APPENDIX II-3-2

Reference manuals of structural design for resilient infrastructure/ public facilities

Preface

Based on the review result of existing guidelines and manuals, etc. in Indonesia, this draft reference manuals were made, aiming at contributing to the concept of strengthening infrastructure and public facilities.

BBB (Build Back Better) is the basic concept of the Project, and its purpose is to recover and reestablish in the region in the short-term stage, and to reinstate regional industry and bring sustainable economic activities back to the disaster damaged region in the mid to long term stage.

It is expected these reference manuals proposed are effectively used in Indonesia during planning and design of infrastructure, so that infrastructure development which contributes to BBB progresses well in the future.

I-3 Countermeasure for Nalodo

* Refer to APPENDIX I-3 Manual for preparing Hazard Maps

I-4 Countermeasure for Flood and Sediment Disaster

* Refer to APPENDIX I-3 Manual for preparing Hazard Maps

I-5 Road Reconstruction

I-5-1 Pavement

I-5-2 Road Reconstruction in Liquefaction Area

I-5-3 Cut Slope

I-5-4 Introduction of Method in Japan

I-5-4-1 Method 1: Ground Improvement with Interlayer Mixing Method

I-5-4-2 Method 2: Porous Concrete

I-5-4-3 Method 3: Chemical Grouting using Sodium Silicate

I-5-4-4 Method 4: Press-in Method

I-5-4-5 Method 5 :Stabilization of Embankment Construction Utilizing Reinforcement with Gravel

I-5-4-6 Method 6: Terra-mesh Reinforced Earth Wall

I-5-4-7 Method Application for the Project

I-6 Bridge Repair and Reinforcement

I-6-1 General Provisions

I-6-2 Investigation

I-6-3 Example of Damage and Deterioration

I-6-4 Repair and Reinforcement: Execution Principle

I-6-5 Repair and Reinforcement Method

I-6-6 References

I-1 Countermeasure for Tsunami[1]

I-1-1 Basic concept of tsunami countermeasure

(1) Target Tsunami

Since tsunami countermeasures require a certain amount of cost, the tsunami to be designed was examined based on the following information. As a result, the tsunami that occurred in September 2018 was selected as the design target tsunami.

- Confirmed tsunami records for the past 100 years and set considering reliability
- Simulation by Japanese researchers indicates scale of Tsunami in 2018 corresponds to high or middle frequency

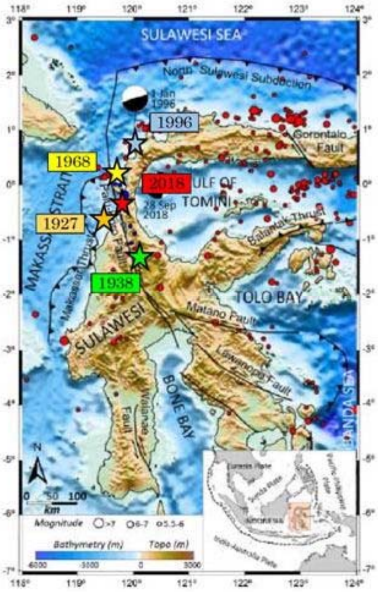


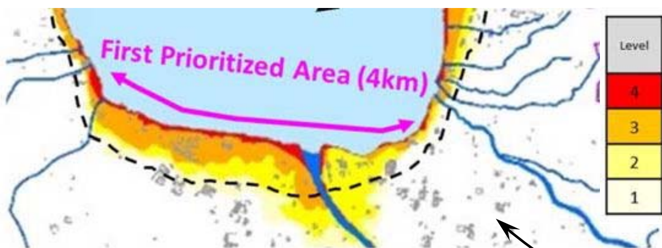
Figure 1 Major earthquakes recorded in Sulawesi

(2) Tsunami Mitigation Strategy

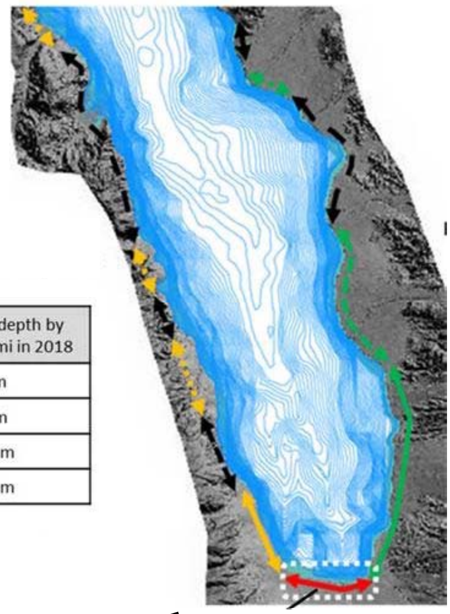
Structural countermeasures, one of the tsunami countermeasures, will be prioritized for a 4 km extension in the Palu bay south, taking into account the distribution of population and assets and the inundation area of the 2018 tsunami (Figure 2).

Terrain characteristics		Flat, wide beach			Narrow beach		
Land use (population)		Low	Medium	High	Low	Medium	High

Applicable countermeasure	Inland forest, Mangrove planting	✓ ✓	✓	✓			---
	Relocation	✓ ✓	✓	✓	✓ ✓	✓	---
	Elevated road		✓	✓ ✓		✓	---
	Building code	✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓	---



Level	Inundation depth by actual tsunami in 2018
4	> 3m
3	1-3m
2	0.3-1m
1	0-0.3m



Source: JICA Experts, JICA Study Team

Figure 2 Selection of priority areas for tsunami countermeasures

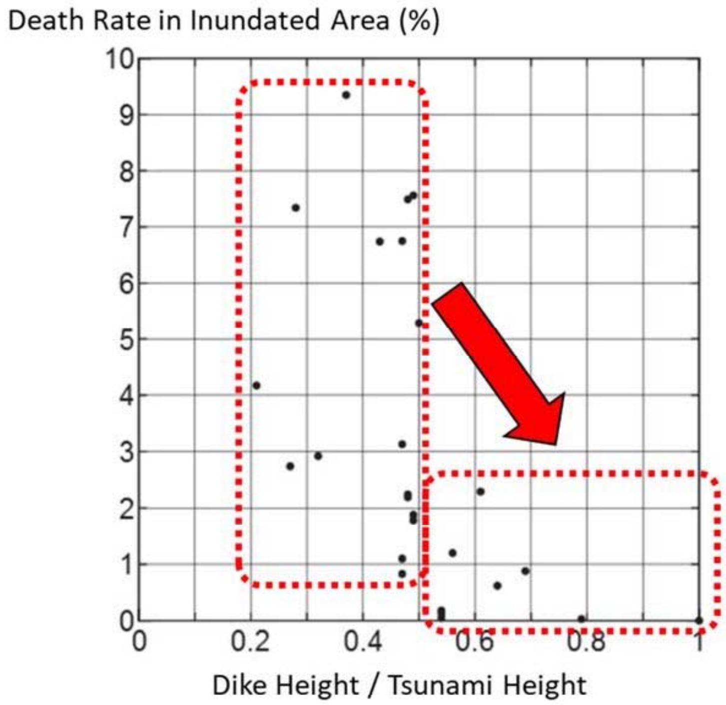
[1] For more detailed data, refer to Appendix II-3-12

Tsunami countermeasures can be roughly divided into two categories: structural countermeasures such as levees and non-structural countermeasures such as evacuation and land use regulations. Since the Meiji era (1868-1912), Japan's tsunami countermeasures have focused on dikes as structural countermeasures, which have not only reduced human casualties but also economic damages (Table 1 Differences in tsunami human suffering in the Sanriku coastal areas of Japan, Figure 3). Based on this experience, and as a result of discussions with the Indonesian side, the tsunami structure countermeasure in Palu Bay was decided to be based on the dike structure.

Table 1 Differences in tsunami human suffering in the Sanriku coastal areas of Japan

	(A) Tsunami in 1896	(B) Tsunami in 2011	(B) / (A)
Magnitude	8.3	9.0	↑
"Number of Dead and Missing" / "Whole Population in Inundated Area"	20.3%	3.6%	↓

Source: Motoyuki Ushiyama and Saki Yokomaku, "Characteristics of Human Damage", Disaster Information, No.10, 2012

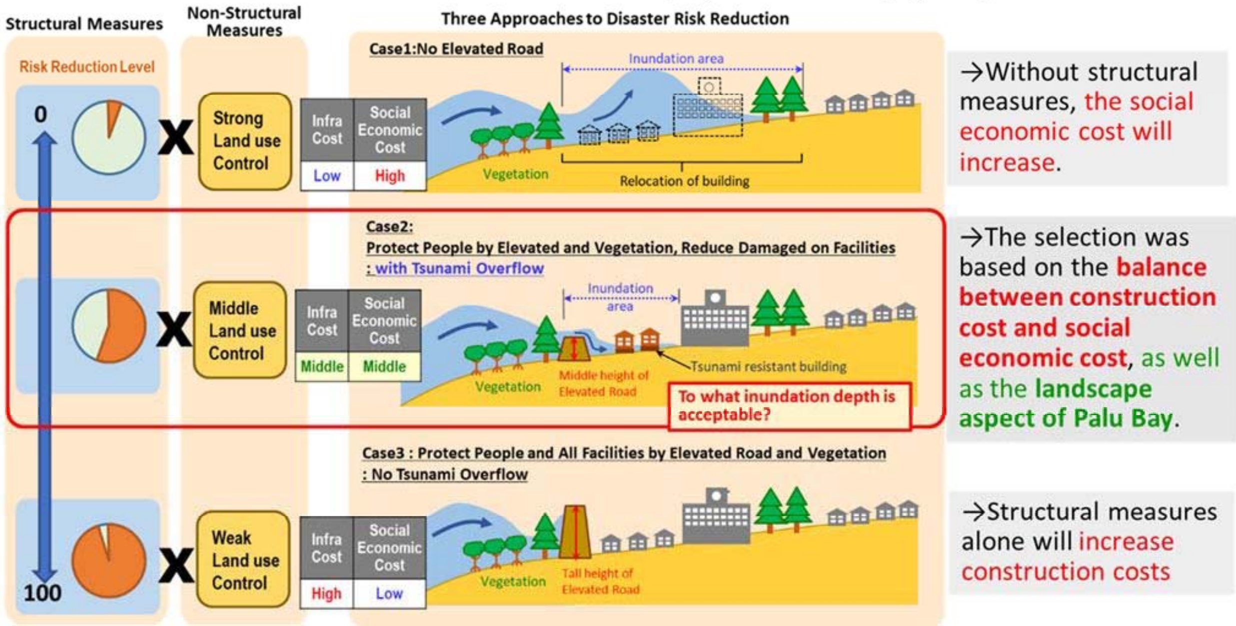


Source: Taro ARIKAWA, Toru NOJI, Hiroaki HIRAANO and Masato ENDO, "Consideration of Seawall Effect on Tsunami Evacuation", Collection of Papers by JSCE, 2016

Figure 3 Relationship between tsunami height, dike height and human damage

(3) Basic policy for tsunami countermeasure

Considering the future occurrence of an earthquake, tsunami and coastal landslide should be taken seriously into account in order to reconstruct the affected coastal areas. In addition to the cost and schedule, the balance between land acquisition and infrastructure development cost has to be carefully examined as well to effectively reconstruct these facilities at the required quality. Countermeasures combined with structural and non-structural measures are proposed as below (Figure 4)

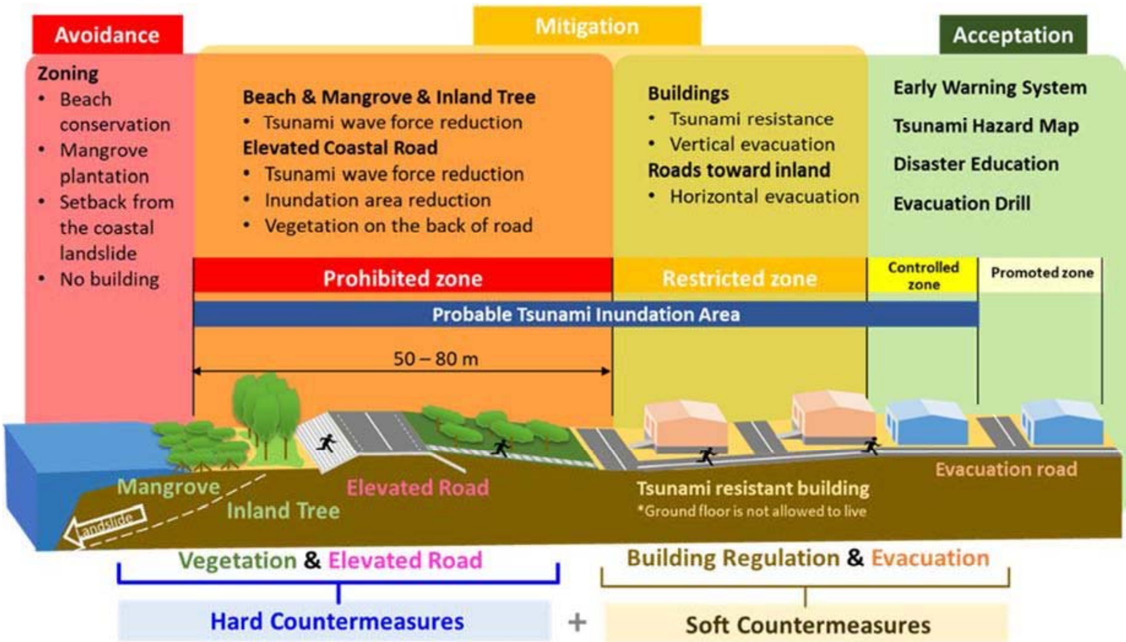


Source: JICA Experts, JICA Study Team

Figure 4 Basic policy for tsunami countermeasure

(4) Multi-layer countermeasure in Palu Bay South

Based on the typical characteristics of Palu Bay South and applicable countermeasures, the following multi-layer countermeasures combined with structural and non-structural measures are selected. Each layer is defined as follows (Figure 5) .



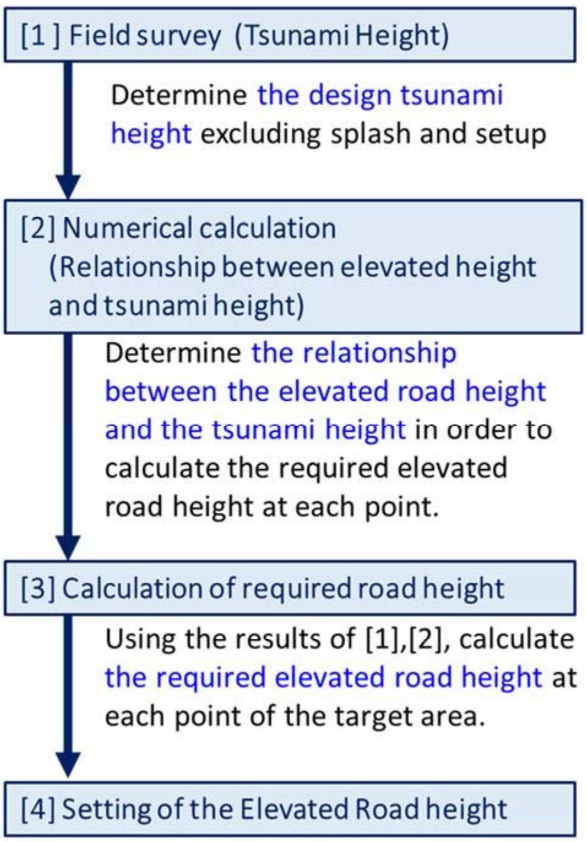
Source: JICA Experts, JICA Study Team

Figure 5 Multi-layer countermeasure in Palu Bay South

- Tsunami Avoidance layer: this layer is defined as an area with beach conservation and mangrove plantation. Setback from the coastal landslide area is needed and no buildings should be built in this area.
- Tsunami Mitigation layer: this layer is defined as a mitigation area. Mangrove shall be planted in order to reduce wave energy and an elevated coastal road shall be constructed with spatial planning and land use control as a part of the multi-layer countermeasure plan.
- Tsunami Acceptation layer: This layer focuses on the organizational preparation for tsunami such as disaster plans, risk maps, early-warning systems, evacuation and medical help.

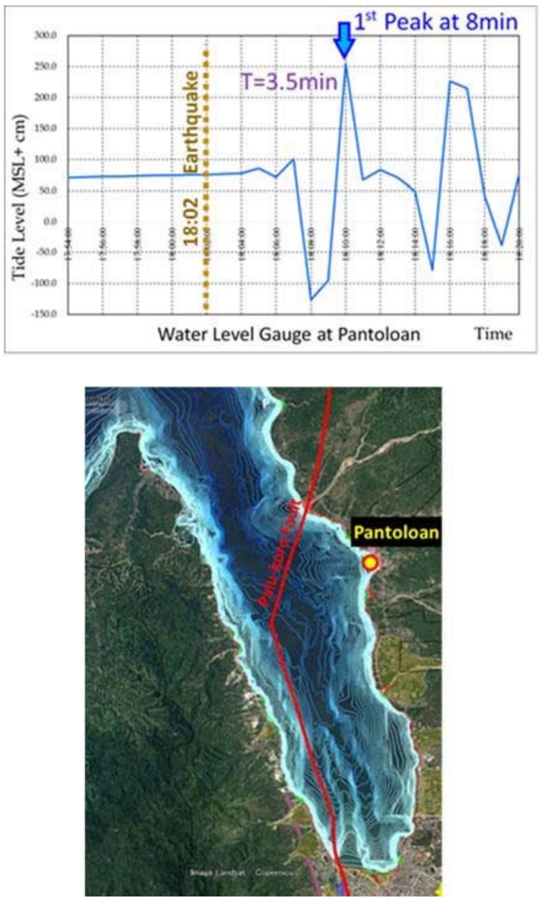
I-1-2 Basic plan of elevated road

The design tsunami height and elevated road height were set according to the following flow (Figure 6). In the numerical analysis of the flow, the tide level data observed at the Pantoloan port in Palu Bay was used.



Source: JICA Study Team

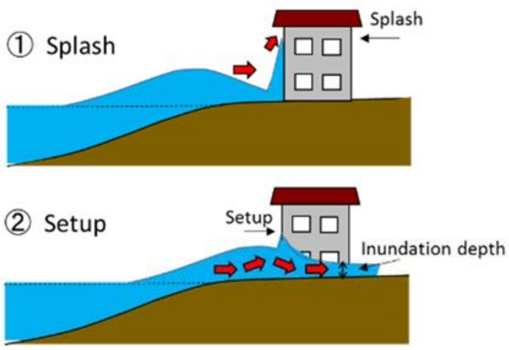
Figure 6 Flow for setting the height of the elevated road



Source: JICA Study Team

Figure 7 Tide level observed at Pantoloan port

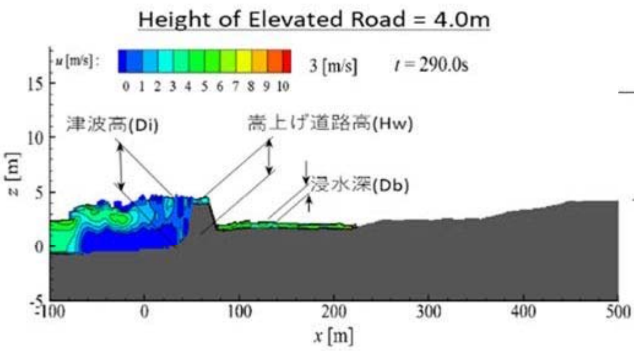
[1]: In the initial tsunami height survey, splashes and setups were included in the measurements. In order to confirm the accurate tsunami heights, the tsunami height survey without them was conducted again.

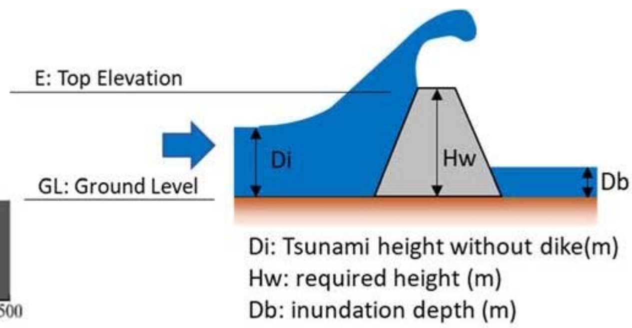


Source: JICA Experts, JICA Study Team

Figure 8 Image of tsunami setup and splash / Situation of tsunami height survey

[2]: The relationship between tsunami height, elevated road height, and inundation depth was confirmed by numerical analysis. Based on the results, the relationship between the elevated road height and the tsunami height was established by deriving the coefficient C, which results in an inundation depth of 1m. Then, using this equation and the tsunami height studied in [1], the required elevated road height is calculated in the next step.

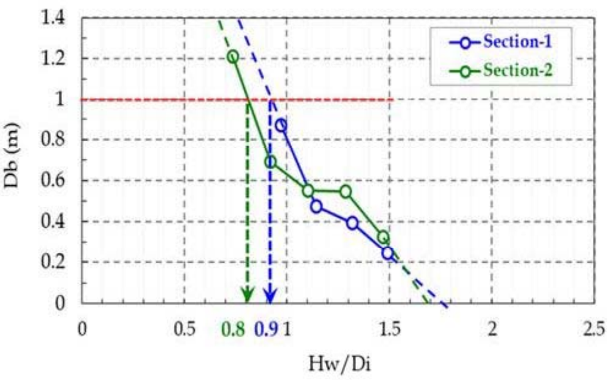




$$H_w = C \cdot D_i$$

Where H_w : required elevated height [m],
C : Coefficient and
D_i : Tsunami depth [m].

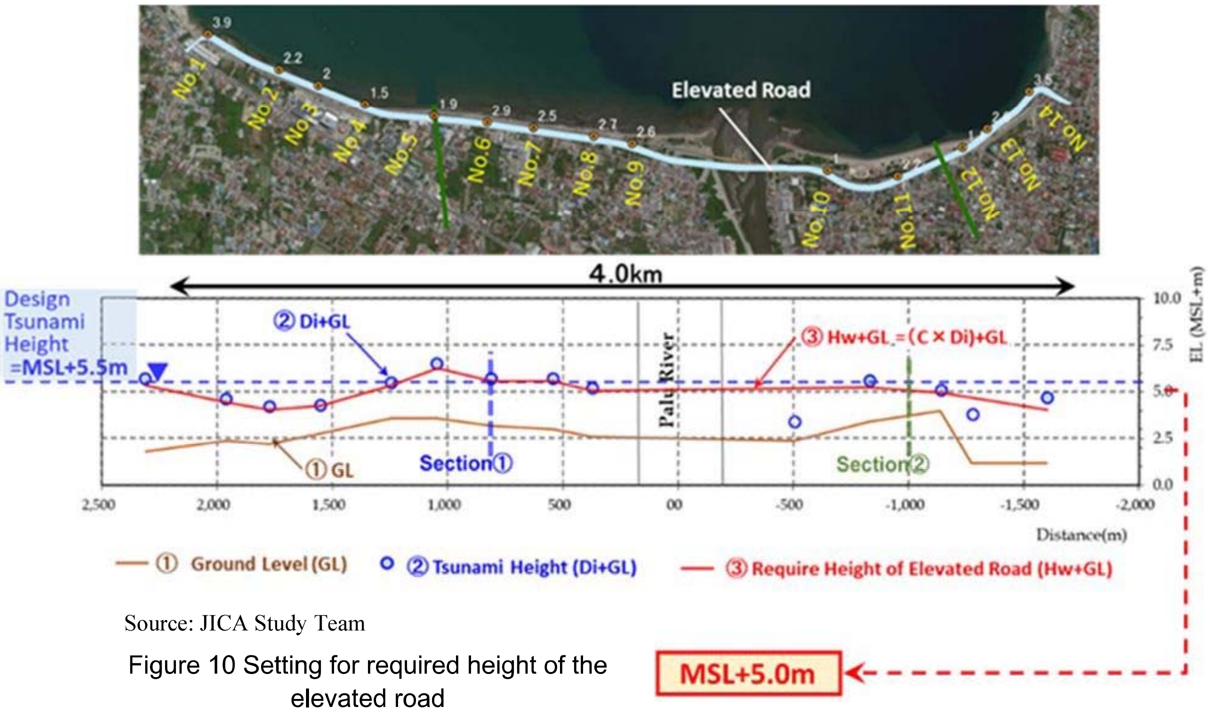
Section No.	C
Section-1	0.91
Section-2	0.80



Source: JICA Experts, JICA Study Team

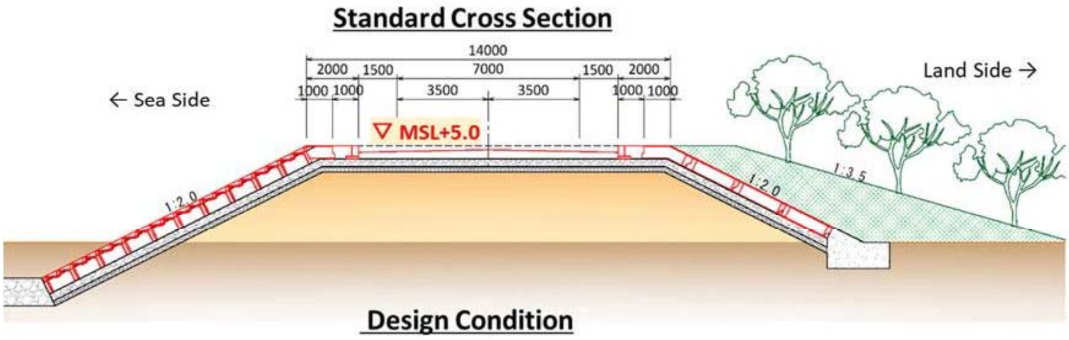
Figure 9 Formulation of tsunami height and elevated road height by numerical analysis

[3] [4]: As a result of the tsunami height survey and numerical analysis, a height of MSL+5.0m was determined as the height of the elevated road needed to keep the inundation depth below 1.0m (Figure 10). Figure 11 shows the standard cross section of the elevated road and the design conditions of the elevated road. It is assumed that this road height can be lowered further if the vegetation in the coastal area planned as a multi-layered defense is expected to have a certain tsunami energy mitigation effect. A summary of the results of the verification of the tsunami energy reduction effect by the vegetation is described in the next section.



Source: JICA Study Team

Figure 10 Setting for required height of the elevated road



Design Condition

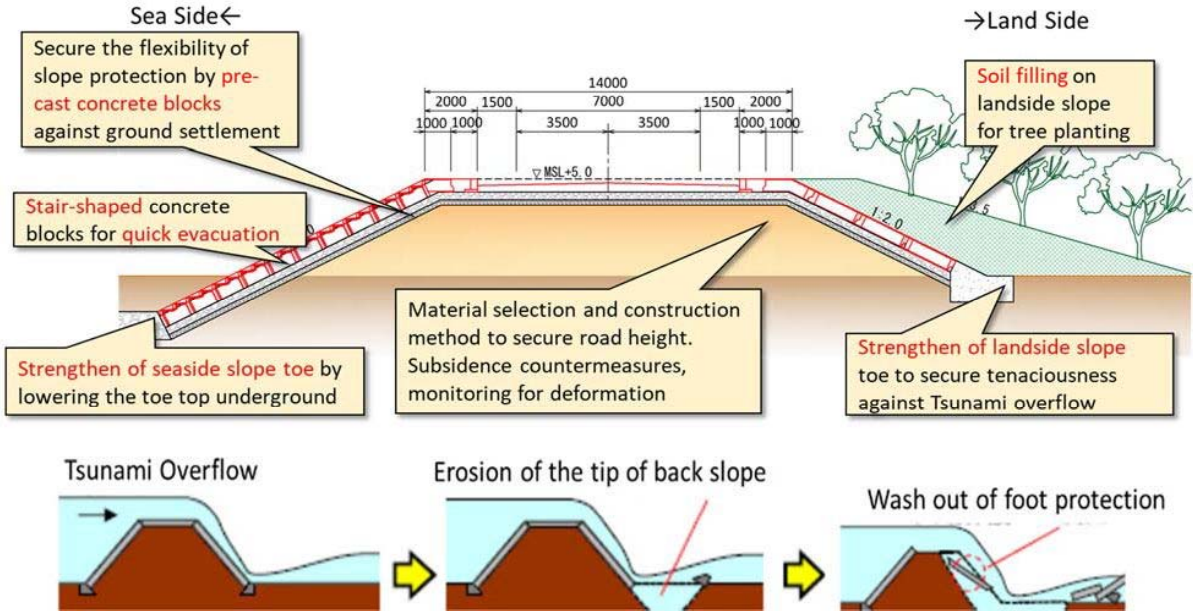
Road Condition		Tsunami Condition	
Road Width	14.0m	Wave Height	MSL+5.5 *
Effective Road Width	10.0m	Wave Period	3.5min *
Road Height	MSL+5.0m	Tide Level	MSL+0.7m *
Length	4.0km	Overflow for Elevated Road	Allow **
Design Speed	60km/h	Inundation Depth	Less than 1.0m **

*: Set based on the 2018 tsunami , **: Basic concept for tsunami countermeasures

Source: JICA Study Team

Figure 11 Cross section and design condition of elevated road

The detailed design of the elevated road will be carried out in the future, and the following figure shows the items that need to be considered in the structure based on the experience of tsunami damage in Japan.

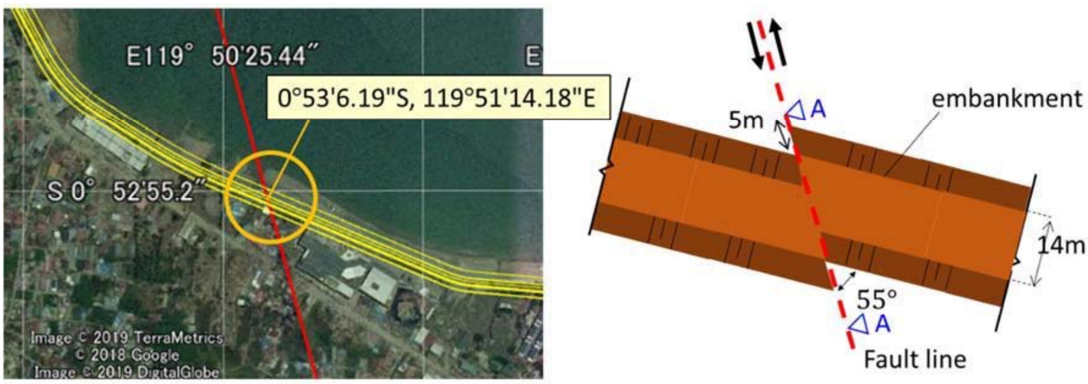


Source: JICA Study Team

Figure 12 Considerations for elevated road structure

I-1-3 Elevated road structure against the earthquake

Elevated coastal road crosses the Palu Koro Fault, therefore, countermeasure against the fault is required. In this project the crest width shall be designed wide enough to cover the distance by fault movement. During last time earthquake the fault has moved about 5m. According to the past study in Japan (TOKIDA Ken-ichi, “Engineering viewpoints on countermeasures for civil engineering structures against surface faulting”, JSCE, No. 752, 2004 and MATSUDA Tokihiko, “Active fault” Iwanami shoten Books, 2000), the ranges of displacements that occurred on the particular active fault line are similar with each time of earthquake. As for the Palu-Koro fault, therefore 5m of maximum horizontal displacement is presumed for structural design purpose, which will be able to be absorbed by 14m crown width of the elevated road.



Source: JICA Study Team

Figure 13 The Palu Koro Fault and distance of movement in the earthquake occurred on Sep, 2018

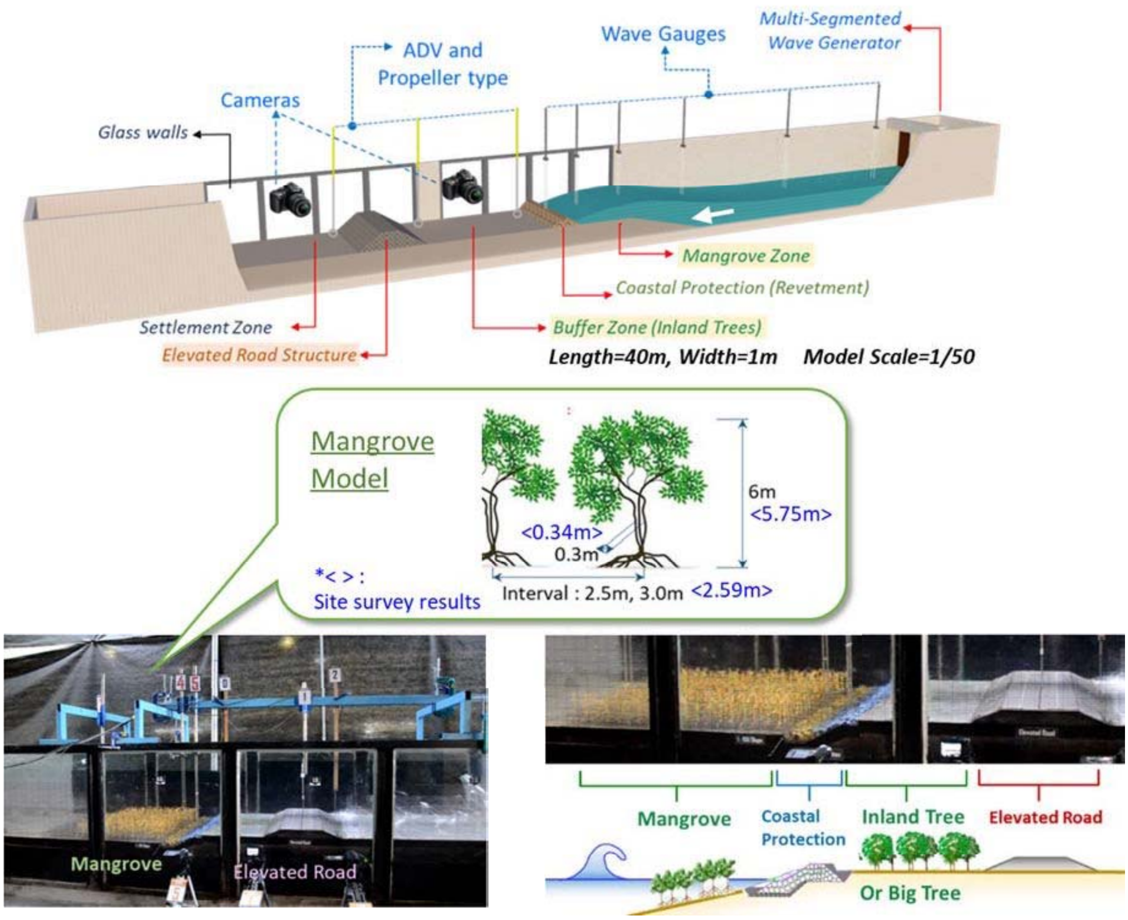
I-1-4 Verification of the tsunami energy reduction effect by the vegetation

The effect of vegetation on tsunami energy reduction was verified by the following two methods.

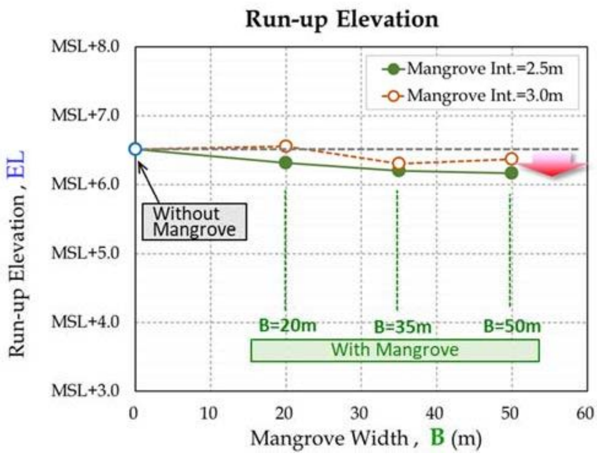
- Method Ⅰ : Physical Model Test : conducted by Balai Pantai Laboratory
- Method Ⅱ : Simulation Analysis : conducted by Prof. Arikawa Laboratory

(1) Method Ⅰ : Physical Model Test

An overview of the hydraulic model experiment is shown in Figure 14. (See Appendix Ⅱ-3-XX for detailed plans and results). The results show that vegetation has a slight effect on tsunami mitigation.



- This graph indicates the results of comparing the run-up elevation in front of the elevated road with and without mangrove.
- Maximum reduction rate of the run-up elevation is about 5%.

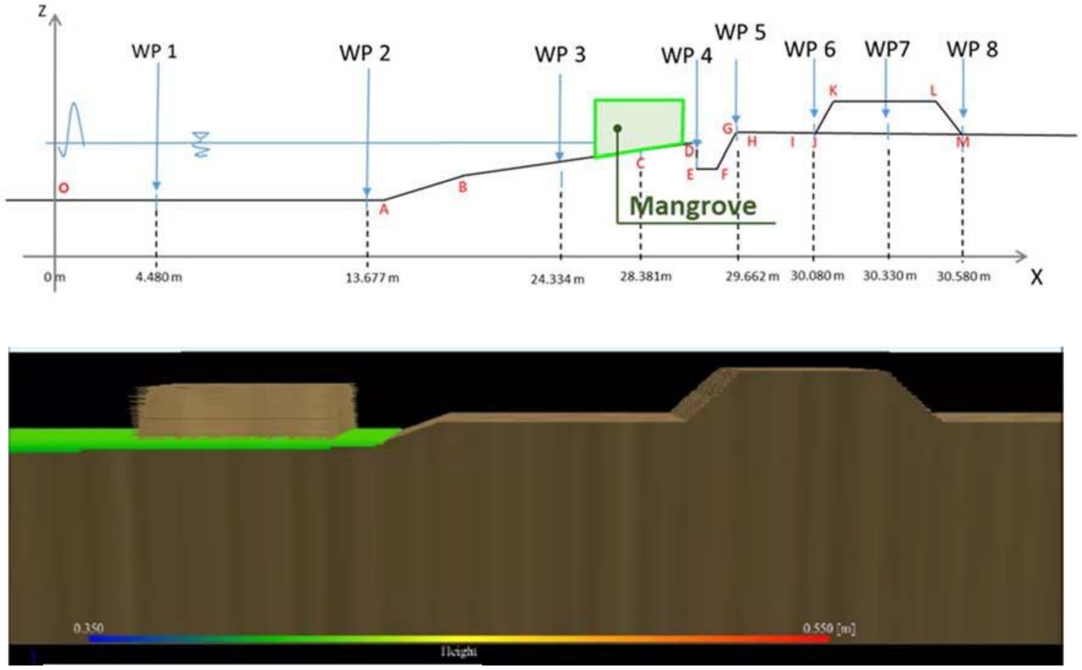


Source: JICA Study Team

Figure 14 Outline of the physical model test

(2) Method II : Simulation Analysis

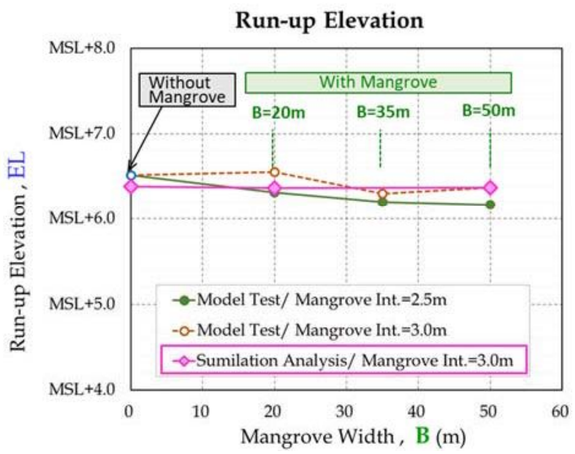
Reproduce the 2018 tsunami wave (wave period is approx. 3.5min) in the simulation analysis and confirm the mitigation effect of mangrove under this condition. Simulation analysis reproducing the wave period of the 2018 tsunami did not show a clear tsunami mitigation effect of mangroves. The impact of the tsunami on the coastal protection was also verified, and the impact was judged to be small based on the analytical values.

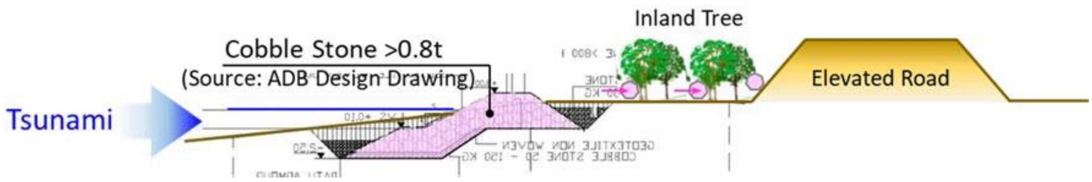


Source: Prof.Arikawa's laboratory

Figure 15 Situation of the simulation analysis

- This graph indicates the results of comparing the run-up elevation in front of the elevated road with and without mangrove.
- An analysis using a tsunami with a longer wave period than the model test did not confirm a clear tsunami mitigation effect by mangroves.





Source: JICA Study Team

Figure 16 Outline of th simulation analysis

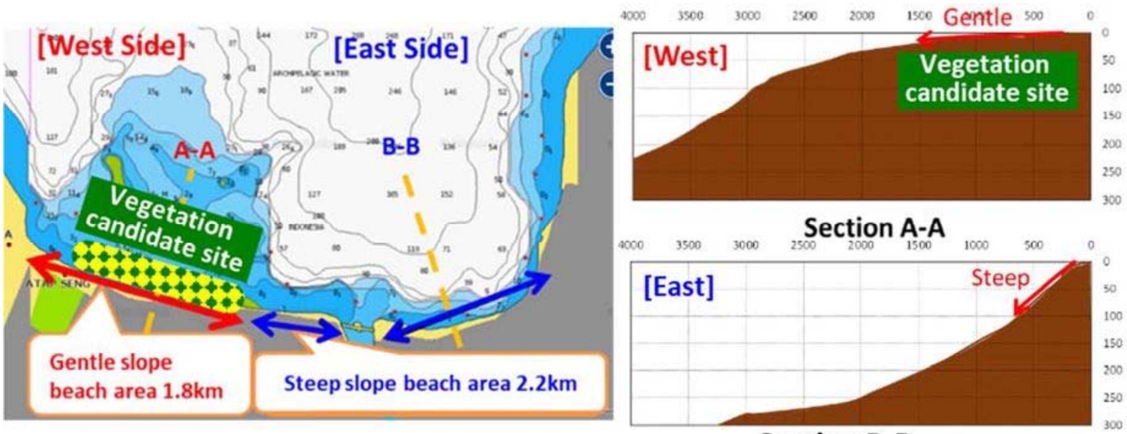
I-1-5 Draft tsunami countermeasure plan for southern Palu Bay

The physical model test and simulation analysis described before did not show a clear tsunami energy reduction effect by vegetation enough to lower the height of the elevated road.

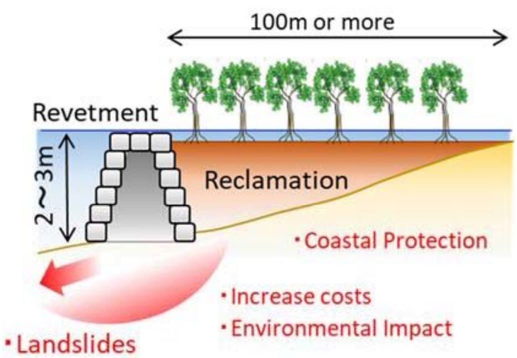
After considering the above results and the various conditions in the Palu bay south, as shown in below (1) to 4)), it was concluded that the height of the elevated road should not be lower than MSL + 5.0m in consideration of the effect of vegetation.

However, it was recommended that vegetation should be planned as much as possible because vegetation can be expected to have effects other than tsunami damage reduction (shown in Table 2).

1) Topographical features : Vegetation cannot be applied to the entire target section due to steep topography. Vegetation limited to the west side, and only about 16% of the tsunami countermeasure extension can secure a mangrove width of 50m or more.
2) Reclamation for vegetation : The reclamation is required to secure a more mangrove area, but it is concerned to further landslides, increased costs, coastal protection and environmental impact.
3) Growth environment : It takes 10 years or more to growing up, and as it is a natural plant, it is affected by various environmental effects such as soil, water depth, waves and so on. Mangrove growth was confirmed only in the northern cove in Palu Bay.
4) Fishing boats : Coordination with local fishing boats is necessary even on the west side of Palu Bay where mangrove vegetation is possible.



