No.117 Select one of the slab symbols **in structural drawings** and reviewers fill out the symbol in column 4, fill out the data source in column 5, and mark check ☑ in column 3.

No.118 As for the thickness of the slab of No.117, reviewers fill out the thickness in column 4, fill out the data source in column 5, and mark check ☑ in column 3.
Reference: BNBC PartⅥ of column 6 and URP checklist of column 8

No.119 This item is for sampling review. If reviewers have confirmed "thickness ≧ 125mm", mark check ☑ in column 3.
Reference: BNBC PartⅥ of column 6 and URP checklist of column 8

ex) thickness of slab=125mm (No.118)
If "thickness of slab≧125mm", hence, judged to be ok.

●Foundation

No.120 As for the type of foundation, reviewers fill out the type in column 4, fill out the data source in column 5, and mark check ☑ in column 3.
Reference: BNBC PartⅥ of column 6

No.121 If the footing or pilecap schedule is described **in structural drawings**, reviewers fill out the data source in column 5, and mark check ☑ in column 3.

No.122 Select one of the foundation symbols **in structural drawings** and reviewers fill out the symbol in column 4, fill out the data source in column 5, and mark check ☑ in column 3.

No.123 As for the depth of footing of No.122, reviewers fill out the depth in column 4, fill out the data source in column 5, and mark check ☑ in column 3.
Reference: BNBC PartⅥ of column 6 and URP checklist of column 8

No.124 This item is for sampling review. If the spacing of footing meets the conditions of column 2, reviewers mark check ☑ in column 3.
Reference: BNBC PartⅥ of column 6 and URP checklist of column 8

ex) depth=550 ㎜ (No.123)
If "depth≧300 ㎜ (on pile)", hence, judged to be ok.

No.125 If the building uses a pile foundation, reviewers fill out the length of the pile in column 4, fill out the data source in column 5, and mark check ☑ in column 3.
If the building does not use a pile foundation, reviewers mark check ☑ for "not confirm" in column 3.

2.4. Overview of Design Report

The design report contains the content shown in BNBC Part 6 Chapter1 1.9 (See section 1.4 of this Manual). The designer confirms that the building is designed according to the codes (BNBC2020) and writes his/her name as the person responsible for the contents of the design report.

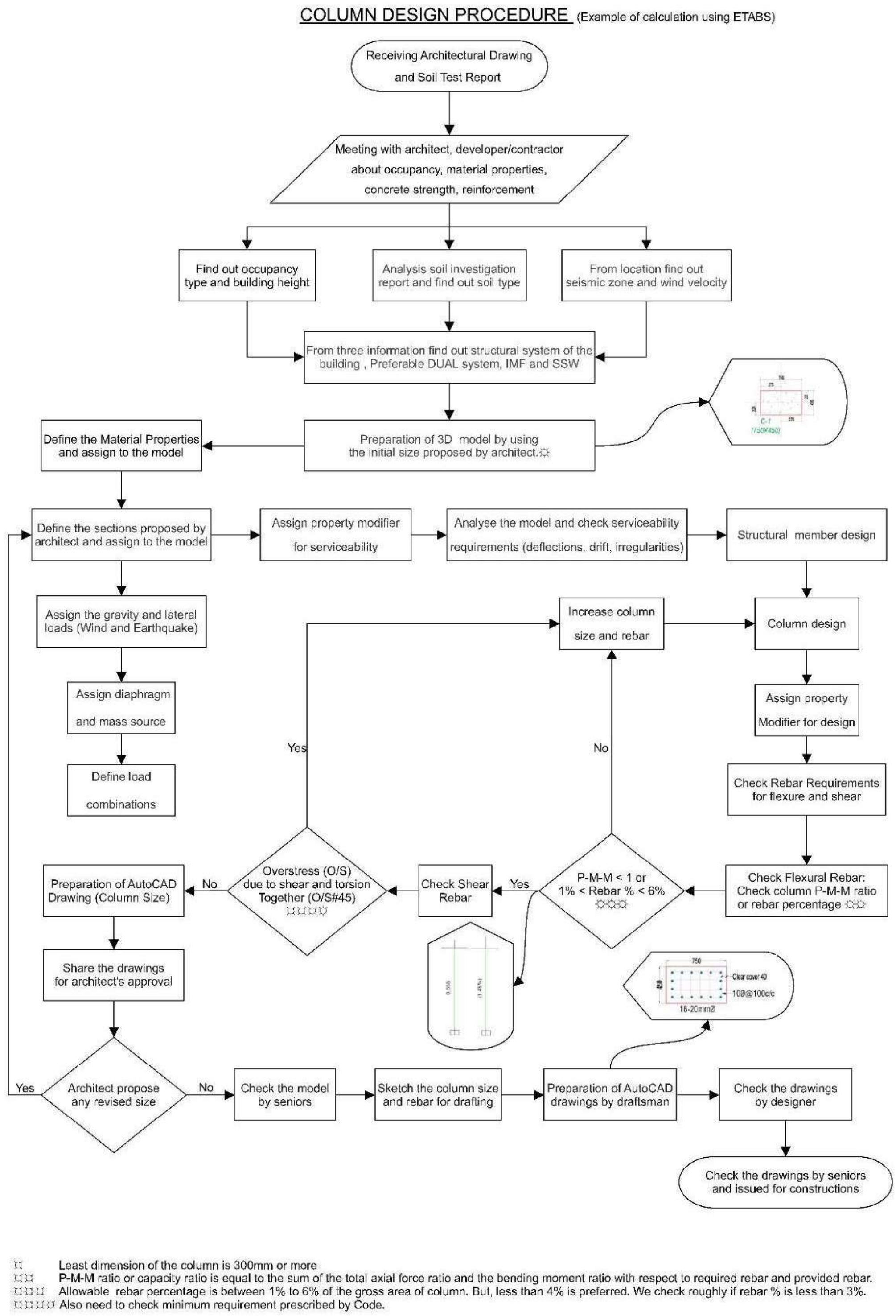
<How to check the design report, drawings, and calculation sheets in design office.>

For example, design report, drawings and calculation sheets are checked by a engineer assigned particularly for that project. If he/she finds any of problem at first, he/she discusses with chief engineer and after that he/she discusses with the principal engineer. Appointed engineer for that project check it thoroughly as per BNBC 2020. Following information have been checked during checking procedures.
(A checklist is a summary of important items for review by RAJUK officials related to the following checks.)

