(b) Field Observation v.s. Prediction by Laboratory Tests

When compared with t_{50} as predicted by the laboratory tests, t_{50} as obtained from the field observations is:-

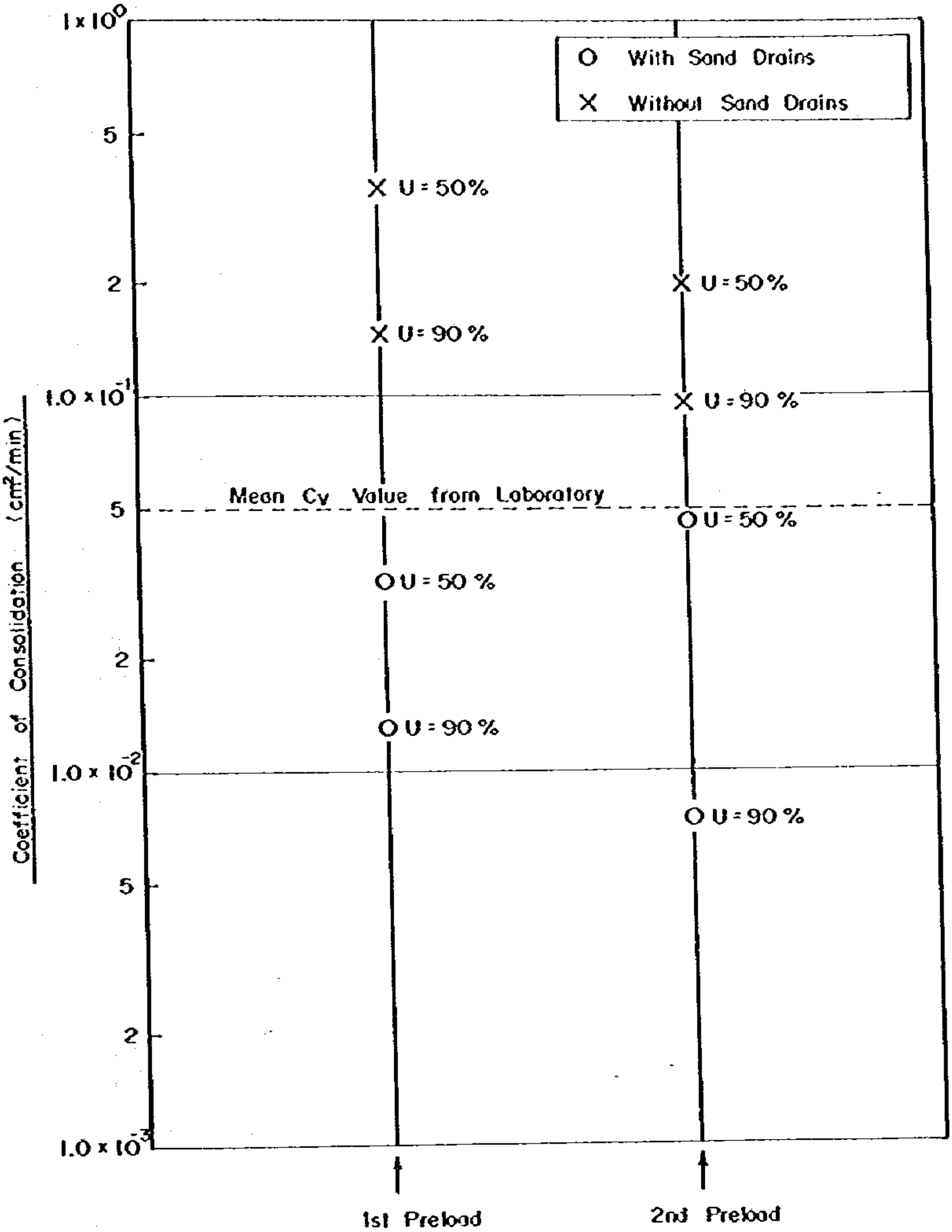
1) faster for areas without sand drains, and
2) slower for areas with sand drains.

This tendency was observed both for the 1st stage preloading and the 2nd stage preloading. Similar results were observed in terms of the time required for 90% consolidation.

Fig. 6-20 compares the time rate of consolidation settlement in terms of the coefficient of consolidation. Higher values mean a faster rate of settlement. It was observed that the rate of settlement in the field was 5 to 10 times faster than that estimated from laboratory tests for areas without sand drains and about 1/2 (2 times slower) for areas with sand drains. However, when we consider that a number of variables and assumptions are involved in the comparison of the time rate of settlement, the theoretical predictions made through the laboratory test and the field observations are considered to be in reasonably good agreement.

6.1.6 Effects of Preloading on Properties of Soft Clay

The effects of preloading on the improvement of soft clay properties were studied by evaluating the properties of soft clay before and after the placement of the preload embankment.



Note : U denotes degree of consolidation

Fig. 6-20 Comparison of Coefficient of Consolidation

Undisturbed soil sampling and vane shear tests were carried out before the placement of the embankment, after approximately 100 days from the placement of the 1st stage preloading, and after about 150 days from the placement of the 2nd stage preloading. The soil properties evaluated were:-

1) Water Content
2) Unit Weight
3) Undrained Shear Strength
4) Preconsolidation Pressure

(1) Water Content and Unit Weight

Water content and unit weight of soft clay before and after the preloading are plotted versus depth in Figs. 6-21 and 6-22 respectively. No significant difference was observed between these parameters before and after the preloading. However, a slight decrease in water content and a slight increase in unit weight were observed in samples from the sand drain area obtained after the 2nd stage preloading.

(2) Undrained Shear Strength

Undrained shear strength was obtained by U-U triaxial compression tests on undisturbed soil samples and by insitu vane shear tests. The results are plotted versus depth in Figs. 6-23 and 6-24. As described in Section 4, the soft clay can be sub-divided into two layers at around R.L.+28 m.

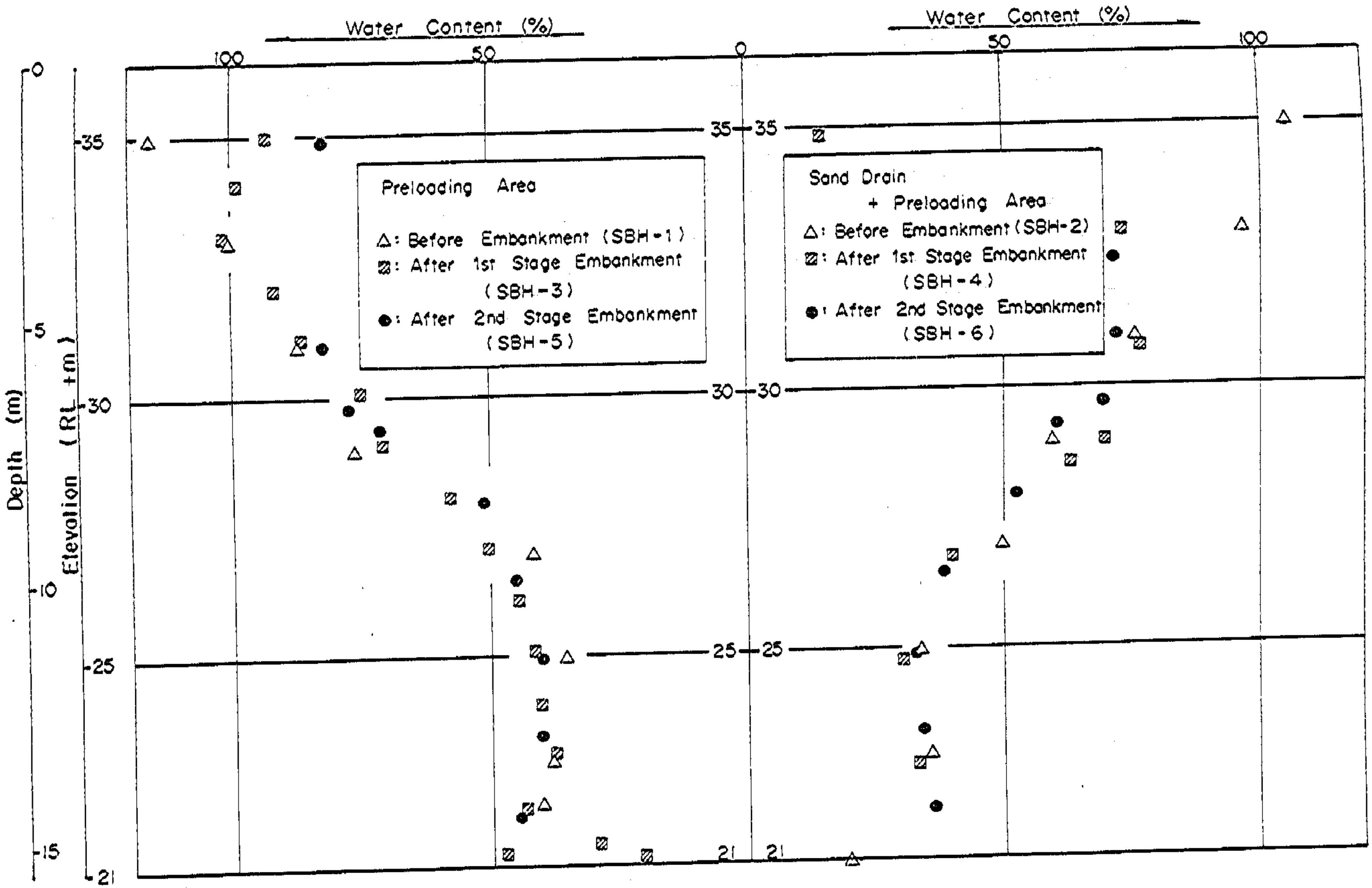


Fig. 6-21 Water Content v.s. Depth

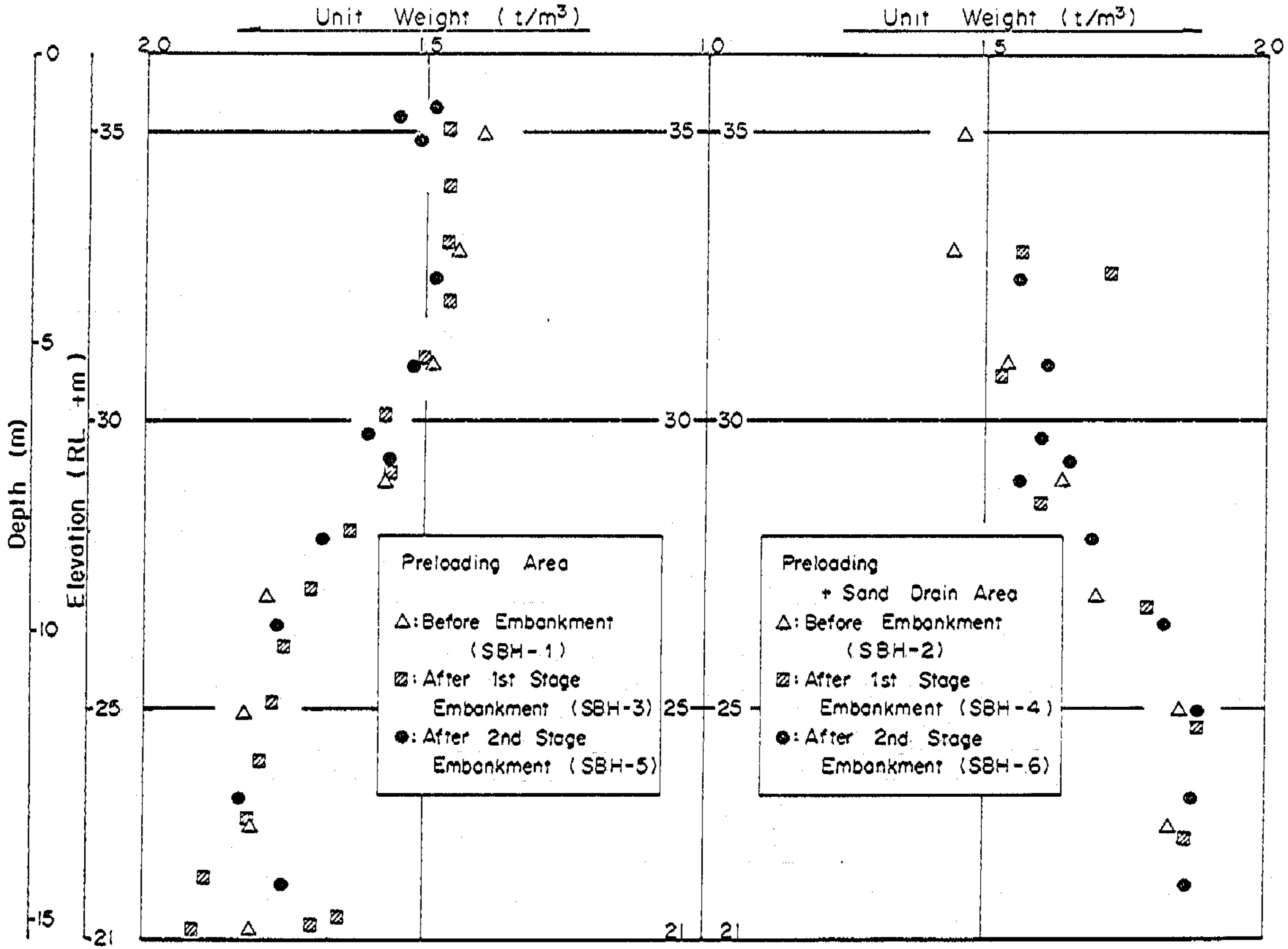


Fig. 6-22 Unit Weight v.s. Depth

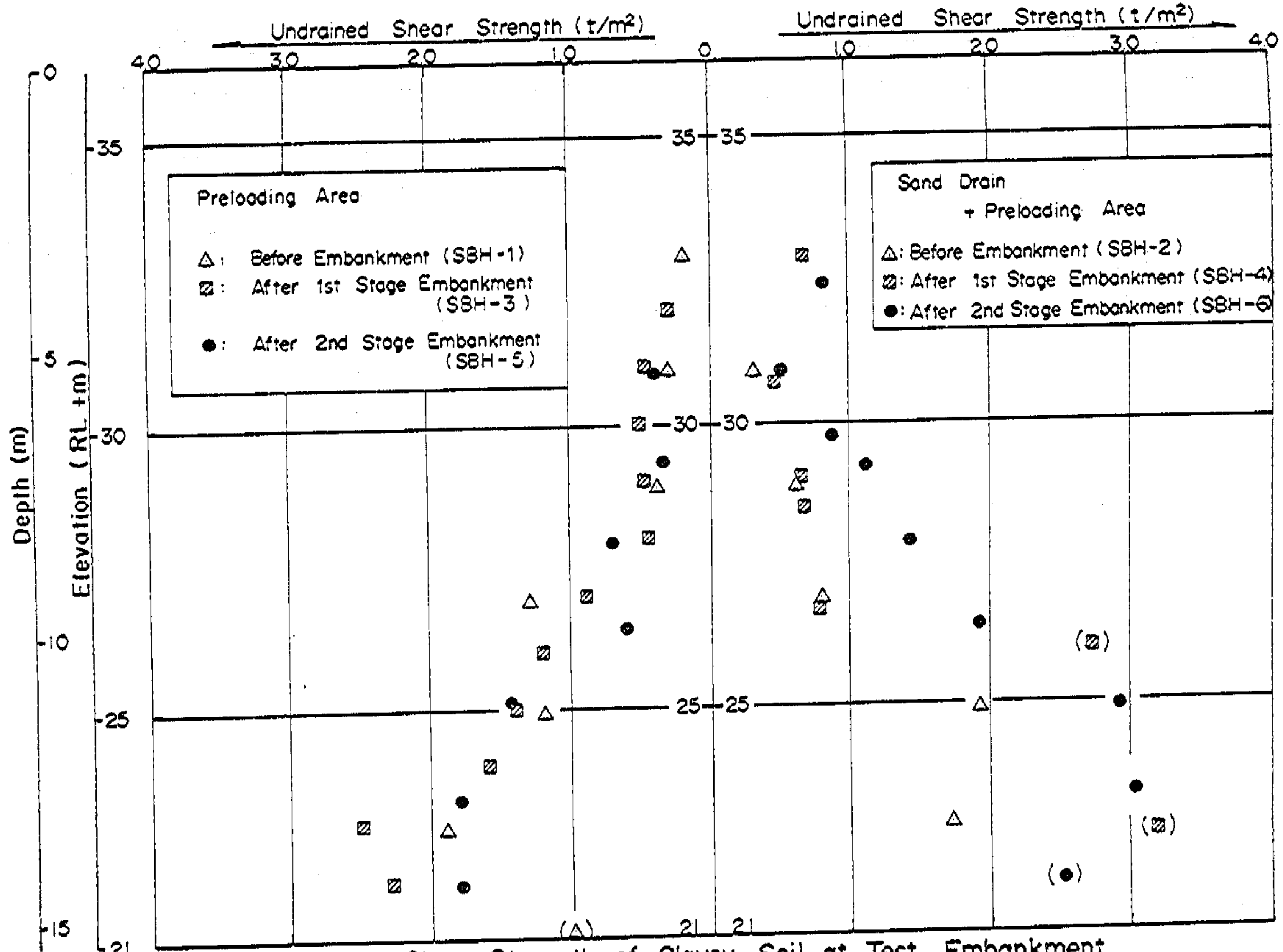


Fig. 6-23 Undrained Shear Strength of Clayey Soil at Test Embankment (U-U Compression Test)

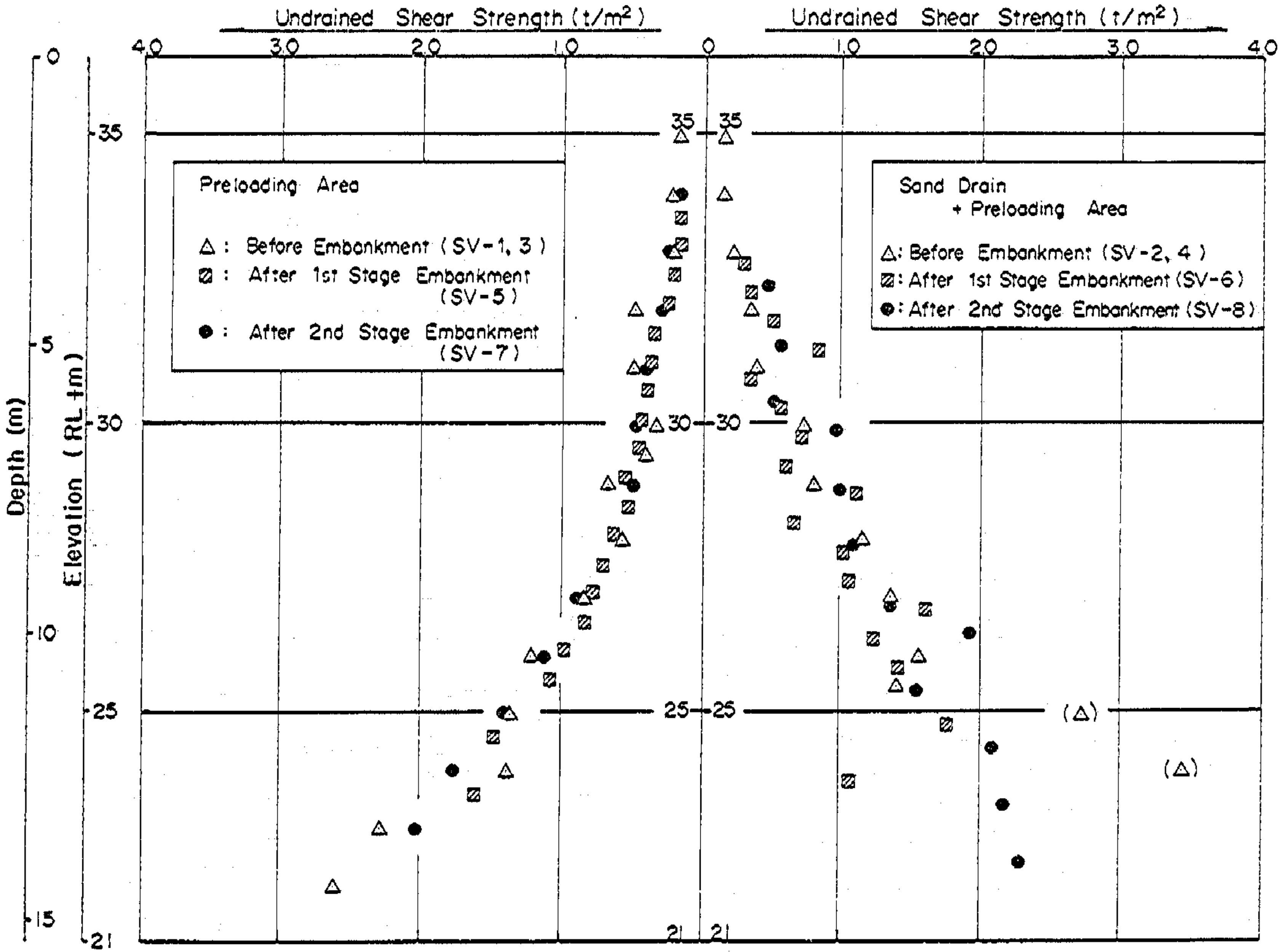


Fig. 6-24 Undrained Shear Strength of Clayey Soil at Test Embankment (In-Situ Vane Test)

An increase in undrained shear strength after the 1st preload is not clearly indicated but subsequent to the 2nd preload is very clear. The increment is more significant in the sand drain area than in the area without sand drains.

Table 6-3 shows average values of the undrained shear strength of soft clay at different stages of preloading. The average values are calculated and compared to determine the tendency towards an increase in strength. An appreciable increase in the undrained shear strength is noticed for the sand drain area, especially after the 2nd stage preloading. It can be seen that the effects of preloading and especially those of sand drains are exhibited in the increase of the undrained shear strength of soft clay.

(3) Preconsolidation Pressure

Results of the laboratory consolidation tests were evaluated, especially in terms of preconsolidation pressures. Fig. 6-25a shows the preconsolication pressure, calculated overburden pressure and overconsolidation ratio before the placement of the preload embankment. The preconsolidation pressure determined by the consolidation tests is in good agreement with the calculated overburden pressure. The overconsolidation ratio of the clay ranges between 1.0 and 1.5. Thus, the soft clay at the site is considered to be normally consolidated.

