Standard Norms and Specification for CSEB Block

CSEB Green Buildings in Nepal

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Center of Resilient Development

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This manual is developed by

Centre of Resilience Development
(CoRD)

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PREFACE

Earthquake is a continuous natural phenomenon of sudden and violent motion of earth caused by volcanic eruption, plate tectonics or man-made explosions that has been changing the earth profile. The magnitude of an earthquake is measured as the amount of energy released at the source, the focal area. An earthquake of magnitude 3 is the smallest normally felt by human beings while the largest recorded under this system are from 8.8 to 8.9 in Magnitude in the Richter scale. The intensity is a measure of how severe the earthquake shaking was at any location, which differs from place to place, and measured most commonly in Modified Mercalli Scale (MMI).

Earthquakes may occur almost everywhere in the world. But certain areas of the world are very susceptible to earthquakes. One of them is Nepal, which ranks 23rd in the world in terms of total natural hazard related deaths which is above 7,000 on the decades from 1988 to 2007 through many devastating earthquake reoccurring every 75-100 years' span.

The primary effect of an earthquake is shaking of a building or infrastructure and this is when the saying "earthquake doesn't kill people, but the buildings do!" comes true. It has different effect on different types of buildings and its parts. i) Structural layout, ii) Quality of materials and construction practices and iii)Lack of earthquake resistance features are the most common reasons for the failure of the building during the shake. The defects usually seen are Lack of structural integrity, roof collapse, out-of-plane wall collapse, in-plane shear cracking, poor quality of construction, foundation problem. This however proves that with appropriate planning, design and technology, the effect can be reduced and lives saved.

Hence various seismic consideration starts from the very first step of soil condition to choice of t he site to the building details like shape, proportion, material, openings, structural elements and many more. Eventually it is possible to build an earthquake resistant building with few alterations and innovative approaches in the conventional building form.

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1. Norms and Standard

1.1 Rate Analysis of Production of CSEB (24X24X9) cm Block with 5% Cement

(Per 1000 Blocks- per day production)

S.N	Items	Quantity	Unit	Rate	Cost	Remark
A.	**Material**					
	i) Soil	2.930	m3			
	ii) Sand	4.186	m3			
	iii) Gravel	1.256	m3			
	iv) Cement	12.690	bags			
	v) Water	440.640	lit			
			Sub-Total (A)=			
B.	**Labor**					
	i) Skilled	3	M/day			
	ii) Semi-skilled	5	M/day			
	iii) unskilled	3	M/day			
			Sub-Total(B) =			
C.	**Equipments/Miscellaneous**	**per year**		**Total Cost**	**Cost/day**	
	Investment Cost (Interest on fixed deposit)	14	%			
	Equipment Depreciation (Press lifespan)	19.6	%			
	Building Depreciation (Site duration)	50	%			
	Maintenance cost (Press lifespan)	per lifespan				
	Miscellaneous (5 % of sum of A and B)	5	%			
			Sub-Total(C) =			
			Grand Total =			
			Cost of unit Block =			

1.2 Calculation of material and manpower required for 1000 CSEB Block production

Material Calculation for production of 1000 blocks

Block Size (24X24X9 cm)	Quantity	Unit
Volume of Block	0.005184	m3
Total volume	5.184	m3
Loose Volume (Add 70%)	8.813	m3
Volume excluding cement	8.372	m3
Soil (35% of material volume)	2.930	m3
Sand (50%of material volume)	4.186	m3

Gravel (15%of material volume)	1.256	m3
Cement (5% of loose Volume)	0.441	m3
	12.690	bags
Total=	8.814	m3
Water (5%of total vol.)	440.64	lit

Manpower required for production of 1000 blocks

Work Type	Skill	Semi Skilled	Unskilled	Total
Preparation (Digging and Sieving)	1	1	-	2
Measuring	-	1	-	1
Mixing	-	2	-	2
Pressing	2	1	-	3
Staking	-	-	3	3
Total =	3	5	3	11

1.3 Calculation of Equipment cost and general date for production of 1000 blocks

Calculation of equipment cost and general data for the production of 1000 blocks

Per day Block production	**10000**
Equipment cost	**160000**
Buildings and infrastructure cost (On-site production)	**60000**
Maintenance cost for the lifespan of the press	**50000**

