**7%**			**7%**
4	75%		4	75%		5	100%		3	50%		5	100%		5	100%		4	75%	
4	75%		3	50%		3	50%		3	50%		3	50%		1	0%		2	25%	
	75%	10%		63%	8%		75%	10%		50%	7%		75%	10%		50%	7%		50%	7%
		7%			**4%**			**16%**			**5%**			**7%**			**11%**			**8%**
2	25%	2%	3	50%	4%	5	100%	8%	2	25%	2%	2	25%	2%	5	100%	8%	5	100%	8%
4	67%	5%	2	0%	0%	5	100%	8%	3	33%	3%	4	67%	5%	3	33%	3%	2	0%	0%
		11%			**12%**			**9%**			**10%**			**11%**			**6%**			**10%**
5	100%		5	100%		4	80%		4	80%		3	60%		1	0%		2	40%	
4	80%		5	100%		5	100%		2	40%		5	100%		2	0%		5	100%	
	90%	5%		100%	6%		90%	5%		60%	4%		80%	5%		0%	0%		70%	4%
4	100%	6%	4	100%	6%	3	67%	4%	4	100%	6%	4	100%	6%	4	100%	6%	4	100%	6%

Appendix 2.D.2 MCA Material scenario

Weight (%)	Aspect Code	Sub-weight	Category	Unit	Solution space requirement -1	Values min. value	Values max. value	Stone masonry in cement mortar Solution Space Value	Stone masonry in cement mortar Score (%)	Stone masonry in cement mortar Final Score (%)	Brick masonry in cement mortar Solution Space Value	Brick masonry in cement mortar Score (%)	Brick masonry in cement mortar Final Score (%)	Confined masonry Solution Space Value	Confined masonry Score (%)	Confined masonry Final Score (%)	Hollow concrete brick masonry Solution Space Value	Hollow concrete brick masonry Score (%)	Hollow concrete brick masonry Final Score (%)	Reinforced Cement Concrete Frames Solution Space Value	Reinforced Cement Concrete Frames Score (%)	Reinforced Cement Concrete Frames Final Score (%)	Concrete in-situ shear wall Solution Space Value	Concrete in-situ shear wall Score (%)	Concrete in-situ shear wall Final Score (%)
										66%			63%			71%			58%			72%			65%
Technical										12%			12%			18%			11%			17%			23%
27%	TE-1020	30%	Seismic Performance Standard	Performance	2	3	5	3	33%	3%	3	33%	3%	4	67%	5%	3	33%	3%	3	33%	3%	5	100%	8%
	TE-1026	20%	Improved Seismic Performance	Possible	3	4	5	4	50%	3%	4	50%	3%	5	100%	5%	4	50%	3%	5	100%	5%	5	100%	5%
	TE-1031	20%	Foundation	Performance	1	1	5	3	50%	3%	3	50%	3%	3	50%	3%	3	50%	3%	4	75%	4%	4	75%	4%
	TE-1032	15%	Life span	Lifespan	2	3	5	4	67%	3%	4	67%	3%	4	67%	3%	3	33%	1%	4	67%	3%	4	67%	3%
	TE-1061-1062-1063	15%	Maintenance	Reliability	2	3	5	3	33%		3	33%		4	67%		4	67%		5	100%		5	100%	
				Maintainability	1	2	5	2	25%		2	25%		2	25%		2	25%		2	25%		2	25%	
				Final Score					29%	1%		29%	1%		46%	2%		46%	2%		63%	3%		63%	3%
Resources										9%			9%			5%			7%			7%			5%
9%	RE-2012-2013-	0%	Material	Availibility	2	2	5	5	100%	0%	3	33%	0%	3	33%	0%	4	67%	0%	4	67%	0%	4	67%	0%
	RE-2021-2022	100%	Labor	Experience	1	2	5	5	100%	9%	5	100%	9%	3	50%	5%	4	75%	7%	4	75%	7%	3	50%	5%
Feasibility										16%			14%			12%			14%			11%			7%