Table 6-3 Undrain Shear Strength of Soft Clay at Different Stages

Area	Stage	Average Undrained Shear Strength (t/m^2)				
		by U-U Triaxial Compression Test		by In-Situ Vane Shear Test		Average
Preloading Only	Before Embankment	SBH-1	0.91	SV-1,3	1.01	0.96
	After 1st Stage Embankment	SBH-3	1.07	SV-5	0.99	1.03
	After 2nd Stage Embankment	SBH-5	1.12	SV-7	1.09	1.11
Preloading + Sand Drain	Before Embankment	SBH-2	1.16	SV-2,4	1.33	1.25
	After 1st Stage Embankment	SBH-4	1.30	SV-6	1.27	1.29
	After 2nd Stage Embankment	SBH-6	1.89	SV-8	1.52	1.71

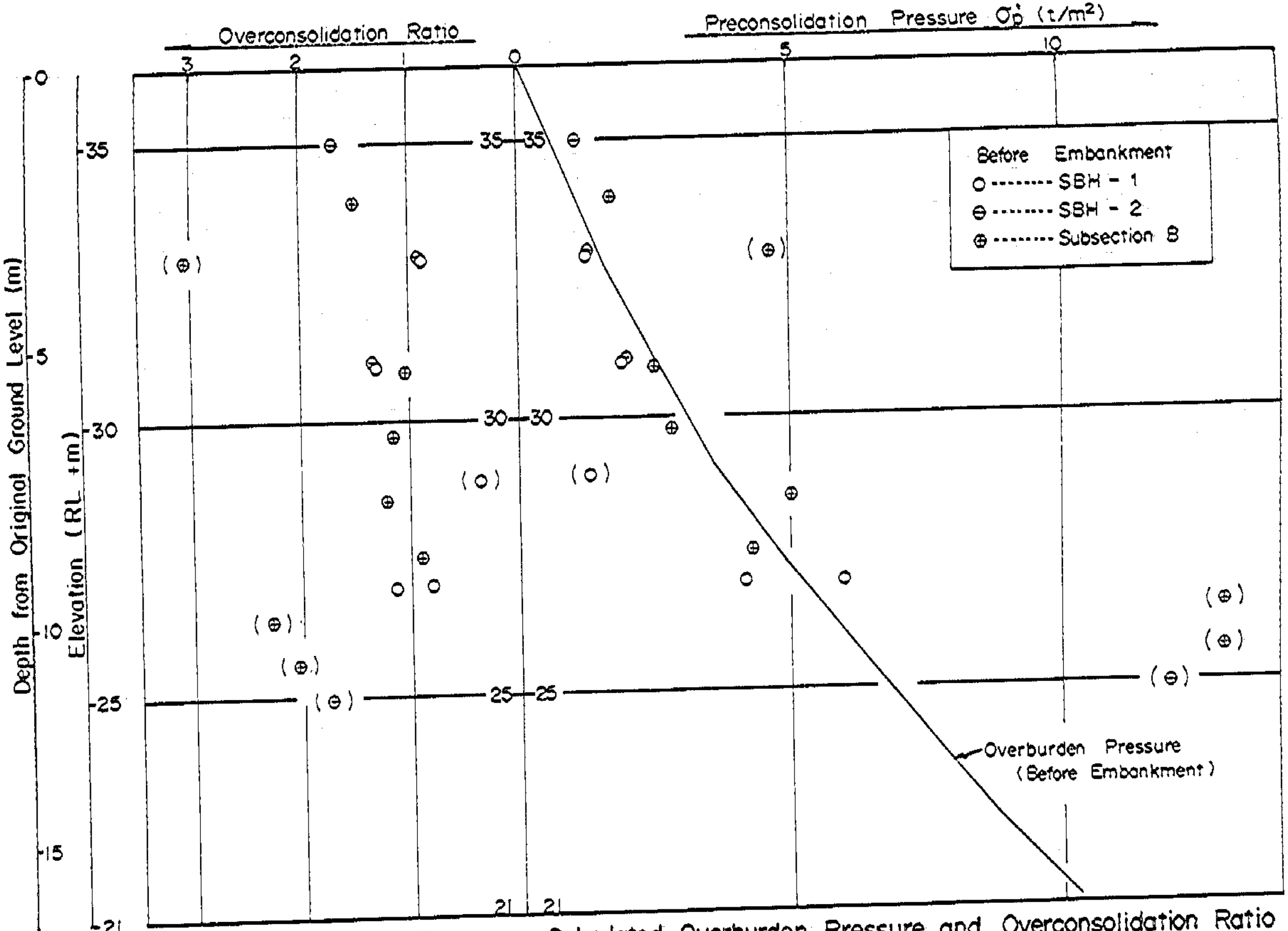


Fig. 6-25a Preconsolidation Pressure, Calculated Overburden Pressure and Overconsolidation Ratio
— Before Placement of Preload Embankment —

Fig. 6-25b shows preconsolidation pressures obtained for soil samples after the 1st stage and 2nd stage preloadings in the area without sand drains. Fig. 6-25c shows those in the area with sand drains. In these figures, an increase in preconsolidation pressure is indicated, with an especially clear indication of increase in the sand drain area. Estimated degrees of consolidation, obtained from the results of settlement observations, are also shown in Fig. 6-25c. Reasonable agreement between the degree of consolidation and the rate of increase in the preconsolidation pressure is indicated. The results on the preconsolidation pressure presented above also evidence the effectiveness of preloading and sand drains.

6.1.7 Summary of Experimental Study

Through the experimental study performed on the ex-mining land of Sentul, the following remarks can be made in summary:-

1) The clayey layer at the pilot test area is found to be very soft and highly compressible. Consolidation settlement amounting to 50 cm to 100 cm has been observed under the load of the test embankment during a period of about 10 months.

2) Preloading is found to be effective for the improvement of soft clay. The effectiveness of preloading is indicated by:-

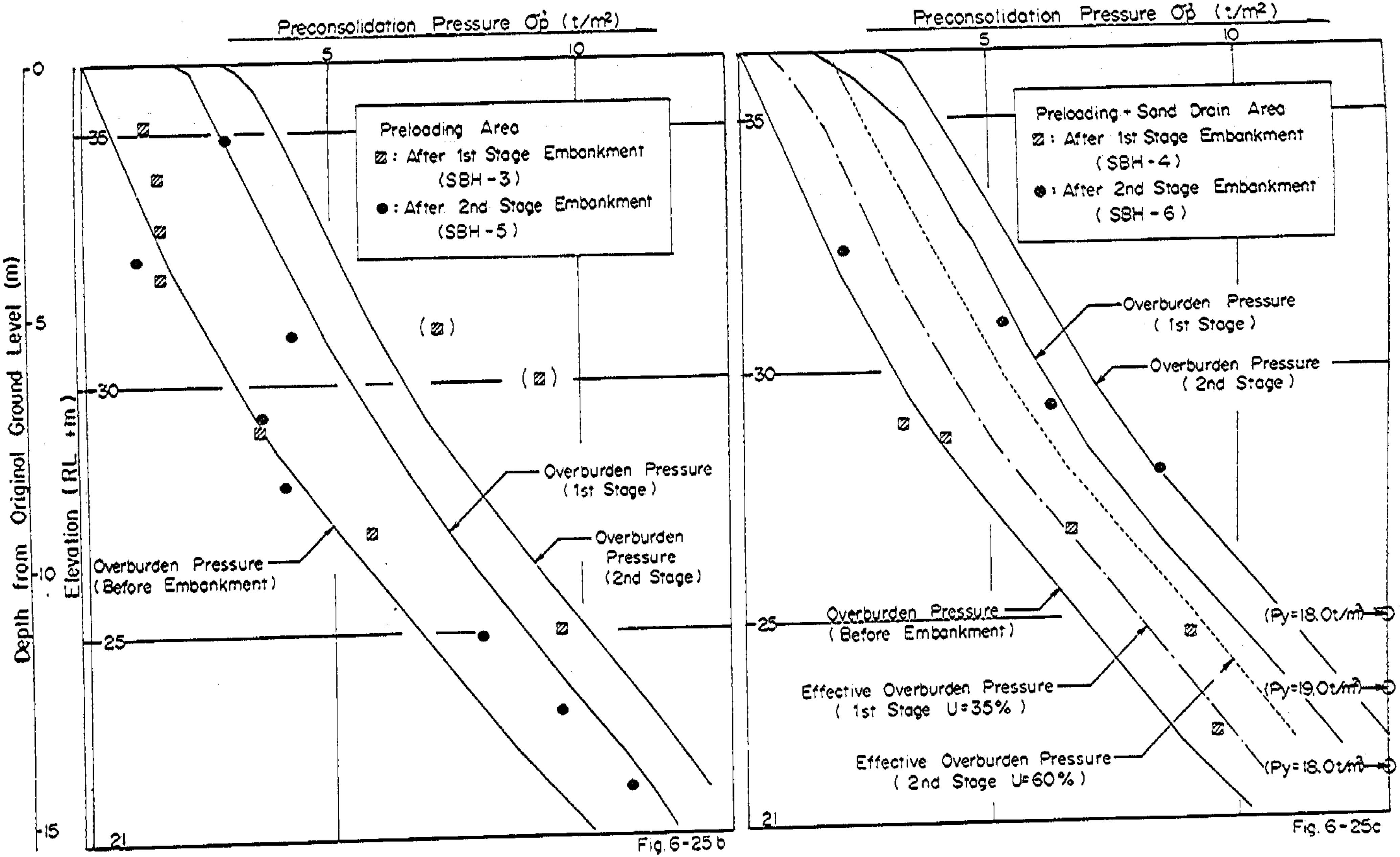


Fig. 6-25b a c Preconsolidation Pressure and Calculated Overburden Pressure

i) progress of settlement with rates sufficiently fast for the practical and economical application, and

ii) an increase in the undrained shear strength.

3) Sand drains are shown to be effective in accelerating the consolidation settlement of clayey layers in ex-mining land as evidenced by:-

i) a faster rate of settlement, and

ii) a greater increase in the undrained shear strength in areas with as opposed to areas without sand drains.

4) Consolidation of soft clay in ex-mining land can be reasonably estimated by theoretical analysis based on the results of laboratory tests. The coefficient of consolidation in horizontal direction, c_h, can be approximated by c_v. Soft clay in ex-mining land can be regarded as more isotropic than the natural clayey deposits.

6.2 Chemical Ground Improvement Methods

Deep mixing methods of soil stabilization using lime or cement as chemical agents were developed and are now widely applied to actual construction sites. Artificially cemented soil (lime-treated soil or cement-treated soil) is a product of this method. To investigate the effectiveness of lime and cement to improve the soft clayey soils in ex-mining land, a series of experiments was executed using a clay sample obtained from the pilot test area of Sentul.

6.2.1 Description of Experiments Performed

A series of experiments was performed to compare the unconfined compressive strength of specimens prepared with different water contents, different mixing ratios of cement or lime, and different curing periods. Conditions employed for preparation of test specimens are summarized in Table 6-4.

When specimens were cured for the required period, they were uniaxially compressed to determine their unconfined compressive strength, q_u. The size of each specimen was 7 cm in height and 3.5 cm in diameter.

6.2.2 Test Results

Results of the tests performed are summarized in Fig. 6-26. Detailed data are presented in Volume 2, Appendix F. The following observations can be made with regard to the results.

Table 6-4 Conditions of Specimens

Water Content of Original Soil Sample	Mixing Ratio of Cement or Lime	Curing Period
70%	5%, 10%	3 days, 7 days, 28 days
90%	5%, 10%	3 days, 7 days, 28 days

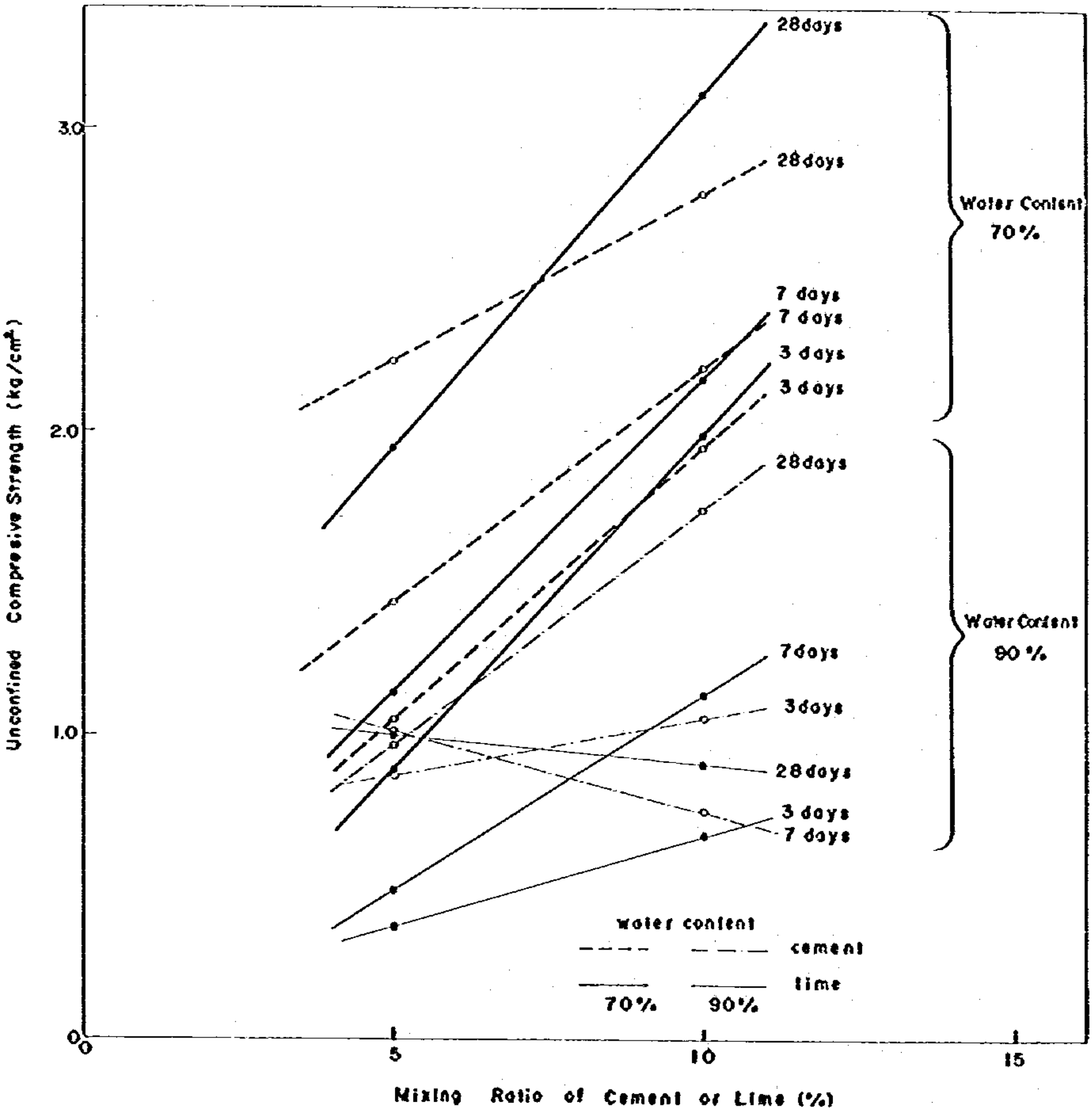


Fig. 6-26 Summary of Chemical Stabilization Tests

(1) The q_u of cement- or lime-mixed specimens are in the range of 0.5 to 3.0 kg/cm^2, which is remarkably higher than the original strength of clay which is 0.02 to 0.15 kg/cm^2. Thus, this method is effective for soft clays in ex-mining land. However, it must be noted that the cost of this method is considerable.

(2) For Soil Samples with Water Contents of 70%

(a) Cement and lime are of approximately the same effectiveness.

(b) When the mixing ratio is increased, q_u obviously increases.

(c) With an increase in the curing period, q_u also increases.

(3) For soil samples with water contents of 90%

(a) Cement and lime are of approximately the same effectiveness.

(b) The difference in strength between mixing ratios of 5% and 10% is not remarkable. Thus, a mixing ratio of approximately 5% may be most appropriate for this case.

6.3 Ground Improvement Methods for Soft Material

The following types of ground improvement methods are evaluated in the present study. The technical applicability of each method is studied together with cost aspects. Ground improvement methods can be classified into 2 groups, namely:-

(1) Soil Improvement

(a) Increase in Soil Density

* consolidation by preloading
* consolidation by dewatering
* compaction by mechanical methods

(b) Chemical Hardening

(2) Replacement

(a) Replacement by Excavation

(b) Compulsory Replacement

The first group (Soil Improvement) can be subdivided into the following methods:-

1) Preloading
2) Preloading with Vertical Drains
   * sand drains
   * paper drains
   * fabric drains
3) Lowering of Ground Water
4) Sand Compaction
5) Dynamic Consolidation
6) Chemical Mixing/Chemical Composer Pile
7) Vibro-Rod/Vibrofloatation
8) Roller Compaction

A detailed description of each ground improvement method is presented in Volume 2, Appendix G.

The applicability and cost aspects of these methods are summarized in Table 6-5 with costs being estimated in Malaysian dollars. The following assumptions are made for the cost estimates:-

1) Machinery for ground improvement is available in Kuala Lumpur.
2) Area of improvement is about 40,000 m^2.
3) Thickness of ground improvement is 5 m for Types B and C ground, and 10 m for Type D ground.
4) Total installation length is in the order of 100,000 m.

Costs for preloading are estimated based on the following conditions:-

1) For low-rise housing, height of preloading is 1.5 m, and for medium- and high-rise housing, it will be 3.0 m. Medium- and high-rise housing will require deep foundations even if preloading is employed. However, in order to avoid future subsidence of the developed area and to maintain infrastructural components such as water supply, sewerage, roads, etc., preloading is required for areas with Type B, C, and D ground.
2) For Type C and D ground, placement of sand mats and surface soil will be required before placement of preloading.

3) Area of preloading will be 3 times the area of the foundation for the proposed structure.

4) Time required for preloading will be:-

* 14 months for Type B ground
* 18 months for Typc C ground
* 36 months for Type D ground

These periods include time required for preparation, placement and removal of preloading earth, and preloading itself. Degrees of consolidation of 50 to 80% will be achieved under the load of preloading.

The following observations can be made based on the results of the study on ground improvement methods for soft material:-

1) Among the ground improvement methods evaluated, preloading is the cheapest if time requirements for ground improvement are not critical.
Generally, ex-mining sites are of considerable size and housing developments are executed in several stages. Thus, preloading can proceed from area to area with sufficient time for completion of the preloading phase. This arrangement will also assist in the continuous use of preloading earth. Therefore, it is judged to be the most recommendable method of soft ground improvement for ex-mining land.
Coordination of advance establishment of land-use

Principle			Measure	Method		(type B, C) (type D) m		Notes
Soil Improvement	Increasing Soil Density	Dewatering	Consoli- dation	Pre-Load			Area of Pre-loading 3xA(bldg)	Slower
				Pre- loading with Vertical Drains	Sa	of	3xA(bldg)	Faster
					Pa		"	"
					Fa		"	"
			Pumping	Ground water Lowering Method	We	ths ths		Assumed that clayey layer (t=5m) is sandwiched by 5m thick sand layers
					De	ths ths		Difficult to estimate effectiveness due to unknown layering of ground
		Compaction	with Machine	Vibro-Rod Meth			Area of Improvement 1.5xA(bldg)	
				Vibrofloatatio			"	
				Sand Compactio Method			"	
				Dynamic Consol Method			"	
				Roller Compact				shollow depth only (up to 1m)
	Hardening		Chemical	Cement or Lime				
				Chemical Compo Method				
Replacement			Excava- tion	Replace- ment by Excavation	Fu Ex			possible up to about 5m deep
					Pa Ex			
			Compul- sory Replace- ment	Compulsory Replacement	Wi of			

ndix H in Volume 2.

TABLE 6-5 GROUND IMPROVEMENT METHOD FOR SOFT MATERIAL

Principle	Measure	Method		Purpose of Ground Improvement: Strength (Increase in strength, increase in coefficient of deformation)	Purpose of Ground Improvement: Compressibility (Improvement of compressibility, into less-compressible material)	Purpose of Ground Improvement: Dynamic Characteristic (Improvement of dynamic characteristics, prevention of liquefaction)	Suitable Material	Cost of Ground Improvement per unit Floor Area, of Building (A (bldg))* Ground Type B	Ground Type C	Ground Type D	Basis for Cost Estimation 1. Machine and equipment are assumed to be available in Kuala Lumpur 2. Construction area: 40,000 m^2 3. Thickness of Improvement: 5m (type B, C), 10m (type D) 4. Total installation: 100,000 m		Notes
Soil Improvement / Increasing Soil Density / Dewatering	Consolidation	Pre-Loading		△	○		Clay, Silt	M$28	M$44	M$47	Height of Pre-loading is 3m	Area of Pre-loading 3xA(bldg)	Slower
	Consolidation	Pre-loading with Vertical Drains	Sand Drain	△	○		Clay, Silt	M$63	M$79	M$117	Height of Pre-loading is 3m, Area of Drain Installation=1.5xA(bldg)	3xA(bldg)	Faster
			Paper Drain	△	○		"	M$60	M$76	M$111	"	"	"
			Fabric Drain	△	○		"	M$57	M$73	M$105	"	"	"
	Pumping	Ground water Lowering Method	Well Point	△	○~△		Clay, Silt	M$78 (M$218)	-	-	interval of header pipe=30m, interval of wellpoint=2m; for t_{50}=5.7 months, *for t_{80}= 16 months		Assumed that clayey layer (t=5m) is sandwiched by 5m thick sand layers
			Deep Well	△	○~△		"	M$28 (M$39)	-	-	installed at grid points of 30mx30m; for t_{50}=5.7 months, *for t_{80}= 16 months		Difficult to estimate effectiveness due to unknown layering of ground
Soil Improvement / Increasing Soil Density / Compaction	with Machine	Vibro-Rod Method		○	○	○	Sand, Sandy Silt	M$50	-	-	including 0.5m of sand for the settlement of layer	Area of Improvement 1.5xA(bldg)	
		Vibrofloatation Method		○	○	○	"	M$54	-	-	"	"	
		Sand Compaction Pile Method		○	○	○	Sand, Silt, Clay	M$76	M$76	M$152	"	"	
		Dynamic Consolidation Method		○	○	○	Sand, Silt	M$50	-	-	"	"	
		Roller Compaction Method		○	○	△	All Material	M$1	-	-			shallow depth only (up to 1m)
Soil Improvement / Hardening	Chemical	Cement or Lime Method		○	○		Clay, Silt, (Sand)	M$309 M$280	M$309 M$280	M$617 M$560	(Lime) (Cement)		
		Chemical Composer Pile Method		○	△	○	"	-	-	-			
Replacement	Excavation	Replacement by Excavation	Full Excavation	○	○		All Material	-	M$90	-	Area of Replacement=2.0 x A (bldg)		possible up to about 5m deep
			Partial Excavation	△	△		"	-	-	-			
	Compulsory Replacement	Compulsory Replacement	With Weight of Fill	△	△		Clay, (Silt)	-	M$90	-			

○ effective
△ subordinate

* Refer to Table H-1 to H-7 in Appendix H in Volume 2.

and housing development planning with execution of soft ground improvement work in accordance with established schedules will play an important role in efficiently carrying out preloading.

2) If ground conditions are deemed suitable, a ground water lowering method using deep wells may also be one of the cheapest methods. However, technical applicability of this method must be evaluated in accordance with the subsurface ground condition at the proposed site.

3) Employment of vertical drains will be effective in accelerating the settlement of ground. However, vertical drains increase the cost of soft ground improvement with the result that employment of the same should be limited to specific areas where urgent improvement is required.

4) Compaction by mechanical methods is effective and economical on sandy grounds. This method is recommended for Type A ground, especially for areas where medium-rise structures are to be errected.

5) Replacement of soft material is expensive and also creates problems related to disposal of the excavated soft material. Therefore, replacement is not generally recommended. However, when time is limited or the

thickness of soft material is not great, replacement may prove to be acceptable.

SECTION 7 ENGINEERING STUDY FOR MASSIVE RECLAMATION AND OTHER EARTHWORKS

SECTION 7

ENGINEERING STUDY FOR MASSIVE RECLAMATION AND OTHER EARTHWORKS

Page

7. ENGINEERING STUDY FOR MASSIVE RECLAMATION AND OTHER EARTHWORKS

Based on the results of the investigations explained in Sections 4 and 5, it is known that the majority of the surface ground of ex-mining land is either 1) very soft clay, 2) soft clay, or 3) loose sand. For the execution of reclamation and other earthworks at ex-mining land, some remarks on processes of massive reclamation and other earthworks are presented in this section.

7.1 Very Soft Clayey Ground ($c_u = 0.1 \sim 0.3$ t/m^2)

7.1.1 Earth Fills

The following guidelines will apply for earth filling works on very soft clayey ground.

1) It is necessary to spread a thin sand layer of 20 to 30 cm in depth on the area at the beginning of the earth filling operation. Appropriate synthetic ground sheets are available to prevent heaving of extremely soft clay.
2) After the first sand layer is stabilized, placement of additional sand layers to a height of about 1 m should be done.
3) The slopes of the fills and/or embankments should be of a vertical to horizontal ratio of about 1 : 4 $\sim$ 5.
4) Special attention must be paid to prevent slope failure during the filling operation.

7.1.2 Excavation

Excavation of the ground can only be performed by manual operation with timber or steel sheet piles being used as earth-supporting structures. It should be noted that deep excavation is practically impossible (limited to say 1 m).

Special attention must be given to ground heave during excavation, and also to the possible collapse of earth-supporting structures.

7.1.3 Settlement

It is anticipated that an extensive amount of settlement will take place resulting from the load of the fill or structures. Special attention must be given to this phenomenon. A detailed study of settlement problems is made in Section 6.

7.1.4 Bearing Pressure

Allowable bearing pressure, Qa, for structures on clayey ground can be estimated as:-

$$Qa = 1.83\ c_u$$

where c_u is the undrained shear strength of the ground. For the very soft clay at the Sentul site, c_u is 0.1 to 0.3 t/m^2 at the ground surface. Thus, Qa is in the range of 0.2 to 0.55 t/m^2. This very small value must be given special note as it is insufficient in the majority of cases to support structures. In addition, individual settlement problems must be separately considered.

7.2 Soft Clayey Ground ($c_u = 1 \sim 1.5$ t/m^2)

7.2.1 Earth Fills

The following guideline will apply for earth filling works on soft clayey ground.

1) It is necessary to spread a thin sand layer of about 30 cm in depth on the ground.
2) Filling by general soils up to a height of about 2.5 m can be made without serious difficulty.
3) The slopes of the fills and/or embankment should be of a vertical to horizontal ratio of about 1 : 2.
4) It is expected that bulldozers equipped with tractors should be able to place fill materials on the site after the placement of a thin sandy layer on the original ground.
5) Attention must be paid to prevent slope failure during filling operations.