1) Topographical features (Steep seabed topography)



2) Concerned to the landslides

3) Severe vegetation environment

Source: JICA Study Team

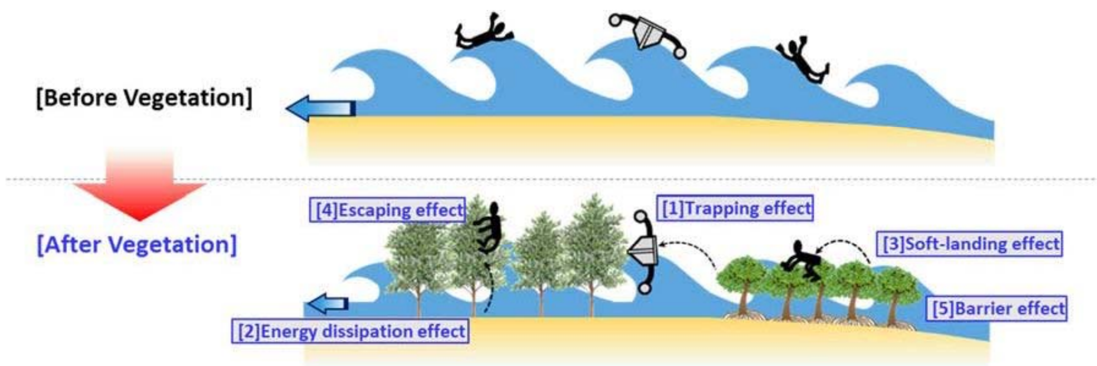
Figure 17 Surrounding conditions in the Palu Bay south

10

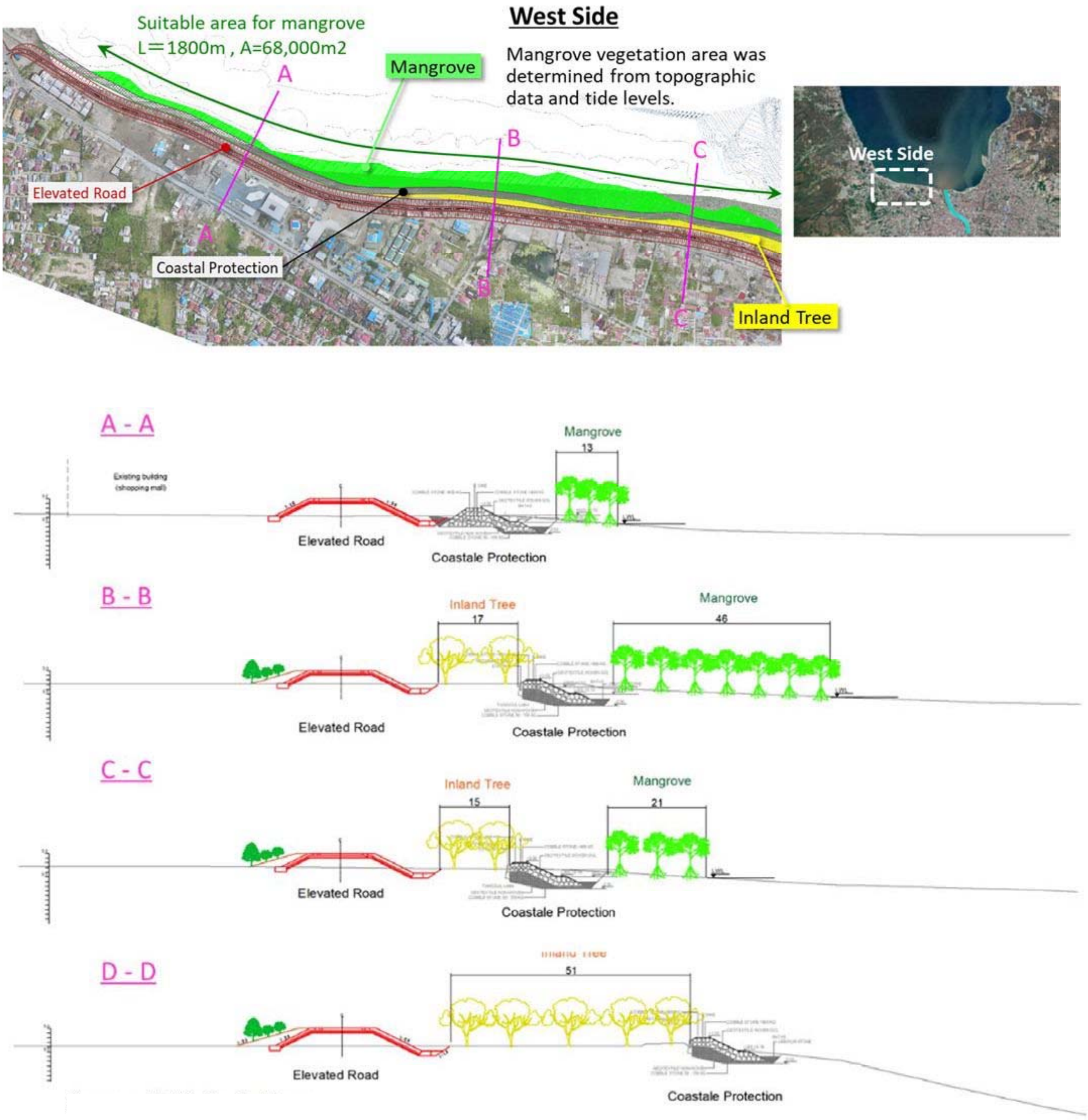
Table 2 Expected effects on vegetation in coastal areas

Vegetation Effect	Contents
[1] Trapping effect	the effect to stop driftwoods (fallen trees, *etc.*), debris (destroyed houses, *etc.*)and other floatage (boats, *etc.*)
[2] Energy dissipation effect	the effect to reduce water flow velocity, flow pressure and inundation water depth
[3] Soft-landing effect	the effect to provide a life-saving means for people to catch tree branches when carried off by tsunamis
[4] Escaping effect	the effect to provide "a way" of escaping by climbing trees from the ground or from the second floor of a building
[5] Barrier effect	the effect to collect wind-blown sand and raise dunes which act as natural barriers against tsunamis
[6] Good landscape effect	the effect to provide a scenic moisture and peace
[7] Habitat environment improvement effect	the effect to providing coastal fauna and flora habitat and breeding environment

Source : ISSN 0386-5878 Technical Note of PWRI No.4177
Planning and Design of TSUNAMI-MITIGATIVE COASTAL VEGETATION BELTS, ICHARM Publication No.18, August 2010

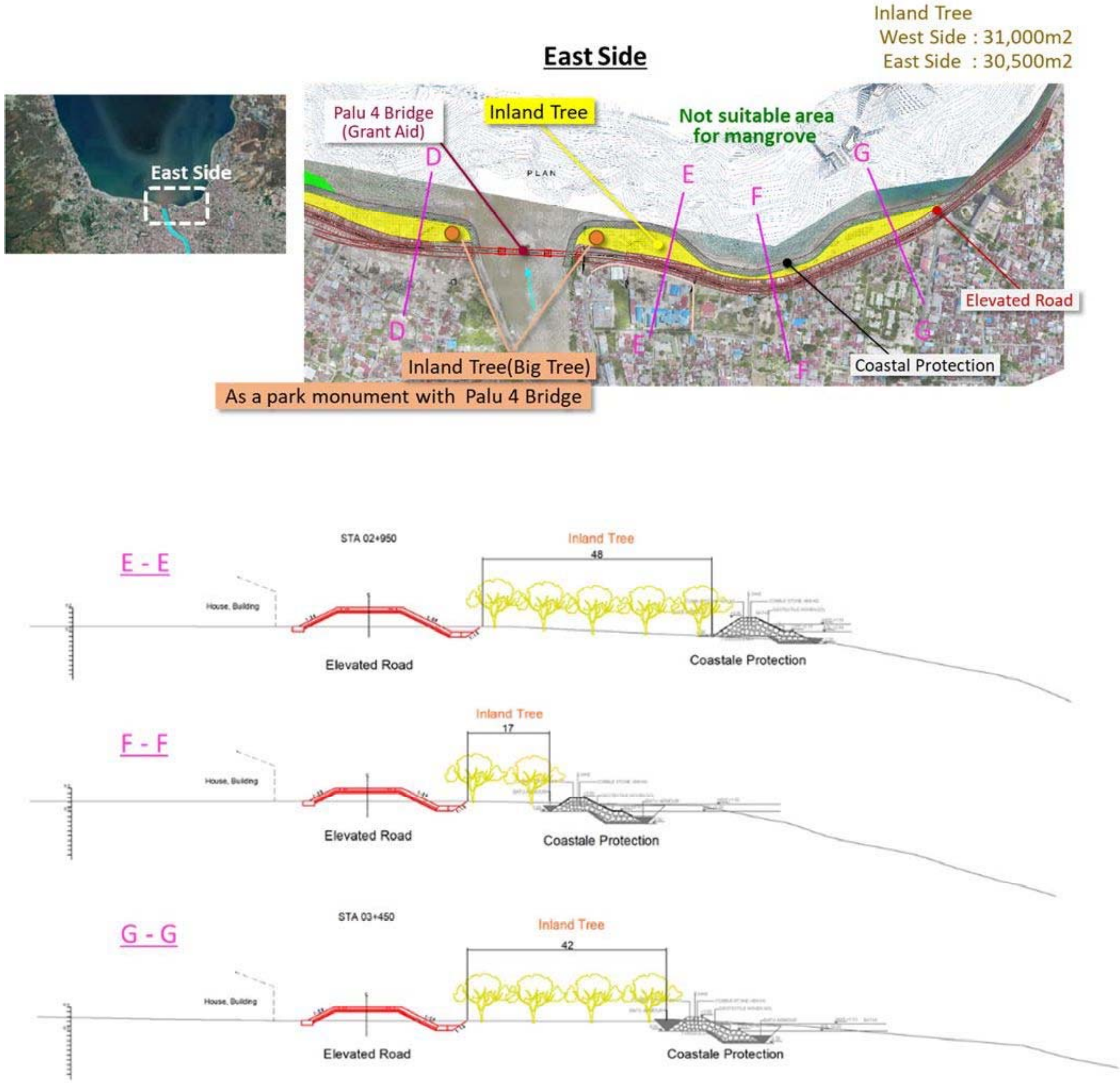


The following figure shows the area where mangroves and Inland trees are expected to grow in the west and east areas of Palu Bay South. This plan is a rough draft, and the vegetation will be studied in detail by the Indonesian side in the future.



Source: JICA Study Team

Figure 18 Proposed vegetation layout plan for Palu Bay south (west side)



Source: JICA Study Team

Figure 19 Proposed vegetation layout plan for Palu Bay south (east side)

Source: JICA Study Team

*Elevated roads, coastal protection and bridge are reproduced from the current plan. Other houses and vegetation are based on the assumed plan.

Figure 20 Reconstruction image of Palu Bay

I-1-6 Tsunami Evacuation Plan

(1) Basic Policy of Evacuation Plan

- The evacuation plan considers two types of tsunamis due to the coastal landslide attributed to an earthquake and fault rupture of earthquake.
- Evacuation plans can be mainly classified into two areas. Palu bay south area where elevated roads are planned and other areas.

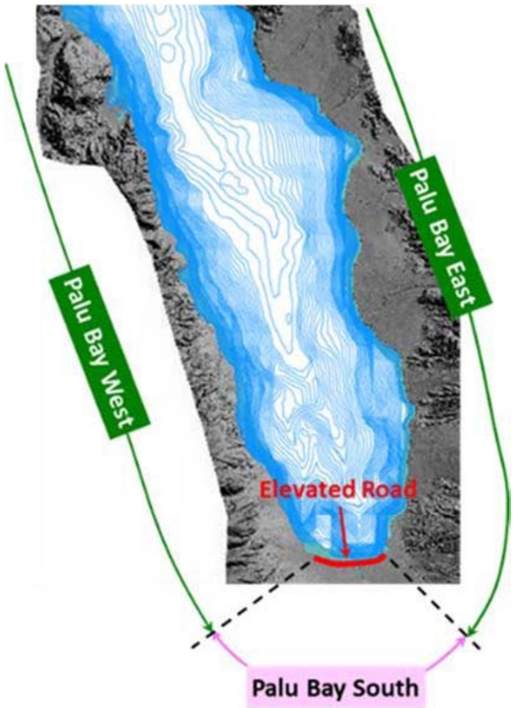
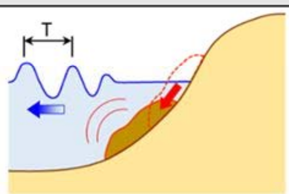
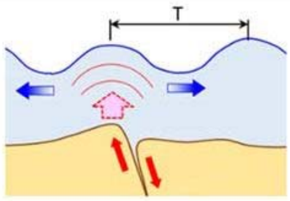


Table 3 Tsunami characteristics to be considered in evacuation planning

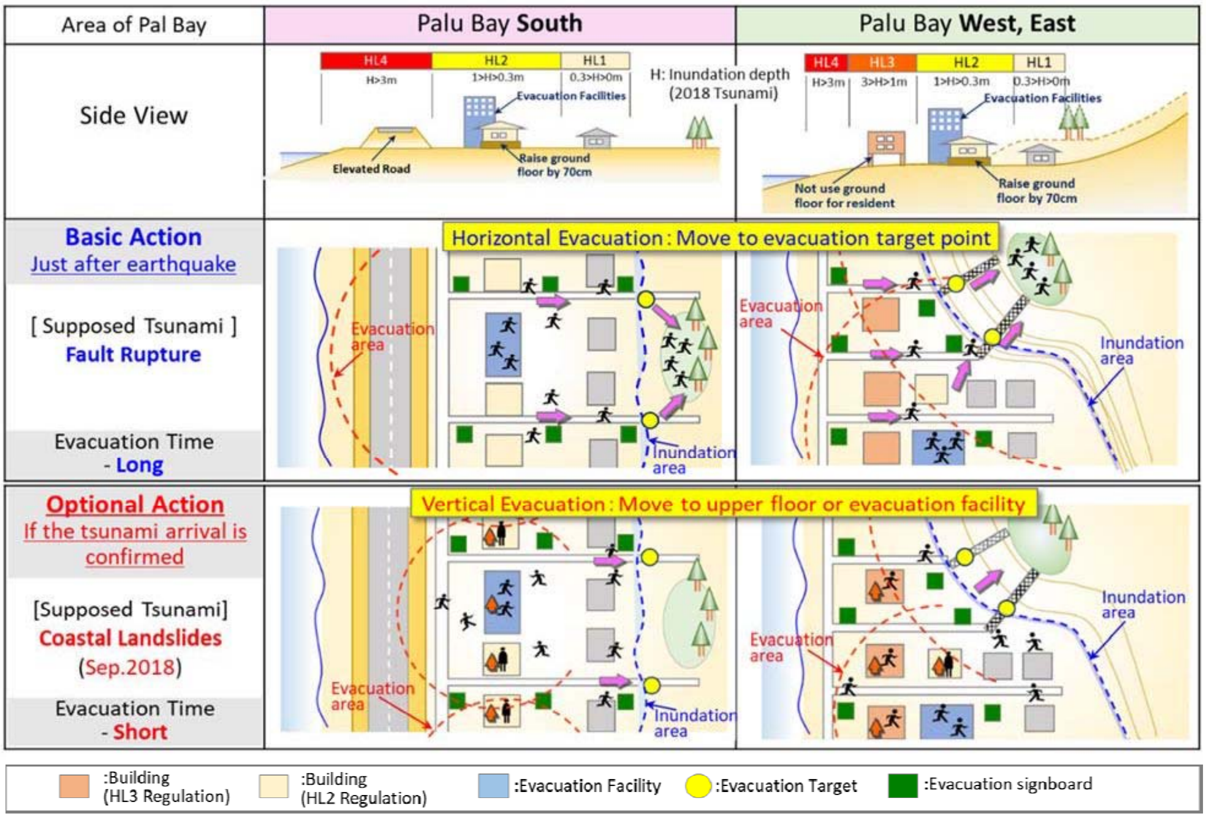
		Couse Image	Wave Length (T)	Tsunami Arrival Time	Evacuation Time
Type of Tsunami	Coastal Landslides (Sep. 2018)		Short	Quick Approx. 5min	Short
	Fault Rupture		Long	Slow Approx. 20min	Long

Source: JICA Study Team

(2) Basic Evacuation Plan [Draft]

As a basic evacuation policy, it was proposed to add vertical evacuation as an option in addition to general horizontal evacuation, taking into account the characteristics of the 2018 tsunami (the evacuation plan including evacuation facilities will be discussed in detail by Indonesia in the future).

Table 4 Basic evacuation plan



Source: JICA Study Team

Source: http://www.town.yoshida.shizuoka.jp/3173.htm , http://www.fj-i.co.jp/tunami2/tawa1.htm

Figure 21 Examples of evacuation facilities

I-1-7 Considerations for future detailed design and construction stage

The following is a list of issues that need to be taken into consideration not only in the detailed design phase but also in the construction and service phases for the elevated road as a tsunami countermeasure.

- Detailed design phase
  - Coordination with vegetation plan and fishing boat mooring plan
  - Coordination with the drainage structure on the inner side of the elevated road
  - (Installation of flap gates at the intersection of the elevated road, etc., as shown in the reference figure)
  - Coordination with the Palu river bank improvement plan and the construction schedule.
  - Coordination with the the Palu 4 bridge project plan and the construction schedule.
  - Coordination with the coastal protection (already constructed)
  - Road surface drainage treatment
  - Slope protection block structure for the elevated road (considering greening, evacuation route, resistance to tsunami, etc., as shown in the reference figure)

- Construction phase
  - Confirmation of the required extra height as a result of settlement investigation by embankment in the detailed design
  - When using locally generated materials for the main body of the raised road, consideration should be given to prevent settlement.
  - In the construction of embankments, the thickness of the embankment and the number of times of compaction should be controlled under appropriate quality control.
  -

- Service phase
  - Confirm the management system and method of the raised road (road, embankment, height, etc.)

* In order for the elevated road to function as a tsunami countermeasure, it is important to maintain the road surface height even after an earthquake.

Source: https://www.nittokasen.co.jp/product/cat05/475/

Figure 23 Example of the flap gate

Source: https://www.nikken-kogaku.co.jp/

Figure 22 Example of slope protection block

I-2 COUNTERMEASURE FOR SEISMIC WAVE FOR BUILDING STRUCTURES

TABLE OF CONTENTS

1. EARTHQUAKE HAZARD

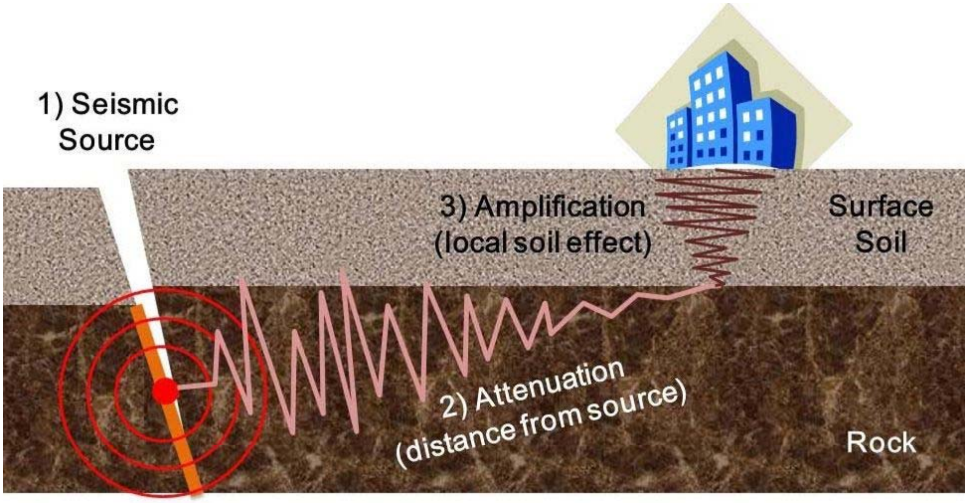


FIGURE 1-1: EARTHQUAKE SHAKING HAZARD

Earthquake hazard (i.e. ground motion or ground shaking) is a combined function of 1) seismic sources, 2) attenuation and 3) soil amplification. Earthquake ground motion (i.e. ground shaking) is generated from seismic sources, attenuated with distance and amplified due to surface soil conditions at local sites. Buildings located closer to seismic sources generally experience stronger ground shaking. In addition, soft soil conditions tend to amplify the ground motion, and therefore careful considerations should be given to the site soil conditions when designing and constructing a building. Soil survey should be performed if existing soil information is not available.

NOTE:

When designing and constructing a building,

- ✧ Check vicinity to seismic sources.
- ✧ Check site soil conditions. Soft soils significantly amplify ground shaking.

1.1. SEISMIC SOURCES

1.1.1. SUBDUCTION ZONES AND ACTIVE FAULTS

Earthquakes are geological phenomena that crustal plates on the surface of the Earth release stress or energy, which has been accumulated due to the movement of plates, i.e. plate tectonics. One major source is originated at the plate boundary, i.e. so-called "Inter-plate" and also known as "Subduction Zone", where typically one plate sinks beneath another plate. When a plate subducts, it drags down the other plates. The dragged plate is then released back, i.e. earthquake occurs, once accumulated stress between the plates exceeds the frictional forces that retain the two plates.

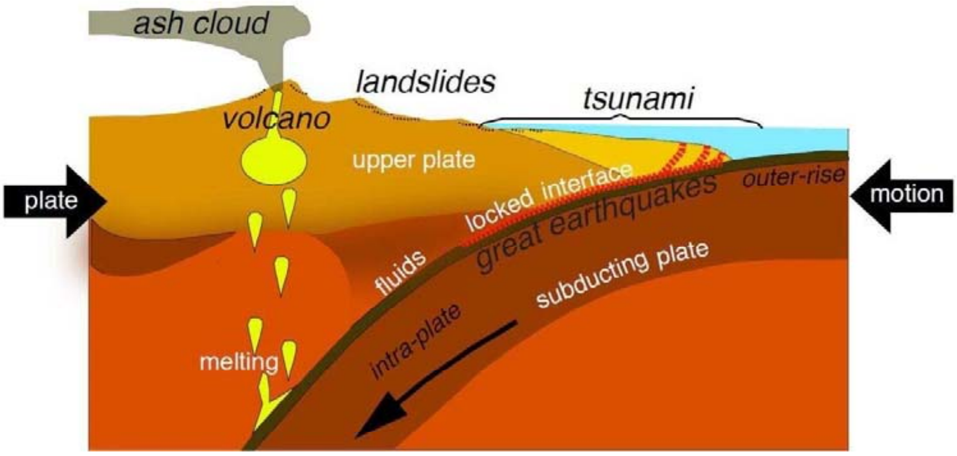


FIGURE 1-2: SCHEMATIC CROSS SECTION OF A TYPICAL SUBDUCTION ZONE (SOURCE: USGS)

An earthquake can also induce tsunami, liquefaction and landslide disasters. Especially major earthquakes in subduction zones often accompany significant tsunamis, since they are typically located along the trenches in the ocean.

> NOTE:
>
> ✧ Earthquakes originated in "Subduction Zones" often generate Tsunamis (e.g. 2004 Sumatra Earthquake and Indian Ocean Tsunami).

Major Subduction Zones affecting Indonesia is summarized in **Figure 1-3**.

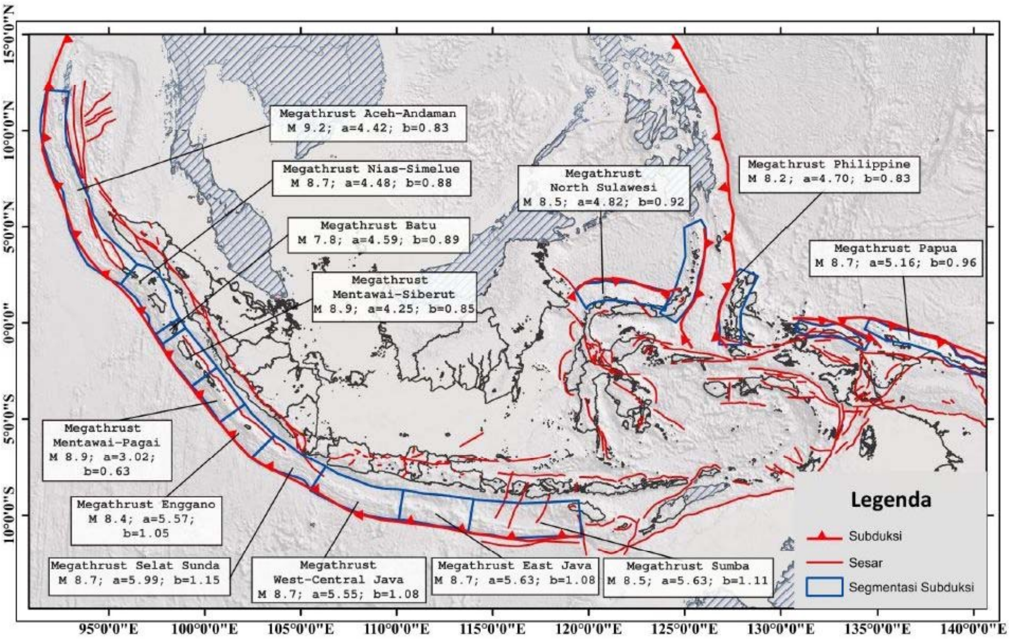


FIGURE 1-3: SUBDUCTION ZONES OF INDONESIA (SOURCE: PETA SUMBER DAN BAHAYA GEMPA INDONESIA TAHUN 2017)

Fault ruptures within the crustal plates, i.e. "Intra-plate", also generate earthquakes. Especially those originated in fault ruptures in shallow depth of continental plates (knows as "Active Faults"), are the other major sources of significant earthquake impacts, since they are typically close to the urbanized areas. There are two types of active faults depending on the direction of fault slip, namely Strike-slip and Dip-slip faults (Strike-slip can be further categorized into Left-lateral and Right-lateral, and Dip-slip into Normal and Reverse).

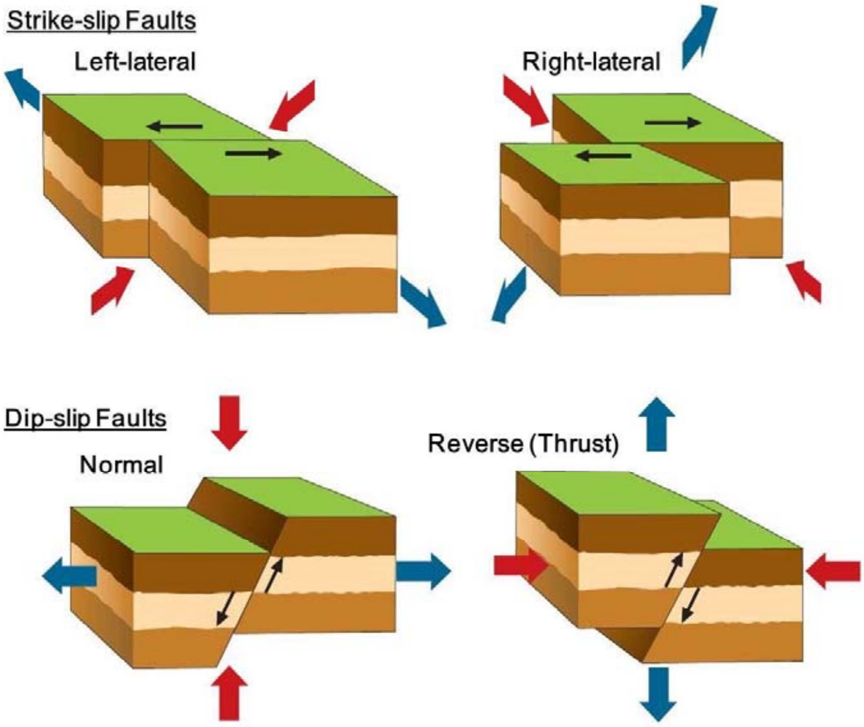


FIGURE 1-4: FAULT TYPES (SOURCE: MINISTRY OF EDUCATION, CULTURE, SPORTS, SCIENCE AND TECHNOLOGY OF JAPAN)

NOTE:

✧ "Active Faults" may exist near high density (populated) areas. Earthquakes originated in "Active Faults" may thus result in significant building damages, especially if buildings are not properly designed and constructed (e.g. 2006 Yogyakarta Earthquake).

1.1.2. MAGNITUDE AND FREQUENCY

Large earthquakes are less frequent and small earthquakes are more frequent. This is known as "Gutenberg–Richter Law", which expresses the relationship between earthquake magnitudes and their frequencies.

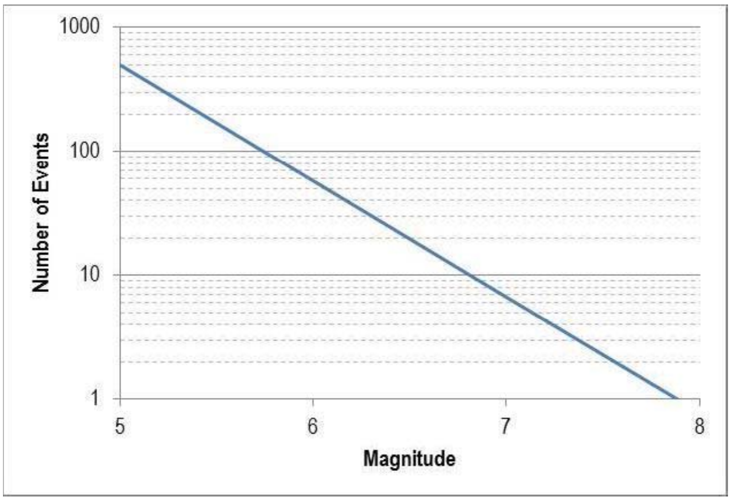


FIGURE 1-5: GUTENBERG RICHTER LAW DRAWN BASED ON EARTHQUAKE RECORDS DURING 1965-1974 IN JAPAN

Although large earthquakes are less frequent, there are number of major earthquakes observed in Indonesia over the last 20 years. The list below summarizes the notable earthquakes that caused significant damage in Indonesia since 1990. Lessons learned derived from these earthquakes indicate that numbers of destroyed houses could have been avoided if they were adequately designed and constructed to be seismic resistant.

TABLE 1-1: MAJOR EARTHQUAKES AND TSUNAMIS IN INDONESIA AFTER 1990 (JICA SURVEY TEAM BASED ON NATURAL HAZARDS VIEWER (NOAA), NATCATSERVICE (MUNICH RE) ETC.)

Earthquake / Tsunami	Date	Eq. Magnitude	Max. Tsunami Height	Deaths/ Missing	Injuries	Houses Destroyed	Houses Damaged	Damage in million USD
Central Sulawesi	2018/09/28	M7.5	10.67m	4,340	4,438	68,451		912
Lombok	2018/07/29 2018/08/05 2018/08/19	M6.4 M7.0 M7.0	- 0.13m -	564	1,886	216,489?		?
Aceh	2016/12/7	M6.5	-	104	600	245	18,752	233
Aceh	2013/07/02	M6.1	-	42	2,500	20,401		?
Indian Ocean	2012/04/11	M8.6/8.2	1m	10	12	?	?	?
Mentawai	2010/10/25	M7.8	7m	431	?	700	?	300
Papua	2010/06/16	M7	-	17	?	2,556		?
Sumatra	2009/09/30	M7.5	0.27m	1,117	1,214	?	181,665	2,200
West Java	2009/09/02	M7	-	81	1,297	?	?	250
Sumatra (Bengkulu)	2007/09/12	M8.4	1m	25	161	56,425		?
Sumatra	2007/03/06	M6.4	-	67	826	43,719		160
Java (Pangandaran)	2006/07/17	M7.7	10m	802	498	1,624	?	55
Yogyakarta	2006/05/27	M6.3	-	5,749	38,568	127,000	451,000	3,100

Earthquake / Tsunami	Date	Eq. Magnitude	Max. Tsunami Height	Deaths/ Missing	Injuries	Houses Destroyed	Houses Damaged	Damage in million USD
Sumatra (Nias-Simeulue)	2005/03/28	M8.6	3m	1,303	340	300	?	200
Indian Ocean	2004/12/26	M9.1	50.9m	167,540	?	?	?	3,000
Papua (Nabire)	2004/11/26	M7.1	-	32	130	328	?	55
Kepulauan Alor	2004/11/11	M7.5	1-2m	34	400	781	16,712	?
Papua (Nabire)	2004/02/05	M7	-	37	682	2678	?	?
Enggano / Bengkulu	2000/06/04	M7.9	-	103	2,174	?	?	6
Central Sulawesi	2000/05/04	M7.6	6m	46	264	10,000		30
Biak	1996/02/17	M8.2	7.7m	164	423	5,043		4.2
Sumatra (Jambi)	1995/10/06	M6.8	-	84	1,868	17,600		?
Java	1994/06/03	M7.8	13.9m	238	423	1,500	?	2.2
Liwa	1994/02/15	M6.9	-	207	2,000	6,000		170
Flores	1992/12/12	M7.8	26.2m	2,500	500	31,785		100

NOTE:

- ✧ Indonesia is prone to earthquake. Buildings must be designed and constructed to be earthquake-resistant.

1.1.3. SEISMIC SOURCE MAP FOR CENTRAL SLAWESI (2017 PUSGEN)

Significant efforts have been made to develop nationwide seismic source maps and hazard maps in Indonesia. The latest source maps and hazard maps were issued in 2017 by PuSGeN (Pusat Studi Gempa Nasional). It represents a comprehensive Probabilistic Seismic Hazard Assessment (PSHA), especially aiming at establishing a basis for seismic design of any civil and building structures. The maps address many different seismic sources (both “Subduction Zones” and “Active Faults”) and probability assessment of each source (i.e. Magnitude-Frequency relationship).

Figure 1-6 shows the seismic sources of Sulawesi. In the north of Sulawesi Island, there is the North Sulawesi Megathrust (“Subduction Zone”). The 2018 Central Sulawesi Earthquake is considered originated from the Palu-Koro fault segments (“Active Faults”). Sulawesi is prone to earthquake and tsunami.

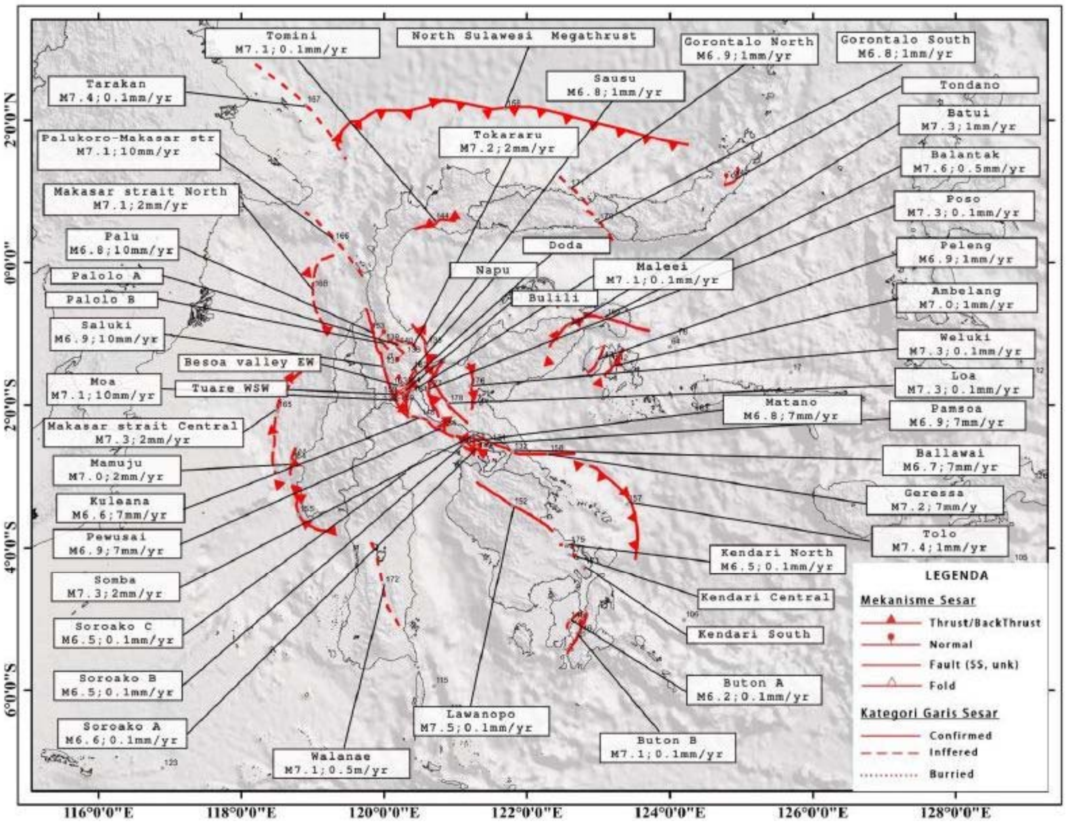


FIGURE 1-6: SEISMIC SOURCES AROUND SULAWESI (SOURCE: PETA SUMBER DAN BAHAYA GEMPA INDONESIA TAHUN 2017)

NOTE:

✧ Sulawesi is also prone to earthquake. Buildings must be designed and constructed to be earthquake-resistant.

1.1.4. 2018 SEPTEMBER 28 CENTRAL SLAWESI EARTHQUAKE

The Central Sulawesi Earthquake on 2018 September 28 of M7.5 occurred along the Palu-Koro Fault zone (see **Figure 1-7** and **Figure 1-8**). Considering the annual slip rate of the Palu-Koro fault (circa 40mm/ year), the calculated recurrence period of this seismic event is approximately 100 years.

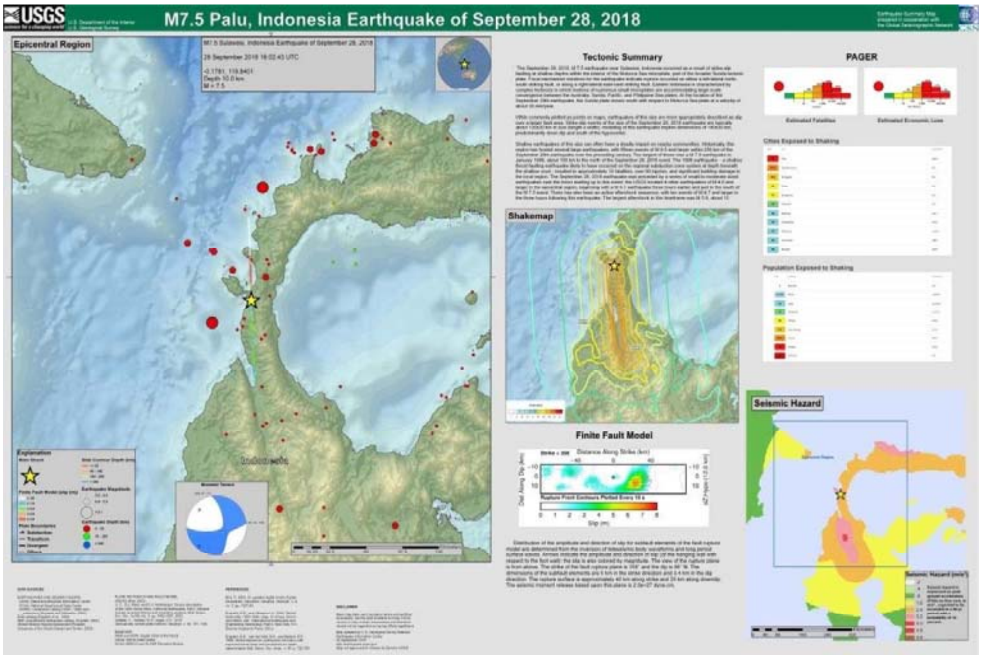


FIGURE 1-7: OUTLINE OF 2018 SEPTEMBER 28 EARTHQUAKE (SOURCE: USGS)

FIGURE 1-8: FAULT SLIP MODEL OF 2018-09-28 EARTHQUAKE (SOURCE: USGS)

The BMKG seismometer in Palu that was just installed before the earthquake with the support of JICA recorded the strong motion of the earthquake (**Figure 1-9**). The observed peak ground acceleration was 281 gal in the East-West direction.

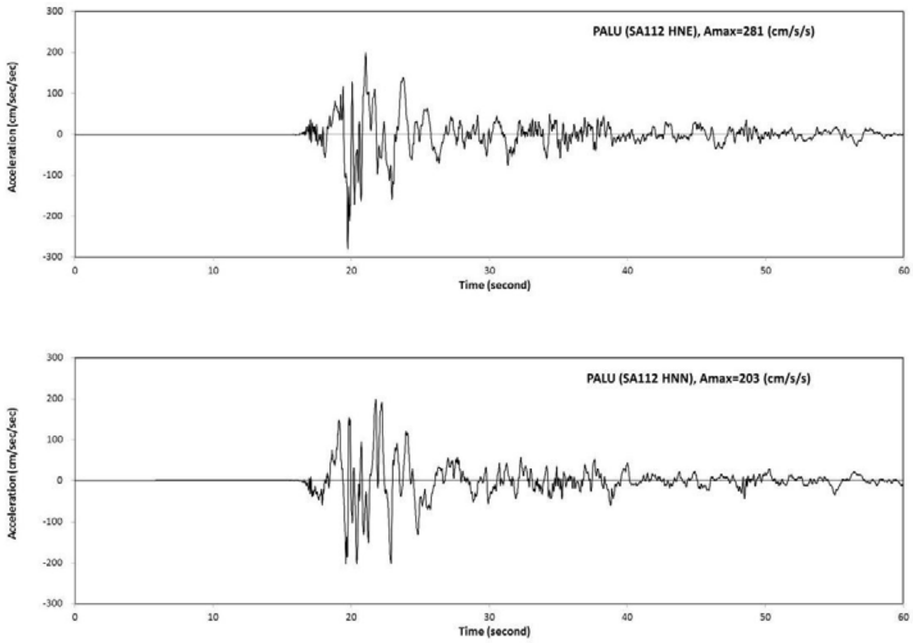


FIGURE 1-9: STRONG MOTION RECORD OF 2018 EARTHQUAKE (ABOVE:EW DIRECTION, BELOW: NS DIRECTION)

Although the observed ground motion records were siginificant, in general they did not exceed the design level defined in the seismic code, i.e. SNI1726:2012 (see **Figure 1-10**). If the buildings had been properly designed and constructed in compliance with the seismic code, there should'nt have been any significant damage.

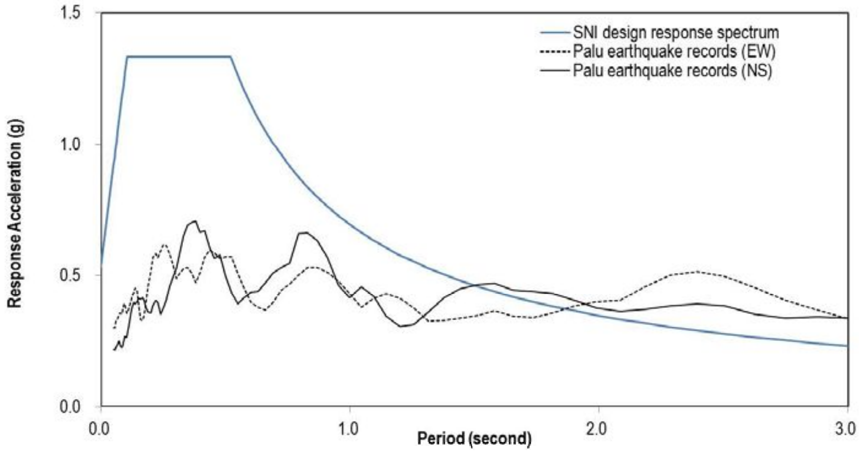


FIGURE 1-10: COMPARISON OF RESPONSE SPECTRUMS (DESIGN BASIS V.S PALU EARTHQUAKE RECORDS

The Central Sulawesi area has been affected by the seismic activities in Palu-Koro fault zones, and therefore this area is prone to earthquake.

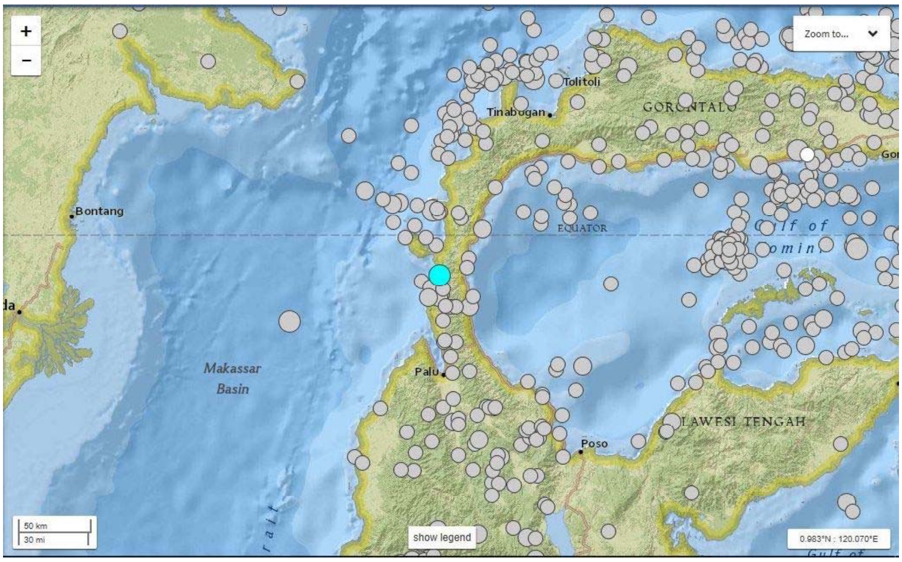


FIGURE 1-11: MAJOR EARTHQUAKES GREATER THAN M5 AROUND PALU (SOURCE: USGS)

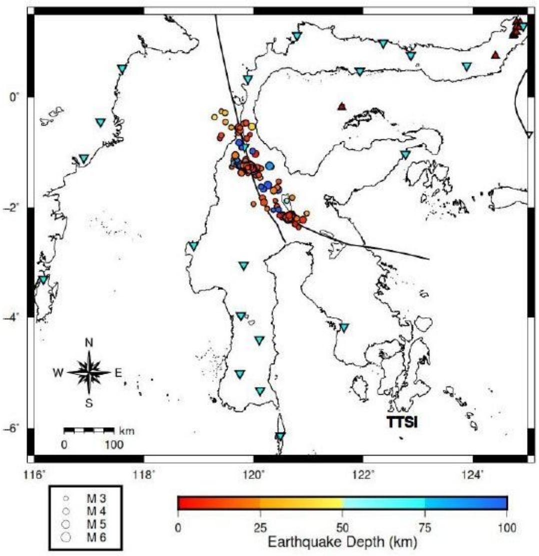


FIGURE 1-12: EARTHQUAKES ALONG PALU-KORO FAULTS (SOURCE: PETA SUMBER DAN BAHAYA GEMPA INDONESIA TAHUN 2017)

NOTE:

✧ Palu, Sigi and Donggala are located on or near the Palu-Koro Fault zone. Buildings must be designed and constructed to be earthquake-resistant according to the seismic code (SNI1726).

1.2. ATTEMUATION

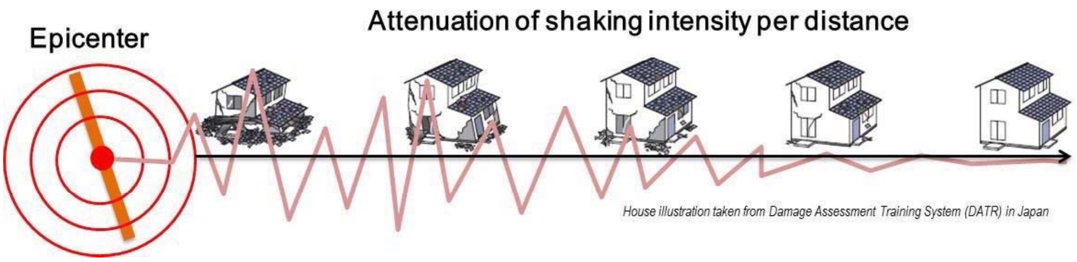


FIGURE 1-13: ATTENUATION OF SHAKING INTENSITY PER DISTANCE

Earthquake "Magnitude" indicates the size of an earthquake. One earthquake normally has one epicenter and one Magnitude (e.g. M7.5). "Shaking Intensity" indicates level of ground shaking at a given location. There are many different intensity scales used in the world (e.g. MMI = VII, PGA = 200gal, JMA Intensity = 5 Lower). One earthquake causes multiple Shaking Intensities at different locations affected by the earthquake. Shaking intensities are typically more significant in the areas near the epicenter, and decrease (i.e. attenuate) with distance from the epicenter.

There are several Shaking Intensity Scales used in the world. **Figure 1-14** and **Figure 1-15** show the JMA Seismic Intensity Scale. **Table 1-2** and **Figure 1-16** are the Modified Mercali Intensity (MMI) Scale, widely used all over the world and in Indonesia as well. **Figure 1-17** shows the Indonesia Earthquake Scale proposed by BMKG.

FIGURE 1-14: JMA SEISMIC INTENSITY SCALE (JAPAN METEOROLOGICAL AGENCY)

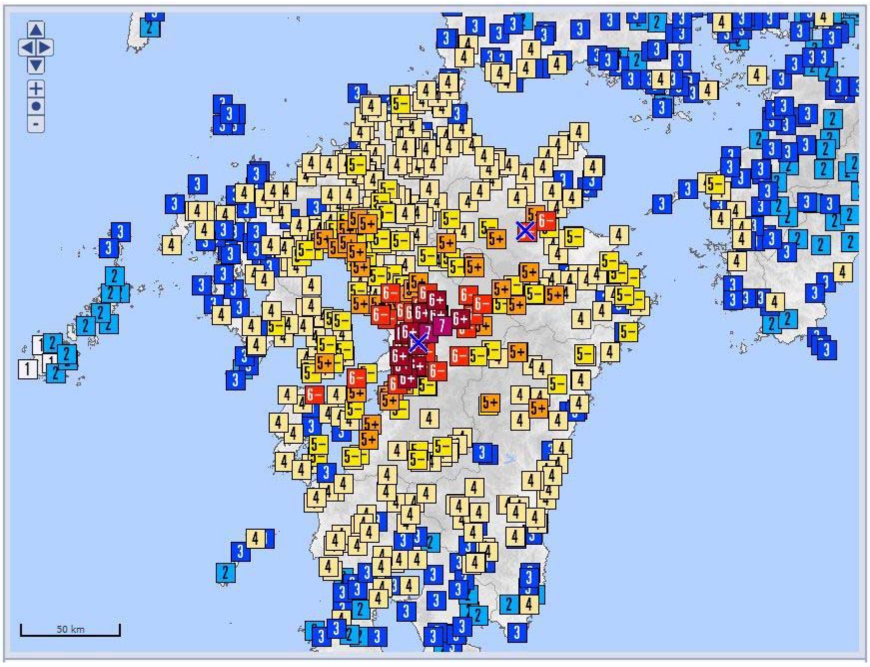


FIGURE 1-15: JMA SEISMIC INTENSITIES OBSERVED IN 2016-04-14 KUMAMOTO EARTHQUAKE (M7.3) IN JAPAN (SOURCE: JAPAN METEOROLOGICAL AGENCY)

TABLE 1-2: MMI (MODIFIED MERCALLI INTENSITY) SCALE (SOURCE: BMKG)

 MMI I: Getaran tidak dirasakan kecuali dalam keadaan luarbiasa oleh beberapa orang	 MMI VII: Tiap-tiap orang keluar rumah. Kerusakan ringan pada rumah-rumah dengan bangunan dan konstruksi yang baik. Sedangkan pada bangunan yang konstruksinya kurang baik terjadi retak-retak bahkan hancur, cerobong asap pecah. Terasa oleh orang yang naik kendaraan.
MMI II: Getaran dirasakan oleh beberapa orang, benda-benda ringan yang digantung bergoyang. 	MMI VIII: Kerusakan ringan pada bangunan dengan konstruksi yang kuat. Retak-retak pada bangunan degan konstruksi kurang baik, dinding dapat lepas dari rangka rumah, cerobong asap pabrik dan monumen-monumen roboh, air menjadi keruh. 