17%	FE-3011	60%	Price Lable	Ranking	0	1	4	4	100%	10%	4	100%	10%	3	75%	8%	4	100%	10%	3	75%	8%	2	50%	5%
	FE-3021-3022	40%	Local economy	Use of local recources	1	2	4	4	100%		3	67%		3	67%		3	67%		3	67%		2	33%	
			National economy	Use of national recources	1	1	5	4	75%		3	50%		3	50%		3	50%		2	25%		2	25%	
				Final Score					88%	6%		58%	4%		58%	4%		58%	4%		46%	3%		29%	2%
Social / cultural										11%			13%			11%			9%			11%			11%
15%	SO-0203	100%	Social/ cultural	Adaptability	1	3	5	3	50%		4	75%		4	75%		4	75%		5	100%		5	100%	
			Architectural embedding	Embedding	1	1	5	5	100%		5	100%		4	75%		3	50%		3	50%		3	50%	
				Final Score					75%	11%		88%	13%		75%	11%		63%	9%		75%	11%		75%	11%
Functional										5%			8%			18%			8%			18%			12%
18%	FU-5011	50%	Building height	Amount of storeys	1	2	5	2	25%	2%	3	50%	5%	5	100%	9%	3	50%	5%	5	100%	9%	5	100%	9%
	FU-5012	50%	Expandability	Possibilities	2	2	5	3	33%	3%	3	33%	3%	5	100%	9%	3	33%	3%	5	100%	9%	3	33%	3%
Sustainable										12%			7%	0		7%	0		9%			7%			7%
14%	SU-6011-6012	50%	Recyclable	Re-usable	0	1	5	4	80%		2	40%		2	40%		4	80%		2	40%		2	40%	
				Recycable	0	2	5	3	60%		2	40%		2	40%		2	40%		2	40%		2	40%	
				Final Score					70%	5%		40%	3%		40%	3%		60%	4%		40%	3%		40%	3%
	SU-6021	50%	Environmental	Impact	1	3	4	4	100%	7%	3	67%	5%	3	67%	5%	3	67%	5%	3	67%	5%	3	67%	5%

Timber construction			Dhajji Dewari			Steel			Interlocking bricks			Light Weight Steel Profile Building			Prefab-framed in-situ concrete			Single Panel Walling System		
Solution Space Value	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*
		70%			***55%***			***70%***			***57%***			***67%***			***56%***			***56%***
		22%			**12%**			**23%**			**14%**			**19%**			**20%**			**16%**
4	67%	5%	3	33%	3%	5	100%	8%	4	67%	5%	4	67%	5%	5	100%	8%	4	67%	5%
5	100%	5%	4	50%	3%	5	100%	5%	4	50%	3%	5	100%	5%	5	100%	5%	5	100%	5%
5	100%	5%	3	50%	3%	5	100%	5%	1	0%	0%	3	50%	3%	3	50%	3%	2	25%	1%
4	67%	3%	4	67%	3%	4	67%	3%	5	100%	4%	4	67%	3%	4	50%	2%	3	33%	1%
3	33%		3	33%		3	33%		4	67%		5	100%		5	100%		5	100%	
5	100%		3	50%		2	25%		2	25%		3	50%		2	0%		2	25%	
	67%	3%		42%	2%		29%	1%		46%	2%		75%	3%		50%	2%		63%	3%
		9%			**2%**			**2%**			**5%**			**5%**			**2%**			**2%**
2	0%	0%	3	33%	0%	3	33%	0%	4	67%	0%	3	33%	0%	3	33%	0%	4	67%	0%
5	100%	9%	2	25%	2%	2	25%	2%	3	50%	5%	3	50%	5%	2	25%	2%	2	25%	2%
		7%			**13%**			**5%**			**14%**			**11%**			**7%**			**10%**
1	25%	3%	3	75%	8%	1	25%	3%	4	100%	10%	2	50%	5%	2	33%	3%	3	75%	8%
3	67%		4	100%		3	67%		3	67%		3	67%		2	0%		2	33%	
3	50%		3	50%		1	0%		3	50%		5	100%		5	100%		2	25%	
	58%	4%		75%	5%		33%	2%		58%	4%		83%	6%		50%	3%		29%	2%
		11%			**9%**			**11%**			**8%**			**11%**			**8%**			**8%**
4	75%		4	75%		5	100%		3	50%		5	100%		5	100%		4	75%	
