International Program on Resilient Society Development

Under Changing Climate (RSDC)

2112681 Engineering for Water Disaster Mitigation

Kasetsart University

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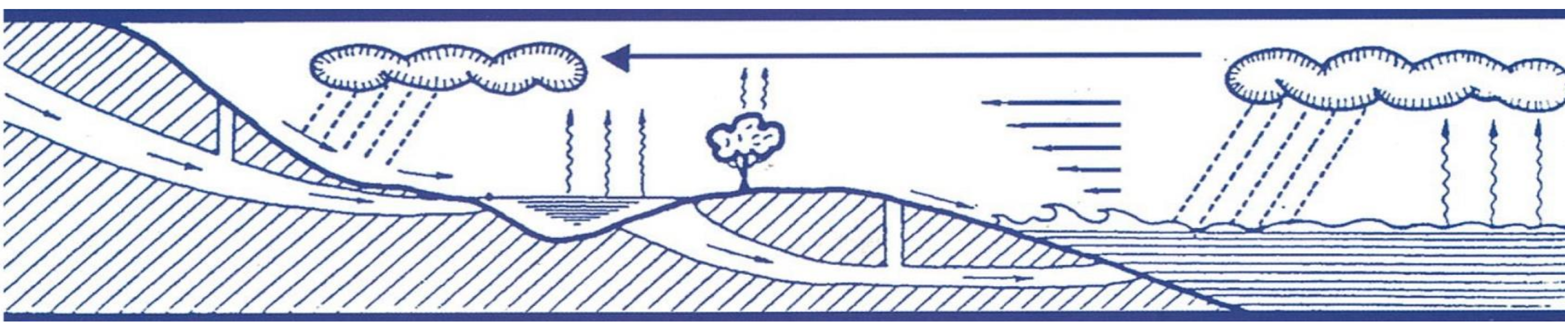

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Chapter 1

Geo-Risk Engineering

1.1 Mathematical Background of Geo-Risk Evaluation

Presents the mathematical background for evaluating slope risk. The basic concepts of the following constituents of this framework are described in detail.

- Reliability-based slope stability analysis
- Hazard modeling
- Evaluation of losses from slope failure
- Evaluation of annual probability and risk of slope failure
- A case study on slopes along a national road in Japan

1.2 Definition of Risk

As a technical term to indicate the degree of hazard in the insurance market around the 17th century and made its first appearance in an English dictionary in the 18th century. The word was thus originally used as an economic term and later became cited in various other fields. During this process, various meanings were attached to the word in each field, which resulted in the various definitions established for it today.

The various meanings of the term “risk” include the following:

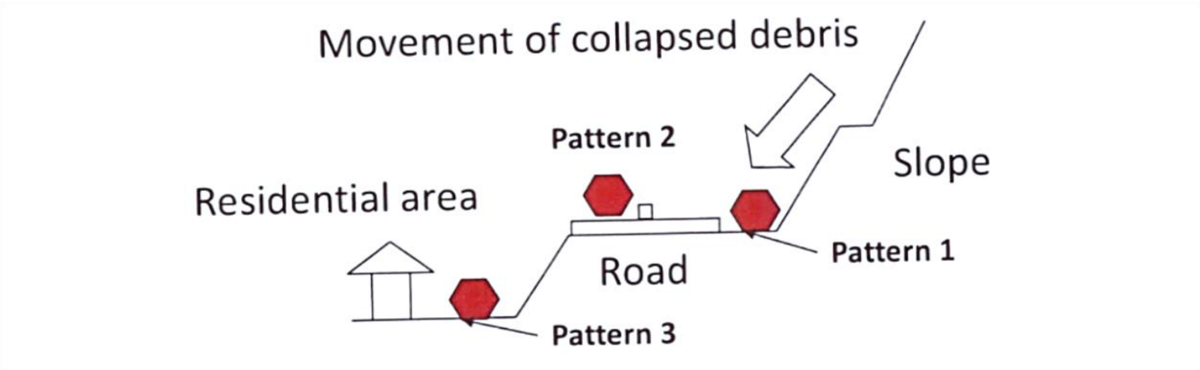
- Possibility of loss
- Probability of loss
- Condition of loss (peril)
- Dangerous status (hazard)
- Property/person exposed to a damage or loss
- Potential loss
- Fluctuation of actual and expected loss
- Uncertainty

In general, risk is broadly categorized into subjective and objective risk. Here, “subjective risk” represents a risk that is comprehensively evaluated by a number of concerned parties through their qualitative judgment based on their subjective views, e.g. based on their experience and intuition. On the other hand, “objective risk” is quantitatively calculated by modeling the indeterminate quantity according to a set of statistical/stochastic theories based on experimental results or past records. This notion of the term "risk" is adopted in the fields of financial and reliability engineering.

This study adopts the risk definition in engineering field as follows:

$$R = \sum_{i=1}^{j} P_i * C_i \tag{1.1}$$

The procedure to evaluate risk due to slope failure in accordance with eq.1.1 is discussed by using an example shown in Figure 1.1. The predicted risk due to slope failure varies depending on damage pattern/scenario. In the case of an example shown in Figure.1, even if a road slope fails, damage pattern would be classified into the following three ones:



Classification of damage pattern

Pattern 1: Collapsed debris stops besides road

Pattern 2: Collapsed debris moves to road

Pattern 3: Collapsed debris move to residential area

Figure 1-1 Damage scenarios due to road slope failure

First, in the case of Pattern 1, while the cost for slope restoration and removal of collapsed debris in predicted, expected loss due to slope failure is relatively smaller than other patterns. Second, in the case of Pattern 2, in addition to the cost for slope restoration and removal of collapsed debris, the compensation cost for vehicles/passengers, which may be hit by collapsed debris and indirect loss for road service interruption during removal of collapsed debris and repair of damage road may be predicted. Third, in the case of Pattern 3, in addition to loss corresponding to Pattern 2, the compensation cost for residents/ house, which may be hit by collapsed debris may be predicted.

In order to sort out the predicted damages mentioned above, the adoption of Event Tree (ET) analysis is very effective. As shown in Figure 1.2, the damage scenarios corresponding to Figure 1.2 are classified into 8 scenarios by using ET.

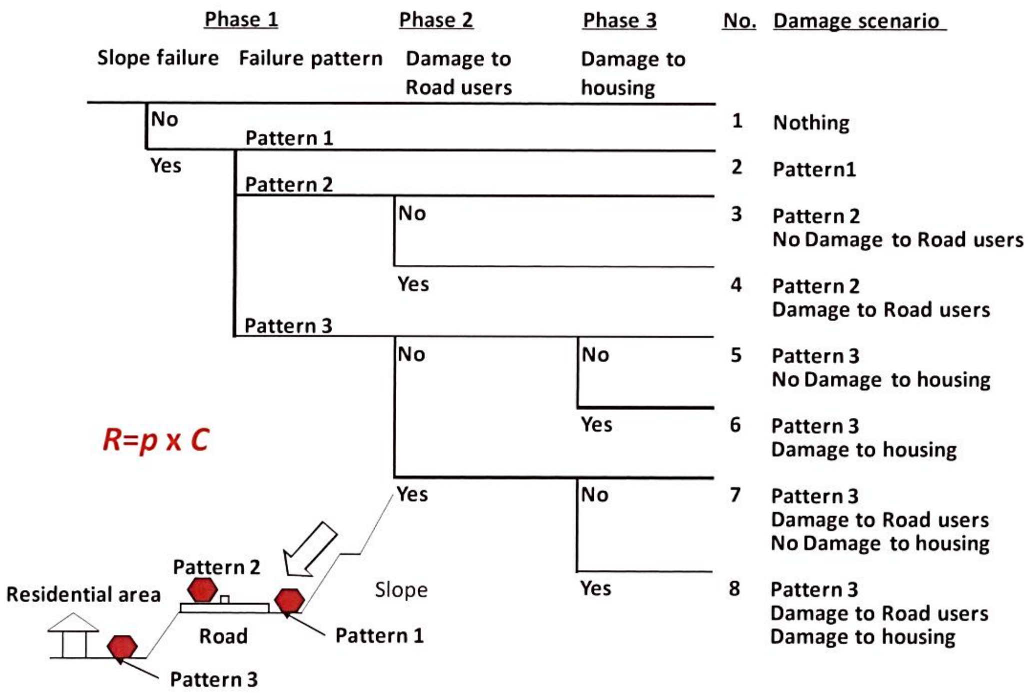


Figure 1-2 Establishment of damage scenario using ET (Event Tree)

The next step is to allocate the probability corresponding to each branch and estimate consequences corresponding to each scenario. Figure 1.3. Shows an example of risk analysis, in which the virtual is allocated for the probability at each branch. Here, it is noted that the probability at the first branch is corresponding to probability of slope failure against hazard level α.

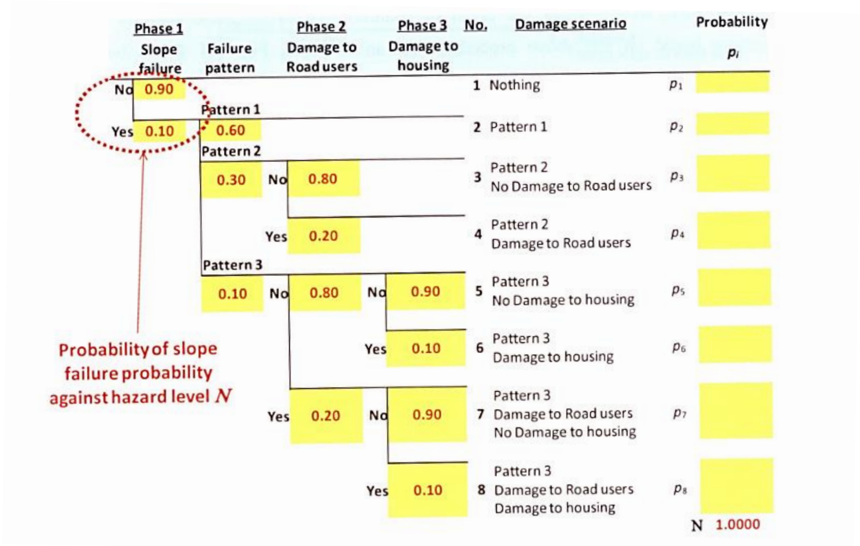


Figure 1-3 An example of slope failure risk analysis Using ET

The following step to calculate risk in accordance with eq.1.1 is to allocate consequence C_i corresponding to each damage scenario. Here, let's assume an example of consequences as shown in Table 1.1. The example considers three kinds of loss, restoration loss, compensation and indirect loss due to diversion during road service interruption, respectively.

Table 1-1 An example of consequences

Probability	Direct Loss		Indirect Loss	Consequence
	Restoration loss	Compensation	Diversion	C_i
P1	0	0	0	0
P2	1	0	0	1
P3	10	0	10	20
P4	10	100	10	120
P5	15	0	20	35
P6	15	200	20	235
P7	15	100	20	135
P8	15	300	20	335

As a next step, let's consider the effect of countermeasures for slope stability on the risk mitigation based on the above procedure. As an example, Figure 1.4. Shows two types of countermeasure are considered.

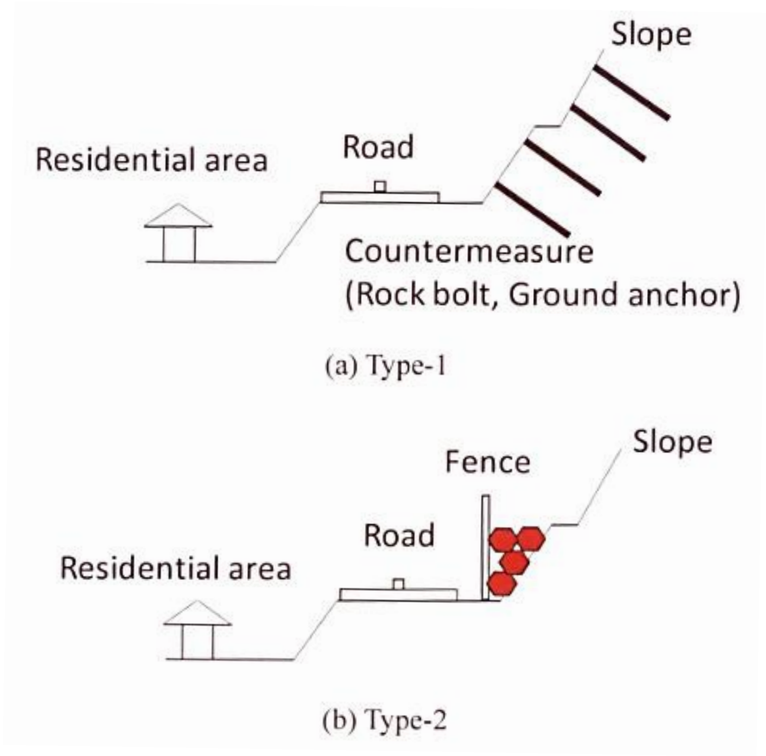


Figure 1-4 Examples of countermeasures for slope stability

While type-1 countermeasure directly has the effect on enforcement of slope stability, type-2 countermeasure has the effect on mitigation of loss alone. Therefore, as shown in ET of Figure 1.5, the adoption of type 1 countermeasure makes the probability corresponding to slope failure vary, and the adoption of type 2 makes the branch probability corresponding to damage pattern vary.

In order to help to understand the procedure to investigate the effect of countermeasure on risk mitigation, let's consider examples of ET shown in both Figure 1.6 and Figure 1.7 in an example shown in Figure 1.6, the probability of slope failure is changed from current value, 0.1 to 0.05 by the adoption of countermeasure. On the other hand, in an example shown in Figure 1.7, each branch probability corresponding to each damage pattern is changed respectively.

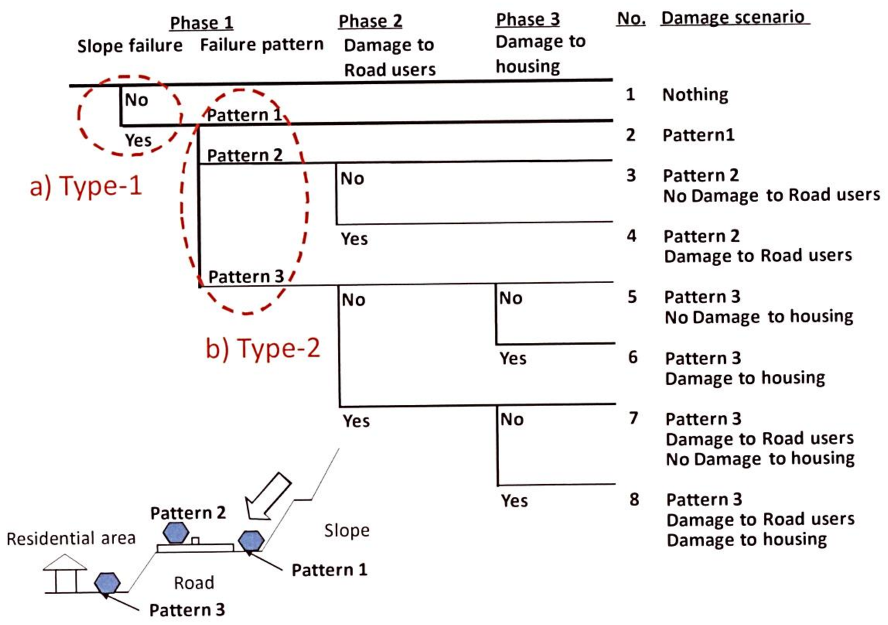


Figure 1-5 The effect of countermeasure on risk mitigation shown in ET

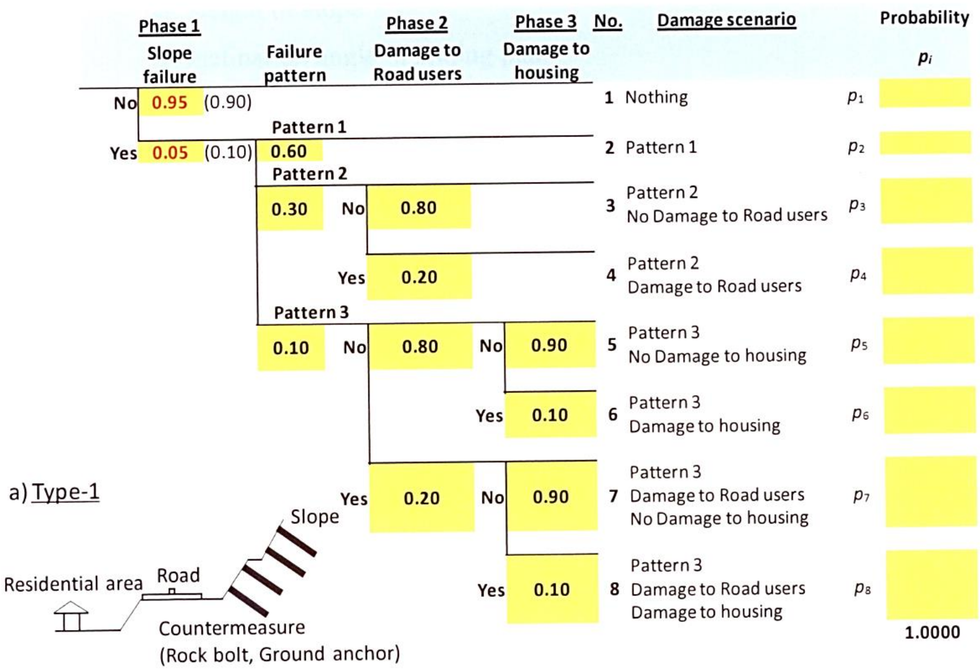


Figure 1-6 An example of ET corresponding to the adoption of type-1 countermeasure