Fixed Cost		Per Year	Per Day
Investment cost (Interests of a fixed deposit)	**14% of total Investment**	**30800**	**132**
Equipment Depreciation: (press lifespan = 6.1 years)	**9.8% of equipment cost**	**15680**	**67**
Building Depreciation (On-site production)	**50% of bldg. cost**	**30000**	**128**
Maintenance cost (Lifespan = 6.1 years)	**50000 for lifespan**	**8196.7**	**35**
Miscellaneous	**5% of material cost**		

Days worked per month	**26**
Months worked per year	**9**
Total working days per year	**234**

2. Example of Rate analysis and cost comparison

2.1 *Rate Analysis of Production of CSEB (24X24X9) cm Block with 5% Cement*

(Per 1000 Blocks- per day production)

S.N	Items	Quantity	Unit	Rate	Cost	Remark
A.	**Material**					
	i) Soil	2.930	m3	220	644.656	2.54%
	ii) Sand	4.186	m3	1659.57	6947.093	27.36%
	iii) Gravel	1.256	m3	1730.19	2172.814	8.56%
	iv) Cement	12.690	bags	710	9010.207	35.49%
	v) Water	440.640	lit	0.25	110.160	0.43%
			Sub-Total (A)=		**18884.930**	74.38%
B.	**Labor**					
	i) Skilled	3	M/day	525	1575.000	6.20%
	ii) Semi-skilled	5	M/day	450	2250.000	8.86%
	iii) unskilled	3	M/day	375	1125.000	4.43%
			Sub-Total(B) =		**4950.000**	19.50%
C.	**Equipments/Miscellaneous**	**per year**		**Total Cost**	**Cost/day**	
	Investment Cost (Interest on fixed deposit)	14	%	30800	131.624	0.52%
	Equipment Depreciation (Press lifespan)	19.6	%	15680	67.009	0.26%
	Building Depreciation (Site duration)	50	%	30000	128.205	0.50%
	Maintenance cost (Press lifespan)	per lifespan		8196.721	35.029	0.14%
	Miscellaneous (5 % of sum of A and B)	5	%	23834.93	1191.746	4.69%
			Sub-Total(C) =		**1553.613**	6.12%
			Grand Total =		25388.543	100.00%
			Cost of unit Block =		**25.389**	

2.2 *Cost comparison between CSEB Block masonry and Brick Masonry*

A. CSEB Masonry Block work in C/S mortar (1:6)

S.No.	Resource	Type	QTY.	Unit	Rate/Unit	Amount	Total Rs.
1	Labor	unskilled	2.4	md.	375.00	900.00	
		Skilled	1.5	md.	525.00	787.50	1687.50
2	Material	CSEB	168	nos.	25.39	4265.28	
		Cement	0.737	bags	710.00	523.14	
		Sand	0.154	cu.m.	1659.57	254.75	
		Water	12.792	lit	0.25	3.20	5046.37

		Scaffolding					
3	Equipment				3%of 1		50.63
							6784.49
				15% contractor overhead			1017.67
				Total			**7802.16**

B. Brick Masonry work in C/S mortar (1:6)

S.No.	Resource	Type	QTY.	Unit	Rate/Unit	Amount	Total Rs.
1	Labor	unskilled	2.4	md.	525.00	1260.00	
		Skilled	1.5	md.	375.00	562.50	1822.50
2	Material	Brick	561	nos.	7.50	4206.73	
		Cement	1.109	bags	710.00	787.28	
		Sand	0.231	cu.m.	1659.57	383.38	
		Water	19.251	lit	0.25	4.81	5382.20
		Scaffolding					
3	Equipment				3%of 1		54.68
							7259.38
				15% contractor overhead			1088.91
				Total			**8348.28**

- Note: The cost of CSEB masonry per m^3 (RS 7802.16) is found cheaper than brick masonry per m^3 (RS 8348.28.28)

2.3 *Calculation of material and labor unit cost*

Labors Unit cost (As per rate for Kathmandu and Lalitpur for 069/070)

Type	Unit	rate
Skilled	nos.	**525**
Semi-skilled	nos.	**450**
Unskilled	nos.	**375**

Materials Unit cost (As per rate for Kathmandu and Lalitpur for 069/070)

Item	Unit	rate
Soil	m3	**220**
Sand	m3	**1659.57**
Gravel	m3	**1730.19**
Cement	bags	**710**
Water	lit	**0.25**
Brick	nos.	**7.5**

3. Specification

3.1 *Scope*

This specification lays down requirements for materials, classification, general quality, dimensions, production procedure and physical requirements of Compressed Stabilized Earthen Block used in green School Building in Nepal.