4	75%		3	50%		3	50%		3	50%		3	50%		1	0%		2	25%	
	75%	11%		63%	9%		75%	11%		50%	8%		75%	11%		50%	8%		50%	8%
		8%			**5%**			**18%**			**5%**			**8%**			**12%**			**9%**
2	25%	2%	3	50%	5%	5	100%	9%	2	25%	2%	2	25%	2%	5	100%	9%	5	100%	9%
4	67%	6%	2	0%	0%	5	100%	9%	3	33%	3%	4	67%	6%	3	33%	3%	2	0%	0%
		13%			**14%**			**11%**			**11%**			**13%**			**7%**			**12%**
5	100%		5	100%		4	80%		4	80%		3	60%		1	0%		2	40%	
4	80%		5	100%		5	100%		2	40%		5	100%		2	0%		5	100%	
	90%	6%		100%	7%		90%	6%		60%	4%		80%	6%		0%	0%		70%	5%
4	100%	7%	4	100%	7%	3	67%	5%	4	100%	7%	4	100%	7%	4	100%	7%	4	100%	7%

Appendix 2.D.3 MCA No subsidy scenario

Weight (%)	Aspect Code	Sub-weight	Category	Unit	Values			Stone masonry in cement mortar			Brick masonry in cement mortar			Confined masonry			Hollow concrete brick masonry			Reinforced Cement Concrete Frames			Concrete in-situ shear wall		
					Solution space requirement -1	min. value	max. value	Solution Space Value	Score (%)	Final Score (%)	Solution Space Value	Score (%)	Final Score (%)	Solution Space Value	Score (%)	Final Score (%)	Solution Space Value	Score (%)	Final Score (%)	Solution Space Value	Score (%)	Final Score (%)	Solution Space Value	Score (%)	Final Score (%)
										74%			67%			68%			65%			72%			63%
Technical										10%			10%			15%			9%			14%			19%
22%	TE-1020	30%	Seismic Performance Standard	Performance	2	3	5	3	33%	2%	3	33%	2%	4	67%	4%	3	33%	2%	3	33%	2%	5	100%	7%
	TE-1026	20%	Improved Seismic Performance	Possible	3	4	5	4	50%	2%	4	50%	2%	5	100%	4%	4	50%	2%	5	100%	4%	5	100%	4%
	TE-1031	20%	Foundation	Performance	1	1	5	3	50%	2%	3	50%	2%	3	50%	2%	3	50%	2%	4	75%	3%	4	75%	3%
	TE-1032	15%	Life span	Lifespan	2	3	5	4	67%	2%	4	67%	2%	4	67%	2%	3	33%	1%	4	67%	2%	4	67%	2%
	TE-1061-1062-1063	15%	Maintenance	Reliability	2	3	5	3	33%		3	33%		4	67%		4	67%		5	100%		5	100%	
				Maintainability	1	2	5	2	25%		2	25%		2	25%		2	25%		2	25%		2	25%	
				Final Score					29%	1%		29%	1%		46%	2%		46%	2%		63%	2%		63%	2%
Resources								0		16%	0		11%	0		7%	0		11%	0		11%	0		9%
16%	RE-2012-2013-	50%	Material	Availibility	2	2	5	5	100%	8%	3	33%	3%	3	33%	3%	4	67%	5%	4	67%	5%	4	67%	5%
	RE-2021-2022	50%	Labor	Experience	1	2	5	5	100%	8%	5	100%	8%	3	50%	4%	4	75%	6%	4	75%	6%	3	50%	4%
Feasibility								0		29%	0		28%	0		22%	0		28%	0		21%	0		14%
30%	FE-3011	80%	Price Lable	Ranking	0	1	4	4	100%	24%	4	100%	24%	3	75%	18%	4	100%	24%	3	75%	18%	2	50%	12%
	FE-3021-3022	20%	Local economy	Use of local recources	1	2	4	4	100%		3	67%		3	67%		3	67%		3	67%		2	33%	
			National economy	Use of national recources	1	1	5	4	75%		3	50%		3	50%		3	50%		2	25%		2	25%	
				Final Score					88%	5%		58%	4%		58%	4%		58%	4%		46%	3%		29%	2%
Social / cultural								0		8%	0		9%	0		8%	0		6%	0		8%	0		8%