7.2.2 Excavation

Excavation of the ground can be performed with timber or steel sheet piles acting as earth-supporting structures. Excavation can also be made with a vertical to horizontal slope of about 1 : 2.

7.2.3 Settlement

It is anticipated that considerable settlement will take place as a result of the load of the fill or structrues.

7.2.4 Bearing Pressure

Allowable bearing pressure will be in the range of 2 to 3 t/m^2.

7.3 Loose Sandy Ground

7.3.1 Earth Fills

Earth filling can be performed without serious difficulty.

7.3.2 Excavation and Drainage

Excavation can be effected with sump-type water pumps or advanced dewatering by well-point or deep-well methods. Special care is needed to maintain slope stability of open cuts during excavation. Careful attention must be paid to avoid boiling of the bottom ground during excavation.

7.3.3 Bearing Pressure

Allowable bearing pressure in the range of 2 to 3 t/m^2 is anticipated. If the ground is properly compacted, higher values can be expected.

7.4 General Remarks

In addition to the observations on earthworks presented above, some general remarks are given below.

7.4.1 Drainage

(1) Drainage of Surface Water

Drainage of surface water including rain water must be properly implemented. Requirements for the drainage of surface water for housing developments located on ex-mining land do not differ from those for general housing developments. Attention should be directed towards ① securing proper formation level of the development area, and ② providing appropriate gradients within the development. These will be important in preventing flooding in the locality by facilitating proper drainage. Paving and/or turfing of the ground surface is also important in avoiding erosion.

(2) Drainage of Ground Water

When the drainage of surface water and an appropriate sewerage system are provided for housing development, drainage of underground water is not required.

However, for some specific situations such as those encompassing excavation for underground construction, drainage of underground water may be required. Wellpoints or deep wells will be effective for sandy ground whereas provision of drainage in clayey ground will be time consuming. In all cases, possible ground settlement should receive attention with solutions possibly to be found in the reduction of ground water levels.

7.4.2 Erosion

Proper measures should be taken to ensure a minimum of ground erosion by various types of surface water including that by rain water. Those generally employed such as paving, turfing, use of vegetation etc. will be effective in the present case to prevent erosion. Additional action such as the placement of surface fill consisting of well-graded general soils will be useful in the prevention of surface erosion. This is especially true in cases where ex-mining land is utilized as the ground is often poorly graded with instances of sand-rich or silt-rich areas which are easily eroded.

SECTION 8 STUDY ON FOUNDATIONS FOR PROPOSED HOUSING

SECTION 8

STUDY ON FOUNDATIONS FOR PROPOSED HOUSING

8. STUDY ON FOUNDATIONS FOR PROPOSED HOUSING

In this section, a study and evaluation on foundations for the proposed housing structures will be performed. Firstly, current practices regarding foundations for housing structures in Malaysia will be reviewed and summarized. Next, suitable types of foundations for low-, medium-, and high-rise structures will be studied together with the necessary types of soft ground improvement. Cost evaluation will also be made and the most recommendable type of foundation will be selected according to the size of the structure and the type of subsurface ground.

8.1 Current Practices for Building Foundations

In the 'Code of Practice for Building Operations', the following 9 types of pile foundations are listed:-

1) Wood Piles
2) Cast-In-Situ Concrete Piles
3) Precast Concrete Piles
4) Steel H-Piles
5) Steel Pipe Piles
6) Sheet Piles
7) Jack Piles
8) Caisson Piles
9) Composite Piles

Among these, piles No.1 through No.4 (i.e. wood piles, cast-in-situ concrete piles, precast concrete piles and steel H-piles) are most commonly used. Descriptions of these piles follow:

8.1.1 Wood Piles

Two types of wood piles, i.e. bakau piles and treated timber piles, are most popular in Malaysia.

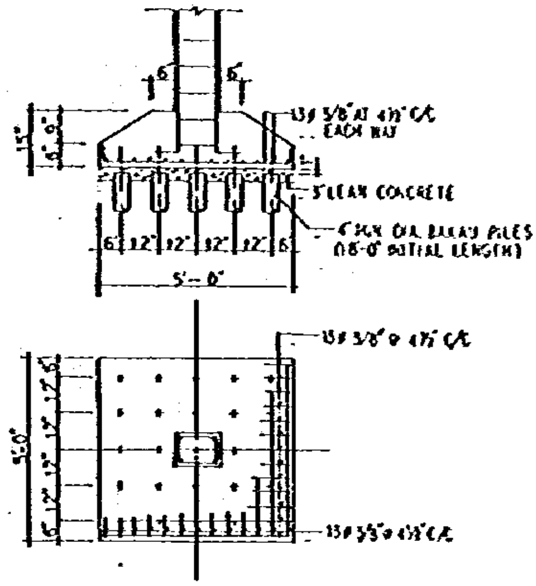
(1) Bakau Piles

'Bakau' is a Malay word meaning 'mangrove' (tropical maritime tree forming massive forests at coastal or river mouth areas). Bakau piles are logs obtained from these trees and are typically 4" to 6" diameter and 20 to 24 ft in length. They are normally used as friction piles, having an allowable load of about 1 ton per pile and are driven with a 400 to 600 lbs weight. Generally, bakau piles are used without jointing. However, for very soft ground a steel-sleeve joint may sometimes be employed. Details of typical bakau piles are given in Fig. 8-1.

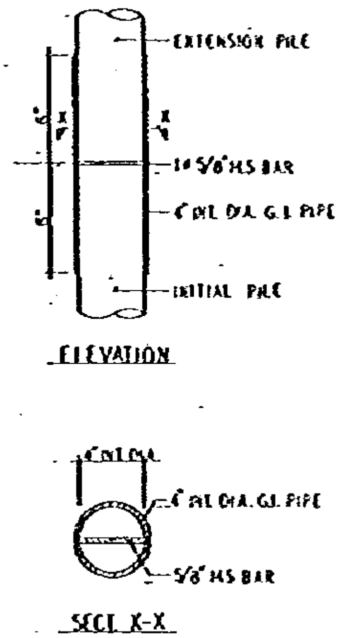
When using bakau piles, the wood decay must be checked. It is reported that wood piles will last for the life of structures if they are located under the groundwater level or in a moist or wet environment. Bakau piles are often closely spaced (average 1 ft), and any reduction of allowable load due to group effect must also be checked.

(2) Treated Timber Piles

Treated timber piles are also very popular in Malaysia. The dimensions of these piles are either 5" x 5", 6" x 6", or 7" x 7" with a standard length of 20 to 24 ft. The treated timber piles are generally manufactured from a broadleaf tree, either 'Kempas-Koompassie Malaccensis' or



PILE CAPS



PILE EXTENSION JOINT DETAIL

Fig. 8-1 Details of Typical Bakau Piles
(After PWD Standard Drawings)

'Keruing-Dipterocarpus spp'. They are pressure treated with a solution of copper chrome/arsenic.

The compressive strength of the pile material should exceed a pressure of 264 kg/cm^2 (3,750 psi) parallel to the grain. The safe working load for treated timber piles is 88 kg/cm^2 (1,250 psi) for compressive stress. Thus, allowable load per pile is:-

14 ton per 5" x 5" pile
20 ton per 6" x 6" pile
27 ton per 7" x 7" pile.

The extent of curvature is limited to:-

Within 1-1/2" (38 mm) for piles with $\ell \geq 20$ft
Within 1" (25 mm) for piles with $\ell < 20$ft

Typical details of the treated timber piles are shown in Fig. 8-2.

Treated timber piles are generally driven by dropping a 2,000 to 4,000 lbs (900 to 1,800 kg) weight from a height of about 3 ft. The piles are usually jointed with steel-sleeve joints. Variation in the allowable load due to joining or resulting from the slenderness ratio is generally not considered. However, in BSCP2004, it is necessary to check the influence of the slenderness ratio by assuming that:-

1) effective length is 2/3 rds of total length, and
2) one end is fixed and the other hinged.

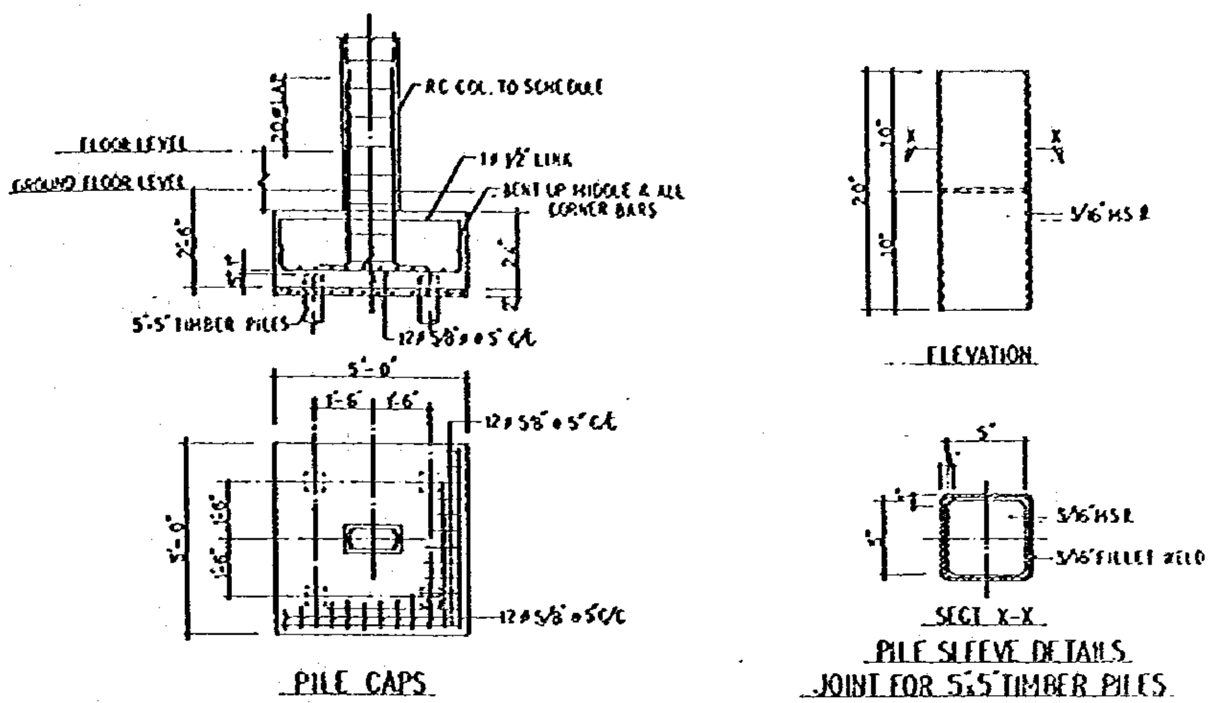


Fig. 8-2 Details of Typical Treated Timber Piles (After PWD Standard Drawings)

The influence of pile curvature may also be serious. Assuming that a 5" x 5" x 20' pile with a 38 mm curvature is used and a 14 ton load is applied, a bending moment of 0.532 t·m (M = 14 x 0.038 = 0.532 t·m) due to eccentricity is obtained. Stress in the pile is calculated from the following equation;

$$\alpha = \frac{P}{A} \pm \frac{M}{Z} = 86.7 \pm 155.8 = 242.5 \sim -69.1 \text{ kg/cm}^2$$

where, P : applied load, = 14 tons

M : bending moment due to eccentricity, = 0.532 ton·m

A : sectional area of pile, = 161.3 cm^2

Z : section modulus of pile, = 341.4 cm^3

In this case, the pile stress is very close to the breaking strength which equals 264 kg/cm^2. Lateral confinement of the surrounding ground and reduction of the vertical load by frictional ground resistance will act to reduce the bending moment with the result that the actual stress placed on piles already driven will not be as great as calculated above. However, the influence of pile curvature requires attention. Fig. 8-3 shows warping of treated timber piles.

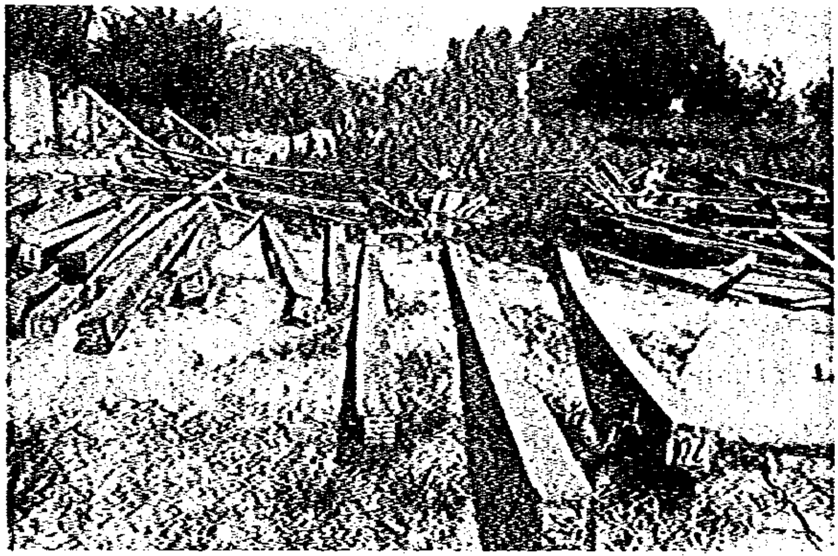


Fig. 8-3 Warping of Treated Timber Piles

8.1.2 Cast-In-Situ Concrete Piles

Cast-in-situ concrete piles are concrete piles that are cast at the construction site. Methods for constructing three types of cast-in-situ concrete piles follow:-

1) Vibro Piles - maximum pile depth : 140 ft.

pile diameter : 13-1/2" ~ 21"

2) Rotary Piles - maximum pile depth : 180 ft.

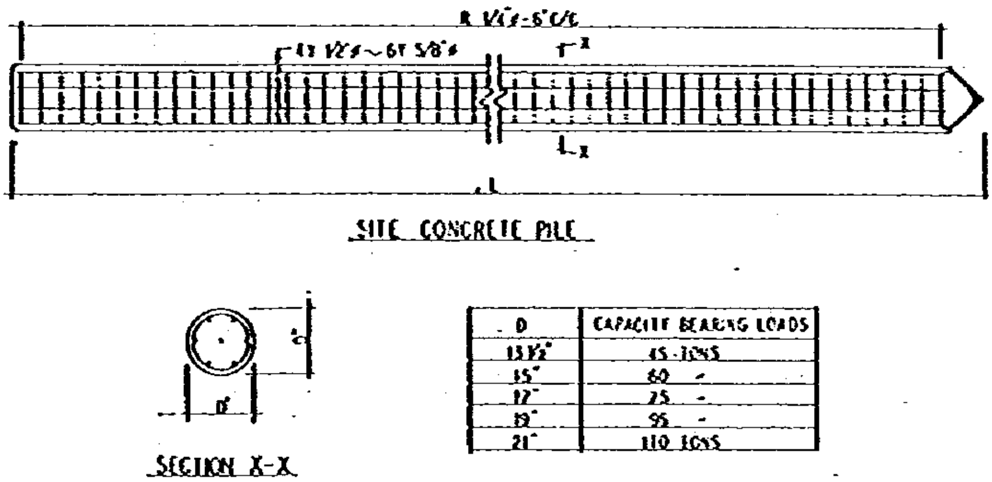
pile diameter : 7" ~ 18"

3) Bored Piles - maximum pile depth : 100 ft.

pile diameter : 19" ~ 24"

Design bearing capacities for vibro piles are 45 tons for a 13-1/2" diameter pile and 110 tons for a 21" diameter pile. Thus, bearing pressure at the pile tip is in the order of 500 ton/m^2, which is relatively high.

Casings are sometimes provided to protect against borehole wall collapse during driving. However, the use of casing is costly. Details of typical vibro piles are illustrated in Fig. 8-4.



D	CAPACITY BEARING LOADS
13 1/2"	45 TONS
15"	60 -
17"	75 -
19"	95 -
21"	110 TONS

Fig. 8-4 Details of Typical Vibro Piles

Quality of cast-in-situ concrete piles is greatly dependent on field performance during construction. Good workmanship by an experienced contractor with sufficient supervision is of fundamental importance. However, this is generally not easy to achieve. Poor bearing conditions at the pile tip and at the necking of the pile body are the most susceptible aspects of cast-in-situ concrete piles. The ground conditions of ex-mining land are generally unfavourable for cast-in-situ concrete piles (very soft deposits at shallow depths with very irregular bedrock surfaces). Thus these piles are generally not recommended for foundations in ex-mining land.

8.1.3 Precast Concrete Piles

Precast concrete piles are reinforced concrete piles with square sections. They are generally cast at the site. Standard concrete strength is σc_{28} = 3,750 psi (260 kg/cm^2) and high tensile steel is used as the main reinforcement. The sectional areas and designated bearing loads of piles in common use are shown below.

12" x 12"	60 ton/pile
14" x 14"	80 ton/pile
15" x 15"	100 ton/pile

The maximum length of the piles, which are made to correspond to a standard length of reinforcement, is 40 ft (about 12 m). The shoe and tip of the piles are reinforced with fabricated steel parts. Jointing is carried out by welding together the bands of upper and lower piles. Pile driving is usually performed with a Delmack hammer or by using a drop weight of 2 to 3 tons.

Details of typical precast concrete piles are shown in Figs. 8-5 and 8-6.

There is only one precast concrete pile manufacturer in Malaysia. As a result, site-cast reinforced concrete piles are utilized. Accordingly, the time required for acquisition of piling is based on the period necessary to manufacture and cure the piles at the site. Some examples of the time required for obtention of piling are:-

* Four months for 320 piles used in a high-rise building
* Six months for a similar number of jointed piles

Further, because it is very difficult to change the length of piles in accordance with changes in the depth of the supporting ground, longer piles are used with the result that a surplus length of 5 to 6 metres is frequently seen extending above the ground.

Where uneven bedrock surfaces in ex-mining land are encountered, extreme care should be exercised during the driving of RC piles as bending at the pile tip may occur, thereby resulting in sizeable damage to the same.

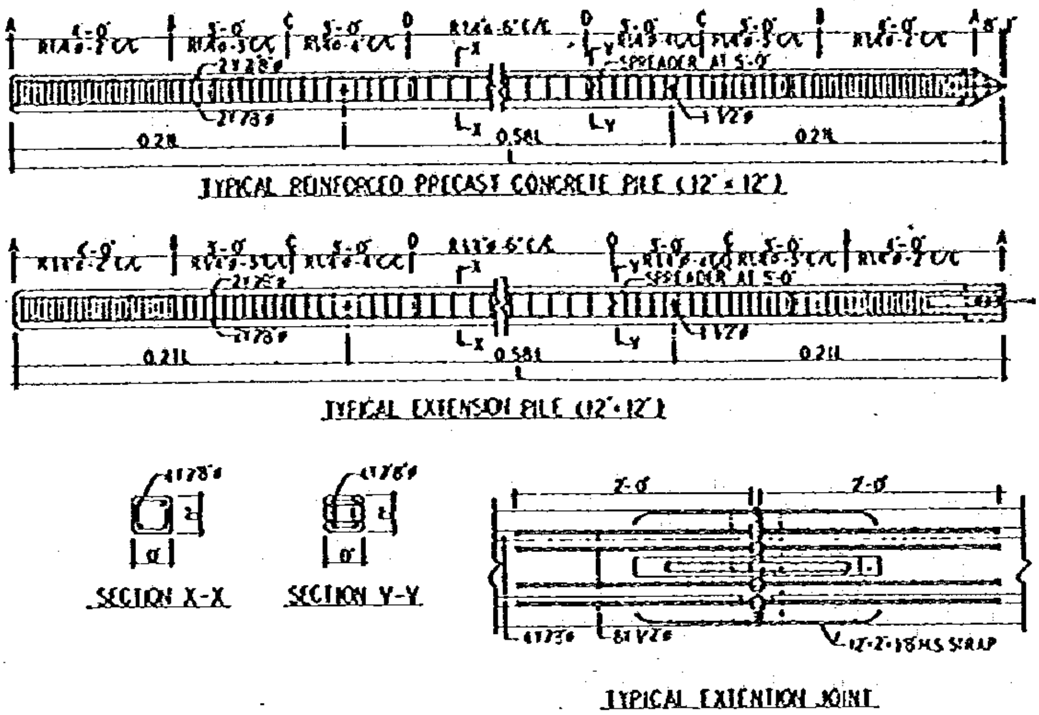


Fig. 8-5 Details of Typical Precast Concrete Piles
(After PWD Standard Drawings)

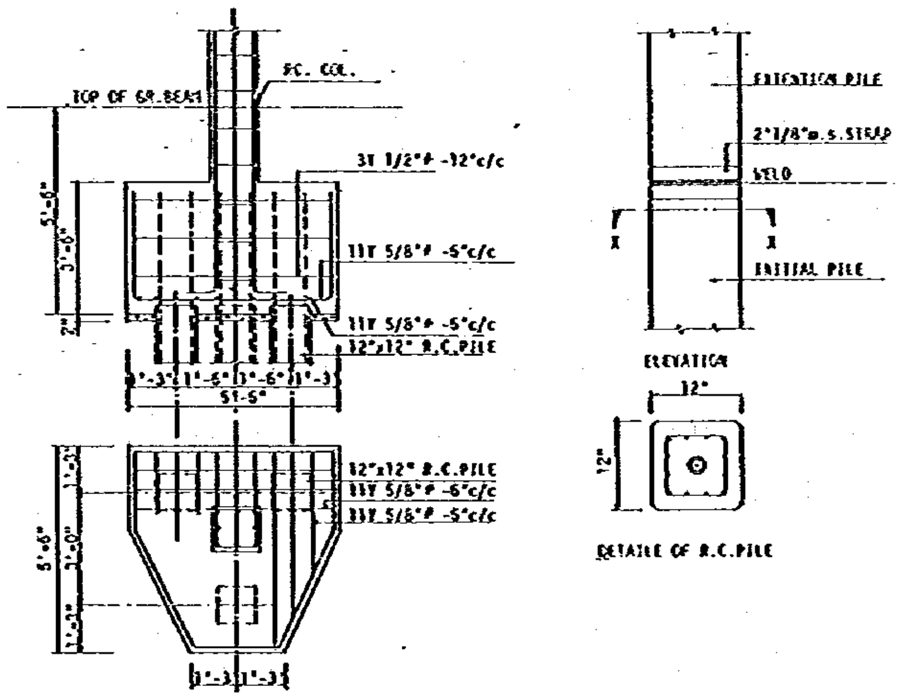


Fig. 8-6 Details of R.C. Pile Cap
(After PWD Standard Drawings)

8.1.4 Steel Piles

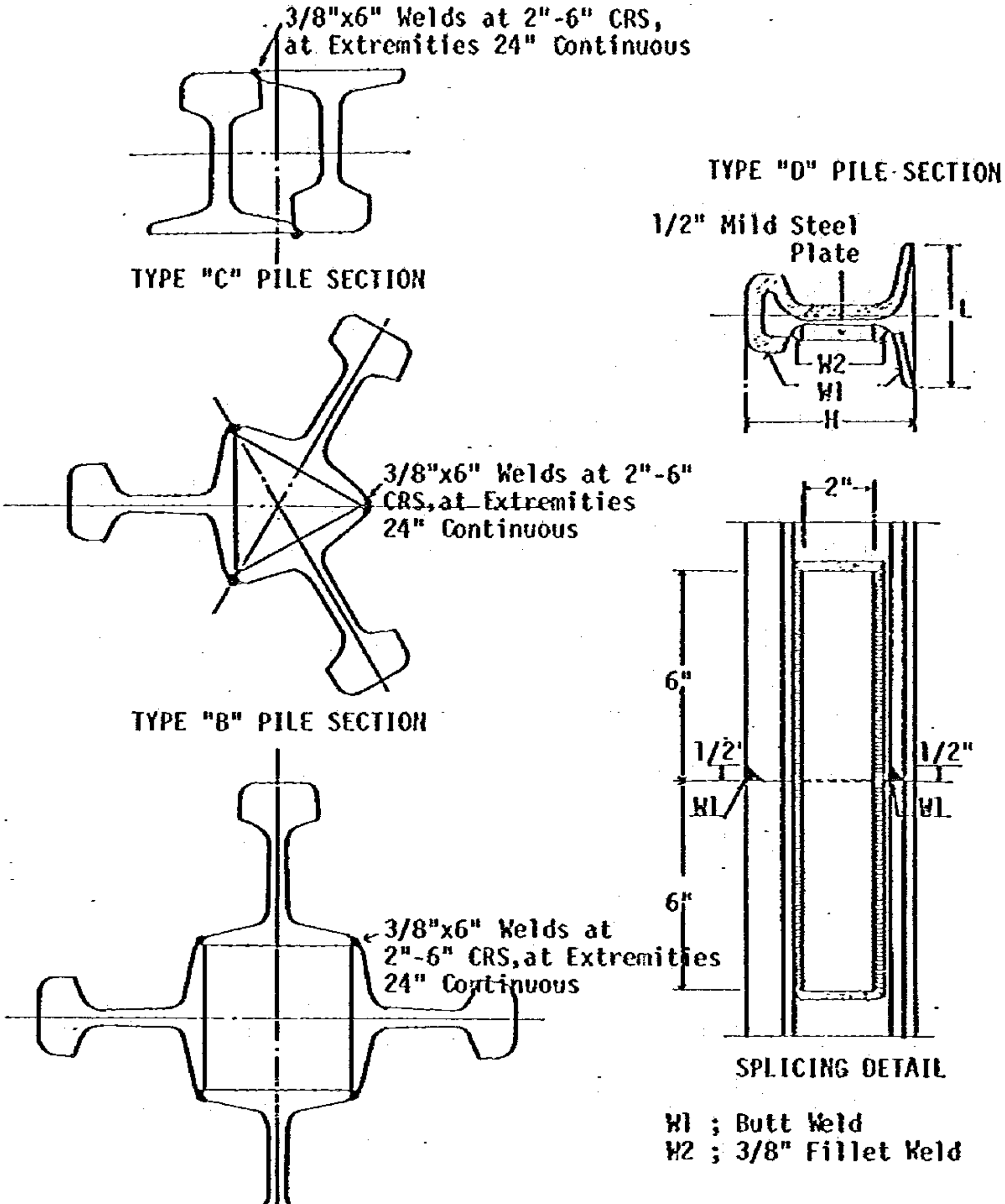
Steel H-piles, steel pipe piles, and used-rail piles are employed in Malaysia. Among these, steel H-piles are the most popular, followed by used-rail piles.