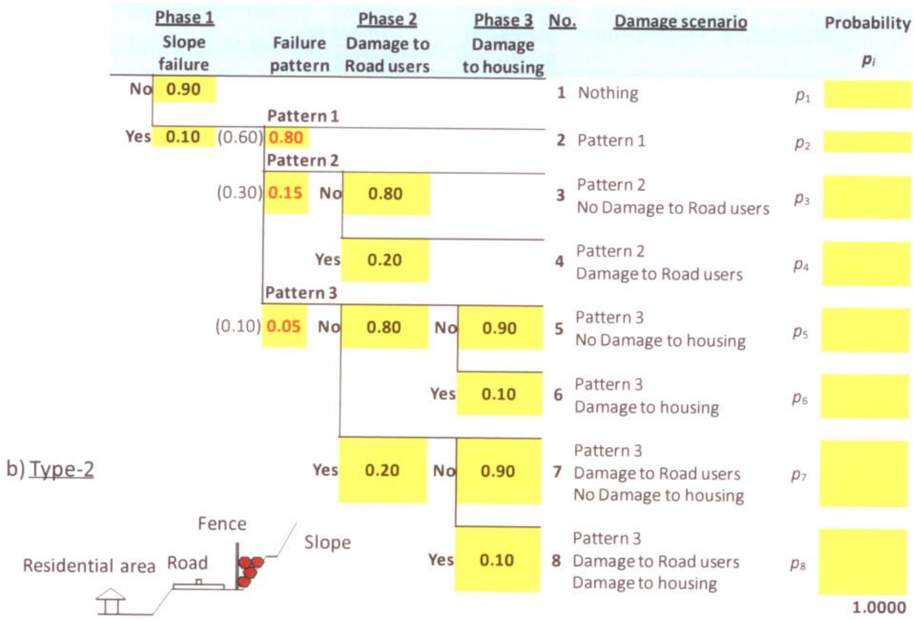


Figure 1-7 An example of ET corresponding to the adoption of type-2 countermeasure

1.2.1 Reliability-Based Slope Stability Analysis

The first step of reliability-based slope stability analysis is to define suitable performance functions that numerically evaluated slope stability. Two types of slope are adopted based on the limit equilibrium method (LEM): the plane sliding method and the circular sliding method (Figure 1.8). The performance functions for these methods are derived as follows.

i) Performance function for the plane sliding method

$$Q = \left(1 - \frac{\gamma_w H_w}{\gamma H}\right)\frac{tan\emptyset}{tan\alpha} + \frac{c}{\gamma H}\frac{1}{sin\alpha cos\alpha} - 1 \qquad (1.2)$$

Where	Q	:	Performance function
	γ_w	:	Unit weight of water
	γ	:	Unit weight of Soil
	H_w	:	Height of water table from sliding plane
	H	:	Height angle of sliding plane
	α	:	Inclination angle of sliding plane
	$\emptyset$	:	Frictional angle of soil

ii) Performance function for the circular sliding method

$$Q = \frac{\sum_{i=1}^{n}(b_i sec\theta_i)}{\sum_{n=1}^{n}(W_i sin\theta_i)}c + \frac{\sum_{i=1}^{n}(w_i cos\theta_i - u_i b_i sec\theta_i)}{\sum_{n=1}^{n}(w_i sin\theta_i)}tan\emptyset - 1 \qquad (1.3)$$

Where	W_i	:	weight of slice *i*
	b_i	:	Width of slice *i*
	θ_i	:	Inclinational angle of the slice base to the horizontal line
	u_i	:	Pore water pressure in slice *i*

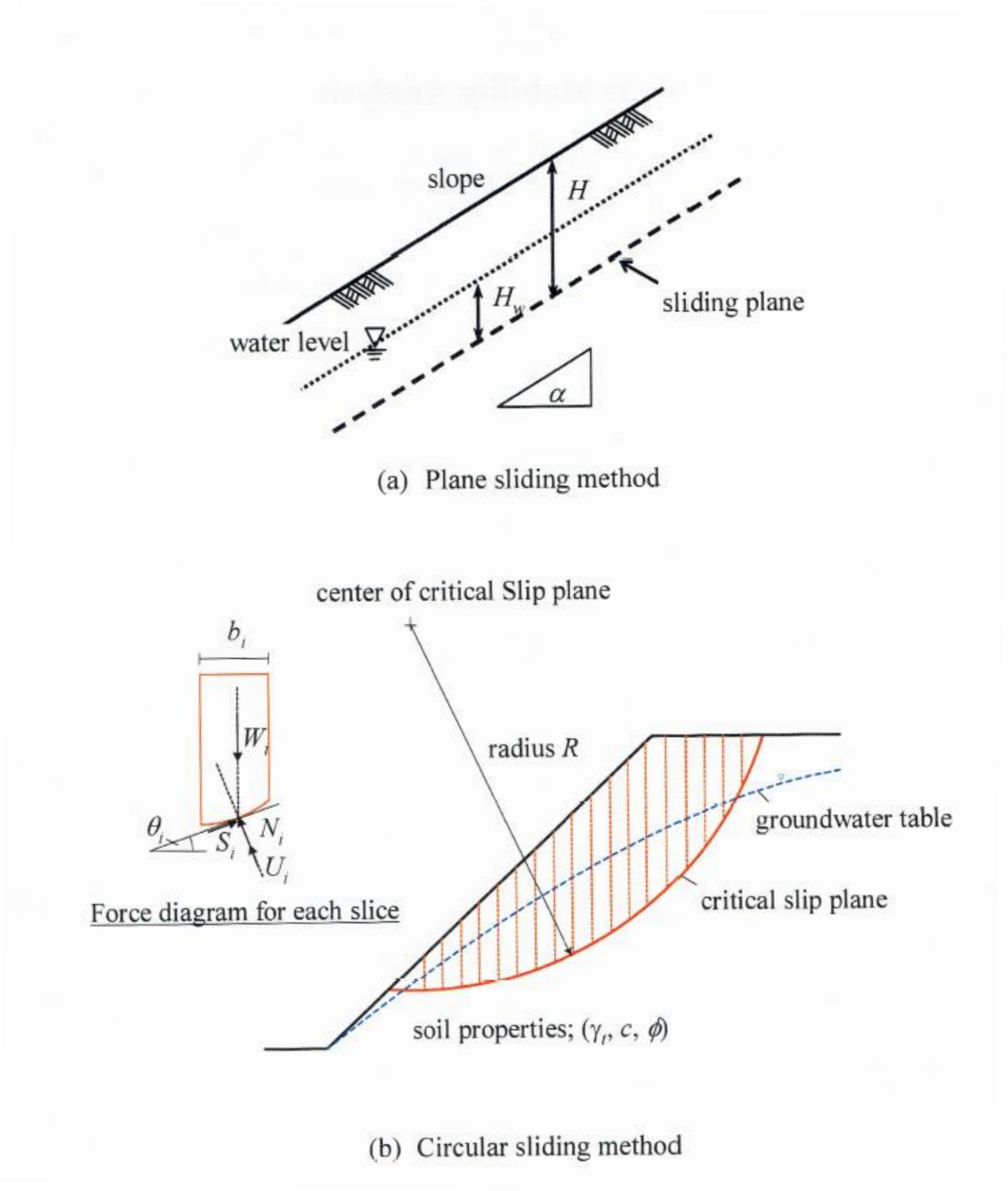


Figure 1-8 Slope failure modeling based on Limit Equilibrium Method (LEM)

Considering that the sum of the first and second terms on the right hand of eq.1.2 and eq.1.3 is equivalent to the factor of safety that is a common index in deterministic stability analysis, the physical meaning of performance equation Q is clearly summarized as:

- $Q < 0$: Unstable
- $Q = 0$: Critical condition
- $Q > 0$: Stable

1.2.2 Hazard Modeling

When modeling a natural hazard, it is usually assumed that the occurrence of a natural hazard follows a Poisson process. Considering a Poisson process in which an event with a hazard level of greater than α occurs with arrival rate $P(\alpha)$ in time period t, exceedance probability of the event $\psi(t{:}\alpha)$ can be represented by:

$$\Psi(t:\alpha) = 1 - exp[-P(\alpha)t] \qquad 0 < t < \infty \qquad (1.4)$$

For a period of one year, the annual exceedance probability of hazard level α is given by:

$$\Psi(\alpha) = 1 - exp[-P(\alpha)] \qquad (1.5)$$

For a rainfall event, which is considered as a hazard here, the maximum amount of rainfall is critical, and the distribution of maximum amount of rainfall is of special concern. The statistics of extreme value are sued to develop a model for the occurrence of a rainfall hazard. The Gumbel distribution shown in Figure 1.9 is suitable here. It has the exceedance probability (ψ) at certain rainfall intensity (α) as follows:

$$\Psi(\alpha) = 1 - exp\left[-e^{-a(\alpha-b)}\right] \qquad (1.6)$$

Where a and b = constant parameters, which can be estimated from the historical records of rainfall.

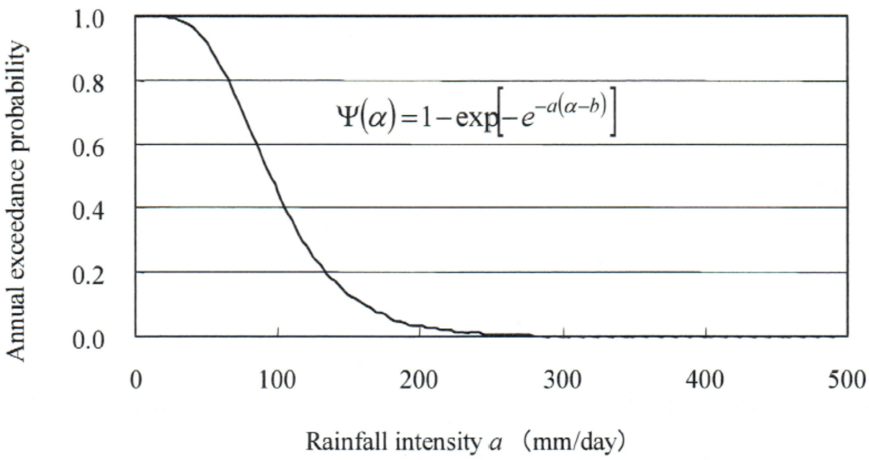


Figure 1-9 Rainfall hazard curve

1.2.3 Evaluation of Loss from Slope Failure

To evaluate the socio-economic loss from a slope failure, losses are classified into direct ones and indirect ones. A direct loss is related to the cost of slope restoration and compensation for damages to vehicles, passengers and private property. An indirect loss is related to the loss to road users caused by diversions during the interruption of road service as a result of a slope failure.

The loss from slope restoration cost (L_R) is given by:

$$L_R = (C_{v0} * V + C_{A0} * A) * (1 + a) + C_{M0} * n \qquad (1.7)$$

Where

C_{v0}	:	Cost of debris removal per unit volume
V	:	Volume of collapsed debris
C_{A0}	:	Cost of slope restoration per unit area
A	:	Area of slope to be restored
a	:	Miscellaneous expense ration
C_{M0}	:	cost of management and labor wage per day
n	:	Number of days of road interruption

The loss from compensation for damages to vehicles, passengers and private property (L_c) is given by:

$$L_C = n_v * \left(C_v * n_p + C_p\right) + C_D \qquad (1.8)$$

Where	n_v	: estimated number of damaged vehicles
	C_v	: Average loss of one vehicle
	n_p	: Average number of passengers per car
	C_p	: Monetary loss one human life
	C_D	: Estimated damage to the surrounding private properties

On the other hand, the indirect loss (L_D), which is regarded as an increase in the traveling cost caused by the interruption of road service after a road slope failure, is given by the sum of traveling energy loss L_D^e and traveling time loss L_D^t. Table 1.2 lists the parameters required to evaluate L_D^t and L_D^e

Table 1-2 Parameter data required to evaluate L_D^t and L_D^e

Types of losses	Required parameters
Traveling energy loss L_D^e	1. Unit value of traveling energy cost corresponding to vehicle type *m* along diversion route, B_m^d
	2. Unit value of traveling energy cost losses corresponding to vehicle type *m* along original route, B_m^0
	3. Traveling distance on diversion route, L^d
	4. Traveling distance on original route, L^o
	5. Daily traffic count corresponding to vehicle type m, N_m
	6. Number of days of road service interruption after a road slope failure, n
Traveling time loss L_D^t	1. Unit value of traveling time corresponding to vehicle type *m*, A_m
	2. Daily traffic count corresponding to vehicle type *m*, N_m
	3. Traveling distance along diversion route, V_d
	4. Traveling distance along original route, V_0
	5. Traveling velocity on diversion route, L^d
	6. Traveling velocity on original route, L^0
	7. Number of days of road service interruption after a road slope failure, *n*

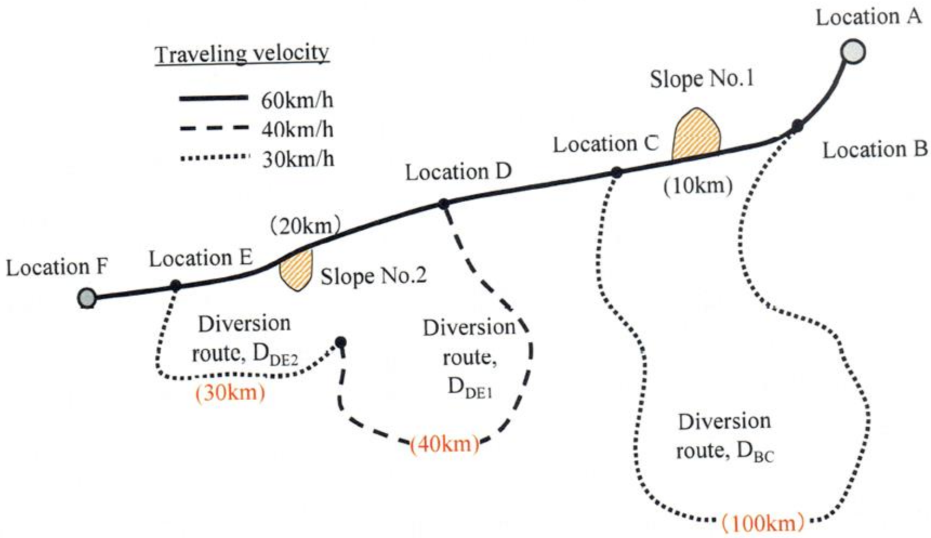


Figure 1-10 Example of diversion route detection

1.2.4 Evaluation of Fluctuations in Pore water Pressure and Groundwater Table Causes by Rainfall

Besides the geological conditions of slope and soil properties, the groundwater level is also one of the important factors in slope stability analysis. To evaluate the probability of slope failure, it is necessary to associate the fluctuations in groundwater level with rainfall intensity. Figure 1.11 shows a model for the mechanism of how groundwater circulation is stimulated by rainfall. The mass balance of water after rainfall is given by:

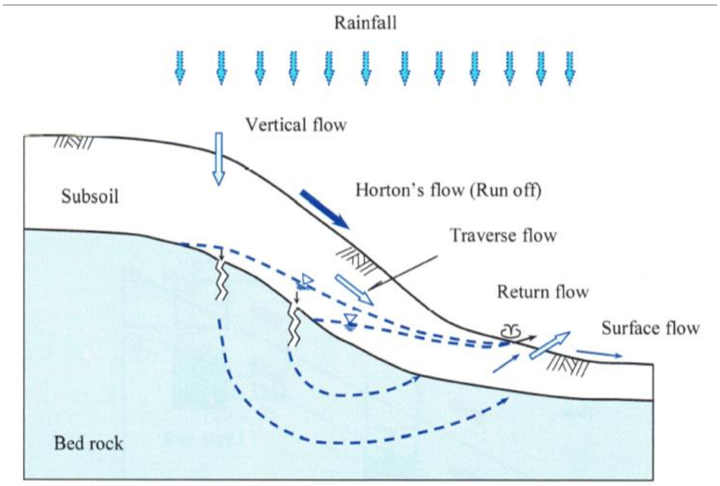


Figure 1-11 Schematic representation of groundwater movement

$$Q_R = Q_E + Q_I + Q_S \tag{1.9}$$

Where	Q_R	:	Amount of rainfall
	Q_E	:	Amount of evaporation
	Q_I	:	Amount of infiltration into subsoil
	Q_S	:	Amount of flow along slope surface

The most important thing to note with regard to Eq. 1.9 is that the amount of infiltration into subsoil, Q_I should be properly associated with the amount of flow along slope surface Q_S. Otherwise, changes in the groundwater level will be overestimated or underestimate. Seepage analysis is usually employed to relate rainfall to changes in the groundwater level. The amount of infiltration into subsoil Q_I is obtained iteratively in the analysis. The problem here is that there is no guarantee you can get a converged solution.