10%	SO-0203	100%	Social/ cultural	Adaptability	1	3	5	3	50%		4	75%		4	75%		4	75%		5	100%		5	100%	
			Architectural embedding	Embedding	1	1	5	5	100%		5	100%		4	75%		3	50%		3	50%		3	50%	
				Final Score					75%	8%		88%	9%		75%	8%		63%	6%		75%	8%		75%	8%
Functional								0		4%	0		5%	0		13%	0		5%	0		13%	0		9%
13%	FU-5011	50%	Building height	Amount of storeys	1	2	5	2	25%	2%	3	50%	3%	5	100%	7%	3	50%	3%	5	100%	7%	5	100%	7%
	FU-5012	50%	Expandability	Possibilities	2	2	5	3	33%	2%	3	33%	2%	5	100%	7%	3	33%	2%	5	100%	7%	3	33%	2%
Sustainable								0		8%	0		5%	0		5%	0		6%	0		5%	0		5%
9%	SU-6011-6012	50%	Recyclable	Re-usable	0	1	5	4	80%		2	40%		2	40%		4	80%		2	40%		2	40%	
				Recycable	0	2	5	3	60%		2	40%		2	40%		2	40%		2	40%		2	40%	
				Final Score					70%	3%		40%	2%		40%	2%		60%	3%		40%	2%		40%	2%
	SU-6021	50%	Environmental	Impact	1	3	4	4	100%	5%	3	67%	3%	3	67%	3%	3	67%	3%	3	67%	3%	3	67%	3%

Timber construction			Dhajji Dewari			Steel			Interlocking bricks			Light Weight Steel Profile Building			Prefab-framed in-situ concrete			Single Panel Walling System		
Solution Space Value	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*
		57%			***56%***			***59%***			***64%***			***61%***			***50%***			***59%***
		18%			**10%**			**19%**			**11%**			**16%**			**17%**			**13%**
4	67%	4%	3	33%	2%	5	100%	7%	4	67%	4%	4	67%	4%	5	100%	7%	4	67%	4%
5	100%	4%	4	50%	2%	5	100%	4%	4	50%	2%	5	100%	4%	5	100%	4%	5	100%	4%
5	100%	4%	3	50%	2%	5	100%	4%	1	0%	0%	3	50%	2%	3	50%	2%	2	25%	1%
4	67%	2%	4	67%	2%	4	67%	2%	5	100%	3%	4	67%	2%	4	50%	2%	3	33%	1%
3	33%		3	33%		3	33%		4	67%		5	100%		5	100%		5	100%	
5	100%		3	50%		2	25%		2	25%		3	50%		2	0%		2	25%	
	67%	2%		42%	1%		29%	1%		46%	2%		75%	2%		50%	2%		63%	2%
0		**8%**	0		**5%**	0		**5%**	0		**9%**	0		**7%**	0		**5%**	0		**7%**
2	0%	0%	3	33%	3%	3	33%	3%	4	67%	5%	3	33%	3%	3	33%	3%	4	67%	5%
5	100%	8%	2	25%	2%	2	25%	2%	3	50%	4%	3	50%	4%	2	25%	2%	2	25%	2%
0		**10%**	0		**23%**	0		**8%**	0		**28%**	0		**17%**	0		**11%**	0		**20%**
1	25%	6%	3	75%	18%	1	25%	6%	4	100%	24%	2	50%	12%	2	33%	8%	3	75%	18%
3	67%		4	100%		3	67%		3	67%		3	67%		2	0%		2	33%	
3	50%		3	50%		1	0%		3	50%		5	100%		5	100%		2	25%	
	58%	4%		75%	5%		33%	2%		58%	4%		83%	5%		50%	3%		29%	2%
0		**8%**	0		**6%**	0		**8%**	0		**5%**	0		**8%**	0		**5%**	0		**5%**
4	75%		4	75%		5	100%		3	50%		5	100%		5	100%		4	75%	
4	75%		3	50%		3	50%		3	50%		3	50%		1	0%		2	25%	
	75%	8%		63%	6%		75%	8%		50%	5%		75%	8%		50%	5%		50%	5%
0		**6%**	0		**3%**	0		**13%**	0		**4%**	0		**6%**	0		**9%**	0		**7%**
2	25%	2%	3	50%	3%	5	100%	7%	2	25%	2%	2	25%	2%	5	100%	7%	5	100%	7%
4	67%	4%	2	0%	0%	5	100%	7%	3	33%	2%	4	67%	4%	3	33%	2%	2	0%	0%
0		**9%**	0		**9%**	0		**7%**	0		**7%**	0		**8%**	0		**5%**	0		**8%**