3.2 *References*

The publications listed in Annex A are necessary adjuncts to this specification.

3.3 *Terminology*

Compressed Stabilized Earthen Block (CSEB): CSEB, is a type of manufactured construction material formed in a mechanical press (Aurum 3000) that forms a compressed block out of an appropriate mix of fairly dry inorganic soil, non-expansive clay, aggregate, and sometimes a small amount of cement or lime as stabilizer.

Sedimentation Test: It is a simplified test carried out in the field to identify the tentative proportion of different ingredient of soil by using a transparent cylindrical bottle of at least one liter capacity.

Aurum 3000: Aurum 3000 machine is hand press machines. The machine consists of a frame, an interchangeable mould, a reverse toggle lever. Other accessories include scoops and bottom plates. The machine is mounted on the ground and secured in position using sand bags or stones. Measured quantity of this mixture is poured in the die of predefined shape and dimensions and is compressed by pulling the lever by hand. Then the compressed block is ejected from the die. The wet compressed blocks are stacked in rows.

3.4 *Materials*

Soil: Soil is the main ingredient of the CSEB. Soil characteristics and climatic conditions of an area shall be evaluated before manufacturing soil building blocks. The soil shall be much more sandy than clayey. Top soil and organic soils shall not be used. The soil, however, shall contain a minimum quantity of silt and clay so as to facilitate cohesion. The proportion of gravel, sand, silt, and clay shall be determined through Sedimentation Test or sieve analysis. Further accuracy requires sieve analysis and hydrometric test.

All soils are not suitable for every building need particularly CSEB. Good soil for CSEB shall contain the following proportion of the four components: gravel, sand, silt and clay. The ingredients shall be mixed thoroughly.

Table 1: Composition of Good Soil for CSEB

Gravel	Sand	Silt	Clay
15%	50 %	15%	20 %

Water: Water is one of the important elements in CSEB production. The quality and quantity of water has much effect on the strength of CSEB. Water for mixing and curing work shall not be salty or blackish and shall be clean drinking water, reasonably and free from objectionable quantities of silt and traces of oils, acid and injurious alkali, salts, organic matter and other deleterious material which will weaken the concrete. The pH value of water shall not be less than 6. Water shall be obtained from the sources approved by the Engineer. Sources of water shall be maintained at such a depth and the water shall be withdrawn in such a manner as to exclude silt, mud, grass or other foreign materials. Containers for transport, storage and handling of water shall be clean.

Sand: Sand for use shall be natural sand. Sand shall be clean, well graded, hard, strong, durable and gritty particles free from injurious amounts of dust, clay, soft or flaky particles, shale, salts, organic matter, loam, mica or other deleterious substances and shall be approved by the Engineer. When the quality of fine aggregate is doubtful, it shall be tested for clay, organic impurities and other deleterious substances as laid down in I.S. 383-1970.

Cement: Cement shall conform to I.S. 12269-1987. Ordinary Portland cement of grade 53 shall be used. Cement required for use shall be as fresh as possible and stored in such a manner as to prevent deterioration by dampness or moist atmosphere or intrusion of foreign matter. Any cement which has deteriorated cracked or which has been damaged shall not be used. When the quality of cement is doubtful, it shall be tested as laid down in I.S. 12269-1987.
The weight of Ordinary Portland Cement shall be taken as 1440 kg. per cu.m. The measurement of proportion of cement should normally be on the bases of weight and each whole bag, undisturbed and sealed, weigh 50 kg.

Soil stabilizer: The chemical admixtures such as lime, cement, and/or fly ash shall be used as a mean of chemically transforming unstable soils into structurally sound construction foundation.
The selection of a stabilizer will depend upon the soil quality and the project requirements. Cement will be preferable for sandy soils and to achieve quickly a higher strength. Lime will be rather used for very clayey soil, but will take a longer time to harden and to give strong blocks.