1.2.5 Annual Probability of Failure and Risk Evaluation

It is possible to calculate reliability index (β) and probability of failure (p_f) by applying reliability analysis. In the hazard curve, the probability of the annual occurrence of hazard event of level α grater, $\Psi(\alpha)$, is correlated to rainfall probability density $\Psi(\alpha)$, as in:

$$1 - \Psi(\alpha) = \int_0^\alpha \varphi(\alpha) d\alpha \tag{1.10}$$

Rainfall probability density $\varphi(\alpha)$ is then given by:

$$\varphi(\alpha) = -\frac{\partial\Psi(\alpha)}{\partial\alpha} \tag{1.11}$$

Combining of the fragility curve shown in Figure 1.12 (a) with the exceedance probability of rainfall hazard shown in figure 12 (b), the annual probability of a slope failure (P_a) is determined by:

$$p_a = \int_0^\infty p_f(\alpha)\,\varphi(\alpha)d\alpha = -\int_0^\infty p_f(\alpha)\frac{\partial\Psi(\alpha)}{\partial\alpha}d\alpha \tag{1.12}$$

In general, the integration in Eq.1.12 can be numerically treated in the following manner:

$$p_a = -\int_0^\infty p_f(\alpha)\frac{\partial\Psi(\alpha)}{\partial\alpha}d\alpha = \sum_{j=1}^{\infty} p_i(a_i)\left[\Psi(\alpha_{j+1}) - \Psi(\alpha_j)\right] \tag{1.13}$$

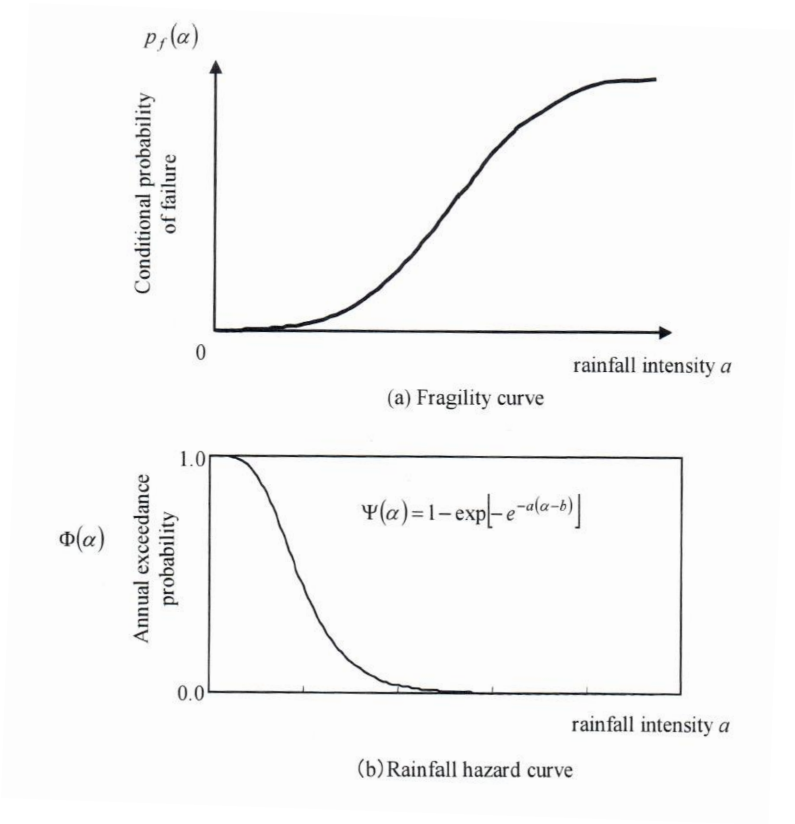


Figure 1-12 Calculation procedure for the annual probability of failure

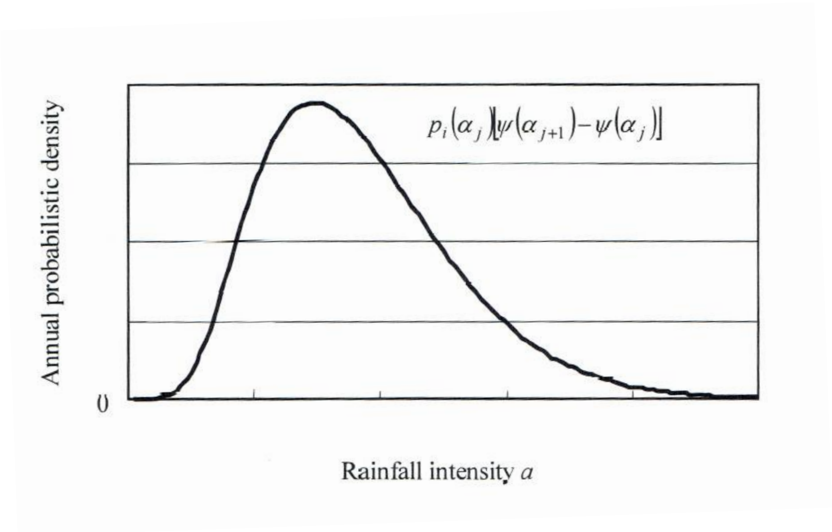


Figure 1-13 Distribution of annual probabilistic density

Here, $p_i(a_i)[\Psi(\alpha_{j+1})\text{-}\Psi(\alpha_j)]$ shown in eq.1.13 represents the annual probabilistic density, as shown in Figure 1.13.

However, the probability of failure alone cannot provide adequate information to help make a reasonable decision on slope stabilization priorities because a highly failure-prone slope may not necessarily cause a great loss to the public. So, to ensure an effective decision-making process, it is necessary to evaluate a slope risk that considers not only the probability of failure but also the loss incurred by such failure. According to the constant loss function, the annual risk is expressed as the product of loss (L) and annual probability of failure (p_a) as in:

$$R_a = p_a * L \tag{1.14}$$

1.3 Conclusion & Recommendation

The cause of disaster can occur in 2 types, first is natural hazard such as climate change, second is man-made hazard such as disorderly land use for economic development. The main issue that we can prevent is man-made hazard which occurred by human. The man-made hazard can have prevented by countermeasures such as dam or retaining wall etc. For the risk response we can separate into two types, first is risk control that we can reduce the risk probability from the hard countermeasures, second is risk transfer which divided the risk to others such as insurance which called soft countermeasures. Moreover, Broad categories of risk we defined to 2 types as well. First, subjective risk is the solution based on the experience from local people or elder people. Second, objective risk is the solution based on mathematics or model that using science to identify. For this course, event tree is used for makes a decision to construct the structure for prevention.

In this case, Thailand need more tools to make a decision to construct the structure. Because Thailand constructs a lot of structure for prevention and mitigation, the event tree is more useful in this case as well.

Chapter 2

Earthquake Disaster

Tectonic earthquakes occur anywhere in the earth where there is sufficient stored elastic strain energy to drive fracture propagation along a fault plane. The sides of a fault move past each other smoothly and a seismically only if there are no irregularities or asperities along the fault surface that increase the frictional resistance. Most fault surfaces do have such asperities and this leads to a form of stick-slip behavior. Once the fault has locked, continued relative motion between the plates leads to increasing stress and therefore, stored strain energy in the volume around the fault surface. This continues until the stress has risen sufficiently to break through the asperity, suddenly allowing sliding over the locked portion of the fault, releasing the stored energy.

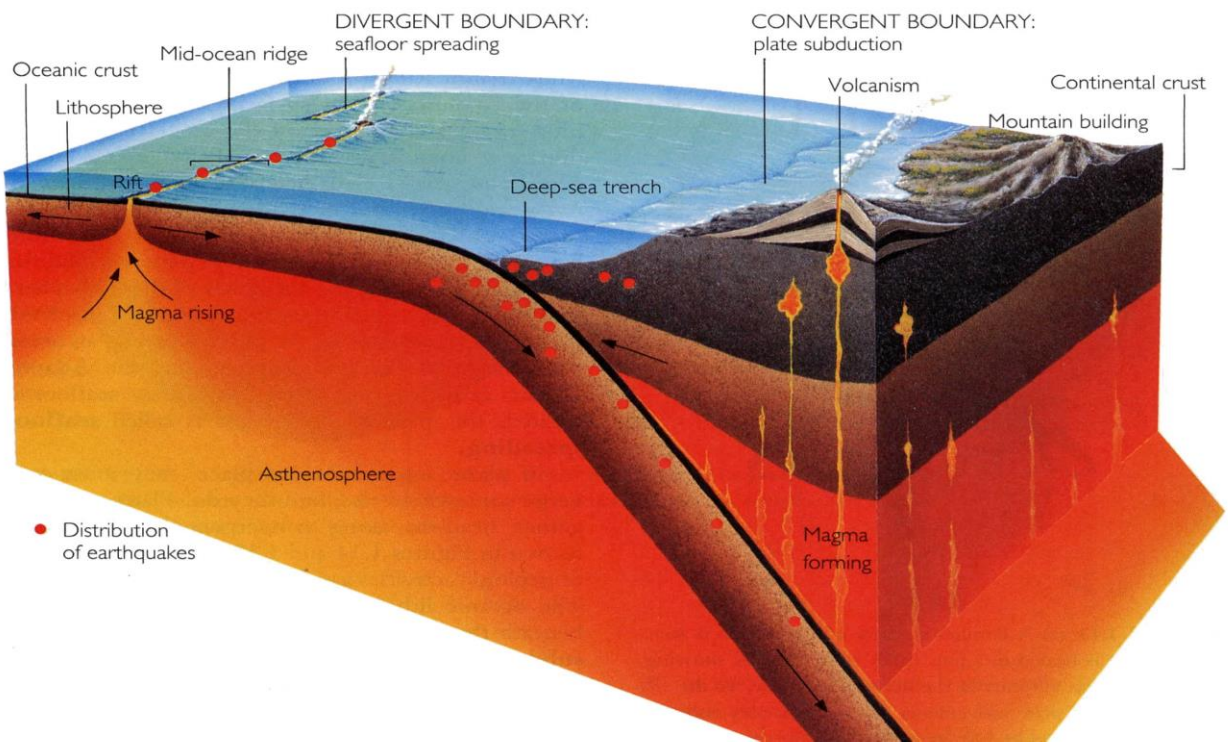


Figure 2-1 Tectonic earthquakes

2.1 Cases study

- **Haiti Earthquake (January 12, 2010)**

  M 7.0, focal depth 13 km Downtown Port au Prince, Death Toll > 200,000

Figure 2-2 Haiti Earthquake in 2010

- **Yogyakarta Earthquake (2006)**

  Magnitude = 6.2, Death Toll = 5,000

Figure 2-3 Yogyakarta Earthquake in 2006

As sound travels through the air or earthquake shaking travels through the ground, the waves lose energy. And so a band sounds louder close to the stage than further back and an earthquake feels stronger close to the fault than further away.

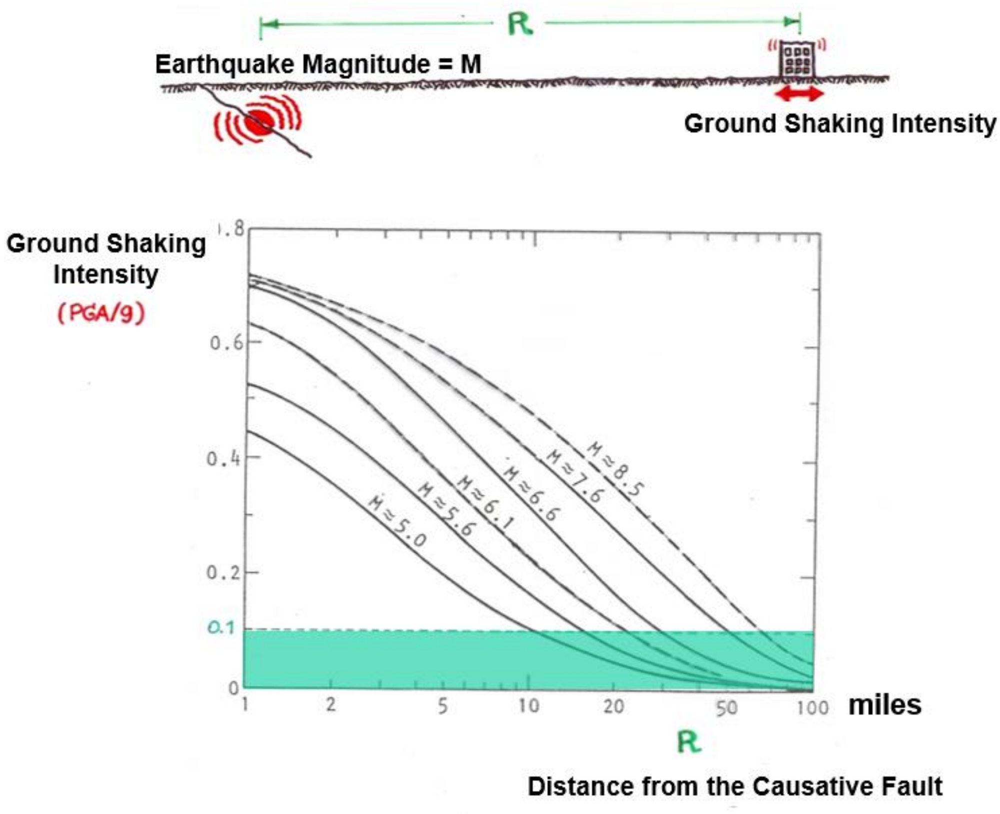


Figure 2-4 Relationship between ground shaking intensity and distance from the causative fault

2.2 Seismic Hazard Assessment

Seismic Hazard Analysis (SHA) has been widely used by engineers, regulators, and planners to mitigate earthquake losses:

- Specifying seismic design levels for individual structures and building codes
- Evaluating the seismic safety of existing facilities
- Planning for societal and economic emergencies (emergency preparedness)
- Setting priorities for the mitigation of seismic risk
- Insurance analysis

2.3 Effective Measures to Mitigate Earthquake Risk

2.3.1 Earthquake-resistant design of new buildings

- Earthquake-resistant design of new buildings
- Ineffective code enforcement
- Engineers are not familiar with seismic design
- Additional cost of construction