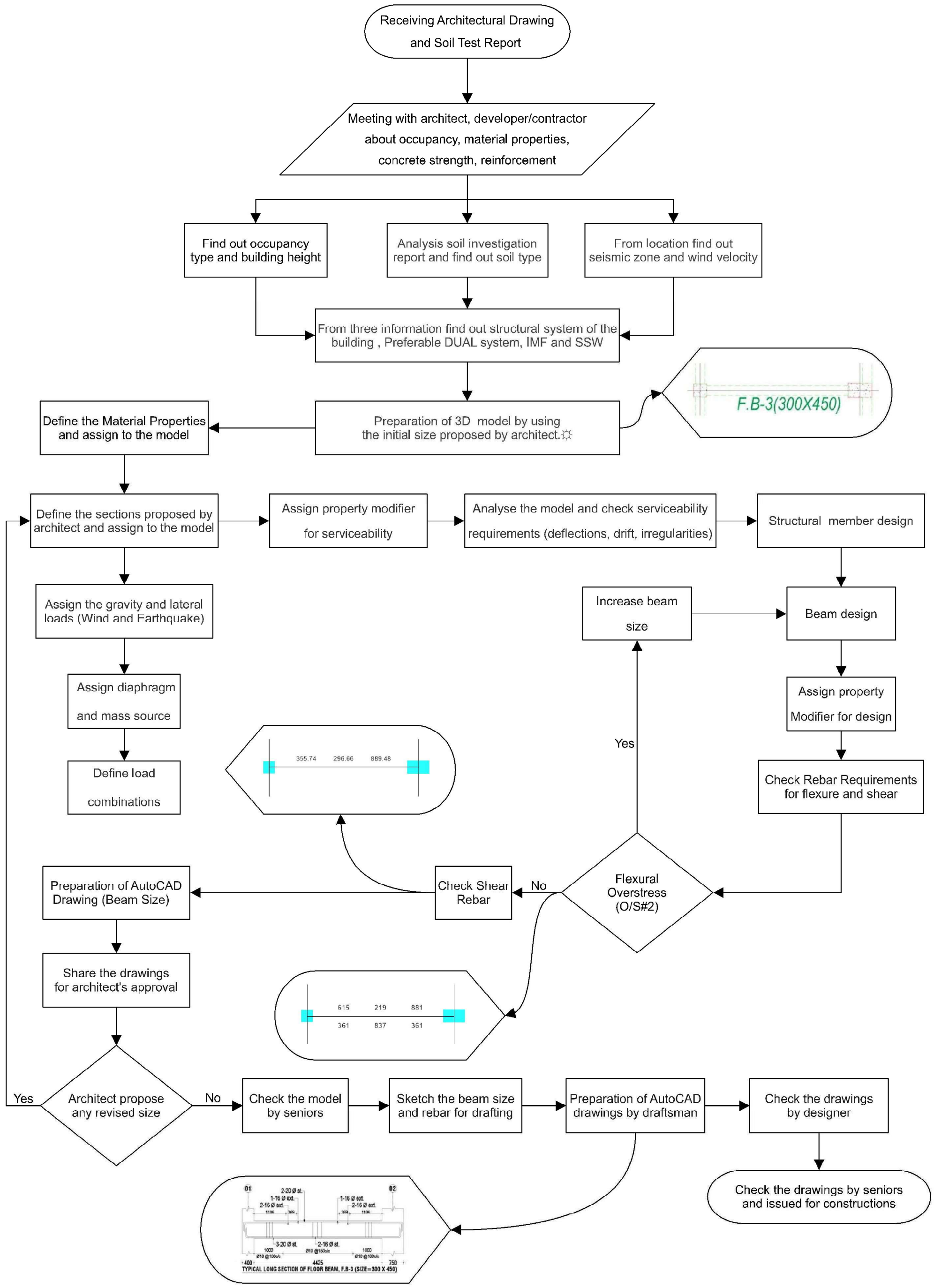
- General description of the structure
- Building design codes.
- Geometry of structure complying architectural requirements.
- Dead loads.
- Live loads.
- Wind loads.
- Seismic loads.
- Material specifications.
- Serviceability check.
- Column adequacy check.
- Beam adequacy check.
- Wall adequacy check.
- Slab adequacy check.
- Foundation adequacy check.
- Structural drawing

2.5. Basic knowledge of structural calculation software

The calculation procedure by ETABS is shown in a flowchart below for each member (column, beam, shear wall, floor).