Table 1: Composition of Good Soil for CSEB for different stabilizer

Soil for cement stabilization: it is more sandy than clayey	Gravel 15%	Sand 50%	Silt 15%	Clay 20%
Soil for lime stabilization: it is more clayey than sandy	Gravel 15%	Sand 30%	Silt 20%	Clay 35%

Table 3: Suitability of stabilizers and their percentage

Stabilizer	Suitability	Min'm %	Avg. %	Max'm %
Cement	Mostly for sandy soil	5%	7%	No technical maximum Economic Max'm: 9 - 10 %
Lime	Mostly for clayey soil	5%	8%	10%

3.5 *Classification*

The CSEB shall be classified on the basis of average compressive strength and water absorption.

Table 4: Classes of CSEB

	Class A	Class B
Dry Compressive Strength (Mpa)	5-7	2-5
Wet Compressive Strength (Mpa)	2-3	1-2
Water Absorption(% by weight)	5-10	10-20

3.6 *General Quality*

CSEB shall be moulded from good soil (with gravel-15%, sand-50%, silt-15% and clay - 20%). CSEB shall be of uniform, regular in shape and size and shall have shapes having each two adjacent plane surfaces at true right angles.

CSEB shall be free from cracks, chips, flaws, stones or lumps of any kind. They shall be free from salt which affect the mortar of the masonry. CSEB shall not show any sign of efflorescence either dry or subsequent to soaking in water. CSEB shall be sound, hard, homogeneous texture.

3.7 *Dimension and Tolerances*

The standard size of CSEB made out of Aurum 3000 shall be are as follows:

Table 5: Dimensions of CSEB

Types	Length (mm)	Breadth (mm)	Height (mm)
Plain full block	240	240	90
U block	240	240	90
Special blocks			
Half block single insert	240	120	90
Full block single insert	240	240	90
Full block double insert	240	240	90

Tolerances shall be specified in accordance with relevant Code of Practices or and as directed and approved by the Supervisor/Engineer

3.8 *CSEB Production Procedure*

Material Selection and Collection: The basic materials required for the production of compressed stabilized earth building blocks are soil, stabilizer, and water. Soils are found naturally but all soils are not suitable for CSEB Production. Some visual inspection and simple testing shall carry to select material sources. Top soil shall be removed as it contains organic matters. Soil below the top soil shall be collected in large quantity as per required and transferred to the site. Collection of soil can be done manually or with the help of excavator and tractor.

Pulverizing and Screening: The materials' lumps shall pulverize in order to disintegrate manually or mechanically. Soil then shall screen in order to remove large size materials and also to get the soil of uniform size which helps for well mixing with sand and cement. Generally screening can be done with 10mm size mesh wire net but done with 2mm size mesh wire net for better performance while mixing.

Testing: Laboratory analysis of the raw material is always necessary for large-scale production of compressed stabilized earth blocks. For small-scale production, however, it is not essential to employ sophisticated tests to establish the suitability of a soil. Simple field tests such as visual identification smell test, touch test, sedimentation test, adhesion test, washing test, Dry strength test, water retention test, consistency test, and cohesion test shall be performed to identify the composition and quality of the soil sample. Among many tests, Sedimentation test shall be at least done to identify different composition of soil. Further accuracy requires sieve analysis and hydrometric test.

Proportioning: Before starting production, tests shall perform to establish the right proportion of soil, stabilizer and water for the production of good quality blocks. The proportions of these materials and water shall then use throughout the production process. To ensure uniformity in the compressed stabilized earth blocks produced, the weight or volume of each material used in the block making process shall measure at the same physical state for subsequent batches of blocks. The volume of soil or stabilizer shall ideally measure in dry or slightly damp conditions. After establishing the exact proportion required of each material, it is advisable to build a measuring device for each material. The dimensions of each measuring box shall be such that their content, when full, is equivalent to the proportion which should be mixed with other materials measured in other boxes.

Mixing: In order to produce good quality blocks, it is very important that mixing be as thorough as possible. Dry materials shall be mixed first until they are of uniform color, then water is added and mixing continued until a homogeneous mix is obtained. Mixing can be performed by hand on a hard surface, with spades, hoes, or shovels.

Water shall add a little at a time, sprinkled over the top of the mix from a watering can with a rose spray on the nozzle. The wet mix shall turn over many times with a spade. A little more water may then be added, and the whole mixture turned over again. This process shall repeat until all the water has been mixed in.