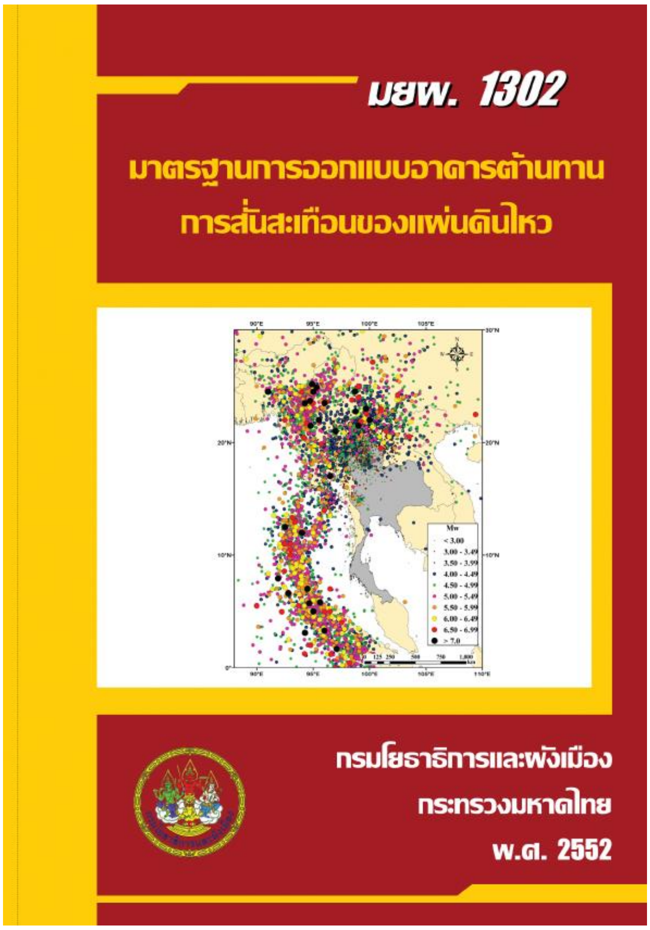


Figure 2-5 Standard code for seismic resisting building design

2.3.2 Seismic retrofitting of some existing vulnerable buildings

- Difficult to evaluate seismic resistance of existing buildings
- High cost
- Need more research to develop practical retrofit measures

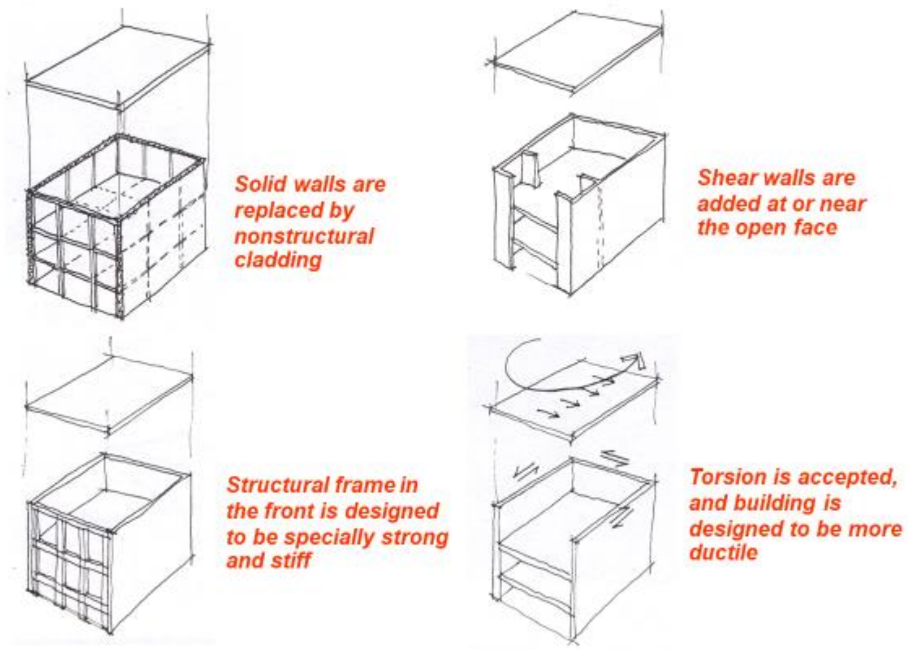


Figure 2-6 Seismic Performance Improvement Options

2.3.3 Develop emergency response plans

- Emergency medical services
- Temporary shelters
- Emergency water and power
- Planning for critical transportation outages

2.3.4 Organize emergency response exercises

2.3.5 Develop mitigation plans

- Identify elements at risks
- Strengthen existing buildings and structures
- Building code enforcement
- Land use planning

2.3.6 Develop recovery plans

- Housing recovery strategy
- Long-term economic recovery planning

2.4 Conclusion & Recommendation

The tectonic earthquakes occur in the place where is sufficient stored elastic strain energy to drive fracture propagation along a fault plane. The sides of a fault move past each other smoothly and a seismically only if there are no irregularities or asperities along the fault surface that increase the frictional resistance. Most fault surfaces do have such asperities and this leads to a form of stick-slip behavior. Once the fault has locked, continued relative motion between the plates leads to increasing stress and therefore, stored strain energy in the volume around the fault surface. This continues until the stress has risen sufficiently to break through the asperity, suddenly allowing sliding over the locked portion of the fault, releasing the stored energy.

Seismic Hazard Analysis (SHA) has been widely used by engineers, regulators, and planners to mitigate earthquake losses by specifying seismic design levels for individual structures and building codes, evaluating the seismic safety of existing facilities, planning for societal and economic emergencies (emergency preparedness), setting priorities for the mitigation of seismic risk and insurance analysis. Japan has some effective measures to mitigate earthquake risk which are earthquake-resistant design of new buildings, develop emergency response plans, organize emergency response exercises, develop mitigation plans and develop recovery plans.

For Thailand, we don’t have a lot of faults as Japan, but they still active. It’s mean that they can occur earthquake anytime. Therefore, we should prepare for prevent the damage from earthquake as well especially in the skyscrapers.

Chapter 3
Land Subsidence

Subsidence is the motion of a surface as it shifts downward relative to a datum such as sea level. The opposite of subsidence is uplift, which results in an increase in elevation. Ground subsidence is of concern to geologists, geotechnical engineers and surveyors.

3.1 Causes of land subsidence

- Natural consolidation of soil deposit
- Soil compaction from surface loading i.e. Landfills, building loads
- Drawdown of water pressure from ground water extraction
- Lowering of ground water table from other causes
- Shrinkage of shallow soils
- Collapse of by loading and wetting
- Underground mining and oil extraction
- Collapse of natural cavities

3.2 Land subsidence problems

Land subsidence problem cause in many cities such as Venice in Italy, Tokyo in Japan, Shanghai in China and Bangkok in Thailand.

In Japan, from the past Japan start to use deep well in 1920. After that there are some research reveal that land subsidence was caused by withdrawal of groundwater. Japanese government use law regulating groundwater for building and basic law for environment control.

In Bangkok, subsidence situation reached crisis level and still going on at present at small rate. It affected around 60 km by 50 km and the maximum accumulative magnitude of surface subsidence is 2 m over 70 years period.

3.2.1 Possible causes of Bangkok land subsidence

- Excessive ground water extraction
- Consolidation of shallow soft clay layer by overburden load or fill/surcharge loads

- Shrinkage of upper part of soft clay layer due to fluctuation of perched water table
- Lateral creep or flow of ground toward river channels.

From previous studies, monitoring of groundwater drawdown and land subsidence with hydraulic-consolidation analyses confirmed that Bangkok land subsidence was principally caused by excessive ground water pumping.

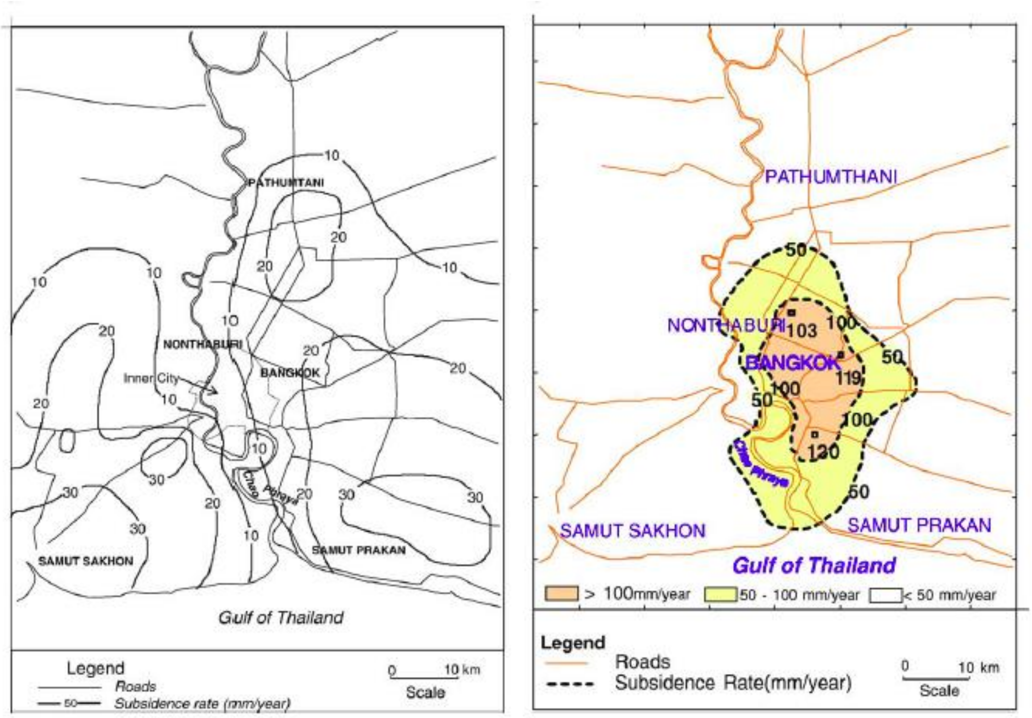


Figure 3-1 Contour line of land subsidence rate of Bangkok in 2002 and 1981

3.2.2 Reasons for uncontrolled situation in the past

- Insufficient tap water supply network
- Lack of town planning for manage city growth
- Cheaper cost of ground water fee than cost of tap water
- Need to allow economic boom of the city by scarifying control of groundwater use

3.2.3 Impacts from land subsidence

- Environment impacts
- Lowering of land surface
- Intensify flood risk
- Contamination of groundwater from sea water intrusion into aquifer layers

3.2.4 Impacts to foundation engineering practices

- Differential settlement/cracks of structures
- Increase in uplift pressure on underground structures from future rebound of ground water level
- Reduction in bearing capacity of pile foundation from future rebound

3.2.5 Effect of land subsidence

- Increase flood risk and deficiency of Bangkok flood protection system
- Differential settlement of building
- Negative skin friction
- Ground water rebound

3.2.6 Problems related to foundation engineering

- Differential settlements and building cracks
- Inefficiency of gravity drain systems
- Change in capacity of piles
- Change in uplift pressure on underground structures

Figure 3-2 Differential settlement building damage

3.3 Geohazard

3.3.1 Ground Subsidence

Subsidence is only possible where the ground material can be displaced into some sort of underground voids, which can only occur in certain rock types. Geohazard of potential subsidence can therefore be recognized largely by rock type on geological maps. All rocks do compact under load. Weak mudstone or sandstone can compact enough to cause settlement of structures, but normally well inside acceptable limits.

3.3.2 Ground improvement

Surcharge: consolidation accelerates under a few meters of placed fill, and almost stops when surcharge is removed, after 6 – 12 months, prior to construction.

Drainage: accelerates water expulsion, and therefore accelerates consolidation; may allow settlement beneath embankment to be completed during construction time. Sand of fibre drains spaced at 1 -3 m. are almost effective at depths < 15 m

Grouting: cannot penetrate clays; 10% cement mixed into clays of LL < 45 increases strength.

Liming: adding 5% lime creates stronger soil; reduces plasticity and shrinkage; stabilizes Montmorillonite by replacing sodium with calcium.

Vibro-compaction: densify sandy, non-cohesive soils with a crane-supported vibrating poker.

Vibro-replacement: feed crushed stone beside poker to create stable stone column in cohesive soil or fill.

Dynamic consolidation: drop 15 t block, 3 – 5 times, 20 m. from crane, at all points on 5 – 10 m. grid, to densify sandy soil, this may also fissure thin clay layers, and thereby accelerate drainage consolidation.

Ground freezing: expensive temporary stabilization of excavation, mainly of tunnels.

Geotextiles: increase shear strength, notably with coarser geogrids, but can only be installed in placed soils, not in undisturbed ground.

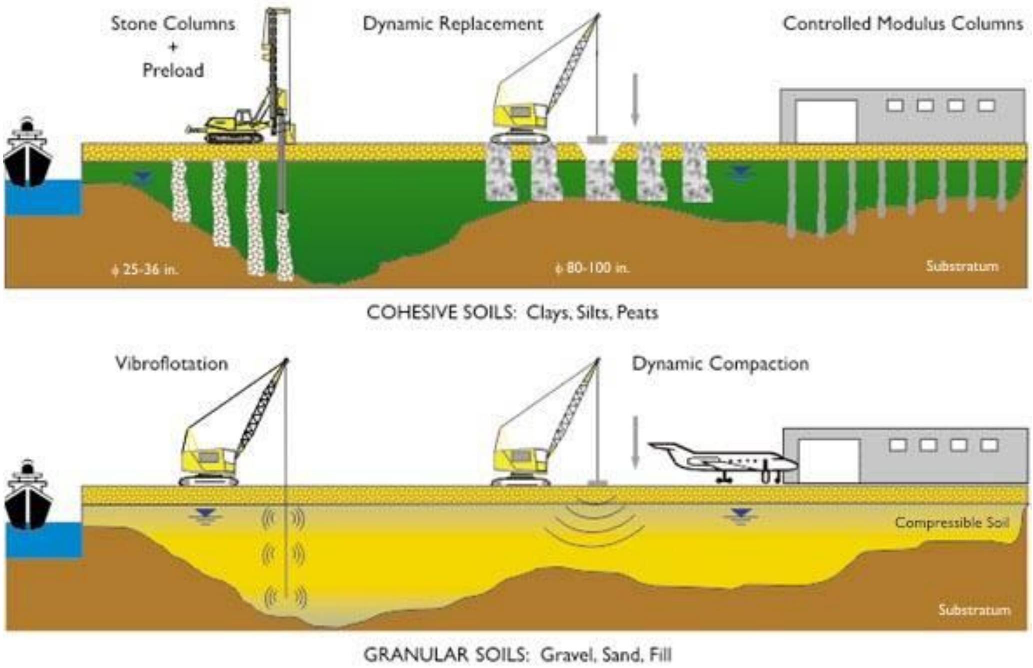
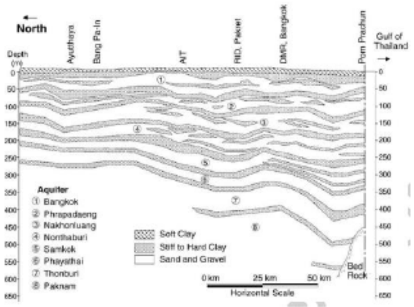


Figure 3-3 Ground improvement to prevent land subsidence

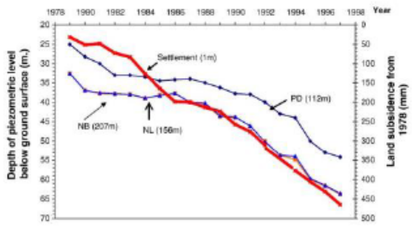
3.4 Land Subsidence in Bangkok

Land Subsidence in Bangkok - Causes

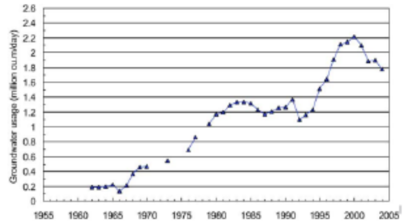


Schematic view of the aquifer system in the Bangkok Plain

- Bangkok is located in a flat low-liying plain area over a thick soft clay, and a system of aquifers.
- Soil subsidence has been being monitored since 1970´s, reaching values as high as 120 mm/year.
- Strong correlation has been found between the piezometric drawdown (mainly caused by an increase in groundwater pumping from the aquifer system) and the soil subsidence.

