Construction Handbook for Building Owners:

Basic knowledge of Appropriate Quality Control

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Foreword

In August 2020, the Department of Urban Development and Building Construction (DUDBC) revised the Nepal National Building Code (NBC) 105: Seismic Design of the Buildings in Nepal. Due to the lack of awareness and knowledge among building owners and contractors, most of the buildings currently being constructed are not as per the approved design drawing. Therefore, it is necessary to enhance the capacity of design checking and construction inspection by the municipalities, the capacity of supervision by the architects and engineers, the capacity of quality control by the contractors, and the awareness of stakeholders. The department has been updating the rules to implement the building code in a more effective manner.

To help improve the above situation, the Ministry of Urban Development (MoUD) and Japan International Cooperation Agency (JICA) concluded the Record of Discussions (R/D) in November 2020 and the technical cooperation project "The Project for Promotion of Nepal National Building Code Compliance for Safer Building Construction (NNBC Project)" that aims to establish a mechanism of building code compliance for safer building construction against earthquakes started in April 2021.

Constructing a house involves agreements between the building owner, designer, contractor, and supervision consultant. The designer prepares a drawing based on the owner's preferences, meeting building codes and by-laws. The contractor then construct the building according to the approved drawings, overseen by the supervision consultant who ensures correct execution and submits supervision reports to the municipality. Building owners, armed with basic construction knowledge, can identify whether the work of contractor's and consultant's work is correct or not. However, having a design drawing and temporary permit doesn't guarantee earthquake resistance; construction must adhere to the approved design drawing using suitable materials and methods.

This booklet provides basic knowledge for constructing an building using appropriate quality control measures. We hope that this booklet will give you the necessary information.

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1. Importance of an engineer in construction works

Effective supervision by an engineer is crucial for construction works, ensuring the strength and earthquake resistance of the building.

- An engineer designs the building following national building codes and by-laws, which makes the approval process easier.
- An engineer supervises the building by following approved design drawings, which makes the building earthquake resistant.
- As an engineer ensures that the building is constructed following the design drawings, the interim and final inspection process by the municipality becomes easier.
- The engineer efficiently manages timelines and resources to keep construction progress smoothly and on schedule.
- Safe buildings are constructed as engineers identify potential risks and manage them properly.
- As an engineer prepares the cost estimate, it helps the building owner to manage the budget required in the building construction process.
- Since an engineer selects better quality construction materials, buildings constructed using such materials are safe during earthquakes.

Figure 1: An engineer checking and supervising whether the building is constructed as per the design drawing or not

2. Selection of construction sites

a) Flat land is suitable for construction work.

b) Avoid building construction at unsuitable places as shown below. If construction is mandatory, consult with an engineer before starting the work.

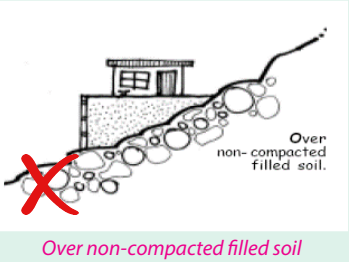
Landslide prone area

A place with is a geological fault.

A river bed or wetland

rock fall area

A steep terrain



Over non-compacted filled soil

Figure 2: - Selection of a construction site

3. Quality of building materials and storage methods

The primary building materials used in construction are cement, sand, aggregate, brick, reinforcement, water, etc. These materials must be used and stored by following set criteria.

a) Cement

- Cement is a binder, a substance which sets and hardens independently, and can bind other materials together.
- The most important use of cement is in the production of mortar and concrete.
- There are various types of cement such as Ordinary Portland Cement (OPC), Portland Pozzolana Cement (PPC), Low heat cement, Rapid hardening cement, White cement etc. OPC and PPC are commonly used in construction.

Figure 3: - Cement used in building construction with the Nepal Standard tag and production date on a sack

- Cement used for concrete should conform to the requirements of Nepal Standard.
- Cement produced more than 3 months ago should not be used. This is because the strength of cement diminishes with time.
- Cement should be stored in air-tight bags in a dry, wind-proof and enclosed room.
- Cement should not be stored directly on the ground. It should be kept on a wooden plank and apart from the wall as shown in figure 4.
- Ordinary Portland Cement (OPC) set faster than Pozzolana Portland Cement (PPC), making it a preferred choice for concrete works.
- The curing time of PPC should be longer than OPC.
- The cement should be smooth when you rub it between fingers.
- The particles of cement should float freely in water for some time before it sinks.

Figure 4: - Systematic storage of cement bags at a construction site

b) Sand

- Sand should be clean.
- Avoid mixing sand with soil, dust, salt or other materials. Mixing these substances can decrease the quality and cause a white powder to appear, as shown in figure 6.
- Coarse sand should be used in concrete work; sand that is too wet should not be used.