 MMI III: Getaran dirasakan nyata dalam rumah. Terasa getaran seakan-akan ada truk berlalu.	 MMI IX: Kerusakan pada bangunan yang kuat, rangka-rangka rumah menjadi tidak lurus, banyak retak. Rumah tampak agak berpindah dari pondamennya. Pipa-pipa dalam rumah putus.
MMI IV: Pada siang hari dirasakan oleh orang banyak dalam rumah, di luar oleh beberapa orang, gerabah pecah, jendela/pintu berderik dan dinding berbunyi. 	MMI X: Bangunan dari kayu yang kuat rusak,rangka rumah lepas dari pondamennya, tanah terbelah rel melengkung, tanah longsor di tiap-tiap sungai dan di tanah-tanah yang curam. 
 MMI V: Getaran dirasakan oleh hampir semua penduduk, orang banyak terbangun, gerabah pecah, barang-barang terpelanting, tiang-tiang dan barang besar tampak bergoyang, bandul lonceng dapat berhenti.	 MMI XI: Bangunan-bangunan hanya sedikit yang tetap berdiri. Jembatan rusak, terjadi lembah. Pipa dalam tanah tidak dapat dipakai sama sekali, tanah terbelah, rel melengkung sekali.
MMI VI: Getaran dirasakan oleh semua penduduk. Kebanyakan semua terkejut dan lari keluar, plester dinding jatuh dan cerobong asap pada pabrik rusak, kerusakan ringan. 	MMI XII: Hancur sama sekali, Gelombang tampak pada permukaan tanah. Pemandangan menjadi gelap. Benda-benda terlempar ke udara. 

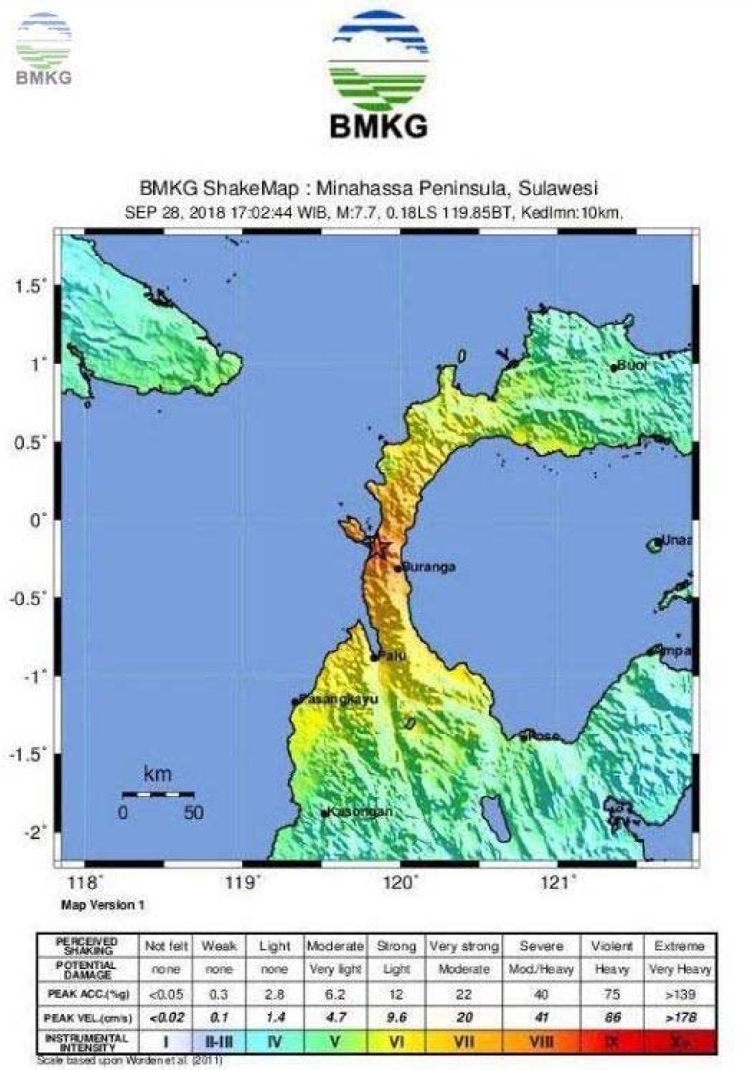


FIGURE 1-16: SHAKEMAP (GROUND MOTION ESTIMATE) FOR 2018-09-28 CENTRAL SULAWESI EARTHQUAKE (SOURCE: BMKG)

Skala SIG BMKG	Warna	Deskripsi Sederhana	Deskrispsi Rinci	Skala MMI	PGA (gal)
I	Putih	TIDAK DIRASAKAN (Not Felt)	Tidak dirasakan atau dirasakan hanya oleh beberapa orang tetapi terekam oleh alat.	I-II	< 2.9
II	Hijau	DIRASAKAN (Felt)	Dirasakan oleh orang banyak tetapi tidak menimbulkan kerusakan. Benda-benda ringan yang digantung bergoyang dan jendela kaca bergetar.	III-V	2.9-88
III	Kuning	KERUSAKAN RINGAN (Slight Damage)	Bagian non struktur bangunan mengalami kerusakan ringan, seperti retak rambut pada dinding, atap bergeser ke bawah dan sebagian berjatuhan.	VI	89-167
IV	Jingga	KERUSAKAN SEDANG (Moderate Damage)	Banyak Retakan terjadi pada dinding bangunan sederhana, sebagian roboh, kaca pecah. Sebagian plester dinding lepas. Hampir sebagian besar atap bergeser ke bawah atau jatuh. Struktur bangunan mengalami kerusakan ringan sampai sedang.	VII-VIII	168-564
V	Merah	KERUSAKAN BERAT (Heavy Damage)	Sebagian besar dinding bangunan permanen roboh. Struktur bangunan mengalami kerusakan berat. Rel kereta api melengkung.	IX-XII	> 564

FIGURE 1-17: INDONESIA EARTHQUAKE SCALE: SKALA INTENSITAS GEMPABUMI (SIG) BMKG (SOURCE: BMKG)

NOTE:

- Earthquake "Magnitude (e.g. M7.5)" indicates a size of an earthquake, while "Intensity (e.g. MMI VII)" indicates a level of ground shaking at each location.
- Buildings located near seismic sources may experience higher levels of ground shaking, and therefore must be designed and constructed with particular attention.

1.3. SITE SOIL CONDITIONS AND SOIL AMPLIFICATION EFFECT

As described, earthquake ground motion or shaking intensity attenuates (i.e. decrease) with distance from the epicenter of the earthquake. **Figure 1-18** shows the reduction of shaking intensity in the 2016 Kumamoto Earthquake in Japan. However, in the area with soft soil conditions, the shaking intensity or the ground motion was amplified (i.e. increased to JMA Intensity 4) compared to the area with hard soil conditions (JMA Intensity 2-3), even though they were located in the same distance from the epicenter.

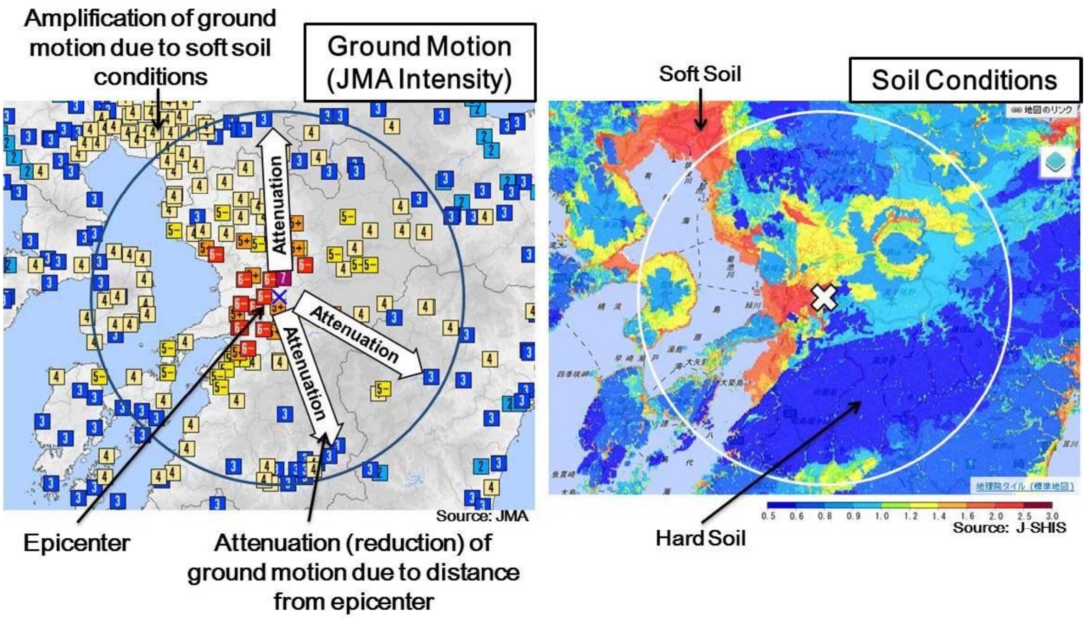


FIGURE 1-18: GROUND MOTION AMPLIFICATION EFFECT OBSERVED IN 2016-04-14 KUMAMOTO EARTHQUAKE (M7.3)

"Standard Penetration Test (SPT)" is the most frequently used soil boring test performed all over the world. The purpose is to identify the soil profile, and to measure the strength of each soil layer using an indicator known as "N-value". High N-value indicates well-compacted firm soil with high density and low value does loose or soft soil.

TABLE 1-3: RELATION BETWEEN N-VALUE AND DENSITY INDEX (MITCHELL AND KATTI, 1981)

SPT N-value	Density Index (%)	Degree of Compaction
0 – 4	0 – 15	Very loose
4 – 10	15 – 35	Loose
10 – 30	35 – 65	Medium
30 – 50	65 – 85	Dense
> 50	85 – 100	Very Dense

The results of SPT are summarized in Soil Boring Log (see example in **Figure 1-19**). In this example, top 10 meters of soil layers are soft and the soil layers below them are relatively firm. Top soil layers may be able to support light-weight, i.e. low-rise building (below 2 floors) if the building foundations are appropriately designed and constructed (e.g. rigid reinforced concrete mat slabs). Heavy-weight, i.e. high-rise buildings should be supported on pile foundations, drilled down to the firm soil layers.

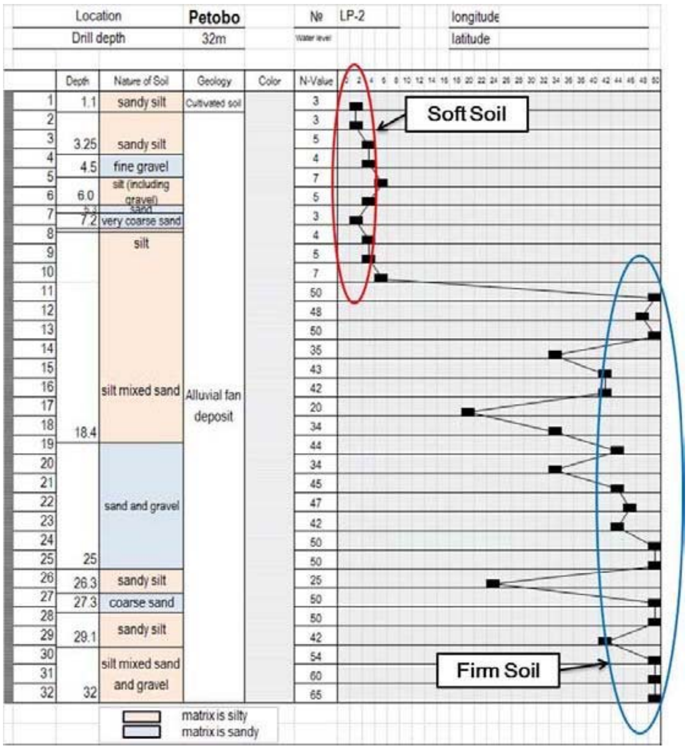


FIGURE 1-19: SPT SOIL BORING LOG

NOTE:

- Check site soil conditions, when designing and constructing a building, since soft soil conditions significantly amplify earthquake ground motion.
- "Standard Penetration Test (SPT)" should be performed when constructing a building with 2 floors or greater.
- Buildings must be designed according to the seismic code (SNI1726), considering the site soil conditions and soil amplification effect.
- Considerations should be given to foundation type considering the site soil conditions.

1.4. SOIL LIQUEFACTION AND BUILDING FOUNDATION

Soft or loose sand soil layers with high water table are susceptible to liquefaction. Strong ground motion likely induces soil liquefaction, since soil particles in saturated soil tend to loose strength and stiffness due to strong shaking. Buildings on liquefied soils lose support and may sink, tilt or even overturn due to uneven settlement or movement of the ground soil, if the foundation systems are not properly designed.

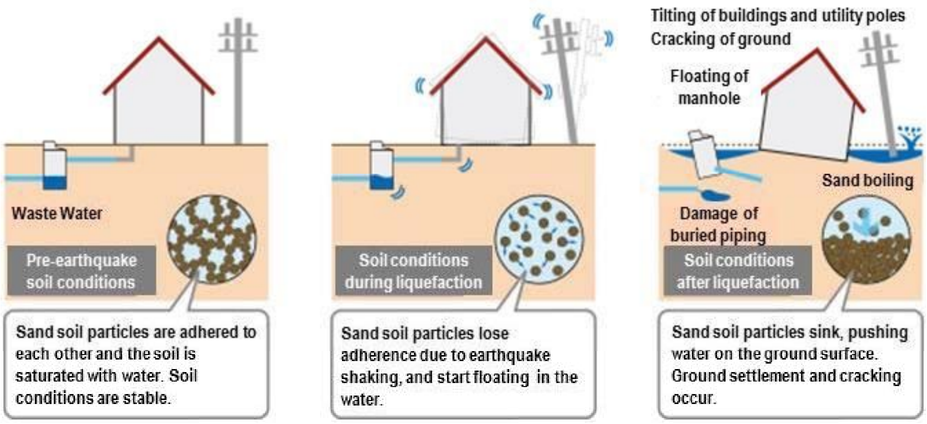


FIGURE 1-20: SOIL LIQUEFACTION (SOURCE: TOKYO METROPOLITAN GOVERNMENT)

When constructing a building on liquefiable soil conditions, soil improvement works should be performed or any appropriate foundation type (e.g. pile foundation) should be adopted.

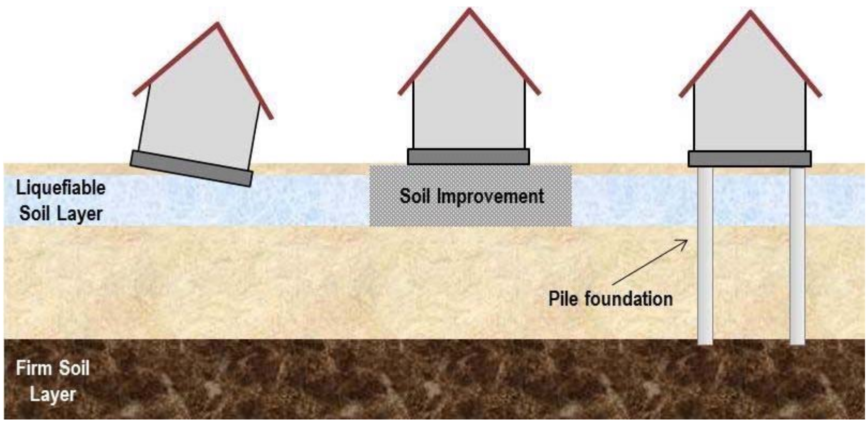


FIGURE 1-21: COUNTERMEASURES TO SOIL LIQUEFACTION

NOTE:

- ✧ Adequate countermeasures should be implemented when constructing a building on the soils susceptible to liquefaction.

2. DESIGN EARTHQUAKE

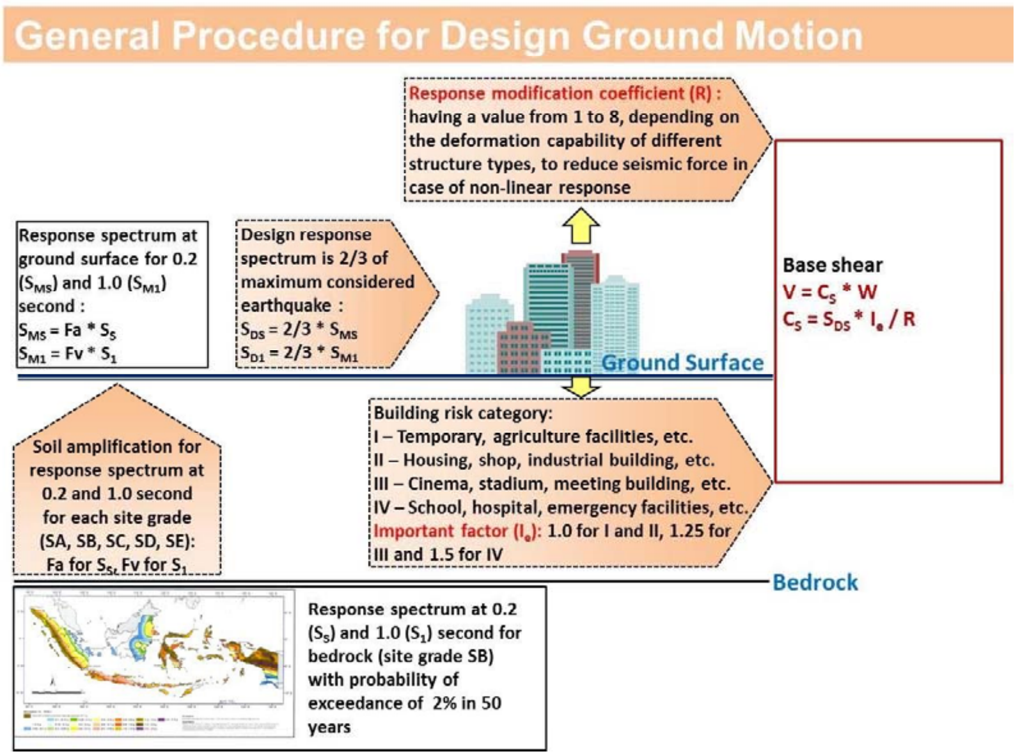


FIGURE 2-1: GENERAL PROCEDURE FOR DESIGN GROUND MOTION (SNI1726)

Figure 2-1 illustrates the process for determining design ground motion for a building according to the Indonesian Seismic Design Code, i.e. SNI1726:2012. Each step in this process is further explained in the following sections.

2.1. 2017 PROBABILISTIC SEISMIC HAZARD MAP OF INDONESIA

Pusat Studi Gempa Nasional (PuSGeN) published the Indonesia Earthquake Source and Hazard Map in 2017, which was accommodated the latest research results on tectonics, subduction zones, active faults and background seismicity (earthquakes without clearly identifies sources). The assessment is largely based on Probabilistic Seismic Hazard Analysis (PSHA), and the ground motion prediction equation, called new generation attenuation (NGA), is used for this probabilistic seismic hazard analysis. The 2017 Indonesia Earthquake Hazard Map includes several kinds of hazard maps for different purposes. Regarding seismic design of building structures, the two hazard maps for different vibration periods (0.2 and 1.0 sec.) at bedrock should be referred (**Figure**

2-2 and **Figure 2-3**). The response spectrum acceleration values in these maps will be used for developing design response spectrum (see Section 2.3).

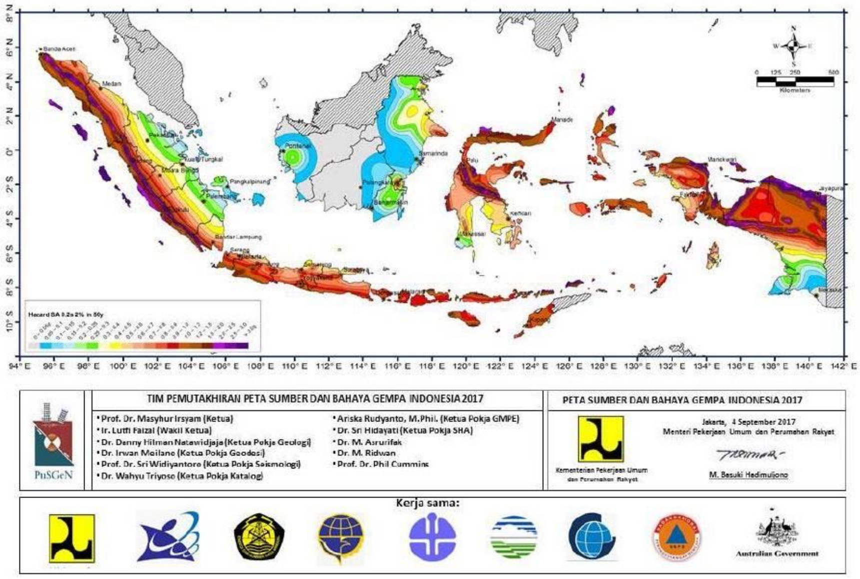


FIGURE 2-2: RESPONSE SPECTRUM ACCELERATION AT 0.2 SECOND WITH 5% DAMPING RATIO IN BEDROCK (SB) FOR EXCEEDING PROBABILITY OF 2% IN 50 YEARS (SOURCE: PETA SUMBER DAN BAHAYA GEMPA INDONESIA TAHUN 2017)

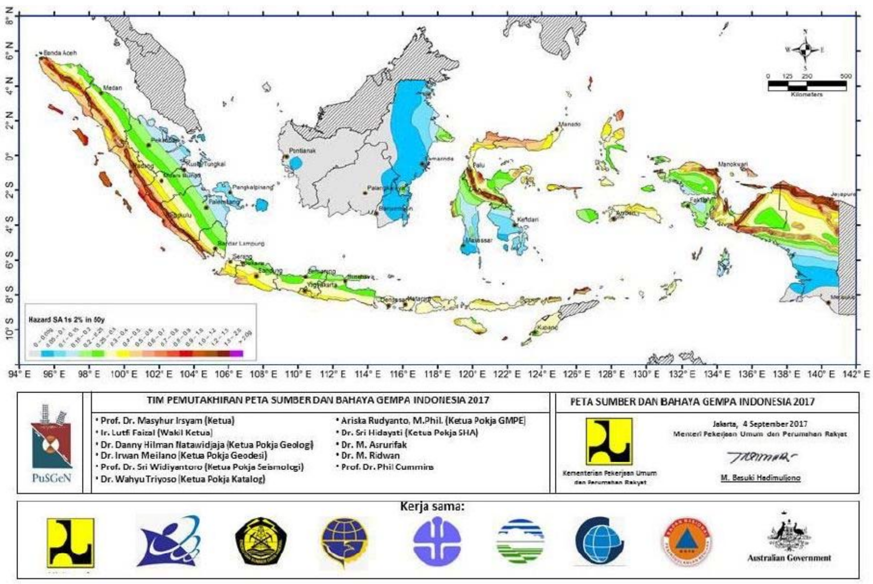


FIGURE 2-3: RESPONSE SPECTRUM ACCELERATION AT 1.0 SECOND WITH 5% DAMPING RATIO IN BEDROCK (SB) FOR EXCEEDING PROBABILITY OF 2% IN 50 YEARS (SOURCE: PETA SUMBER DAN BAHAYA GEMPA INDONESIA TAHUN 2017)

2.2. SOIL AMPLIFICATION FACTOR

As described in Section 1.3, the site soils above the bedrock may amplify the ground motion transferred at the bedrock. This is considered as Soil Amplification Factors (Fa and Fv) in SNI1726.

Ground motion at ground surface:

$$SM_S = Fa * S_S$$

$$SM_1 = Fv * S_1$$

Where S_S is acceleration spectral response for a period of 0.2 second as defined in **Figure 2-2**; S_1 is acceleration spectral response foe a period of 1.0 second as defined in **Figure 2-3**; Fa and Fv as defined in **Table 2-1** and **Table 2-2** respectively.

TABLE 2-1: SOIL AMPLIFICATION FOR S_S: FA

Fa					
Site	S_S				
	<=0.25	0.50	0.75	1.00	>=1.25
SA	0.8	0.8	0.8	0.8	0.8
SB	1.0	1.0	1.0	1.0	1.0
SC	1.2	1.2	1.1	1.0	1.0
SD	1.6	1.4	1.2	1.1	1.0
SE	2.5	1.7	1.2	0.9	0.9

TABLE 2-2: SOIL AMPLIFICATION FOR S_1: FV

Fv					
Site	S_1				
	<=0.10	0.20	0.30	0.40	>=0.50
SA	0.8	0.8	0.8	0.8	0.8
SB	1.0	1.0	1.0	1.0	1.0
SC	1.7	1.6	1.5	1.4	1.3
SD	2.4	2.0	1.8	1.6	1.5
SE	3.5	3.2	2.8	2.4	2.4

Where SA: hard rock; SB: Rock; SC: hard soil, very dense and soft rock; SD: medium soil; SE: soft soil; SF: special soil, which require specific geotechnical and specific-site response analysis.

2.3. MAXIMUM CONSIDERED EARTHQUAKE AND DESIGN RESPONSE SPECTRUM

The Maximum Considered Earthquake (MCE) spectral-response acceleration is calculated though the above steps. The design spectral-response acceleration is calculated using the following equations. It is known from past earthquake experiences in various countries that the ground motion acceleration is not fully transferred to building structures due to various reasons, such as interaction between soil and structure.

Design Ground Motion:

$SD_S = 2/3 * SM_S$

$SD_1 = 2/3 * SM_1$

Then, design response spectrum is created using SD_S and SD_1 ().

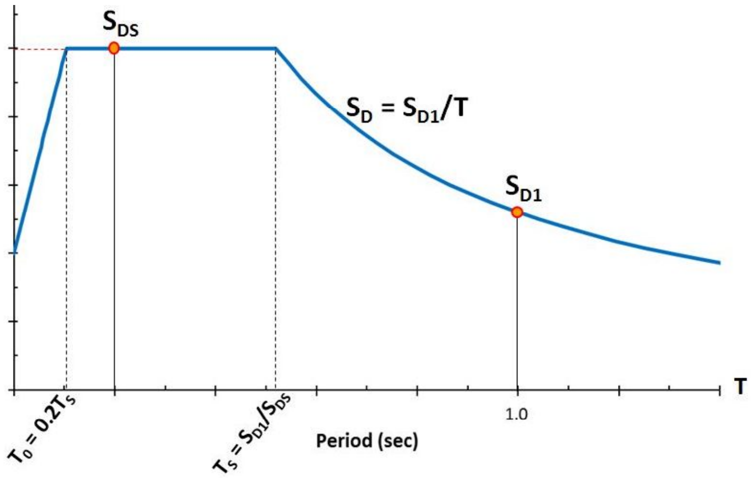


FIGURE 2-4: LOWER LIMIT OF DESIGN RESPONSE SPECTRUM

2.4. LOAD COMBINATION

The required load combinations according to SNI1726 are as follows.

Allowable stress design:

$(1+0.14SDS)DL+0.7\rho QE+H+F$

Ultimate strength design

$$(1+0.2SDS)DL+\varrho QE+LL$$

Where QE: Effect of earthquake force

3. BASIC CONCEPT OF SEISMIC DESIGN

This Chapter describes the basic concept of seismic design according to the design standards in Indonesia.

3.1. IMPORTANCE FACTOR

Important buildings shall be designed with particular attention and higher seismic forces, in order to secure their functionality in the event of any major earthquake.

In accordance with ground motion intensity and importance of building (referred as Risk Category in SNI1726), different design requirements are set as Seismic Design Category "A" to . For "A" in **Table 3-1**, seismic design of non-structural elements is not required; for "C" and over, geotechnical investigation report, including slope instability, liquefaction, etc. are required.

TABLE 3-1: SEISMIC DESIGN CATEGORY

S_{DS} / S_{D1} / S_1 Value	Risk Category	
	I or II or III	IV
S_{DS} < 0,167 or S_{D1} < 0,067	A	A
0,167 ≤ S_{DS} <0,33 or 0,067 ≤ S_{D1} <0,133	B	C
0,33 ≤ S_{DS} <0,50 or 0,133 ≤ S_{D1} <0,20	C	C
0,50 ≤ S_{DS} or 0,20 ≤ S_{D1}	D	D
0,75 ≤ S_1	E	F

The Risk Categories are given in SNI1726 according to the table below.

TABLE 3-2: DEFINITION OF RISK CATEGORY

Risk Category	Definition
I	Building having a low risk to human life, such as: ◆ Facilities of agriculture, plantation, livestock and fishery ◆ Temporary facilities, storehouse, etc.
II	All buildings except those of risk category of I, III and IV, such as: ◆ Housing, shop house, office house,, mall, industrial building, etc.
III	Buildings having a high risk to human life, such as: ◆ Cinema, meeting building, stadium, child care facilities, prison, etc.
IV	Building indicated as essential facilities, such as: ◆ School, hospital, firefighting facilities, emergency response facilities, etc.

The Importance Factors are defined based on Risk Categories as follows, so that important buildings are designed with higher seismic capacities. The application of Importance Factor is described in Section 3.3.1.

TABLE 3-3: RISK CATEGORY AND IMPORTANCE FACTOR

Risk Category	Importance Factor (Ie)
I or II	1.0
III	1.25
IV	1.5

3.2. STRENGTH AND DUCTILITY

“Strength” indicates that a building structure resists seismic forces with rigid structural elements, while “Ductility” indicates a structure accommodates seismic forces with flexible structural elements. “Strength” is the force level when a structure yields (i.e. is damaged). After yielding the structure starts plastic deformation. A non-ductile structure cannot accommodate plastic deformation and fails immediately after yielding point.

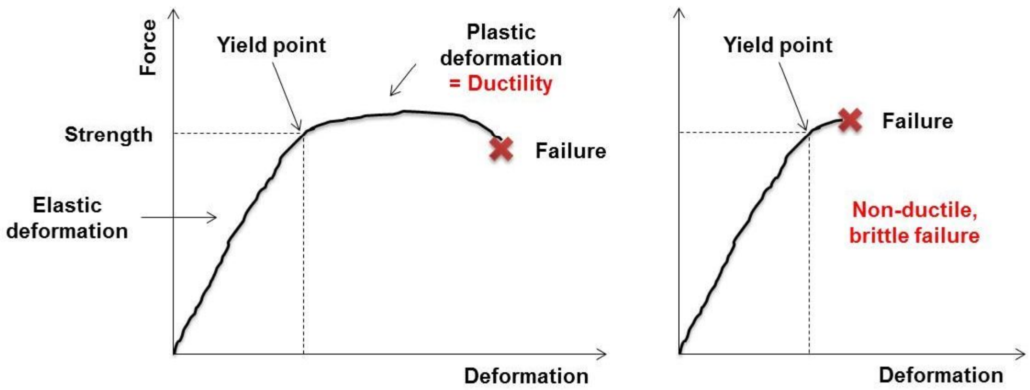


FIGURE 3-1: CONCEPT OF STRENGTH AND DUCTILITY

A structure can be design to be rigid enough to resist seismic forces (e.g. many shear walls or bracing), and / or to be flexible and ductile enough to accommodate and absorb seismic forces or energy (e.g. moment frame without shear wall or bracing). The total energy consumptions can be equivalent (i.e. similar level of seismic capacity) regardless of the strategy or philosophy adapted for the design, of source if the structure is appropriately designed.

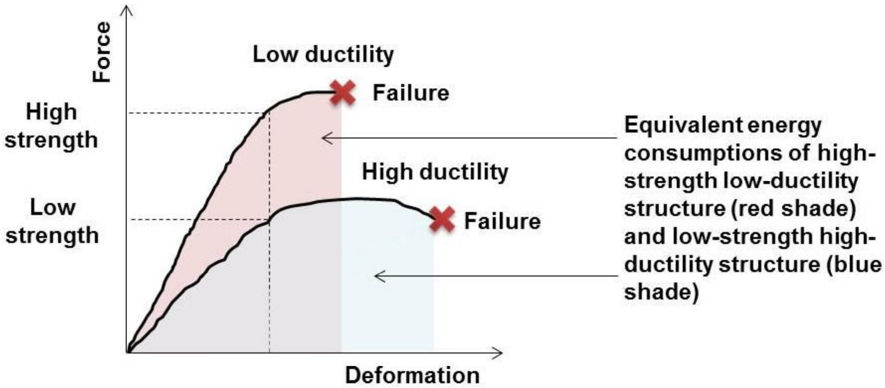


FIGURE 3-2: STRENGTH AND DUCTILITY DESIGN STRATEGY

3.2.1. STRUCTURAL DUCTILITY FACTOR

The SNI1726 allows reducing seismic design loading, considering elastic deformation of ductile building structures (until reaching to a failure mode) as follows. The application of Structural Ductility Factor is described in Section 3.3.1.

TABLE 3-4: RESPONSE MODIFICATION FACTOR

Structural Type	Response Modification Factor
B. Frame System	
1. Steel frame with eccentric bracing	8
2. Steel frame with special concentric bracing	6
3. Steel frame with regular concentric bracing	3.25
4. Special reinforced concrete shear wall	6
5. Regular reinforced concrete shear wall	5
6. Detail plain concrete shear wall	2
7. Regular plain concrete shear wall	1.5
8. Medium precast shear wall	5
9. Regular precast shear wall	4
16. Special reinforced brick shear wall	5.5
17. Medium reinforced brick shear wall	4
18. Regular reinforced brick shear wall	2

3.3. STRUCTURAL CHARACTERISTICS AND ANALYSIS PROCEDURE

Based on the Seismic Design Category defined in **Table 3-1** and structural characteristics, three analyses methods or procedures are defined in SNI1726.

TABLE 3-5: APPLICABLE ANALYSIS PROCEDURE

Seismic design category	Structure characteristics	Analysis of equivalent lateral force	Analysis of various response spectrum	Procedure of earthquake history response
B, C	Building Risk Category I or II of light frame construction with the height of not exceeding 3 levels	I	I	I
	Other buildings with Risk Category I or II, with a height not exceeding 2 levels	I	I	I
	All other structures	I	I	I
D, E, F	Building with Risk Category I or II of light frame construction with the height of not exceeding 3 levels	I	I	I
	Other buildings with Risk Category I or II with the height not exceeding 2 levels	I	I	I
	Regular structure with T < 3.5Ts and all the structures of light frame construction	I	I	I
	Irregular structure with T < 3.5Ts and having only horizontal irregularity of "Inner angle irregularity", "Diaphragm discontinuity irregularity", "Transverse shift irregularity to the field" or "Non-parallel system irregularity", or vertical irregularity of "Discontinuity of field direction in vertical lateral force resisting element irregularity", Discontinuity in the level lateral strength irregularity" or "Discontinuity in excessive level lateral strength irregularity"	I	I	I
	All other structures	TI	I	I

NOTE: I: Allowed, TI: Not allowed

The "equivalent lateral force procedure" is based on the calculation of Base Shear. The "various response spectrum procedure" can be performed by a modal analysis using the design response spectrum. The "earthquake history response procedure" requires development of earthquake time history and dynamic structural response analysis. For the majority of buildings that structural calculations are required "various response spectrum procedure" would be recommended with the use of structural analysis software such as ETABS or SAP2000.

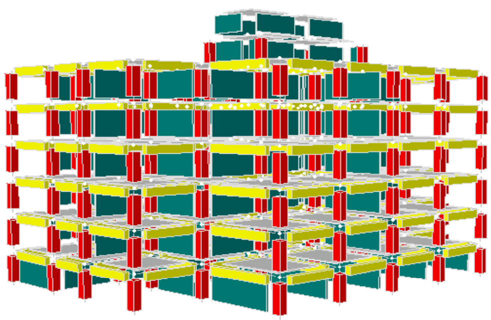


FIGURE 3-3: EXAMPLE OF STRUCTURAL ANALYSIS MODEL FOR "VARIOUS RESPONSE SPECTRUM PROCEDURE"

3.3.1. EQUIVALENT LATERAL FORCE PROCEDURE AND BASE SHEAR

In the "equivalent lateral force procedure", Design Base Shear is defined as follows.

$$V = Cs * W$$

$$Cs = SDS * Ie / R$$

Where V: Design base shear, W: Building weight; Cs: Base shear coefficient; Ie: Importance factor; R: Response modification factor

3.4. INDONESIAN NATIONAL STANDARD (SNI) FOR STRUCTURAL DESIGN

Design and calculations of each structural element should be performed according to the relevant design standard depending on the structural type.

TABLE 3-6: STRUCTURAL DESIGN CODES IN INDONESIA

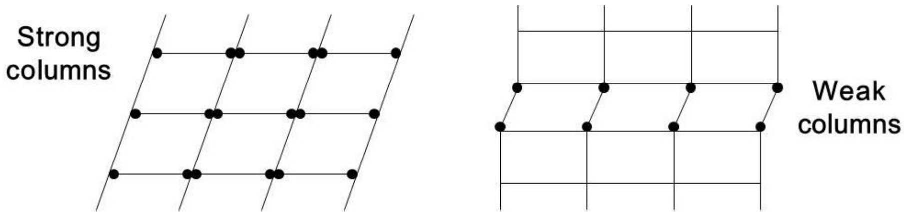
Design Code	Contents
SNI 1729:2015	Specification for steel building structure
SNI 2847:2013	Structural concrete requirements for buildings
SNI 7973:2013	Design specifications for wood construction

Since the SNI design codes have been developed based on the US codes, they typically apply ultimate strength design rather than allowable stress design.

4. BEST PRACTICES FOR SEISMIC DESIGN OF BUILDING STRUCTURES

When planning and designing a building structure, considerations should be given to:

- ✧ Clear load path (i.e. understand seismic loading and distribution of forces within the structure)
- ✧ Well balanced seismic-force-resisting system (no irregularity, no discontinuity, no excessive concentration of seismic forces)
- ✧ Ensure ductility to avoid sudden failure or collapse of a structure
  - ➢ Sufficient reinforcement for shear forces in reinforced concrete structure
  - ➢ Weak Column (Strong Beam) results in sudden collapse, and therefore structures should be planned as Strong Column (Weak Beam)



4.1. AVOID IRREGULARITY

Any significant irregularity in a building structure, either horizontal or vertical, may result in concentration of earthquake forces to particular structural members, which are likely damaged during an earthquake. This kind of irregularity is avoidable with well-considered structural planning and design.

4.1.1. AVOID PLAN (HORIZONTAL) IRREGULARITY

A plan or horizontal irregularity may likely introduce undesirable torsional forces in a structure due to the unbalance between the center of gravity (or weight) and the center of stiffness.

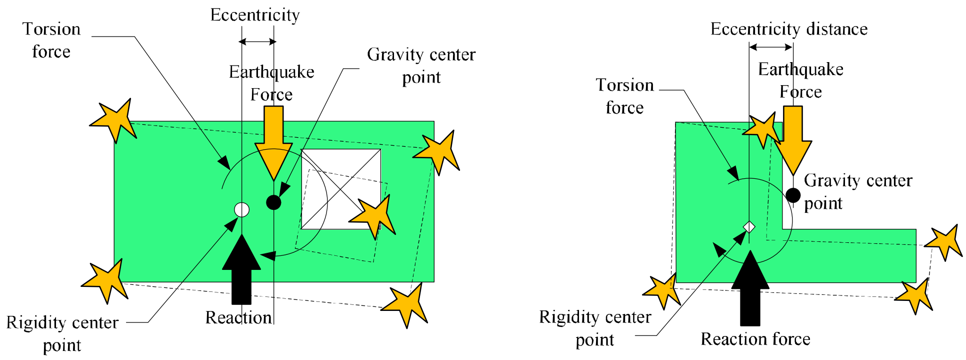


FIGURE 4-1: TORSIONAL RESPONSE DUE TO PLAN IRREGULARITY

This can be avoided by separating a building structure into building blocks and connecting them with expansion joints.

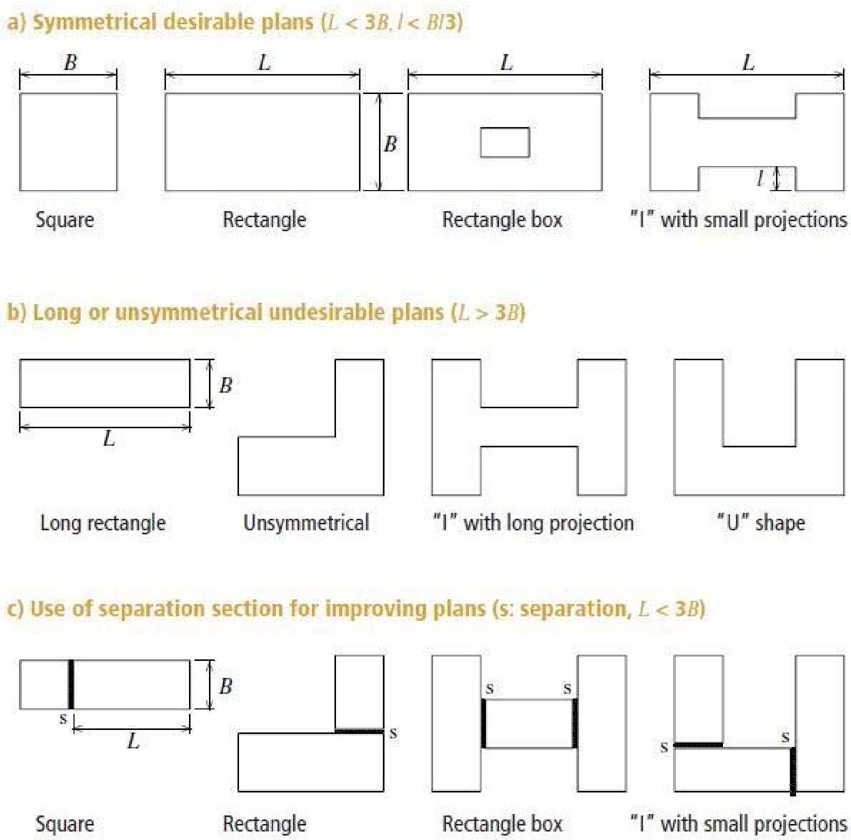


FIGURE 4-2: PLAN OF BUILDING BLOCKS (SOURCE: GUIDELINES FOR EARTHQUAKE RESISTANT NON-ENGINEERED CONSTRUCTION, UNESCO)

4.1.2. AVOID ELEVATION (VERTICAL) IRREGULARITY

An elevation or vertical irregularity may cause soft-story effects and excessive concentration of seismic forces in a certain floor level due to abrupt change of story stiffness's.

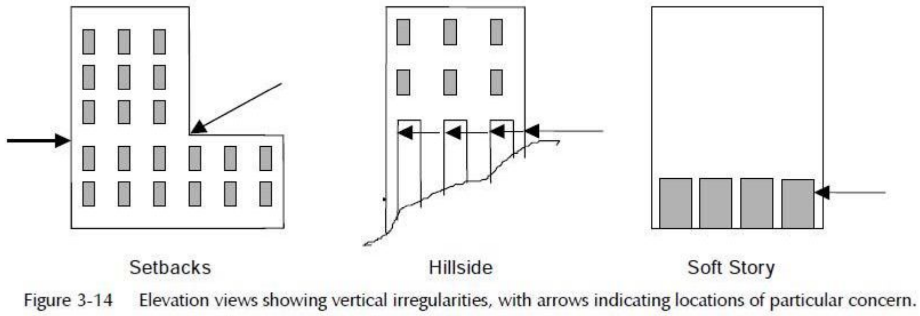


FIGURE 4-3: ELEVATION VIEWS SHOWING VERTICAL IRREGULARITIES, WITH ARROWS INDICATING LOCATIONS OF PARTICULAR CONCERN (SOURCE: FEMA154)

These irregularities are avoidable with well-considered structural planning and design.

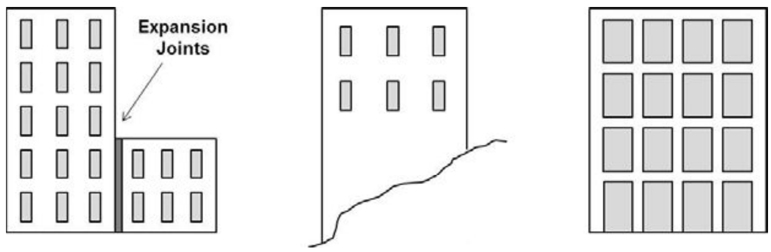


FIGURE 4-4: EXAMPLE FOR AVOIDING VERTICAL IRREGULARITIES

4.2. AVOID DISCONTINUITY

Any discontinuity is also a source of potential damage in a structure due to excessive concentration of seismic sources. Structural discontinuities should be avoided as much as possible. In case they cannot be avoided, structural elements and members where concentrations of seismic forces are expected should be designed to withstand those forces and stresses.

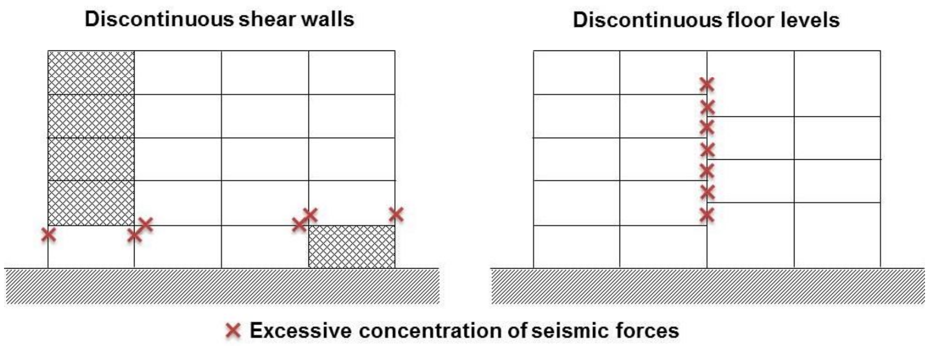


FIGURE 4-5: STRUCTURAL DISCONTINUITY

4.3. AVOID CONCENTRATION OF SEISMIC FORCES

There are several other cases that can cause undesirable concentration of seismic forces, such as short columns and short span girders / beams. Columns and beams that are shorten by side walls, hanging walls or partial walls experience high levels of shear stresses, and are likely damaged especially if those partial walls are not properly considered in the structural analysis model (partial walls are typically considered as non-structural walls and thus not included in the structural analysis models).

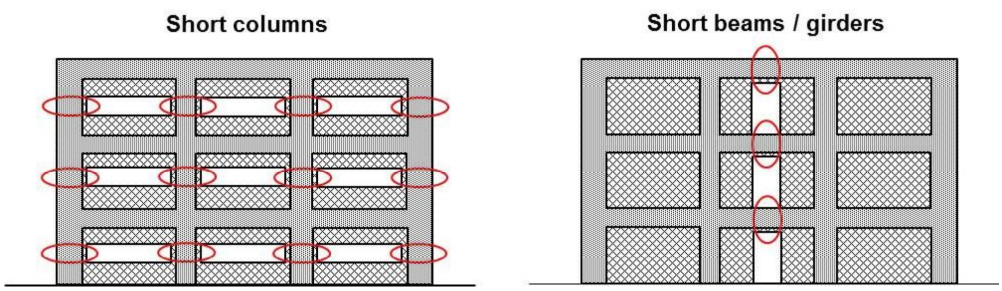


FIGURE 4-6: SHORT COLUMNS AND SHORT BEAMS

Partial walls should be separated from the columns and/ or beams by structural slits in order to avoid undesirable concentration of seismic forces.