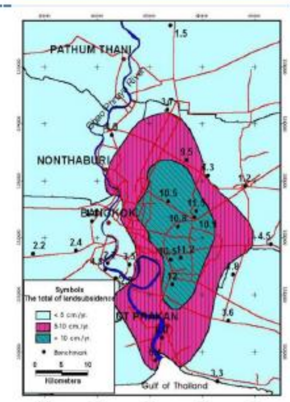


Ground subsidence and piezometric drawdowns of aquifers along the time

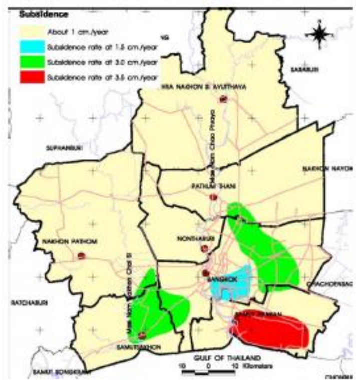


Groundwater pumping rate in the Bangkok Plain along the time

Land Subsidence in Bangkok - Causes



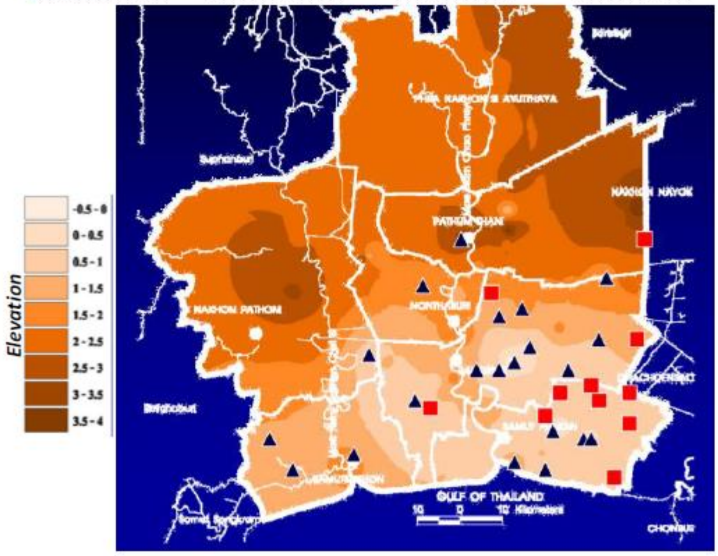
Land Subsidence in 1981, Bangkok



Land Subsidence in 1997, Bangkok

- During 1980´s to early 1990´s several measures were implemented to regulate and reduce groundwater use, which caused the reduction in the land subsidence rate in the Bangkok Metropolis.
- After 1993, during an economic growth, the city expanded rapidly into the outskirt areas where tap water were not available, and high water extraction was developed, leading to soil subsidence in the vicinity of the new wells.
- The above facts are the main cause of the spatial variability in the pumping rates in Bangkok.

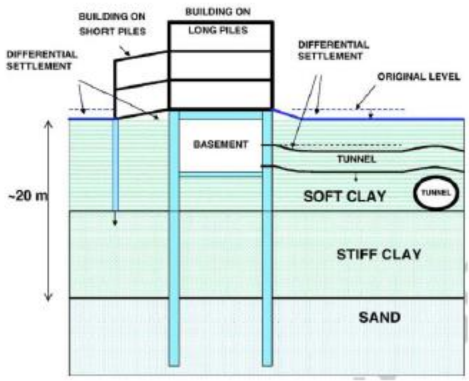
Land Subsidence in Bangkok - Consequences



Elevation Map – Bangkok 2005

The land subsidence process generated zones with elevations under the medium sea level; in these areas, permanent pumping systems are required to evacuate the water (accumulated by rainfall or other sources). Additionally, the overall subsidence increase the vulnerability against floods and sea water intrusion.

Land Subsidence in Bangkok - Consequences



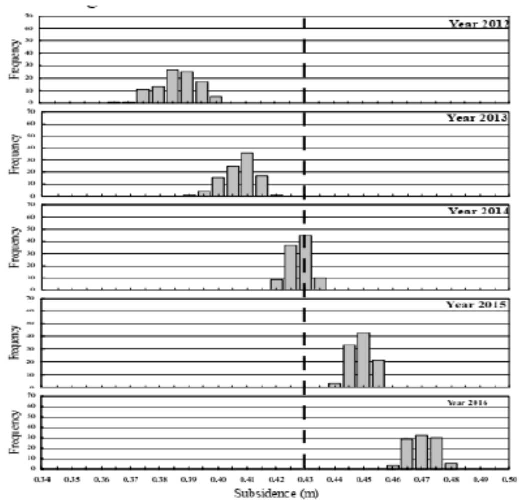
Damages induced by differential settlements induced by land subsidence, Bangkok

Schematic pattern of differential settlements caused by Land Subsidence, Bangkok

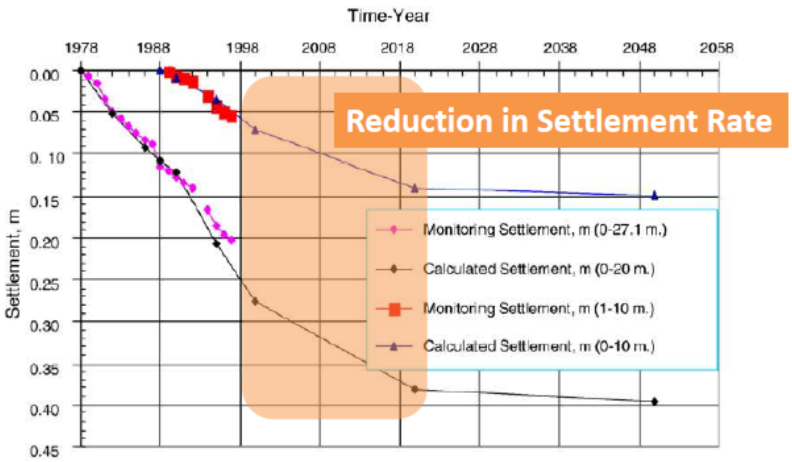
Differential settlement has been recorded, causing extensive damage to different types of structures. In many cases, the differential settlement is caused by differences in the foundation structures and the different settlement rate among the soil layers, causing extensive damage not only to surface infrastructure, but also underground facilities.

Land Subsidence in Bangkok during 2012-2016

It is important to mention that even when the soil subsidence rate has been reduced during the last decade, some researches and monitoring indicates that this process still may cause some problems



Land Subsidence in Bangkok – Applied Countermeasures



Comparison between predicted and measured time-rate differential settlements

What measures were done to reduce settlement rate?

Land Subsidence in Bangkok – Applied Countermeasures

The main cause of land subsidence is **Groundwater Extraction**
There are mainly two countermeasures

Imposition of Economic Measures

- Implementation of *GW* use charge
- Implementation of preservation charge
- Levying surcharges and penalizing violators of regulations

- Imposition of Economic Measures resulted in a considerable drop of *GW* use after 2001.

Development of technology especially infrastructure

3.5 Conclusion & Recommendation

This chapter is talking about Land Subsidence that it is a big problem in many countries even in Thailand. The professor who taught us many reasons that it may be caused of land subsidence such as heavy rainfall, ground water etc. And including damage of land subsidence when it occurs.

Figure 3-4 Land Subsidence

In my opinion, this knowledge is useful. Because in Bangkok has this problem as well. Therefore, we can solve in the right way to reduce rate or protect land subsidence in Bangkok.

Chapter 4
Landslide Disaster

A landslide, also known as a landslip or Mudslide is a form of mass wasting that includes a wide range of ground movements, such as rock falls, deep failure of slopes, and shallow debris flows. Although the action of gravity is the primary driving force for a landslide to occur, there are other contributing factors affecting the original slope stability.

4.1 Types of landslide

4.1.1 Man-made landslide

Slope failure and landslide are caused by cut or fill slope and disturb the slope balance by human.

Figure 4-1 Na Nai roadside landslide on October 25, 2007

4.1.2 Natural landslide

Natural landslide is the effect that soil and rock become foldable from excessive rainfall caused debris flow affected large area.

Figure 4-2 Landslide from heavy rainfall, Brazil

4.2 Physical factors affecting landslide

4.2.1 Static factors

- Geologic structure
- Slope angle and elevation
- Surface and groundwater
- Top soil characteristics
- Engineering soil properties
- Land use and land cover

4.2.2 Triggered factors

- Rainfall: The mechanism of rainfall are groundwater level rising and to increase degree of saturation or perch water table. After the water content of soil increasing, soil strength will decrease and cause landslide.
- Earthquake

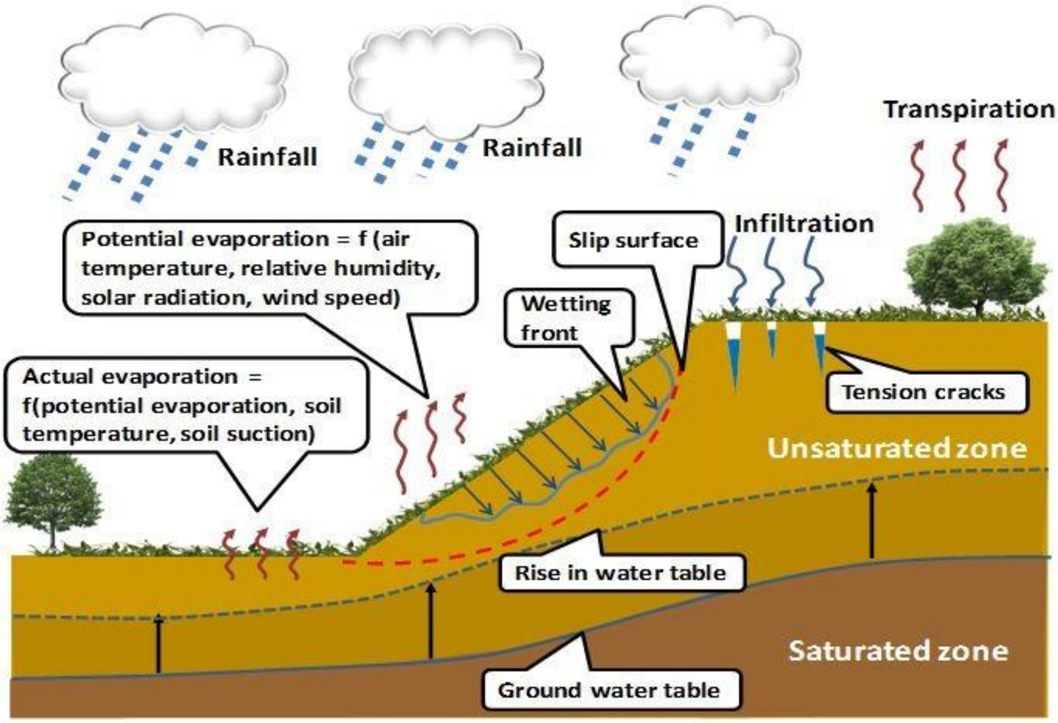


Figure 4-3 Landslide mechanism due to heavy rainfall

4.3 The countermeasures to landslide

1) Improve in engineering standard

2) Law enforcement

3) Zoning

4) Early warning system

5) Community based mitigation

6) Management schemes in VH and H hazard/risk zone

- Limitation of some construction
- Special attention in surface water drainage and land cover
- Special design standard
- Landslide impact assessment for new project
- Install instrument and warning sensors in potential failure area and install alarming system in risk area
- Protection structure from debris and landslide mass flow
- Educate PAR

7) Indirect warning

- Use measured rainfall data from rain gauge or predicted precipitation spatially
- Smaller area required high measuring rate
- Main drawback if no rain gauge in the landslide source area
- Warning criteria can be obtained from statistical or analytical method

8) Direct warning

- Suitable for limited and high consequence area or area of active landslide
- Requires details investigation
- Require criteria for each sensor or set of sensors

4.4 Measured parameters

- Surface movement of cracked ground
- Movement of deeper layers
- Pore water pressure, deep and shallow depth
- Moisture change in shallow depth
- Soil suction changes
- Water level increase in flow channel
- Ground vibration
- Movement of debris flow
- Increase of tension force in rock anchor

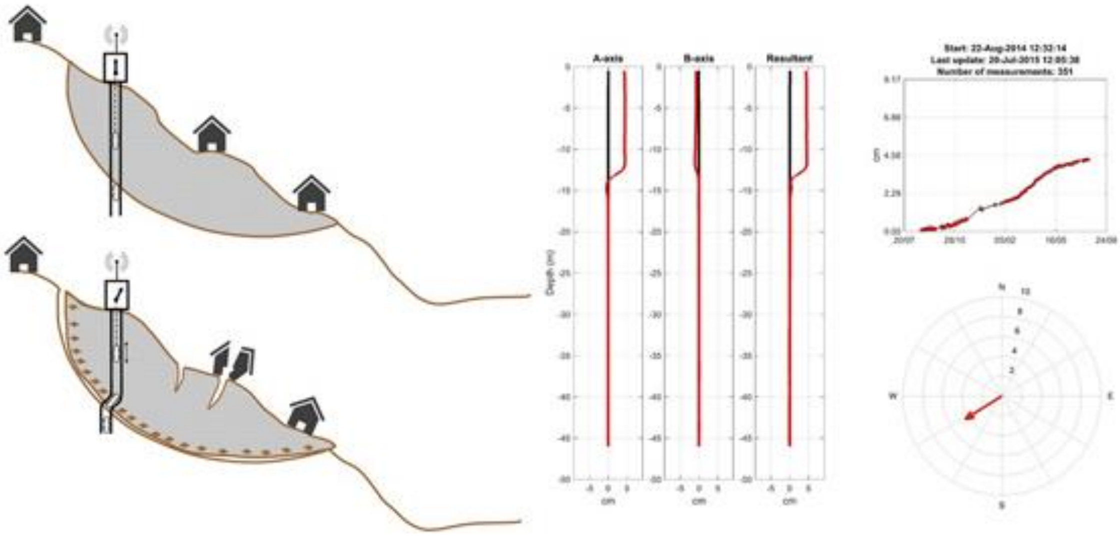


Figure 4-4 Ground displacement measurement with Inclinometer

Figure 4-5 Soil moisture measurement with piezometer

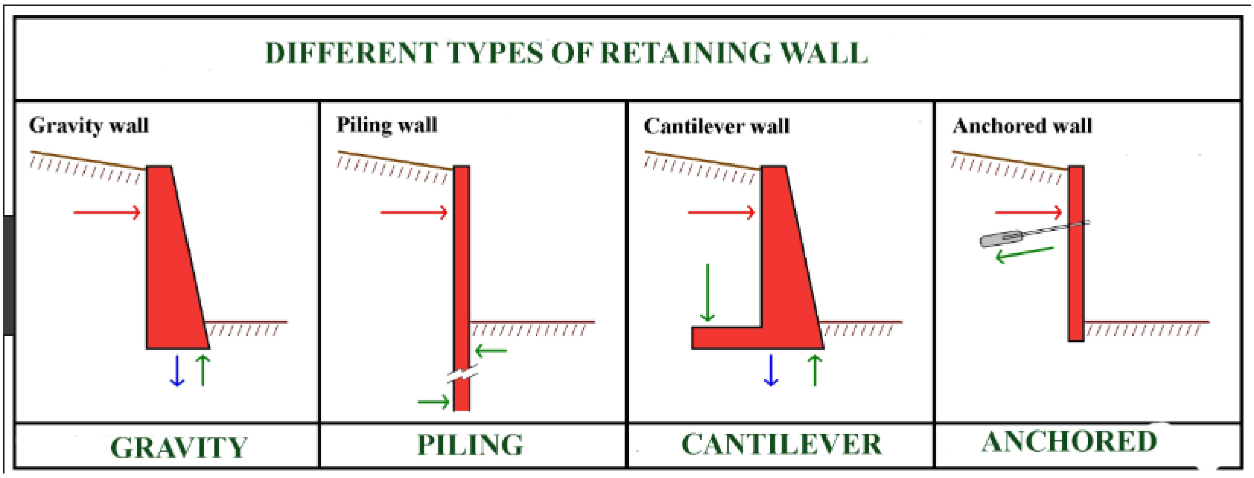


Figure 4-6 Some kinds of structure to prevent land slide.

Figure 4-7 Some kinds of structure to prevent land slide.(for construction)

4.5 Conclusion & Recommendation

This chapter is taking about a landslide, also known as a landslip or Mudslide is a form of mass wasting that includes a wide range of ground movements, such as rock falls, deep failure of slopes, and shallow debris flows. The professor taught many case in Thailand and outside Thailand and the reasons that may be cause land slide for example by Man-made and by natural. And then taught about how we can prevent or prepare from landslide disaster.

