

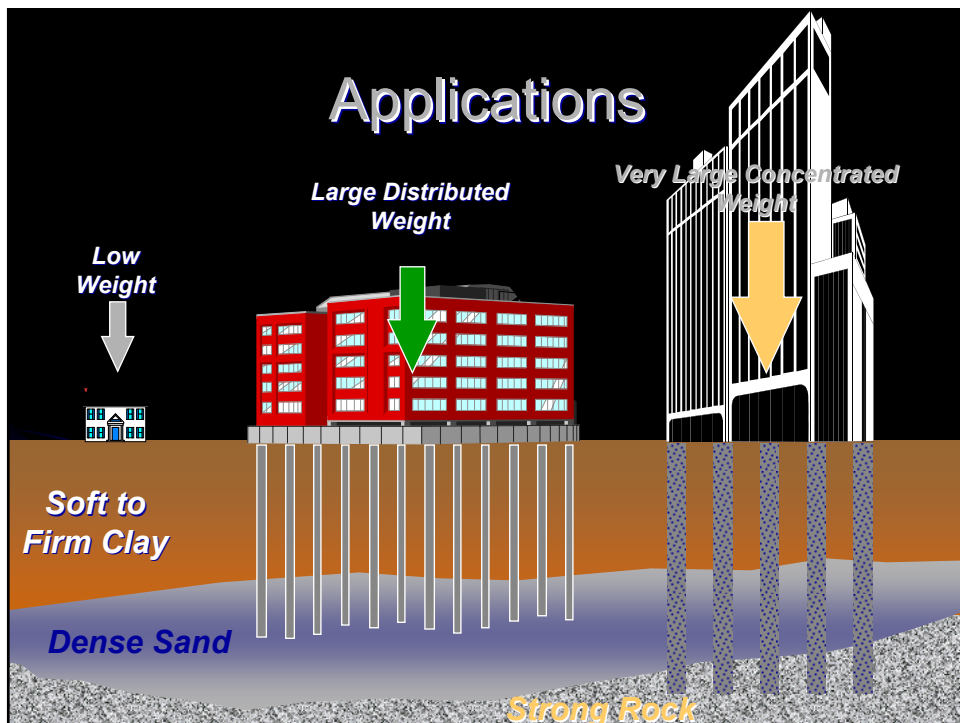
# FOUNDATION ENGINEERING

## BFC 4043



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2.0 DEEP FOUNDATION



# FOUNDATION SYSTEMS

“The foundation is the building element which distributes and transmits the building load to the earth.”

## CLASSIFICATIONS OF PILES ARE BASED ON...

- 1. Function or Action**
- 2. Composition or Material**
- 3. Method of Installation**

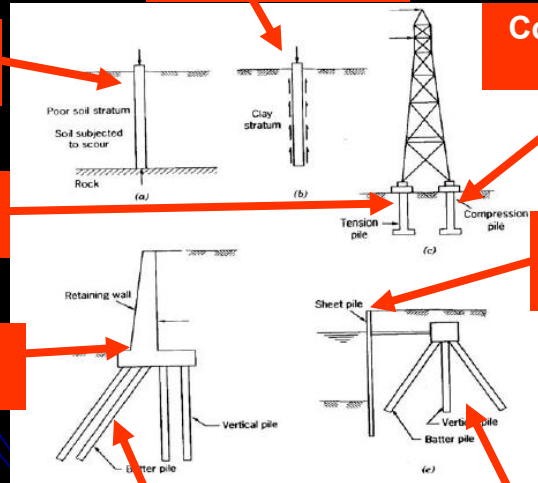
# 1. CLASSIFICATION: Function or Action

## Friction Piles

End Bearing Piles

Tension or Uplift Piles

Laterally Loaded Piles



Compactions Piles

Fender Piles

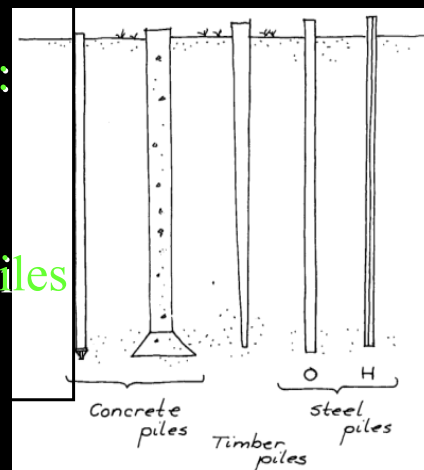
Batter Piles

Anchor Piles

# 2. CLASSIFICATION: Composition or Material

Piles can be divided into:

- Steel piles
- Concrete piles
- Wooden (timber) piles
- Composite piles





## STEEL PILES

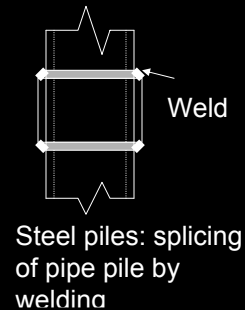
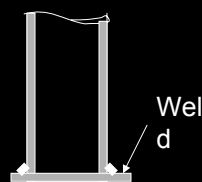
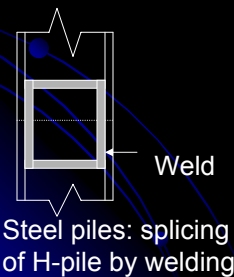
2a

- are usually rolled-H, fabricated shapes, or pipe pile.
- Pipe piles are normally, although not necessarily, filled with concrete after driving. Prior to driving, the bottom end of the pipe pile usually is capped with either a flat or a cone-shaped point welded to the pipe. Sometimes, the pipe is driven open-ended instead of capped, and soil is removed after the completion of driving.
- Corrosion is a negative aspect of steel piles. Corrosive agents such as salt, acid, moisture and oxygen are common enemies of steel. Steel piles in disturbed soils appear to corrode more rapidly due to an apparent higher oxygen content in the disturbed soil than in an undisturbed soil.
- soils that have a pH of less than 7 (acidic) are corrosive.
- Coating such piles with paint or encasing them in a concrete shell may provide some protection against corrosion, although the paint may be damaged during the installation process.
- Sometimes additional thickness of steel (over the actual design cross-sectional area) is recommended in order reduced such corrosive effects.

## STEEL PILES

2a

- Generally are either pipe piles or rolled steel H-section pipes.
- Usual length of piles : 50-200 ft (15-60 m)
- Maximum length of pile : Practically unlimited
- Usual load : 67-270 kip (300-1200 kN)



### □ Advantages:

- a. Easy to handle with respect to cutoff and extension to the desired length.
- b. Can stand high driving stresses.
- c. Can penetrate hard layers such as dense gravel, soft rock.
- d. High load-carrying capacity.

### □ Disadvantages :

- a. Relatively costly material.
- b. High level of noise during pile driving.
- c. Subject to corrosion.
- d. H-piles may be damaged or deflected from the vertical during driving through hard layers or past major obstructions.

## JKR RECOMMENDATIONS: Steel H-Piles

- Expensive + not popular
- suitable for limestone area
- maximum 1 connection (between piles)
- ordinary size between 200mmX200mm to 350mmX350mm
- Allowable capacity between 510kN to 1650kN



2a



2b

**CONCRETE  
PILES**

# CONCRETE PILES

2b

- concrete piles are much immune to the detrimental effects of the corrosive elements.
- Concrete piles can be divided into two basic categories:
  - Precast piles
  - Cast-in-situ piles
- Precast piles can be prepared by using ordinary reinforcement, and they can be square or octagonal in cross section. The reinforcement enable the pile to resist the bending moment caused by lateral load.
- Cast-in-situ or cast-in-place, piles are built by making a hole in the ground and then filling it with concrete. Various type of cast-in-place concrete pile have been patented by their manufacturers. These piles can be divided into two broad categories. They are cased and uncased.



2b

- ❑ Precast piles
  - Can be prepared by using ordinary reinforcement.
  - Can also be prestressed by the use of high-strength steel pressing cables.
  - Usual length of piles : 10-15 m (precast)  
10-35 m (pre-stressed)
  - Maximum length of pile : 30 m (precast)  
60 m (pre-stressed)
  - Usual load : 67-675 kip (300-3000 kN)



2b

- Advantages:

- a. Can be subjected to hard driving.
- b. Corrosion resistant.
- c. Can be easily combined with concrete superstructure.