The dimensions and designated bearing loads of steel H-piles commonly in use in Malaysia are shown below:

Size	Weight (lb/ft)	Working Load Generally Employed in Malaysia (tons)
8" x 8"	36	60 ∿ 70
10" x 10"	42	80 ∿ 90
12" x 12"	53	90 ∿ 100
14" x 14"	89	150 ∿ 170

Steel H-piles are judged to be one of the most recommendable types of foundations for housing structures in ex-mining land.

Used-rail piles are also employed in Malaysia. They are used in the form of either single-rail or multi-rail piles with jointing being effected by welding. Possible problems encountered with rail piles are the reliability of the material as it has been previously used, the reliability of welded joints, and the slenderness ratio. The latter is especially true for single-rail piles. Rail-pile combinations and configurations are shown in Fig. 8-7.



Working Load of Piles				
WEIGHT	TYPE"A"	TYPE"B"	TYPE"C"	TYPE"D"
80 lb/yd	252 Tons	190 Tons	126 Tons	63 Tons
98 lb/yd	310 Tons	231 Tons	154 Tons	77 Tons
120 lb/yd	380 Tons.	285 Tons	190 Tons	95 Tons

Fig. 8-7 Details of Rail Piles

Rail piles may be used as they are relatively cheap and also as they fall within tolerable limits when driven into uneven bedrock surfaces. However, as previously noted, these piles are used materials and may have been damaged through earlier use. It is therefore necessary that the use of rail piles be limited to cases where structural strength is not in doubt.

8.2 Tolerable Settlement of Foundations

In general, when buildings are constructed on soft soil, piles for foundations are driven into solid strata. However, when deep supporting ground is encountered or when the building in question is light in weight, this method is a very un-economical. As alternatives, direct foundations, friction piles, or soil improvement methods are employed. The problem associated with the latter methods is differential settlement of foundations due to differences in ground settlement. Differential settlement of foundations will cause cracks in the superstructures. Structural designs to cope with this problem are given in the guidelines regarding reinforced concrete structures as found in the "Standard for Building Foundations" by the Architectural Institute of Japan. The following is an outline of the relevant guidelines.

8.2.1 Differential Settlement

Table 8-1 shows values proposed as tolerable differential settlements on the basis of the results of many studies and actual measurements, which are determined so as to not cause cracks in superstructures.

A larger value can be adopted when the time period required to reach 100 percent consolidation is of considerable length as deformation of the building can follow the differential settlement owing to the creep of concrete.

8.2.2 Maximum Tolerable Settlement

It is generally recognized that the greater the total settlement of the foundation, the larger the differential settlement. Table 8-2 shows recommended values of maximum tolerable settlement.

For raft foundations where maximum tolerable settlement is large, the ground-floor height and piping must be properly designed in advance to allow for possible settlement. In planning building construction on ground where consolidation settlement is anticipated, it is important to compute the settlement of the ground to ascertain whether the value falls within the range of the allowable values. In the event that analysis indicates an exceeding of these values, the following measures should be taken:

(1) Light-Weight Superstructures

Settlement is attributable to the load of a building. The most effective way to reduce this load is a reduction in the number of floors planned or the weight of the roof.

Table 8-1 Tolerable Differential Settlement

(cm)

Foundation	Isolated Foundation	Continuous Foundation	Raft Foundation
Standard	1.5	2.0	2.0 ∿ (3.0)
Maximum	3.0	4.0	4.0 ∿ (6.0)

Note: Values in parentheses to be used in cases where sufficient stiffness is secured by double slabs or strong ground beams.

Table 8-2 Maximum Tolerable Settlement

(cm)

Foundation	Isolated Foundation	Continuous Foundation	Raft Foundation
Standard	5	10	10 ∿ (15)
Maximum	10	20	20 ∿ (30)

Note: Values in parentheses to be used in cases where sufficient stiffness is secured by double slabs or strong ground beams.

(2) Increase in Structural Stiffness

Increased stiffness in the horizontal members of superstructures makes it possible to reduce the differential settlement of foundations. As a general practice it is desirable to increase the height of ground beams.

(3) Equalization of Weight Distribution

If the weight of a building is eccentric, greater differential settlement will naturally result. The design of buildings should be executed in such a way to produce an even distribution of weight.

As mentioned in Section 2.3.3, the main superstructures of low-cost housing in Malaysia are constructed of reinforced concrete in which concrete blocks and bricks are used as wall materials. Because the dominant loads are vertical ones, the majority of cross-sectional areas, including both horizontal members and ground beams consolidating the bottom of columns on the ground floor, are generally small. In some cases, no ground beams are used at all. While these practices are generally acceptable in the event of possible consolidation settlement, ground beams comprising a high level of stiffness must be employed to reduce differential settlement.

Finally, it should be noted that ground clearance of the first floor of most buildings in Malaysia is only about 10 cm. Due consideration must be given to this condition when the design of a building is based on a raft foundation as the allowable settlement is large.

8.3 Uneven Bedrock Formations

As has been repeatedly noted, the surfaces of bedrock formations at ex-mining sites undulate to such an extreme degree that damage may possibly result to foundation piles during driving. The existence of uneven bedrock surfaces also implies variations in the thickness of the soft, compressible, clayey layers, which cause uneven settlement of structures. This phenomenon is one of the most important and difficult aspects of providing foundations for structures at ex-mining sites. Fig. 8-8 shows variations in the length of rail piles driven within a 40 m distance at the Sentul site. The piles were driven by dropping a weight of 3 tons from a height of about 3 feet. Extreme variation in the depth of the harder layer is clearly indicated.

8.4 Foundation Cost Evaluation

With reference to the results of the study in Section 6 and the foregoing portion of this section, technical applicability of possible foundations and the improvement methods of soft ground are studied for the different types of housing structures, i.e. low-, medium-, and high-rise. Variations in subsurface ground conditions at the ex-mining sites are also considered, i.e. Types A, B, C and D. For the technically applicable foundation types, a series of cost studies is performed with the following items being examined in detail:-

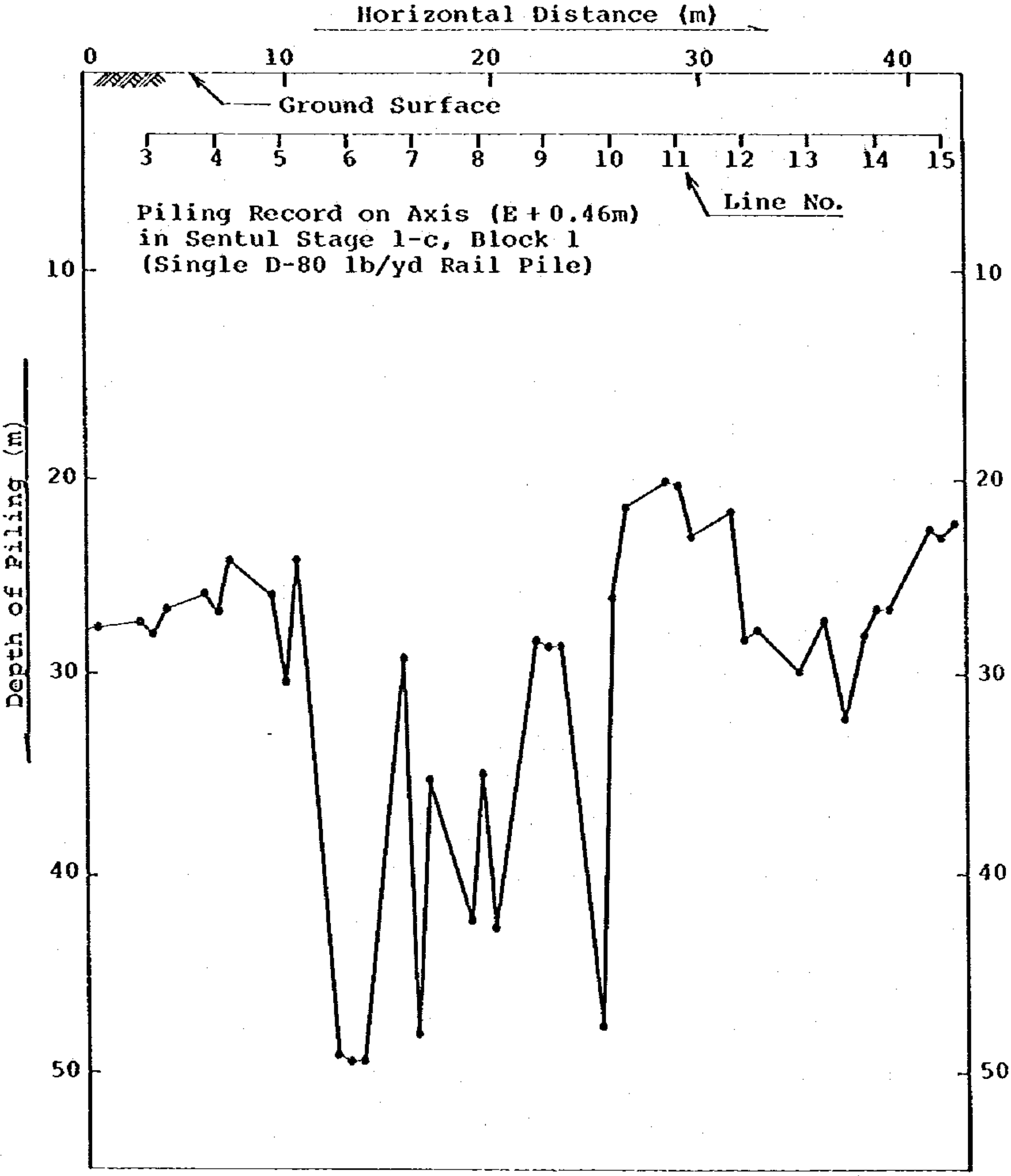


Fig. 8-8 Variation in Rail-Pile Depth at Sentul

1) Preloading and Surface Compaction

2) Ground Improvement Methods other than Preloading

3) Pile Foundations

Costs of foundations and soft ground improvement for the proposed housing development on ex-mining land are summarized and tabulated in Tables 8-3a to 8-3e. Further details of the aforementioned cost studies are given in Appendix H of Volume 2 with Tables H-1 and H-7 providing an overall summary of the results obtained.

8.5 Recommended Types of Foundations and Ground Improvement Methods

Subsequent to and based on the foregoing foundation engineering and cost evaluation studies, recommended types of foundations and/or soft ground improvement methods were selected for the various housing structures and subsurface ground conditions. The results are summarized and presented in Table 8-4.

Table 8-3a Cost Study on Foundation and Soft Ground Improvement, Type A Ground

Size of Building	Type of Foundation/Soil Improvement Method	Cost of Foundation and Soil Improvement per Unit Floor Area of Building (M$/$m^2$)	Assumed Pile Length	Conditions/Comments
Low-Rise [1F]	(1) Direct Foundation (Individual Footing, Strip Footing, Raft) + Surface Compaction by Mechanical Compactor	M$1/$m^2$		A-1 Costs for clearing, grubbing and surface compaction only.
Medium-Rise [5F]	(2) Direct Foundation + Compaction of Sand Layer (D = 5m)			A-2 Depth of soil improvement : 5m Initial N-value : 5 N-value after improvement : 15 Allowable bearing pressure: 10 t/m^2 A-3 For methods 2-1 through 2-4, necessary improvement of ground area equals 1.5 times floor area of building.
	2-1 Vibro-Rod	M$33.3/$m^2$ x 1.5 ≒ M$50/$m^2$		
	2-2 Dynamic Consolidation	M$33.5/$m^2$ x 1.5 ≒ M$50/$m^2$		
	2-3 Vibroflotation	M$36.0/$m^2$ x 1.5 ≒ M$54/$m^2$		
	2-4 Composer Pile	M$50.7/$m^2$ x 1.5 ≒ M$76/$m^2$		
	(3) Pile Foundation			A-4 Assuming pile is driven to firm layer. A-5 Material and pile-driving costs only. A-6 Unit cost of piles calculated assuming 30% more required than number of piles calculated from structural design load. A-7 Pile lengths of 10.5, 11.5, and 13m correspond to standard depth of 10m to firm layer. Pile length of 30m is for firm layer at deeper depths.
	3-1 Treated Timber Pile	M$46.4/$m^2$	10.5m	
	3-2 Steel Pile	M$152.1/$m^2$	30m	
High-Rise [18F]	(4) Pile Foundation			
	4-1 Steel Pile	M$283.1/$m^2$	13m	
		M$653.3/$m^2$	30m	
	4-2 RC Pile	M$175.2/$m^2$	11.5m	

Table 8-3b Cost Study on Foundation and Soft Ground Improvement, Type B Ground

Size of Building	Type of Foundation/Soil Improvement Method	Cost of Foundation and Soil Improvement per Unit Floor Area of Building (M$/m²)	Assumed Pile Length	Conditions/Comments
Low-Rise (1F)	(1) Direct Foundation + Preloading (H=1.5m)	5.8 x 3 = 17.4		B-1 Preloading material is normal earth available around site. B-2 Preloading necessary to cover area equal to 3 times floor area of building. B-3 Pile lengths of 10.5, 11.5, and 13m correspond to standard depth of 10m to firm layer. Pile length of 30m is for firm layer at deeper depths.
Medium-Rise (5F)	(2) Pile Foundation + Preloading (H=3m)			
	2-1 Treated Timber Pile	46.4 + 27.6* = 74.0	10.5m	
	2-2 Steel Pile	152.1 + 27.6 = 179.7	30m	
High-Rise (18F)	(3) Pile Foundation + Preloading (H=3m)			
	3-1 Steel Pile	283.1 + 27.6 = 310.7	13m	
		653.3 + 27.6 = 680.9	30m	
	3-2 RC Pile	175.2 + 27.6 = 202.8	11.5m	

* 9.2 x 3 = M$27.6/m² (Refer to condition B-2)

Table 8-3c Cost Study on Foundation and Soft Ground Improvement, Type C Ground

Size of Building	Type of Foundation/Soil Improvement Method	Cost of Foundation and Soil Improvement per Unit Floor Area of Building (M$/$m^2$)	Assumed Pile Length	Conditions/Comments
Low-Rise [1F]	(1) Direct Foundation + Preloading (H=1.5m)	10.6 x 3 = 31.8		C-1 Preloading material is normal earth available around site. Sand blanket is required (H=0.5m). C-2 Preloading necessary to cover area equal to 3 times floor area of building.
Medium-Rise [5F]	(2) Pile Foundation + Preloading (H=3.0m)			C-3 Pile lengths of 10.5, 11.5, and 13m correspond to standard depth of 10m to firm layer. Pile length of 30m is for firm layer at deeper depths.
	2-1 Treated Timber Pile	46.4 + 43.5* = 89.9	10.5m	
	2-2 Steel Pile	152.1 + 43.5 = 195.6	30m	
	(3) Direct Foundation + Replacement	45 x 2 = 90	X	C-4 Soil replaced to depth of 5m. C-5 For replacement, necessary to improve ground area equal to 2 times floor area of building.
High-Rise [18F]	(4) Pile Foundation (t=0.5m) + Preloading (H=3.0m)			
	4-1 Steel Pile	283.1 + 43.5 = 326.6	13m	
		653.3 + 43.5 = 696.8	30m	
	4-2 RC Pile	175.2 + 43.5 = 218.7	11.5m	

* 14.5 x 3 = M$43.5/$m^2$ (Refer to condition C-2)

Table 8-3d Cost Study on Foundation and Soft Ground Improvement, Type D Ground

Size of Building	Type of Foundation/Soil Improvement Method	Cost of Foundation and Soil Improvement per Unit Floor Area of Building (M\$/m²)	Assumed Pile Length	Conditions/Comments	
Low-Rise [1F]	(1) Direct Foundation + Preloading (H = 3.0m)	11.1 x 3 = 33.3	—	D-1 Preloading material is normal earth available around site. Sand blanket is required (H=0.5m). D-2 Preloading necessary to cover area equal to 3 times floor area of building. D-3 Pile lengths of 10.5, 11.5, and 13m correspond to standard depth of 10m to firm layer. Pile length of 30m is for firm layer at deeper depths.	Same as on Type C ground. However, longer time required for preloading and more settlement by preloading.
Medium-Rise [5F]	(2) Pile Foundation + Preloading (H = 3.0m)				
	2-1 Treated Timber Pile	46.4 + 46.5* = 92.9	10.5m		
	2-2 Steel Pile	152.1 + 46.5 = 198.6	30m		
High-Rise [18F]	(3) Pile Foundation + Preloading (H = 3.0m)				
	2-1 Steel Pile	283.1 + 46.5 = 329.6	13m		
		653.3 + 46.5 = 699.8	30m		
	2-2 RC Pile	175.2 + 46.5 = 221.7	11.5m		

* 15.5 x 3 = M\$46.5/m^2 (Refer to condition D-2)

Table 8-3e Cost Study on Foundation and Soft Ground Improvement, Type E Ground

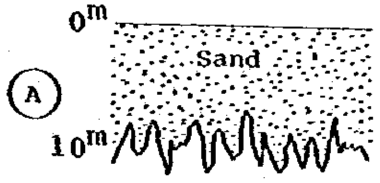
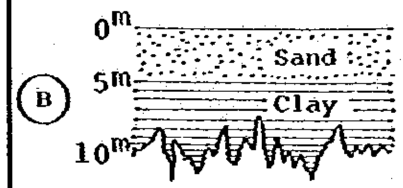
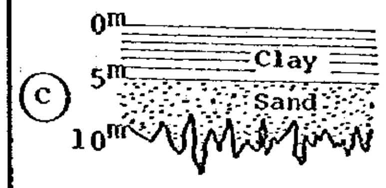
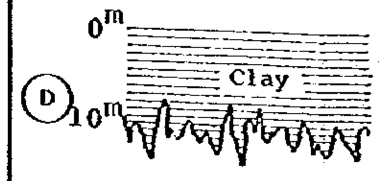
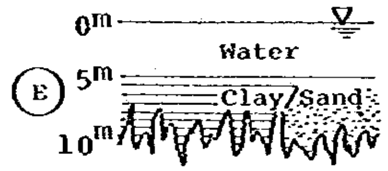
Size of Building	Type of Foundation/Soil Improvement Method	Cost of Foundation and Soil Improvement per Unit Floor Area of Building (M$/m²)	Assumed Pile Length	Conditions/Comments	
Low-Rise [1F]	(1) Direct Foundation + Fill (H=5m) with Preloading (H=1.5m)	41.0 x 3 = 123.0		E-1 Fill and preloading to cover 3 times floor area of building.	Type E ground is not to be used unless necessary as cost of treatment is expensive and time consuming.
Medium-Rise [5F]	(2) Pile Foundation + Fill (H=5m) with Preloading (H=2.0m)			E-2 Fill and preloading materials to be normal earth available around site. Sand blanket (H=1.0m) is also required.	If necessary, fill with sandy materials and follow procedures for Type B ground.
	2-1 Treated Timber Pile	46.4 + 126.6* = 173.0	10.5m	E-3 Pile lengths of 10.5, 11.5, and 13m correspond to standard depth of 10m to firm layer. Pile length of 30m is for firm layer at deeper depths.	
	2-2 Steel Pile	152.1 + 126.6 = 278.7	30m		
High-Rise [18F]	(3) Pile Foundation + Preloading (H=2.0m)				
	3-1 Steel Pile	283.1 + 126.6 = 409.7 653.3 + 126.6 = 779.9	13m 30m		
	3-2 RC Pile	175.2 + 126.6 = 301.8	11.5m		

* 42.6 x 3 = M$126.6/m² (Refer to condition E-1)

Ground Condition / Size of Structure	0m (A) 10m	0m Water 5m Clay/Sand (E) 10m
Low Rise (1 - 2F)	Surfac ... ired Direct (Indiv Strip	Not to be used unless necessary as cost of treatment is expensive and time consuming. If necessary, fill with sandy materials and follow procedures as in (B)
Medium Rise (4 - 5F)	Compact ... ired Vibro Dynar Vibro Compo Direct (2nd ch Surf Treat (or	Same as above
·High Rise (17 - 18F)	Surface ... ired Steel P (or RC/ Bored	Same as above

Note: Preloadi able.

Table 8-4 Recommended Types of Foundations and Ground Improvement Methods

Size of Structure \ Ground Condition					
Low Rise (1 - 2F)	Surface Compaction ↓ Direct Foundation (Individual Footing, Strip Footing, Raft)	Preloading (H = 1.5m) + Surface Compaction ↓ Direct Foundation	Sand Mat + Surface Soil (with Compaction) + Preloading (H = 1.5m) ↓ Direct Foundation	Same as (C) * Longer time required for preloading * More settlement by preloading	Not to be used unless necessary as cost of treatment is expensive and time consuming. If necessary, fill with sandy materials and follow procedures as in (B)
Medium Rise (4 - 5F)	Compaction of Sand Layer (D ≒ 5m) Vibro-Rod Dynamic Consolidation Vibroflotation Composer Pile ↓ Direct Foundation [2nd choice] Surface Compaction ↓ Treated Timber Pile (or RC/PC Pile)	Preloading (H = 3m) + Surface Compaction ↓ Treated Timber Pile (or RC/PC Pile)	Sand Mat + Surface Soil (with Compaction) + Preloading (H = 3m) ↓ Treated Timber Pile (or RC/PC Pile) [2nd choice] Replacement of Clay Layer ↓ Direct Foundation	Same as (C) * Longer time required for preloading * More settlement by preloading [2nd choice: ×]	Same as above
High Rise (17 - 18F)	Surface Compaction ↓ Steel Pile (or RC/PC Pile, Bored Pile)	Preloading (H = 3m) + Surface Compaction ↓ Steel Pile (or RC/PC Pile, Bored Pile)	Sand Mat + Surface Soil (with Compaction) + Preloading (H = 3m) ↓ Steel Pile (or RC/PC Pile, Bored Pile)	Same as (C) * Longer time required for preloading * More settlement by preloading	Same as above

Note: Preloading for ground Types B and C can be replaced by 'ground water lowering methods' where applicable.

SECTION 9 COMMENTS AND RECOMMENDATIONS ON TIN MINING OPERATION

SECTION 9

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9. COMMENTS AND RECOMMENDATIONS ON TIN MINING OPERATION

Tin is one of the natural resources with which Malaysia is blessed. Malaysia's tin production relative to that of other countries and its importance to the Malaysian society and economy are discussed in Section 3. It is a fact that the subsurface ground of ex-mining land has been markedly disturbed and its strength has been reduced. As stated in Sections 6, 7, and 8, it is, however, quite possible to use such land if appropriate methods are followed. It would be very wasteful to cease tin-mining operations solely because the ground condition of ex-mining land makes reusing the land difficult. And once an area has undergone urban development, it would be extremely difficult to extract tin or any other natural resources from the ground. The value of tin mining is not derived only from the sale of the tin-ore. The efficient use of mining process by-products and of abandoned mining land could be of great social and economic worth. The following comments on tin-mining operations are put forth with the intent of promoting such secondary development.