Machine can use for mixing. It should have paddles or blades that move separately from the container. A concrete mixer shall not use for mixing the wet soil , since the latter will tend to stick on the sides of the rotating drum. Hand-mixing methods are often more satisfactory, more efficient and cheaper than mechanical mixing, and are less likely to produce small balls of soil that are troublesome at the block moulding stage.

Moulding: Special precautions shall be taken during moulding in order to produce blocks of uniform size and shall be well compacted to achieve dense and compressed blocks. A machine, Aurum 3000, can be used for the production of CSEB which can produce 1000 blocks per day. The internal faces of the machine mould shall be moisten with a mould releasing agent (reject oil) in order to get well shaped and neat surfaced blocks.

Transporting and storing and curing CSEB: The produced CSEB should be properly carried to the site for storing and curing. Proper handling shall be done during transportation. The site selected for storing shall be well leveled ground and protected from direct exposed to hot dry weather conditions which prevent block shrinkage and warping. It is done till the CSEB production completes. The curing should be done with portable water for a period of three weeks to achieve its maximum strength.

3.9 *Physical Requirements*

Some physical requirements shall be as given in table 6.

BASIC DATA ON CSEB

PROPERTIES	SYMBOL	UNIT	CLASS A	CLASS B
28 day dry compressive strength (+20% after 1 year)	σ_d	Mpa	5 -7	2 - 5
28 day wet compressive strength (after 24 hours immersion)	σ_w	Mpa	2 - 3	1 - 2
28 day dry tensile strength (on a core)	τ	Mpa	1 - 2	0.5 - 1
28 day dry bending strength	β	Mpa	1 - 2	0.5 - 1
28 day dry shear strength	S	Mpa	1 - 2	0.5 - 1
Poisson's ratio	μ	-	0.15 - 0.35	0.35 - 0.50
Young's Modulus	E	Mpa	700 - 1000	-

Apparent bulk density	γ	Kg/m3	1900-2200	1700-2000
Coefficient of thermal expansion	-	mm/m^{o}C	0.010-0.015	-
Swell after saturation (24 hours immersion)	-	mm/m	0.5 - 1	1 - 2
Shrinkage (due to natural air drying)	-	mm/m	0.2 - 1	1 - 2
Permeability		mm/sec	1.10-5	-
Total water absorption	-	% weight	5 - 10	10 - 20
Specific heat	C	KJ/Kg	~ 0.85	0.65 - 0.85
Coefficient of conductivity	λ	W/m^{o}C	0.46 – 0.81	0.81 – 0.93
Damping coefficient	m	%	5 - 10	10 - 30
Lag time (for 40 cm thick wall)	d	h	10 - 12	5 - 10
Coefficient of acoustic attenuation (for 40 cm thick wall at 500 Hz)	-	dB	50	40
Fire resistance *	-	-	Good	Average
Flammability *	-	-	Poor	Average

Dry Compressive strength: The block when tested in accordance with the procedure laid down in IS 3495 (Part 3): 1992 shall have 28 days dry compressive strength of various classes as given in Table 4.

Wet Compressive strength: The blocks when tested in accordance with the procedure laid down in IS 3495 (Part 3): 1992 shall have 28 days dry compressive strength of various classes as given in Table 4.

Water absorption: The blocks when tested in accordance with the procedure laid down in IS 3495 (Part 2): 1992 shall have water absorption of various classes as given in Table 4.

Efflorescence: The blocks when tested in accordance with the procedure laid down in IS 3495 (Part 3): 1992, the rating of efflorescence shall not be more than 'moderate' as specified in code.

3.10 *Sampling and Testing*

Sampling and Testing of blocks shall be done in accordance with procedure describe in IS 5454:1978 and IS 3495: 1992.

Annex A: References

1. I.S. 3495: 1992 Methods of tests of burnt clay building bricks
2. I.S. 5454: 1978 Methods for sampling of clay building bricks
3. I.S. 383: 1970 Specification for Course and Fine aggregates from natural Sources for Concrete
4. I.S. 12269: 1987 Specification for 53 Grade Ordinary Portland cement
5. http://www.earth-auroville.com/compressed_stabilised_earth_block_en.php