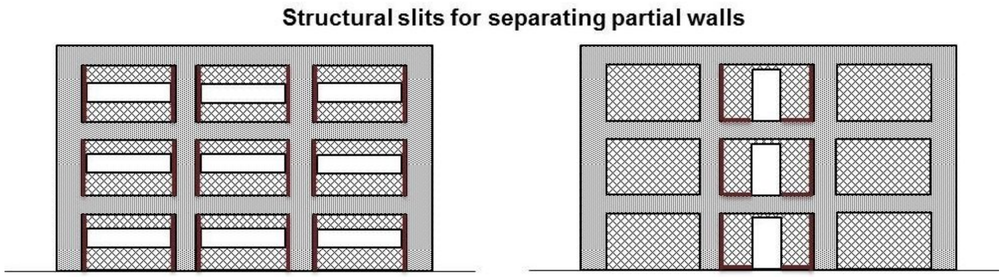
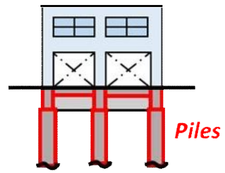
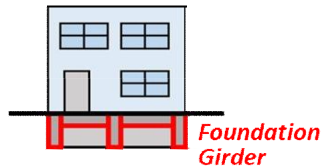
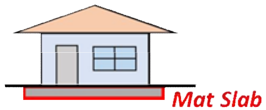
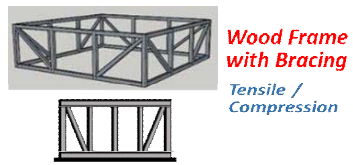
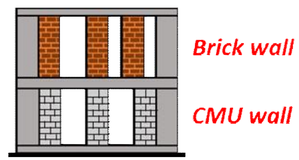


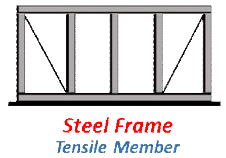
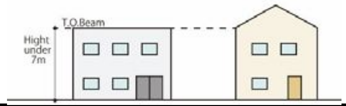
FIGURE 4-7: STRUCTURAL SLITS FOR AVOIDING SHORT COLUMNS / BEAMS

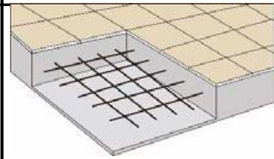
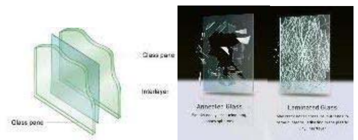
I-2-5 Building Design Guideline

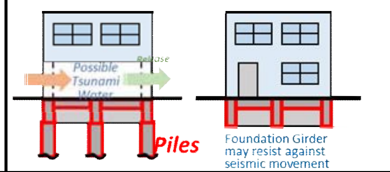
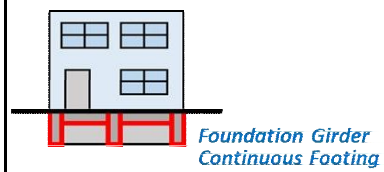
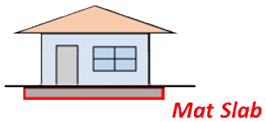
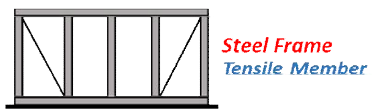
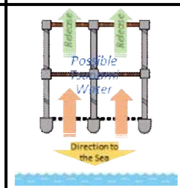
This table is prepared to set general guideline for designers and IMB design reviewers including TABG members to set the early building design stage concept development concerned about construction target area disaster impact. The guideline is set for small scale building and medium/large scale buidling as well as key disaster types of earthquake, tsunami and liquefaction landslide (Nalodo) to maximize building's disaster resilient performance even before the structural calculation incorporating Indonesian Micro Zonation factors.

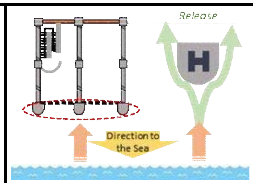
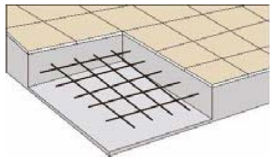
Small Scale Buildings

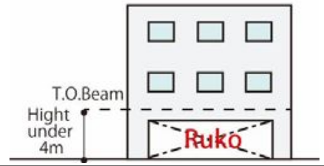
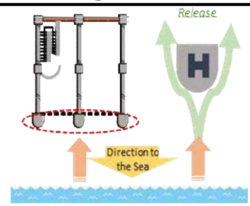
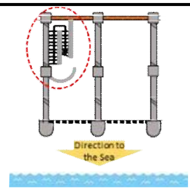
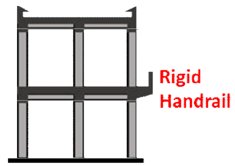
	Foundation	Pile Foundation	Pile foundation shall anchor to bed rock layer (where piles are required). Structural design of pile foundation shall comply with the national building code and its calculation criteria.	
		Continuous Footing	All column bases shall be tied with continuous foundation girders or continuous footings. Structural design of foundation girders and continuous footings shall comply with the national building code and its calculation criteria.	
		Mat Slab Foundation	Mat slab shall cover entire building footprint as a monolithic structural slab. Structural design of mat slab foundation shall comply with the national building code and its calculation criteria.	
	Above Ground Structure	Reinforced Concrete	Structural frame shall be tied with foundation. Structural design of reinforced concrete structure shall comply with the national building code and its calculation	
		Wood Structure	Structural bracing shall be set at appropriate corners to enhance rigidity of the structure. Structural frame shall be tied with foundation. Structural design of wood framing shall comply with the national building code and its calculation criteria.	
		Masonry Structure Only masonry based wall structure for two or more story high building is not recommended.	Structural design of masonry wall shall comply with the national building code and its calculation criteria. Structural concrete bearing walls shall be located at appropriate building corners to increase structural rigidity. Structural frame shall be tied with foundation. Buildings with two stories or more shall use Concrete Masonry Unit (CMU) wall system with proper reinforcing bars (both vertical and horizontal). The structural design must comply with the structural bearing wall design criteria (structural system at the ground level of any buildings with two or more stories. Floor slabs of any buildings with two or more stories shall use structural slabs and all CMU walls shall be structurally tied to the slabs.	

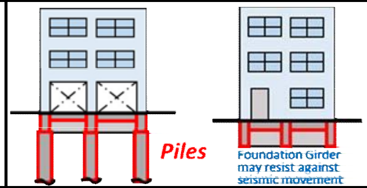
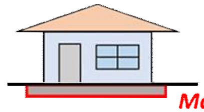
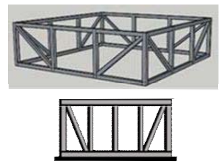
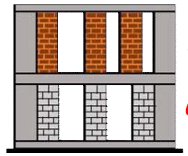
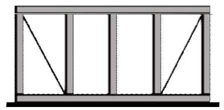
Earthquake (Active Fault)		Steel (incl'd LGS*) Frame Structure * LGS: Light Gauge Steel Frame system	Structural bracing shall be set at appropriate corners to enhance rigidity of the structure. Structural frame shall be tied with foundation. Structural design of steel framing shall comply with the national building code and its calculation criteria. Horizontal bracing shall be installed at floor slabs where required to make the building structural rigidity.	
	Builiding Form	Reinforced Concrete	Buildings with maximum three (3) stories or with the height of less than 12m.	
		Wood Structure	Buildings with maximum two (2) stories (top of the top beam shall be maximum 7m)	
		Masonry Structure	Buildings with maximum two (2) stories (top of the top beam shall be maximum 7m)	
		Steel (incl'd LGS) Frame Structure	Buildings with maximum three (3) stories by steel framing system (buildings with LGS frame system shall be single story only) or with the height of less than 12m.	
	Mechanical, Electrical and Plumbing	Water Supply	Flexible joints is recommended to be used at the main water supply system entry at the building perimeter.	
		Electricity / Emergency Generator System	Flexible joints is recommended to be used at the main power supply system entry at the building perimeter.	
		Air Conditioning System	Any sleeve opening to the structural members is prohibited as it reduces structural strength.	
		Ventilation System	Any sleeve opening to the structural members is prohibited as it reduces structural strength.	

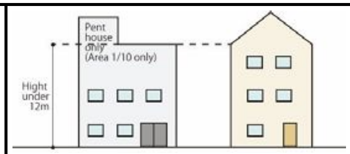
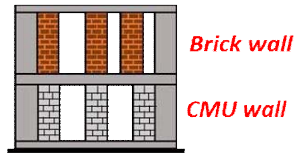
	Finishes	Ceiling Finishes	Ceiling panels should be maximum 600mm x 600mm in size and light weight material. Suspension system shall hold panels properly to reduce fall off while make them flexible for seismic move.	
		Wall Finishes	Wall finishes shall be installed in such way that fall off or detachment does not occur. Where mortar plastering finish is applied, wire mesh shoud be installed as a base.	
		Floor Finishes	Structural slab is recommended even for the ground floor. Tile finishes may be easier for repair.	
		Glass and Glazing	Laminated glass panels or film applied glass panels are recommended in order to avoid broken glass dispersals, especially for any public buildings or large commercial buildings.	
	Others	Seismic Reinforcement	Any buildings to be constructed near an active fault (distance in approx. 50m ???) shall be considered with special seismic reinforcement to the structural members (up sizing member dimensions, providing additional bracing, etc.).	
		Door and Door Frame	Use of seismic reinforced door frame is recommended, especially for any public buildings and large size commercial facilities.	
		Emergency Exit Door	Panic bar installation is recommended, especially for public buildings and large size commercial facilities.	

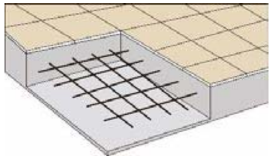
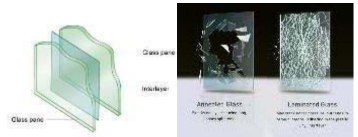
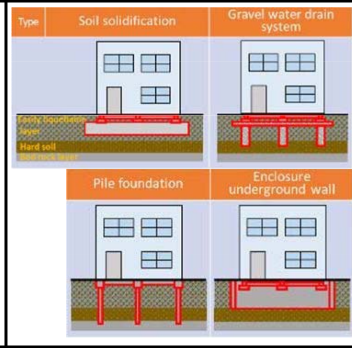
	Foundation	Pile Foundation	Pile foundation shall anchor to bed rock layer (where piles are required). Structural design of pile foundation shall comply with the national building code and its calculation criteria. Friction piles may not be allowed where loose sand layer becomes structural concern. Any foundation system concerned about avoidance of building move or displacement due to tsunami water loading.	
		Continuous Footing	All column bases shall be tied with continuous foundation girders or continuous footings. Structural design of foundation girders and continuous footings shall comply with the national building code and its calculation criteria.	
		Mat Slab Foundation	Mat slab shall cover entire building footprint as a monolithic structural slab. Structural design of mat slab foundation shall comply with the national building code and its calculation criteria. Where a building is closer to the sea dike, mat slab foundation may be carefully studied for selection.	
	Above Ground Structure	Reinforced Concrete	Structural frame shall be tied with foundation. Structural design of reinforced concrete structure shall comply with the national building code and its calculation	
		Wood Structure	Not applicable	
		Masonry Structure	Not applicable	
		Steel Frame Structure	Structural bracing shall be set at appropriate corners to enhance rigidity of the structure. Structural frame shall be tied with foundation. Structural design of steel framing shall comply with the national building code and its calculation criteria. Horizontal bracing shall be installed at floor slabs where required to make the building structural rigidity. No LGS framing is allowed.	
	Builiding Form	Reinforced Concrete	Buildings with maximum three (3) stories or with the height of less than 12m. Structural load bearing walls shall be set in perpendicular to the coastal line on the ground level.	
		Wood Structure	Not applicable	
		Masonry Structure	Not applicable	

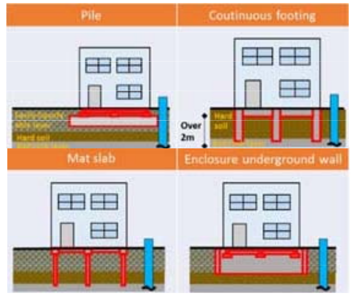
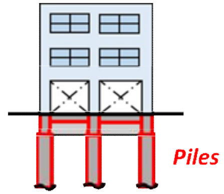
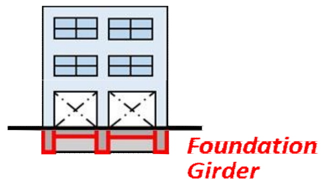
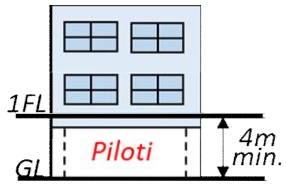
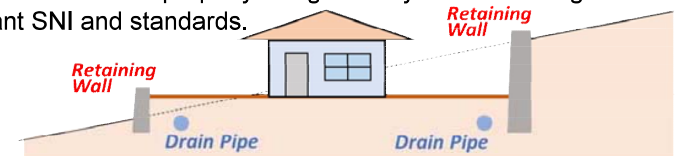
Tsunami ZRB-3		Steel Frame Structure	Steel frame structure could be acceptable if ground level structural members are covered by concrete to protect steel members agains tsunami damage. Thikness of concrete covering could consider minimum 75mm.	
	Mechanical, Electrical and Plumbing	Water Supply	It is recommended to apply salt / salinity damage measures. Flexible joints is recommended to be used at the main water supply system entry at the building perimeter.	
		Electricity / Emergency Generator System	It is recommended to apply salt / salinity damage measures. Flexible joints is recommended to be used at the main power supply system entry at the building perimeter.	
		Air Conditioning System Ventilation System	Any sleeve opening to the structural members is prohibited as it reduces structural strength. It is recommended to apply salt / salinity damage measures.	
		Ventilation System	Any sleeve opening to the structural members is prohibited as it reduces structural strength. It is recommended to apply salt / salinity damage measures.	
	Finishes	Ceiling Finishes	Ceiling panels should be maximum 600mm x 600mm in size and light weight material. Suspension system shall hold panels properly to reduce fall off while make them flexible for seismic move.	
		Wall Finishes	Wall finishes shall be installed in such way that fall off or detachment does not occur. Where mortar plastering finish is applied, wire mesh shoud be installed as a base.	
		Floor Finishes	Structural slab is recommended even for the ground floor. Tile finishes may be easier for repair.	
		Glass and Glazing	Laminated glass panels or film applied glass panels are rcommended in order to avoid broken glass dispersals, especially for any public buildings or large commercial buildings.	

	Others	Ground Level Profile	Ground level structure shall be piloti type space as it is open space not used for over night living purpose (sleeping in particular). The piloti space could be utilised for commercial retail purposes during the day time. It is considered as locally called RUKO type.	
		Floor Height	Floor height of the second floor at the top face of 2nd floor beam should be 4m or higher. ←tentative height	
		Ground Level Column Profile	It is recommended to design round or any profile that is effective to disperse tsunami water load (such as round column plan toward sea direction).	
		Staircase between 1st & 2nd Flooor	It is recommended to install structural load bearing walls pallarel to the sea direction, and design and profile of staircase and stape details should be in such way to disperse the tunali water load.	
		Second Floor	It is recommended to have reinforced concrete balcony where designed with no use of glass maerials.	
		Emergency Exit Door	Panic bar installation is recommended, especially for public buildings and large size commercial facilities.	

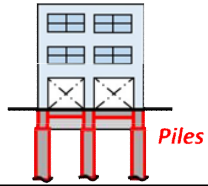
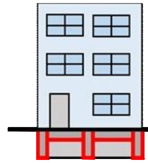
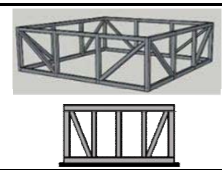
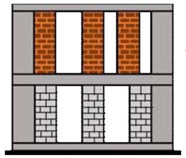
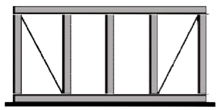
	Foundation	Pile Foundation	Pile foundation shall not be used where land slide risk is higher, such as the areas of alluvial fan between hills.	
		Continuous Footing	All column bases shall be tied with continuous foundation girders or continuous footings. Structural design of foundation girders and continuous footings shall comply with the national building code and its calculation criteria. Deeper ground tie girders may be considered to reach shallow bed rock layer where sand layer is thin around 2m in depth.	
		Mat Slab Foundation	Mat slab shall cover entire building footprint as a monolithic structural slab. Structural design of mat slab foundation shall comply with the national building code and its calculation criteria.	
	Above Ground Structure	Reinforced Concrete	Structural frame shall be tied with foundation. Structural design of reinforced concrete structure shall comply with the national building code and its calculation	
		Wood Structure	Structural bracing shall be set at appropriate corners to enhance rigidity of the structure. Structural frame shall be tied with foundation. Structural design of wood framing shall comply with the national building code and its calculation criteria. Minimize the building footprint and make the floor plan as simple square or rectangular shape as possible.	
		Masonry Structure Only masonry based wall structure for two or more story high building is not recommended.	Structural design of masonry wall shall comply with the national building code and its calculation criteria. Structural concrete bearing walls shall be located at appropriate building corners to increase structural rigidity. Structural frame shall be tied with foundation. Buildings with two stories or more shall use Concrete Masonry Unit (CMU) wall system with proper reinforcing bars (both vertical and horizontal). The structural design must comply with the structural bearing wall design criteria (structural system at the ground level of any buildings with two or more stories.	
		Steel (incl'd LGS) Frame Structure	Structural bracing shall be set at appropriate corners to enhance rigidity of the structure. Structural frame shall be tied with foundation. Structural design of steel framing shall comply with the national building code and its calculation criteria. Horizontal bracing shall be installed at floor slabs where required to make the building structural rigidity. LGS framing is not allowed for any building in two (2) story or higher.	

Builiding Form	Reinforced Concrete	Buildings with maximum three (3) stories or with the height of less than 12m.	
	Wood Structure	Buildings with maximum two (2) stories or with the height of less than 7m.	
	Masonry Structure	Only single story building is allowed with masonry structure (It could be allowed for two (2) story building, if reinforced concrete (RC) load bearing walls, RC lintels, tie-beams and structural slabs are used for ground level structure with reinforced CMU walls are designed.).	
	Steel (incl'd LGS) Frame Structure	It is allowed to design a building up to two (2) stories, however single story building is only allowed with LGS frame structure.	
Mechanical, Electrical and Plumbing	Water Supply	Flexible joints is recommended to be used at the main water supply system entry at the building perimeter.	
	Electricity / Emergency Generator System	Flexible joints is recommended to be used at the main water supply system entry at the building perimeter.	
	Air Conditioning System Ventilation System	Any sleeve opening to the structural members is prohibited as it reduces structural strength.	

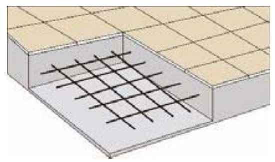
Finishes	Ceiling Finishes	Ceiling panels should be maximum 600mm x 600mm in size and light weight material. Suspension system shall hold panels properly to reduce fall off while make them flexible for seismic move.	
	Wall Finishes	Wall finishes shall be installed in such way that fall off or detachment does not occur. Where mortar plastering finish is applied, wire mesh should be installed as a base.	
	Floor Finishes	Structural slab is recommended even for the ground floor. Tile finishes may be easier for repair.	
	Glass and Glazing	Laminated glass panels or film applied glass panels are recommended in order to avoid broken glass dispersals, especially for any public buildings or large commercial buildings.	
Others	Soil Improvement	Each building needs to consider soil replacement measure in order to reduce under ground water, and possible soil replacement methods are replacing sand with gravel, improvement by cement milk mix, gravel water discharge columns, etc. It is important to apply soil improvement with gravel replacement to lower underground water level under and around the building.	

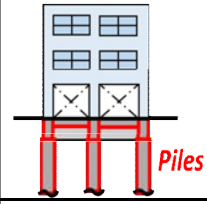
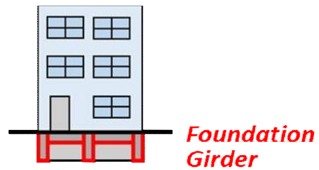
		Ground Water Discharge	Where land area is at large, pipe well may be installed to lower underground water level. (Water discharge may affect to the building as ground level disorientation so that the building may sink unevenly. Therefore, selection of well location shall be carefully identified.)	
Flood	Foundation	Pile Foundation	Pile foundation shall anchor to bed rock layer (where piles are required). Structural design of pile foundation shall comply with the national building code and its calculation criteria.	
		Continuous Footing	All column bases shall be tied with continuous foundation girders or continuous footings. Structural design of foundation girders and continuous footings shall comply with the national building code and its calculation criteria.	
	Building Form	Above Ground Structu	Above ground structure shall be more than two story with piloti on the ground level without any function except storage. The first floor level shall be higher than 4m.	
Sediment Flow	Others	Ground Level Control and Retaining Wall	Where ground level control (cut or fill) is required for a new development, appropriate retaining wall(s) shall be installed to prevent any slope failure. The maximum allowed retaining wall or any retaining structure is 5m, and underground water discharge system including pipes and drainage shall be installed in properly designed way. The retaining wall or similar system shall be designed in compliance to all relevant SNI and standards. 	

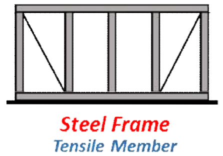
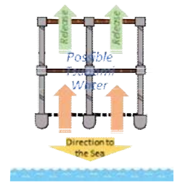
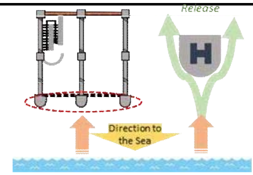
Medium to Large Scale Buildings (required for TABG's Building Permit): same as Jakarta)

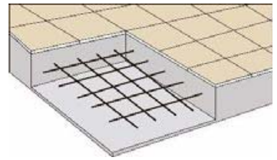
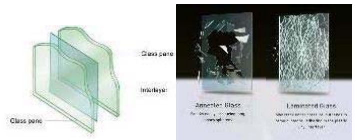
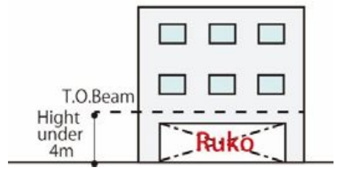
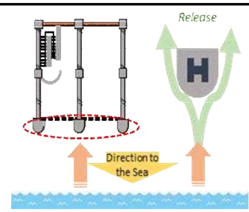
	Foundation	Pile Foundation	Pile foundation shall anchor to bed rock layer (where piles are required). Structural design of pile foundation shall comply with the national building code and its calculation criteria.	
		Continuous Footing	All column bases shall be tied with continuous foundation girders or continuous footings. Structural design of foundation girders and continuous footings shall comply with the national building code and its calculation criteria.	
		Mat Slab Foundation	Not applicable (Buildings with large floor area may take mat slab with effective expansion joints to make the area smaller, and in such case it is possible to	
	Above Ground Structure	Reinforced Concrete	Structural frame shall be tied with foundation. Structural design of reinforced concrete structure shall comply with the national building code and its calculation	
		Wood Structure	Structural bracing shall be set at appropriate corners to enhance rigidity of the structure. Structural frame shall be tied with foundation. Structural design of wood framing shall comply with the national building code and its calculation criteria.	
		Masonry Structure (limited to one or two story buildings) Only masonry based wall structure for two or more story high building is not recommended.	Structural design of masonry wall shall comply with the national building code and its calculation criteria. Structural concrete bearing walls shall be located at appropriate building corners to increase structural rigidity. Structural frame shall be tied with foundation. Buildings with two stories or more shall use Concrete Masonry Unit (CMU) wall system with proper reinforcing bars (both vertical and horizontal). The structural design must comply with the structural bearing wall design criteria (structural system at the ground level of any buildings with two or more stories. Floor slabs of any buildings with two or more stories shall use structural slabs and all CMU walls shall be structurally tied to the slabs.	
		Steel Frame Structure	Structural bracing shall be set at appropriate corners to enhance rigidity of the structure. Structural frame shall be tied with foundation. Structural design of steel framing shall comply with the national building code and its calculation criteria. Horizontal bracing shall be installed at floor slabs where required to make the building structural rigidity.	

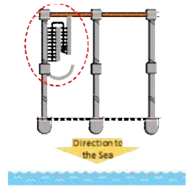
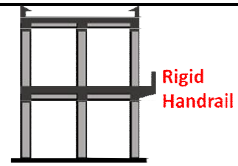
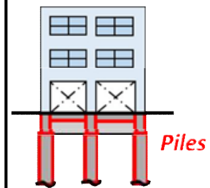
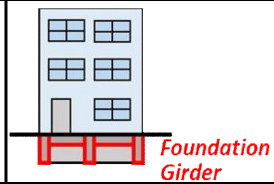
Earthquake (Active Fault)

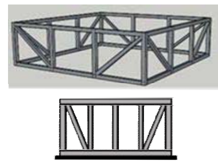
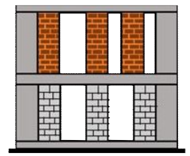
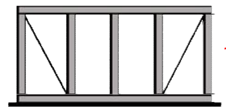
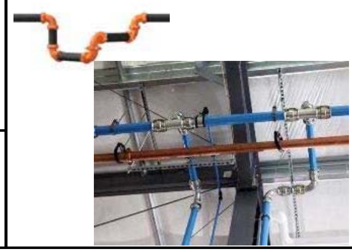
Building Form	Reinforced Concrete	Any buildings with height less than 31m ←tentative height	to be Discussed with Cipta Karya
	Wood Structure	Not applicable	
	Masonry Structure	Not applicable (Two (2) story buildings with large floor area may be applicable)	
	Steel Frame Structure	Any buildings with height less than 31m ←tentative height	to be Discussed with Cipta Karya
Mechanical, Electrical and Plumbing	Water Supply	Flexible joints is recommended to be used at the main water supply system entry at the building perimeter. Each building shall be studied for detailed design.	
	Electricity / Emergency Generator System	Flexible joints is recommended to be used at the main water supply system entry at the building perimeter. Each building shall be studied for detailed design.	
	Air Conditioning System Ventilation System	Any sleeve opening to the structural members is prohibited as it reduces structural strength. It is recommended to apply salt / salinity damage measures. Each building shall be studied for detailed design, when beam depth is much greater. In such cases, the location and size of sleeve opening shall follow the designated regulation and criteria including specific sleeve opening reinforcement.	
Finishes	Ceiling Finishes	Ceiling panels should be maximum 600mm x 600mm in size and light weight material. Suspension system shall hold panels properly to reduce fall off while make them flexible for seismic move.	
	Wall Finishes	Wall finishes shall be installed in such way that fall off or detachment does not occur. Where mortar plastering finish is applied, wire mesh shoud be installed as a base.	
	Floor Finishes	Structural slab is recommended even for the ground floor. Tile finishes may be easier for repair.	
	Glass and Glazing	Laminated glass panels or film applied glass panels are rcommended in order to avoid broken glass dispersals. Large glass wall design may be prohibited, and detaield design consultation should be necessary.	

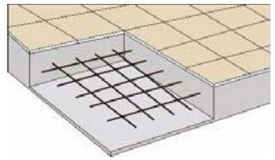
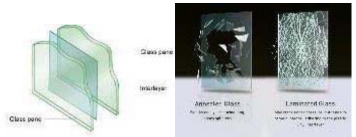
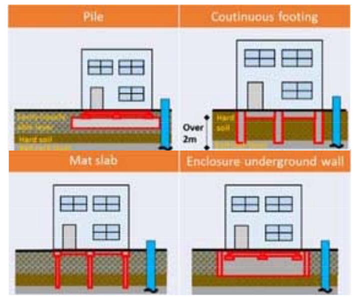
	Others	Seismic Reinforcement	Any buildings to be constructed near an active fault (distance in approx. 50m ???) shall be considered with special seismic reinforcement to the structural members (up sizing member dimensions, providing additional bracing, etc.). Short columns should be avoided, and careful arrangement of structural joints is recommended in case of larger buildings.	
		Expansion Joint	In case of large or long building, expansion joint should be considered, and dimensional variation of structural displacement or movement shall be carefully calculated taking micro zonation factor.	
		Door and Door Frame	Use of seismic reinforced door frame is recommended, especially for any public buildings and large size commercial facilities.	
		Emergency Exit Door	Panic bar installation is recommended, especially for public buildings and large size commercial facilities.	
	Foundation	Pile Foundation	Pile foundation shall anchor to bed rock layer (where piles are required). Structural design of pile foundation shall comply with the national building code and its calculation criteria. Friction piles may not be allowed where loose sand layer becomes structural concern. Any foundation system concerned about avoidance of building move or displacement due to tsunami water loading.	
		Continuous Footing	All column bases shall be tied with continuous foundation girders or continuous footings. Structural design of foundation girders and continuous footings shall comply with the national building code and its calculation criteria.	
		Mat Slab Foundation	Not applicable	

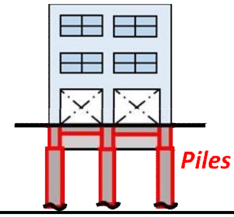
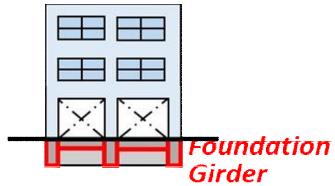
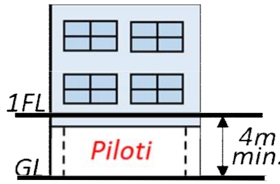
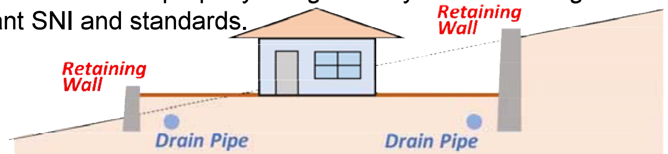
Above Ground Structure	Reinforced Concrete	Structural frame shall be tied with foundation. Structural design of reinforced concrete structure shall comply with the national building code and its calculation	
	Wood Structure	Not applicable	
	Masonry Structure	Not applicable	
	Steel Frame Structure	Structural bracing shall be set at appropriate corners to enhance rigidity of the structure. Structural frame shall be tied with foundation. Structural design of steel framing shall comply with the national building code and its calculation criteria. Horizontal bracing shall be installed at floor slabs where required to make the building structural rigidity. No LGS framing is allowed.	
Building Form	Reinforced Concrete	Buildings with maximum five (5) stories or with the height of less than 20m.← tentative height Structural load bearing walls shall be set in perpendicular to the coastal line on the ground level.	
	Wood Structure	Not applicable	
	Masonry Structure	Not applicable	
	Steel (incl'd LGS) Frame Structure	Buildings with maximum five (5) stories or with the height of less than 20m.← tentative height Steel frame structure could be acceptable if ground level structural members are covered by concrete to protect steel members agains tsunami damage. Thikness of concrete covering could consider minimum 75mm.	
Mechanical, Electrical and Plumbing	Water Supply	Flexible joints is recommended to be used at the main water supply system entry at the building perimeter. Each building shall be studied for detailed design.	 
	Electricity / Emergency Generator System	It is recommended to apply salt / salinity damage measures. Flexible joints is recommended to be used at the main power supply system entry at the building perimeter.	
	Air Conditioning System Ventilation System	Any sleeve opening to the structural members is prohibited as it reduces structural strength. It is recommended to apply salt / salinity damage measures. Each building shall be studied for detailed design, when beam depth is much greater. In such cases, the location and size of sleeve opening shall follow the designated regulation and criteria including specific sleeve opening reinforcement.	

Tsur ZRI	Finishes	Ceiling Finishes	Ceiling panels should be maximum 600mm x 600mm in size and light weight material. Suspension system shall hold panels properly to reduce fall off while make them flexible for seismic move.	
		Wall Finishes	Wall finishes shall be installed in such way that fall off or detachment does not occur. Where mortar plastering finish is applied, wire mesh shoud be installed as a base.	
		Floor Finishes	Structural slab is recommended even for the ground floor. Tile finishes may be easier for repair.	
		Glass and Glazing	Laminated glass panels or film applied glass panels are rcommended in order to avoid broken glass dispersals. Large glass wall design may be prohibited, and detaield design consultation should be necessary.	
	Others	Floor Height	Ground level structure shall be piloti type space as it is open space not used for over night living purpose (sleeping in particular). The piloti space could be utilised for commercial retail purposes during the day time. It is considered as locally called RUKO type.	
		Ground Level Column Profile	Floor height of the second floor at the top face of 2nd floor beam should be 4m or higher. ←tentative height	

		Staircase between 1st and 2nd Floor	It is recommended to design round or any profile that is effective to disperse tsunami water load (such as round column plan toward sea direction). It is recommended to install structural load bearing walls pallarel to the sea direction, and design and profile of staircase and stape details should be in such way to disperse the tunali water load.	
		Second Floor Level	It is recommended to have reinforced concrete balcony where designed with no use of glass maerials.	
		Expansion Joint	In case of large or long building, expansion joint should be considered, and dimensional variation of structural displacement or movement shall be carefully calculated taking micro zonation factor.	
		Emergency Exit Door	Panic bar installation is recommended, especially for public buildings and large size commercial facilities.	
	Foundation	Pile Foundation	Pile foundation shall not be used where land slide risk is higher, such as the areas of alluvial fan between hills.	
		Continuous Footing	All column bases shall be tied with continuous foundation girders or continuous footings. Structural design of foundation girders and continuous footings shall comply with the national building code and its calculation criteria. Deeper ground tie girders may be considered to reach shallow bed rock layer where sand layer is thin around 2m in depth.	
		Mat Slab Foundation	mat slab shall cover entire building footprint as a monolithic structural slab. Structural design of mat slab foundation shall comply with the national building code and its calculation criteria. mat slab foundation shall not be considered for tall or large buildings.	

Above Ground Structure	Reinforced Concrete	Structural frame shall be tied with foundation. Structural design of reinforced	
	Wood Structure	Structural bracing shall be set at appropriate corners to enhance rigidity of the structure. Structural frame shall be tied with foundation. Structural design of wood framing shall comply with the national building code and its calculation criteria. Minimize the building footprint and make the floor plan as simple square or rectangular shape as possible.	
	Masonry Structure Only masonry based wall structure for two or more story high building is not recommended.	Structural design of masonry wall shall comply with the national building code and its calculation criteria. Structural concrete bearing walls shall be located at appropriate building corners to increase structural rigidity. Structural frame shall be tied with foundation. Buildings with two stories or more shall use Concrete Masonry Unit (CMU) wall system with proper reinforcing bars (both vertical and horizontal). The structural design must comply with the structural bearing wall design criteria (structural system at the ground level of any buildings with two or more stories. Floor slabs of any buildings with two or more stories shall use structural slabs and	
	Steel (incl'd LGS) Frame Structure	Structural bracing shall be set at appropriate corners to enhance rigidity of the structure. Structural frame shall be tied with foundation. Structural design of steel framing shall comply with the national building code and its calculation criteria. Horizontal bracing shall be installed at floor slabs where required to make the building structural rigidity. LGS framing is not allowed for any building in two (2)	
Building Form	Reinforced Concrete	Buildings with maximum five (5) stories or with the height of less than 20m.←	to be Discussed with Cipta Karya
	Wood Structure	Buildings with maximum three (3) stories	
	Masonry Structure	Only single story buildings or larger floor area buildings are allowed.	
	Steel (incl'd LGS) Frame Structure	Buildings with maximum five (5) stories or with the height of less than 20m.← tentative height	to be Discussed with Cipta Karya
Mechanical, Electrical and Plumbing	Water Supply	It is recommended to apply salt / salinity damage measures. Flexible joints is recommended to be used at the main water supply system entry at the building perimeter.	
	Electricity / Emergency Generator System	It is recommended to apply salt / salinity damage measures. Flexible joints is recommended to be used at the main power supply system entry at the building perimeter.	

Liquefactic		Air Conditioning System Ventilation System	Any sleeve opening to the structural members is prohibited as it reduces structural strength. It is recommended to apply salt / salinity damage measures. Each building shall be studied for detailed design, when beam depth is much greater. In such cases, the location and size of sleeve opening shall follow the designated regulation and criteria including specific sleeve opening reinforcement.	
	Finishes	Ceiling Finishes	Ceiling panels should be maximum 600mm x 600mm in size and light weight material. Suspension system shall hold panels properly to reduce fall off while make them flexible for seismic move.	
		Wall Finishes	Wall finishes shall be installed in such way that fall off or detachment does not occur. Where mortar plastering finish is applied, wire mesh shoud be installed as a base.	
		Floor Finishes	Structural slab is recommended even for the ground floor. Tile finishes may be easier for repair.	
		Glass and Glazing	Laminated glass panels or film applied glass panels are rcommended in order to avoid broken glass dispersals. Large glass wall design may be prohibited, and detaield design consultation should be necessary.	
	Others	Bed Rock & Load Bearing Soil	Any sites that require deep (long) pile foundation to reach bed rock layer should not be considered for a large or tall building development. （＊）	

		Expansion Joint	In case of large or long building, expansion joint should be considered, and dimensional variation of structural displacement or movement shall be carefully calculated taking micro zonation factor.	
		Door and Door Frame	Use of seismic reinforced door frame is recommended, especially for any public buildings and large size commercial facilities.	
		Emergency Exit Door	Panic bar installation is recommended, especially for public buildings and large size commercial facilities.	
Flood	Foundation	Pile Foundation	Pile foundation shall anchor to bed rock layer (where piles are required). Structural design of pile foundation shall comply with the national building code and its calculation criteria.	
		Continuous Footing	All column bases shall be tied with continuous foundation girders or continuous footings. Structural design of foundation girders and continuous footings shall comply with the national building code and its calculation criteria.	
	Building Form	Above Ground Structu	Above ground structure shall be more than two story with piloti on the ground level without any function except storage. The first floor level shall be higher than 4m.	
Sediment Flow	Others	Ground Level Control and Retaining Wall	Where ground level control (cut or fill) is required for a new development, appropriate retaining wall(s) shall be installed to prevent any slope failure. The maximum allowed retaining wall or any retaining structure is 5m, and underground water discharge system including pipes and drainage shall be installed in properly designed way. The retaining wall or similar system shall be designed in compliance to all relevant SNI and standards. 	

QUALITY CONTROL MANUAL
FOR CONCRETE WORK

APRIL 2019

PROJECT FOR DEVELOPMENT OF REGIONAL DISASTER RESILIENCE PLAN IN CENTRAL SLAWESI

IN THE REPUBLIC OF INDONESIA

Part 1. Basic Knowledge P1-1

PART-1 BASIC KNOWLEDGE

1-1 What is Concrete?

1-1-1. Concrete is the most popular construction material in the world, because;

- Any kind of shape it can form
- Easy to get materials to cast concrete
- Strong and durable
- It can be casted at any places (on the ground, in the sea, in the river and underground, etc.).
- Low price

1-1-2. Concrete is not the same with Cement paste and Mortar

- "Cement paste" is composed of cement and water only.
- "Mortar" is composed by cement, water and sand only.
- "Concrete" is the mixed material of cement, water, sand and aggregate (gravel).

Table-1: Composition of Cement Paste, Mortar and Concrete

Name	Materials
Cement Paste	Cement | Water
Mortar	Cement | Water | Sand
Concrete	Cement | Water | Aggregate (Sand | Gravel stone)

1-1-3. Concrete has high durability

- Standard durability of concrete is different by its strength as shown Table-2.
- Concrete made by correct knowledge and procedure could achieve long durability of more than 100 years.
- Normally, a building would be designed with the concrete strength of 21N/mm^2 to 24 N/mm^2, its target of durability is around 65 years.
- However, the standard durability of concrete which made by incorrect knowledge and procedure is seriously reduced, even if use concrete strength of 24N/mm^2 or 30 N/mm^2.

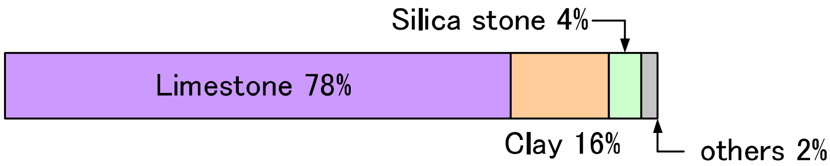
Table-2: Standard Durability of Concrete depends on the Concrete Strength

Durability class	**Planed durability period**	**Required Concrete strength (N/mm^2)**
Short life span	Approx. 30 years	18
Normal life span	Approx. 65 years	24
Long life span	Approx. 100 years	30
Most long life span	Approx. 200 years	36

1-2 Characteristics of Cement

1-2-1 Core material

Figure-1: Main material of Portland cement is Limestone



1-2-2 Main ingredients of Portland cement

Tabel-3: Main Ingredient of the Portland Cement

SiO_2	Al_2O_2	Fe_2O_3	CaO	MgO	SO_3	Others
21.06%	5.15%	2.80%	64.17%	1.46%	2.02%	

CaO: Calcium oxide, SiO_2: Silicon dioxide, Al_2O_2: Aluminum oxide, Fe_2O_3: Ferric oxide, SO_3: Sulfur trioxide, MgO: Magnesium oxide

1-2-3 Main chemical compound

Tabel-4: Main Chemical Compound of the Portland Cement

Mark		C_3S	C_2S	C_3A	C_4AF
Character	Speed of hydration	Very fast	Fast	Slow	Fast
	Period of revelation of strength	**Within 1 day**	**3 to 7 days, and continue up to 28 days**	**After 28 days**	Not affect to strength

C_3S: Silica lime, C_2S: Silica lime, C_3A: Aluminate lime, C_4AF: Iron Aluminates lime

As shown in the above table, the speed of hydration of;

- C_3S is very fast (within one (1) day from concrete pouring day)
- C_2S is fast (3 to 7 days and continue up to 28 days from concrete pouring day)
- C_3A is very slow (after 28 days from concrete pouring day)

Thus, the concrete strength doesn't reach designed level (hardness) at one time. Mainly, the hydration continues from the first day of pouring concrete and up to 28 days, and the hydration will continue even after 28 days

⇩

Therefore, the continuous curing (sprinkle water) work up to minimum 28 days is very important.

1-3 Typical Characteristics of Concrete

1-3-1 Strong to compression force, weak for tension force, bending moment and shear force.

Table-5 Typical Characteristics of Concrete

Kind of stress	Characteristics
Compressive force	Strong
Tension force	Weak
Bending moment	Weak
Shear force	Weak

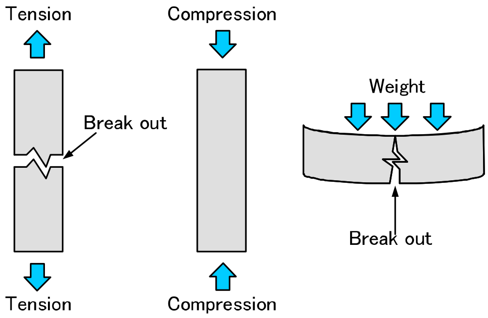


Figure-2 Typical Characteristics

1-3-2 Weakness for deformation

Concrete may crack due to stretch of only 0.01 to 0.02% (=0.1mm to 0.2mm per 1.0m).

1-3-3 Weakness for salty or chloride content

Concrete is strong alkaline material, however it is weak against salty content.

- ◆ Target of permissible amount of salt or chloride content in the concrete is less than 0.3 kg/m^3.
- ◆ Before mixing concrete, inspect the amount of chloride content in the mixing water, sand and aggregate.
- ◆ If concrete contains a lot of chloride content, durability of the structure should seriously reduce.

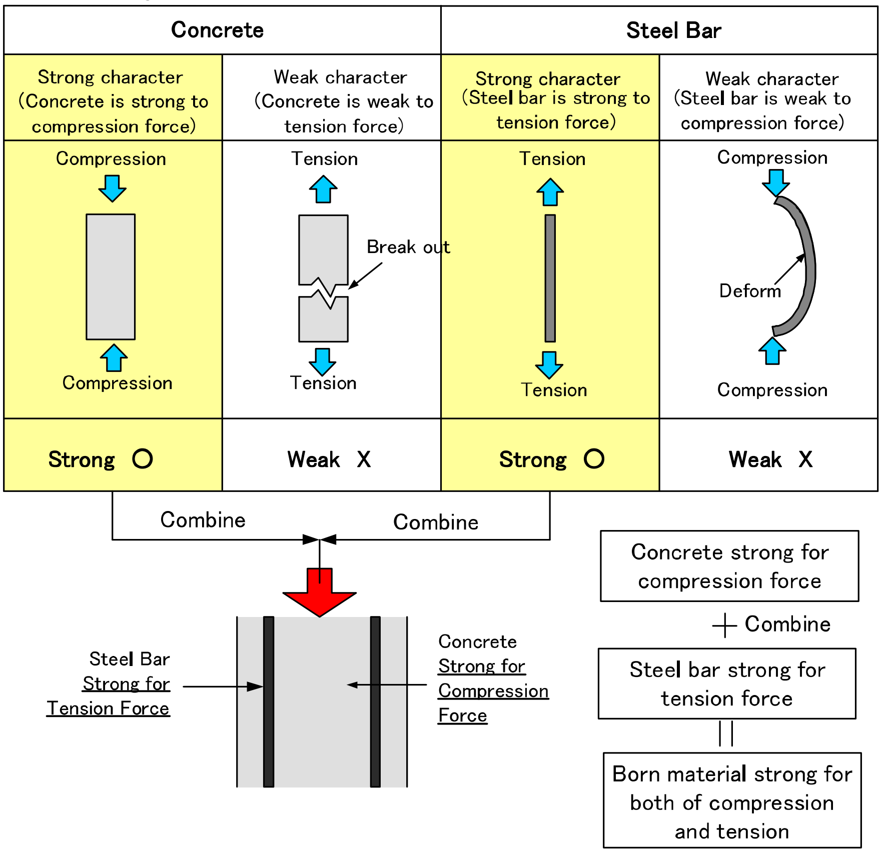
Figure-3: Column Damage by Salt Content

1-4 General Definition of Reinforced Concrete

1-4-1 Characteristics of concrete and steel bar

- Reinforced Concrete is composed of concrete and steel bar.
- Concrete has resisting strength against compression force and weakness against tension force.
- Steel bar has resisting strength against tension force and weakness against compression force.
- Accordingly, reinforced concrete is the material, which has both of strong character of concrete and steel bar as shown Fig-4.

Figure-4: Character of the Concrete and Steel Bar



1-4-2 Mechanism of reinforced concrete

Reinforced concrete is the combined structure with concrete characteristic of compression strength and steel bar characteristic of tension strength.

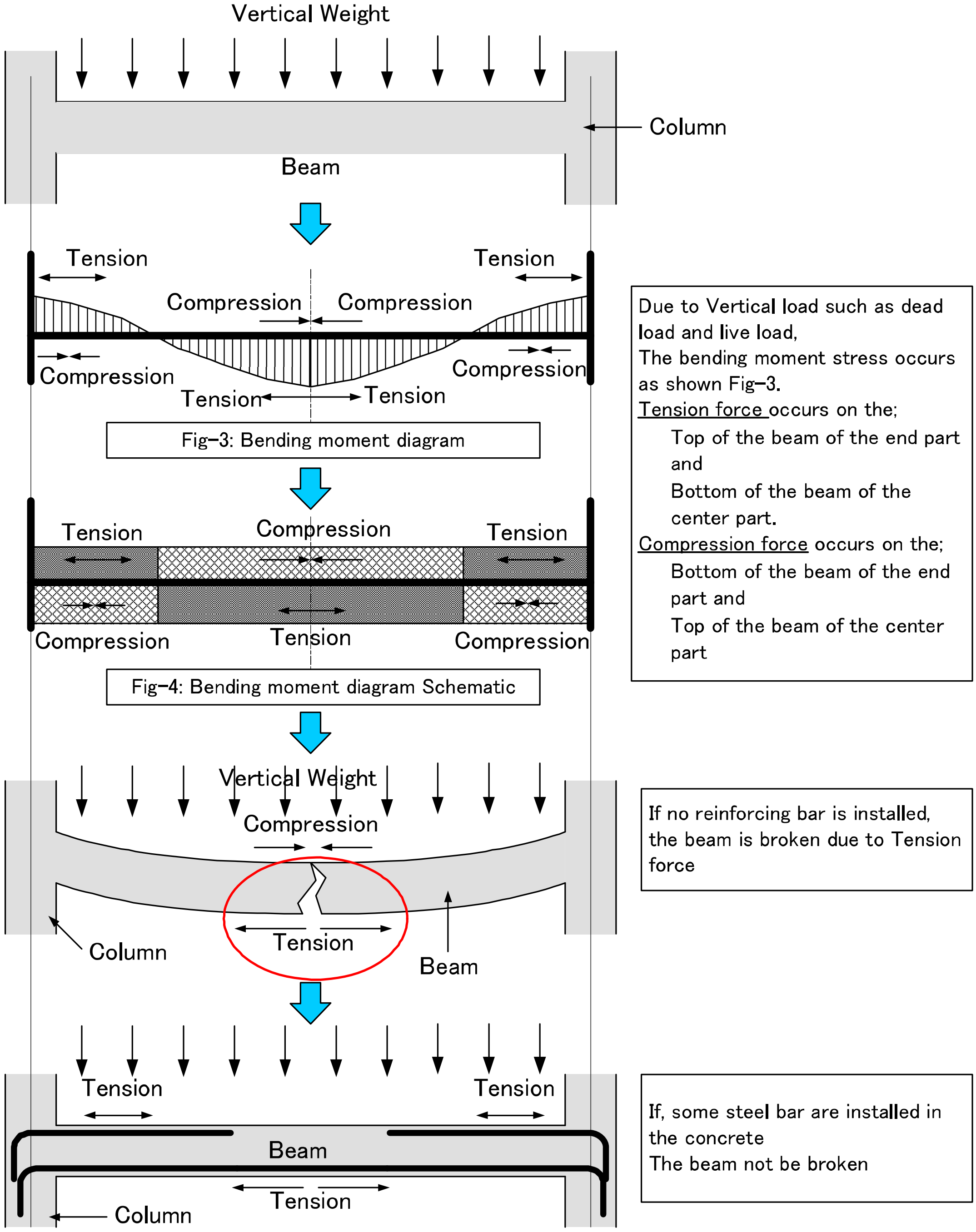


Figure-5: Mechanism of Reinforced Concrete

1-4-3 Importance of bond strength between concrete and steel bar

- The medium that adheres (sticks) concrete and steel bars is the bonding strength of concrete.
- Therefore, executing proper concreting work is very important in order to gain enough bonding strength around steel bars.