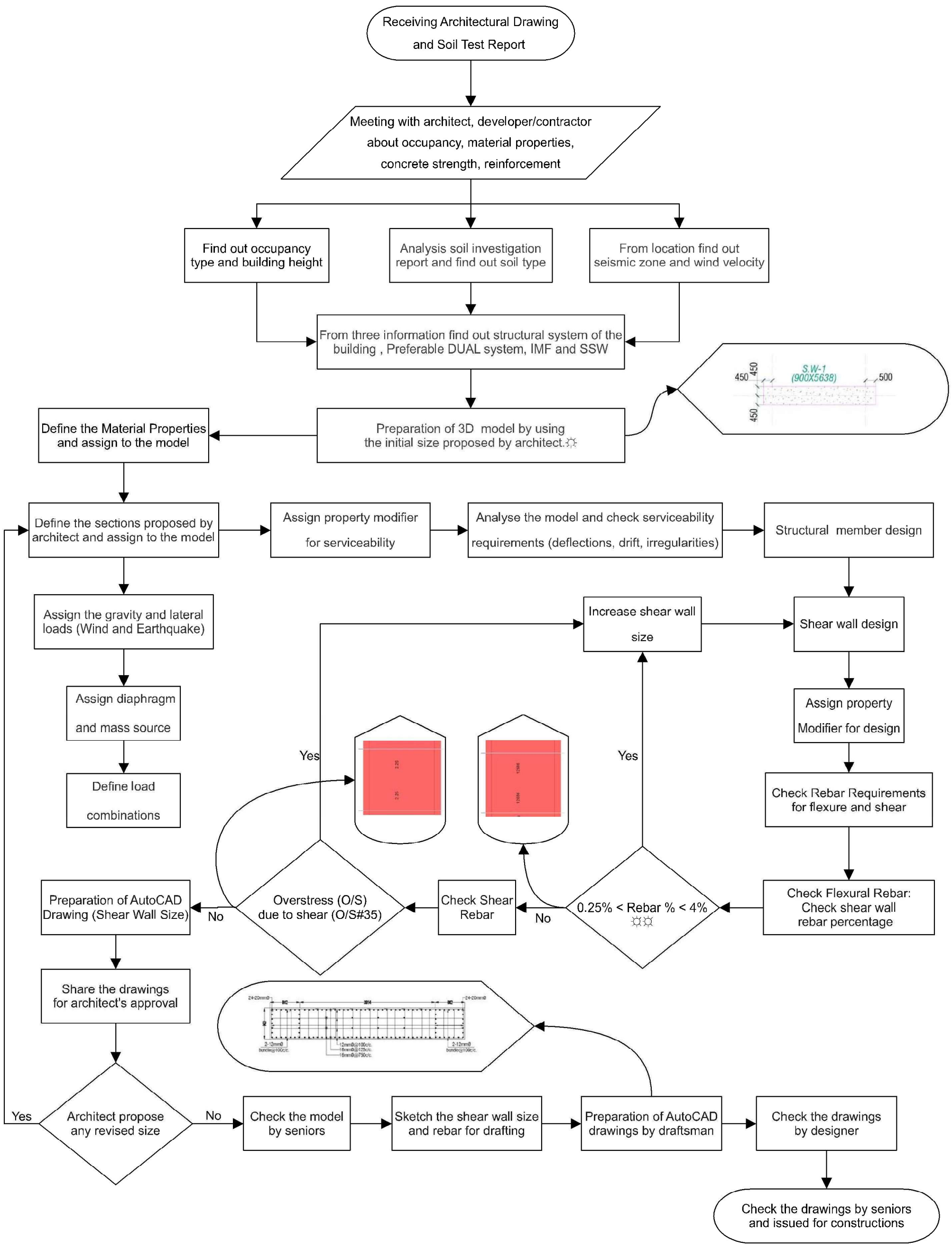


BEAM DESIGN PROCEDURE (Example of calculation using ETABS)



☼ Least dimension of the beam width is 250mm or more

SHEAR WALL DESIGN PROCEDURE (Example of calculation using ETABS)



☼ Least dimension of the shear wall is 300mm or more

☼☼ Allowable rebar percentage is between 0.25% to 4% of the gross area of shear wall. But, less than 3% is preferred. We check roughly if rebar % is less than 3%.

SLAB DESIGN PROCEDURE

Slab is not designed through ETABS.
It is easy to calculate by manual considering gravity loads (dead, super dead and live load) only

Chapter 3. Possible enforcement measures

楢府さん文章差替

3.1 Introduction of building codes and building regulations

In many countries, building codes are introduced to improve the quality of buildings and built environment. Building regulation is also introduced to implement the codes such as,

1) design review and issuance of building permits before construction,

2) site inspection during construction work, and

3) completion inspection upon completion of construction work (often related to permit to use/occupy the completed buildings).

However, many countries face difficulties in enforcement of building regulations and achieving compliance to the codes. These situations cause serious incidents which should have been prevented by compliance with codes. The 2023 Turkey-Syria Earthquake is a recent example of this case, where certain numbers of new buildings totally collapsed.

3.2 Efforts for effective enforcement

Under the situation mentioned in the previous section, many countries have been working to improve this issue for a long time. Their approaches are not only simply strengthening regulatory schemes such as strengthening of capacity of regulatory authorities, or penalty for violation but also in various ways. This chapter shows overview of these efforts for discussion on improvement of building regulation in Bangladesh.

3.3 An approach for effective enforcement of building regulation

In this chapter, for an approach for effective enforcement of building regulation, analysis on main stakeholders and their willingness/unwillingness to comply with building codes is conducted. Then, the structure of analysis tool for the approach, “willingness analysis”, is explained.

3.3.1 Main stakeholders

Main stakeholders relating to construction of buildings are shown in Figure 1.

1) building owners/customers

The owners of buildings are one of the main stakeholders in constructing buildings, who are the person or organizations who are going to construct buildings with their budget. They are required to apply for building permits (Article No. 13, The Dhaka Building Construction Rules 2008), accept site inspection by regulatory authorities (Article No. 15 (7) and (8), The Dhaka Building Construction Rules 2008) and obtain occupancy certificate when construction is completed (permission to use the constructed buildings. Article No. 18 and 19, The Dhaka Building Construction Rules 2008)). They employ architects and engineers for designing the buildings and then make contracts with contractors to construct the buildings. In order to control the construction work to realize the building by the contractor in accordance with the design, they are required to hire professionals to supervise the construction work on their behalf (Article No. 15 (2), The Dhaka Building Construction Rules 2008).

2) designers (engineers and architects)
The designers of the buildings (architects and engineers) are employed by the owners to design buildings and prepare design documents (drawings, specifications, etc.) based on their technical knowledge. Under building regulation, they are required to design in compliance with building codes (Article No. 21, The Dhaka Building Construction Rules 2008).
3) contractors
The contractors construct buildings based on contracts with the owners in accordance with design documents. The contractors employ site engineers, foremen, and workers. They procure building materials with inspection of quality in accordance with the design documents.

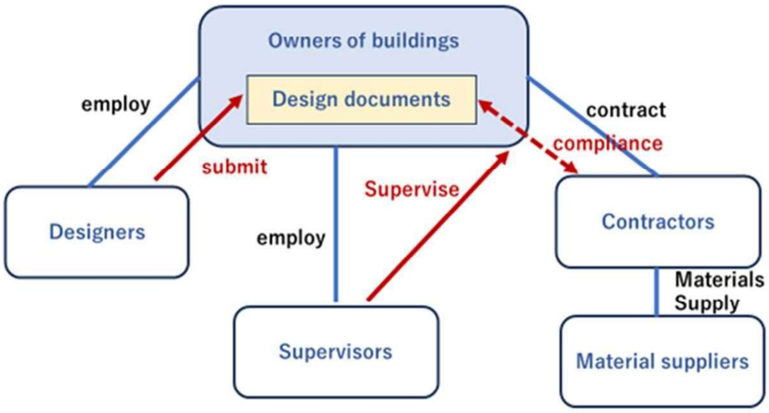


Figure 1 Main stakeholders and relations between them

3.3.2 Structure of Willingness analysis
The structure of "willingness analysis" is shown in Figure 2.
(1) "Own willingness" is willingness which each of stakeholders has by nature. From the view point of building regulation, each stakeholder has own willingness to follow the regulations and at the same time negative ones (not to follow them). This analysis aims to find approaches for effective implementation of building regulations by increase of the willingness to follow the regulation or reduction of unwillingness (negative willingness) by utilizing influential factors of "encouragement to willingness" and "pressure" in addition to the ordinary approaches of "authoritative regulation/ regulation by police power".
(2) "Encouragement" is environments or conditions to encourage the targeted stakeholder to follow regulations by increase of willingness or reduction of negative ones.
(3) "Pressure" is influence by other stakeholders to the targeted stakeholder.
(4) In addition to "willingness" and the influential factors ("encouragement" and "pressure"), this chapter discusses possible ways to strengthen the ordinary regulation ("authoritative regulation" or "regulation by police power") in other ways than simple way of strengthening of regulatory authorities.