Figure 4-8 Landslide at Nan province, Thailand

In my opinion, this knowledge is useful. Because landslide disaster when it collapses. It will made heavy damage that sometime people die in suddenly. The way to protect that we had learnt from RSDC program may can help us or prevent from landslide disaster.

Chapter 5
Flooding

5.1 Thailand Floods 2011

Severe flooding occurred during the 2011 monsoon season in Thailand. The flooding began at the end of July triggered by the landfall of Tropical Storm Nock-ten. These floods soon spread through the provinces of northern, northeastern, and central Thailand along the Mekong and Chao Phraya river basins.

The World Bank has estimated 1,425 trillion baht (US$46.5 billion) in economic damages and losses due to flooding, as of 1 December 2011. Most of this was due to the manufacturing industry, as seven major industrial estates were inundated in water as much 3 meters (10 feet) deep during the floods. Disruptions to manufacturing supply chains affected regional automobile production and caused a global shortage of hard disk drives which lasted throughout 2012.

The World Bank's estimate for this disaster means it ranks as the world's fourth costliest disaster as of 2011 surpassed only by the 2011 earthquake and tsunami in Japan, 1995 Kobe earthquake, and Hurricane Katrina in 2005.

Figure 5-1 Thailand Floods in 2011

5.1.1 Causes of 2011 flood

- Rainfall pattern and volume: Heavy/continuous rainfalls (40% higher in the North and 22% higher in the Central region)
    - Haima: 26 June, accumulative rainfall > 100 mm
    - Nock-ten: 30 July – 1 August, accumulative rainfall > 150 mm
    - Haitang: 26-28 September, accumulative rainfall > 180 mm
    - Nesat: 2-3 October, accumulative rainfall > 120 mm
    - Nalgae: 6-7 October, accumulative rainfall > 100 mm
    - Monsoon Trough: 10-12, 15-19 August and 8-12 September

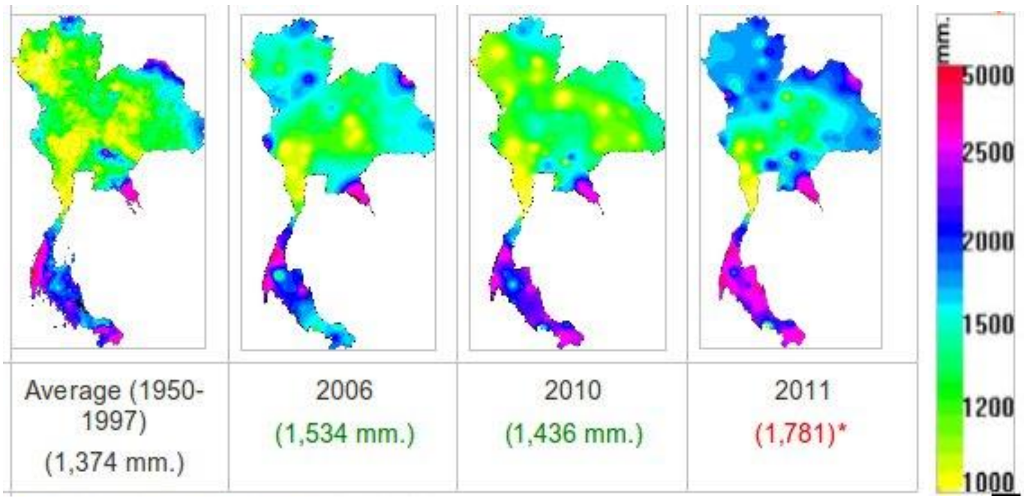


Figure 5-2 Accumulative rainfall in Thailand on 1 January – 30 November, 2011

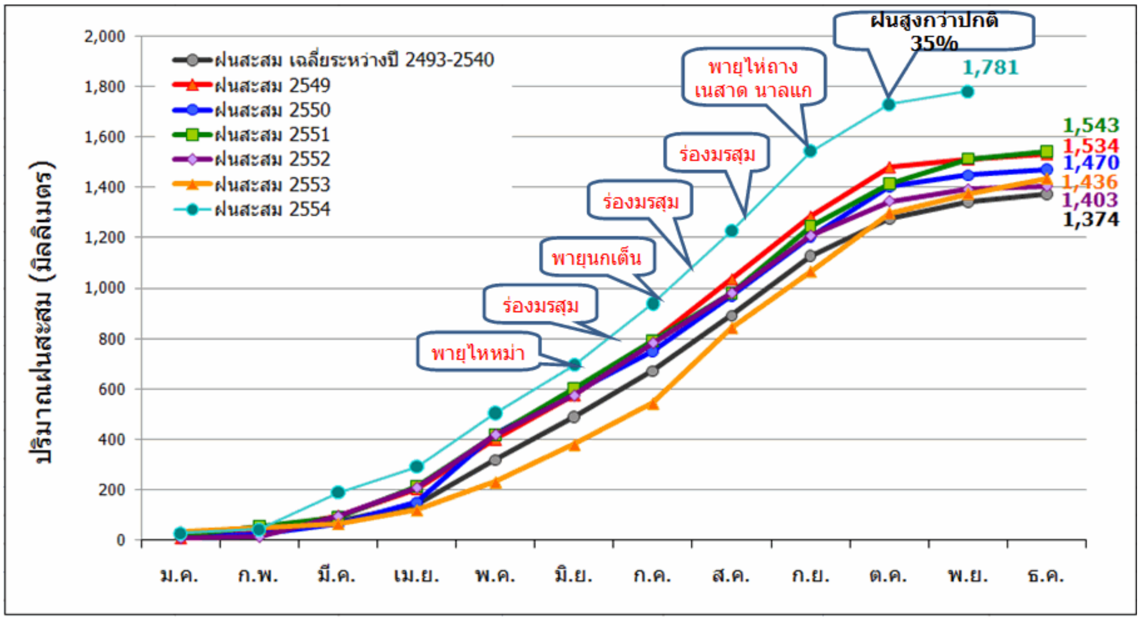


Figure 5-3 Accumulative rainfall in Thailand, 2011

- Water management for irrigation
- Failures of main structures: Bangchomsri flood gate, Singburi Province

Figure 5-4 Bangchomsri flood gate, Singburi (14 September 2011)

- Ineffective flood warning system
- Unsystematic rescue and communication system

5.1.2 Prevention and Mitigation Principles

1) Short term planning

- Make use of existing structures with the consideration of local characteristics in each area
- Enhance storage and drainage capacity
- Prevent flood in community and economic zones
- Supportive measures (facility, recovery, data/warning, volunteer) to reduce loss
- Flood warning system and single command

2) Long term planning

- Upstream plan (reforestation and reservoir)
- Midstream plan (floodplain management)
- Downstream plan (management of land use and development, floodway)
- Administration (organization, compensation regulations, data base, prediction and warning)
  - Decision Support System (DSS): A decision support system allows decision-makers to combine personal judgment with computer output, in a user-machine interface, to produce meaningful information for support in a decision-making process. Such systems are capable of assisting in solution of all problems (structured, semi-structured, and unstructured) using all information available on request. They use quantitative models and database elements for problem solving. They are an integral part of the decision-maker's approach to problem identification and solution. The purpose of DSS is not to replace humans but to support decision-makers in making informed choices. In the end, the time and the steps necessary to find a satisfactory solution to a problem are essentially shortened.

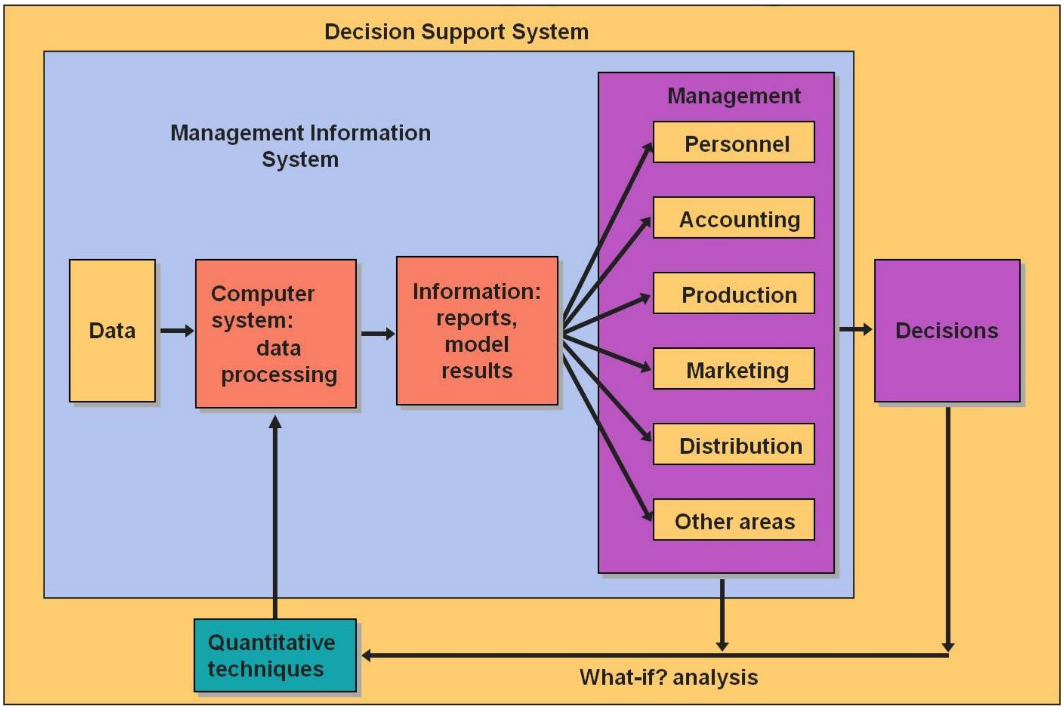
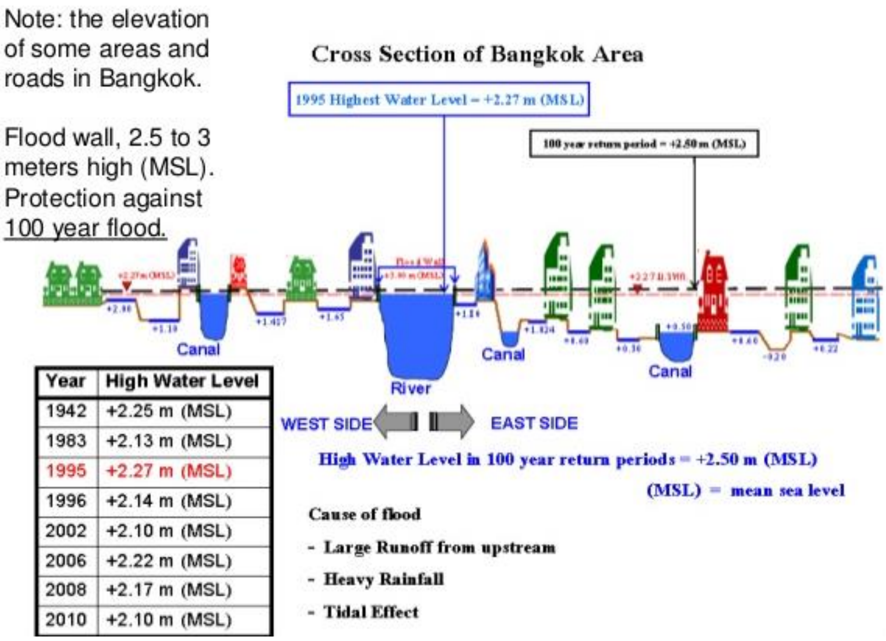


Figure 5-5 Decision support system

- Social aspect (understanding, acceptance and participation)

5.2 Flood Mitigation and Management in Bangkok Metropolitan Area



Year	High Water Level
1942	+2.25 m (MSL)
1983	+2.13 m (MSL)
1995	+2.27 m (MSL)
1996	+2.14 m (MSL)
2002	+2.10 m (MSL)
2006	+2.22 m (MSL)
2008	+2.17 m (MSL)
2010	+2.10 m (MSL)

Figure 5-6 Bangkok cross section

5.2.1 Causes of flooding in Bangkok

- Heavy rainfall intensity (local flood)
- Overflow from river bank due to high discharge from the northern part
  - During the rainy season most of the exceed discharge from the northern part of Bangkok flow to the Chao Phraya River which can receive the average flow without causing overflow of 2,500-3,000 cubic meter per second. Any runoff exceed from these will raise the water level more than +2.00 m. (MSL) which overtop the river bank where ground elevation are low.
- Effect of high tides from the sea
  - The Chao Phraya River is strongly influenced by the tides from the Gulf of Thailand especially at the lower part between 25-56 km. from the mouth of the river. The highest tides occur in October to December of each year which can inundate some low area especially the combination of heavy rainfall and the high discharge from the north which cause severe flood in Bangkok area.
- Land subsidence
  - Pumping of groundwater is one of the main cause for land subsidence. The subsidence rate was so high as 10 cm per year in the eastern suburban of Bangkok during the past decade. Metropolitan Waterworks Authority (MWA) stopped the groundwater pumping for water supply since 1986. From observed data, the average land subsidence rate in BMA has gradually reduced from 10 cm per year to 1-2 cm per year from 1978-2007, in the last 5 year (2003-2007) the average land subsidence rate as reduced to 0.97 cm per year.
- Low efficiency of drainage system

5.2.2 Flood Protection Measures

- Structural measures
  - Polder system

    To prevent overtop the riverbank and overland flow from surrounding area consist of dikes, pumping station, and control gate.

- Dikes

  Dike on the eastern Bangkok which initiated by the King in 1980 call King's dike. It was constructed 72 km from the north through the south to prevent overland flow from the eastern floodplain in to the city.

- Pumping stations

  To increase the drainage capacity pumping stations have been designed and allocated at the mouth of the canals along the Chao Phraya River to alleviate the internal flood from the storm water inside the polder area which total capacity 1,638 cms.

- Drainage tunnels and pipes

  BMA has implemented the drainage tunnels in case of where the drainage system are insufficient. The tunnels will drain the exceed storm water through the tunnels lying 15-22 m. underground surface and pump out to the river by high capacity pumps. Now there are 7 drainage tunnels which 19 km long and 155 cms. Of pumping capacity.

- Canal improvement

  Storm water runoff is normally drain to the canals and then to the Chao Phraya River. There are 1,655 canals which total length 2,600 km. The width of the canals from a meters to 50 meters. The drainage capacity of the canal are decreasing, some have been filled up and the width is reduced by illegal intrusion. To improve the canals by dredging the depth between 1-3 m, and also to construct the concrete retaining walls along both banks.

- Retention area

  Where the drainage capacity of the canals is too small to bring the storm water runoff to the pumping station, and some areas are low and no retention area is available. BMA has provided 25 retention ponds total storage capacity 12.88 Mm^3 to keep storage volume for early rainfall detention in order to decrease peak runoff during rain.

- Flood control center

  Flood control center was established in 1990, which utilize computer technology for systematic and management of operation of flood protection. The center is comprised of one master station which is located in DDS office and 69 remote terminal units (SCADA) scattered around Bangkok. The center has basic functions in monitoring and collect of hydrological data (rainfall and water level), facilities operation conditions, flood damage situation and water quality data by using an online system. The various data are processing and transmit to facilities operators and flood fighting team.

- Non-structural measures
  - Flood fighting

    The flood fighting work is a regular work of the department. The activities will be fully effectively during the emergency condition. The preparation start from the beginning of the year until the end of the rainy season.

  - Land use control

    The engineering measures are very expensive and flood is a natural phenomenon. Flood damage can be avoided by comprehensive land use planning. BMA has implemented Bangkok Land Use Comprehensive Plan and Regulation in 2006. The plan was mention proper zoning of the land according to flood risk. The green area was designed to preserve for the storm water retention function.

  - Public information and education

    Set up the public relation program for flood forecasting and warning system by coordination: Meteorological Department, streamflow forecasting by Royal Irrigation Department (RID), and forecasting and telemetering system of Electricity Generating Authority of Thailand (EGAT). Establish a permanent flood marks and flood warning board to inform the people about the affected areas and flood protection schemes.