- Disadvantages:

- a. Difficult to achieve proper cutoff.
- b. Difficult to transport.



□ Cast-in-situ piles

- Built by making a hole in the ground and filling it with concrete.
- Divided into two broad categories:
  - a. Cased
  - b. Uncased

2b

□ Cased cast-in-situ piles

- Usual length of piles : 15-50 ft (5-15 m)
- Maximum length of pile : 100-130 ft (30-40 m)
- Usual load : 45-115 kip (200-500 kN)
- Advantages :
  - a. Relatively cheap.
  - b. Possibility of inspection before pouring concrete.
  - c. Easy to extend.
- Disadvantages
  - a. Difficult to splice after concreting.
  - b. Thin casings may be damaged during driving.



2b

□ Uncased cast-in-situ piles

- Usual length of piles : 15-50 ft (5-15 m)
- Maximum length of pile : 100-130 ft (30-40 m)
- Usual load : 65-115 kip (300-500 kN)
- Advantages :
  - a. Initially economical.
  - b. Can be finished at any elevation.
- Disadvantages
  - a. Voids may be created if concrete is placed rapidly.
  - b. Difficult to splice after concreting.
  - c. In soft soil, the sides of the hole may cave in, thus squeezing the concrete.

**JKR RECOMMENDATIONS:  
Reinforced Concrete Piles**



2b

- when bakau + timber piles are not suitable
- very common used + can fit into almost all cases
- not really suitable to limestone areas + soft ground with sand lenses
- allowable capacity ranged from 400 kN to 4000 kN
- commercial piles



## TIMBER PILES

**2c**

- One of the oldest type of piles and still one of the most common (cheapest).
- Wood piles are made from tree trunks with the branches and bark removed.
- The installation of this type of pile is by driving. Normally, the pile is driven with the small end down. It cannot withstand hard driving stress therefore to avoid damage to the pile top, a metal band or a cap may be used.
- Overdriving of the timber piles may result in splitting, crushing or shearing of the pile.
- For the decay reason, wood piles are almost always cut off below the permanent groundwater. Furthermore, most frequently wooden piles are treated with preservatives such as creosote oil, which is impregnated into the wood. This is an effective mean of preventing dry-rotting as well as against damage from most animal and plant attacks.

## TIMBER PILES

2c

Usual length of piles : 30-50 ft (10-15 m)

❑ Maximum length of piles : 30 m

❑ Usual load : 100-200 kN

### Advantages :

- Economical.
- Easy to handle.

### Disadvantages:

- Decay above water table
- Can be damaged in hard driving.



## JKR RECOMMENDATIONS: Bakau Piles

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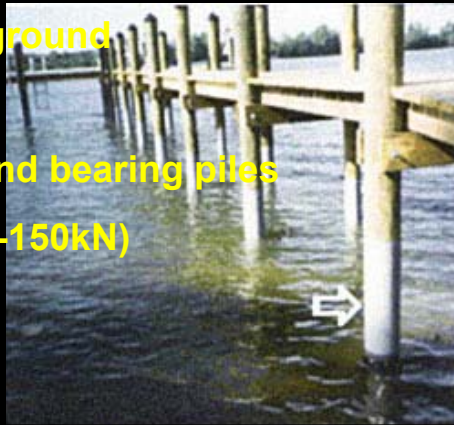
- cannot be used to all JKR projects!
- sizes between 75mm – 100mm diameter
- all. Bearing capacity, 5kN – 10kN (0.5 – 1 tonne)
- Max. load = 10 kN = 1 tonne
- minimum distance between piles = 300mm



## JKR RECOMMENDATIONS: Treated Wood Piles

2c

- used when bakau is not suitable
- not economic at soft ground
- only 1 connections
- can be as friction or end bearing piles
- allowable load (120kN-150kN)



## COMPOSITE PILES

- The upper and lower portions of composite piles are made of different materials. Composite piles may be made of steel and concrete or timber and concrete.
- Steel and concrete pile consist of a lower portion of steel and an upper portion of cast-in-place concrete.
- Timber and concrete piles usually consist of a lower portion of timber pile below the permanent water table and an upper portion of concrete.
- It is difficult to form proper joints between two dissimilar materials, and, for that reason, composite piles are not widely used.