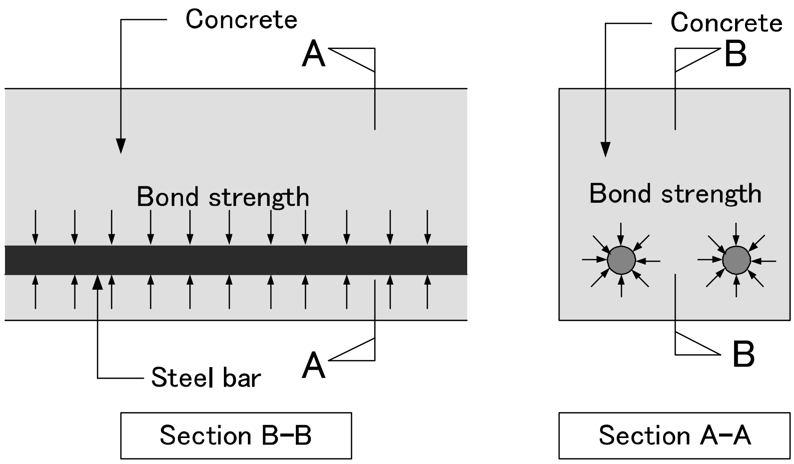


Figure-6: Adhere (bonding) re-bars and concrete

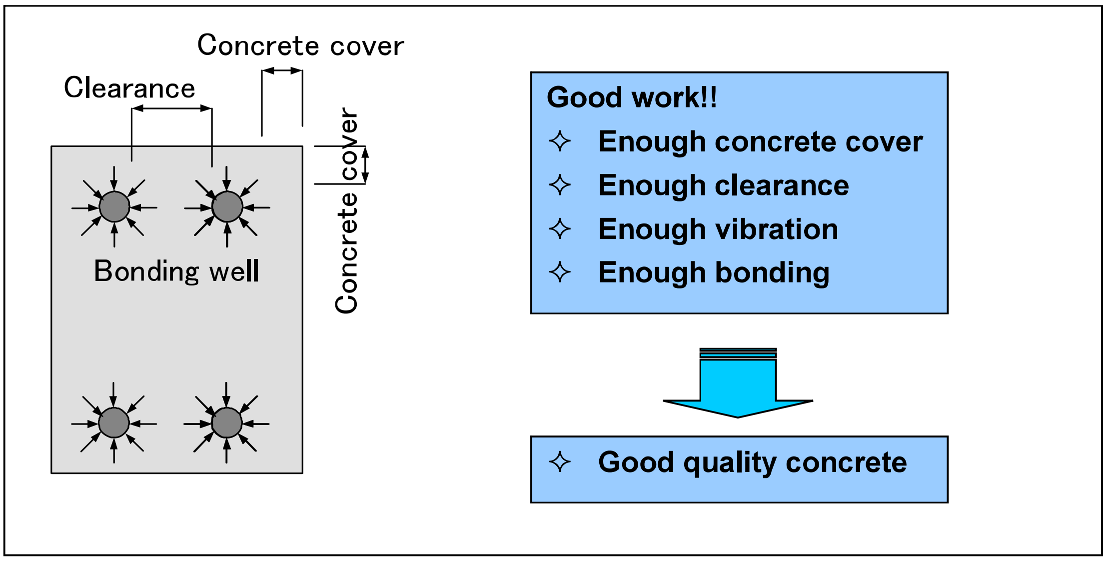
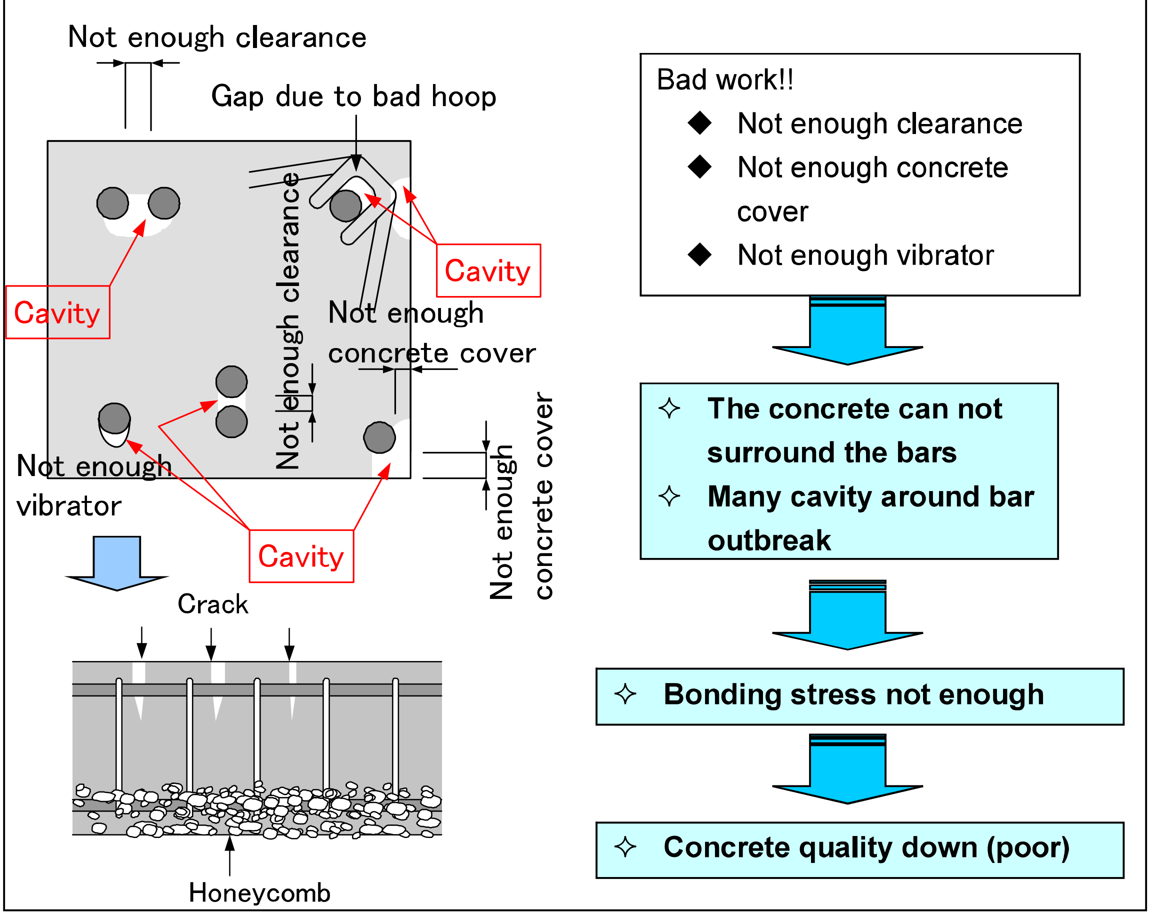


Fig-7 Example of the bad concrete work



1-4-4 Importance of concrete cover

- Concrete has strong alkaline character. Therefore, concrete surface could take neutralization by carbon dioxide, water and other toxic substance in the air.
- The neutralization outbreaks the concrete cracks.
- Concrete cracks outbreak corrosion to the steel bar.
- Finally, the durability of the structure will be reduced rapidly.

  <u>The neutralization of concrete is connected directly to durability loss.</u>

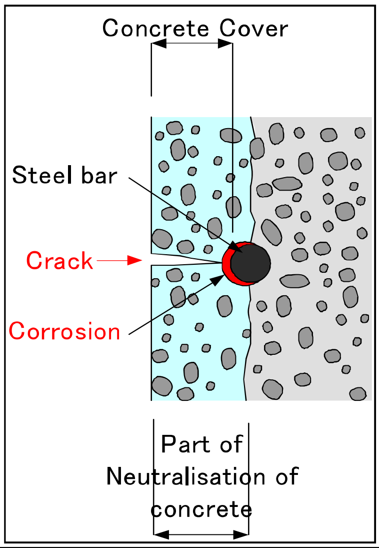


Figure-8: Section of Concrete

- Commonly considered speed of the neutralization

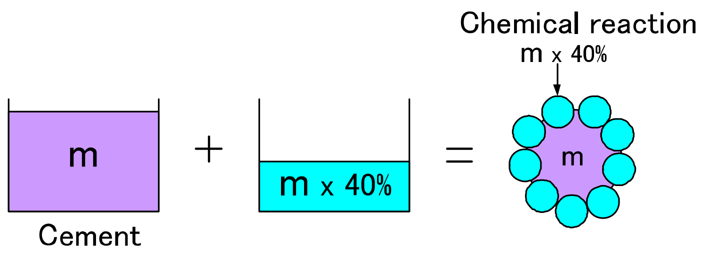
Table-6: Relation between Concrete Cover Thickness and Standard Durability

Thickness of concrete cover	Standard durability
Up to 1.0cm	Around 7 years
Up to 2.0cm	Around 30 years
Up to 3.0cm	Around 60 years

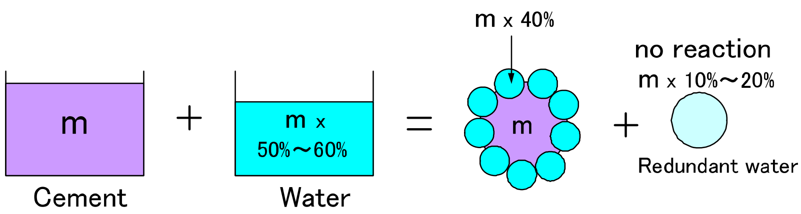
The above data illustrates that securing enough concrete cover thickness is very important in order to achieve longer durability.

1-4-5 Necessary amount of water

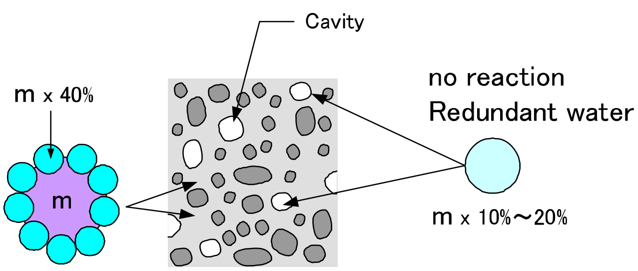
Cement makes chemical reaction with water approximately 25% and absorb water approximately 15% of its mass (m), totally react with water approximately 40%. However, concrete should be mixed with water at the amount of m x 50～60%. It means that around 10～20% of water [redundant water] becomes the cause of large bubbles in concrete. The large bubbles reduce concrete strength significantly.



Necessary amount of water for chemical reaction: m x 40%



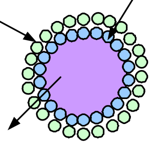
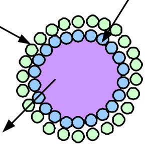
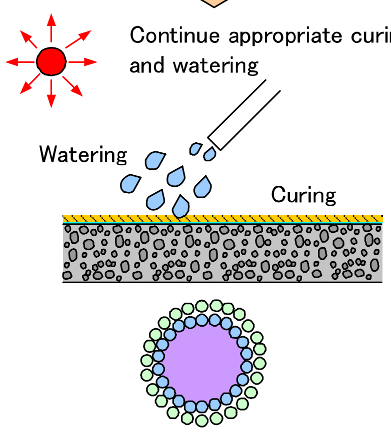
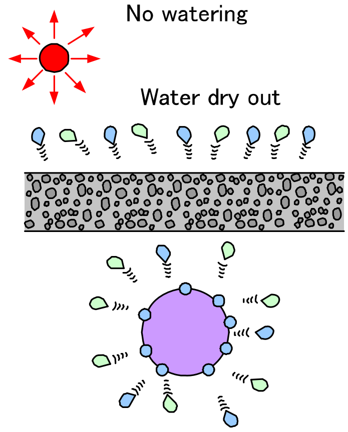
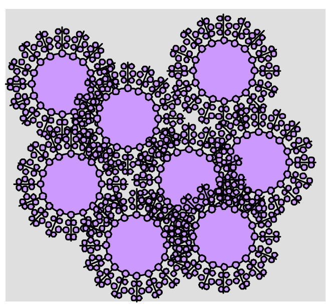
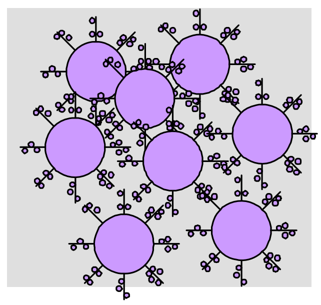
Necessary amount of water for chemical reaction is around m x 40%, therefore, if the cement is mixed with 50% to 60% water of the mass, 10～20% water has no chemical reaction (Redundant water).



Around 10～20% of redundant water may cause of developing cavity in concrete and cause to reduce strength of concrete. Therefore, the use of too much water is not good for concrete.

1-4-6 Importance of continuous curing and watering after pouring concrete

In order to make a good quality concrete, maintaining appropriate moisture condition after pouring concrete by curing (concrete surface protection against dry out) and watering is very important.

	In the case of appropriate water condition	In the case of dry condition
Just after Pouring	Water for chemical reaction Water in the Concrete  Particle of cement	Water for chemical reaction Water in the Concrete  Particle of cement
5～6 hour after Pouring	Continue appropriate curing and watering Watering Curing  Keep appropriate moisture condition	No protection, no curing No watering Water dry out  In the dry condition Water essential for chemical reaction are dry-out.
5～7 days after Pouring	Sufficient Chemical reaction and crystallization  Good dencity Concrete	Insufficient Chemical reaction and crystallization  Poor dencity Concrete

1-5. Trial Mixing of Concrete

1-5-1. Purpose of the trial mixing

(1) Control quality of concrete as one of the most important aspect.
(2) Confirm not only 28 days strength but also quality of the fresh concrete as checking the concrete strength is very important.
(3) In the case of ready mixed concrete produced by authorized factory, trial mixing may not necessary.

Note: This clause particularly applies to the site mixing concrete.

Table-7: Main Items to be confirmed through the Trial Mixing

	Items	Judgment and/or Standard
(1)	Slump	±1.0 cm of the technical specification
(2)	Air Contents	4.5%±1.0 % (=3.5% to 5.5%)
(3)	Concrete Temperature	By thermometer
(4)	Salinity Contents	Amount of chloride ions shall be less than 0.3kg/m^3
(5)	Segregation	Visual observation
(6)	Compression Strength	Compression Test (Refer to 1-6-6)

(4) Basic factors of concrete strength

1) **Amount of cement (C)**
2) **Amount of Water (W)**
3) **Amount and density of coarse aggregate (stone)**
4) **Amount of sand**

✧ If water and cement ratio (W/C) is small (=amount of cement is large):
◎ Concrete strength becomes high.
◎ Durability becomes long.
◎ Slump becomes small → Hard concrete → Suitable for Civil work
× Concrete work for building construction becomes difficult.
× Liable to have crack

✧ If water and cement ratio (W/C) is large (=amount of water is large):
◎ Concrete strength becomes low.
◎ Durability becomes short.
◎ Slump becomes large → Concrete becomes soft → Concrete pouring work becomes easy.
× Liable to have crack because of much water → Cement milk leaks easily → Many honeycomb could outbreak.

✧ If amount of sand is large:
× Slump becomes large.
× Concrete strength becomes low.

✧ If amount of coarse aggregate (stone) is large:
◎ Slump becomes small.
◎ Concrete strength becomes high.

✧ If density of coarse aggregate is light:
× Concrete strength becomes low.

✧ If air content is high:
× Concrete strength becomes low.

The concrete strength could be either high and low depending on various factor and condition. Therefore, the planning of concrete mix proportion is the first step for making high quality concrete.

1-5-2 Procedure of concrete mix proportion design

(1) Decide maximum size of aggregate (stone) considering the dimension on structural elements.
(2) Decide amount of air contents (target max 4.5%), kind of cement and slump.
(3) Decide target concrete strength considering the concrete design strength.
(4) Decide water (W) and cement (C) ratio (=W/C).
(5) Decide amount of water
(6) Decide amount of cement
(7) Decide unit weight of coarse aggregate (stone) and fine aggregate (sand)

1-5-3 Design strength and target strength for quality control

The Concrete strength is in general not allowed to have lower strength than the designed strength. However, the concrete strength is not always the same, even if the same mixing proportion is taken (sometimes lower than the designed strength, and sometimes higher than the designed strength).

Therefore, it is necessary to make a target strength, which takes into account the uneven quality of concrete in order to satisfy the design strength.

Recommendation of the Target strength is follows;

Fq= Fc + 3.0 N/mm^2

For example;
In the case of Fc=250K
→ Target strength of concrete mixing proportion shall be Fq=280K

Note:

- ✧ Design strength (Fc) is the required strength by the structural design.
- ✧ Target strength (Fq) is the strength for quality control of the concrete considering quality variation (especially reduced) due to negative factor during concrete mixing and pouring work.

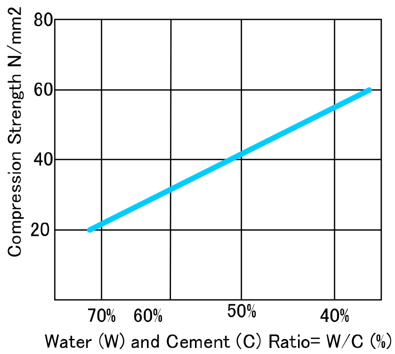
1-5-4 Key-points for making good concrete

Table-8: Key-Points for making Good Quality Concrete.

Materials		Key Points
(1)	Water	**Reduce water ratio as much as possible**
(2)	Aggregate (stone)	**Increase stone as much as possible**
(3)	Hardness (Slump)	**Make concrete hard as much as possible**

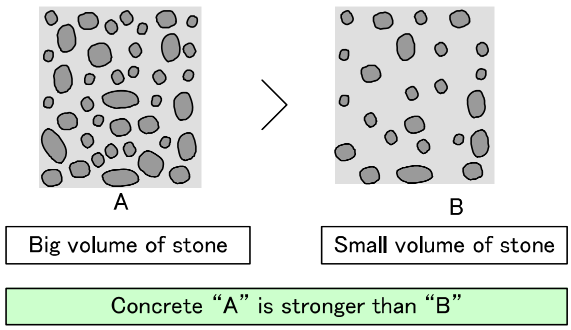
(1) <u>Reduce water</u>

In case of the soft concrete, which contains lot of water, it tends to easily crack due to redundant water for chemical reaction. As shown in right figure, the compression strength increases inversely proportional to the water and cement ratio.



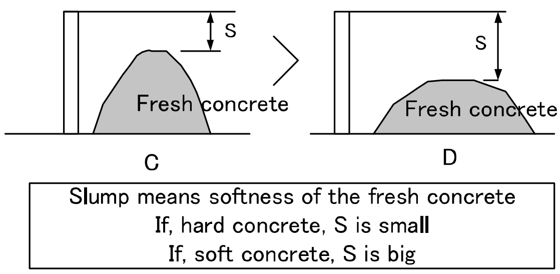
(2) <u>Increase coarse aggregate (stone)</u>

The durability of A (Concrete contains large volume of stones) is higher than B (Concrete contains small volume of stone: lesser density).



(3) <u>Make hard concrete</u>

Concrete, which has small slump (hard concrete), could have even quality due to no material (cement and aggregate) separation.



1-5-5 Preparation and method of trial mixing

Step1. Planning of Mixing Proportion

Step2. Trial Mixing by Mixer

Step3. Check Moisture Content and Slump

Step4. Check Air Content by Tester

Step5. Sampling for Strength Test

Step6. Concrete Compressive Strength Test

1-15

1-5-6 Concrete test

(1) Compressive test

1) Check the compressive strength
- ✧ One (1) sampling order for each work segment
- ✧ Each sampling order takes 6 cylinders for tests (3 for 7 days, 3 for 28 days)

2) Test piece
- ✧ Height of test piece is 2 times of its width
- ✧ Fill the concrete in the mold divided into 2 layers

Test Piece Sampling for Compressive Strength

Compressive Strength Test

3) Method

① Clean the cylinder mold and coat the inside lightly with form oil, then place on a clean, level and firm surface, such as steel plate.

② Collect a sample. (See Sampling)

③ Fill 1/2 the volume of the mold with concrete then compact by rodding 25 times. Cylinders may also be compacted by vibrating using a vibrating table.

④ Fill the mold to overflowing and rod 25 times into the top of the first layer, then top up the mold till overflowing.

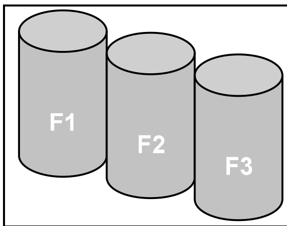
⑤ Level off the top with the steel float and clean any concrete from around the mold. Make top surface as smooth and flat as possible.

⑥ Cap, clearly tag the cylinder, and put it in a cool dry place to set for at least 24 hours.

⑦ After the mold is removed from the cylinder, they should be sent to the laboratory, where test pieces are cured and crushed to test compressive strength.

4) Judgment of the compression test result
   - ✧ Concrete shall be required that the average of 3 pieces is more than design strength + 3N/mm2

The result of the compression test

	**Average of 3 pieces =(F1+F2+F3)/3 shall be ≧ Fq (Design Strength + 3N/mm2)**

↓

If, less than Fq;

↓

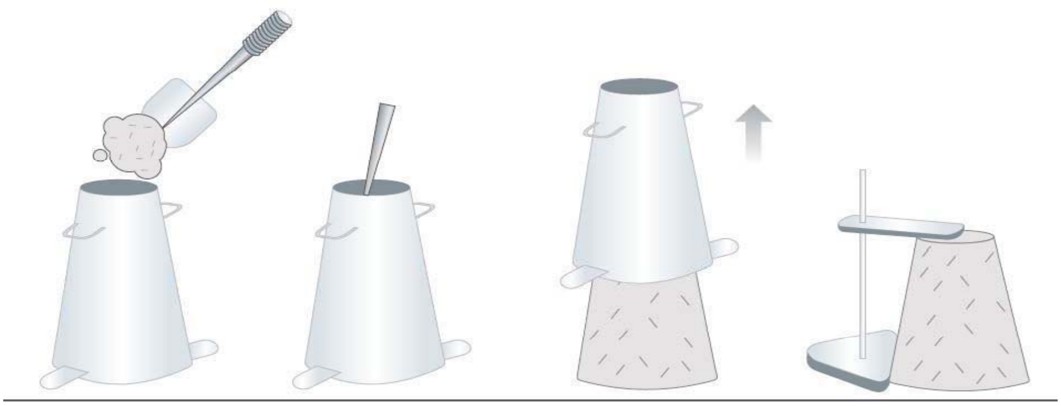
5) If Trial Mixing was failed…….
- ✓ Check, confirm and analyze again about following points.
- ✓ Analyze mixing proportion. Water-cement ratio.
  Unit water contents…etc.
- ✓ Check for cement specification, date and conditions:
  Wet or dry, Fresh or old…etc.
- ✓ Check for aggregate specifications and conditions:
  Grain size, Water contents…etc.
- ✓ Analyze water contents and slump at the mixing concrete time.
- ✓ Confirm concrete curing method after mixing concrete.

↓

Concrete test again

(2) Slump test

1) Clean the cone. Dampen with water and place on the slump plate. The slump plate should be clean, firm, level and non-absorbent. Collect a sample of concrete to perform the slum test.
2) Stand firmly on the foot-pieces and fill 1/3 the volume of the cone with the sample. Compact the concrete by 'rodding' 25 times (Rodding means to push a steel rod in and out of the concrete to compact it into the cylinder, or slump cone. Always rod in a definite pattern, working from outside into the middle.).
3) Now fill to 2/3 and again rod 25 times, just into the top of the first layer.
4) Fill to overflowing, rodding again this time just into the top of the second layer. Top up the cone till it overflows.
5) Level off the surface with the steel rod using a rolling action. Clean any concrete from around the base and top of the cone, push down on the handles and step off the foot-pieces.
6) Carefully lift the cone straight up making sure not to move the sample.
7) Turn the cone upside down and place the rod across the up-turned cone.
8) Take several measurements and report the average distance to the top of the sample. If the sample fails by being outside the tolerance (i.e. the slump is too high or too low), another sample must be taken. If this also fails the remainder of the batch should be rejected.

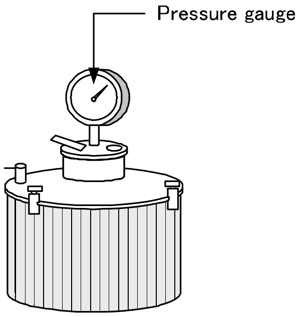


1 → 2 → 3 → 4

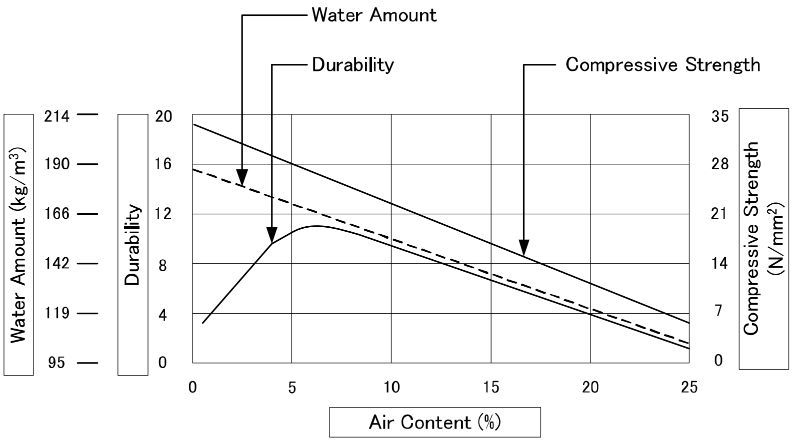
(Every procedure should be completed in less than 2.5 minutes)

(3) Air content test

1) Air content test shall be made at the same time of the slump test.
2) If air content increases, concrete compression strength decrease
3) Appropriate air contents shall be about 4.5 % at standard level.



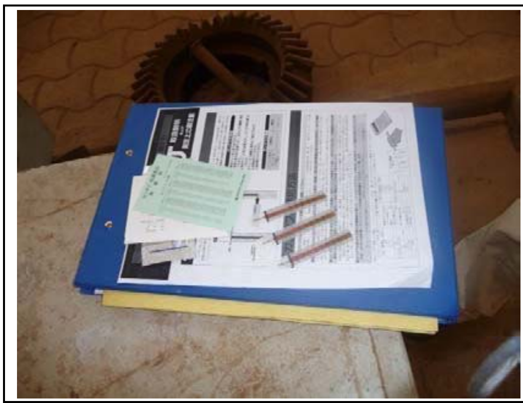
Air content Measuring tool



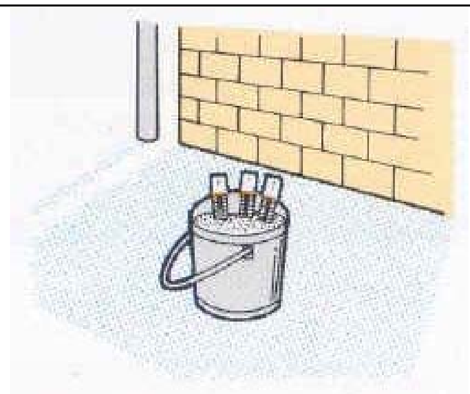
(4) Chloride content

Check of chloride content of concrete

1) Test each work segment for placing concrete
2) Volume of chloride content shall be **less than 0.3kg/m^3**
3) Test must be done in the shade



Test tool



Test image

Chloride Test Strip

PART-2 EXECUTION

2-1 Concrete Works

2-1-1. Watering to the form work before pouring concrete

Dried form absorbs water of fresh concrete, and causes poor density of concrete. Therefore, applying water to the dried form before pouring concrete as shown in Figure-10 is very important for produce high density concrete. When concrete is poured without watering, water contents of the fresh concrete will be absorbed by the dried form, and concrete density become very poor as shown in Figure-11.

Figure-10: Essential Procedure of Pouring to produce High Density Concrete

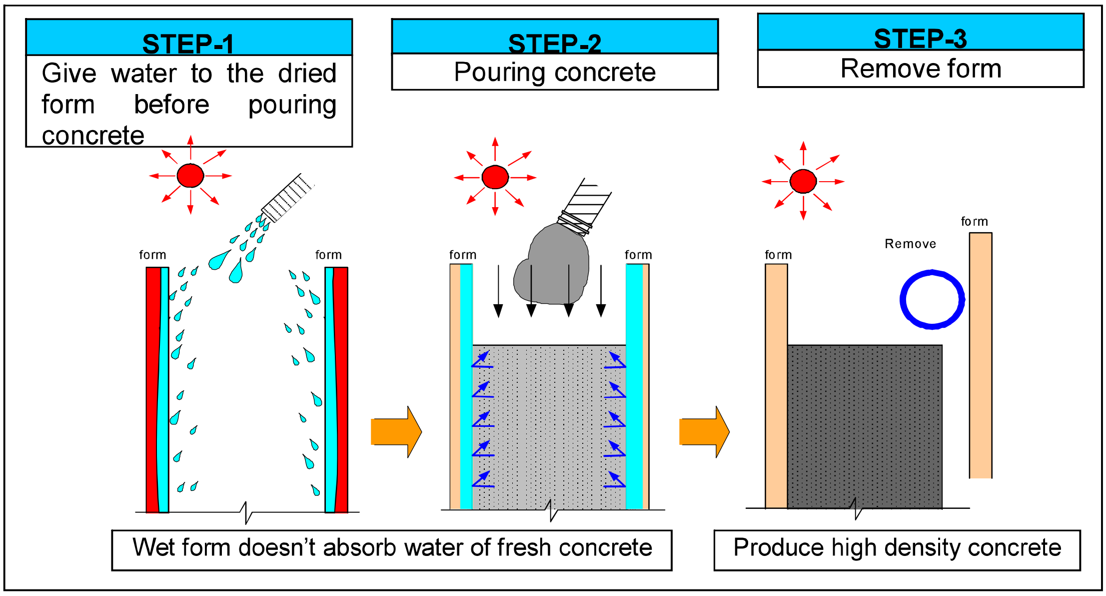
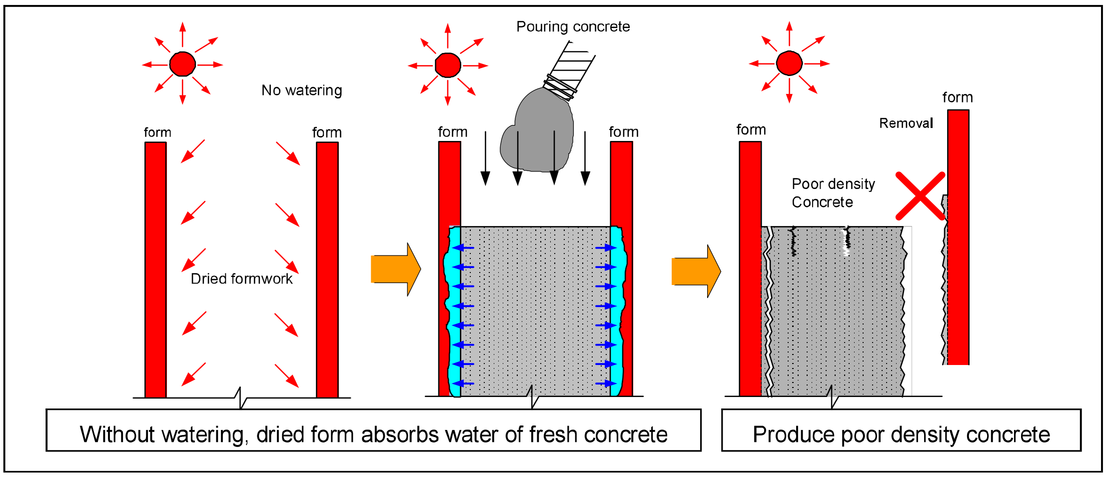


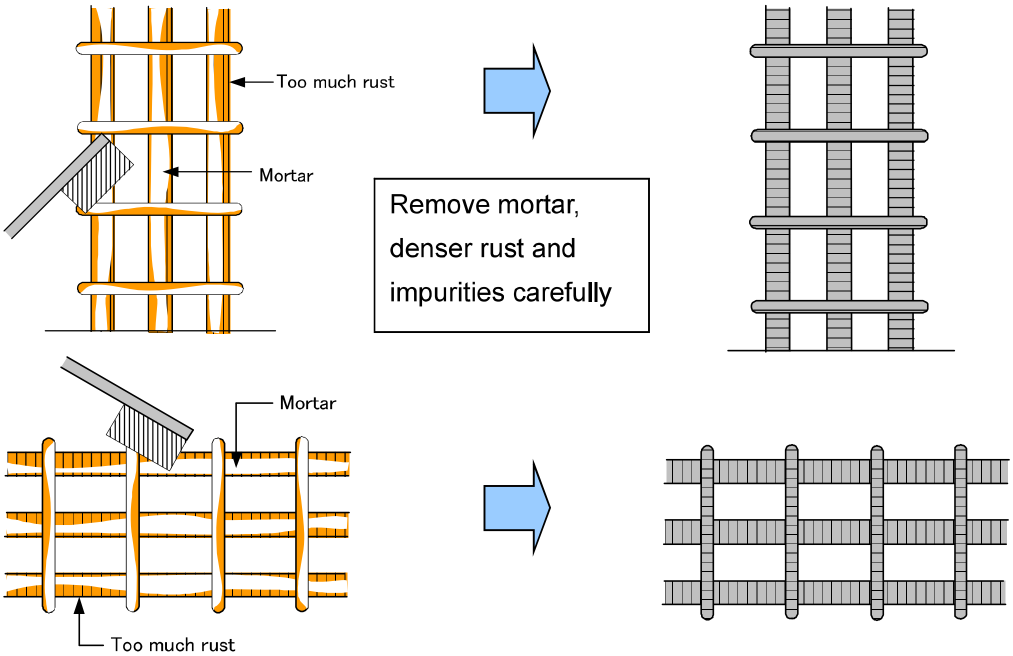
Figure-11: Inappropriate Procedure of Pouring Concrete



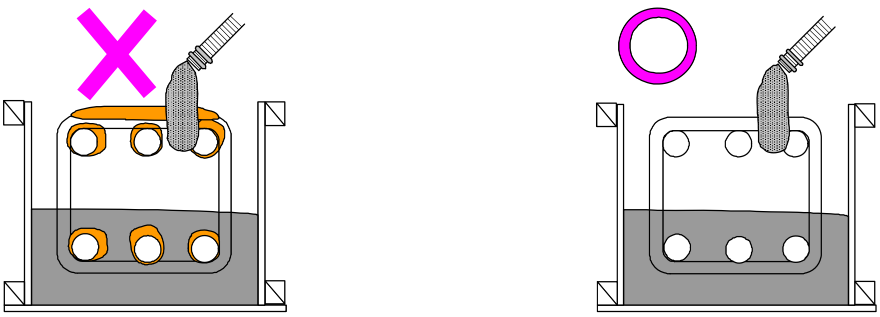
2-1-2. Clean up

(1) Clean up of the Reinforcing bar

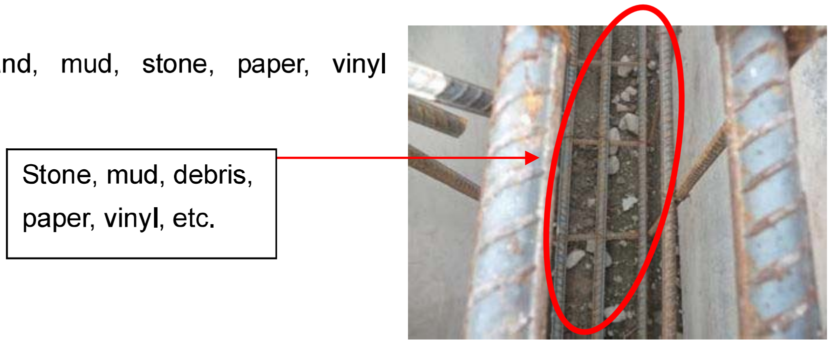
Before pouring concrete, remove mortar, denser rust and impurities that adhered to or struck with reinforcing bars.

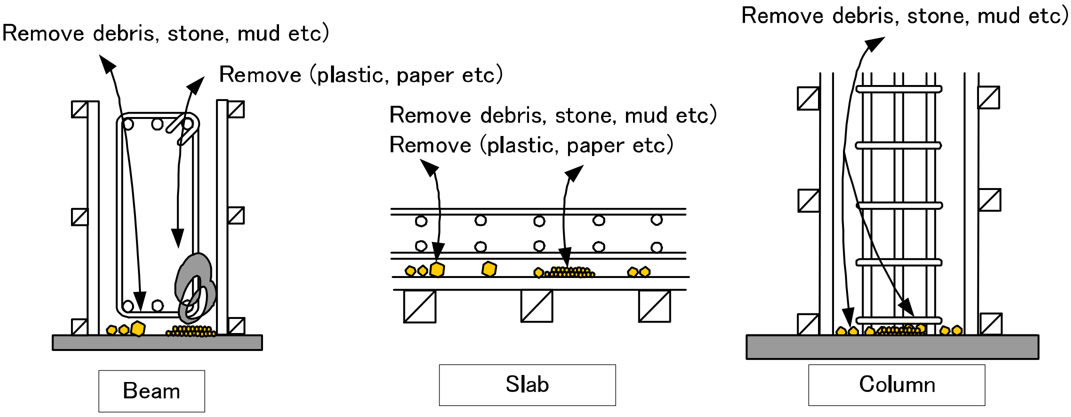


Don’t pour the concrete before removing the mortar, denser rust and impurities.

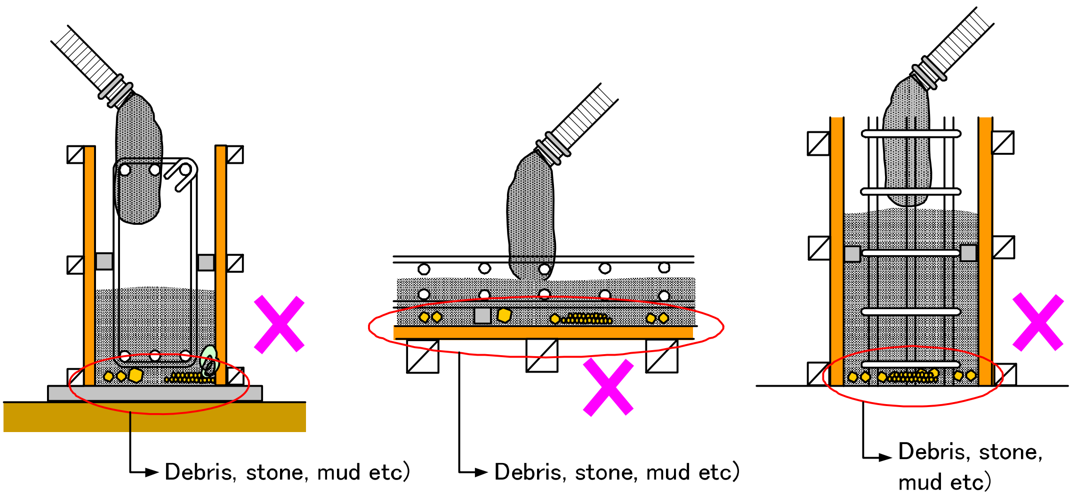


(2) Remove debris, sand, mud, stone, paper, vinyl materials, etc.





Do not pour concrete before removing the stone, debris, paper and vinyl materials, etc.



2-1-3. Pouring concrete for columns

(1) Do not shoot concrete directory from the top of the column.

Pouring concrete for column shall be made through a vertical shoot and discharge fresh concrete carefully.

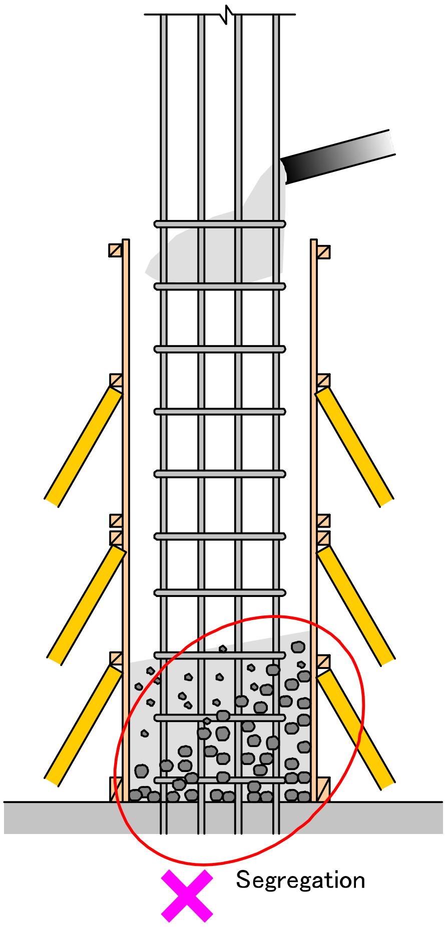


Figure-12: Direct pouring
Do not shoot the concrete directory from the height of the column in order to avoid the aggregate segregation at bottom of the column.

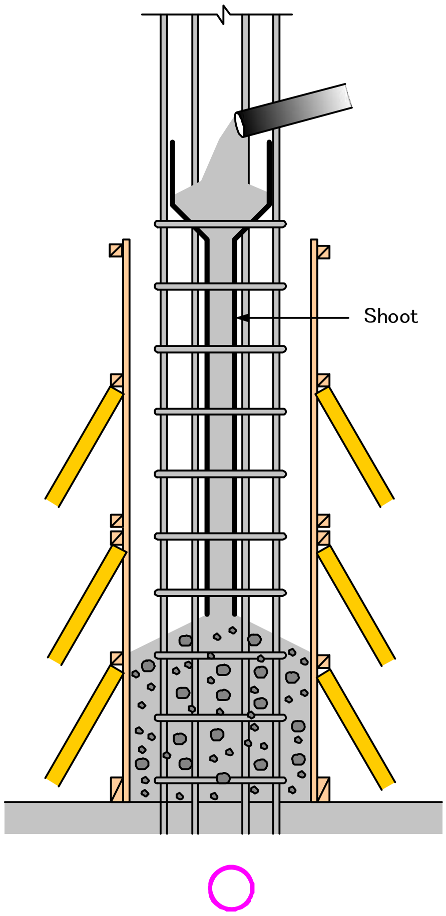
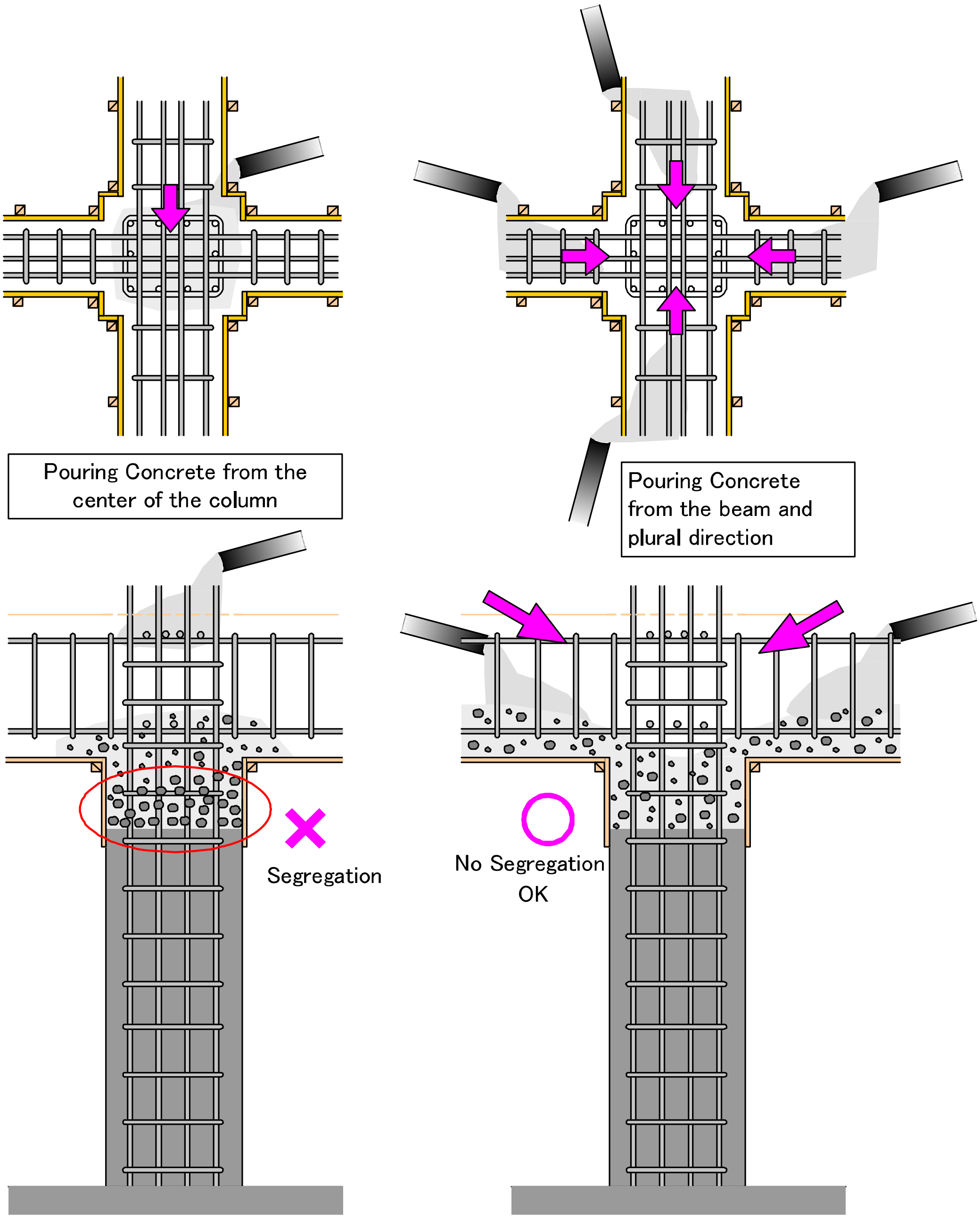


Figure-13: Steel shoot
Use a vertical shoot and pouring concrete uniformly.

(2) Pouring concrete at the top of columns

Pouring concrete at the top of column shall be made from the beams and plural direction. Do not shoot the concrete from the center of the column where the reinforcing bars are crowded.



2-6

(3) Pouring concrete for long column

Concrete pouring (H=4.0m or taller) shall use vertical shoot as shown Figure-13, or prepare opening and collecting pocket at the center of the column as shown Figure-16. Discharge concrete carefully. Do not pour the concrete directory as shown Figure-14 and Figure-15 in order to avoid segregation at the bottom of column.