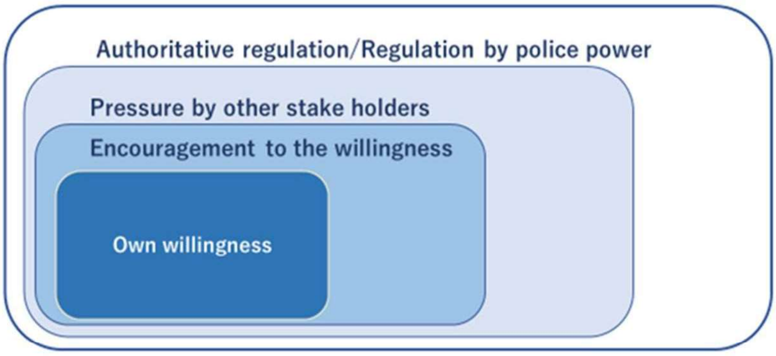


Figure 2. Structure of "willingness analysis" relating to building regulation

3.4 Possible ways/measures for effective enforcement on the issue of compliance to building codes

In this section, the difference between "building codes" and "zoning codes" are discussed first. Then, analysis of the issue, "not comply with codes: building codes" is conducted on the three stakeholders, namely "owner", "designer", and "contractor".

3.4.1 Building codes and zoning codes

First, it should be noted that there are two kinds of codes/standards for building regulation. One is codes/standards which define the building itself in quality such as safety, comfort, etc., which are usually called "building codes". Another one is those from view point of urban planning such as regulation of usage/occupancy of buildings, height of building, floor area, etc., which are called "zoning codes" or "urban planning codes". (In Bangladesh, some issues like floor area ratio, ground coverage are stipulated in the Dhaka Building Construction Rule 2008)

On the cases of zoning codes, violation of the codes will simply benefit the owners of buildings, whereas the people living surrounding the building suffer disadvantage from it by crowded urban conditions, etc. On the other hand, non-compliance with building codes usually causes both advantages and disadvantages to the owners. For example, non-compliance with structural requirements might offer cost reduction to the owners of the building, but at the same time, it will increase risks of damage by future earthquakes, strong winds or other incidents for the owner. These two codes (building codes and zoning codes) have different aspects and should be discussed separately. This section is devoted to "building codes".

3.4.2 Analysis of "owner" of the issue "not comply with codes: building codes"

(1) Own willingness of owner

Most requirements of building codes are stipulated to ensure quality of buildings such as safety, comfort, public health/hygiene, and so on, which will benefit the owners of buildings. In this context, the owners have certain own willingness to follow building codes. On the other hand, they have another motivation to reduce construction cost which is contradictive to their own willingness stated before.

Under this situation, the owners sometimes choose to construct buildings non-compliant to the codes intentionally. The background of this behavior could be analyzed that the owners do not understand or evaluate values to be realized by the codes. In case of earthquakes, it may be difficult for ordinary owners to understand the safety against large scale earthquakes because they occur quite rarely and people tend to or hope to think large scale earthquakes would not occur during life time of his buildings or their buildings could escape damage even if they occur. To cope with this situation, awareness raising of future risk is a natural and proper approach although it is a tough job because of the long periods of occurrence.

In this approach, it should be noted that the level of awareness varies widely. In case of building collapse of the Rana Plaza building in Bangladesh without impact from outside in 2013, shops and branch offices of banks were locked by the management considering safety of workers because of sinister symptoms of cracking in walls, whereas owners of garment factories forced their workers to work inside the building. In this case, poor awareness of the factory owners is one of the causes of the large number of casualties. This fact implies awareness raising activities should start with group of people of higher awareness in the society and then expand the target people for the next steps.

Another aspect relating to the owners is the complex situation on "owners" discussed below. The original situation of relationships between the owners and buildings are, 1) owners invest in buildings, and 2) the owners use them by themselves. In this case, the owners directly understand the quality of buildings. However, recent situations produce cases as below which are different from the original relationship. On these kinds of buildings, the owners are not directly affected by possible incidents. Where pursuance of responsibility for accidents caused by non-compliance with codes are not fully implemented, the owners tend to prioritize reduction of cost than the quality of buildings.

* Complicated situation of "owner" of buildings in recent days

- Rental houses or offices: used/occupied by dwellers or tenants
- Shopping centers, hotels, etc.: used by customers, visitors, etc.
- Ownership type apartments: upon completion, housing units are to be sold by developers and occupied by purchasers (dwellers)

Possible approaches in these cases are discussed in the following sections of Encouragement and Pressure.

(2) Encouragement for owner

In cases of buildings used/occupied by people other than the owners (ownership holders), those users/occupants could give encouragement. Usually people with high education/awareness or people from global companies or developed countries are more conscious of quality of buildings such as comfort, safety, and tend to choose buildings of better quality. For those people, information dissemination will work such as posted panels in public areas, publicity such as disclosure in websites, etc. Figure 3 is an example to show compliance with the updated Fire Safety Law in Japan. This would contribute to attract tourists or visitors who are conscious of safety through market mechanism. This type of approach could be applied to certain types of buildings of which users are more aware of quality or risk.

Figure 3 Left: A certificate showing meeting the requirements of the updated Fire Safety Law is posted at a reception of a hotel in Japan in order to appeal guests on fire safety of the hotel. Right: Close up of the certificate

(3) Pressure for owner

The financial institutions could give pressure to the owners. Since compliance with codes strongly influences the quality of buildings, the financial institutions have a strong interest in this issue. They want their collaterals (buildings constructed with budget from their loan) to have quality and be durable enough to bring the owners sufficient income for a long time for repayment of the loan. Contribution by suppliers of services is expected to work in similar way as well. It would be very strong pressure on the owners because buildings could not function without supply of electricity, water, sewage, and so on.

(4) Measures to strengthen “regulation”

Design review and site inspection by regulatory authorities are the main measures to secure compliance with codes. They are the main pillars of the building regulation and should be strictly implemented. However, those activities are limited in stages (usually design review at application for building permits, site inspections at interim and final/completion stage), and time spent for them. Therefore, effective ways should be pursued including a heavier penal system.

The common difficulty for this issue is the technical capacity of regulatory authorities. One possible approach to this problem is strengthening “self or voluntary review” by designer side before applying for building permits (review by managing designers and expert designers stated in 1.4.1 in Chapter 1).

Other authoritative regulations specific to designers or contractors will support the building regulation. This will be discussed in 3.4.3 and 3.4.4.

3.4.3 Analysis of “designer” on the issue “not comply with codes: building codes”

(1) Own willingness of designer

Basic motivation of designers is to create a good design with full utilization of their professional knowledge and skills. However, sometimes the capacity of each designer is not enough to design buildings fully compliant with codes. Some others might design non-compliant to the codes intentionally to save time for designing work. To improve the situation, capacity development and raising ethics of professionals are necessary. This issue is further discussed in the next section.