The Damaged Cause by Driving Condition

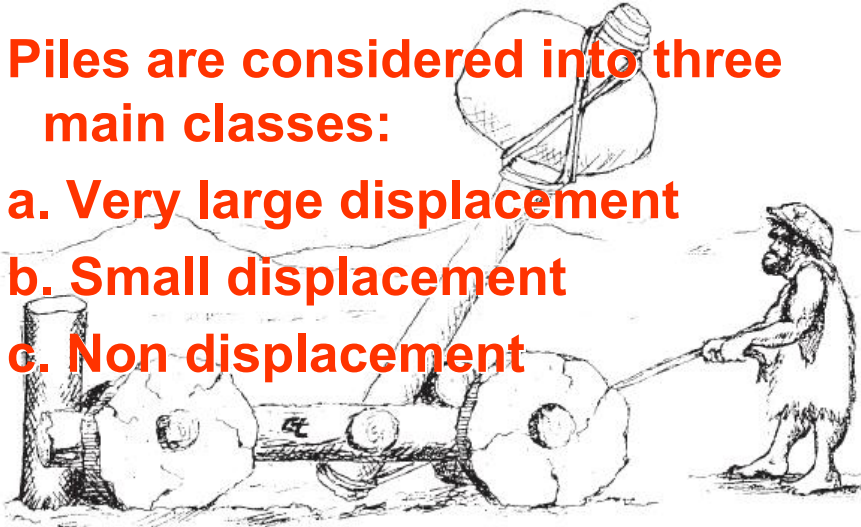


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### 3. CLASSIFICATION: Based on Method of Installations

Piles are considered into three main classes:

- a. Very large displacement
- b. Small displacement
- c. Non displacement



## Large Displacement Piles

3a

- × Driven and cast-in-place
- × Driven precast reinforced or prestressed concrete piles
- × Timber piles



## Driven and cast-in-place

3a

### Advantages

- ✘ Can be driven to a predetermined set
- ✘ Pile lengths are readily adjustable

### Disadvantages

- ✘ Cannot be driven where headroom is limited
- ✘ Noise, vibration and ground displacement may cause a nuisances or may damage adjacent structure

## Driven precast reinforced or prestressed concrete piles

3a

### Advantages

- ✘ Stable in squeezing ground, for example , soft clay, silts and peat
- ✘ Pile material can be inspected before piling

### Disadvantages

- ✘ Cannot readily be varied in length
- ✘ May be damage due to hard driving.

## DISPLACEMENT PILES

3a

- Refer to piles that are driven, thus displacing the soil and include those piles performed , partially performed or cast in place.
- The types of displacement piles :
  - 1) Precast reinforced concrete piles
  - 2) Steel preformed piles
  - 3) Composite piles
  - 4) Driven In-situ / cast-in-place piles

## THE ADVANTAGES OF DISPLACEMENT PILES

3a

- Can be driven to long lengths
- Can be designed to withstand high bending and tensile stresses
- Material forming piles can be inspected for quality and soundness before driving.

## THE DISADVANTAGES OF DISPLACEMENT PILES

- May break during driving, necessitating replacement piles.
- Noise, vibration and dust levels due to driving may be unacceptable.
- Not suitable for situations with low headroom.

## Small displacement pile

3b

- ✘ Example of these piles are rolled steel section, screw piles or open ended tubes and hollow section where the soil is removed during penetration.
- ✘ Rolled steel section piles are easily handled and can be driven hard. They can be driven in very long lengths and the pile length can be readily varied.
- ✘ Screw piles are valuable in marine works because they can resist both tensile and compressive forces.



## NON-DISPLACEMENT PILES

3c

- Sometimes referred to as replacement piles but more commonly as bored piles.
- They are formed by boring / removing a column of soil and replaced with steel reinforcement and wet concrete cast through a funnel or tremie pipe.

### THE ADVANTAGES OF NON-DISPLACEMENT PILES

- Can be installed in very long length.
- Can be installed without appreciable noise or vibration.
- No ground heave.
- Length can readily be varied to suit the level of bearing stratum.

3c

### THE DISADVANTAGES OF NON-DISPLACEMENT PILES

- Concrete in shaft susceptible to squeezing or necking in soft where conventional types are used.
- Special techniques needed for concreting in water-bearing soils.
- Concrete cannot be readily inspected after installation.