9.1 Use of By-Products of Tin Ore Extraction

The by-products of tin ore extraction, in order of their separation from the ore are:-

1) Rocks and coarse gravel expelled through the rock chute,
2) Fine gravel, sand and slime washed out from the sluice, and

3) Heavy minerals other than cassiterite (tin-ore)

The heavy minerals such as ilmenite, zircon, monazite, etc., are already sold extensively, therefore their use is not discussed here. Fig. 9-1 summarized the use of the by-products mentioned above and the use of bedrock exposed by gravel-pump mining.

9.1.1 Rocks and Coarse Gravel

The major material expelled through the rock chute is coarse gravel (ø = 1 to 10 cm), which is used as base course and coarse aggregate in concrete. When the gravel is used as concrete aggregate, it must be well washed and graded. The quantity of gravel is quite small, less than 5% of the total excavation volume, therefore it is advisable and profitable to sell it rather than to use it for backfilling. In 1980, the selling price of coarse gravel ranged from M\$10/m^3 to M\$20/m^3.

9.1.2 Fine Gravel and Sand

A considerable amount of fine gravel and sand washed out from the sluice is used in the construction of civil works. It must be well-washed before being used as fine aggregate in concrete. The selling price is in the range of M\$4 to M\$8/m^3.

Part of the sand may be used as silica sand for the production of glass, etc. The Malaysian Sheet Glass Sdn. Bhd. extracts silica sand from ex-mining sand and uses it in the production of glass. The plant extracted about 45,000 tons of

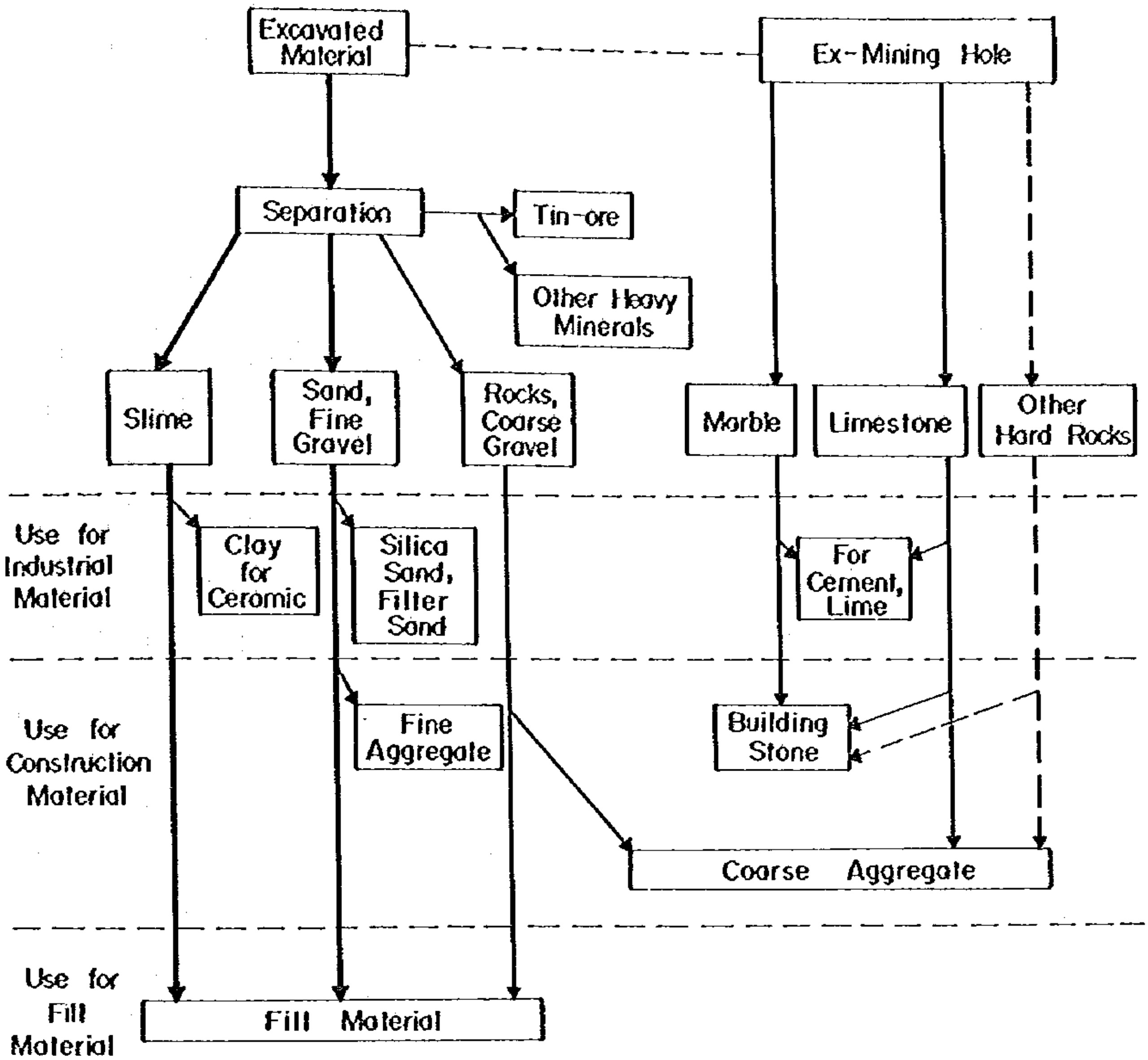


Fig. 9-1 Use of By-Products of Tin-Mining

silica sand in 1979, and its production cost was about M$30/ton (P.C. Aw, 1980). The market prices of silica sand and silica powder for that year were M$60 to M$120/ton and M$100 to M$400/ton respectively. These facts clearly demonstrate the profitability of such utilization.

Generally speaking, the sand content of the virgin ground is less than 50%; that of dredged tailings is about 60% to 80%. In the Federal Territory, most of the mines are exploiting ore deposits lying beneath the previously dredged tailings. This circumstance increases sand production ratios. Not all the mining sand can be sold because its use is required as backfill material and/or as preloading material. In view of this, up to 20% of the sand can be sold, without seriously affecting the future reclamation of ex-mining land.

9.1.3 Slime

Particles finer than sand are suspended in water and transported to sedimentation ponds to settle out as slime. Slime properties are source-dependent and vary greatly. In principle, slime can be used directly as various grades of ceramic material; simple mixtures of clay minerals can be used as high-grade ceramics. P.C. Aw (1978) reported that most slime from ex-mining land is equivalent to ball-clay, which to date, has been imported from Britain. The price range of ball-clay, as reported in the Industrial Minerals Magazine (August 1978) is listed below:-

Airdried, shredded, bulk, FOB £6 - £16/ton

(M$32 - M$86/ton)

Pulverized, air floated, bagged, FOB £22 - £42/ton

(M$119 - M$227/ton)

The price of ball-clay varies widely depending upon clay quality, and the quantity purchased.

The quantity of slime produced during mining is very large, because the virgin ground is more than 50% silt and clay. It is recommended to use slime for purposes other than fill material because slime exhibits poor soil properties as fill material. 20% to 30% of the slime can be used for other purposes without being detrimental to land reclamation if reclamation is well planned. The exact volume which can be sold will be determined primarily by the final backfill formation level. Even so, the outside demand for slime probably does not exceed 20% or 30% of the slime produced.

9.1.4 Bedrock

Marble, limestone and other rocks which are also unearthed in the mining process can be used as building materials, as aggregate for concrete or asphalt, as building stone, and as an ingredient of cement and lime. Smoothing the exposed bedrock surface by removing riffles and pinnackles is very advantageous if structures requiring deep foundations are planned to occupy the site after reclaimation. The price of building stone depends upon quality, primarily the luster and appearance of the polished surface. The price range of unpolished marble slab was M$220 to M$330/ton in 1978. Today the price of coarse aggregate, for use in concrete and asphalt, ranges between M$8 and M$18/m^3.

In the course of mining excavation, significant deposits of kaolin clay, ball clay, brick clay and other types of clay are sometimes discovered. These can be used in the manufacture of ceramics. In 1978, the general market price of kaolin was M$60 to M$80/ton for standard grade and M$250/ton for high grade.

It is believed that quality of gravel, sand and slime produced during mining operations can be improved, thereby increasing their value, without much additional cost, to the industry. They are already almost totally separated from each other through floatation in sluices, and need only to be slightly better cleaned and graded. In particular, the sale of slime for industrial use is highly recommended, since it is present in large quantities and it is also not very suitable as backfill material.

9.2 Proposed Arrangement of Mining Operation

As explained in Sections 5 and 8, ex-mining land can be generally divided into five types, designated as Types A, B, C, D and E. From an engineering viewpoint, it is easiest to design and construct structures for sandy sites like Type A. Where sand is amply available, it is therefore recommended to backfill the mined areas with sand only, in order to produce Type A ground. There is even a possibility of reducing future foundation costs by backfilling with compacted sandy soil in dry condition.

Type B ground, which is slime deposits covered with sand, is also a relatively good ground condition. Since there is not always enough sand to produce Type A ground only, the creation of Type B ground will be necessary at most mines.

The most serious engineering problem with Type B ground is settlement due to consolidation of the underlying slime. Consolidation continues for a long time; it generally takes more than a few years to complete the settlement. Even if consolidation due to the fill overburden is completed, consolidation will begin anew if addition load is applied, such as that from structures supported by direct foundation. It is therefore essential to consolidate the ground, taking into account future structural loading, before construction commences.

Reducing the time duration of consolidation is costly as explained in Sections 6 and 8. Therefore it is most economical to preload Type B ground before its planned utilization. It is possible to do this within the context of normal mining operations, using the discharged tailings as preload. The additional height of the layer of preload will vary individually from case to case depending upon the slime thickness and properties, overburden thickness, construction timing, proposed structure weight and foundation type. This preloading soil can then be removed and used as preloading material for adjacent sites. Fig. 9-2 illustrates such a preloading process.

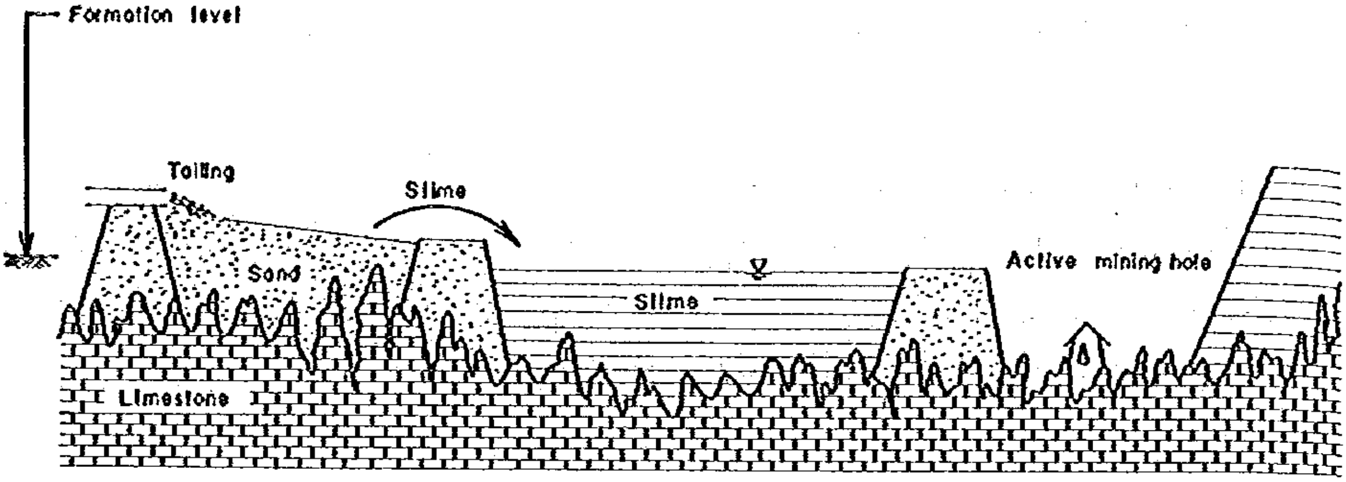


Fig. 9-2a

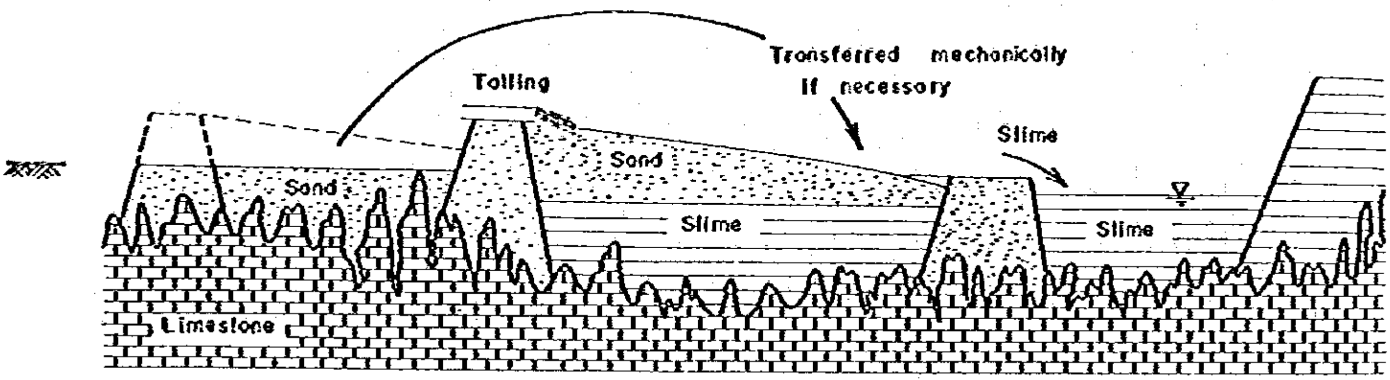


Fig. 9-2b

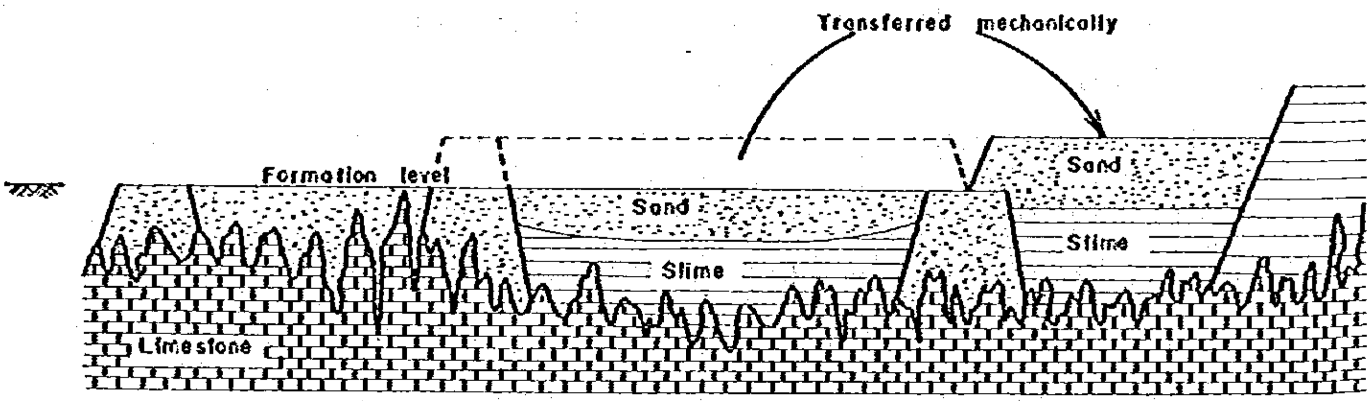


Fig. 9-2c

Fig. 9-2 Preloading with Sandy Tailings

Avoiding the formation of a single, thick layer of slime would also be a very effective way to reduce the period of consolidation. This can be accomplished by making minor modifications to the present mining operations.

Type C and Type D grounds have slime deposits at the ground surface, D being entirely slime to bedrock, C being underlying by sand. It is recommended that the production of these conditions be completely avoided as they are defective for construction purposes. When slime must be deposited, it should be covered by sand in order to form Type B ground.

Type E ground is insufficiently backfilled and therefore becomes filled with water. This is a consequence of an imbalance between excavation and backfilling, i.e. loss of soils. It is recommended to use such mining ponds as sites for sewage treatment works, water reservoirs, recreation ponds and future dumping areas for waste soil, etc. as designated in the Master Plan of the Federal Territory.

The implementation of all the comments and recommendations stated above in 9.1 and 9.2 would be much more effective and greatly simplified if the Master Plan of the Federal Territory were officially implemented. Then, the future use of land would be known at the time of mining operations, and it would be possible to locate and form each type of ground intentionally. It would also be possible to place preloads, and to optimally separate sand and/or slime for industrial use without much financial burden or inconvenience to the mining industry.

It is concluded that the efficient use of ex-mining land and tin-mining by-products is completely dependent not only upon foreknowledge of land-use zoning but also upon official implementation of the Master Plan.

SECTION 10 COST STUDY AND DEVELOPMENT MODEL

SECTION 10

COST STUDY AND DEVELOPMENT MODEL

10. COST STUDY AND DEVELOPMENT MODEL

In order to study the economic and financial aspects of the implementation of housing development on ex-mining land, it is necessary to summarize the unit cost of development and to set up typical development models. At the beginning of this section, costs of the various components of housing developments on ex-mining land are summarized. At the latter part of this section, typical housing development models are established with reference to the current practice in Malaysia. Costs cited are those current in 1980. Fig. 10-1 explains the flow of the cost study.

10.1 Cost Study

In this subsection, the unit costs of various items for housing development are studied and presented.

10.1.1 Price of Land

The prices of land in Kuala Lumpur in 1978 and 1979 are shown in Table 2-15 (see Section 2). From this table, the cost of land for housing development in 1979 is summarized in the left column of Table 10-1, and by applying the rate of increase during 1978 to 1979 the land prices for 1980 are estimated as shown in the column at the right.

However, for the housing development by the public sector, ex-mining land is generally available without any cost for land acquisition. Thus, costs for the acquisition of ex-mining land will not be included in this cost study.

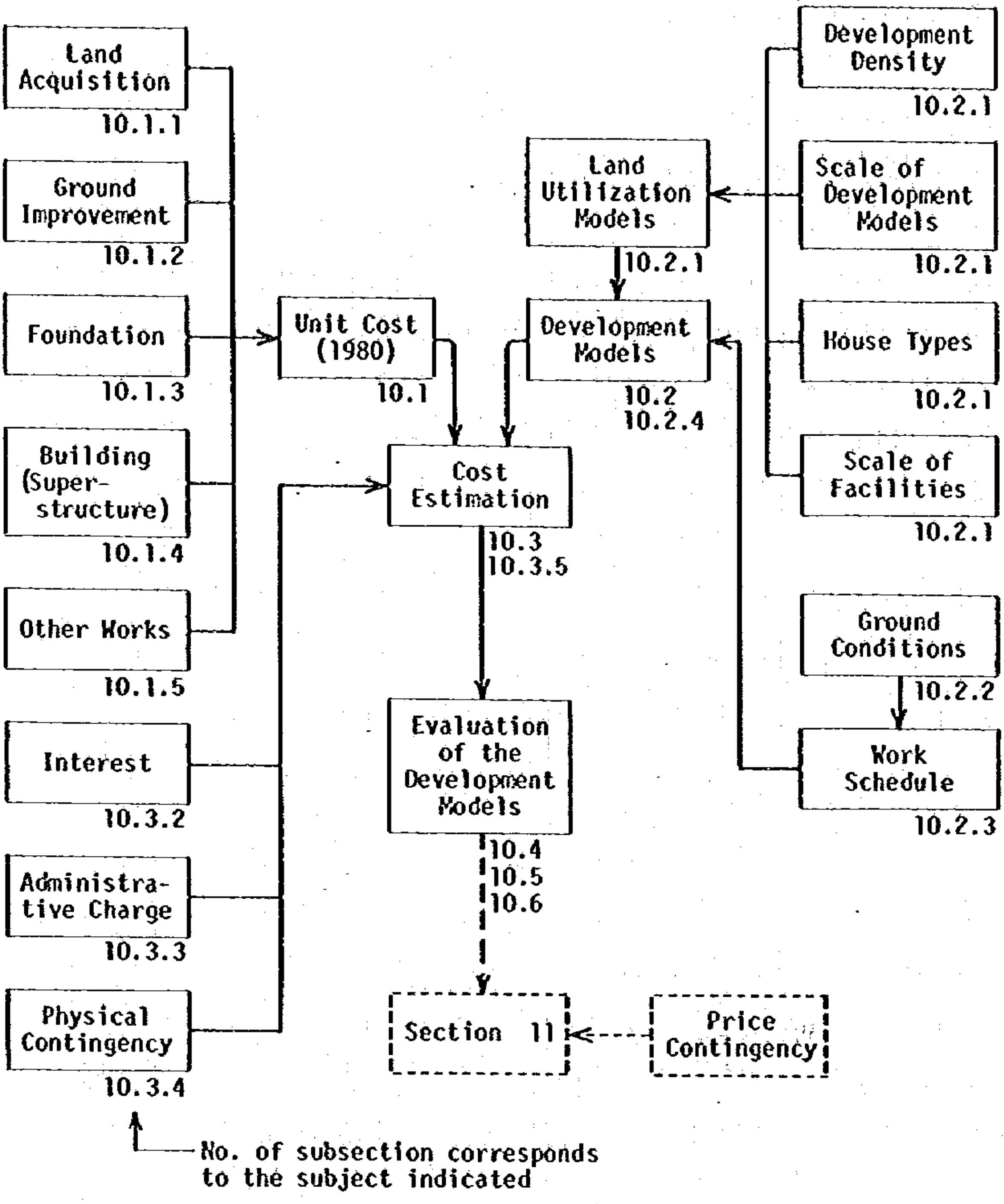


Fig. 10-1 Flow Chart of Cost Study

Table 10-1 Land Prices in and around Kuala Lumpur

Location			Land Prices (M$/ft²) in 1978	Land Prices (M$/ft²) in 1979	Rate of Increase 1978-1979	Estimated Land Prices in 1980 (M$/ft²)
Residential Area	TIONG NAM Settlement (Central Area)		29 ∿ 33	35 ∿ 40	20%	42∿48
Residential Area	MUKIM of SETAPAK and AMPANG		5∿6.2	6.2∿6.8	17%	7.3∿8.0
Development Land	MUKIM of K.L.	Land w/Road Frontage	1.15∿1.38	1.61	27%	2.04
Development Land	MUKIM of K.L.	Interior Land	0.69∿0.92	1.01∿1.24	39%	1.40∿1.72
Development Land	MUKIM of K.L.	Non-residential Land	0.35∿0.46	0.58∿0.69	57%	0.91∿1.08
Development Land	MUKIM of Batu		0.46∿1.15	0.58∿1.50	27%	0.74∿1.91
Ex-Mining Land			-	-	-	0∿0.5

10.1.2 Cost of Ground Improvement

(1) Ground Conditions of Ex-Mining Land

Of the 5 types of typical subsurface ground of ex-mining land (see Table 5-9 in Section 5), Type E is rather exceptional for housing development. Therefore, the costs of development on only the other 4 types of ground (shown in Fig. 10-2) will be evaluated in this section.

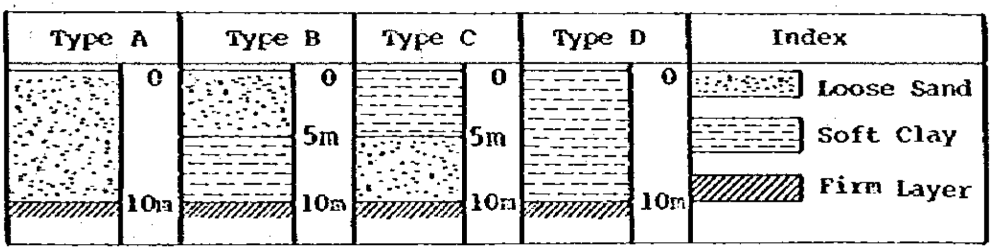


Fig. 10-2 Ground Conditions of Ex-Mining Land

(2) Cost of Ground Improvement

To construct stable structures and to eliminate long term settlement, various grades of ground improvement are necessary depending on the proposed structures and ground conditions.

The costs of ground improvement for the 4 types of ex-mining land are shown in Table 10-2.