5	100%		5	100%		4	80%		4	80%		3	60%		1	0%		2	40%	
4	80%		5	100%		5	100%		2	40%		5	100%		2	0%		5	100%	
	90%	4%		100%	5%		90%	4%		60%	3%		80%	4%		0%	0%		70%	3%
4	100%	5%	4	100%	5%	3	67%	3%	4	100%	5%	4	100%	5%	4	100%	5%	4	100%	5%

Appendix 2.D.4 MCA Subsidy scenario

Weight (%)	Aspect Code	Sub-weight	Category	Unit	Values			Stone masonry in cement mortar			Brick masonry in cement mortar			Confined masonry			Hollow concrete brick masonry			Reinforced Cement Concrete Frames			Concrete in-situ shear wall		
					Solution space requirement -1	min. value	max. value	Solution Space Value	Score (%)	Final Score (%)	Solution Space Value	Score (%)	Final Score (%)	Solution Space Value	Score (%)	Final Score (%)	Solution Space Value	Score (%)	Final Score (%)	Solution Space Value	Score (%)	Final Score (%)	Solution Space Value	Score (%)	Final Score (%)
										67%			59%			67%			57%			71%			66%
Technical										12%			12%			17%			11%			17%			22%
26%	TE-1020	30%	Seismic Performance Standard	Performance	2	3	5	3	33%	3%	3	33%	3%	4	67%	5%	3	33%	3%	3	33%	3%	5	100%	8%
	TE-1026	20%	Improved Seismic Performance	Possible	3	4	5	4	50%	3%	4	50%	3%	5	100%	5%	4	50%	3%	5	100%	5%	5	100%	5%
	TE-1031	20%	Foundation	Performance	1	1	5	3	50%	3%	3	50%	3%	3	50%	3%	3	50%	3%	4	75%	4%	4	75%	4%
	TE-1032	15%	Life span	Lifespan	2	3	5	4	67%	3%	4	67%	3%	4	67%	3%	3	33%	1%	4	67%	3%	4	67%	3%
	TE-1061-1062-1063	15%	Maintenance	Reliability	2	3	5	3	33%		3	33%		4	67%		4	67%		5	100%		5	100%	
				Maintainability	1	2	5	2	25%		2	25%		2	25%		2	25%		2	25%		2	25%	
				Final Score					29%	1%		29%	1%		46%	2%		46%	2%		63%	2%		63%	2%
Resources								0		20%	0		13%	0		8%	0		14%	0		14%	0		12%
20%	RE-2012-2013-	50%	Material	Availibility	2	2	5	5	100%	10%	3	33%	3%	3	33%	3%	4	67%	7%	4	67%	7%	4	67%	7%
	RE-2021-2022	50%	Labor	Experience	1	2	5	5	100%	10%	5	100%	10%	3	50%	5%	4	75%	8%	4	75%	8%	3	50%	5%
Feasibility								0		9%	0		8%	0		7%	0		8%	0		6%	0		4%
10%	FE-3011	40%	Price Lable	Ranking	0	1	4	4	100%	4%	4	100%	4%	3	75%	3%	4	100%	4%	3	75%	3%	2	50%	2%
	FE-3021-3022	60%	Local economy	Use of local recources	1	2	4	4	100%		3	67%		3	67%		3	67%		3	67%		2	33%	
			National economy	Use of national recources	1	1	5	4	75%		3	50%		3	50%		3	50%		2	25%		2	25%	
				Final Score					88%	5%		58%	4%		58%	4%		58%	4%		46%	3%		29%	2%
Social / cultural								0		11%	0		12%	0		11%	0		9%	0		11%	0		11%
14%	SO-0203	100%	Social/ cultural	Adaptability	1	3	5	3	50%		4	75%		4	75%		4	75%		5	100%		5	100%	
			Architectural embedding	Embedding	1	1	5	5	100%		5	100%		4	75%		3	50%		3	50%		3	50%	
				Final Score					75%	11%		88%	12%		75%	11%		63%	9%		75%	11%		75%	11%
Functional								0		5%	0		7%	0		17%	0		7%	0		17%	0		11%