(2) Encouragement for designer

To enhance ethics of professionals, awareness raising activities is effective. Enhancement of technical capacity could be realized through various activities such as seminars, training programs, and so on. Qualification schemes of professionals can be categorized into this group. Many countries have introduced some kinds of schemes such as membership of professional organizations, registration to local governments or others. Recently CPD system (Continuing Professional Development) is introduced in many countries to upgrade and update technical knowledge after obtaining the qualification, which is expected to contribute to encourage willingness to comply with codes. Award schemes by governments or associations of professionals could encourage designers to produce better designs.

(3) Pressure for designer

Design review by superiors or managing designers should be basic procedures to give pressure to designers for code-compliance. Further, in some countries, peer review by outside professionals is spontaneously implemented by owners of high awareness who have strong will to have buildings of good quality. Japan introduced compulsory peer review on structural design and calculation stated in 1.4.1 in Chapter 1.

(4) Measures to strengthen "regulation"

The possible approach to enhance compliance with codes is to review by superiors/managing designers before application for building permits as stated in the previous section. One possible way to strengthen the effect is to make it mandatory. The legal regulatory scheme for architects and engineers would be a basis of this way. The Kenchiku-shi/Architectural engineers Law in Japan is an example. It stipulates managing architectural engineers in consulting business have responsibility to supervise their technical staff in addition to qualification of architectural engineers, penalties against misconduct and others. Further, review by experts on structural design and EMS design (electrical, mechanical, and plumbing design) for large scale buildings is made mandatory by the revision of the Law in 2006. Further, compulsory structural calculation review for large buildings at application of building permits is introduced as well by the revision of the Law in 2006. (Originally, the Kenchiku-si Law was enacted almost at the same time as the Building Standard Law in 1950 to support each other to ensure the quality of buildings.)

3.4.4 Analysis of "contractor" on the issue "not comply with codes: building codes"

(1) Own willingness of contractor

The main motivation/willingness of contractors is to earn profits. Constructing buildings of good quality could be another motivation when market mechanism works that buildings of quality create reputation in market, consequently bring more opportunities to gain next contracts. It seems that this market mechanism works less in developing countries than in developed countries.

(2) Encouragement for contractor

In case the market mechanism regarding reputation stated in the previous section works well, that mechanism would be encouragement for compliance with building codes. Award schemes by governments or associations of business would accelerate the mechanism. (In Japan various organizations implement warding schemes for the purpose)

(3) Pressure for contractor

There seems no effective pressure for contractors.

(4) Measures to strengthen “regulation”

Since the main motivation of contractors is to earn profits, many countries introduce legal regulatory schemes to ensure quality of buildings. Those include supervision by professionals employed by owners, and inspection by regulatory authorities. The owners are required to employ professionals to supervise construction work by contractors (called “supervision”) in Bangladesh (Article No. 15 (2), The Dhaka Building Construction Rules 2008). However, this scheme is not well implemented in Bangladesh. Some owners do not employ supervisors because they are not so much interested in the quality of buildings and choose to save the cost of fee for supervisors.

Regulatory authorities also conduct site inspections to ensure the quality of buildings (conformity with the design which obtains building permits). However, this could not be complete and detailed manner. As occasions of inspection (one time during construction and another upon completion in Bangladesh) and working time for inspections are limited, inspection by authorities has to rely on records of supervision. The inspection by authorities could be regarded as a cross check on supervision by owners. Considering this situation, encouragement to owners to employ reliable professionals and instruct them to conduct strict supervision should be the basic approach.

Many developed countries enacted a law specific to regulate contractors/construction business. The Construction Business Law in Japan which was enacted in 1949 is an example. One of objectives of the law is to ensure quality of construction work. For the objective, it requires contractors to obtain licenses for construction business and defines qualifications for site engineers for quality control for construction work. It could give penalties for misconduct or violation, which could collaborate with building regulation to ensure quality of buildings.

3.5 Possible ways/measures for effective enforcement on the issue of compliance to zoning codes

In this section, analysis only on “owner” is conducted. Since “designer” and “contractor” do not have specific willingness or interest in the issue and they usually just follow instructions of owners. Therefore, analysis of “designer” and “contractor” is not conducted.

3.5.1 Own willingness of owner

By ignoring zoning codes, the owners could design buildings more freely without limit of use/occupation of buildings, height of buildings, floor area and so on. In other words, they could obtain more benefits from the same building lots. There seems no disadvantage which affects the owners with this ignorance/incompliance of zoning codes.

3.5.2 Encouragement for owner

There seems no encouragement on this issue.

3.5.3 Pressure to owner

Pressures against non-compliance with zoning codes could be given by financial institutions and suppliers of services similar way described in 3.4.2 (3). In this situation, financial institutions and service suppliers would have risk to be criticized that they support the building owners who do not comply with building codes and give bad influence to society.

3.5.4 Measures to strengthen “authoritative regulation”

On zoning codes, the neighboring community has stronger incentive because they will suffer from consequences which are caused by non-compliance with zoning codes such as crowded urban conditions, higher buildings than permitted, and so on. In addition, they can easily recognize incompliance because many of non-compliances with zoning codes could be detected visually from outside by people without technical knowledge (in case of building codes, technical knowledge is often needed). In Japan, important information on construction projects is required to be posted at construction sites for several objectives including the one mentioned above for neighboring community (Figure 4).

Figure 4 Outline and important information on construction work must be shown at the construction site in Japan such as use/occupancy of buildings, number of stories, height, floor area, coverage area of buildings, name of the owners, name of designers, name of contractors, etc.. If neighboring people are skeptical, he/she can inform the regulatory authority.

3.6 Concluding remarks

Building regulation is very difficult task. In case of Japan, the first regulation was introduced in 1919 and enormous efforts have been made by all the relevant people since then. During the procedures, they have been seeking for every possible way and requesting various stakeholders for collaboration as stated in the previous section. For the procedures, every approach was examined whether it is implementable by the regulatory authorities with their capacity and acceptable for relevant stakeholders such as building owners, architects, engineers, society, and so on. The Implementability and acceptability differ from country to country. Therefore, it is recommended to figure out every possible way referencing the experience of Japan and other countries and examine it from the viewpoints.

Annex

Annex (1)

① [Occupancy category] Choose from *Ⅰ～Ⅳ. (e.g. Ⅱ for residential)*

BNBC Part6 Chapter1 1.2.3

1.2.3 Building and Structure Occupancy Categories

Buildings and other structures shall be classified, based on the nature of occupancy, according to Table 6.1.1 for the purposes of applying flood, surge, wind and earthquake provisions. The occupancy categories range from I to IV, where Occupancy Category I represents buildings and other structures with a low hazard to human life in the event of failure and Occupancy Category IV represents essential facilities. Each building or other structure shall be assigned to the highest applicable occupancy category or categories. Assignment of the same structure to multiple occupancy categories based on use and the type of load condition being evaluated (e.g., wind or seismic) shall be permissible.