5.3 Thailand flooding

Tropical Storm Sonca

Track map of Tropical Storm Sonca of the 2017 Pacific typhoon season in Figure 1. The background image is from NASA. Tracking data is from NOAA. The points show the location of the storm at 6-hour intervals. The color represents the storm's maximum sustained wind speeds as classified in the Saffir–Simpson scale, and the shape of the data points represent the nature of the storm. Saffir–Simpson scale Tropical depression have maximum sustained winds less than or equal to 62 km/h. Tropical storm have maximum sustained winds between 63 to 118 km/h.

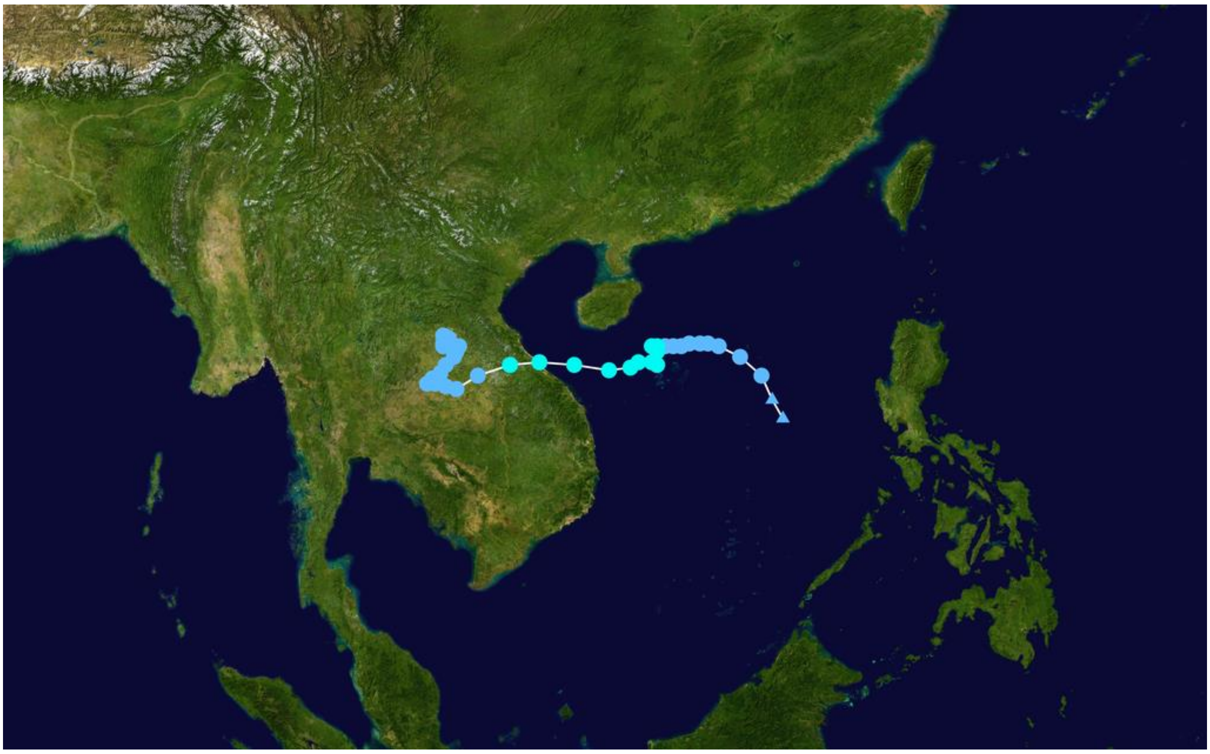


Figure 5-7 Map plotting the track and intensity of the storm, according to the Saffir–Simpson scale

On July 21, both the JMA and the JTWC reported that Tropical Depression 08W had developed approximately 582 km to the south of Hong Kong. After moving westward for a couple of days, the system strengthened into a tropical storm by both agencies while nearing the island province of Hainan, receiving the name *Sonca*. By July 24, Sonca reached its maximum intensity with a minimum pressure of 994 hPa. Early on July 25, the JTWC issued its final advisory as the system made landfall over in Quảng Trị Province, Vietnam.

Flash floods across Thailand killed 23 people and affected 44 out of 76 provinces in Thailand. The hardest hit province was Sakon Nakhon as shown in Figure 2, Northeast Thailand as the storm forced the closer of Sakon Nakhon Airport lasting for 3 days. Damages in Sakon Nakhon exceeded 100 million baht (US$3 million).

Figure 5-8 Sakon Nakhon province flood in 2017

Flood in Sakon Nakhon province

1) Cause

- Heavy rainfall: Storm Sonca
- Drainage system: Nong Han Lagoon is a large natural lagoon. The capacity of this lagoon is 266 million cubic meters. It receives water from Phu Phan Mountain and surrounding area. The water from Nong Han Lagoon will flow into the Mekong River. It can drainage water 15 million cubic meters per day. The water level in Nong Han Lagoon is high during the tropical storm Sonca, it will effect to drainage system at Sakon Nakhon province as shown in Figure 3.
- Development and Urban planning: When the city is developed, some river disappear because people build road and it disturbs the river as an obstruction as shown in Figure 4. The effective of drainage system will be decreased.
- Dam failure: Huai Sai Kamin Dam failure.

5.4 Conclusion & Recommendation

Flooding may occur as an overflow of water from water bodies, such as a river, lake, or ocean, in which the water overtops or breaks levees, resulting in some of that water escaping its usual boundaries, or it may occur due to an accumulation of rainwater on saturated ground in an areal flood. While the size of a lake or other body of water will vary with seasonal changes in precipitation and snow melt, these changes in size are unlikely to be considered significant unless they flood property or drown domestic animals. Floods can also occur in rivers when the flow rate exceeds the capacity of the river channel, particularly at bends or meanders in the waterway. Floods often cause damage to homes and businesses if they are in the natural flood plains of rivers. While riverine flood damage can be eliminated by moving away from rivers and other bodies of water, people have traditionally lived and worked by rivers because the land is usually flat and fertile and because rivers provide easy travel and access to commerce and industry.

The floods in Thailand especially on 2011, it occurs uncontrol cause of rainfall pattern and the number of typhoons that coming in the country. This disaster is the main disaster in Thailand which we need to consider more than the other disasters. The 2P2R method have to use in Thailand especially preparedness for floods. Moreover, The decision support system

(DDS) need to improve the efficiency in order to use in the country and making a better way to resilience society in Thailand.

Chapter 6
Site Visit (Ayutthaya Province)

6.1 Asian Institute of Technology

6.1.1 The Regional Integrated Multi-Hazard Early Warning System

The Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) is an international and intergovernmental institution, owned and managed by its Member States, for the generation and application of early warning information. RIMES evolved from the efforts of countries in Africa and Asia, in the aftermath of the 2004 Indian Ocean tsunami, to establish a regional early warning system within a multi-hazard framework for the generation and communication of early warning information, and capacity building for preparedness and response to trans-boundary hazards. RIMES was established on 30 April 2009, and was registered with the United Nations on 1 July 2009. RIMES operates from its regional early warning center located at the campus of the Asian Institute of Technology in Pathumthani, Thailand.

Aim: RIMES provides regional early warning services and builds capacity of its Member States in the end-to-end early warning of tsunami and hydro-meteorological hazards.

Mission: Building capacity and providing actionable warning information towards forearmed, forewarned and resilient communities.

12 Member States: Bangladesh, Cambodia, Comoros, India, Lao PDR, Maldives, Mongolia, Papua New Guinea, Philippines, Seychelles, Sri Lanka and Timor-Leste.

19 Collaborating Countries: Afghanistan, Armenia, Bhutan, China, Indonesia, Kenya, Madagascar, Mauritius, Mozambique, Myanmar, Nepal, Pakistan, Russian Federation, Somalia, Tanzania, Thailand, Uzbekistan, Vietnam, and Yemen.

RIMES was registered with the United Nations under Article 102 on 1 July 2009, and has been supported since inception by UNESCAP and DANIDA.

RIMES address both high-impact, low-frequency hazards, such as tsunamis, as well as low-impact, but high-frequency hazards, such as extreme weather events, for the optimum use of its technological facilities, while giving Member States a wider range of decision-support information.

Member States financially support RIMES operations, at a cost much lower than that required for establishing individual early warning systems for high-impact, low-frequency hazards. RIMES integrates risk information at different time scales to meet early warning information needs of diverse users. RIMES provides an interface between global centers of excellence and national and local level institutions to bring the best of science and practices for enhanced performance of early warning systems RIMES acts as a test-bed for identifying promising new and emerging technologies and research products, and pilot testing and making these operational through demonstration of tangible benefits.

The Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) is an international and intergovernmental institution, owned and managed by its Member States, for the generation and application of early warning information. RIMES evolved from the efforts of countries in Africa and Asia, in the aftermath of the 2004 Indian Ocean tsunami, to establish a regional early warning system within a multi-hazard framework for the generation and communication of early warning information, and capacity building for preparedness and response to trans-boundary hazards. RIMES was established on 30 April 2009, and was registered with the United Nations on 1 July 2009. RIMES operates from its regional early warning center located at the campus of the Asian Institute of Technology in Pathumthani, Thailand.

6.1.2 Heritage Structure

The heritage structures are very complex for retaining because they are very old and deteriorate. Therefore, we have to study by using 3D printing to create the model and test by physical model in many case. In this case we learn about how to treat Wat Chaiwatthanaram.

6.2 Wat Chaiwatthanaram

Wat Chaiwatthanaram is a Buddhist temple in the city of Ayutthaya Historical Park, Thailand, on the west bank of the Chao Phraya River, outside Ayutthaya Island. It is one of Ayutthaya's best known temples and a major tourist attraction. Wat Chaiwatthanaram lies on the west bank of Chao Phraya River, south west of the old city of Ayutthaya. It is a large compound part of Ayutthaya Historical Park; however not a part of Historic City of Ayutthaya, a UNESCO World Heritage Site.

Figure 6-1 Wat Chaiwatthanaram

6.2.1 Cause

In 2011, Thailand witnessed its worst flooding in half a century, leaving severe impairments to the country's economy, industrial sector, and society. Factors that contributed to flood crisis range from natural to manmade. Consequently, floodwaters inundated 90 billion square kilometers of land, more than two-thirds of the country, ranking the natural disaster as the world's fourth costliest disaster as of 2011. The flood crisis impacted a total of 4,039,459 households and 13,425,869 people; 2,329 houses were completely destroyed, while 96,833 houses were partially damaged; death toll reached to 657 people and 3 were reported missing. As of December 2011, Word Bank estimated damages to have reached THB 1,440 billion. Because of the major effects on the industrial sector, unemployment has stemmed due to the closure of multiple factories. Moreover, the UNESCO World Heritage site, Wat Chaiwatthanaram and surrounding historical buildings including an ancient fortress, were hit by floods after an embankment collapsed in Ayutthaya town. The temple lies on the west bank of Chao Phraya River in Ayutthaya and has been threatened by floods and heavy rains for months, but the temporary mud and sand bag barriers, some three meters high, collapsed under the weight and power of the river in full flood.

Figure 6-2 the 2011 Thailand flood

6.2.2 Prevention

The new model is a result of last year's research on the severe flood that hit Ayutthaya in 2011. The model created by UNESCO Bangkok, in cooperation with the Fine Arts Department, Bangkok Office, the UNESCO Institute for Water Education, the Asian Institute of Technology, the Hydro and Agro Informatics Institute and the Asian Development Bank was unveiled in Ayutthaya. The temporary floodwall was built with 3 meters height and 220 meters width along the Chao Phraya River. The floodwall will be set up in rainy season and fold in dry season.

Figure 6-3 Floodwall along the Chao Phraya River at Wat Chaiwatthanaram

Figure 6-4 RSDC Members

6.3 Conclusion & Recommendation

This field trip, we went to 2 places consist of Asian Institute of Technology and Wat Chaiwatthanaram. In Asian Institute of Technology, we went to study in 2 places which are The Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) and heritage structure presentation. RIMES is an international and intergovernmental institution, owned and managed by its Member States, for the generation and application of early warning information. We learn how to establish a regional early warning system within a multi-hazard framework for the generation and communication of early warning information, and capacity building for preparedness and response to trans-boundary hazards.

Wat Chaiwatthanaram is a Buddhist temple in the city of Ayutthaya Historical Park, Thailand, on the west bank of the Chao Phraya River, outside Ayutthaya Island. Wat Chaiwatthanaram lies on the west bank of Chao Phraya River, south west of the old city of Ayutthaya. In 2011, Wat Chaiwatthanaram and surrounding historical buildings including an ancient fortress, were hit by floods after an embankment collapsed in Ayutthaya town. Therefore, the temporary floodwall was built with 3 meters height and 220 meters width along the Chao Phraya River. The floodwall will be set up in rainy season and fold in dry season.

Chapter 7
Site Visit (Samut Prakan Province & Chachoengsao Province)

7.1 National Disaster Warning Center

The unstable of global weather condition has increased its frequent intensely trend of disaster. Thus, early warning system is considered as an important mechanism to prevent and reduce the effects of disaster, so all relevant agencies must well performed to collaborate and coordinate their own functions for disaster prevention. Therefore, people who reside in risk prone areas are able to access to early warning messages and they can prepare themselves before disaster occur.

According to the Reorganization of Ministry, Sub Ministry and Department Act (No.17), B.E. 2559, the National Disaster Warning Center, Office of the Permanent Secretary, Ministry of Information and Communication Technology has been transferred to Department of Disaster Prevention and Mitigation and it has effective since 16 September 2016. The merging between two organizations will enhance and unify a national warning system efficiently and upgrade early warning system to international standard in all dimensions as the followings;

Increasing Effective Early Warning System: It will cover all the tracking weather monitoring condition as well as the forecasting trend of disaster and provide warning message dissemination. As a result, all agencies concerned will have proper guideline and procedure for disaster preparedness according to disaster risk and its severity.

Proactive multi agencies early warning cooperation: It will create the integration of early warning system from the policy maker under the unified command system and also the integration of operation level for disaster preparedness in its area.

Unified Early Warning Dissemination Network: It will enhance the integration, exchange data and early warning messages to support the commanders at all level to have sufficient information to prepare effectiveness disaster management plan and make the proper decision.

Providing Accurate Early Warning Messages and Reliable data: The integrated tool, equipment and technology between two organizations are significant means to monitor and forecast disaster trend included the linkage of volunteer networks to monitor weather condition and observe the unnatural situation at their area level could designate disaster event, risk prone area, trend and the ending of disaster accurately.

Increasing Early Warning Data and Messages Accessibility to the Public: In accordance to the development of Early Warning System and incorporatethe role and responsibilityof early warning dissemination between DDPM and National Early Warning Center, it will increase the public accessibility of early warning messages in risk prone areas rapidly and improve people's capacities to promptly prepare for disaster in advance.

In conclusion, the transferable early warning system mission from National Early Warning Center to Department of Disaster Prevention and Mitigation, Ministry of Interior Is provided and upgraded the national early warning system functionally and systematically under the unified system. Besides, it is enhanced the early warning system to international standard and complied with National Disaster Prevention and Mitigation Plan 2015 which is recognized an important of early warning system to the people in risk prone area. In addition, it is considered as a crucial mechanism of the national agenda "Safety Thailand" to disaster resilient.

Figure 7-1 RSDC Member

7.2 Chollaharn Pijit Operation and Maintenance Project

(Drainage Project for Survarnabhumi Airport)

This project is one of the Royal Development Projects of His Majesty the late King Bhumibol Adulyadej. The project is belonging to Royal Irrigation Department (RID). 4 units of 4.8MW pumps are designed to prevent water flood in new airport area, Suvarnabhumi Airport, along the canal to ocean. Suvarnabhumi Drainage Pumping Project Supply and Construction of 115/11kV, 20 MVA Substation Project. The substation is located at old Sukhumvit road 47th kilometers, Samutprakarn, Thailand. Due to, the airport area is low land in rainy season or when flood come. It is difficulty to discharge water. Thus, the project was created to solve problem.

Figure 7-2 Area of project.

Figure 7-3 Drainage structure

Figure 7-4 Presentation of project

Figure 7-5 RSDC member

7.3 Hong Thong Temple

Located at Samutparkan province, eastern side of Bangpoo Resort. This is a temple which used to locate on land, however, now it locates on the sea. Due to shoreline erosion, land around the temple was gone continuously. People try to protect temple by using coastal structure like breakwater, bamboo fence and grow mangrove (Figure 12). Because of those countermeasures rate of shoreline erosion was decrease.