Table 10-2 Unit Costs of Ground Improvement

Ground	Structure	Improvement Method	Unit Cost** (M$/m²)	Unit Cost** (M$/ft²)	Period for Improvement
Type A	Low-Rise	Surface Compaction Only	1.0	0.1	2 Months
	Medium-Rise				
	High-Rise				
Type B	Low-Rise	Surface Compaction + Preloading (H = 1.5 m)	17.4	1.62*	1 Year
	Medium-Rise	Surface Compaction + Preloading (H = 3.0 m)	27.6	2.57*	1 Year
	High-Rise				
Type C	Low-Rise	Sand Mat + Surface Soil + Surface Compaction + Preloading (H = 1.5 m)	31.8	2.95*	1.5 Years
	Medium-Rise	Sand Mat + Surface Soil + Surface Compaction + Preloading (H = 3.0 m)	43.5	4.04*	1.5 Years
	High-Rise				
Type D	Low-Rise	Sand Mat + Surface Soil + Surface Compaction + Preloading (H = 1.5 m)	33.3	3.09*	3 Years
	Medium-Rise	Sand Mat + Surface Soil + Surface Compaction + Preloading (H = 3.0 m)	46.5	4.32*	3 Years
	High-Rise				

* Required area of ground improvement is 3 times the area of the foundation of housing structures. Thus, unit costs shown in this table are 3 times the ground improvement cost per unit ground area.

** Refer to Tables 8-3a to 8-3d (Tables H-1 and H-7 in Volume 2 for more details).

10.1.3 Cost of Foundations

The load per unit area of one floor of each type of structure is as follows (refer to Section 2):-

Low-Rise	0.72 t/m^2	(147.6 lbs/ft^2)
Medium-Rise	0.78 "	(159.9 ")
High-Rise	0.93 "	(190.5 ")

The load per unit area of the foundation of each type of structure is as follows:-

Single-Storey	0.72 x 1 =	0.72 t/m^2	(147.6 lbs/ft^2)
5-Storey	0.78 x 5 =	3.90 "	(799.6 ")
18-Storey	0.93 x 18 =	16.74 "	(3,432.2 ")

The types and cost of foundations will be different according to the size of the structure (refer to Section 8). With the necessary improvement of soft ground, the following types of foundations will be used at the indicated unit costs.

Table 10-3a Unit Costs of Foundations

Type of Structure	Type of Foundation	Unit Cost**	
		(M$/$m^2$)	(M$/$ft^2$)
Single-Storey	Individual or Strip Footing	0.0	0.0*
5-Storey	Direct Foundation with Deep Ground Improvement or Treated Timber Pile	46.4	4.4
18-Storey	Steel Pile or RC Pile	175.2	16.5

* Cost of foundations for low-rise structures is included in cost of superstructures.
** Refer to Tables 8-3a to 8-3e (Tables H-1 and H-7 in Volume 2 for more details).

However, as a fundamental condition in the present study, contents of Table 10-3a are prepared in accordance with the requirement that the depth to the top of the foundation layer is 10 m. Therefore, the lengths of treated timber piles, RC piles, and steel piles are assumed to be 10.5 m, 11.5 m, and 13 m, respectively. However, in many locations in ex-mining land, longer foundations are needed due to a greater depth to the foundation layer.

In order to determine the influence of deeper foundations on the total construction cost, an additional case for 30 m deep foundations is studied. This depth of 30 m is based on results obtained from piles driven at Sentul as presented in Fig. 8-8 of Section 8. Unit costs and types of 30 m deep foundations are tabulated in Table 10-3b below.

Table 10-3b Unit Costs of 30 m Deep Foundations

Type of Structure	Type of Foundation	Unit Cost*	
		(M$/m^2)	(M$/ft^2)
5-Storey	Steel Pile	152.1	14.4
18-Storey	Steel Pile	653.3	61.2

* Refer to Table 8-3a (Table H-7 in Volume 2 for more details).

10.1.4 Cost of Superstructures

(1) Model of Housing Unit for the Present Cost Study

Typical models of low-cost housing are contained in:

"Pelan Pelan Rumah Kos Rendah" (jpn: 1980)

"Rekabentuk Rumah Awam Kos Rendah" (jpn: 1978)

Table 10-4 shows typical areas of the rooms of low-cost housing units. The average low-cost housing unit contains three living rooms and has a floor area of about 500 ft^2. In the present study, a housing unit with a floor area of 500 ft^2 will be used as the standard for all types of structures, i.e. for low-, medium-, and high-rise buildings. Fig. 10-3 shows the standard model of low-cost housing unit applied in the present cost study.

The number of inhabitants per unit after the minimum standard is: 3 persons x 3 rooms = 9 persons. However, considering a possible improvement in the standard, 5 persons are used as the inhabitants per unit in the present study. Thus, in the following study, population is calculated by:-

Population = 5 Persons x No. of Housing Units

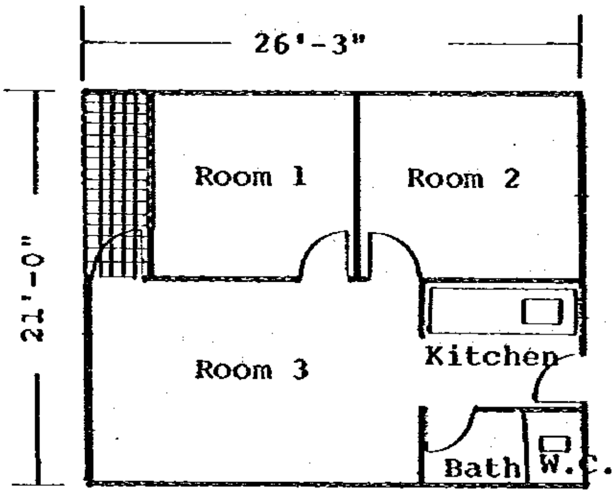
(2) Housing Layout Models for the Present Cost Study

Housing layout models for 3 types of structures, i.e. low-, medium-, and high-rise applied in this cost study are shown in Figs. 10-4 to 10-6.

Table 10-4 Typical Floor Area of Low-Cost Housing Unit Rooms*

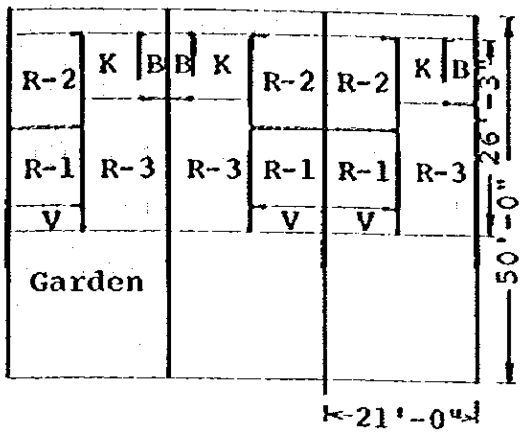
Type	Living Room 1	Living Room 2	Living Room 3	Living Room 4	Kitchen	Bath-room & Toilet	Total of Private Areas	Balcony Terrace	Remarks
P5/3/1	184	110	128	-	61	31	514	37	5-Storey
P5/2/1	126	145	-	-	47	24	342	39	"
D1/4/1	190	95	95	84	93	27	584	130	Single-Storey Terrace House
D1/4/2	176	120	80	80	70	20	546	44	"
D1/3/2	207	126	126	-	118	38	615	135	"
D1/3/3	180	121	99	-	58	33	491	124	"
D2/3/2	240	120	120	-	52	26	558	-	Double-Storey Terrace House
D17/2/1	123	142	-	-	47	21	333	37	17-Storey

* measurements in ft^2



Floor Area	500 ft^2
Veranda Area	50 ft^2
Total Area	550 ft^2

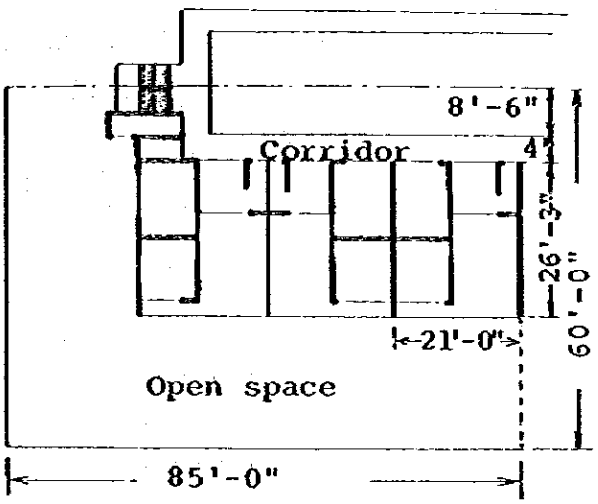
Fig. 10-3 Standard Model of Low-Cost Housing Unit Adopted in Present Cost Study



Site Area per Housing Unit:	1,050 ft^2
Foundation Area per Housing Unit (including veranda):	550 ft^2

R-1: Room 1 K: Kitchen
R-2: Room 2 B: Bath & Toilet
R-3: Room 3 V: Veranda

Fig. 10-4 Housing Layout Model (Single-Storey)



Number of Housing Units per Building:

3 x 4 x 5 = 60 units

Site Area per Housing Unit:

60ft x 85ft x 4 ÷ 60 = 340 ft^2

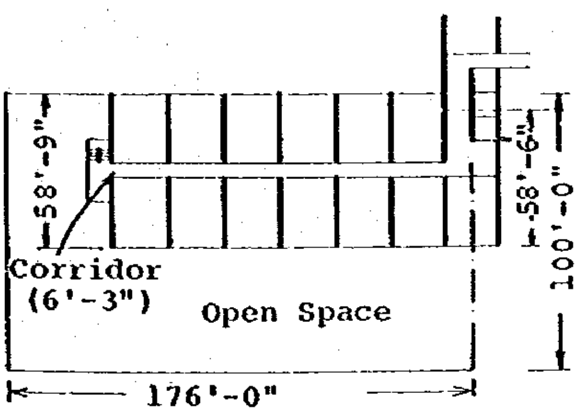
Foundation Area per Housing Unit:

1,995 ft^2 x 4 ÷ 60 = 133 ft^2

Floor Area per Housing Unit:

1,995 ft^2 x 4 ÷ 12 = 665 ft^2

Fig. 10-5 Housing Layout Model (5-Storey)



Number of Housing Units per Building:

26 x 18 = 468 units

Site Area per Housing Unit:	150 ft^2
Foundation Area per Housing Unit:	37 ft^2
Floor Area per Housing Unit:	660 ft^2

Fig. 10-6 Housing Layout Model (18-Storey)

(3) Cost of Superstructure per Housing Unit

The construction cost of housing structures for 1978 is summarized in Table 10-5. From this table it can be seen that low-rise houses costed about M$9.0/ft^2, medium-rise houses costed about M$12.5/ft^2, and high-rise houses costed about M$15.0/ft^2 in 1978. On the other hand, the annual rate of increase in construction costs (as given in Table 2-5) is 23.8% to 31.0% with the average being 27.4%. Thus, by applying an annual rate of increase of 27.4%, i.e. 62% for a total of 2 years, costs for 1980 can be estimated. Table 10-6 indicates estimated construction costs of superstructures for 1980. Table 10-7 shows a breakdown of construction costs of the superstructures. Table 10-8 shows the cost of the mechanical works.

10.1.5 Other Works

(1) Roads

With regard to unit costs of access service roads and drains, examples for 1978 have been reported to be 25,000 to 35,000 M$/acre (Rekabentuk Rumah Awam Kos Rendah). For main access roads, costs for pavement and base course will be added to the cost of access service roads. Thus, costs for main access roads are estimated by increasing those for access service roads by 50%. In addition, medium values are adopted for the model costs of main and access roads.

Table 10-5 Construction Cost of Superstructures (1978)

Type	Storey	Floor Area (ft²/unit)	Construction Cost (M$/Unit)			Unit Cost of Superstructure (M$/ft²)
			Total	Foundation	Superstructure	
Low-Rise	Single	336	3,100	—	3,100	9.2
		387	3,300		3,300	8.5
		387	3,500		3,500	9.0*
		458	4,000		4,000	8.7
		520	4,500		4,500	8.7
		647	5,500		5,500	8.5
		750	5,400		5,400	7.2
	Double	351	3,800	—	3,800	10.8**
		352	3,300		3,300	9.4*
		395	3,600		3,600	9.1
		479	4,100		4,100	8.6
		558	4,800		4,800	8.6
Medium-Rise	5	381	6,000	600	5,400	14.2
		551	6,600	700	5,900	10.7
High-Rise	17	370	6,200	600	5,600	15.1

* Bangalow house
** With structure for additional building

Notes: 1) Costs of interior finishing, interior plumbing, footings, etc. included

2) Table prepared after 'Rekabentuk Rumah Awam Kos Pendah'

Table 10-6 Estimated Construction Cost of Superstructures for 1980

Model	Construction Cost in 1978 (M$/ft²)	Rate of Increase during 1978 to 1980	Estimated Construction Cost in 1980	
			(M$/ft²)	(M$/Unit)
Low-Rise	9.0	62%	14.6	8,045
Medium-Rise	12.5	"	20.3	11,165
High-Rise	15.0	"	24.3	13,365

Table 10-7 Breakdown of Construction Cost of Superstructures (1980)

(M$ per Unit)

	Total Cost	Architectural Works	Electrical Works*	Mechanical Works**
Low-Rise	8,045	7,335	710	Nil
Medium-Rise	11,165	10,345	710	110
High-Rise	13,365	11,885	710	770

* Based on information obtained from hearings on case-histories from City Hall

** See Table 10-8

Table 10-8 Cost of Mechanical Works

Location	Sentul (1979)	Sentul (End of '80)	Cheras (End of '80)	Total
No. of Blocks No. of Units	3 Blocks 768 Units (17-Storey)	2 Blocks 512 Units (17-Storey)	5 Blocks 1,020 Units (18-Storey)	2,300 Units
Lift (1979) Pump (1979) Firefighting (1979)	M$339,200 17,650 57,573	- - -	- - -	- - -
	↓converted*			
Lift (1980) Pump (1980) Firefighting (1980)	M$390,080 20,298 66,212	M$353,200 - -	M$771,600 - -	M$1,514,800) 86,510

Cost per Unit

(a) Lift (1980) .... 1,514,800/2,300 ≒ M$660/Unit
(b) Pump + Firefighting (1980) .. 86,510/768 ≒ M$110/Unit

Cost of Mechanical Works

(a) Low-Rise .... ≒ Nil
(b) Medium-Rise ≒ Pump + Firefighting ≒ M$110/Unit
(c) High-Rise ≒ Lift + Pump + Firefighting ≒ M$770/Unit

* Converted by 15% inflation ratio

Pedestrian paths will be constructed as shown in Fig. 10-7. As for the unit cost of the pedestrian paths, an example of 5,200 to 10,400 M$/acre (afore-mentioned data - 1978) has been reported, and the medium value has been adopted.

The percentage rise in constructional costs for 1978 to 1980 has been established at 32% by using an annual increase rate of 15% for general civil works. Table 10-9 summarizes unit construction costs for roads.

(2) Parking Lot

The unit construction cost of parking lots is estimated to be 80% of that for access service roads with the unit cost being established as follows:-

$$39,600 \times 0.8 \fallingdotseq 31,700 \text{ M\$/acre}$$

(3) Parks and Other Open Spaces

The same unit cost as that for pedestrian paths will be applied for construction of parks and playgrounds. Also, the same construction unit cost will be applied to the private area of each housing unit. For other spaces such as green areas or open spaces, M$4,600/acre is used as the unit cost for 1980 (see Table 10-10).

(4) Water Supply and Drainage

Construction costs for water supply and drainage per residential unit are fixed as shown in Table 10-11.

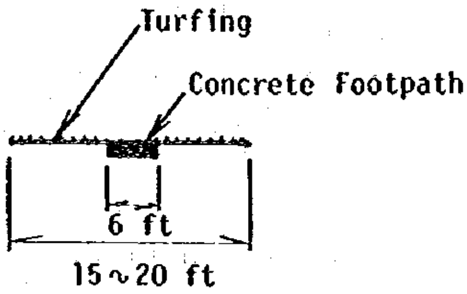


Fig. 10-7 Standard of Pedestrian Paths

Table 10-9 Construction Cost of Roads

Type	Construction Cost of Road in 1978 (M$/acre)	Rate of Increase during 1978 to 1980*	Estimated Construction Cost of Road in 1980 (M$/acre)
Main Access Road	45,000	32%	59,400
Access Service	30,000	32%	39,600
Pedestrian Path	7,800	32%	10,300

* Assumed/estimated to be 15% per year

Table 10-10 Construction Cost of Parks and Open Spaces

Type	Unit Price in 1980 (M$/acre)
Park	10,300
Open Space	4,600

Table 10-11 Cost for Water Supply and Drainage

Type	Unit Price in 1980 (M$/unit)
Water Supply	200
Drainage	650

10.2 Establishment of Development Models

10.2.1 Ground Utilization Models

As shown in Table 10-12, 9 different ground utilization models are established based on the conditions described below. High density development models with low-rise houses and very high-density development models with low-rise and medium-rise houses are unpractical to establish.

(1) Development Density

The ground utilization models are established in 4 cases of development density, as shown below:

Model	Density
Low-Density Development Model	60 Persons/Acre
Medium-Density "	100 "
High-Density "	200 "
Very High-Density "	250 "

(2) Scale of the Development Models

The development models are established per 100 acres of development area.

(3) House Types

The house types are selected for 3 types, i.e. low-rise, medium-rise and high-rise houses.

Low-Rise Houses	:	Single-Storey
Medium-Rise Houses	:	5-Storey
High-Rise Houses	:	18-Storey

Table 10-12 Ground Utilization Models for 100 Acre Areas

Unit: acre

Development Density			Low-Density (60 persons/acre)			Medium-Density (100 persons/acre)			High-Density (200 persons/acre)		Very High-Density (250 persons/acre)
Population			6,000 Persons			10,000 Persons			20,000 Persons		25,000 Persons
Number of Houses*1			1,200 Houses			2,000 Houses			4,000 Houses		5,000 Houses
House Structure Type			Low-Rise	Medium-Rise	High-Rise	Low-Rise	Medium-Rise	High-Rise	Medium-Rise	High-Rise	High-Rise
Ground Utilization Models (acres)	Housing	(Building Area)*2	(15.19)	(3.67)	(1.02)	(25.32)	(6.11)	(1.70)	(12.22)	(3.40)	(4.25)
		Site Area	28.95	9.38	4.14	48.25	15.63	6.89	31.26	13.78	17.23
	Roads	Main Access	15.00	15.00	15.00	16.00	16.00	16.00	18.52	18.52	20.00
		Access Service	1.79	1.79	1.79	2.99	2.99	2.99	5.98	5.98	7.45
		Pedestrian	5.79	-	-	7.35	-	-	-	-	-
	Parking Lot		2.34	2.34	2.34	3.91	3.91	3.91	7.82	7.82	9.78
	Parks		4.55	4.55	4.55	6.00	6.00	6.00	10.76	10.76	12.63
	Other Open Spaces		31.10	56.46	61.70	0.56	40.53	49.27	≒ 0	17.46	1.88
	School		9.10	9.10	9.10	12.64	12.64	12.64	21.08	21.08	25.28
	Other Facilities		1.38	1.38	1.38	2.30	2.30	2.30	4.60	4.60	5.75
	Total		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

*1: 5 persons per house *2: Building area is included in site area

(4) Scale of Facilities

(a) Roads

i) Main Access Roads

For main access roads, a standard is established for maintaining 15% of the development area in case of low-density development models (60 persons/acre), and 20% of the area in case of very high-density development models (250 persons/acre).

The percentages of the area of main access roads for medium- and high-density development models are superimposed using the percentages for low- and very high-density development models as follows:-

For the medium-density development model (100 persons/acre)

$$(100 - 60) \times \frac{(20\% - 15\%)}{(250 - 60)} + 15\% = \underline{16.0\%}$$

For the high-density development model (200 persons/ cre)

$$(200 - 60) \times \frac{(20\% - 15\%)}{(250 - 60)} + 15\% = \underline{18.5\%}$$

ii) Access Service Roads

According to Rekabentuk Rumah Awam Kos Rendah, the necessary area for access service roads is 50 ft^2/house to 80 ft^2/house. For the standard in the present study, a medium value of 65 ft^2/ house is employed and the following percentages of the total development area are calculated.

60 Persons/Acre:	65 ft^2/house x 60 persons/acre	
	÷ 5 persons/house	
	= 780 ft^2/acre	
	= 1.79% of the development area	
100 Persons/Acre:	1,300 ft^2/acre	
	= 2.99% of the development area	
200 Persons/Acre:	2,600 ft^2/acre	
	= 5.98% of the development area	
250 Persons/Acre:	3,250 ft^2/acre	
	= 7.45% of the development area	

iii) Pedestrian Paths

Pedestrian reserves will be established only for low-rise housing districts as shown in Fig. 10-8.

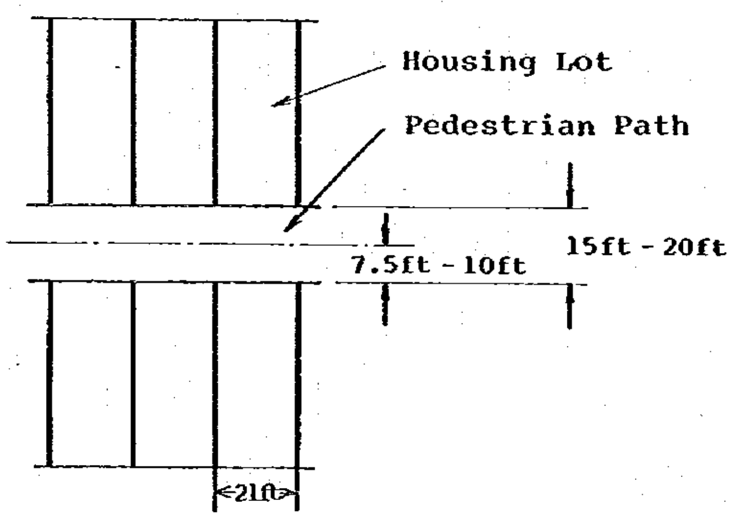


Fig. 10-8 Model of Pedestrian Path

For the low density development model (60 persons/acre), a 20 ft-wide pedestrian path is employed. Thus:-

$$20' \div 2 \times 21' = 210\ ft^2/house$$
$$= \underline{5.79\%}\ \text{of the development area}$$

For the medium-density development model (100 persons/acre), a 15 ft-wide pedestrian path is employed. Thus:-

$$15' \div 2 \times 21' \fallingdotseq 160\ ft^2/house$$
$$= \underline{7.35\%}\ \text{of the development area}$$

(b) Parking Lots

According to the Report of Minimum Standard for Low-Cost Housing (refer to Section 2), the parking lots are as follows:

Car	14,000 ft^2/1000 Persons	
Motorcycle	50 No./1000 P.	(≒1,000 ft^2/1000 p.)
Bicycle	180 No./1000 P.	(≒2,000 ")
Total	≒ 17,000 ft^2/1000 Persons	

Converting 17,000 ft^2/1000 persons into area per house, it will be 85 ft^2/house and this will be regarded as the standard for the cost study. Thus, the percentages of parking lots to development areas are as follows:

60	Persons/Acre:	85 ft^2/house x 12	houses/acre	=	2.34%
100	"	: 85 ft^2/house x 20	"	=	3.91%
200	"	: 85 ft^2/house x 40	"	=	7.82%
250	"	: 85 ft^2/house x 50	"	=	9.78%

(c) Parks

In the afore-mentioned Minimum Standard, 0.5 to 1 acre/1000 persons is specified for parks. For the low-density development model (60 persons/acre), the medium value of 0.75 acre/1000 persons is employed. Thus:-

0.75 acre/1000 persons x 60 persons/acre x 100
= 4.55%

For the very high-density development model, the low value of 0.5 acre/1000 persons is employed. Thus:-

0.5 acre/1000 persons x 250 persons/acre x 100
= 12.63%

The percentages of park area for medium- and high-density development models are superimposed using the percentages for low- and very high-density development models as follows:-

For the medium-density development model
(100 persons/acre)

$$(100 - 60) \times \frac{(12.5\% - 4.5\%)}{(250 - 60)} + 4.55\% = \underline{6.00\%}$$

For the high-density development model
(200 persons/acre)

$$(200 - 60) \times \frac{(12.5\% - 4.5\%)}{(250 - 60)} + 4.55\% = \underline{10.76\%}$$

(d) Schools

According to the Minimum Standard, the area for schools will be 1.5 acre/1000 persons. This standard will be used for low-density development models (60 persons/acre) in this study. But in higher density models, this standard will be reduced, and in case of 250 persons/acre, school area will be 1.0 acre/ 1000 persons. These will be converted to 9.1%, and 25.3% of the development area respectively. For the medium- and high-density development models, the percentages for low- and very high-density development models are superimposed as follows:-

For the medium-density development model (100 persons/acre)

$$(100 - 60) \times \frac{(25.00\% - 9.00\%)}{(250 - 60)} + 9.10\% = \underline{12.64\%}$$

For the high-density development model (200 persons/acre)

$$(200 - 60) \times \frac{(25.00\% - 9.00\%)}{(250 - 60)} + 9.10\% = \underline{21.08\%}$$

(e) Areas for Other Facilities

Lots will be required for shops, community centers, clinics, funeral parlours, etc. However, only 50 ft^2 per house will be necessary to cover all requirements. Thus, the following percentages are calculated:

60 Persons/Acre:	50 ft^2/house x 12	houses/acre	=	1.38%
100 "	:	50 ft^2/house x 20	"	=	2.30%
200 "	:	50 ft^2/house x 40	"	=	4.60%
250 "	:	50 ft^2/house x 50	"	=	5.75%

10.2.2 Models of Ground Conditions

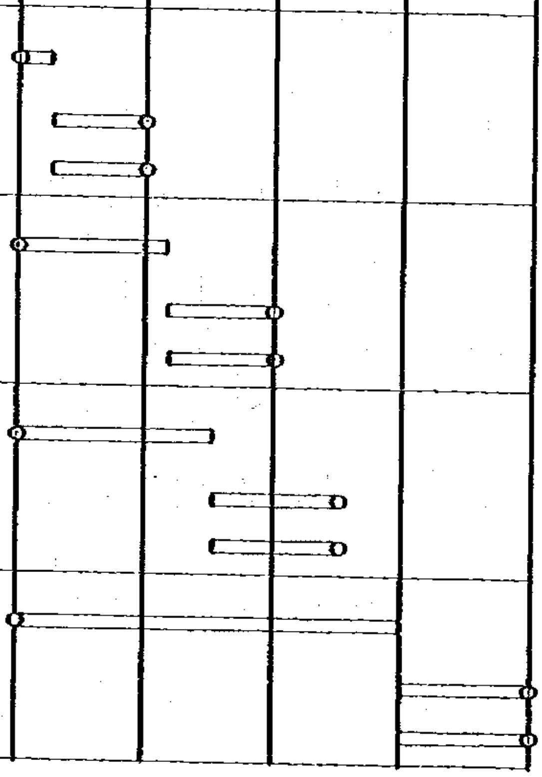
As previously indicated, 4 types of ground conditions of ex-mining land, i.e. Types A, B, C & D will be considered as standard models in the present study.