Table 6.1.1: Occupancy Category of Buildings and other Structures for Flood, Surge, Wind and Earthquake Loads.

Nature of Occupancy	Occupancy Category
Buildings and other structures that represent a low hazard to human life in the event of failure, including, but not limited to: • Agricultural facilities • Certain temporary facilities • Minor storage facilities	I
All buildings and other structures except those listed in Occupancy Categories I, III and IV	II
Buildings and other structures that represent a substantial hazard to human life in the event of failure, including, but not limited to: • Buildings and other structures where more than 300 people congregate in one area • Buildings and other structures with day care facilities with a capacity greater than 150 • Buildings and other structures with elementary school or secondary school facilities with a capacity greater than 250 • Buildings and other structures with a capacity greater than 500 for colleges or adult education facilities • Healthcare facilities with a capacity of 50 or more resident patients, but not having surgery or emergency Treatment facilities • Jails and detention facilities Buildings and other structures, not included in Occupancy Category IV, with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure, including, but not limited to: • Power generating stations[a] • Water treatment facilities • Sewage treatment facilities • Telecommunication centers Buildings and other structures not included in Occupancy Category IV (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, hazardous waste, or explosives) containing sufficient quantities of toxic or explosive substances to be dangerous to the public if released.	III
Buildings and other structures designated as essential facilities, including, but not limited to: • Hospitals and other healthcare facilities having surgery or emergency treatment facilities • Fire, rescue, ambulance, and police stations and emergency vehicle garages • Designated earthquake, hurricane, or other emergency shelters • Designated emergency preparedness, communication, and operation centers and other facilities required for emergency response • Power generating stations and other public utility facilities required in an emergency • Ancillary structures (including, but not limited to, communication towers, fuel storage tanks, cooling towers, • Electrical substation structures, fire water storage tanks or other structures housing or supporting water, or other fire-suppression material or equipment) required for operation of Occupancy Category IV structures during an emergency • Aviation control towers, air traffic control centers, and emergency aircraft hangars • Community water storage facilities and pump structures required to maintain water pressure for fire suppression • Buildings and other structures having critical national defense functions Buildings and other structures (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, or hazardous waste) containing highly toxic substances where the quantity of the material exceeds a threshold quantity established by the authority having jurisdiction.	IV

[a] Cogeneration power plants that do not supply power on the national grid shall be designated Occupancy Category II

Annex (2)

② [Zone] Dhaka falls under Zone2.
BNBC Part6 Chapter2 2.5.4.2

2.5.4.2 Seismic zoning

The intent of the seismic zoning map is to give an indication of the Maximum Considered Earthquake (MCE) motion at different parts of the country. In probabilistic terms, the MCE motion may be considered to correspond to having a 2% probability of exceedance within a period of 50 years. The country has been divided into four seismic zones with different levels of ground motion. Table 6.2.14 includes a description of the four seismic zones. Figure 6.2.24 presents a map of Bangladesh showing the boundaries of the four zones. Each zone has a seismic zone coefficient (Z) which represents the maximum considered peak ground acceleration (PGA) on very stiff soil/rock (site class SA) in units of g (acceleration due to gravity). The zone coefficients (Z) of the four zones are: Z=0.12 (Zone 1), Z=0.20 (Zone 2), Z=0.28 (Zone 3) and Z=0.36 (Zone 4). Table 6.2.15 lists zone coefficients for some important towns of Bangladesh. The most severe earthquake prone zone, Zone 4 is in the northeast which includes Sylhet and has a maximum PGA value of 0.36g. Dhaka city falls in the moderate seismic intensity zone with Z=0.2, while Chittagong city falls in a severe intensity zone with Z=0.28.

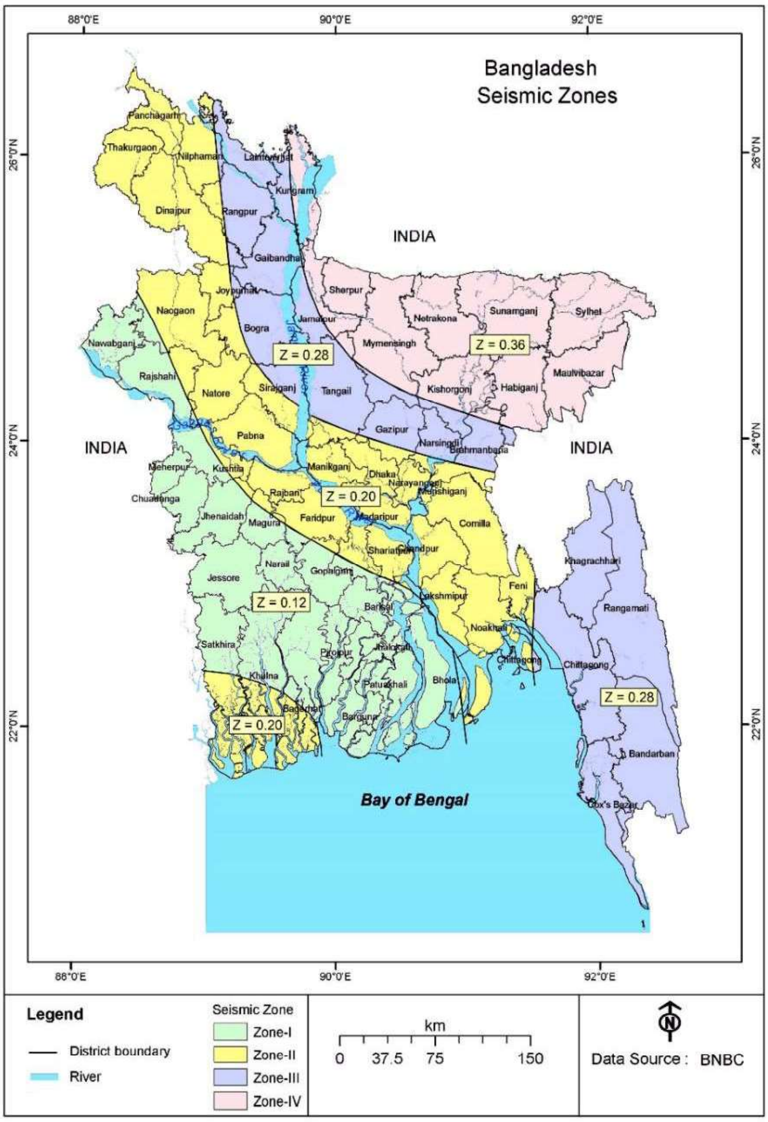


Figure 6.2.24 Seismic zoning map of Bangladesh

Annex (3)

③ [Site Class] Classified based on soil properties.