Figure 7-6 Hong Thong Temple

Figure 7-7 Breakwater line

Figure 7-8 Satellite photograph in 2018

7.4 Conclusion and Recommendation

This field trip, we went to 3 places consist of National Disaster Warning Center, Chollaharn Pijit Operation and Maintenance Project and Hong Thong Temple. We learn about the warning system in Thailand especially about tsunami warning system. The transferable early warning system mission from National Early Warning Center to Department of Disaster Prevention and Mitigation, Ministry of Interior Is provided and upgraded the national early warning system functionally and systematically under the unified system.

Chollaharn Pijit Operation and Maintenance Project is one of the Royal Development Projects of His Majesty the late King Bhumibol Adulyadej. The project is belonging to Royal Irrigation Department (RID). 4 units of 4.8MW pumps are designed to prevent water flood in new airport area, Suvarnabhumi Airport, along the canal to ocean. Due to, the airport area is low land in rainy season or when flood come. It is difficulty to discharge water. Thus, the project was created to solve problem.

Hong Thong Temple located at Samutparkan province, eastern side of Bangpoo Resort. This is a temple which used to locate on land, however, now it locates on the sea. Due to shoreline erosion, land around the temple was gone continuously. People try to protect temple by using coastal structure like breakwater, bamboo fence and grow mangrove. Because of those countermeasures rate of shoreline erosion was decrease.

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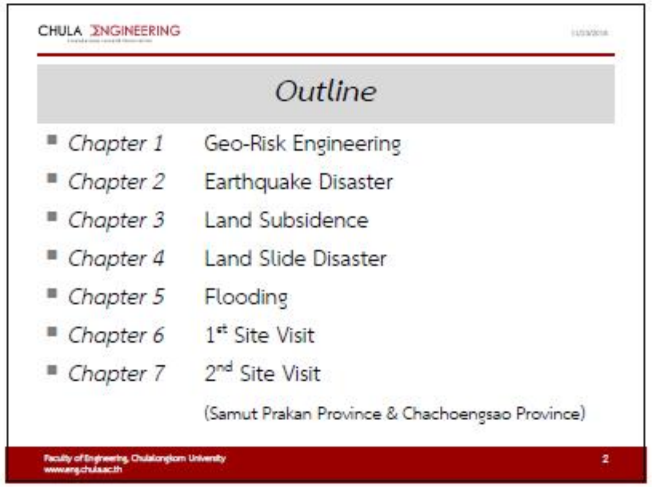
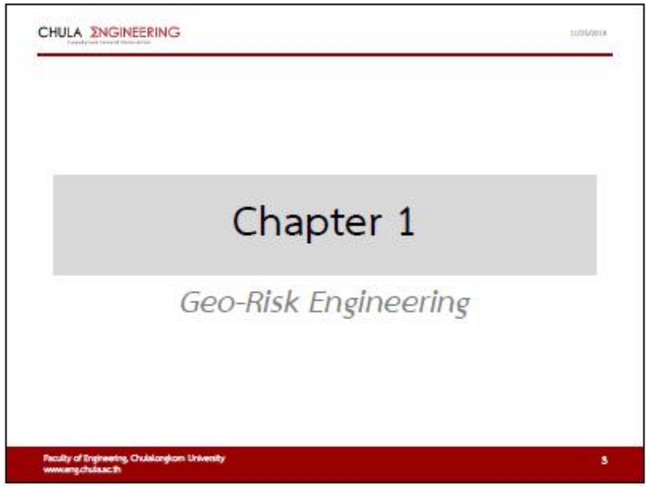
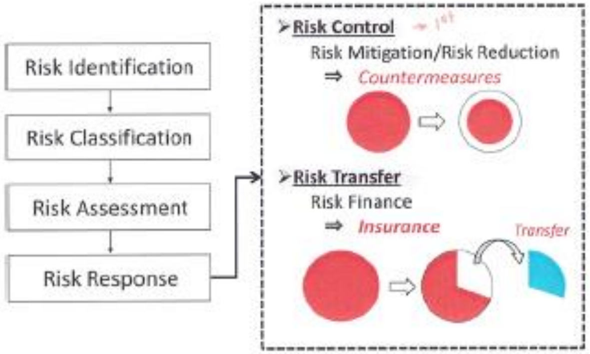




Flow of Risk Management



1.2 Broad categories of risk

- Subjective risk
  - Semi – quantitative indicator
  - Determined based on Personal experience and intuition (questionnaire surveys and brainstorming sessions)
- Objective risk
  - Quantitative indicator
  - Determined based on specific past data (mathematical or statistical or probability models)

Expected losses $R = \sum_{i=1}^{J} P_i C_i$

Design Based on a Certain Hazard level α

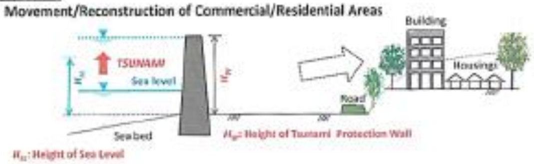
Risk Mitigation/Recovery/Restoration

Response 1

Establishment of Early Warning System for Evacuation

Response 2

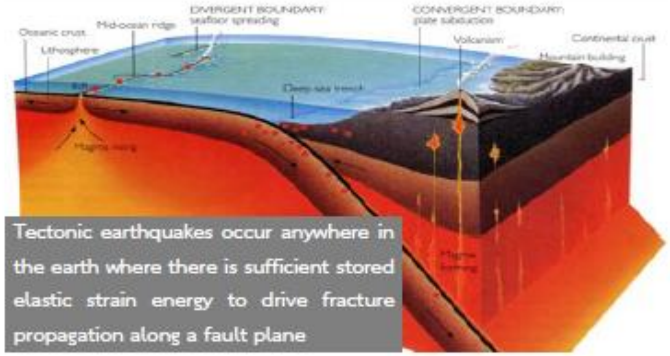
Movement/Reconstruction of Commercial/Residential Areas



Chapter 2

Earthquake Disaster

2.1 Earthquake disaster



Tectonic earthquakes occur anywhere in the earth where there is sufficient stored elastic strain energy to drive fracture propagation along a fault plane

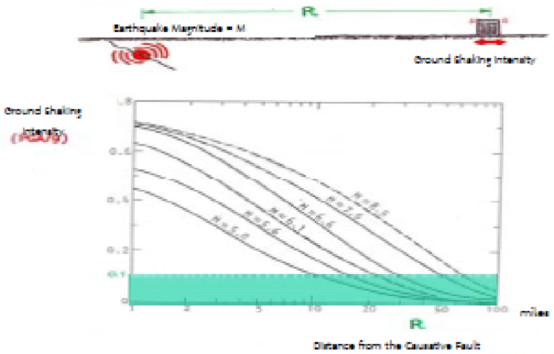
Yogyakarta Earthquake (2006)

Magnitude = 6.2
Death Toll = 5,000

Haiti Earthquake (Jan 12, 2010)

M 7.0, focal depth 13 km
Downtown Port au Prince
Death Toll > 200,000

2.2 EQ magnitude



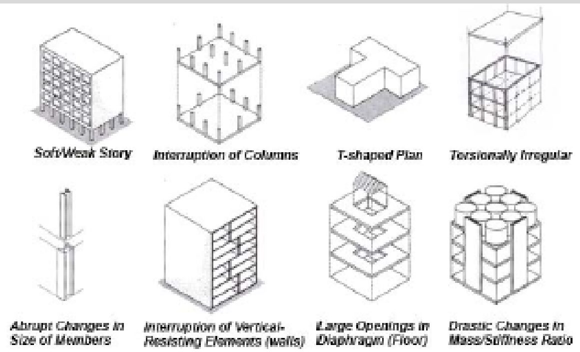
2.3 Seismic Hazard Assessment

- Specifying **seismic design** levels for individual structures and **building codes**
- **Evaluating** the seismic safety of **existing facilities**
- **Planning** for societal and economic **emergencies**
- **Setting priorities** for the mitigation of seismic risk
- **Insurance** analysis

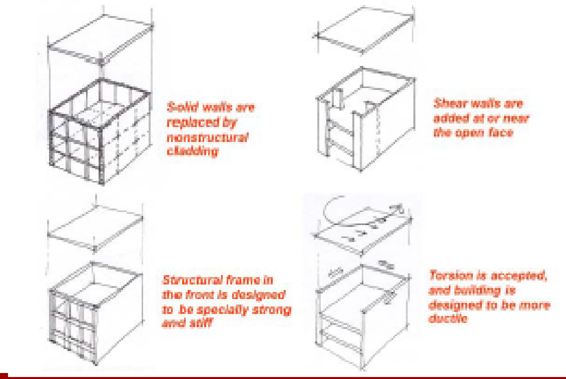
2.4 Effective Measures to Mitigate Earthquake Risk

- Earthquake-resistant design of new buildings
- Seismic retrofitting of some existing vulnerable buildings
- Post-Earthquake Emergency Response

2.5 Avoidance of Configuration Irregularity



2.6 Seismic Performance Improvement Options



2.7 Develop emergency response plans

- **Emergency medical** services
- Temporary **shelters**
- **Emergency water and power**
- Planning for critical **transportation** outages

Chapter 3

Land Subsidence

Causes of land subsidence

- Natural consolidation of soil deposit
- Soil compaction from surface loading i.e. Landfills, building loads
- Drawdown of water pressure from ground water extraction
- Lowering of ground water table from other causes
- Shrinkage of shallow soils etc.

Land subsidence problems

- Land subsidence problem cause in many cities such as Venice in Italy, Tokyo in Japan, Shanghai in China and Bangkok in Thailand.
- In Bangkok, subsidence situation reached crisis level and still going on at present at small rate. It affected around 60 km by 50 km and the maximum accumulative magnitude of surface subsidence is 2 m over 70 years period.

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Possible causes of Bangkok land subsidence

- Excessive ground water extraction
- Consolidation of shallow soft clay layer by overburden load or fill/surcharge loads
- Shrinkage of upper part of soft clay layer due to fluctuation of perched water table
- Lateral creep or flow of ground toward river channels.

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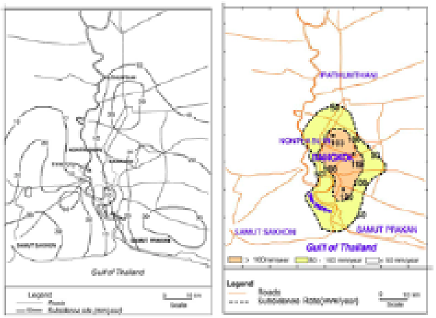

Contour line of land subsidence rate of Bangkok in 2002 and 1981

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Reasons for uncontrolled situation in the past

- Insufficient tap water supply network
- Lack of town planning for manage city growth
- Cheaper cost of ground water fee than cost of tap water
- Need to allow economic boom of the city by scarifying control of groundwater use

Impacts from land subsidence

- Environment impacts
- Lowering of land surface
- Intensify flood risk
- Contamination of groundwater from sea water intrusion into aquifer layers.

Land Subsidence in Ramkamhaeng University, 1981

Chapter 4

Landslide Disaster

- A landslide, also known as a landslip or Mudslide is a form of mass wasting that includes a wide range of ground movements, such as rock falls, deep failure of slopes, and shallow debris flows.

Types of landslide

Man-made landslide

- Slope failure and landslide are caused by cut or fill slope .

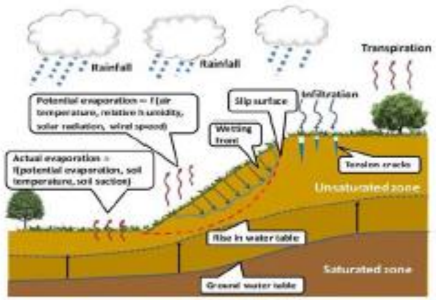
Natural landslide

- Natural landslide is the effect that soil and rock become foldable from excessive rainfall caused debris flow affected large area.

Landslide from heavy rainfall, Brazil

Triggered factors

- Rainfall: The mechanism of rainfall are groundwater level rising and to increase degree of saturation or perch water table. After the water content of soil increasing, soil strength will decrease and cause landslide.
- Earthquake

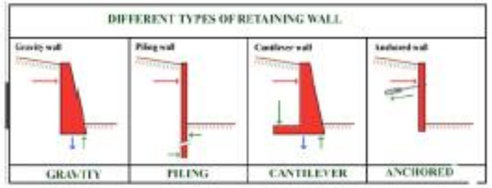


Landslide mechanism due to heavy rainfall

The countermeasures for landslide

For example

1) Improve in engineering standard
2) Law enforcement
3) Zoning
4) Early warning system
5) Community based mitigation
6) Construct something to protect landslide.



Some kinds of structure to prevent land slide.

Some kinds of structure to prevent land slide.(for construction)

Chapter 5

Flooding

Thailand Floods 2011

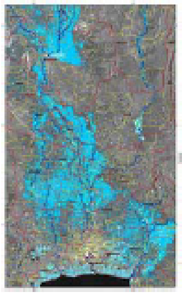


Figure 5.1 Thailand Floods 2011

5.1 Causes

Uncontrol	Control
• Rainfall pattern and volume	• Water Management for irrigation • Damages of main structures • Ineffective flood warning system • Unsystematic communication system

5.2 Prevention and Mitigation

Midstream:
- Absorbing flood peak and increasing irrigated floodplain
- Land use regulation

Upstream:
- Forest and Land Rehabilitation
- More reservoirs
- Land use regulation

Downstream:
- Floodways
- Protection for important economic zone
- Land use regulation

Prevention and Mitigation

- Administration
  - Database
  - Prediction and Early warning system
  - Decision Support System (DSS)
- Social aspect
  - Public awareness
  - Public participation and support

Operational Flood Forecasting (DSS)

Data
↓
Bias adjustment
↓
Simulation
↓
DSS

Chapter 6

Ayutthaya Province

1st Site Visit

Phra Nakhon Si Ayutthaya Province

AIT

Chai Watthanaram Temple

6.1 AIT

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Objective

- The Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES)
  - Climate change model
  - Ocean tsunami model
  - application of early warning information

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Objective

- Antient place retaining
  - How to treat Chaiwatthanaram temple.
  - Use 3D Model to do the physical model.

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6.2 Wat Chaiwatthanaram

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Cause

The 2011 Thailand flood

Solution

Floodwall along Chao Phraya River

Chapter 7

2^{nd} Site Visit

Visiting Places

- National Disaster Warning Center
- Drainage Project For Suvarnabhumi Airport
- Wat Hong Thong: Coastal erosion

7.1 National Disaster Warning Center

Objective

- early warning system is considered as an important mechanism to prevent and reduce the effects of disaster
- To learn about the disaster warning system in Thailand.

Department of Disaster Prevention and Mitigation

7.2 Drainage Project For Suvarnabhumi Airport

Objective

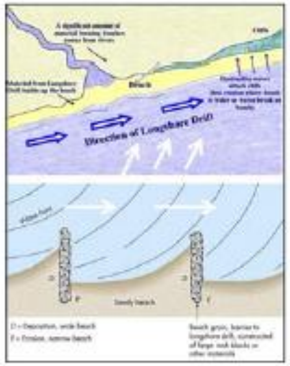
- To be a main canal for drainage water from area around Suvarnabhumi airport
- To follow flooding and pumping work for flooding management in Lower Chaophraya Basin
- To be linkage road between Sukhumvit-Thepharak and Bankna-Trat Road in order to reduce traffic problem
- To storage water for agriculture
- To promote Development Guidelines for Sustainable Agro-Tourism

7.2 Wat Hong Thong: coastal erosion

Bang Pakong District, Chachoengsao, Thailand

Longshore Transport

- Wave move to shoreline
  - Onshore-offshore Transport
  - Longshore Transport
- Longshore Transport is factor to transport sediment



Pattern of coastal changing	Coastal Protection Measures
▪ Erosion $Sediment_{in} < Sediment_{out}$ ▪ Deposition $Sediment_{in} > Sediment_{out}$ ▪ Equilibrium $Sediment_{in} = Sediment_{out}$	▪ Hard Solution ▪ Breakwater ▪ Seawall ▪ Groins ▪ Soft Solution ▪ Beach nourishment ▪ Mangrove Afforestation

Breakwater

To reduce the intensity of wave action

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