17%	FU-5011	50%	Building height	Amount of storeys	1	2	5	2	25%	2%	3	50%	4%	5	100%	9%	3	50%	4%	5	100%	9%	5	100%	9%
	FU-5012	50%	Expandability	Possibilities	2	2	5	3	33%	3%	3	33%	3%	5	100%	9%	3	33%	3%	5	100%	9%	3	33%	3%
Sustainable								0		11%	0		7%	0		7%	0		8%	0		7%	0		7%
13%	SU-6011-6012	50%	Recyclable	Re-usability	0	1	5	4	80%		2	40%		2	40%		4	80%		2	40%		2	40%	
				Recycability	0	2	5	3	60%		2	40%		2	40%		2	40%		2	40%		2	40%	
				Final Score					70%	5%		40%	3%		40%	3%		60%	4%		40%	3%		40%	3%
	SU-6021	50%	Environmental	Impact	1	3	4	4	100%	7%	3	67%	4%	3	67%	4%	3	67%	4%	3	67%	4%	3	67%	4%

Timber construction			Dhajji Dewari			Steel			Interlocking bricks			Light Weight Steel Profile Building Systems			Prefab-framed in-situ concrete			Single Panel Walling System		
Solution Space Value	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*	*Solution Space Value*	*Score (%)*	*Final Score (%)*
		66%			***51%***			***68%***			***55%***			***64%***			***55%***			***56%***
		21%			**12%**			**22%**			**13%**			**19%**			**20%**			**15%**
4	67%	5%	3	33%	3%	5	100%	8%	4	67%	5%	4	67%	5%	5	100%	8%	4	67%	5%
5	100%	5%	4	50%	3%	5	100%	5%	4	50%	3%	5	100%	5%	5	100%	5%	5	100%	5%
5	100%	5%	3	50%	3%	5	100%	5%	1	0%	0%	3	50%	3%	3	50%	3%	2	25%	1%
4	67%	3%	4	67%	3%	4	67%	3%	5	100%	4%	4	67%	3%	4	50%	2%	3	33%	1%
3	33%		3	33%		3	33%		4	67%		5	100%		5	100%		5	100%	
5	100%		3	50%		2	25%		2	25%		3	50%		2	0%		2	25%	
	67%	3%		42%	2%		29%	1%		46%	2%		75%	3%		50%	2%		63%	2%
0		**10%**	0		**6%**	0		**6%**	0		**12%**	0		**8%**	0		**6%**	0		**9%**
2	0%	0%	3	33%	3%	3	33%	3%	4	67%	7%	3	33%	3%	3	33%	3%	4	67%	7%
5	100%	10%	2	25%	3%	2	25%	3%	3	50%	5%	3	50%	5%	2	25%	3%	2	25%	3%
0		**5%**	0		**8%**	0		**3%**	0		**8%**	0		**7%**	0		**4%**	0		**5%**
1	25%	1%	3	75%	3%	1	25%	1%	4	100%	4%	2	50%	2%	2	33%	1%	3	75%	3%
3	67%		4	100%		3	67%		3	67%		3	67%		2	0%		2	33%	
3	50%		3	50%		1	0%		3	50%		5	100%		5	100%		2	25%	
	58%	4%		75%	5%		33%	2%		58%	4%		83%	5%		50%	3%		29%	2%
0		**11%**	0		**9%**	0		**11%**	0		**7%**	0		**11%**	0		**7%**	0		**7%**
4	75%		4	75%		5	100%		3	50%		5	100%		5	100%		4	75%	
4	75%		3	50%		3	50%		3	50%		3	50%		1	0%		2	25%	
	75%	11%		63%	9%		75%	11%		50%	7%		75%	11%		50%	7%		50%	7%
0		**8%**	0		**4%**	0		**17%**	0		**5%**	0		**8%**	0		**11%**	0		**9%**
2	25%	2%	3	50%	4%	5	100%	9%	2	25%	2%	2	25%	2%	5	100%	9%	5	100%	9%
4	67%	6%	2	0%	0%	5	100%	9%	3	33%	3%	4	67%	6%	3	33%	3%	2	0%	0%
0		**12%**	0		**13%**	0		**10%**	0		**10%**	0		**12%**	0		**7%**	0		**11%**
5	100%		5	100%		4	80%		4	80%		3	60%		1	0%		2	40%	
4	80%		5	100%		5	100%		2	40%		5	100%		2	0%		5	100%	
	90%	6%		100%	7%		90%	6%		60%	4%		80%	5%		0%	0%		70%	5%
4	100%	7%	4	100%	7%	3	67%	4%	4	100%	7%	4	100%	7%	4	100%	7%	4	100%	7%