BNBC Part6 Chapter2 2.5.3.2

2.5.3.2 Site classification

Site will be classified as type SA, SB, SC, SD, SE, S_1 and S_2 based on the provisions of this Section. Classification will be done in accordance with Table 6.2.13 based on the soil properties of upper 30 meters of the site profile. Average soil properties will be determined as given in the following equations:

$$\bar{V}_s = \sum_{i=1}^{n} d_i / \sum_{i=1}^{n} \frac{d_i}{V_{si}} \qquad (6.2.31)$$

$$\bar{N} = \sum_{i=1}^{n} d_i / \sum_{i=1}^{n} \frac{d_i}{N_i} \qquad (6.2.32)$$

$$\bar{S}_u = \sum_{i=1}^{k} d_{ci} / \sum_{i=1}^{k} \frac{d_{ci}}{s_{ui}} \qquad (6.2.33)$$

Where,

n = Number of soil layers in upper 30 m

d_i = Thickness of layer i

V_{si} = Shear wave velocity of layer i

N_i = Field (uncorrected) Standard Penetration Value for layer i

k = Number of cohesive soil layers in upper 30 m

d_{ci} = Thickness of cohesive layer i

s_{ui} = Undrained shear strength of cohesive layer i

The site profile up to a depth of 30 m is divided into n number of distinct soil or rock layers. Where some of the layers are cohesive, k is the number of cohesive layers. Hence $\sum_{i=1}^{n} d_i = 30$ m, while $\sum_{i=1}^{k} d_{ci} < 30$ m if $k < n$ in other words if there are both cohesionless and cohesive layers. The standard penetration value N as directly measured in the field without correction will be used.

The site classification should be done using average shear wave velocity $\bar{V}_s$ if this can be estimated, otherwise the value of $\bar{N}$ may be used.

Following is the summary of Table 6.2.13.

Earthquake Load: Site Class

Site Class	Description	Avg. Shear wave Vel	Avg. SPT	Avg. Undrained Shear Strength
SA	Rock like	>800	---	---
SB	Very dense sand or very stiff clay	360-800	>50	>250
SC	Dense or medium dense sand or stiff clay	180-360	15-50	70-250
SD	Loose to medium dense sand or soft to firm clay	<180	<15	<70
SE	SC or SD underlain by stiffer material V_s>800	---	---	---
S_1	Soft soil with PI>40	<100	---	10-20
S_2	Liquefiable sand or sensitive clay etc.	---	---	---

Annex (4)

④ Seismic Design Category (SDC) is determined by [Occupancy Category], [Zone], and [Site Class].

e.g. When [Occupancy Category＝Ⅱ], [Zone＝2], [Site Class＝SD], SDC = D.

BNBC Part6 Chapter2 2.5.5.2

2.5.5.2 Seismic design category

Buildings shall be assigned a seismic design category among B, C or D based on seismic zone, local site conditions and importance class of building, as given in Table 6.2.18. Seismic design category D has the most stringent seismic design detailing, while seismic design category B has the least seismic design detailing requirements.

Following is the summary of Table 6.2.18 (BNBC Part6 Chapter2 2.5.5.2)

Seismic Design Category

Site Class	Occupancy Category I, II and III			
	Zone 1	Zone 2	Zone 3	Zone 4
SA	B	C	C	D
SB	B	C	D	D
SC	B	C	D	D
SD	C	D	D	D
SE, S_1, S_2	D	D	D	D

Annex (5)

⑤ Type of Structural Systems (with height limit) is determined by SDC.

e.g., When SDC D, choose one of the followings.

- A. BEARING WALL SYSTEMS, 1. Special RC shear walls
- B. BUILDING FRAME SYSTEMS, 5. Special RC shear walls
- C. MOMENT RESISTING FRAMES, 4. RC SMF
- D. DUAL SYSTEMS: SMF, 3. Special RC shear walls
- E. DUAL SYSTEMS: IMF, 2. Special RC shear walls

BNBC Part6 Chapter2 2.5.5.4

2.5.5.4 Type of structural systems

The basic lateral and vertical seismic force–resisting system shall conform to one of the types A to G indicated in Table 6.2.19. Each type is again subdivided by the types of vertical elements used to resist lateral seismic forces. A combination of systems may also be permitted as stated in Sec 2.5.5.5.

The structural system to be used shall be in accordance with the seismic design category indicated in Table 6.2.18. Structural systems that are not permitted for a certain seismic design category are indicated by "NP". Structural systems that do not have any height restriction are indicated by "NL". Where there is height limit, the maximum height in meters is given.

The response reduction factor, R, and the deflection amplification factor, C_d indicated in Table 6.2.19 shall be used in determining the design base shear and design story drift. The selected seismic force-resisting system shall be designed and detailed in accordance with the specific requirements for the system.

Seismic force resisting systems that are not given in Table 6.2.19 may be permitted if substantial analytical and test data are submitted that establish the dynamic characteristics and demonstrate the lateral force resistance and energy dissipation capacity to be equivalent to the structural systems listed in Table 6.2.19 for equivalent response modification coefficient, R, and deflection amplification factor, C_d values.

Following is the summary of Table 6.2.19 (BNBC Part6 Chapter2 2.5.5.4)

R, Cd and Height Limitations

Structural System	R	C_d	SDC B	SDC C	SDC D
			Height Limit (m)		
A. BEARING WALL SYSTEMS					
1. Special RC shear walls	5	5	NL	NL	50
2. Ordinary RC shear walls	4	4	NL	NL	NP
B. BUILDING FRAME SYSTEMS					
5. Special RC shear walls	6	5	NL	NL	50
6. Ordinary RC shear walls	5	4.25	NL	NL	NP
C. MOMENT RESISTING FRAMES					
4. RC SMF	8	5.5	NL	NL	NL
5. RC IMF	5	4.5	NL	NL	NP
6. RC OMF	3	2.5	NL	NP	NP
D. DUAL SYSTEMS: SMF					
3. Special RC shear walls	7	5.5	NL	NL	NL
4. Ordinary RC shear walls	6	5	NL	NL	NP
E. DUAL SYSTEMS: IMF					
2. Special RC shear walls	6.5	5	NL	NL	50
4. Ordinary RC shear walls	5.5	4.5	NL	NL	NP
F. DUAL SHEAR WALL-FRAME : RC OMF AND ORDINARY RC SHEAR WALL	4.5	4	NL	NL	NP

Notes:

Seismic design category, NL = No height limit, NP = Not permitted. Number represents maximum allowable Height (m).

Annex (6)

⑥ There are requirements by each SDC (for concrete to be used, rebar strength and detailing).