Figure 5: - This type of Sand can be used for building construction

Figure 6: - White powder (Efflorescence) seen on wall and brick

c) Aggregate

Figure 7: - This types of aggregate can be used for building construction

- The aggregate must be clean and made of hard stone. It should not have soil, dirt or any organic or inorganic materials, and it should not be round.
- The size of aggregate for column and beam should be less than or equal to 40 mm (1.5 in).
- The size of the aggregate used for the slab should be 20 mm (0.78 in) or smaller.

d) Brick

- The bricks shall be free from cracks, defect, grit and other impurities such as lime, iron and deleterious salts. If salt is present, it will result in the appearance of white powder (refer to figure 6).
- Bricks should be strong, well-burnt, uniform in shape, red and smooth.
- Brick should not break when dropped from a height of 1 meter (3 ft) onto a hard surface. You can perform this check using the method shown in figure 8.
- When two bricks strike, they should produce a metallic ringing sound.
- When the brick if soaked for an hour, it shouldn't absorb over 1/6th of its dry weight.

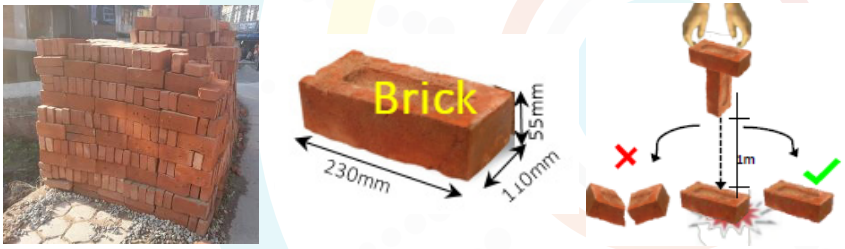


Figure 8: - Brick storage, dimension and method of testing

e) Reinforcement used in concrete works

- Reinforcement should be free from rust, cracks. As rust can spread internally, decreasing its quality.
- While purchasing reinforcement, priority should be given to quality and storage should be on shed to prevent rusting.
- Check NS 191-2046 Standard issued by the Nepal Bureau of Standards and Metrology when purchasing reinforcement.
- The materials should be bought from among the brands that have obtained Nepal Standard tags.

Figure 9: - Tags of reinforcement with NS standard, weight, and size

Figure 10: - Storage of reinforcement at a construction site

- Use ductile reinforcement with uniform thickness and diameter, free from cracks, breaks, or not showing brittle behavior during bending.
- Use only those brands that have specified weight, size with Nepal Standard for reinforcement, as indicated on the tag.
- Use only the specified size of reinforcement mentioned in the design drawings.

f) Scaffolding and formwork

- Wood and steel are used to make scaffolding and formwork for concrete work.
- All scaffolding members shall be checked for their strength and stiffness and properly tied up before installation.
- Nowadays, steel scaffolding and formwork are becoming popular. These structures are made in factories or workshops.
- In case of finishing work such as plastering, painting and distempering, planks should be fitted and tied together.
- Where ladders are used, bags filled with sand shall be tied up at the ends to prevent any damage by sliding.
- If there is loose soil on the ground floor, it should be well compacted. Scaffolding and formwork should rest on a hard surface.

Figure 11: - Steel poles and planks used as scaffolding and formwork

g) Stone

- The stone should be hard, durable, and strong.
- Use only durable and crack-free stones for masonry walls, avoiding easily breakable or soft stones, as their use can weaken the structure.

Figure 12: - Usable and unusable stone

- Dress the stone thoroughly for strong joints in masonry construction.
- Use uniform-sized stones for the masonry wall.
- Use long and flat stones instead of round or smooth river stones, as the joints are weaker in round or smooth river stones.
- Through stone should be used every 2 feet in stone masonry.

h) Timber

- Unless otherwise stated, the timber should be Sal wood of the best quality obtained from an approved saw mill.
- Freshly harvested wood is brittle, damp and prone to rotting and warping, thus requiring proper drying before use.

Figure 13: - Proper storage of timber

- All the timber shall be seasoned and free from decay, harmful fungus & insect attacks and from any other damage of harmful nature.

i) Water

- Water to be used in mixing concrete should be free from oils, acids alkalis, organic material or other deleterious substances.
- Water should be as clean as drinking water. Impure water weakens the compressive strength of the concrete, making the reinforcement more susceptible to rusting.