10.2.3 Work Schedule

The work schedule will vary depending on ground conditions. For ground condition Types A, B, C and D, the following work schedule can be established. For simplicity of calculation, the timing of payments for each type of the construction work is fixed as shown in Table 10-13.

Table 10-13 Work Schedule Models

Type of Work Schedule	Ground* Condition	Work	1st year	2nd year	3rd year	4th year
I	Type A	Improvement of Subsurface Ground				
		Building Works				
		Other Works				
II	Type B	Improvement of Subsurface Ground				
		Building Works				
		Other Works				
III	Type C	Improvement of Subsurface Ground				
		Building Works				
		Other Works				
IV	Type D	Improvement of Subsurface Ground				
		Building Works				
		Other Works				



* Refer to Fig. 10-2.

o Payment for work

10.2.4 Development Models

As shown in Table 10-14, 36 types of development models are established for the cost study.

Table 10-14 Development Models

Development Model Number	Ground Utilization Model: Development Density	Ground Utilization Model: House Type	Ground Condition *1	Work Schedule *2: Type	Work Schedule *2: Total Period	Interest
1	Low Density (60 persons/acre)	Low-Rise (Single-Storey)	Type A	Type I	1 year	7.5% annual compound interest
2			Type B	Type II	2 years	
3			Type C	Type III	2.5 "	
4			Type D	Type IV	4 "	
5		Medium-Rise (5-Storey)	Type A	Type I	1 year	
6			Type B	Type II	2 years	
7			Type C	Type III	2.5 "	
8			Type D	Type IV	4 "	
9		High-Rise (18-Storey)	Type A	Type I	1 year	
10			Type B	Type II	2 years	
11			Type C	Type III	2.5 "	
12			Type D	Type IV	4 "	
13	Medium Density (100 persons/acre)	Low-Rise (Single-Storey)	Type A	Type I	1 year	
14			Type B	Type II	2 years	
15			Type C	Type III	2.5 "	
16			Type D	Type IV	4 "	
17		Medium-Rise (5-Storey)	Type A	Type I	1 year	
18			Type B	Type II	2 years	
19			Type C	Type III	2.5 "	
20			Type D	Type IV	4 "	
21		High-Rise (18-Storey)	Type A	Type I	1 year	
22			Type B	Type II	2 years	
23			Type C	Type III	2.5 "	
24			Type D	Type IV	4 "	
25	High Density (200 persons/acre)	Medium-Rise (5-Storey)	Type A	Type I	1 year	
26			Type B	Type II	2 years	
27			Type C	Type III	2.5 "	
28			Type D	Type IV	4 "	
29		High-Rise (18-Storey)	Type A	Type I	1 year	
30			Type B	Type II	2 years	
31			Type C	Type III	2.5 "	
32			Type D	Type IV	4 "	
33	Very High Density (250 persons/acre)	High-Rise (18-Storey)	Type A	Type I	1 year	
34			Type B	Type II	2 years	
35			Type C	Type III	2.5 "	
36			Type D	Type IV	4 "	

*1 Refer to Fig. 10-2
*2 Refer to Table 10-13

10.3 Development Cost of Each Development Model

The development cost for each type of development model is calculated by evaluating the following items:-

1) Cost of Construction Work
2) Interest
3) Investigation, Design, Office Expenses
4) Contingency

10.3.1 Cost of Construction Work for Each Development Model

The cost of construction work includes the following items:

1) Cost of Building (Superstructure)
2) Cost of Foundation
3) Cost of Ground Improvement
4) Cost of Infrastructure
5) Cost of Landscaping

The cost of all items for each development model is calculated and summarized in Tables 10-15 to 10-19.

10.3.2 Interest Rate

Interest is assumed to be 7.5% per year compounded annually. This rate is currently being applied to the loan from the Malaysian Government for the low-cost housing scheme of the Kuala Lumpur City Hall. Interest is calculated only for ground improvement in this cost study.

Table 10-15 Cost of Superstructures for Development Models

(per 100 acres)

Density	Type of House Structure	Unit* Cost (M$/Unit)	No. of Units (Nos.)	Total Cost of Superstructure (M$ 1,000)
60 Persons/Acre	Low-Rise Medium-Rise High-Rise	8,045 11,165 13,365	1,200 1,200 1,200	9,654 13,398 16,038
100 Persons/Acre	Low-Rise Medium-Rise High-Rise	8,045 11,165 13,365	2,000 2,000 2,000	16,090 22,330 26,730
200 Persons/Acre	Medium-Rise High-Rise	11,165 13,365	4,000 4,000	44,660 53,460
250 Persons/Acre	High-Rise	13,365	5,000	66,825

* Refer to Table 10-6

Table 10-16 Cost of Foundations for Development Models

(per 100 acres)

Density	Type of House Structure	Unit*1 Cost (M$/ft^2)	Conv. Factor (ft^2 to acre)	Building*2 Area (Acre)	Cost of Foundation (M$1,000)
60 Persons/Acre	Medium-Rise High-Rise	4.4(14.4) 16.5(61.2)	43,516 43,516	3.67 1.02	703 (2,300) 732 (2,716)
100 Persons/Acre	Medium-Rise High-Rise	4.4(14.4) 16.5(61.2)	43,516 43,516	6.11 1.70	1,170 (3,829) 1,221 (4,527)
200 Persons/Acre	Medium-Rise High-Rise	4.4(14.4) 16.5(61.2)	43,516 43,516	12.22 3.40	2,340 (7,657) 2,441 (9,055)
250 Persons/Acre	High-Rise	16.5(61.2)	43,516	4.25	3,005(11,319)

*1 Refer to Table 10-3
*2 Refer to Table 10-12

Note: *Foundation costs for low-rise houses are included in the cost of superstructures.

*Figures in parentheses are for 30 m deep foundations.

Table 10-17 Cost for Ground Improvement (per 100 acres)

Development Model No.	Compaction for Whole Area			Type of Ground	Ground Improvement			Sub-Total*1 (M$ 1,000)	Interest*2		Total Cost (M$ 1,000)
	Unit Cost (M$/ft²)	Area (Acre)	Sub-Total (M$ 1,000)		Unit Cost (M$/ft²)	Area (Acre)	Sub-Total (M$ 1,000)		Term*3 (Year)	Amount (M$ 1,000)	
1				A	-		-	435	1	33	468
2				B	1.52	15.19	1,005	1,440	2	224	1,664
3				C	2.83		1,870	2,305	2.5	459	2,764
4				D	3.02		1,996	2,431	4	816	3,247
5				A	-		-	435	1	33	468
6				B	2.47	3.67	394	829	2	129	958
7				C	2.83		452	887	2.5	176	1,063
8				D	3.02		482	917	4	308	1,225
9				A	-		-	435	1	33	468
10				B	2.47	1.02	110	545	2	85	630
11				C	2.83		126	561	2.5	112	673
12				D	3.02		134	569	4	191	760
13				A	-		-	435	1	33	468
14				B	1.52	25.32	1,675	2,110	2	328	2,438
15				C	2.83		3,118	3,553	2.5	707	4,260
16				D	3.02		3,328	3,763	4	1,262	5,025
17				A	-		-	435	1	33	468
18	0.1	100	435	B	2.47	6.11	657	1,092	2	170	1,262
19				C	2.83		752	1,187	2.5	236	1,423
20				D	3.02		803	1,238	4	415	1,653
21				A	-		-	435	1	33	468
22				B	2.47	1.70	183	618	2	96	714
23				C	2.83		209	644	2.5	128	772
24				D	3.02		223	658	4	221	879
25				A	-		-	435	1	33	468
26				B	2.47	12.22	1,313	1,748	2	272	2,020
27				C	2.83		1,505	1,940	2.5	386	2,326
28				D	3.02		1,606	2,041	4	685	2,726
29				A	-		-	435	1	33	468
30				B	2.47	3.40	365	800	2	125	925
31				C	2.83		419	854	2.5	170	1,024
32				D	3.02		447	882	4	296	1,178
33				A	-		-	435	1	33	468
34				B	2.47	4.25	457	892	2	139	1,031
35				C	2.83		523	958	2.5	191	1,149
36				D	3.02		559	994	4	333	1,327

*1 Cost of ground improvement for Types B, C & D is obtained by:-
(Area of Foundation) x (Land Improvement Unit Cost - M$0.1)
(Refer to Table 10-2)

*2 Annual compound interest of 7.5% is applied

*3 Refer to Table 10-13

Table 10-18 Cost of Infrastructure for Development Models

(per 100 acres)

		Density Model	Unit[*1] Cost (M$/Acre)	[*2] Area (Acre)	Total Cost (M$1,000)
Cost of Road Construction	Main Access Road	60 Persons/Acre	59,400	15.00	891
		100 Persons/Acre	59,400	16.00	950
		200 Persons/Acre	59,400	18.52	1,100
		250 Persons/Acre	59,400	20.00	1,188
	Service Road	60 Persons/Acre	39,600	1.79	71
		100 Persons/Acre	39,600	2.99	118
		200 Persons/Acre	39,600	5.98	237
		250 Persons/Acre	39,600	7.45	295
	Pedes-trian Path	60 Persons/Acre	10,300	5.79	60
		100 Persons/Acre	10,300	7.35	76
Cost of Car Park		60 Persons/Acre	31,700	2.34	74
		100 Persons/Acre	31,700	3.91	124
		200 Persons/Acre	31,700	7.82	248
		250 Persons/Acre	31,700	9.78	310
			Unit Cost (M$/Unit)	No. of Units	Total Cost (M$1,000)
Cost of Water Supply and Drainage		60 Persons/Acre	200	1,200	240
		100 Persons/Acre	200	2,000	400
		200 Persons/Acre	200	4,000	800
		250 Persons/Acre	200	5,000	1,000
		60 Persons/Acre	650	1,200	780
		100 Persons/Acre	650	2,000	1,300
		200 Persons/Acre	650	4,000	2,600
		250 Persons/Acre	650	5,000	3,250

*1 Refer to Table 10-9
*2 Refer to Table 10-12

Table 10-19 Cost of Landscaping

(per 100 acres)

	Density Model	House Structure Type	Unit Cost (M$/Acre)	Area*1 (In Acres)	Total Cost (M$1,000)
Parks	60 Persons/ Acre	All Types	10,300	4.55	47
	100 Persons/ Acre	All Types	10,300	6.00	62
	200 Persons/ Acre	All Types	10,300	10.76	111
	250 Persons/ Acre	All Types	10,300	12.63	130
Other Open Spaces	60 Persons/ Acre	Low-Rise Medium-Rise High-Rise	4,600 4,600 4,600	31.10 56.46 61.70	143 260 284
	100 Persons/ Acre	Low-Rise Medium-Rise High-Rise	4,600 4,600 4,600	0.56 40.53 49.27	3 186 227
	200 Persons/Acre	High-Rise	4,600	17.46	80
	250 Persons/Acre	High-Rise	4,600	1.88	9
Private Area*2	60 Per-Persons/ Acre	Low-Rise Medium-Rise High-Rise	4,600 4,600 4,600	(28.95 - 15.19) (9.38 - 3.67) (4.14 - 1.02)	63 26 14
	100 Persons/ Acre	Low-Rise Medium-Rise High-Rise	4,600 4,600 4,600	(48.25 - 25.32) (15.63 - 6.11) (6.89 - 1.70)	105 44 24
	200 Persons/ Acre	Medium-Rise High-Rise	4,600 4,600	(31.26 - 12.22) (13.78 - 3.40)	88 48
	250 Persons/ Acre	High-Rise	4,600	(17.23 - 4.25)	60

*1 Refer to Table 10-12

*2 Private areas are calculated: Land area for one unit minus building area for one unit

10.3.3 Investigation, Design, and Office Expenses

Investigation and design expenses are assumed to be 3% of the cost of civil works. Office expenses are assumed to be 2% of the cost of civil works.

10.3.4 Contingency

Two types of contingencies are considered, i.e. physical contingency and price contingency. The physical contingency is considered to be 5% of the cost of civil works in the present cost study. Price contingency will be discussed in Section 11.

10.3.5 Development Cost for the 36 Development Models

Development costs of the 36 development models are calculated using the components studied above. Relevant calculations are summarized in Table 10-20. Development costs per house unit are also calculated and shown on the right side of the table for the purpose of comparison. Order in cost per house unit is also indicated on the right side of the table.

Figs. 10-9a to 10-9c show the breakdown of development costs for representative models. It is seen that construction costs for superstructure constitute major portion of the development cost (60% to 80% of the total cost). Breakdown of development costs for the case of 30 m deep foundations for medium- and high-rise housing is also shown in the right side of Figs. 10-9b and 10-9c.

10.4 Evaluation of Results

The results of the calculation of development cost per housing unit are plotted and shown in Figs. 10-10 to 10-12. development cost per unit is plotted versus development density in Fig. 10-10, versus the size of structures in Fig. 10-11, and versus ground condition in Fig. 10-12. The following observations can be made on the results:-

1) The cheapest case is Case 13 [Low-rise structures with medium density (100 persons/acre) on Type A ground], and is M$10,833 per unit.

2) The most expensive case is Case 12 [High-rise structures with low-density (60 persons/acre) on Type D ground], and is M$18,271 per unit.

3) Development cost per unit increases sharply with the size of structures, i.e. relatively cheap for low-rise housing (between M$10,800 and M$14,300), and considerably more expensive for high-rise housing (between M$16,800 and M$18,300). For medium-rise housing, the unit cost is between M$14,500 and M$16,300. The difference between low-rise and high-rise housing on the same ground or with the same density condition is between M$4,000 and M$6,500.

4) Ground condition affects the development cost, more sensitive for low-rise structures and less sensitive for high-rise structures. Differences in development

Table 10-20 Development Cost for Each Development Model

Development Model Number	Ground Utilization Model: Development Density	Ground Utilization Model: House Type	Ground Conditions (Type)	Civil Works (M$1,000): Building: Architectural Works	Building: Electrical Works	Building: Mechanical Works	Building: Sub-Total	Foundation *	Land Development: Ground Improvement (Including Interest)	Infrastructure: Road	Infrastructure: Car Park	Infrastructure: Water Supply and Drainage	Infrastructure: Sub-Total	Landscaping: Parks	Landscaping: Open Space	Landscaping: Private Area	Landscaping: Sub-Total	Land Development: Sub-Total	Sub-Total	Investigation, Design, etc. (M$1,000)	Physical Contingency (M$1,000)	Total (M$1,000)	No. of Houses	Unit Cost (M$)	Order in Cost
1	60 Persons/Acre	Low-Rise	A	8,802	852	-	9,654	-	468	1,022	74	1,020	2,116	47	143	63	253	3,090	12,744	637	637	14,018	1,200	11,682	2
2			B						1,664									4,286	13,940	697	697	15,334		12,778	4
3			C						2,764									5,386	15,040	752	752	16,544		13,787	7
4			D						3,247									5,869	15,523	776	776	17,075		14,229	8
5		Medium-Rise	A	12,414	852	132	13,398	703 (2,300)	468	962			2,056		260	26	333	2,857	16,958	848	848	18,654		15,545	16
6			B						958									3,347	17,448	872	872	19,192		15,993	18
7			C						1,063									3,452	17,553	878	878	19,309		16,091	19
8			D						1,225									3,614	17,715	886	886	19,487		16,239	20
9		High-Rise	A	14,262	852	924	16,038	732 (2,716)	468						284	14	345	2,869	19,639	982	982	21,603		18,003	33
10			B						630									3,031	19,801	990	990	21,781		18,151	34
11			C						673									3,074	19,844	992	992	21,828		18,190	35
12			D						760									3,161	19,931	997	997	21,925		18,271	36
13	100 Persons/Acre	Low-Rise	A	14,670	1,420	-	16,090	-	468	1,144	124	1,700	2,968	62	3	105	170	3,606	19,696	985	985	21,666	2,000	10,833	1
14			B						2,438									5,576	21,666	1,083	1,083	23,834		11,917	3
15			C						4,260									7,398	23,488	1,174	1,174	25,836		12,918	5
16			D						5,025									8,163	24,253	1,213	1,213	26,679		13,340	6
17		Medium-Rise	A	20,690	1,420	220	22,330	1,170 (3,829)	468	1,068			2,892		186	44	292	3,652	27,152	1,358	1,358	29,868		14,934	11
18			B						1,262									4,446	27,946	1,397	1,397	30,740		15,370	14
19			C						1,423									4,607	28,107	1,405	1,405	30,917		15,459	15
20			D						1,653									4,836	28,336	1,417	1,417	31,170		15,585	17
21		High-Rise	A	23,770	1,420	1,540	26,730	1,221 (4,529)	468						227	24	313	3,673	31,614	1,581	1,581	34,776		17,388	29
22			B						714									3,919	31,860	1,593	1,593	35,046		17,523	30
23			C						772									3,977	31,918	1,596	1,596	35,110		17,555	31
24			D						879									4,084	32,025	1,601	1,601	35,227		17,614	32
25	200 Persons/Acre	Medium-Rise	A	41,380	2,840	440	44,660	2,340 (7,657)	468	1,337	248	3,400	4,985	111	-	88	199	5,652	52,652	2,633	2,633	57,918	4,000	14,480	9
26			B						2,020									7,204	54,204	2,710	2,710	59,624		14,906	10
27			C						2,326									7,510	54,510	2,726	2,726	59,962		14,991	12
28			D						2,726									7,910	54,910	2,746	2,746	60,402		15,101	13
29		High-Rise	A	47,540	2,840	3,080	53,460	2,441 (9,055)	468						80	48	239	5,692	61,593	3,080	3,080	67,753		16,938	22
30			B						925									6,149	62,050	3,103	3,103	68,256		17,064	26
31			C						1,024									6,248	62,149	3,107	3,107	68,363		17,091	27
32			D						1,178									6,402	62,303	3,115	3,115	68,533		17,133	28
33	250 Persons/Acre	High-Rise	A	59,425	3,550	3,850	66,825	3,005 (11,319)	468	1,483	310	4,250	6,043	130	9	60	199	6,710	76,540	3,827	3,827	84,194	5,000	16,839	21
34			B						1,031									7,213	77,103	3,855	3,855	84,813		16,963	23
35			C						1,149									7,391	77,221	3,861	3,861	84,943		16,989	24
36			D						1,327									7,569	77,399	3,870	3,870	85,139		17,028	25

* Figures in parentheses are for 30 m deep foundations.

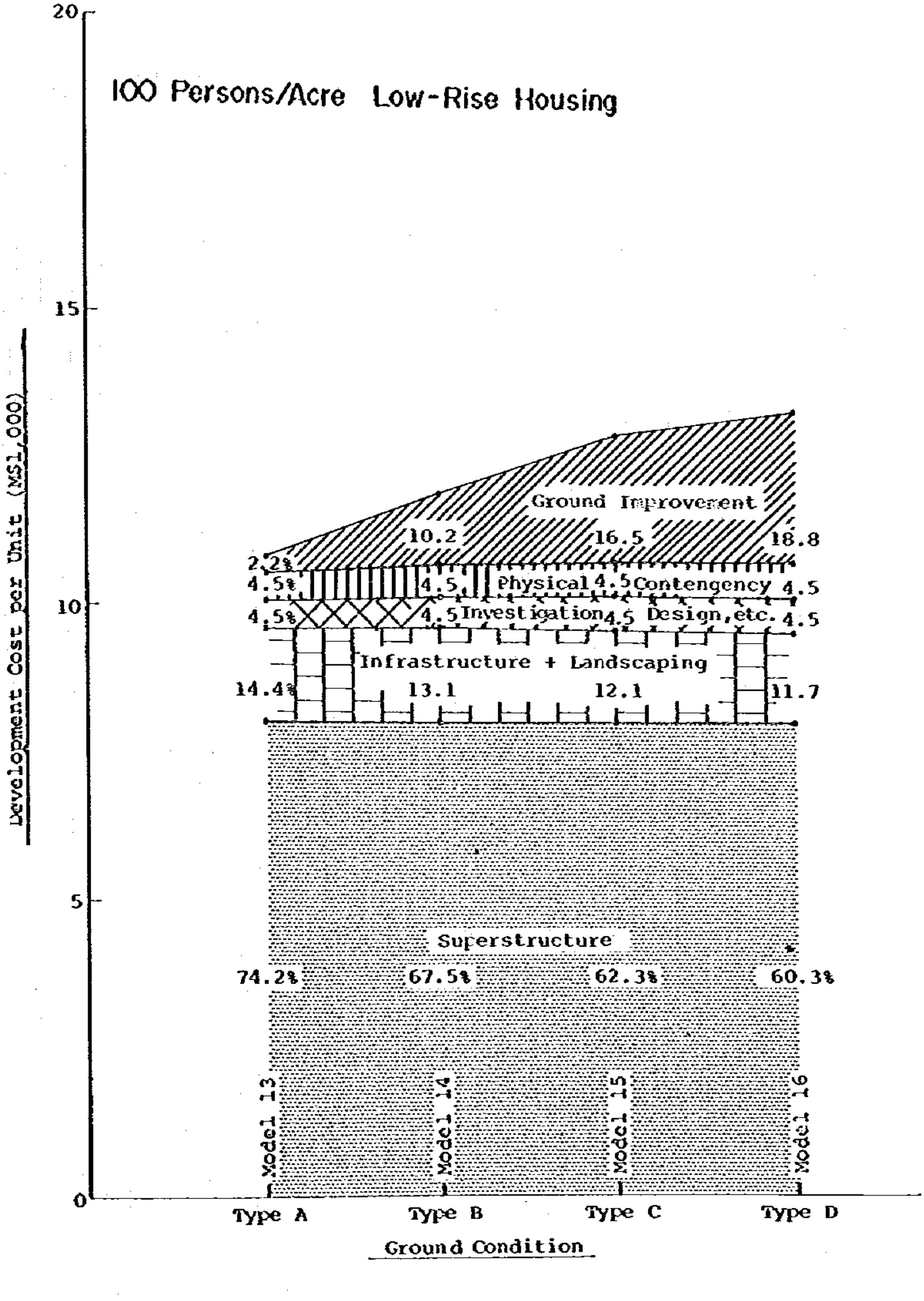


Fig. 10-9a Breakdown of Development Cost (1)