Seismic Detailing

- SDC D structures shall satisfy the requirements of special seismic detailing as given in Sections 8.3.3 to 8.3.8
- SDC C structures shall be built to satisfy the requirements of intermediate seismic detailing as given in Sec 8.3.10
- SDC B structures shall be built to satisfy the requirements of ordinary detailing as given in Sec 8.3.9

◆Following is the definition of “standard hooks”.

general	BNBC Part6 Chapter8

8.1.2.1 Standard hooks

The term "standard hook" as used in this Code shall mean one of the following:

(a) 180° bend plus an extension of at least 4 bar diameters, but not less than 65 mm at the free end of the bar.

(b) 90° bend plus an extension of at least 12 bar diameters at the free end of the bar.

(c) For stirrup and tie anchorage

(i) For 16 mm diameter bar and smaller, a 90° bend plus an extension of at least 6 bar diameters at the free end of the bar,

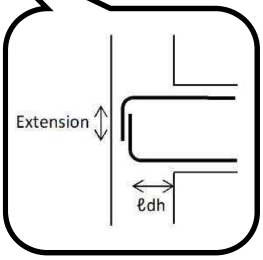
(ii) For 19 mm to 25 mm diameter bars, a 90° bend plus an extension of at least 12 bar diameters at the free end of the bar,

(iii) For 25 mm diameter bar and smaller, a 135° bend plus an extension of at least 6 bar diameters at the free end of the bar,

(iv) For closed ties and continuously wound ties, a 135° bend plus an extension of at least 6 bar diameters, but not less than 75 mm.

(d) Seismic hook is defined as a hook on a stirrup, hoop, or crosstie having a bend not less than 135°, except that circular hoops shall have a bend not less than 90°. Hooks shall have a six-diameter (but not less than 75 mm) extension that engages the longitudinal reinforcement and projects into the interior of the stirrup or hoop.

◆Following is the description of "Development of Reinforcement (in tension)" (ℓd、ℓdh)



general	BNBC Part6 Chapter8

8.2.1 Development of Reinforcement - General

Calculated tension or compression stress in reinforcement at each section of reinforced concrete members shall be developed on each side of that section by embedment length, hook or mechanical device, or a combination thereof. Hooks may be used in developing bars in tension only.

8.2.2 Limitation

The values of $\sqrt{f'_c}$ used in Sec 8.2 shall not exceed 8.3 MPa. In addition to requirements stated here that affect detailing of reinforcement, structural integrity requirements of Sec 8.1.12 shall be satisfied.

8.2.3 Development of Deformed Bars and Deformed Wires in Tension

8.2.3.1 Development length for deformed bars and deformed wire in tension, l_d shall be determined from either Sec 8.2.3.2 or Sec 8.2.3.3 and applicable modification factors of Sections 8.2.3.4 and 8.2.3.5, but l_d shall not be less than 300 mm.

general	BNBC Part6 Chapter8

8.2.6 Development of Standard Hooks in Tension

8.2.6.1 Development length l_{dh} for deformed bars in tension terminating in a standard hook shall be computed as the product of the basic development length for deformed bars, l_{dh} of Sec 8.2.6.2 below and the applicable modification factor(s) of Sec 8.2.6.3, but l_{dh} shall be not less than $8d_b$ nor less than 150 mm.

8.2.6.2 For deformed bars, l_{dh} shall be $\frac{0.24\psi_e f_y d_b}{\lambda\sqrt{f'_c}}$ with ψ_e taken as 1.2 for epoxy-coated reinforcement, and λ taken as 0.75 for lightweight concrete. For other cases, ψ_e and λ shall be taken as 1.0.

◆Following is the description of lap splices

general	BNBC Part6 Chapter8

8.2.12.2 Lap splices

(a) Lap splices shall not be used for 36 mm diameter bars and larger, except as provided in Sections 8.2.14.2 Chapter 8 and 6.8.8.2.3 Chapter 6.

(b) Lap splices of bundled bars shall be based on the lap splice length required for individual bars within the bundle, increased in accordance with Sec 8.2.5. Individual bar splices within a bundle shall not overlap. Entire bundles shall not be lap spliced.

(c) Bars spliced by noncontact lap splices in flexural members shall not be spaced transversely farther apart than one-fifth the required lap splice length, nor 150 mm.

◆Following is the description of "Development length of bars (in tension) in the SMF" (ℓd、ℓdh)

8.3.7.4 Development length of bars in tension	**SMF**	BNBC Part6 Chapter8

(a) The development length, l_{dh}, for bar sizes 10 mm to 36 mm in diameter with a standard 90° hook shall be not less than (i) $8d_b$, (ii) 150 mm, and (iii) the length required by Eq. 6.8.12.

$$l_{dh} = \frac{f_y d_b}{5.4\sqrt{f_c'}} \qquad (6.8.12)$$

For light-weight concrete, l_{dh} for a bar with a standard 90° hook shall not be less than (i) $10d_b$, (ii) 190 mm, and (iii) 1.25 times the length required by Eq. 6.8.12. The 90° hook shall be located within the confined core of a column or a boundary element.

(b) For bar sizes 10 mm to 36 mm diameter, the development length, l_d for a straight bar shall be not less than (i) 2.5 times the length required by (a) above, if the depth of the concrete cast in one lift beneath the bar does not exceed 300 mm, and (ii) 3.5 times the length required by (a) above, if the depth of the concrete cast in one lift beneath the bar exceeds 300 mm.

(c) Straight bars terminated at a joint shall pass through the confined core of a column or of a boundary member. Any portion of the straight embedment length not within the confined core shall be increased by a factor of 1.6.

◆Following is the provision for concrete strength under exposure conditions.

general	BNBC Part6 Chapter8

8.1.7.8 Corrosive Environments: If a thickness of cover for corrosive environment or other severe exposure conditions greater than the concrete covers specified in Sections 8.1.7.1 to 8.1.7.6 is required, such greater thicknesses shall be specified. For corrosion protection, a specified concrete cover for reinforcement not less than 50 mm for walls and slabs and not less than 65 mm for other members may be used. For precast concrete members a specified concrete cover not less than 40 mm for walls and slabs and not less than 50 mm for other members may be used.

Minimum compressive strength of concrete f_c' for the corrosive environment or other severe exposure conditions shall be 25 MPa with minimum cement of 400 kg per cubic meter. Coarse aggregate shall be 20 mm down well-graded stone chips and fine aggregate shall be coarse sand of minimum FM 2.20.

For any non-structural member like drop wall, railing, fins etc., 12 mm down well graded stone chips may be used as coarse aggregate.

Use of brick chips (khoa) as coarse aggregate is strictly prohibited for the corrosive environment or other severe exposure conditions.

Water cement ratio shall be between 0.4-0.45. Potable water shall be used for all concreting.