## BORE PILES...

3c

- Bored cast-in-situ piles are built by making a hole in the ground and then filling it with concrete.
- Various types of its are currently used in construction and most of them have been patented by their manufacturers.
- Large diameter bored piles are non displacement piles which are commonly used where large vertical loads or bending moments must be carried by a single unit.
- Bored piles founded in rock provide an effective means of minimizing foundation settlements and a small number of high capacity bored piles can often provide significant savings in pile cap costs over other, lower capacity, pile types.
- Being non displacement type piles, bored piles can be installed with little or no vibration, and with much lower noise levels than driven piles.



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- Soil and or rock is removed using purpose designed drill tools including soil and rock augers, drilling buckets, core barrels, and down hole hammer drills. Drilling to depths of up to 60 meters and to diameters from 300mm to in excess of 2 metres is possible in soil and rock.
- Various methods of support for the sides of bored piles during construction are available. These can be selected to suit the type of formation being drilled, the ground water regime encountered, and site environmental constraints
- Shaft support methods available include:
  - a) Vibrated temporary casing.
  - b) Drilled temporary casing.
  - c) Oscillated temporary casing.
  - d) Permanent liners.
  - e) Drilling under water.
  - f) Drilling under bentonite.
  - g) Drilling under polymer fluids.



## Some Figures...

3c



Tanah Runtuh



Pengorekan Borepile



Masukkan Besi Tetulang



Masukkan Besi Tetulang

# Some Figures...

3c



Kerja Penguatan Konkrit



Pendatar (Vibrator)



Konkrit Yang Siap Dituang



Sarana (Casing) Dibuat Keluar

## WHAT IS A MICROPILE?

1. a small diameter (less than 300mm), replacement, drilled pile composed of placed or injected grout, and having some form of steel reinforcement to resist a high proportion of the design load
2. also commonly referred to as minipiles
3. can be used to upgrade the capacity of existing foundation elements, to mitigate or eliminate ongoing settlement, or to improve an existing foundation's resistance to seismic loading from earthquakes

## TYPICAL DESIGN & INSTALLATION

1. Micropiles come in a variety of forms, dependent principally on the reason for its implementation and its required design load capacity
2. One common micropile design employs thick-walled steel casing that is drilled into the ground to target depth and left in place permanently, then reinforced with internal steel reinforcing bars and cement grout.
3. The vast majority of micropiling projects require the use of small, nimble (and very expensive) drill rigs called mini-rigs to successfully negotiate narrow access, low headroom spaces

## APPLICATIONS :

### For Structural Support

1. Foundation for new structures
2. Seismic retrofitting
3. Underpinning of existing foundation
4. Repair / Replacement of existing foundations
5. Arresting / Prevention of movement
6. Upgrading of foundation capacity



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### For In Situ Reinforcement

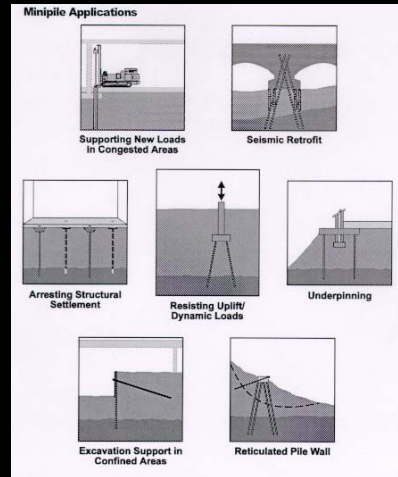
1. Embankment, slope and landslide stabilization
2. Soil strengthening and protection
3. Settlement reduction
4. Structural stability.

### DESIGN ASPECTS

1. Analytically viewpoint: settlement, bursting, buckling, cracking, and interface considerations;
2. Practical viewpoint: corrosion protection and compatibility with the existing ground and structure;
3. Economical viability.