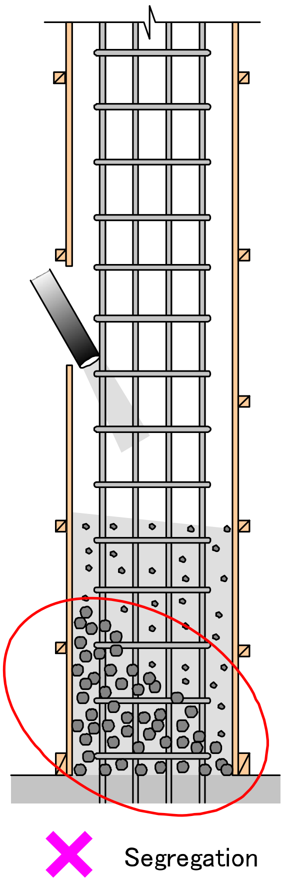


Figure-14: Direct pouring

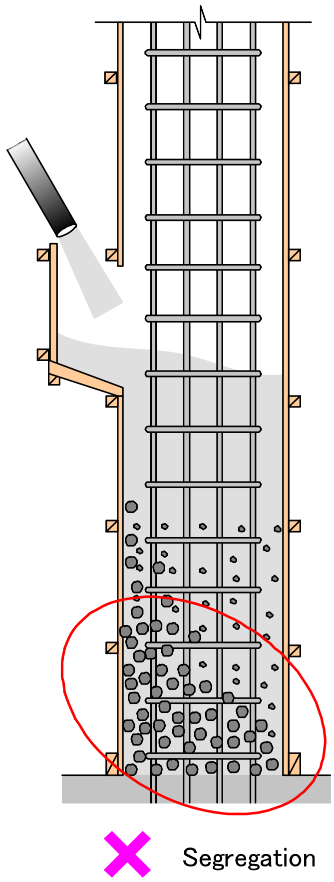


Figure-15: Same as direct pouring

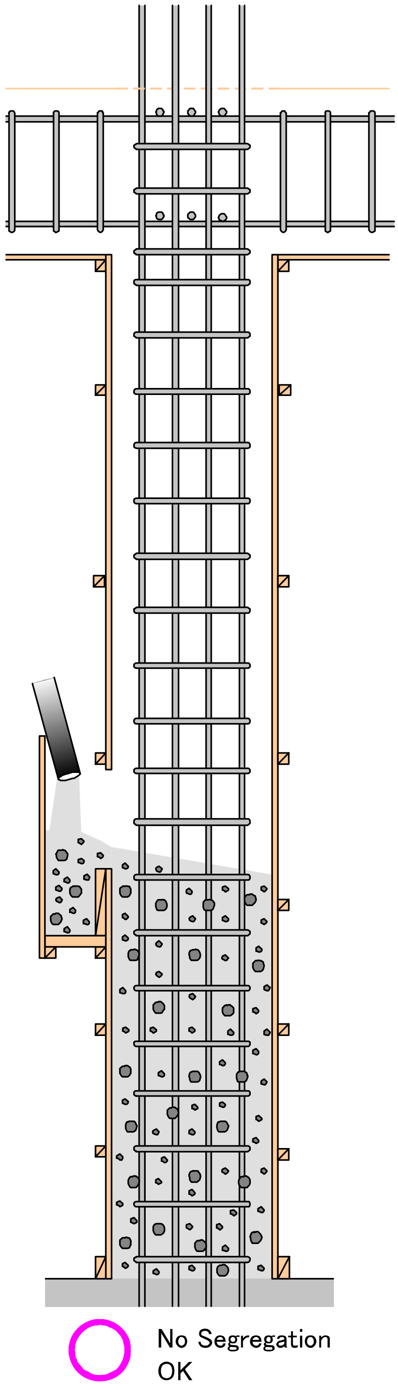


Figure-16: Correct pouring

(4) Influence of the segregation

- In case of long column (H=4.0m or taller), when concrete is poured directory from the top of the column, segregation will occur due to large size aggregate sink down and they concentrate at the bottom of column.
- The concrete strength normally becomes stronger in proportion to the amount of the aggregate. Therefore, where segregation occurs, the concrete strength at the bottom part of column could become higher than expected strength up to approximately 120%, and the concrete strength at the top part of column could become smaller than expected up to approximately 80% of expected strength as shown in Figure-17.

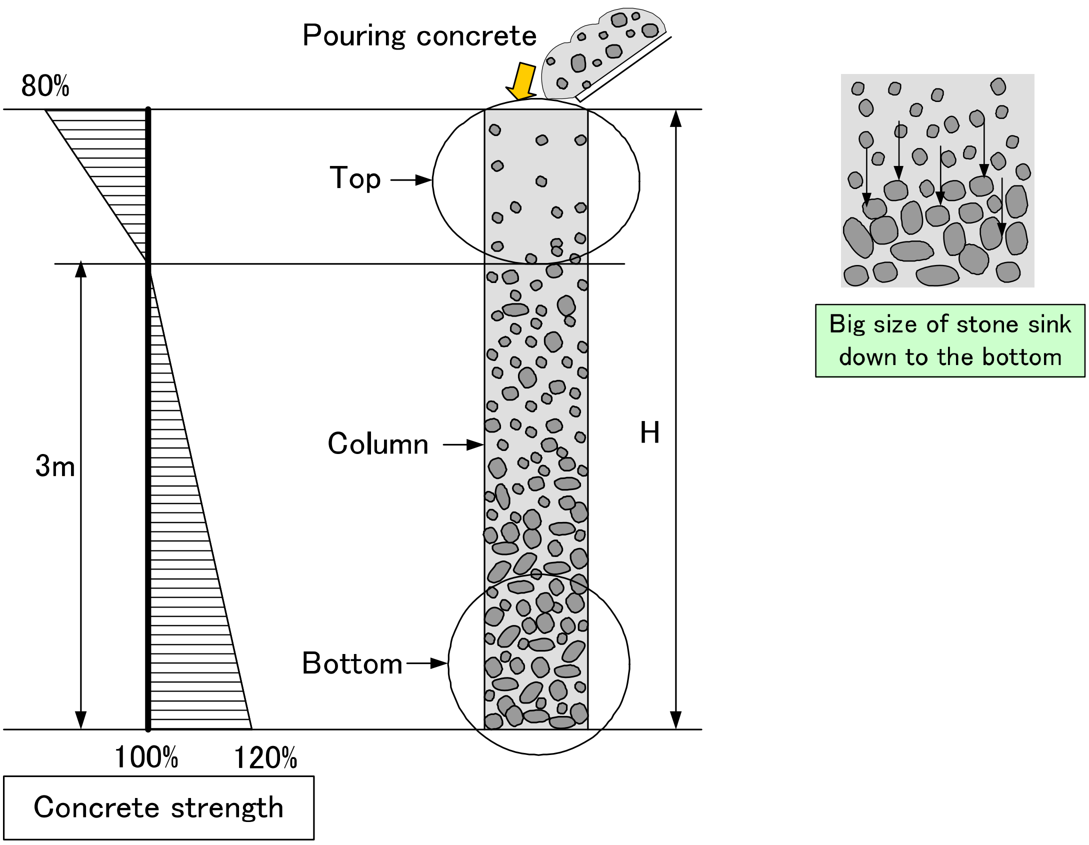
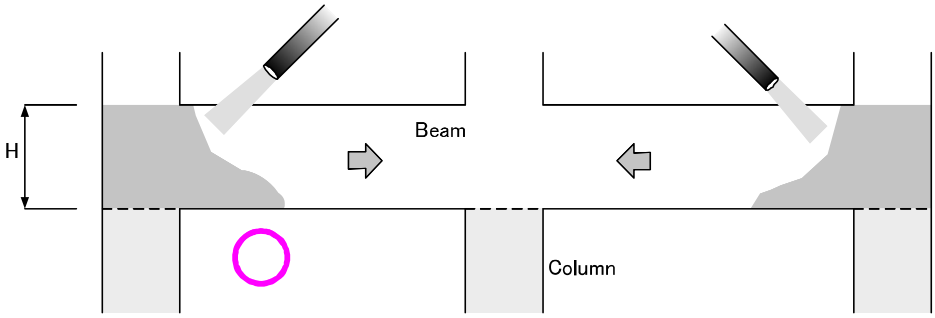


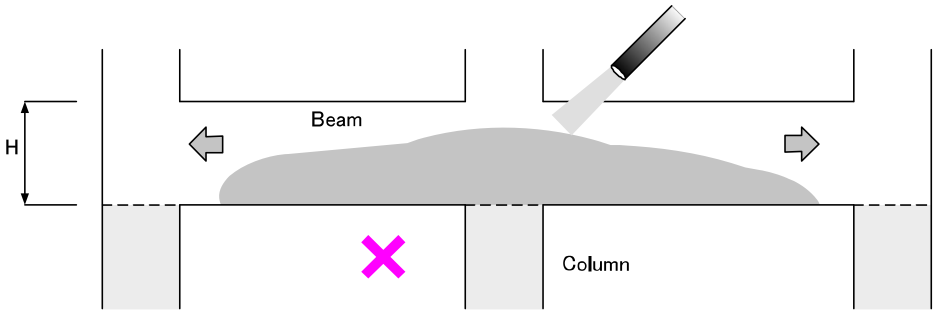
Figure-17: Reduce concrete strength due to Segregation

2-1-4. Pouring concrete for beams

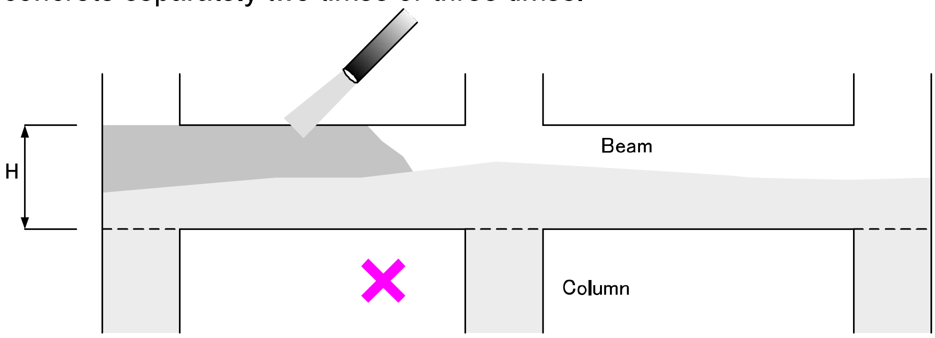
(1) The beam concrete shall be poured from the outer end to the center.



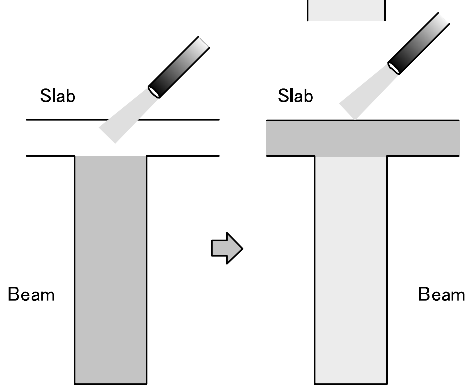
(2) Do not pour concrete from the center to the outer end.



(3) Concrete shall be poured up to beam height (H) by one time, don't pour the concrete separately two times or three times.



(4) In case of deep beam, concrete for slab shall be poured after confirmation of the settlement of the fresh concrete of the beam.



2-1-5. Pouring concrete for slabs

(1) Slab concrete shall be poured from the far side in as shown in Figure-18. Do not pour concrete from the center side as shown in Figure-19.

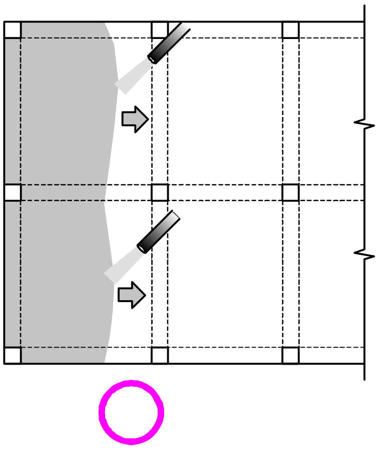


Figure-18: Pouring Concrete from the far side

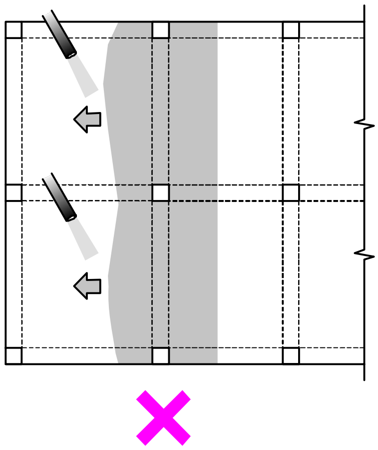


Figure-19: Pouring Concrete from the near side

(2) Slab concrete shall be poured while moving backward as shown in Figure-20. Do not pour concrete while moving forward as shown in Figure-21.

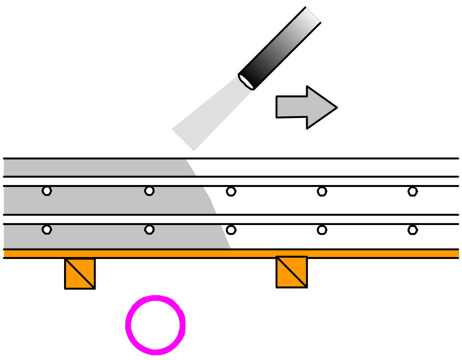


Figure-20: Pouring Concrete while moving backward

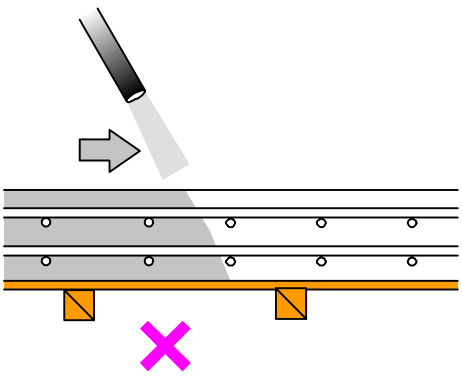


Figure-21: Pouring Concrete while moving forward

2-1-6. Construction joint

(1) Construction joint shall be horizontal or vertical and located near the center of the span for beams and floor slabs as shown in Figure-22. Do not make construction joint of slabs nearby columns and Beams as shown in Figure-23.

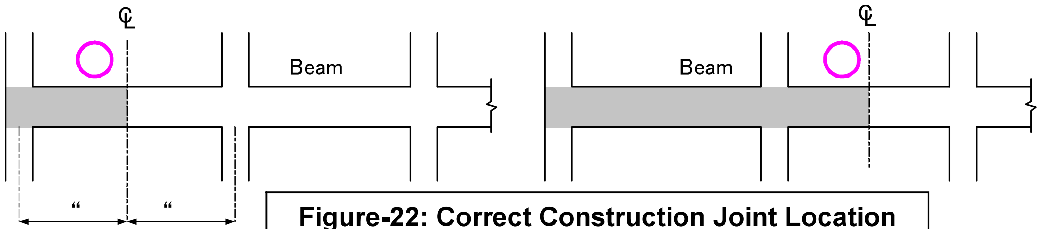


Figure-22: Correct Construction Joint Location

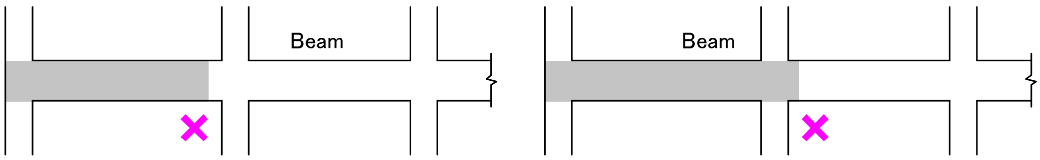


Figure-23: Incorrect Construction Joint Location

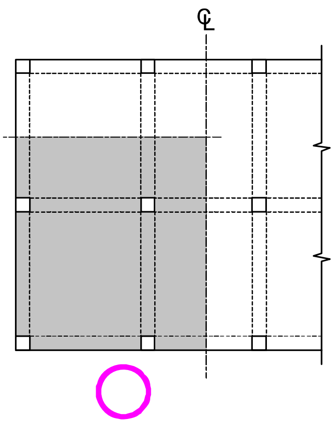


Figure-24: Correct Construction Joint Location

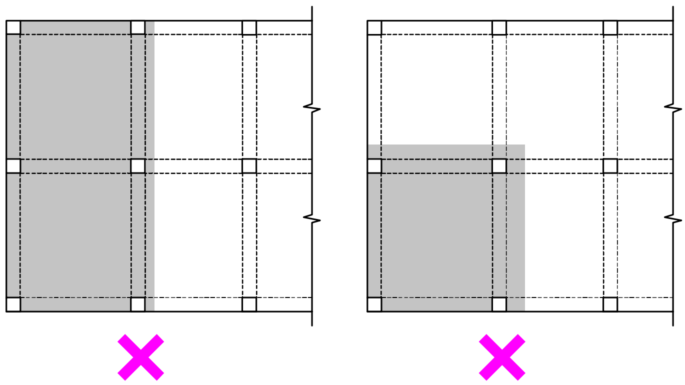


Figure-25: Incorrect Construction Joint Location

(2) Partition plates shall be used for joints of successive pours such that mortar, cement paste will not leak out as shown in Figure-26 & 28. Where the horizontal construction joint is on the outer surfaces, it shall be made straight using driving rulers. Do not pour concrete without stopper as shown in Figure-27& 29.

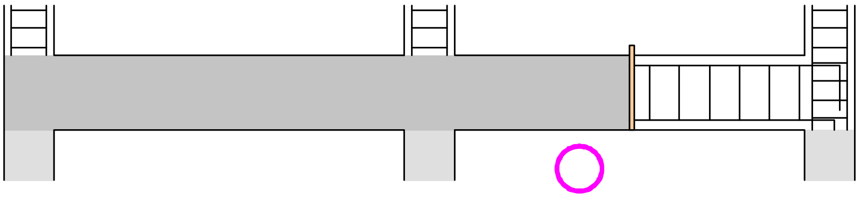


Figure-26: Appropriate Location of Construction Joint and Stopper

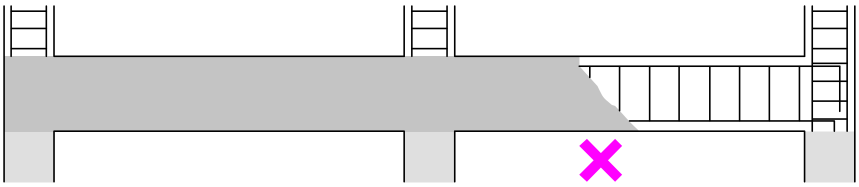


Figure-27: No Concrete Stopper for Construction Joint

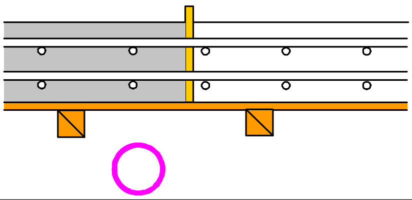


Figure-28: Correct Concrete Stopper

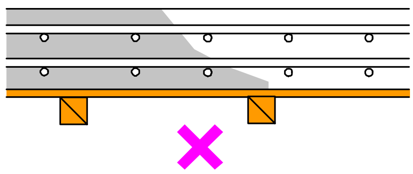


Figure-29: No Concrete Stopper

(3) In case of column, the construction joint shall be horizontal or gentle curve as shown in Figure-30. Do not make construction joint obliquely or make dent as shown in Figure-31.

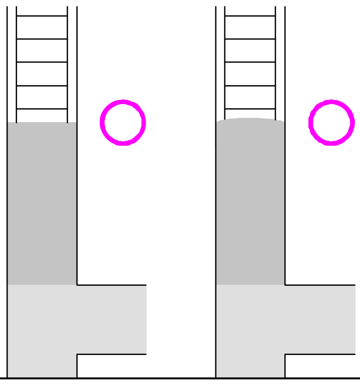


Figure-30: Correct Construction Joint

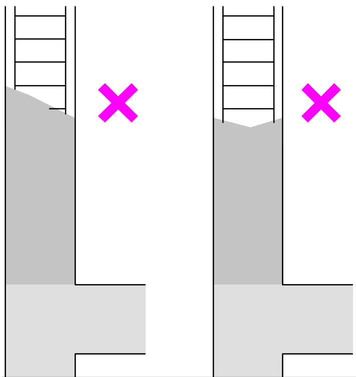


Figure-31: Incorrect Construction Joint

(4) Laitance and weak concrete shall be removed from the surface of construction joint to expose sound concrete.

1) Vertical or horizontal stopper shall be used for construction joint as shown in Figure-32.
2) Laitance and weak concrete shall be removed by chipping as shown in Figure-33.
3) Before pouring concrete, watering shall be carried out to the construction joint as shown in Figure-34.

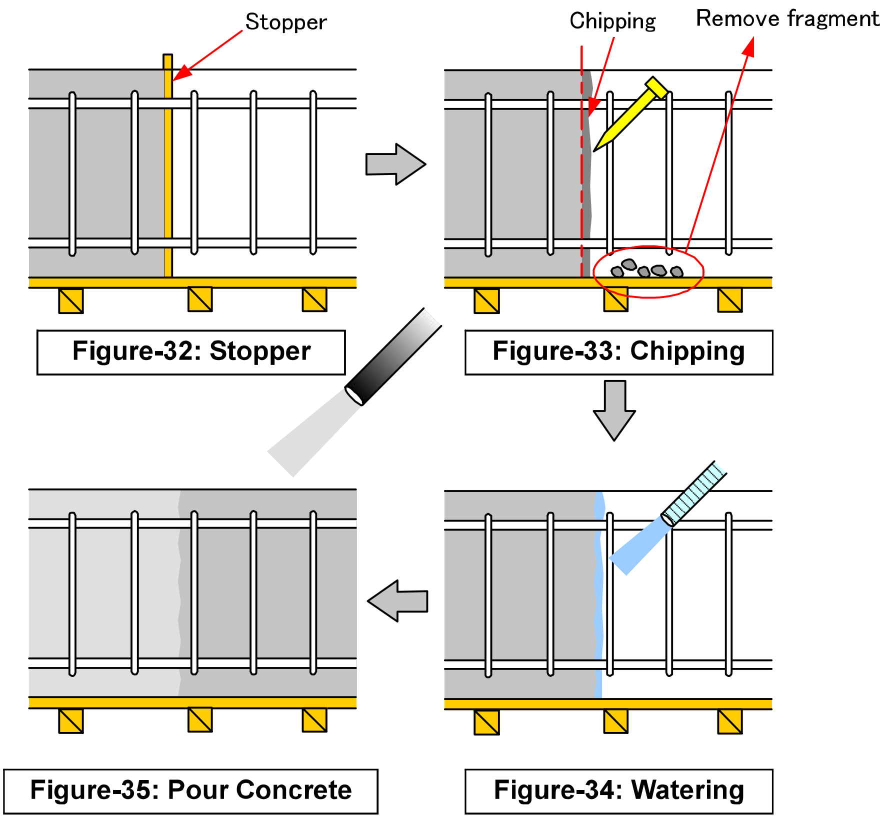


Figure-32: Stopper

Figure-33: Chipping

Figure-35: Pour Concrete

Figure-34: Watering

2-1-7. Vibrator

(1) Compaction of concrete shall be made by a vibrator and/or a compaction stick.

(2) A vibrator shall be uses vertically as shown in Figure-36. Do not use vibrator diagonally as shown in Figure-37.

(3) Do not stir concrete by a vibrator as shown in Figure-38.

(4) Spacing of vibrator insert shall be less than 60cm as shown in Figure-36, and vibrating time shall be 5 to 10 seconds for one time and up to the moment that cement paste appears on the surface of fresh concrete.

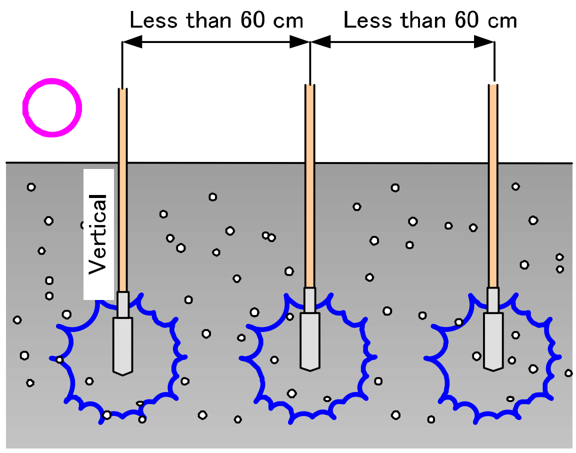


Figure-36: Correct Use of Vibrator

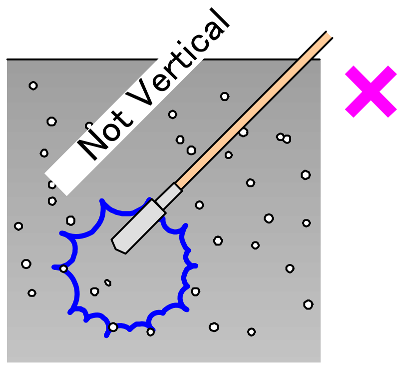


Figure-37: Incorrect Use of Vibrator

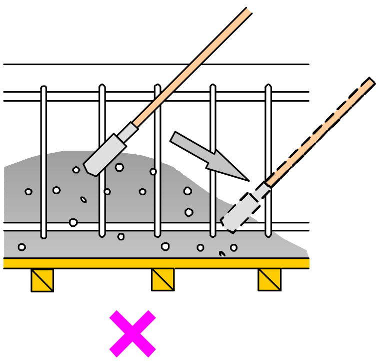


Figure-38: Incorrect Use of Vibrator

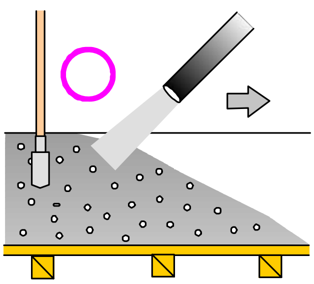


Figure-39: Correct Use of Vibrator

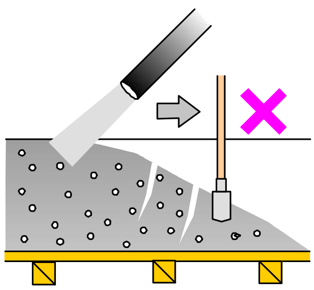


Figure-40: Incorrect Use of Vibrator

(5) Compaction and vibrating shall be carefully applied to make sure that every corner of the form and re-bar as shall be filled and covered by concrete as shown in Figure-41.

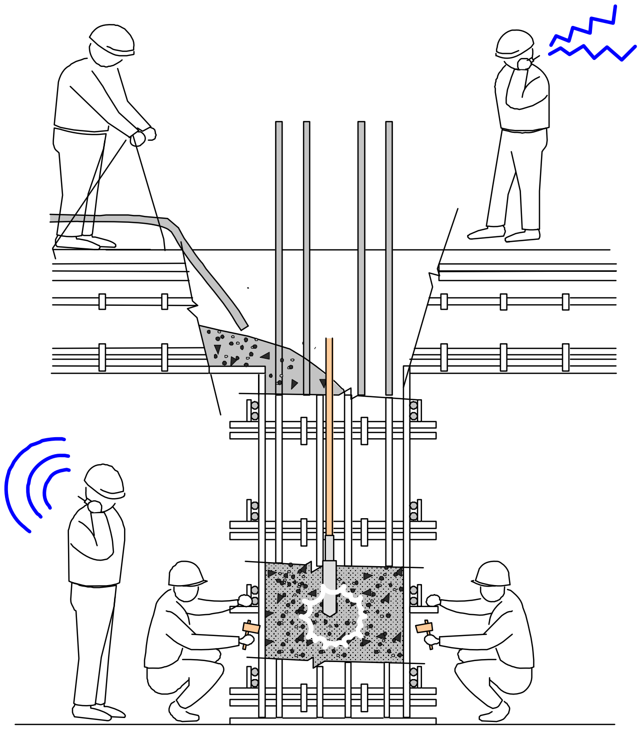


Figure-41: Correct Concrete Pouring Method

2-1-8. Honeycomb

Honeycomb will outbreak due to no vibration, wrong pouring work, leakage of cement milk from the gap of poor form, etc. as shown in Figure-42.

In the event that serious defect is found, approval for repair technique by the supervisor shall be sought, and the work shall be subject to inspection by the supervisor after the repair.

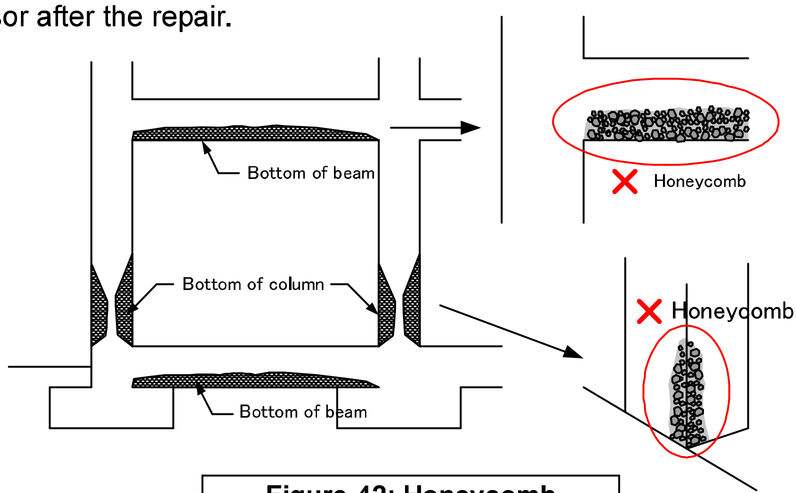


Figure-42: Honeycomb

Method of repair of the honeycomb

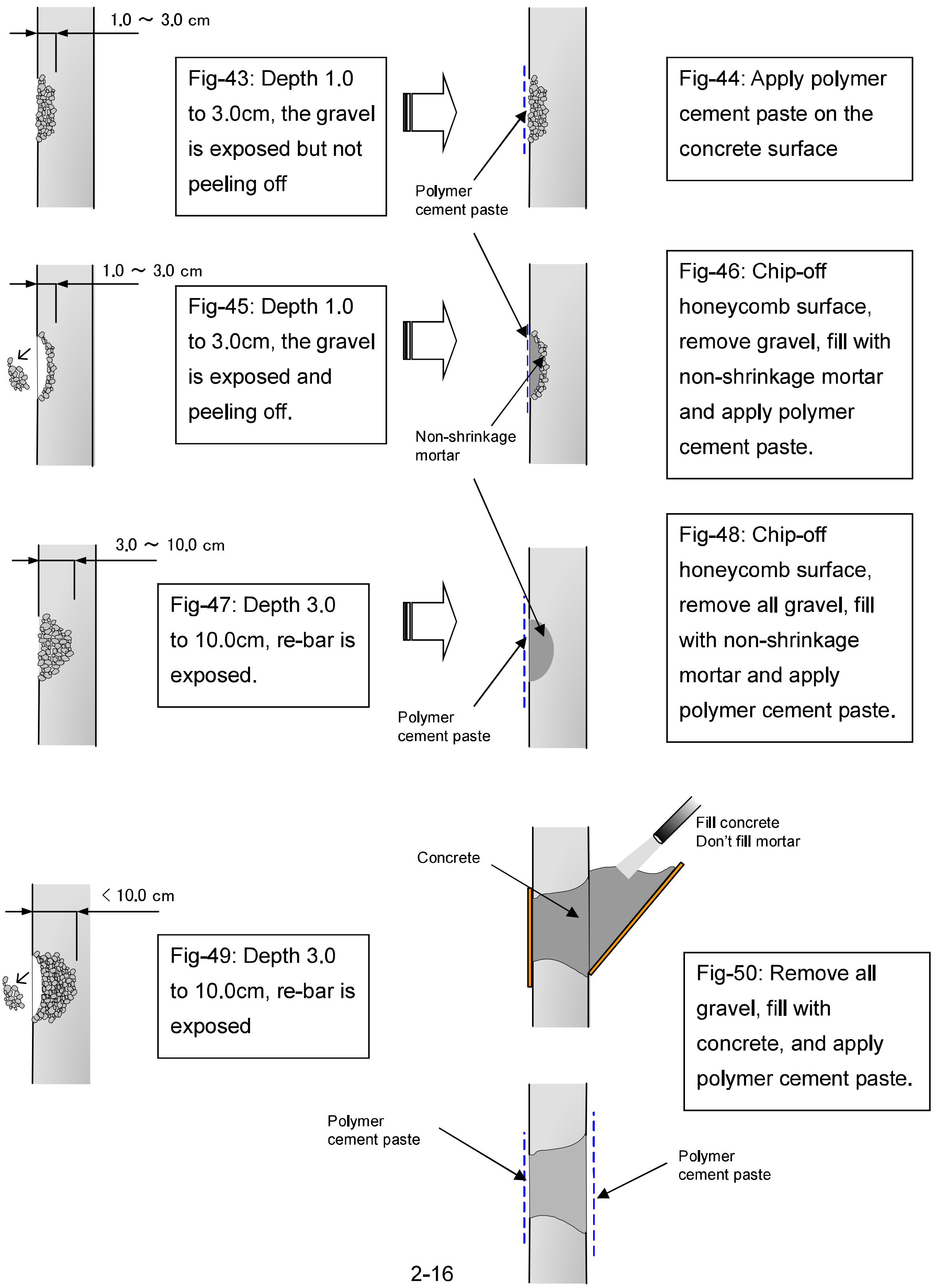


Fig-43: Depth 1.0 to 3.0cm, the gravel is exposed but not peeling off

Fig-44: Apply polymer cement paste on the concrete surface

Fig-45: Depth 1.0 to 3.0cm, the gravel is exposed and peeling off.

Fig-46: Chip-off honeycomb surface, remove gravel, fill with non-shrinkage mortar and apply polymer cement paste.

Fig-47: Depth 3.0 to 10.0cm, re-bar is exposed.

Fig-48: Chip-off honeycomb surface, remove all gravel, fill with non-shrinkage mortar and apply polymer cement paste.

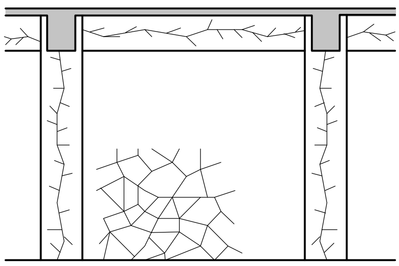
Fig-49: Depth 3.0 to 10.0cm, re-bar is exposed

Fig-50: Remove all gravel, fill with concrete, and apply polymer cement paste.

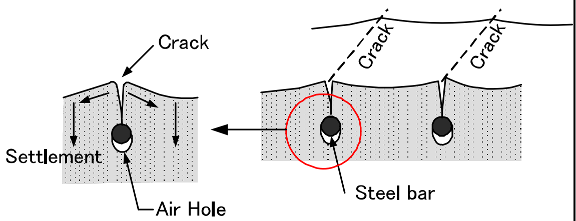
2-1-9. Crack

Most of cracks outbreak due to drying and shrinkage of concrete caused by evaporation of moisture through the process of solidification. Small cracks do not affect structure as the serious problem, but large cracks reduce durability and give serious damage to the structure.

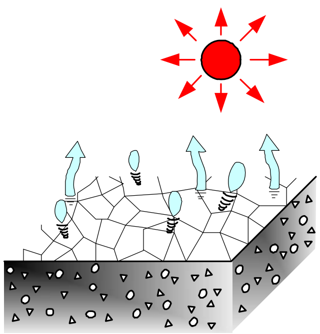
(1) Crack due to Alkali-aggregate reaction



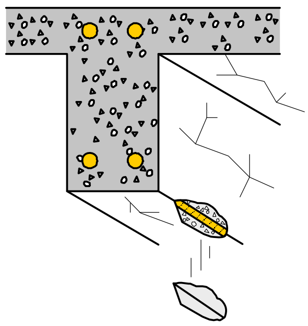
(2) Crack due to settlement



(3) Crack due to early evaporation of moisture



(4) Crack due to lack of concrete cover thickness



(1) Crack due to Alkali-aggregate reaction

Alkali-aggregate reaction outbreaks netlike or tortoise cracks

(2) Crack due to settlement of fresh concrete

Settlement of fresh concrete due to leakage of cement paste, settlement and/or deformation of form and/or support, air hole by bleeding outbreak cracks along the steel bar just after one (1) to six (6) hours from pouring concrete.

(3) Crack due to early evaporation moisture caused by insufficient moisture curing for fresh concrete.

(4) Crack due to lack of concrete cover thickness.

Where concrete cover is thin, cracks may outbreak along the main bar, and concrete may peel off.

- As the countermeasure to prevent the crack outbreak, to know the cause is very important. Crack outbreak can be preventable and/or be reduced by correct knowledge of concrete work.

The following table shows main cause and countermeasure for the crack outbreak caused by drying shrinkage.

Period	Cause	Countermeasure
Up to 7 days	• Early solidification • Contain too much muddy substance • Sedimentation • Speedy pouring • Deformation and/or settlement of form and/or support • Early loading • Dry out in a short period	• Watering to form before pouring concrete • Adequate concrete cover • Insert spacer and supporter • Fix bar tightly to prevent moving when pouring concrete • Store materials with proper method (no storage of materials directly on the ground) • Vibrate concrete carefully • Pouring moderately • Strong form and support • No gaps on form work • Keep adequate period for form support. • Keep moisture curing 7 days or longer • No loading after 7 days at least • Others
Up to 28 days	• Drying and shrinkage • Lack of moisture curing • Early removal of support • Loading and vibration	
After 28 days	• Drying and shrinkage • Poor concrete strength • Corrosion of steel bar • Lack of concrete cover • Lack of amount of steel bar • Concentrate stress • Overloading • Temperature stress	

The following table shows desirable characteristics of coarse aggregate to prevent and/or reduce crack outbreaks caused by Alkali-aggregate reaction.

Material	Characteristics	Description
Quality	• Hard stone • Large elastic module	Limestone rock, Andesite, Granite, Basalt, Slate, etc.
Impurity substance	• No muddy content	• Decantation Test Less than 1.0% for coarse aggregate and less than 3.0% for fine aggregate
	• No chloride	• Salty content shall be less than 0.1%
Water absorption	• Small absorption	Less than 3.0% for coarse aggregate, less than 3.5% for fine aggregate, and less than 2.0% for gravel stone
Grain diameter	• Large	
Solid content	• Large	• Around 55% to 65 %

2-2 Formwork

2-2-1 Material

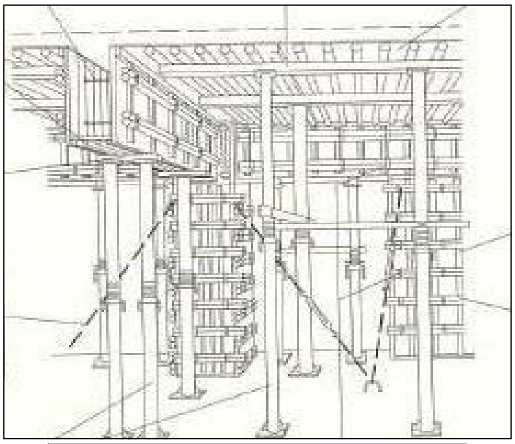


Figure-51: Formwork

- Formwork shall be made of timber, plywood, plastic coated plywood or steel panel.
- Surface of formwork shall be clean.
- Surface coating material (liquid) shall be applied to formwork.
  With coating material, concrete will be fine surface by applying coating liquid, and plywood forms could be reused two or three times more.
- Formwork shall be stored with weather protection.
- Reuse of formworks to other works shall be less than 2 times because reuse makes poor quality of forms.

2-2-2 Vertical alignment of columns

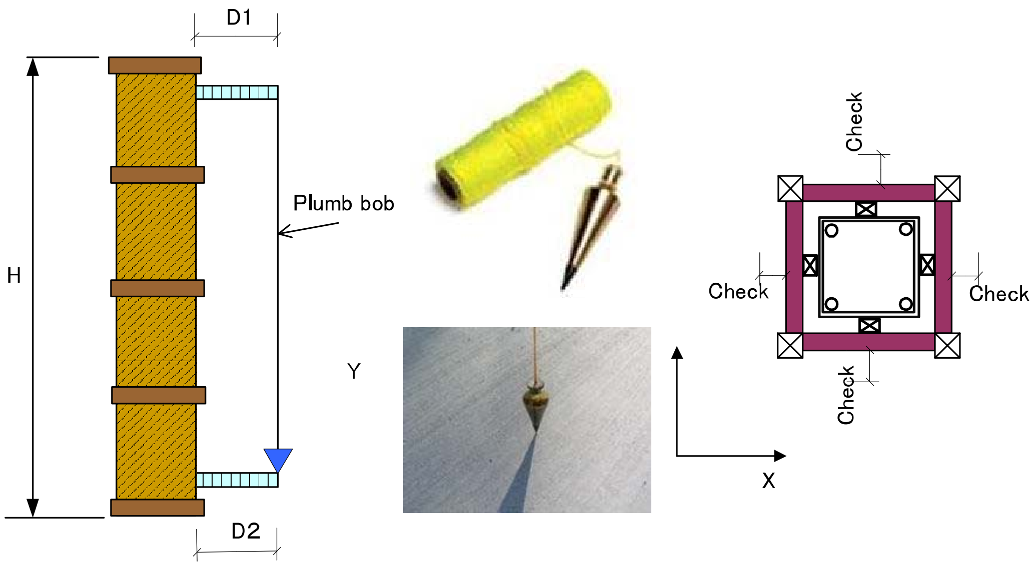


Figure-52: Column Vertical Alignment Check

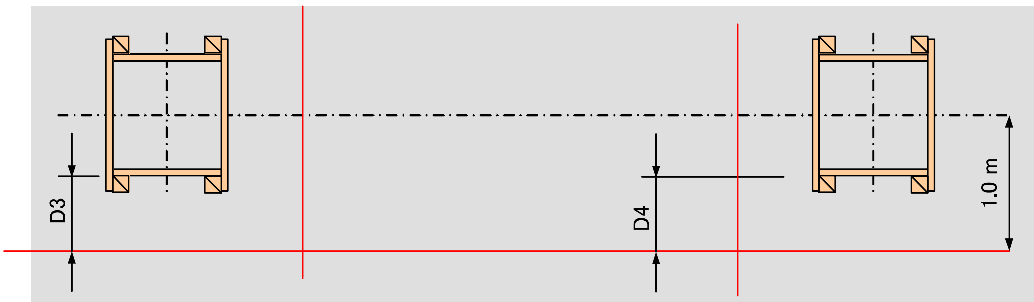
◆ Check distance D1 and D2 for every direction, vertical tolerance (=D1-D2) shall be within the figures shown in Table-10.

Table-10: Allowable Tolerance for Vertical Elements (by ACI)

Column total height	Column Position	Vertical Tolerance (D1-D2)
Column (H<30m)	Corner column	Less than 13mm
	Other column	Less than 25mm
Column (H>30m)	Corner column	Less than H/2000 and 76mm
	Other column	Less than H/1000 and 152mm

◆ Before fixing the form, the vertical line alignment shall be inspected. If inspection value is more than tolerance allowance, the form shall be removed and rebuilt.

2-2-3 Horizontal alignment



◆ Check distance D3 and D4 for every direction, and horizontal tolerance (=D3-D4) shall be within the figure shown in Table-11.

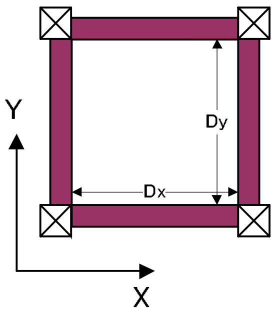
Table-11: Allowable Tolerance for Horizontal Elements (by ACI)

Name of the element	Horizontal tolerance (D3-D4)
Girder, Beam, Slab, etc.	Less than 25mm

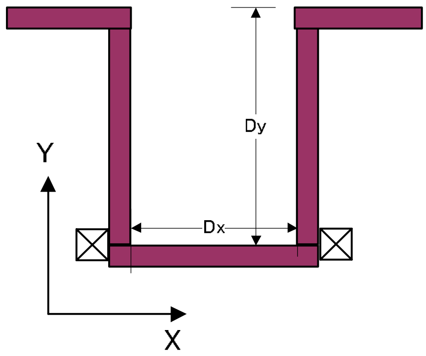
◆ Before fixing the form, the horizontal line alignment shall be inspected, if inspection value is over than tolerance, the form shall be removed and rebuilt again.

2-2-4 Inside measurement

- ◆ Check inside dimension



Column



Beam

Table-12: Allowable Tolerances for Cross-Sectional Dimensions (By ACI)

Element	Design dimension	Tolerance of Dx and Dy
Column, Beam Foundation, and Slab	Less than 30cm	+10mm and -6.0mm
	Over 30cm and less than 90cm	+13mm and -10.0mm
	Over 90cm	+25mm and -19.0mm

- ◆ Before fixing the form, inside dimensions shall be inspected. If inspection value is more than the allowable tolerance, the form shall be removed and rebuilt.

2-2-5 Concrete cover

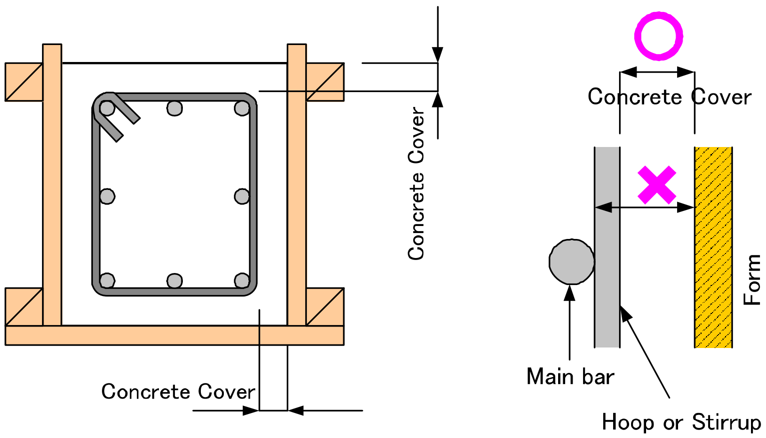
- ◆ Check concrete cover

Unless otherwise specified in the design drawing, the minimum concrete cover shall be of the dimensions listed in Table-14.

Table-14: Minimum cover thickness

Type of structural elements			Minimum of Protective Concrete Cover thickness
Elements not in contact with soil	Slabs and Walls	With finishing	20mm
		No finishing	30mm
	Columns and Beams	With finishing	40mm
		No finishing	40mm
Elements having contact with soil	Columns, Beams, Floors, Slabs and Walls		50mm
	Foundation and Retaining Wall		70mm

- Concrete cover shall be the distance between the surface of the hoop or stirrup and inside of the form as shown below.



- Before fixing the form, the concrete cover shall be inspected, if inspection value is less than minimum thickness, the form shall be removed and rebuilt.

2-2-6 Position of sleeves (openings)

- The position of sleeve holes shall be set within a zone of H/2 (half of beam depth) as shown in Figure-53. Do not make sleeve holes outside of the H/2 zone as shown in Figure-54.
- Diameter of sleeve shall be less than 1/3H (1/3 of beam depth) and minimum distance L shall be larger than H. Allowable zone of sleeve hole is within 1/2H.

- Where a sleeve hole is made, additional sleeve opening reinforcement shall be set in accordance with SNI Standards.