4. Concrete works

a) Concrete mixing

- Mix the concrete ingredients (cement, sand, aggregate and water) in the specified ratio by using a concrete mixture machine for at least 2 minutes.
- Improperly mixed concrete weakens its strength, increasing the risk of structural collapse or damage during an earthquake.
- The ratio of cement, sand, aggregate, and water should be as specified in table 1 for the concrete grade.
- Additional 10% of cement should be used for manual mixing if it is not possible to use concrete mixture machine.

b) Water/cement ratio

- Water/cement ratio is the most critical factor for the strength of concrete.
- In concrete mixing, the right amount of water is crucial. Insufficient water makes improper mixing, while excessive water increases workability but weakens the structure. Adhering to engineer-specified water cement ratio mentioned in the specification is essential for optimal results.
- The quantity of water required for nominal mix of concrete is specified in table 1

Table 1: - Example of typical mix proportion for reinforced concrete

S. N	Concrete grade	Cement bag	Sand bag	Aggregates bag	Water (By weight) litre
1	M15	1	2	4	32
2	M20	1	1.5	3	30
3	M25	1	1	2	27

Note – 1 bag of cement = 50 kg

c) Placing and compaction of concrete

- When pouring concrete for foundations, walls, columns, beams, slabs, etc., avoid pouring from a height exceeding 1.5 meters (4.5 feet) to prevent honeycomb and maintain the compressive strength of concrete.
- When concrete work has to be done at a difference of more than 30 minutes, construction joint should be placed.
- Cement slurry should be used while connecting old and new concrete works.
- The placing and compaction of concrete shall be done under direct supervision of a supervision consultant.

Figure 14: - Pouring concrete from a greater height causes segregation.

Figure 15: - Compaction and levelling after pouring concrete

- Compact and level the entire concrete thickness, paying special attention to corners and around the reinforcement after pouring concrete.

Figure 16: - Honeycomb seen in concrete without the use of vibrator.

- Vibrator should be used for compaction. Use a needle vibrator for compacting beams, columns, and foundations, and a surface vibrator for thin slabs.
- Excessive vibration should be avoided because it causes segregation in the concrete.

d) Curing of concrete

- Concrete curing is the process of keeping the outer surface of freshly poured concrete wet or preventing it from drying out. It's important to cure concrete for a minimum of 14 days.
- Curing is done after concrete hardening, typically 24 hours after placement.
- If moisture is not maintained on the outer surface in time, cracks may appear on the concrete surface, affecting the quality of work.

Figure 17: - Curing in column and slab

- To cure the concrete, cover its outer surface with jute sack. Water should be added frequently to maintain freshness
- Keep flat parts like slabs and floors moist by pounding, keep vertical parts such as column moist by using jute sacks (As shown in figure 17).

e) Remedial treatment of concrete surfaces

- After the removal of formwork, the concrete surface needs to be checked by the supervision consultant for any flaws.

- Inspect for cracks or honeycombs after removing the form; repair with cement sand mortar.
- If a substantial gap, hole, or defect in reinforcement is found during inspection, consult with the supervision consultant for technical guidance and consider techniques such as injection grouting or shotcrete for effective repairs.

Figure 18: - Substantial gap, hole, or defect found during inspection in concrete.

f) Compressive strength of concrete

- Compressive strength of concrete is the ability of material or structure to bear the loads on it without any crack or deflection.
- Compressive strength of concrete refers to ability of concrete to withstand loads.
- The strength of concrete depends on factors like ratio, quality of cement, sand, aggregate, water and curing duration.
- The project for promotion of Nepal national building code compliance for safer building construction (NBCC) has updated building construction working procedure, requiring testing of the strength of concrete used in buildings. Test samples must be prepared in a 15cm x15 cm x15cm cube mouid and preserved according to set standards from preparation to the testing day.

g) Removal of formwork

- Remove formwork carefully by avoiding shocks or preventing other damages in the concrete.
- Before removing the formwork, carefully consider the order of removal.

Table 2: Time for formwork to be in Place

Part of Structure	Days	
	Normal Temperature	Cold Temperature
Column & Walls	1	2
Beam Sides, Cornice	2	4
Slabs 125 mm	7	14
Slab less than 125 mm	14	28
Soffit of beam	21	28

5. Conversion Table

Quantity	Units	Symbol	Description
Length	metre	m	1 metre = 100 centimetres (cm) 1 metre = 1000 millimetres (mm) 1 metre = 39.37 inch = 3.281 ft
	kilometre	km	1 kilometre = 1000 metres 1 kilometre = 0.621 mile
	inch	inch	1 inch = 2.54 cm = 25.4 mm
	centimetre	cm	1 cm = 0.394 inch
	foot	ft	1 foot = 30.48 cm
Area	ropani	ropani	1 ropani = 5476 sq.ft
	aana	aana	1 ropani = 16 aana 1 aana = 342.25 sq.ft
	paisa	paisa	1 paisa = 85.56 sq.ft
	dam	dam	1 dam = 21.39 sq.ft
Mass	kilogram	kg	1 kg = 1000 gram
	pound	lb	1 kg = 2.205 pound
	tonne	t	1 tonne = 1000 kg

508.74 sq.m	= 1 ropani	= 16 aana	= 5476 sq.ft
31.79 sq.m	= 1 aana	= 4 paisa	= 342.25 sq.ft
7.94 sq.m	= 1 paisa	= 4 dam	= 85.56 sq.ft
6772.41 sq.m	= 1 bigha	= 20 kattha	= 72900 sq.ft
338.62 sq.m	= 1 kattha	= 20 dhur	= 3645 sq.ft
1 dhur	= 182.25 sq. ft		

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