### Mode of Load Transfer

1. The system must be capable of sustaining the anticipated loading requirements within acceptable settlement limits



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## MICROPILE COMPONENTS (INTERNAL DESIGN)

### Reinforcing steel

- The reinforcement to be used is dictated by the purpose of the micropile, its working load, and its permitted elastic deflection
- When such micropiles have to act in tension, the reinforcement will consist of high-strength bars

### Grout

- Most commonly the grout consists of simply cement and water. The type of cement will be dictated by the nature of the groundwater or by the strength/time requirements.
- Water should always be fresh and potable but with a chloride ion content of less than 500 mg/liter. Cement grout should be sufficiently fluid to allow efficient pumping and injection, and sufficiently stable to resist displacement and erosion after injection.
- The principal variable affecting the properties of cement grout is the water-cement ratio (w/c). The amount of water determines the rate of bleeding, subsequent plasticity, and ultimate strength of grout.

### Grout-Steel Bond

- This interface is fundamental in that it is a mechanism of load transfer from steel to ground.
- Bond stresses are assumed to be uniformly distributed along the element.
- In the majority of cases, the grout-steel bond consideration does not govern the design: internal load capacity, or grout-ground capacity are the principal controls.

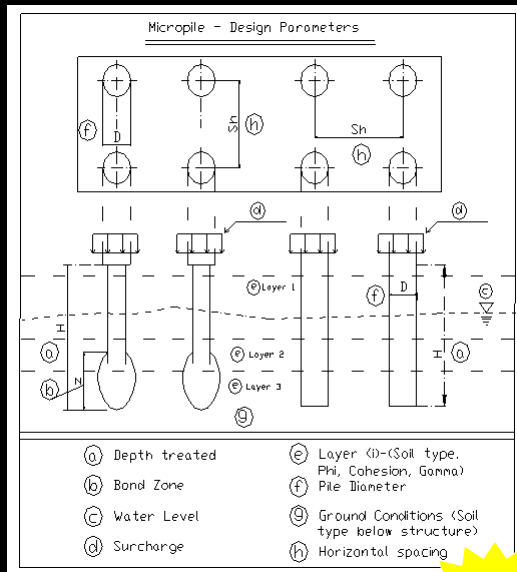
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## LOAD TRANSFER (EXTERNAL DESIGN)

**Grout-Ground Bond** – Drilling and grouting methods used for micropiles act to produce excellent bond characteristics in the load-transfer zone.

Codes or regulations are available (FIP, 1982; PTI, 1986; BS, 1989), and published data (Littlejohn and Bruce, 1977; Littlejohn, 1990; Xanthakos, 1991).

Deeper discussion about the design of Single, Groups, and Network of micropiles are presented in the FHWA-RD-96 Volume II report.



## DESIGN PARAMETERS

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## EXAMPLE OF MICROPILE : DRILLED MICROPILE DESIGN PROCEDURES

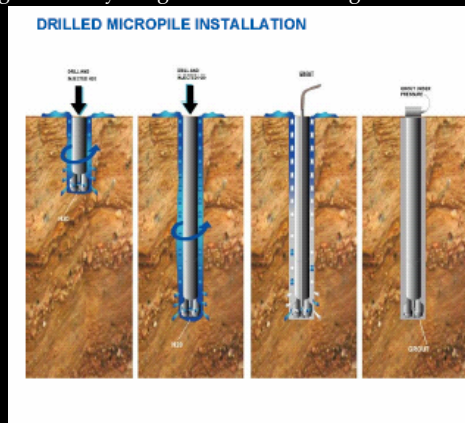
Drilled micropiles must be designed to take the required compression, tension, and lateral load applied. This is accomplished by analyzing the pile's structural and geotechnical capacities. The structural capacity of the pile is governed by the grout and reinforcing steel strengths.

### APPLICATIONS

1. Structural Foundation Support
2. Structural Underpinning
3. Soil/Slope Stabilization

### ADVANTAGES

1. High bearing capacity
2. Measure 6"-12" in diameter
3. Permeability of the stabilized soil can be predetermined
4. Special installation of up to 200 tons
5. Installation in areas presenting difficult access and/or low headroom
6. Minimal disturbance/vibration to adjacent structures



**3c**

## **ACKNOWLEDGEMENT....**

**Apart of this presentation are from my former students efforts, Sem. 1 2003/04... I'm thank you for their support and works!**

### **Other References,**

- B.M., Das : Principles of Foundation Engineering
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- Monash University, Australia
- Ir Mohamed bin Daud, JKR, Kelantan

*Thank you...*

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**GOOD LUCK!!!!**