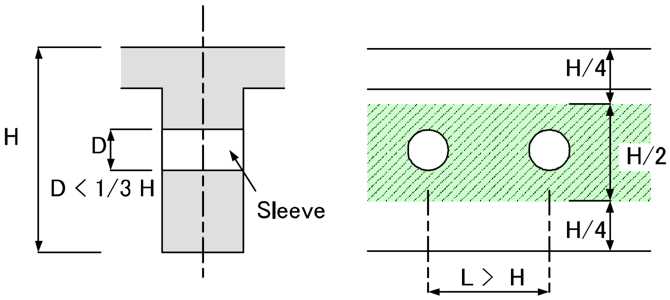


Figure-53: Correct Position

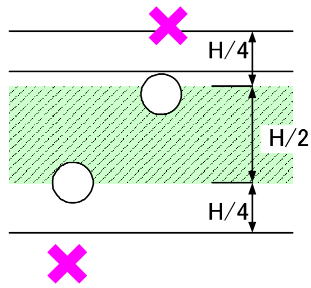


Figure-54: Incorrect Position

2-2-7 Assembling

- Do not oversight any gap or space of the formwork. Cement milk must leak to outside.
- Every connection and joint of the form panels shall be inspected. If any gaps or spaces are discovered (Figure-55 and Figure-56), the form shall be removed and rebuilt. Otherwise, serious problem will outbreak (Figure-58 and Figure-59).

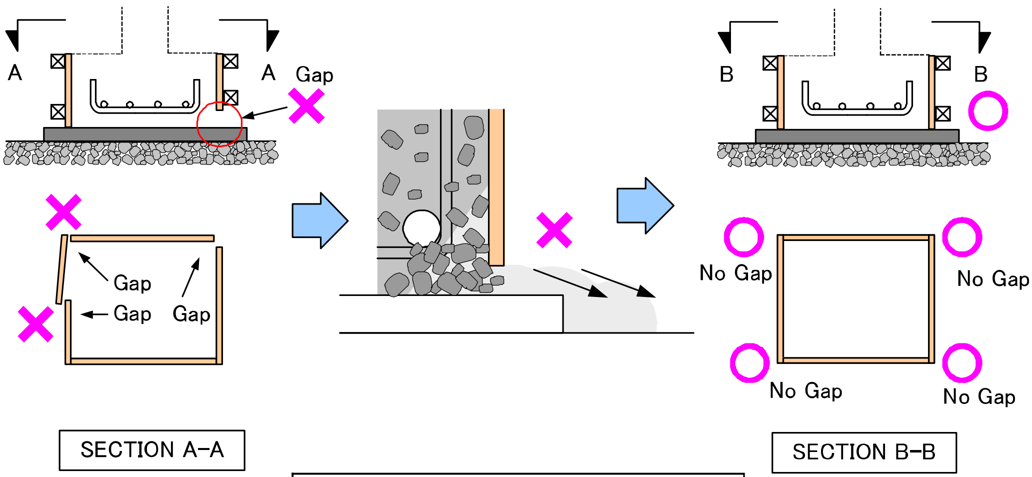


Figure-55: Incorrect Formwork

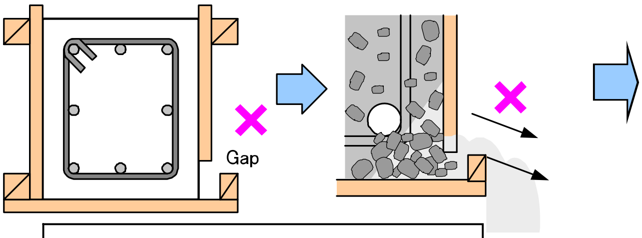


Figure-56: Incorrect Formwork

Figure-57: Honeycomb

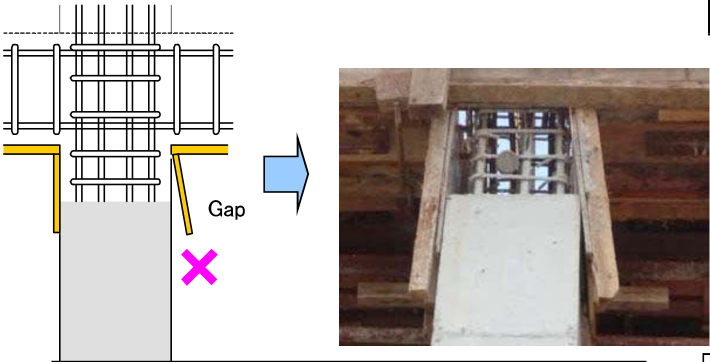


Figure-58: Incorrect Formwork

Figure-59: Outbreak of Serious Problem

2-2-8 Support

(1) Supports shall not be stood directly on the ground as shown in Figure-60.

(2) Supports shall be stood on the strong base or pedestal as shown in Figure-61 and/or concrete base slab as shown in Figure-62.

(3) Supports shall be fixed firmly and shall not be moved vertically and horizontally.

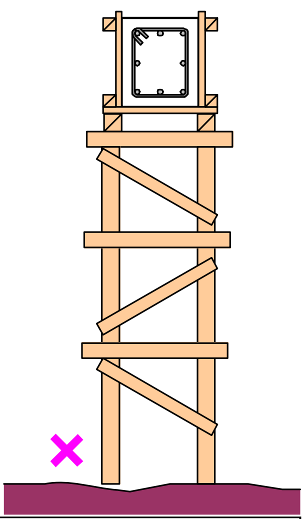


Figure-60: On Ground

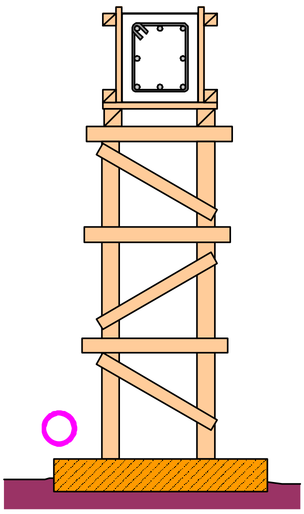


Figure-61: On Base

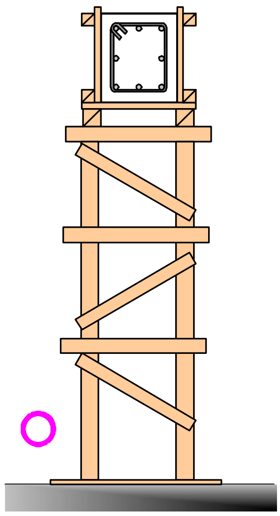


Figure-62: On Concrete

2-2-9 Removal of formwork

(1) Form shall not be removed until the minimum standing times was elapsed.

(2) Minimum standing time shall be determined as shown in Table-15 and Table-16 in terms of the age or compression strength of concrete.

(3) Supports (or columns) supporting a cantilever beam, canopy, beam with large span, large-size floor slab or an extremely large working load shall be kept for longer periods as required.

(4) Support shall not be replaced. Sheathing boards below floor slabs and beams shall be removed after taking out the supports by general rule.

Table-15: Minimum Standing Time for Sheathing Boards

Type of cement	Normal Portland cement
Based on age of Concrete (days)	3 days
Based on compression strength of Concrete	Until compression strength exceeds 5 N/mm^2

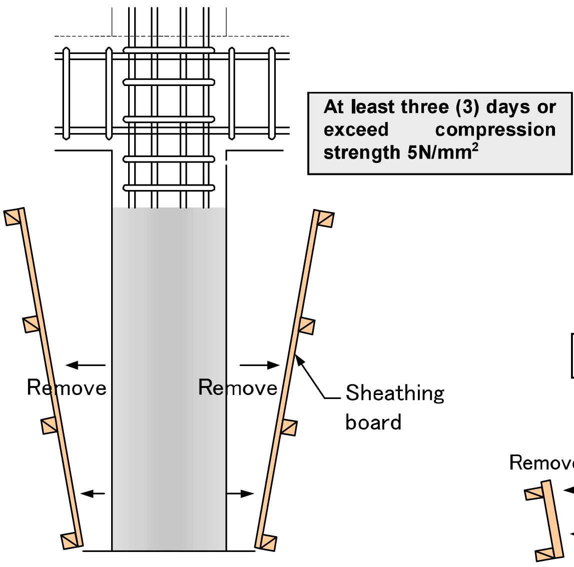


Figure-63: Column

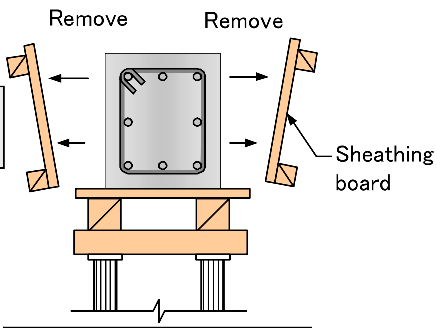


Figure-64: Beam

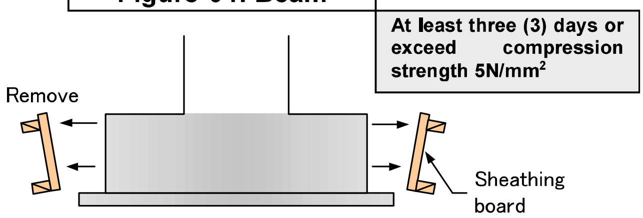


Figure-65: Foundation

Table-16: Minimum Standing Time for Supports

Type of cement	Normal Portland cement	
Position	Under floor slab	Under beam
Based on age of Concrete (days)	17 days	28 days
Based on compression strength of Concrete	Until compression strength is over 85% of design strength or exceeds 12 N/mm^2, and load and external force during work was verified to be safe by structural calculation.	Until compression strength is over design strength or exceeds 12 N/mm^2, and load and external force during work was verified to be safe by structural calculation.

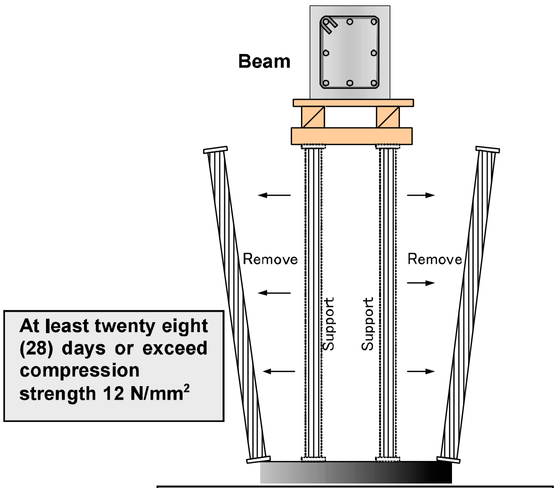


Figure-66: Column Support

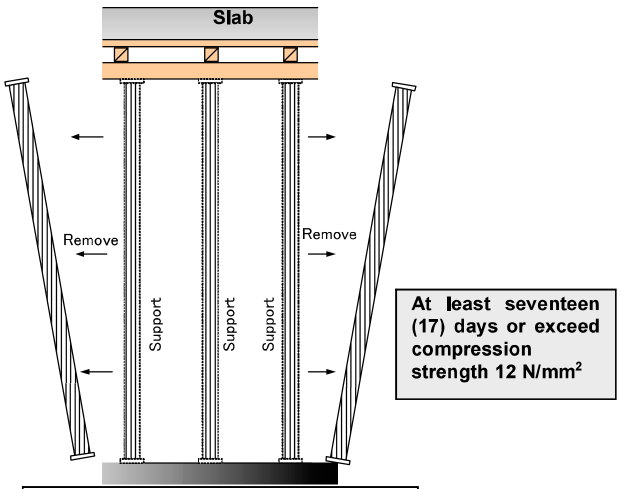
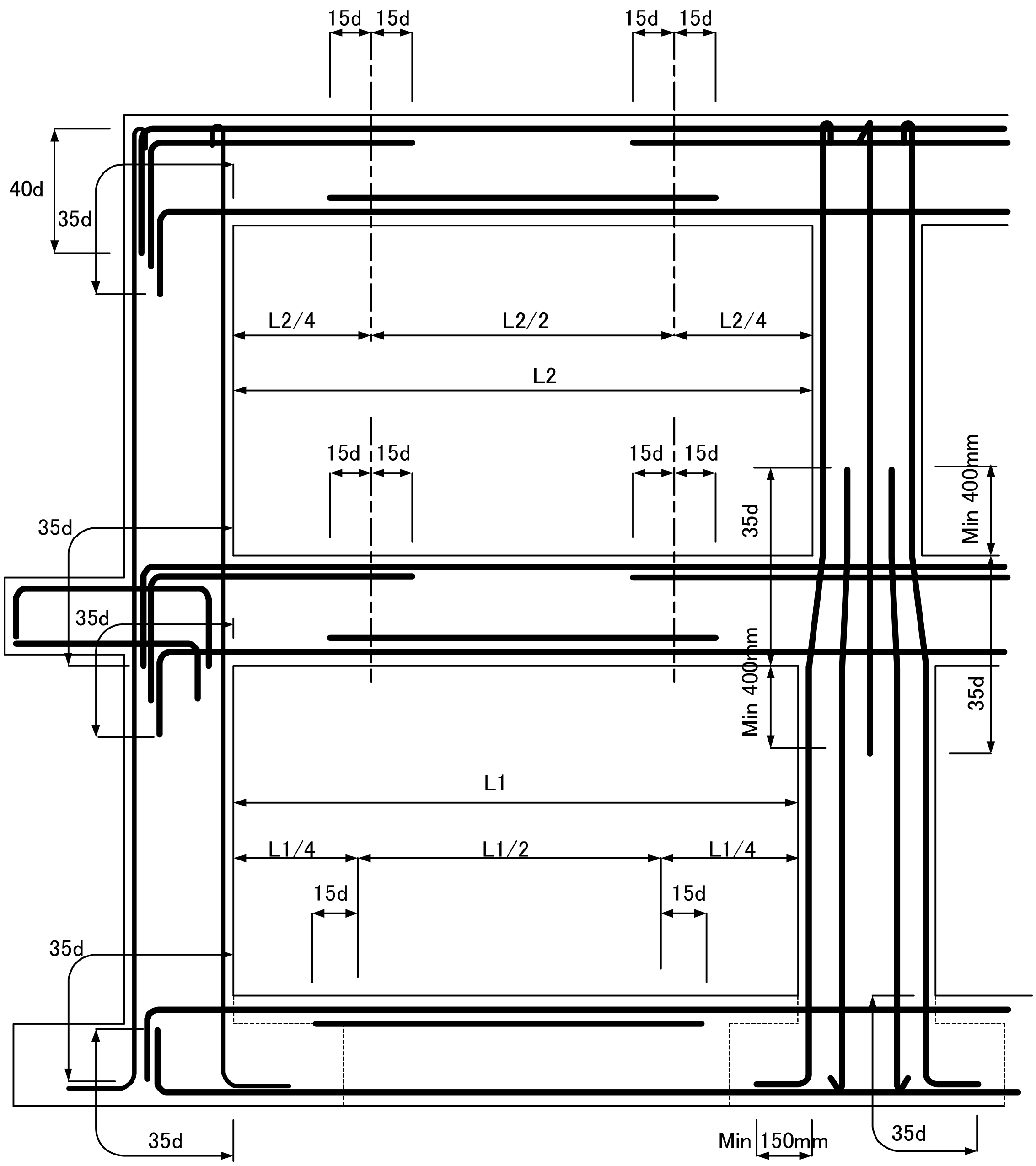


Figure-67: Beam Support

2-3 Steel Bar Work (Reinforcement)

2-3-1. Standard bar arrangement

(1) Main frame



Note: “d” means diameter of steel bar

Figure-70: Standard Bar Arrangement

(2) Standard hoop arrangement and Anchor of small beam and slab

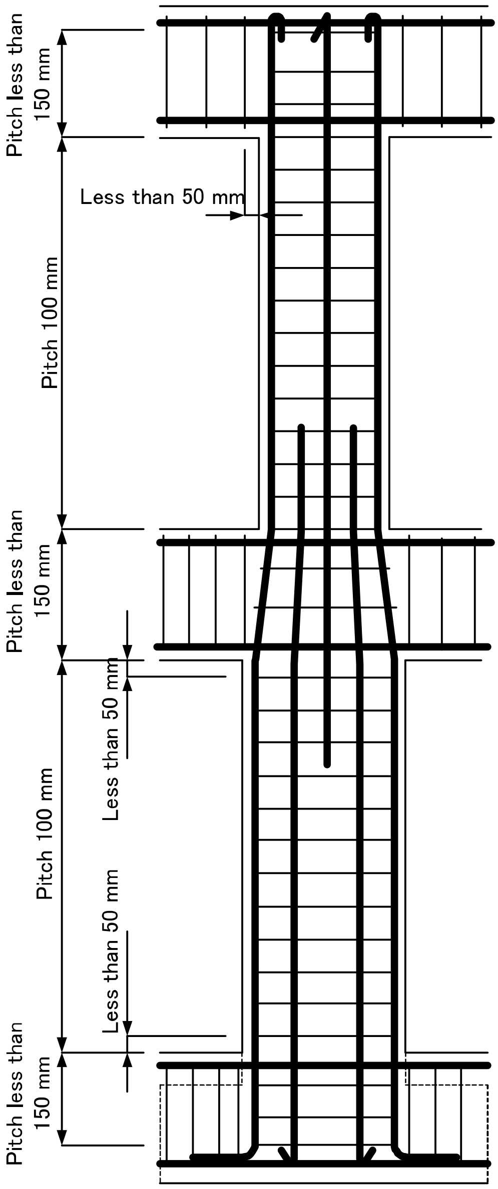


Figure-71: Hoop Arrangement

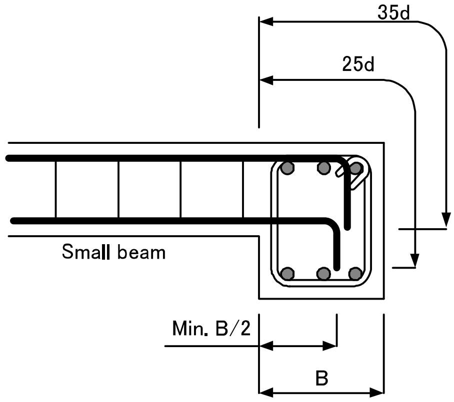


Figure-72: Anchor Beam to Beam

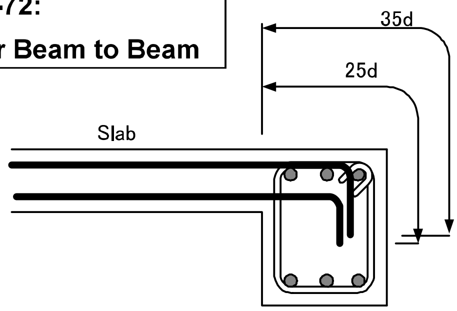


Figure-73: Anchor Slab to Beam

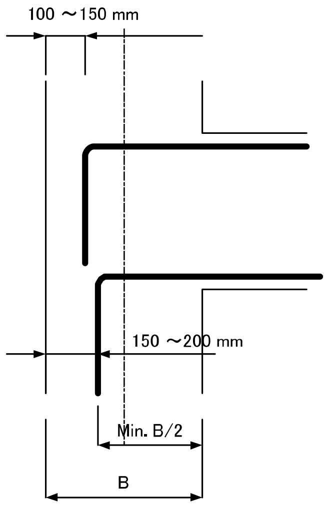


Figure-74: Anchor Position of Main Bar

2-3-2. Tolerance deformation of bar arrangement

(1) Main bar

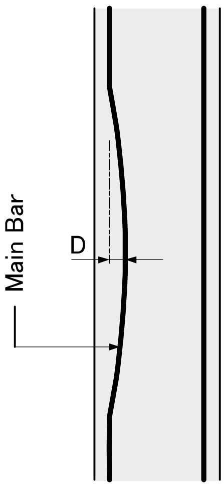


Figure-75: Column

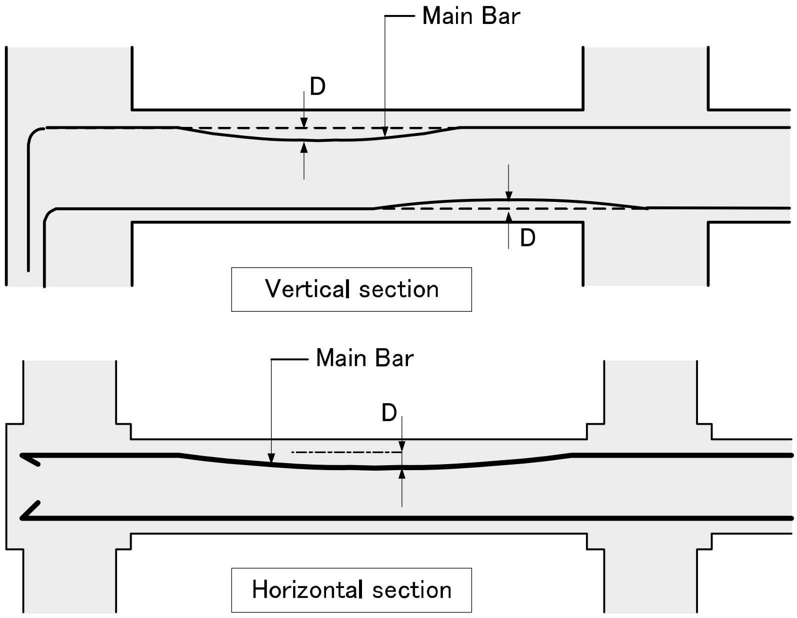


Figure-76: Beam

Note: Deformation of main bar "D" shall less than 1.0 cm

(2) Hoop and Stirrup

"X" represents bar spacing specified by design drawings, "D" shall be less than 1.0cm, X1 and X2 shall be less than X + 1.0cm, X3 shall be less than X/2.

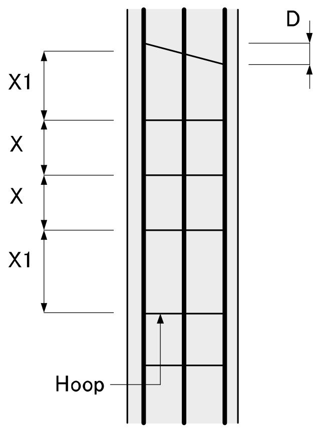


Fig-77: Column

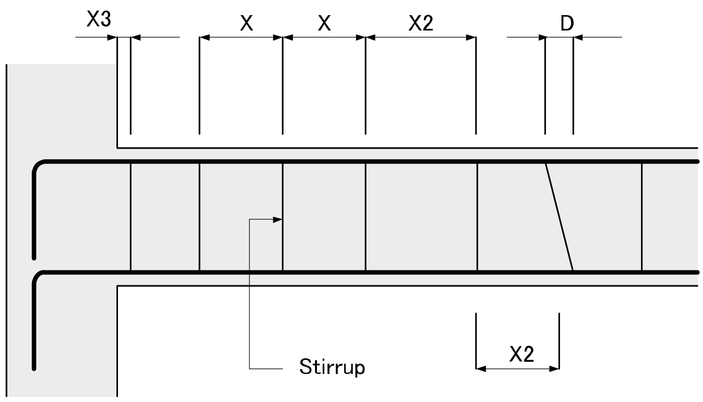


Fig-78: Beam

2-3-3. Bar lapping

(1) Location of the bar lapping shall be set in the areas shown in Figure-80 to avoid locations where large tension force should be expected due to seismic loading as shown Figure-79.

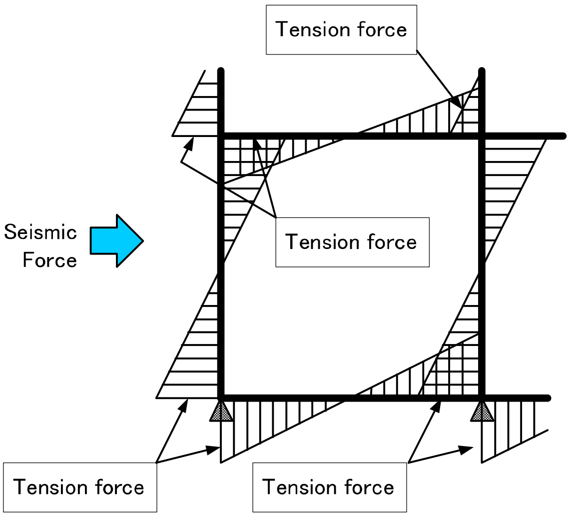


Figure-79: Typical Bending Moment Diagram

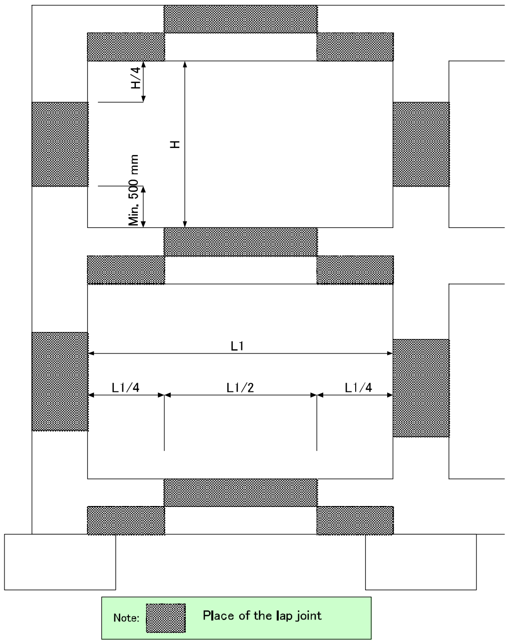


Figure-80: Bar Lap Zone

(2) Lap length and/or Anchor length shall be more than the figure shown in the following Table-20.

Table-20: Minimum Lap Splice and Anchorage Length

Type of Bar	Concrete Compressive Strength (N/mm²)	Bar Size	Without Hook				With Hook			
			L1 (mm)	L2 (mm)	L3		L1 (mm)	L2 (mm)	L3	
					Small Beam (mm)	Slab (mm)			Small Beam (mm)	Slab (mm)
BJTD30 (SD295A) (SD295B) (SD345) -	21-27	D10	400	350	250	150	300	250	150	
		D13	520	455	325	150	390	325	195	
		D16	640	560	400	160	480	400	240	
		D19	760	665	475	190	570	475	285	
		D22	880	770	550	220	660	550	330	
		D25	1000	875	625	250	750	625	375	

(3) Location of neighboring bar lapping shall be set in particular locations shown in Figure-81 and Figure-82.

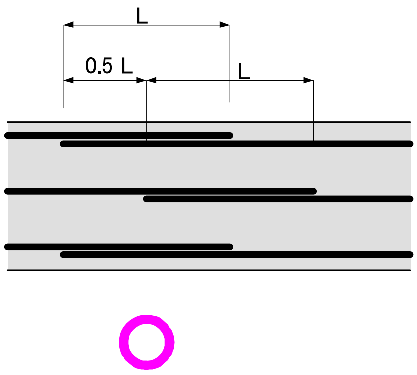


Figure-81: Correct Lapping

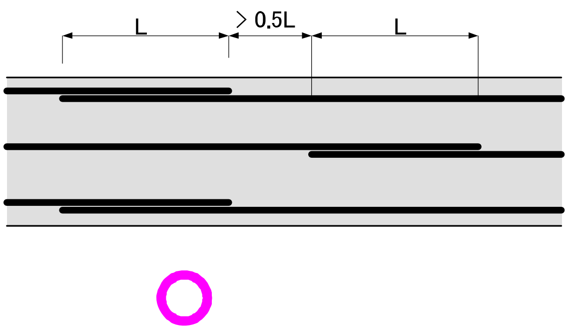


Figure-82: Correct Lapping

(4) Do not make lap joint at the same locations as shown in Figure-83 and Figure-84. In case of lap joint at the same location, cracks may outbreak at higher possibility as shown Figure-85.

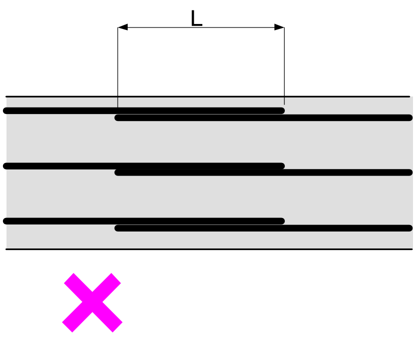


Figure-83: Incorrect Lapping

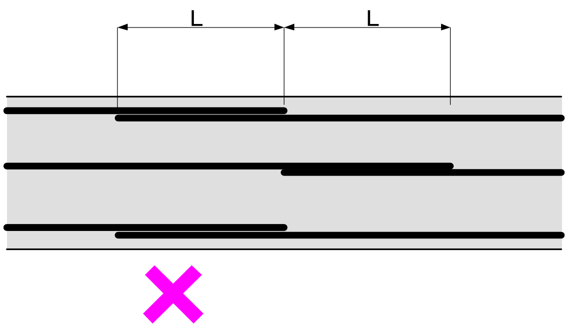


Figure-84: Incorrect Lapping

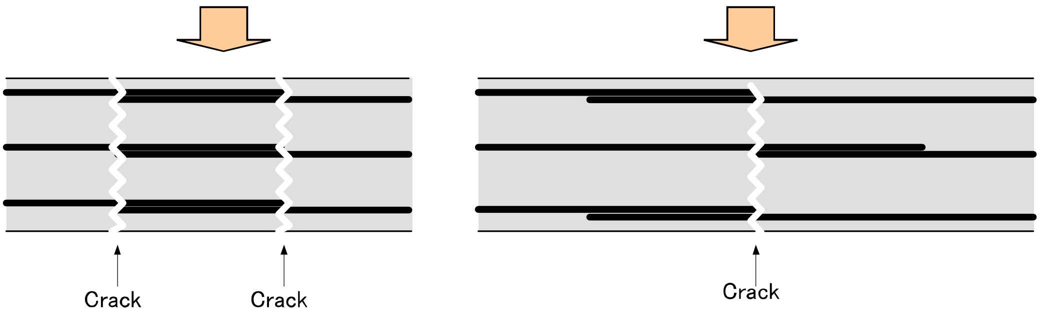


Figure-85: Crack due to Incorrect Bar Lapping

(5) Bar Lapping location of columns

1) Bar lapping of columns shall be set within the locations shown in Figure-86.
2) Do not make lap joint at the locations shown in Figure-87.

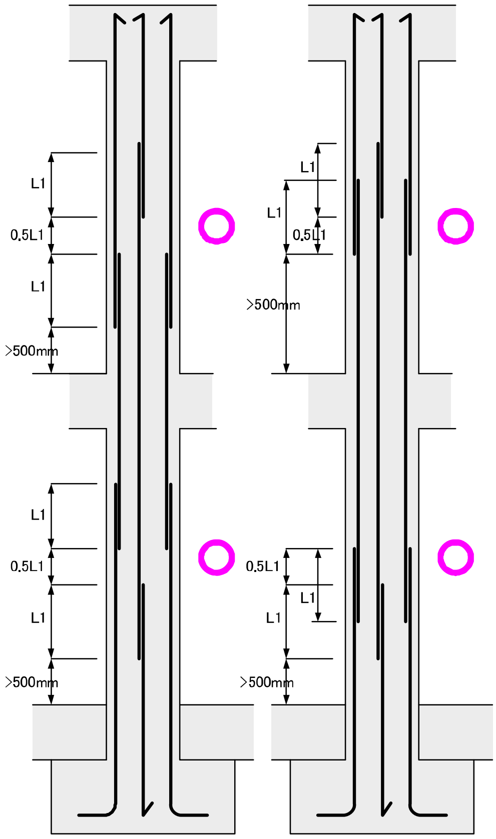


Figure-86: Correct Bar Lap Position

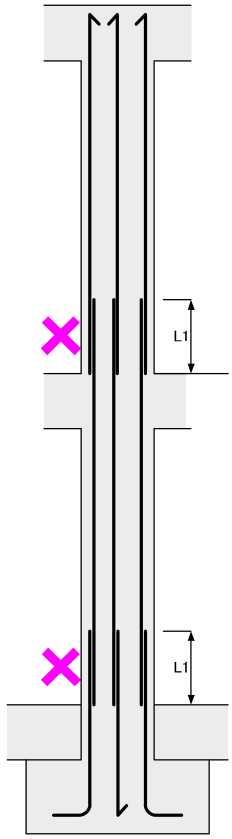


Figure-87: Incorrect Lap Position

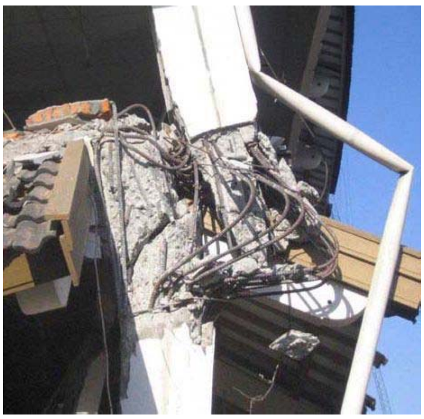


Figure-88: Structural Destruction (@ Column and Beam)

Fig-89: Lap at Bottom of Column

2-3-4. **Bar anchor**

(1) Bar anchor length shall comply with the dimensions shown in Figure-70 and Table-20.

(2) Main bar of columns shall be anchored up to zone that exceeds H/2 of the footing as shown in Figure-91. If anchor is set in the location shown in Figure-92, cracks will occurred as shown in Figure-93.

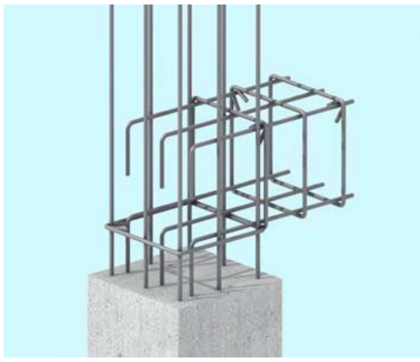


Fig-90: Typical anchor image

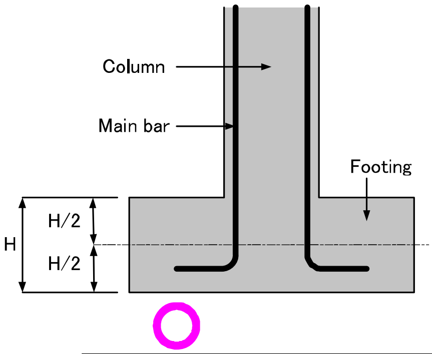


Fig-91: Correct anchor

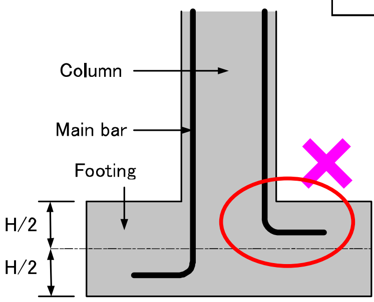


Fig-92: Incorrect anchor

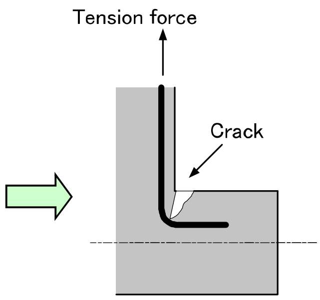


Fig-93: Crack Outbreak

(3) Main bar of beams shall be anchored into the connecting columns up to zone that exceeds B/2 as shown in Figure-94.

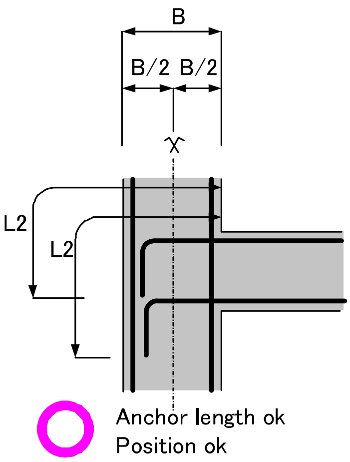


Figure-94: Correct Anchor

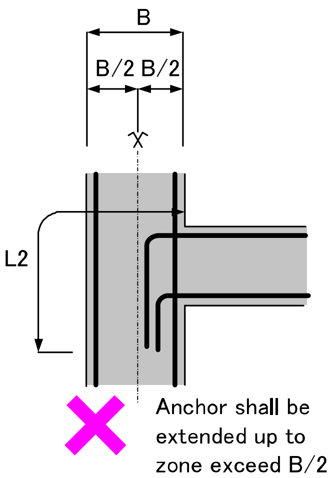


Figure-95: Incorrect Anchor

2-3-5. Bar arrangement for different dimension

(1) In case of small column dimension changes (slope is less than 1:6) as shown in Figure-96, the main bars of column shall be bent as slope.

(2) In case of large column dimension changes (slope is larger than1:6) as shown in Figure-97, the main bars of column shall not be bent.

(3) Same manner shall be applied to the bar arrangement of beams.

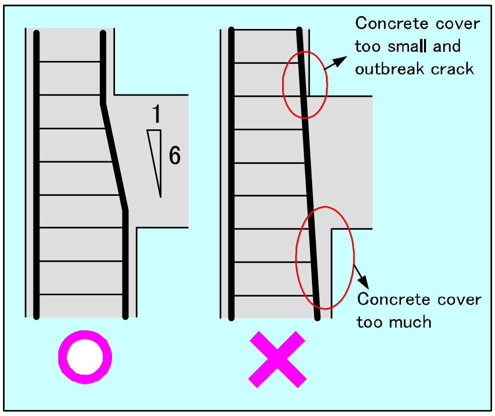


Figure-96: Small Column Size Difference

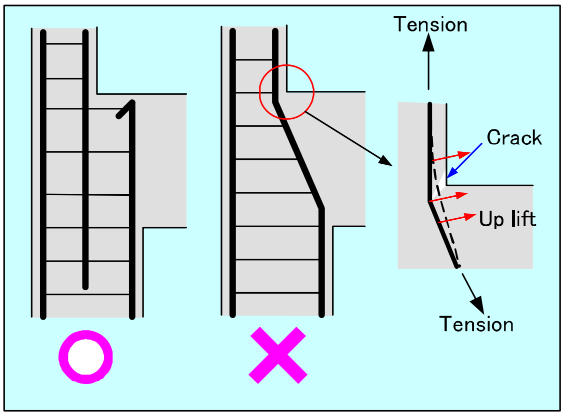


Figure-97: Large Column Size Difference

2-3-6. Supporting bar

(1) In case of cantilever beam or slab as shown in Figure-98, additional supporting bars shall be installed in order to avoid the sagging down of main bars due to the weight of fresh concrete.

(2) In case of the double layer bar arrangement as shown in Figure-99, tie bar shall be installed in order to avoid sagging down of main bars due to the weight of fresh concrete.

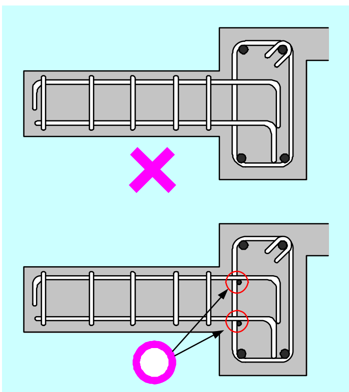


Figure-98: Cantilever Beam

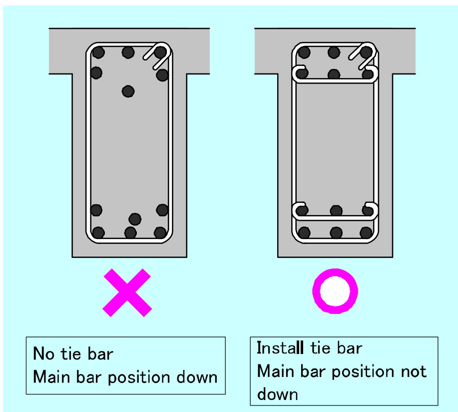


Figure-99: Double Layer Bar

2-3-7. Bar bending schedule

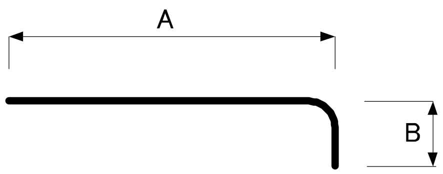
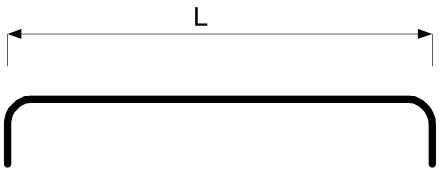
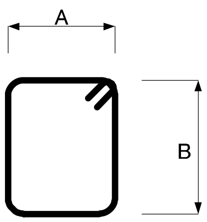
(1) Bar cutting and bending schedules must be prepared by structural engineer.

(2) Bar cutting and bending work shall be made on the construction site based on the provided bar cutting and bending schedules.

(3) Do not cut and bend bars without cutting and bending schedules.

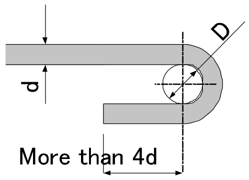
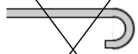
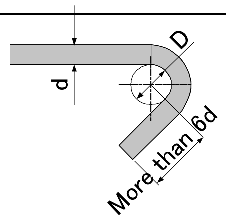
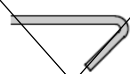
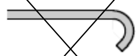
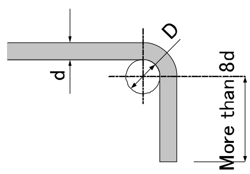
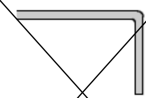
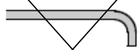
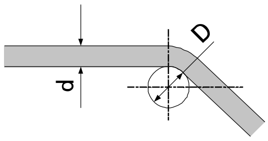
(4) Tolerance of the bar bending shall conform to the specification shown in Table-21.

Table-21: Tolerance of bar bending work

Items	Method of measuring	Tolerance
Main bar		**A, B** **±15mm** (in case less than D25)
Overall length after cut and bend		**L** **±20mm**
Hoop and Stirrup		**A, B** **± 5mm**

(5) Type and standard dimension of steel bar end

Table-22: Detail of Standard Hook and Bending Schedule

Bending Shape		D Under 16mm Dia.	D 19 to 38mm Dia.	Previous location	✕	✕
180°		More than 3d	More than 4d	Main bars for Column and beam etc.	 Too Small bend	 Short hook
135°		More than 3d	More than 4d	Stirrup, Hoop, Spiral bar	 Too Small bend	 Short hook
90°		More than 3d	More than 4d	Stirrup, Hoop, Spiral bar	 Too Small bend	 Short hook
Less than 90°		More than 4d	More than 6d			

- ✧ Deleteriously bent or defective bars shall not be used.
- ✧ Once steel bars are bent, do not re-bend to use

(6) Bend direction
Deformed bar shall be bent laterally to the rib as shown in Figure-100. Do not bend right angle to the rib as shown Figure-101.

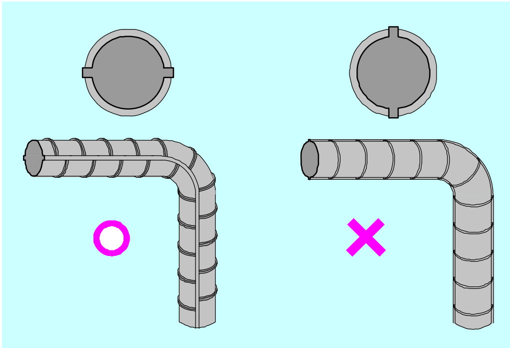


Figure-100: Correct Bend | Figure-101: Incorrect Bend

2-3-8. Bar assembling

(1) Securing enough concrete cover is very important factor for quality of concrete.

(2) Unless otherwise noted, the minimum concrete cover shall conform to the specification shown in Figure-23.

Table-23: Standard of Concrete Cover Thickness for Steel Bars

Type of structural elements			Minimum protective concrete cover thickness
Elements not in contact with soil	Slabs and Walls	with finishing	20mm
		without finishing	30mm
	Columns and Beams	with finishing	40mm
		without finishing	40mm
Elements contact with soil	Columns, Beams, Floors, Slabs and Walls		50mm
	Foundation and Retaining Wall		70mm

(3) Concrete cover shall have the thickness between concrete outside surface and outside surface of the hoop or stirrup as shown in Figure-102.

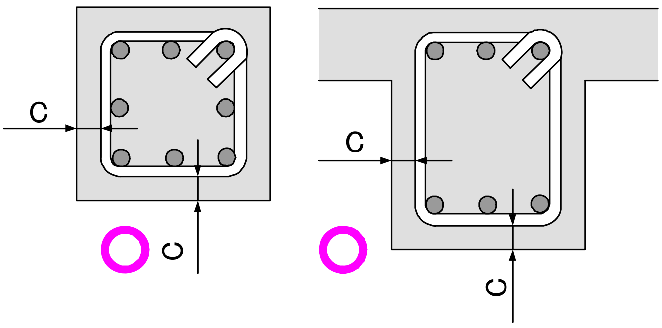


Figure-102: Correct Concrete Cover

2-38

(4) Concrete cover shall not be measured by the thickness between concrete outside surface and outside surface of the main bars (inside face of hoop or stirrup) as shown in Figure-103.

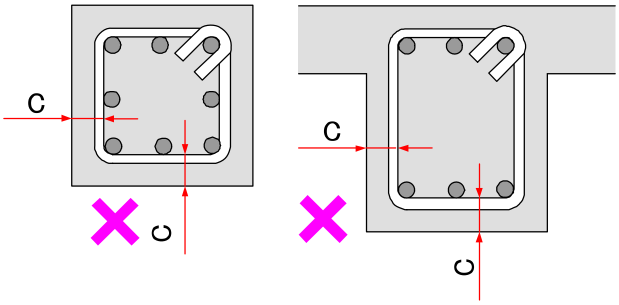


Figure-103: Incorrect Concrete Cover

(5) Spacer

1) In order to secure adequate concrete cover, spacers shall be installed as shown in Figure-105 and Figure-106.

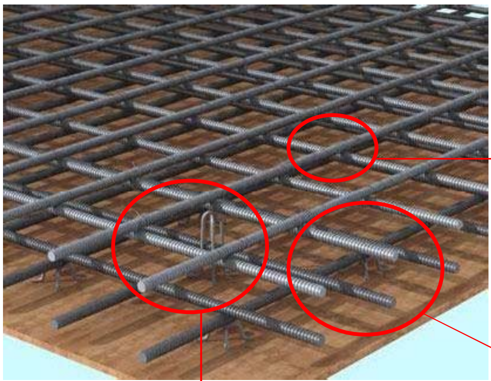
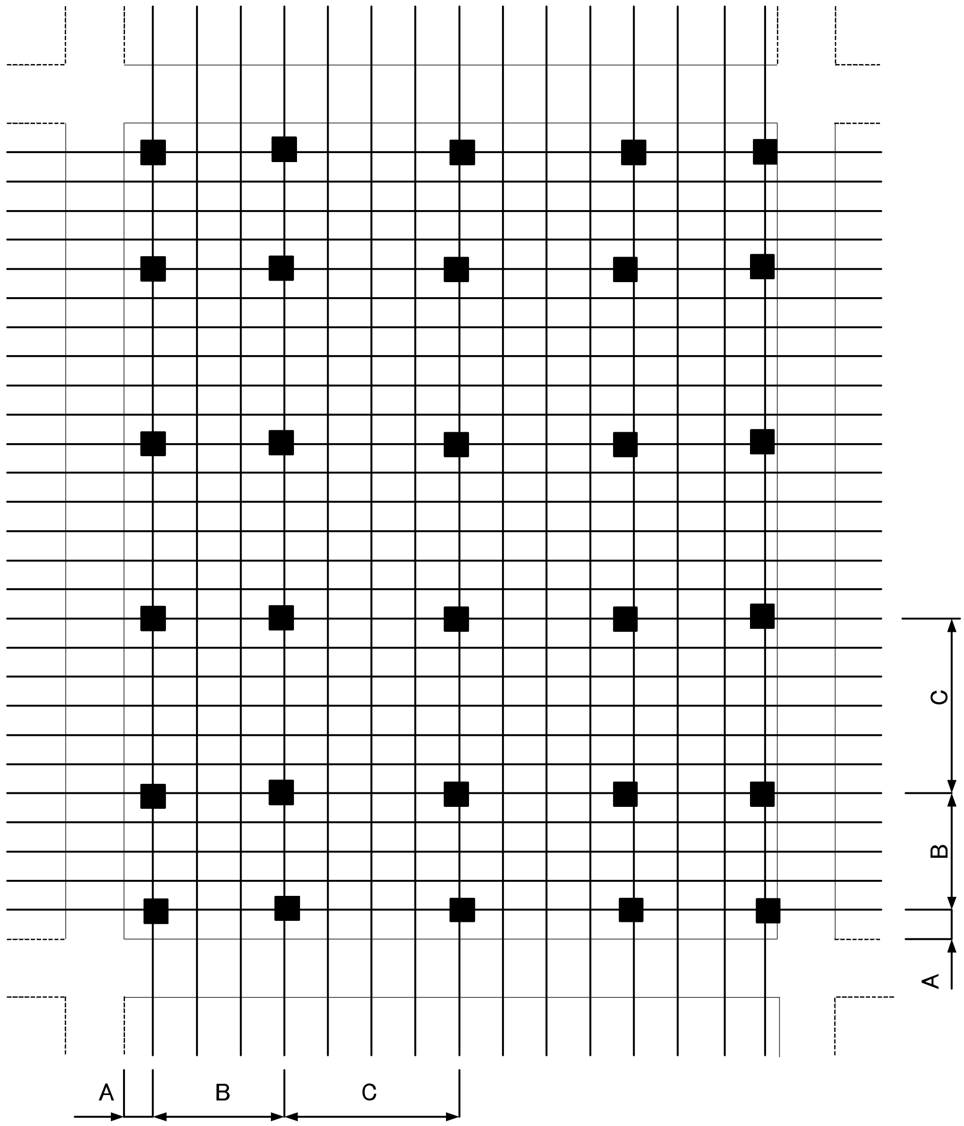


Figure-104: Bar Binding

Figure-105: Spacer for Upper Bar

Figure-106: Spacer for Lower Bar

2) The standard spacing of spacers for slab shall conform to the locations shown in Figure-107.



■ Spacer position (Upper bar and Bottom bar)
A: Less than 10cm
B: Less than 90cm
C: Around 90cm

Figure-107: Spacer Arrangement for Slab

3) Girder

Spacer shall be provided both side and bottom side as shown in Figure-108, and spacing shall conform to the dimensions shown in Figure-110.

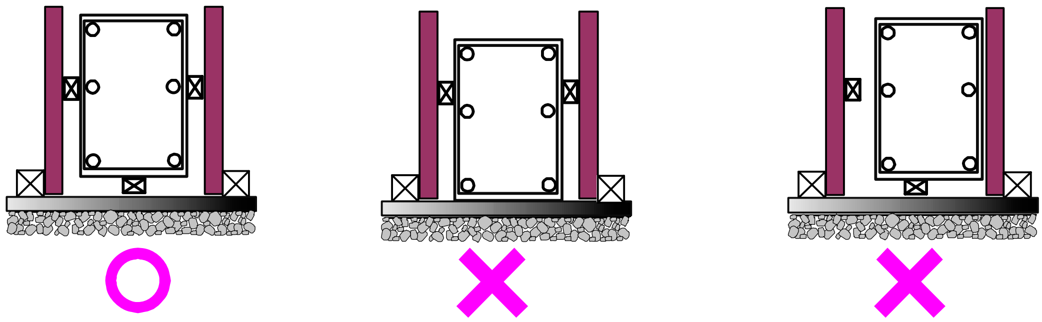


Figure-108: Correct Installation

Figure-109: No Spacer (Incorrect)

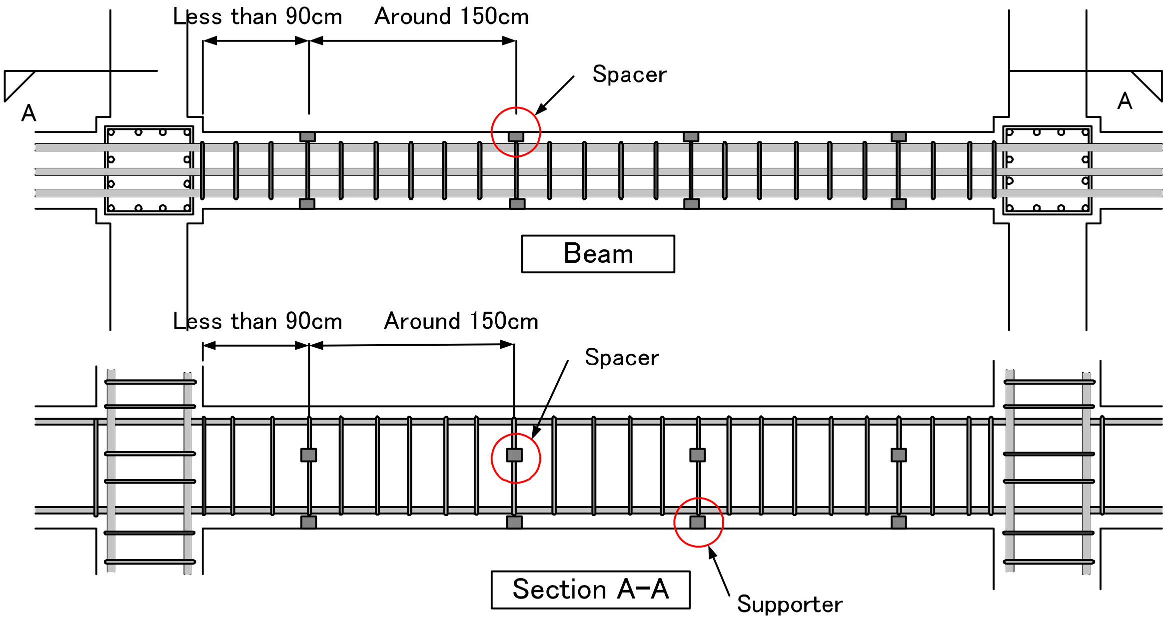


Figure-110: Standard Spacing of Beams

4) In case of columns, spacers shall be provided to four (4) sides as shown in Figure-113, and spacing shall conform to the dimensions shown in Figire-114.

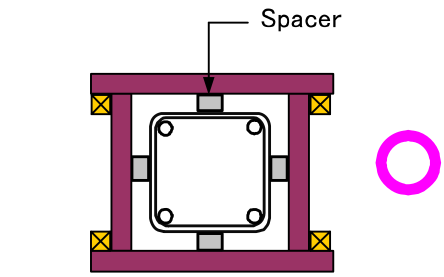


Figure-111: Correct Installation

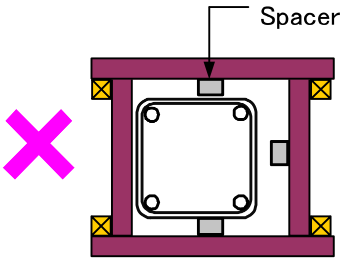


Figure-112: No Spacer (Incorrect)

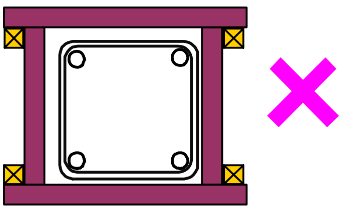


Figure-113: No Spacer (Incorrect)

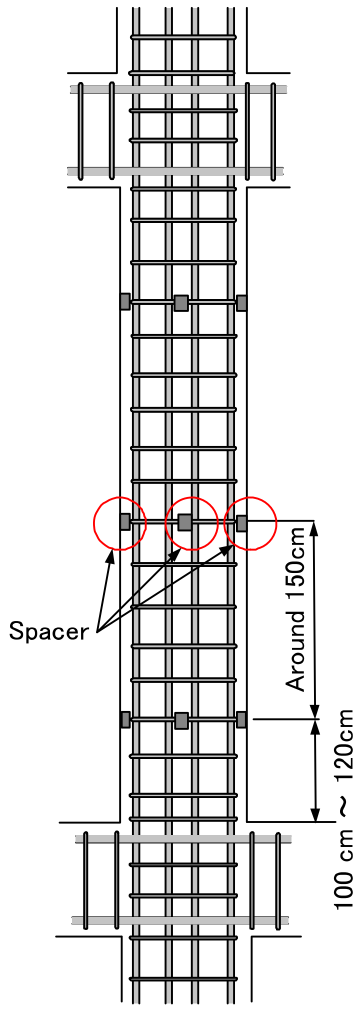
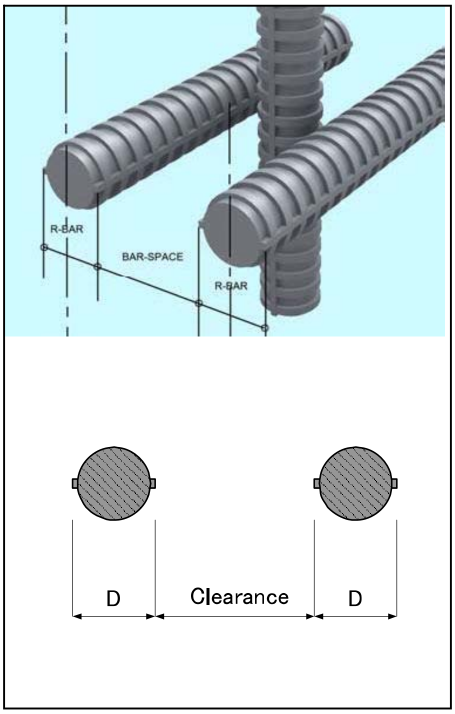


Figure-114: Standard Spacer Allocation

2-3-9. Clearance of reinforcing bars

(1) The clearance between reinforcing bars shall be larger than following manners.

1) Larger than 1.25 times of maximum size of coarse aggregate
2) Larger than 25 mm
3) Larger than 1.5 times of steel bar diameter (1.5 x D)



(2) In case of lapping bars, clearance shown in Figure-115 shall conform to 1) 2) 3) prescribed above clause.

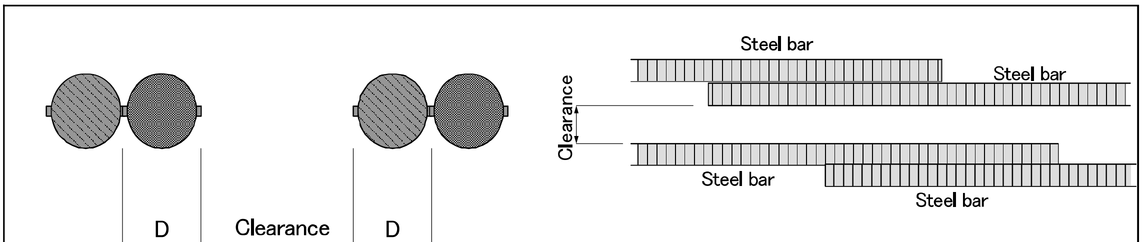


Figure-115: Bar Lapping

(3) Especially, special attention shall be given to the columns located to the corners of building because of highly crowded bar arrangement as shown in Figure-116.

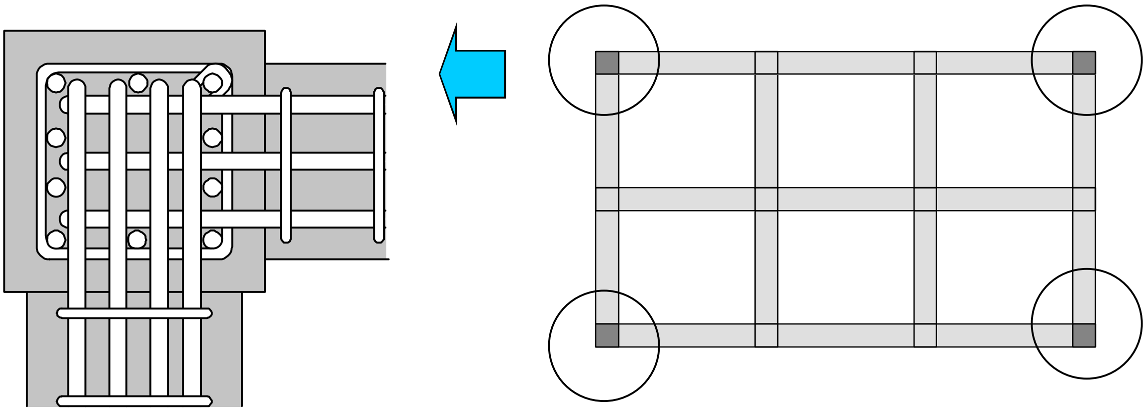


Figure-116: Dense Bar Concentration in Corner Columns

(4) Figure-117 and Figure-118 illustrate the example of wrong bar arrangement of columns. In these cases, steel bars shall be dismantled and re-assembled again in order to secure clearance between neighboring bars.

Figure-117: Wrong Bar Arrangement at Column Bottom

Figure-118: Wrong Bar Arrangement at Column Top

(5) Where the bar arrangement appropriately secures enough clearance as shown in Figure-119, the fresh concrete could be poured tightly without any cavity developed. However, in case of bad bar arrangement without enough clearance as shown in Figure-120, cavity (air hole) must outbreak in the poured concrete.

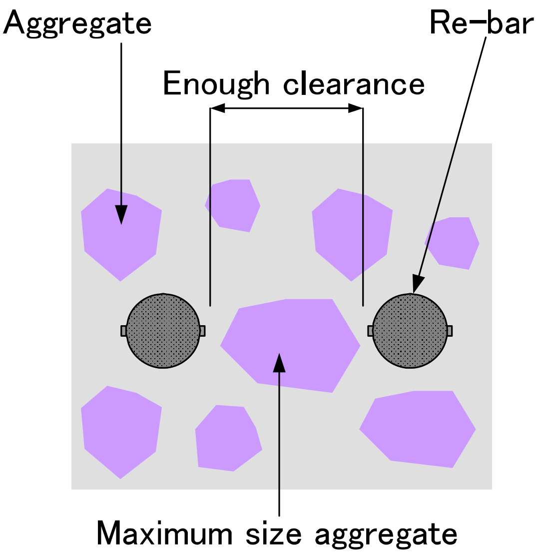


Figure-119: Good Concrete Pouring Result

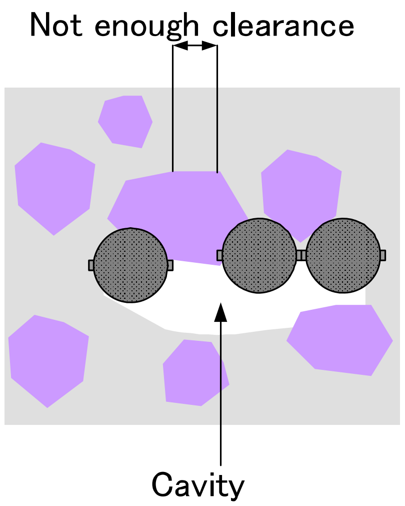


Figure-120: Bad Concrete Pouring Result

2-4 Material Stock and Storage

2-4-1 Cement

(1) Material

1) Portland cement shall conform to the requirement of SNI-15-2049-2004
2) Each consignment package of cement shall be sampled at the mill site, and the mill certificate issued by the manufacture must be checked by the contractor to record.
3) Stock period of cement shall nevertheless not exceed 90 days for bagged cement and 180 days for bulk cement.

(2) Storage

Cement shall be stored in a house protected from rain or other humidity condition, and shall not be stored on the ground directly. Cement shall be stored on the pallet or equivalent at a height of more than 30cm from the ground. Cement bags shall be stored in stack layer less than 10 courses.

Figure-121: Pallet Stack

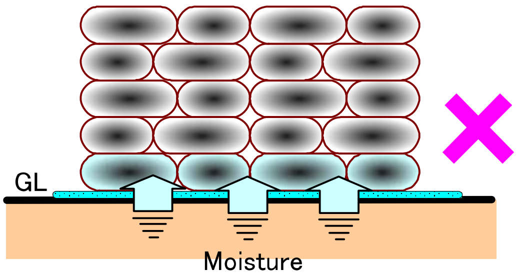


Figure-122: Wrong Cement Store

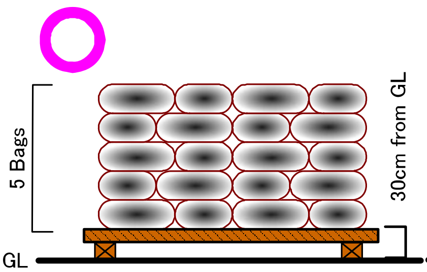


Figure-122: Lesser Stack Better

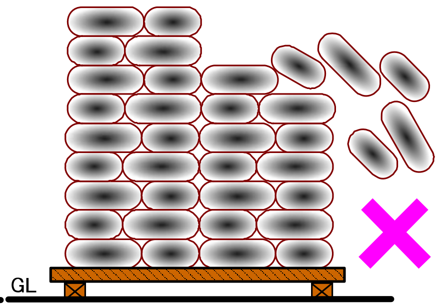


Figure-123: More Stack for Falloff

2-4-2 Steel bar

(1) Steel bars shall not be stored on the ground directory as shown in Figure-125.

(2) Steel bars shall be stored on the timber sleepers with more than 10cm height (space) from the ground as shown in Figure-124

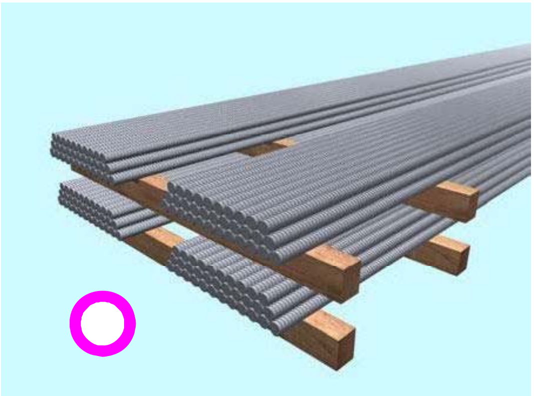


Figure-124: Correct Stock

Figure-125: Incorrect Stock

2-4-3 Aggregate

(1) Sand and Aggregate shall be stored separately as shown in Figure-126.

(2) Sand and Aggregate shall not be stored on the ground directory.

(3) Sand and Aggregate shall be protected from rain as shown Figure-126.

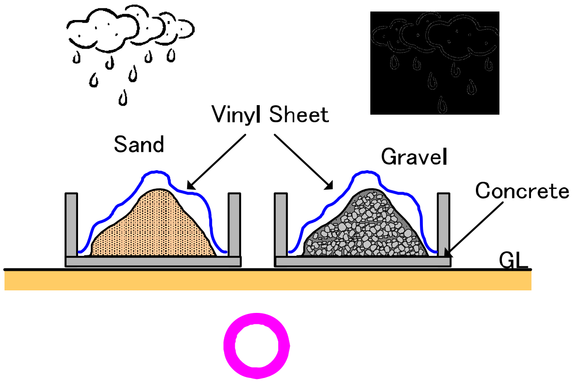


Figure-126: Correct Stock

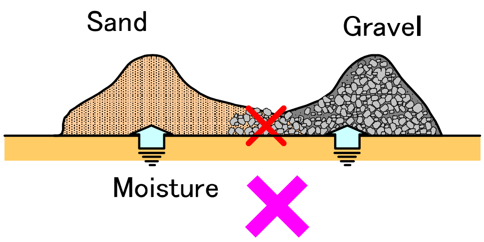


Figure-127: Incorrect Stock

I-5 Road Reconstruction

"Build Back Better" is the basic concept of the Project, and its purpose is to recover and reestablish in the region in the short-term stage, and to reinstate regional industry and bring sustainable economic activities back to the disaster damaged region in the mid to long term stage.

Based on the Project concept: BBB, Road and Bridge sector has determined "Basic Policy" described as following.

- Ensuring redundancy at the time of disaster
- Selection of a structural form that allows early restoration at the time of disaster
- Ensuring seismic performance in accordance with route importance

To satisfy the above basic concepts for road, 1. Pavement, 2. Road Planning in Liquefaction Area, and 3. Cut slope are significant elements in road planning on target area. The manual mainly looks into those elements for mitigating related risk caused by disaster.

Regarding the above elements; 1. Pavement, 2. Road Planning in Liquefaction Area, and 3. Cut slope, there are related existing regulations, guidelines and manuals in Indonesia, however, lack standardization and various conditions for design have been founded, for example;

1) Road slope design standards and manuals are published, but there is no description for stable gradient of cut slope,

2) Steep slope are applied to minimize the cost, so slope failure can occur especially in case of earthquake.

This manual is expected to use for supplementation with existing documents.

In this manual, firstly describes the general outline of each element: 1. Pavement, 2. Road Planning in Liquefaction Area, and 3. Cut slope, and shows applied/to be assumed to apply method on design in the Project.

At the end of the manual, new methods will be provided, which has the possibility to apply in Indonesia, for user`s reference.

I-5-1 Pavement

(1) Survey of Pavement

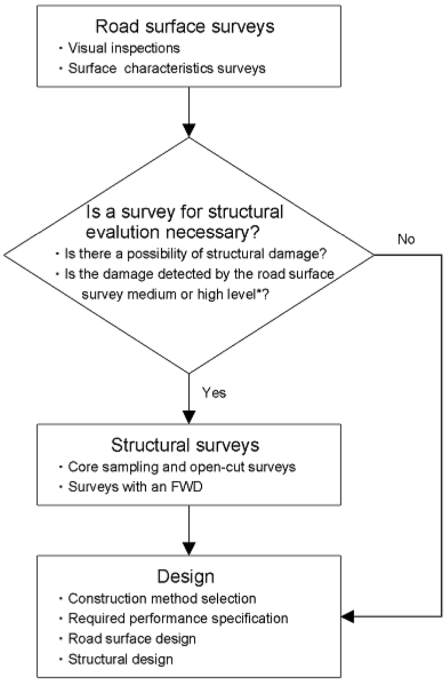
(a) Surveys

Pavement repair is based on precisely ascertaining actual damage and its causes, selection of appropriate repair methods.

Pavement damage surveys are classified into "road surface surveys" and "structural surveys." Road surface surveys include visual inspections performed mainly by observation and surface characteristics surveys using surveying and testing devices, tools, or other instruments used for measurement and evaluation. Structural surveys examine the interior conditions of pavement and subgrade.

(b) Survey workflows

Figure I-5-1-1 shows a survey workflow.



Source: Maintenance Guidebook for Road Pavement in Japan, 2013 edition

Figure I-5-1-1 Survey Flow

In the case of emergency restoration of pavement, road surface surveys would be applied, but performing a structural survey is desirable if the road surface survey results suggests structural damage is due to a cause in the binder or layers underneath, or under the concrete slab, or if there is significant damage.

(c) Road surface surveys

Pavement road surface surveys are implemented to ascertain road surface conditions through visual inspection mainly by visual observation and surface characteristics surveys using surveying and testing devices, tools, and other instruments to perform quantitative evaluation. The following described methods are used for visual inspections and surface characteristics surveys.

Visual inspections

Visual inspections evaluate damage by visual observation or by using simple tools (e.g., a scale) and infers (identifies) damage causes based on available data and other information (e.g., traffic volumes and climate conditions). The results of visual inspections are used as data for damage evaluations and Judgments regarding the need for structural surveys (with consideration given to engineers' experience.

and other factors). Visual inspections, such as observing and recording detailed road surface cond1t10ns, are principally performed by walking along the road. If a walking inspection is difficult, a vehicle should be used to observe road surface conditions.

Table I-5.1 Overview of visual inspections

Survey item	Details
Cracking	Conditions of cracks Cracking Cracking level Checking for materials separated from the bottom
Rutting	Rutting level Accumulated water level and water splashing level
Faulting and surface roughness (Corrugation, depressions, bumps, and blistering)	Height difference from the surrounding area Checking for materials separated from the bottom
Potholes	Areas and depths of potholes Surrounding conditions (oil leakage, filler ooze, etc.)
Polishing, flushing, and bleeding. (Degradation of skid resistance)	Polishing areas Accumulated water level and water splashing level
Scattering of porous asphalt pavement aggregates	Areas and depths of aggregate scattering Accumulated water level and water splashing level
Void choking and clogging in porous asphalt pavement	Choking levels Accumulated water level and water splashing level
Partial occurrence of bumps in porous asphalt pavement (Lateral flow)	Rutting level Accumulated water level and water splashing level
Stripping	Oozing of filler components onto the pavement surface Areas and depths of partial sinking

Source: Maintenance Guidebook for Road Pavement in Japan, 2013 edition

Surface characteristics surveys

Surface characteristics surveys use surveying and testing devices, tools, or other instruments to convey the pavement's surface condition (damage level) as a numeric value, including crack ratio measurement, rut depth measurement, and surface roughness measurement on paved surfaces. The results of surface characteristics surveys are used to infer (identify) the causes of damage and to qualitatively evaluate the local or complex damage to sections subject to maintenance and repair as well as the surface characteristics thereof. The results thus serve as reference data for the selection and design of repair methods or for the evaluation of the necessity of carrying out a structural survey.

(d) Structural surveys

Structural surveys are performed to ascertain the pavement's interior and pavement structure detailed by deflection measurement with FWD (falling weight deflectometer), cutting core sampling, open-cut surveys, and other approaches.

Results of deflection measurement with FWD can be used to judge whether pavement has a sufficient bearing capacity. Analysis of measured deflection can be used to detect damaged layers.

The characteristics of cracking portions, such as cracks' widths and depths, can be directly measured by cutting core sampling.

The characteristics of rutting portions, such as whether deformation has developed only at the surface course or has reached the binder course, can be revealed by measuring the thickness of each layer's cut core.

Open-cut surveys involve cutting of road surfaces, making them significantly extensive surveys.

(2) Evaluation for Existing Pavement

Major damage to asphalt pavement includes cracking, rutting, and reduction of surface roughness. Other damage includes faulting, potholes, and stripping.

(a) Cracking

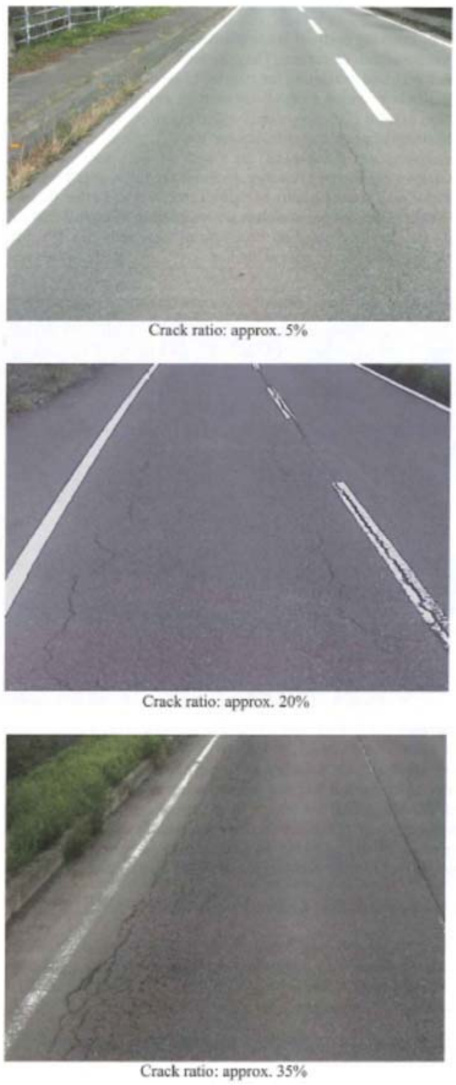
Road surface survey evaluation uses cracking levels determined by visual inspection and crack ratios determined by surface characteristics surveys to decide whether to implement repair.

A repair method should be selected by referring to criteria for the classes for selecting a construction method listed in Table I-5.2. Figure I-5-1-2 shows example photographs for estimating crack ratios from the results of visual inspections.

Table I-5.2 Criteria for classes for selecting a construction method based on crack ratios

	L	M	H
Crack ratio (%)	Approx. 15 or lower	Approx. 15 to 35	Approx. 35 or higher

Source: Maintenance Guidebook for Road Pavement in Japan, 2013 edition



Source: Maintenance Guidebook for Road Pavement in Japan, 2013 edition

Figure I-5-1-2 Examples of Estimated Crack Ratios Levels by Visual Inspection

(b) Rutting

Rutting evaluations based on road surface surveys are used to determine whether to implement repair and select repair methods in consideration of the inferred causes of rutting from its shapes and occurrence modes, roadside environments, previous construction records, and other factors.

Repair methods should be selected by referring to the criteria for classes for selecting a construction method listed in Table I-5.3. Figure I-5-1-3 shows examples.

Table I-5.3 Criteria for classes for selecting a construction method based on rut depth

	L	M	H
Rut depth (mm)	Approx. 20 or less	Approx. 20 to 35	Approx. 35 or more

Source: Maintenance Guidebook for Road Pavement in Japan, 2013 edition

Rut depth: approx. 15 mm

Rut depth: approx. 30 mm

Rut depth: approx. 40 mm

Source: Maintenance Guidebook for Road Pavement in Japan, 2013 edition

Figure I-5-1-3 Photographic Examples of estimated levels of rut depths by Visual Inspection

(c) Evaluation of other types of damage

Potholes

Potholes are small bowl-shaped depressions on the pavement surface/base course, usually less than one meter in diameter. They generally have sharp edges and vertical sides near the top of the hole. Their growth is accelerated by free water collecting inside the hole. Potholes are reproduced when traffic abrades small pieces of pavement surface. The pavement then continues to disintegrate because of poor surface quality, weak spots in the base or subgrade, or because of severe alligator cracking. Most potholes are due to structurally related distress and should not be confused with ravelling and weathering. When holes are created by high-severity alligator cracking, they should be identified as potholes. Possible causes of potholes are expected as follows:

- Too low Asphalt content
- Excessive heating of asphalt
- Poor quality mixture
- Lack of compaction allowing ingress of water
- Excessive axle loads
- Mechanical damage to the road due to poor reinstatement of roads after services installations
- Injury to pavement
- Spills or leakages

Source: JICA Study Team

Figure I-5-1-4 Shape of Potholes

If countermeasure is not executed properly, it allows water to enter the pavement causing softening and weakening of the pavement and lower layers. This may cause early failure of the pavement. If left unrepaired, damage can rapidly expand. Creates poor ride quality for motorists and may reduce traffic speed. If large, can cause damage to vehicles and increase the risk of an accident.

Bleeding

Bleeding is a film of bituminous material that covers the pavement surface and which creates as shiny, glass-like appearance. It occurs when asphalt fills the void of the mix during hot weather and then migrates to the pavement surface. Possible causes of bleeding are expected as follows:

- Excessive application of binder with respect to stone size
- Excessive prime coat incorporated into the seal
- Excessive binder in underlying surface (patch or flushed area)

- Primer seal covered before volatiles in primer binder evaporated

Source: JICA Study Team

Figure I-5-1-5 Shape of Bleeding

If countermeasure is not executed properly, road surface becomes slippery and hazardous to traffic. If excessive, separation and breaking away of surface layer due to traffic.

Edge damage

Edge damage is a difference in elevation between the pavement edge and the shoulder and occurs along the edge of the pavement. Possible causes of edge damage is expected as follows:

- Shoulder wear (formation of step)
- Erosion by water
- Insufficient compaction at edges of bituminous pavement
- Road too narrow
- Excessive axle loads

Source: JICA Study Team

Figure I-5-1-6 Shape of Edge damage

If countermeasure is not executed properly, it will deteriorated sharply during rainy season and traffic will worsen defect.

Reduction of surface roughness

Surface roughness, which may cause bad ride quality, noise, and vibration when reduced, requires appropriate maintenance and administration. It is evaluated in terms of pavement's longitudinal irregularity level. The surface roughness of long sections should be evaluated by measuring with a device such as a 3-meter profilometer. Reduced surface roughness is generally classified as road surface damage, but in some cases, it is classified as structural damage due to insufficient bearing capacity or other causes.

Faulting

Faulting leads to bad ride quality and causes moving vehicles to generate noise and vibration, as well as structural damage in some cases. Thus, it is essential to implement appropriate maintenance and administration on faulting on road surfaces, with consideration given to roadside environments, traffic conditions, and other factors. Emergency actions may be required if the faulting is serious. Faulting is generally classified as road surface damage but, in some cases, it is classified as damage due to insufficient compaction of the base course and layers underneath or as structural damage.

(3) Maintenance and Repair Methods for Pavement

Table I-5.4 lists major maintenance and repair methods for asphalt pavement. Table I-5.5 shows types of damage and guidelines for repair methods according to the classes for selecting a construction method.

Table I-5.4 Overview of maintenance and repair methods for pavement

Method	Overview
Patching and run-off of faulting	➢ Fills potholes, depressions, faulting, etc. in emergencies. ➢ Uses hot/cold mixtures based on bituminous or resin binder, etc. as pavement materials.
Sealant injection	➢ Fills relatively wide cracks with joint-sealing compound, etc. ➢ Sometimes performed as a preventive maintenance method. ➢ Generally uses hot compound as filler. Other types used include emulsion, cutback, and resin, etc. ➢ Uses materials appropriate for crack widths and depths.
Cutting	➢ Cuts and removes protrusions, etc. on road surfaces to eliminate unevenness and faulting. ➢ Often performed as overlay pretreatment or surface treatment.
Surface treatment	➢ Forms a sealing layer thinner than 3 cm on pavement. ➢ Sometimes used as a preventive maintenance method.
Washing of void choking	➢ Recovers the draining and noise reduction functions of porous asphalt pavement, etc. by removing mud and dust, etc. captured in its voids. ➢ Captured matter is removed by spraying pressurized water toward pavement to wash off the matter or other approaches. ➢ This method is considered effective when performed before pavement function declines substantially.
Thin overlay	➢ Placing of hot mixture thinner than 3 cm on pavement. ➢ Sometimes performed as a preventive maintenance method for wearing courses, etc.
Rutting overlay	➢ Placing of hot mixture thinner than 3 cm only on the rutting portions of pavement. ➢ Applied mainly to portions worn by abrasion, etc.; unsuitable for portions with rutting formed by flows. ➢ Often performed as leveling before overlay.
Replacement	➢ Replaces all or part of existing pavement's base course. ➢ Replacement and stabilization of subgrade or base course are sometimes performed.

Local replacement	➢ Used to locally replace the surface course, binder course, or base course if it is judged that maintenance of existing pavement that has been locally substantially damaged cannot be achieved by other methods. ➢ Generally performed on portions that have developed large local cracks when performing replacement of surface and binder courses or overlay.
Overlay	➢ Placing of bot mixture 3 cm of thicker on pavement. ➢ If local defective portions are included, local replacement, etc. will be performed first.
Replacement of surface and binder courses (Mill and overlay)	➢ Replaces pavement layers as deep as surface or binder course. ➢ The method is called mill and overlay when removing asphalt mixture layers by cutting.
Base course recycling	➢ Uses a road stabilizer or other device to crush asphalt mixture layers on-site; to mix crushed materials with cement, asphalt emulsion, and other additional materials; and to compact the mixture to construct stabilized base course.
Surface recycling	➢ Scarifies and loosens asphalt mixture layers on-site while beating them, mixes the loosened materials with additional asphalt mixture and rejuvenators whenever necessary, and spreads and compacts the materials to reconstruct surface courses.

Source: Maintenance Guidebook for Road Pavement in Japan, 2013 edition

Table I-5.5 Types of damage to pavement and guidelines for selecting repair methods according to the classes for selecting a construction method

Damege to asphalt pavement \ Maintenance and repair method		Damage classification	Maintenance method							Repair method					
			Patching and run-off of faulting	Sealant injection	Open-cut	Surface treatment	Washing of void choking	Thin overlay	Rutting Overlay	Replacement	Local Replacement	Overlay	Replacement of surface and binder course (Open-cut overlay)	Base course recycling	Surface recycling
Cracking	▪Linear cracking ▪ Fatigue cracking ▪ Rutting ▪ Cracking at construction joints ▪ Reflection cracking ▪ Cracking due to thermal stress ▪ Cracking due to frost heaving	Road surface damage/ Structural damage		L,(M)						M,H	L,M	M,H	M,H	M,H	M,H
	▪Alligator cracking ▪ Cracking due to decrease in bearing capacity or settlement of subgrade or base course ▪ Cracking due to stripping of binder course	Road surface damage/ Structural damage	L,M							M,H	L,M		M,H	M,H	
	Cracking due to frost heaving and thawning	Structural damage		L,M						M,H	L,M			M,H	M
	Cracking due to degradation or aging of asphalt mixtures	Road surface damage/ Structural damage	L			M,H		M,H					M,H		M,H
	Cracking around structures	Road surface damage/ Structural damage	○	○							◎				
Rutting	Rutting due to compressive deformation of subgrade or base course	Structural damage	L			L		L,M		M,H	M,H			M,H	
	Rutting due to plastic deformation of asphalt mixtures	Road surface damage/ Structural damage	L		M	L		L,M				M,H	M,H		M
	Rutting due to abrasion of asphalt mixtures	Road surface damage	L			L		L,M	M,H			M,H	M,H		M
Decrease in surface roughness	Longitudinal irregularities	Road surface damage/ Structural damage	○					○		◎		○	○	◎	○
Other types of damage	Faulting	Road surface damage/ Structural damage	○		○						◎				
	Potholes	Road surface damage/ Structural damage	○								◎				
	Stripping	Road surface damage/ Structural damage								◎	◎		○,◎		
	Polishing (decreased skid resistance)	Road surface damage				M,H		H				H	H		H
	Corrugation	Road surface damage						○				○	○		
	Depressions	Road surface damage/ Structural damage	○								◎				
	Bumps	Road surface damage/ Structural damage	○		○						◎		○,◎		
Damage unique to porous asphalt pavement	Scattering of aggregates	Road surface damage	○			○							○		
	Void choking	Road surface damage					○						○		
	Void clogging	Road surface damage											○		
	Partial bumps (lateral flow)	Structural damage									◎		◎		

Remarks
- L, M, and H : Classes for selecting a construction method
- (M) : Method applied only to road surface damage
- ○ : Method applied to road surface damage
- ◎ : Method applied to structural damage

Source: Maintenance Guidebook for Road Pavement in Japan, 2013 edition

(4) Application in the Project

To grasp the current pavement condition of Inner Ring Road, which is one of the sub-project, survey and evaluation are carried out. The survey method is a visual survey for prompt restoration of the pavement. The surveyed road is as shown in the figure below.

Figure I-5-1-7 Location Map of Palu Inner Ring Road

Following Table I-5.6 and Table I-5.7 are shown the evaluation of pavement and the example of evaluation.

Table I-5.6 Evaluation of Pavement

Evaluation	Status	Countermeasure
A	No damage	Monitoring
B	Partial damage	Partial reconstruction
C	Large damage or No pavement	Reconstruction or Construction

Table I-5.7 Example of Evaluation

No.	Station (km)	Crack ratio	Rut depth	Amout of faulting	Evaluation	Remarks
1	0.0 ~ 3.0	1	1	1	A	No damage
2	3.0 ~ 3.5	1	1	1	A	No damage
3	3.5 ~ 4.2	-	-	-	C	No pavement
4	4.2 ~ 5.7	1	1	1	A	No damage
5	5.7 ~ 7.5	1	1	1	A	No damage(except no pavement section)
	7.1	-	-	-	C	No pavement
6	7.5 ~ 7.7	1	1	1	A	No damage
7	7.7 ~ 8.9	-	-	-	C	No pavement
8	8.9 ~ 12.1	1	1	5	B	Partial damage
9	12.1 ~ 14.9	1	1	5	B	Partial damage
	12.6 ~ 13.1	-	-	-	C	No pavement
10	14.9 ~ 19.1	1	1	5	B	Partial damage
	16.9 ~ 17.4	-	-	-	C	No pavement
11	19.1 ~ 20.0	5	1	5	C	No pavement
12	20.0 ~ 21.0	1	1	3	B	Partial damage
13	21.0 ~ 22.3	1	1	1	A	No damage
14	22.3 ~ 24.6	1	1	1	A	No damage
15	24.6 ~ 25.7	-	-	-	C	No pavement
16	25.7 ~ 31.6	1	1	1	A	No damage
17	31.6 ~ 32.6	1	1	1	A	No damage
18	32.6 ~ 32.9	-	-	-	C	No pavement
19	32.9 ~ 35.5	-	-	-	C	No pavement
20	35.5 ~ 36.4	1	1	1	A	No damage
21	36.4 ~ 45.4	1	1	5	B	Partial damage

Note) A : No damage (Monitoring), B : Partial damage (Partial reconstruction), C : Large damage or No pavement (Reconstruction or Construction)

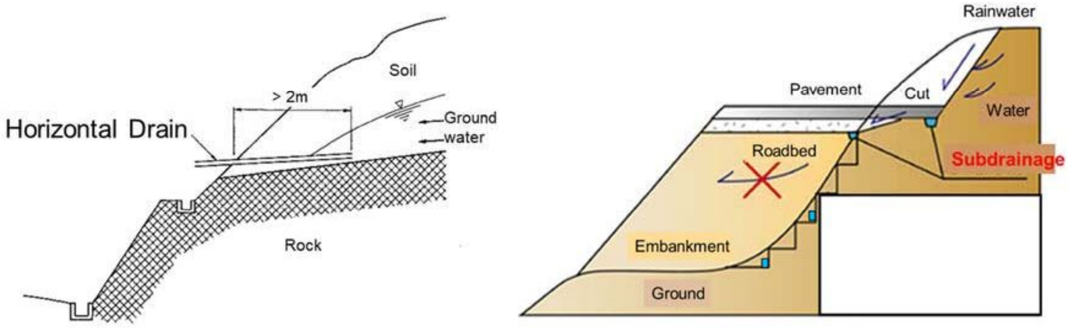
I-5-2 Road Reconstruction in Liquefaction Area

In consideration of a mechanism of liquefaction, water treatment is the most effective method for mitigation of liquefaction hazard since the shake by an earthquake cannot be avoidable. Soft ground treatment also can be considerable, but application is limited, only for small-scale area, since the soil treatment in wide vulnerable area is too expensive.

(1) Drainage Treatment

Groundwater Level Lowering

Drain method as one of the mitigation measures against liquefaction has been widely used with soil improvement. Liquefaction area is high groundwater level and required the drainage system toward outside of the embankment area.



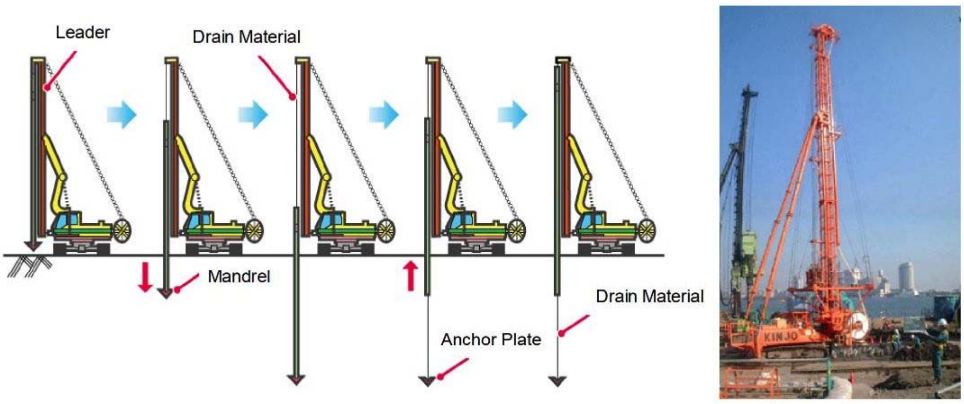
Source: JICA Survey Team

Figure I-5-2-1 Horizontal Drain and Subdrainage

DEPP Method (Dissipation Excess Pore Water Pressure Method)

The DEPP method (Dissipation Excess Pore Water Pressure Method) drains excess pore water generated during an earthquake by vertically placing synthetic resin drains at predetermined intervals in sand soil. It is a liquefaction prevention method that allows it to flow into the interior early and suppress the rise in excess pore water pressure.

Since the drain material is placed on the sand ground together with the steel protection tube by a static press-in type casting machine during placement, quietness is maintained without disturbing the surrounding ground while protecting the drainage capacity of the drain material. And it can be installed quickly. In addition, it is one of the least expensive measures among the liquefaction measures. Figure I-5-2-2 is shown the construction image of DEPP method.



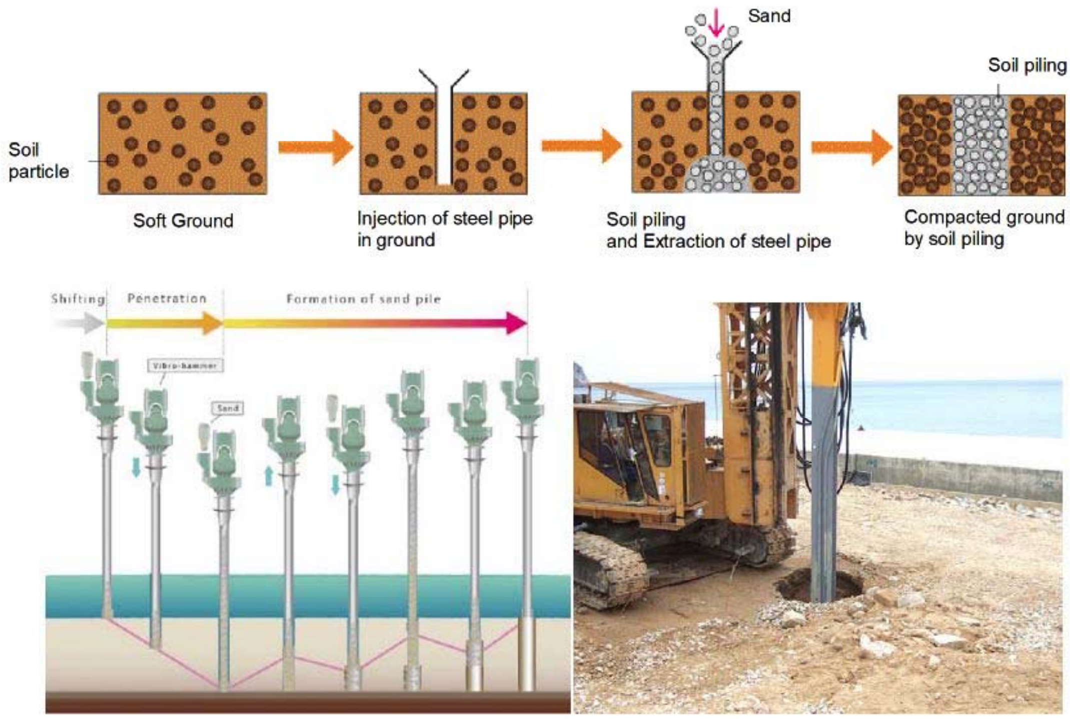
Source: https://www.rncc.co.jp/tech/tc_3/19

Figure I-5-2-2 DEPP Method

(2) Soft Ground Treatment

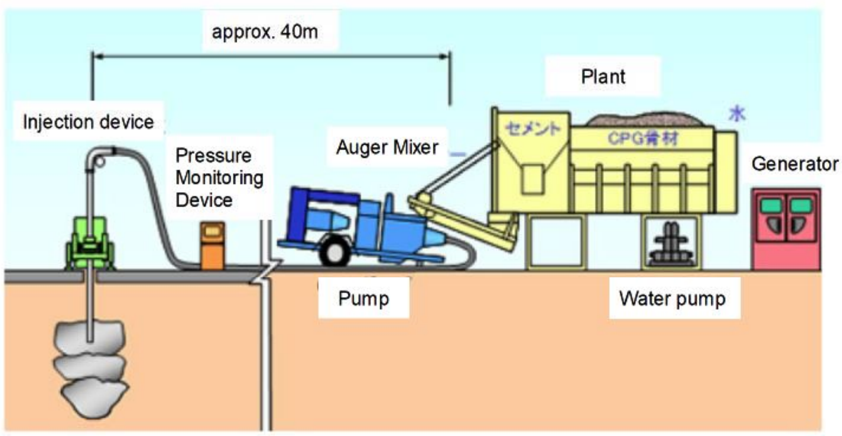
1) Compaction Method

The compaction method is aimed at increasing bearing capacity, suppressing deformation and preventing liquefaction by compacting loose sandy ground and increasing the density of the ground. It can be classified into vibration compaction method and static compaction method. As a vibration compaction method, there are Sand compaction pile method (the most used method), Vibrating rod method, Vibro-tamper method, Vibro-rotation method, etc. The static compaction method is applied when it is difficult to implement the vibration compaction method such as in urban areas or areas adjacent to houses. There are sand pile method and compaction grouting (CPG) method as static compaction method.



Source: Tokyo Metropolitan Government Site (http://www.shijou.metro.tokyo.jp/toyosu/dojou/taisaku/outline/step/step07/)

Figure I-5-2-3 Image of Vibration Compaction Method (Sand Compaction Pile Method)



Source: Honma Construction Company (https://www.honmagumi.co.jp/technology/298/)

Figure I-5-2-4 Image of Static Compaction Method (CPG Method)