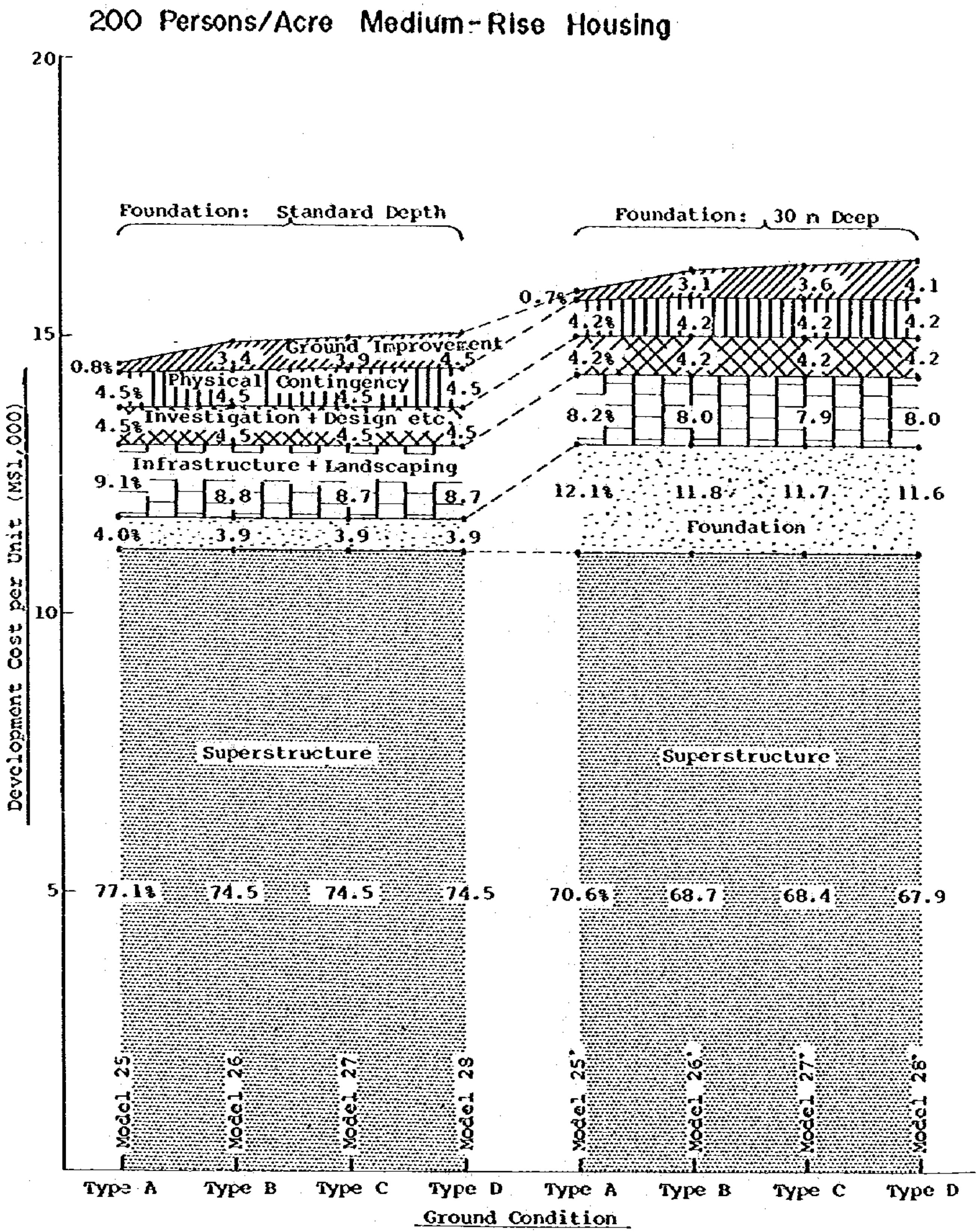


Fig. 10-9b Breakdown of Development Costs (2)

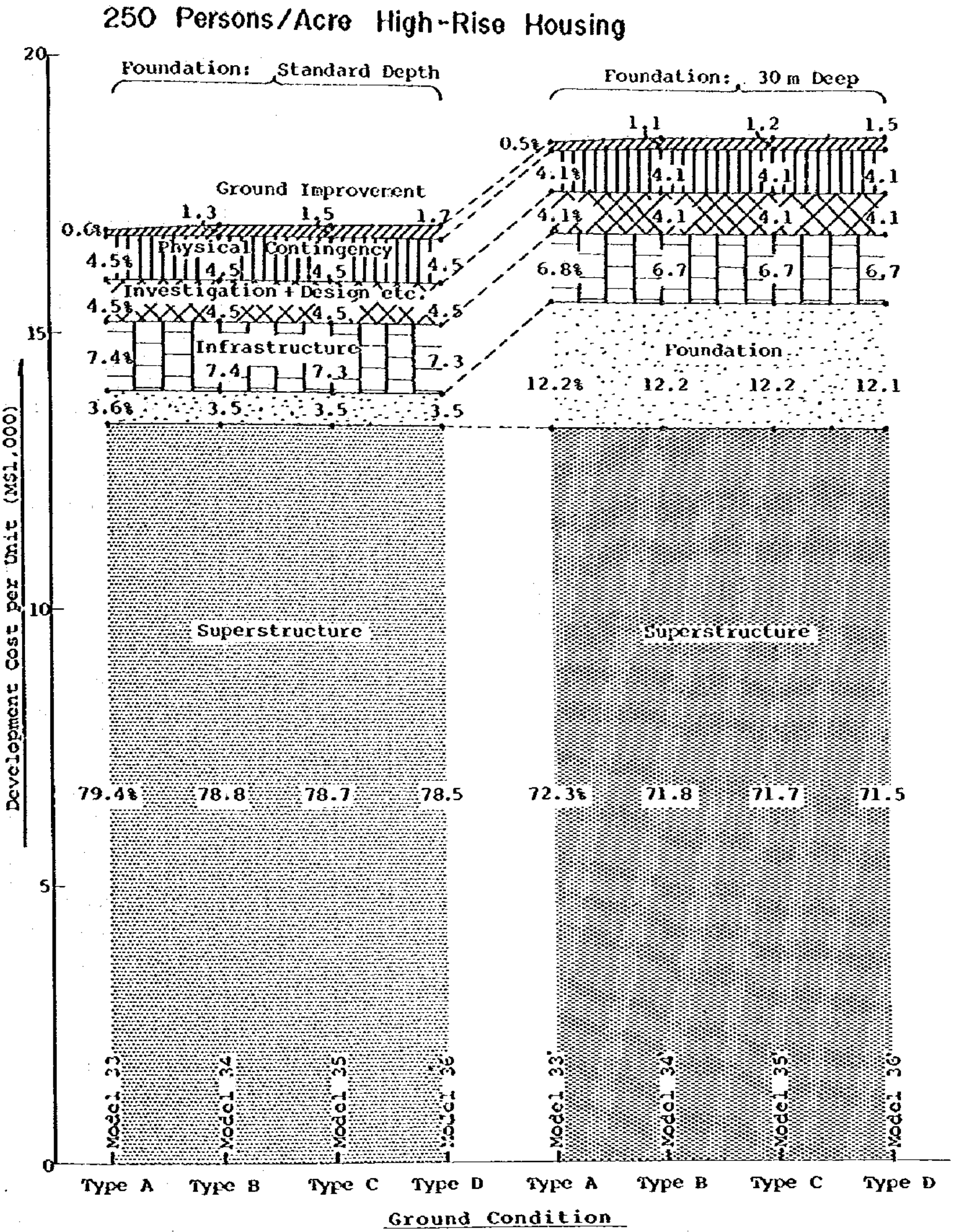


Fig. 10-9c Breakdown of Development Costs (3)

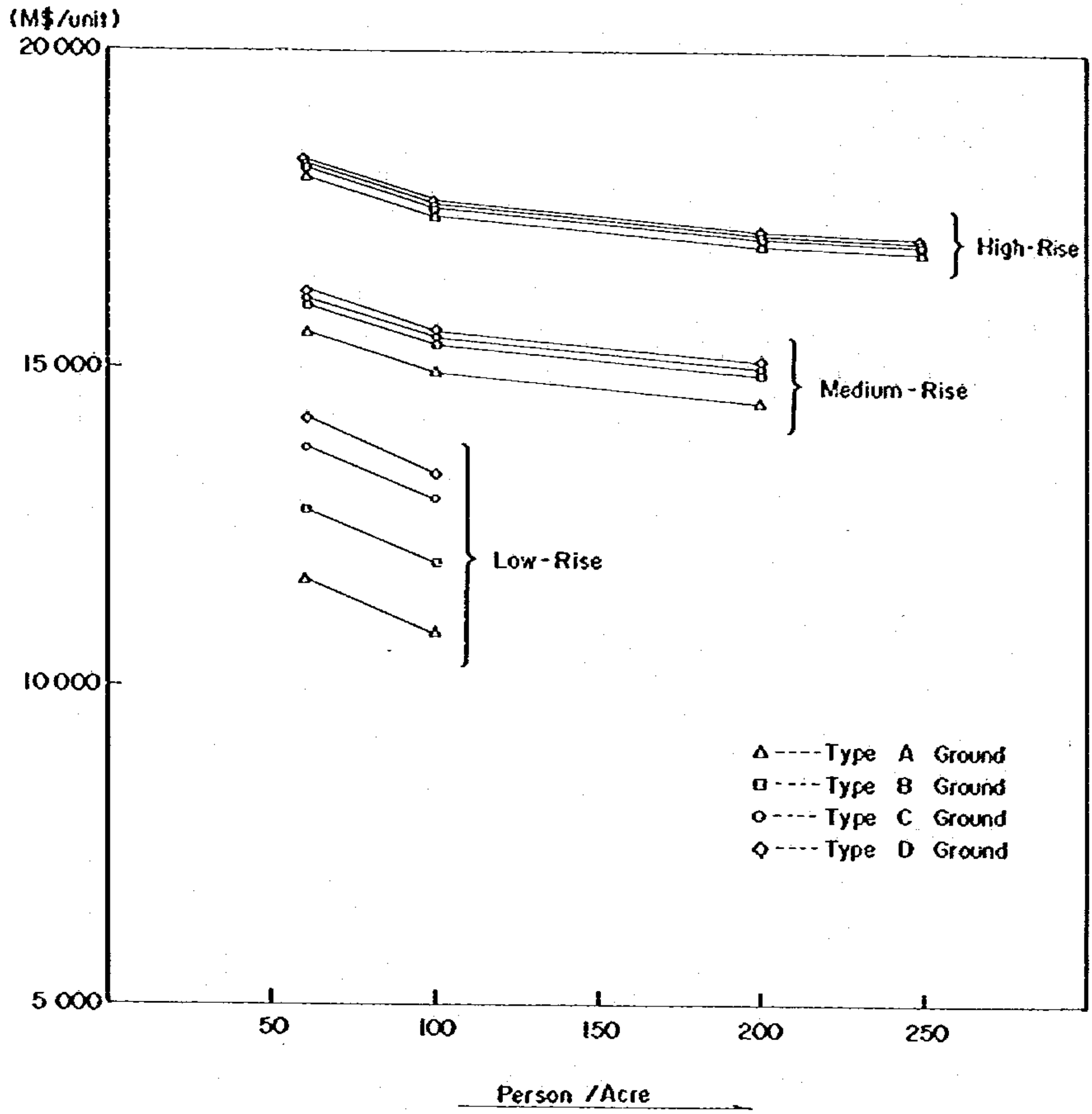


Fig. 10-10 Comparison of Development Cost per Unit
(w. r. t. Density)

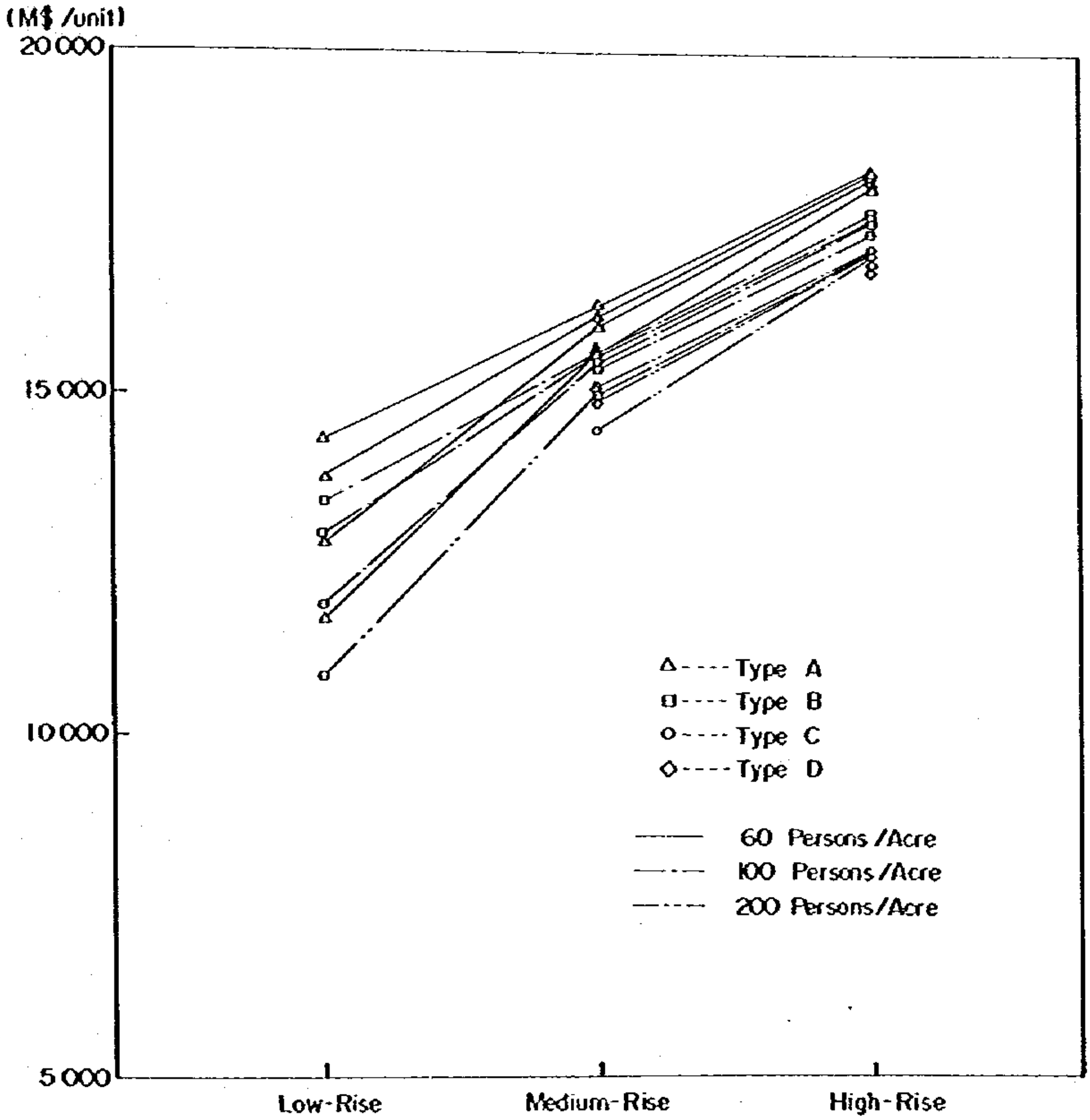


Fig. 10-11 Comparison of Development Cost per Unit (w. r. t. Size of Structures)

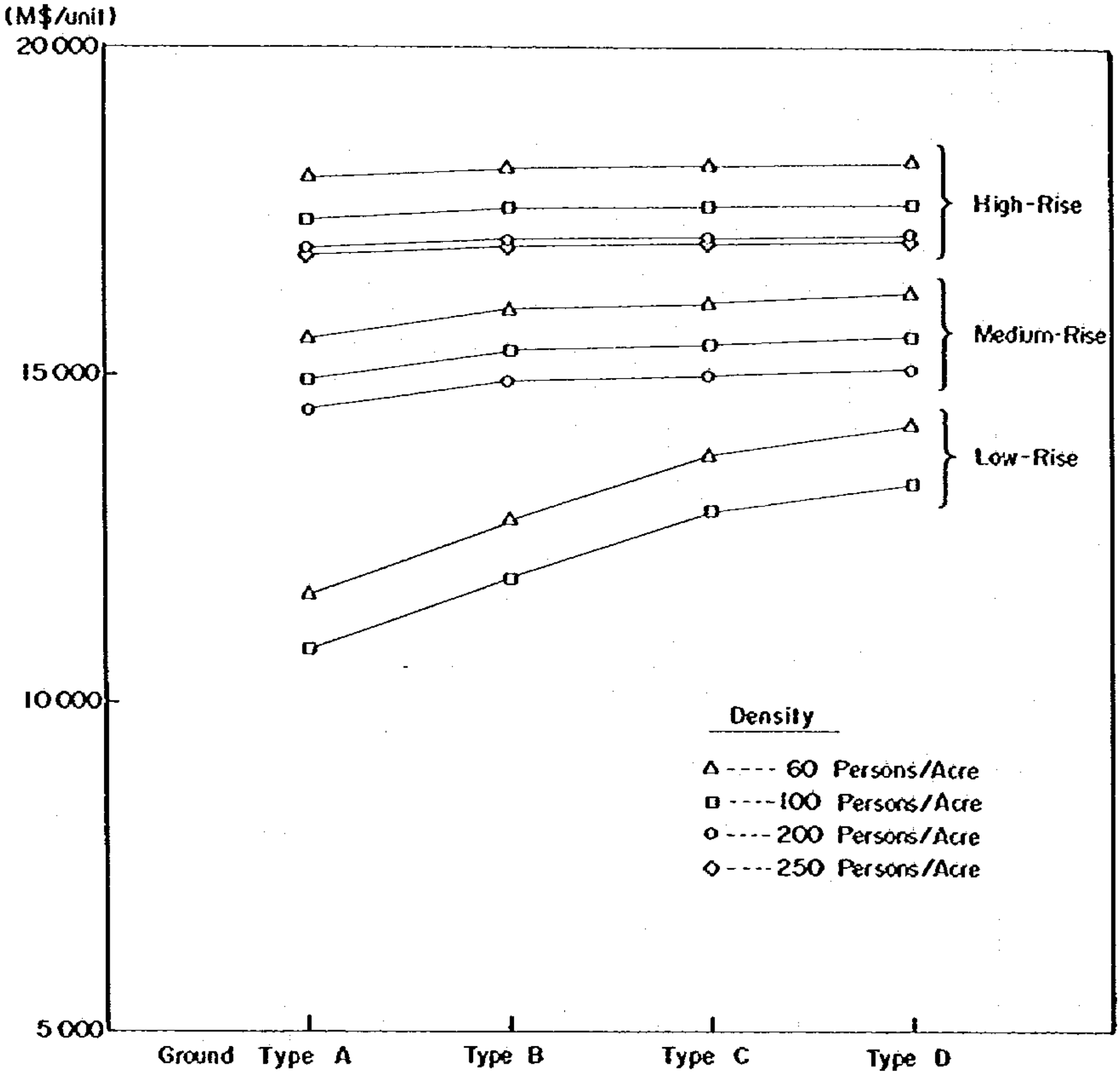


Fig. 10 · 12 Comparison of Development Cost per Unit (w. r. t. Ground Condition) cost per unit between ground Types A and D are about M$2,500 (ranges M$2,507 to M$2,547) for low-rise units and about M$200 (ranges M$189 to M$268) for high-rise units.

5) Development density also influences the construction cost. High-density development gives cheaper unit costs than low-density development.

10.5 Influence of Land Cost

As noted at the beginning of this section, costs for land acquisition are not included in the cost study presented above. This is because ex-mining land is generally available without cost for housing developments executed by the public sector. However, the various properties surrounding ex-mining land obviously have market values. Therefore, even ex-mining land which is improved and developed for housing development by the public sector must be evaluated and utilised with due consideration for the implicit land value.

Land prices per square foot as of 1980 are more than M$20 for premium land, M$7 to M$12 for general housing land, and M$3 to M$5 for land in suburban areas (Section 2). Further evaluation of development costs of low-cost housing including the implicit land value is performed for the following 3 cases:

1) For a land price of M$3/$ft^2$

2) For a land price of M$5/$ft^2$

3) For a land price of M$10/$ft^2$

Fig. 10-13 shows the difference in development cost per unit between ① housing development using ex-mining land after ground improvement, and ② housing development using general land purchased at the prevailing market price. It is seen from Fig. 10-13 that in all cases, housing development using ex-mining land after ground improvement is cheaper than the developments using non ex-mining land purchased at market prices. The difference in development cost for each case is calculated and shown in Table 10-21. This difference is larger for low-rise structures and becomes smaller for high-rise structures.

10.6 Optimum Development Model

For selection of the most appropriate housing development model, due consideration must be given to land prices even in cases where ex-mining land is acquired cheaply by the public sector. For the best use of the available land space, optimum development models must be selected with reasonable consideration of land value as may be represented by the prevailing land price.

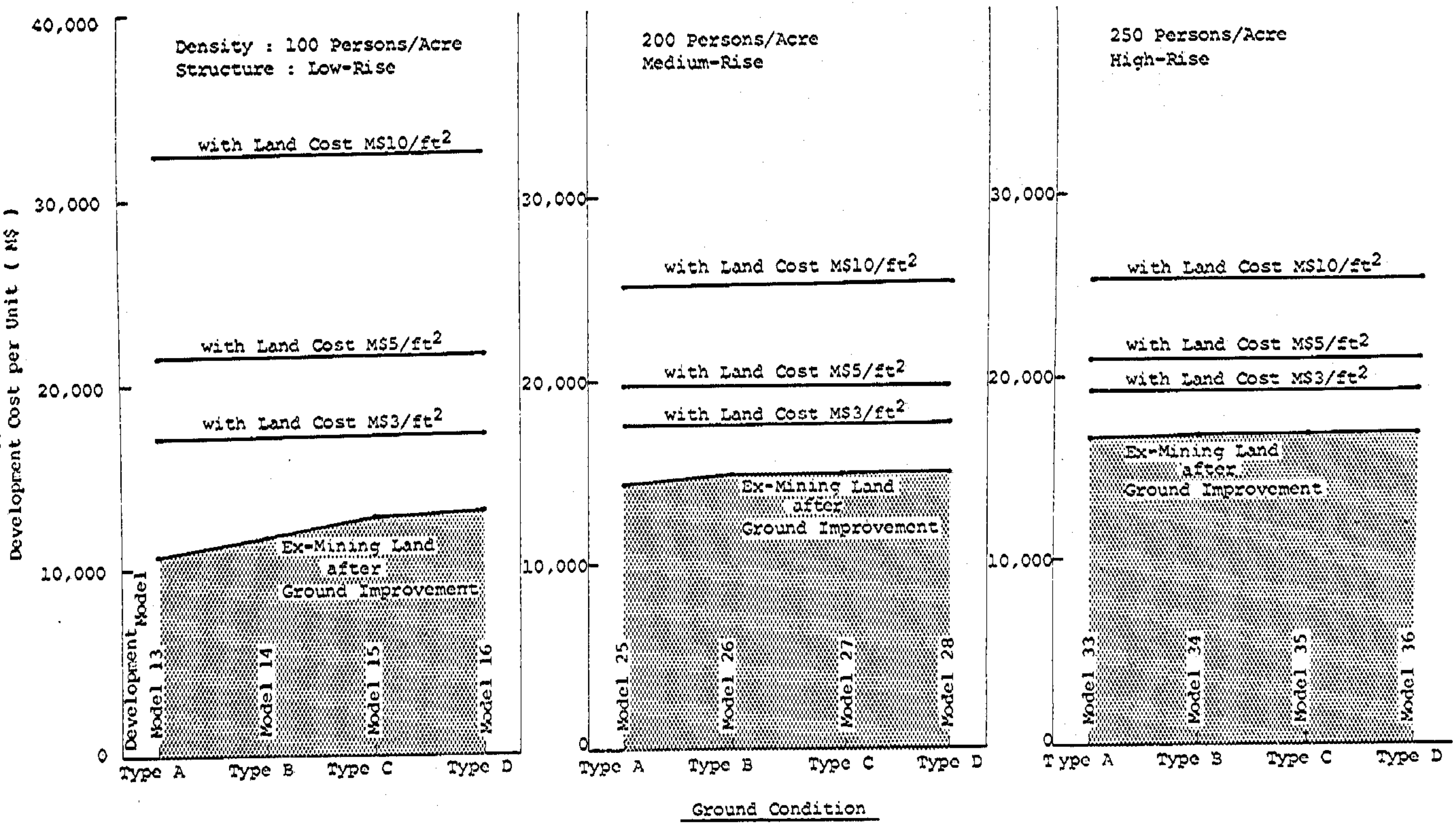


Fig. 10-13 Differences in Development Costs by Land Prices

Table 10-21 Difference of Development Cost per Unit by Land Prices

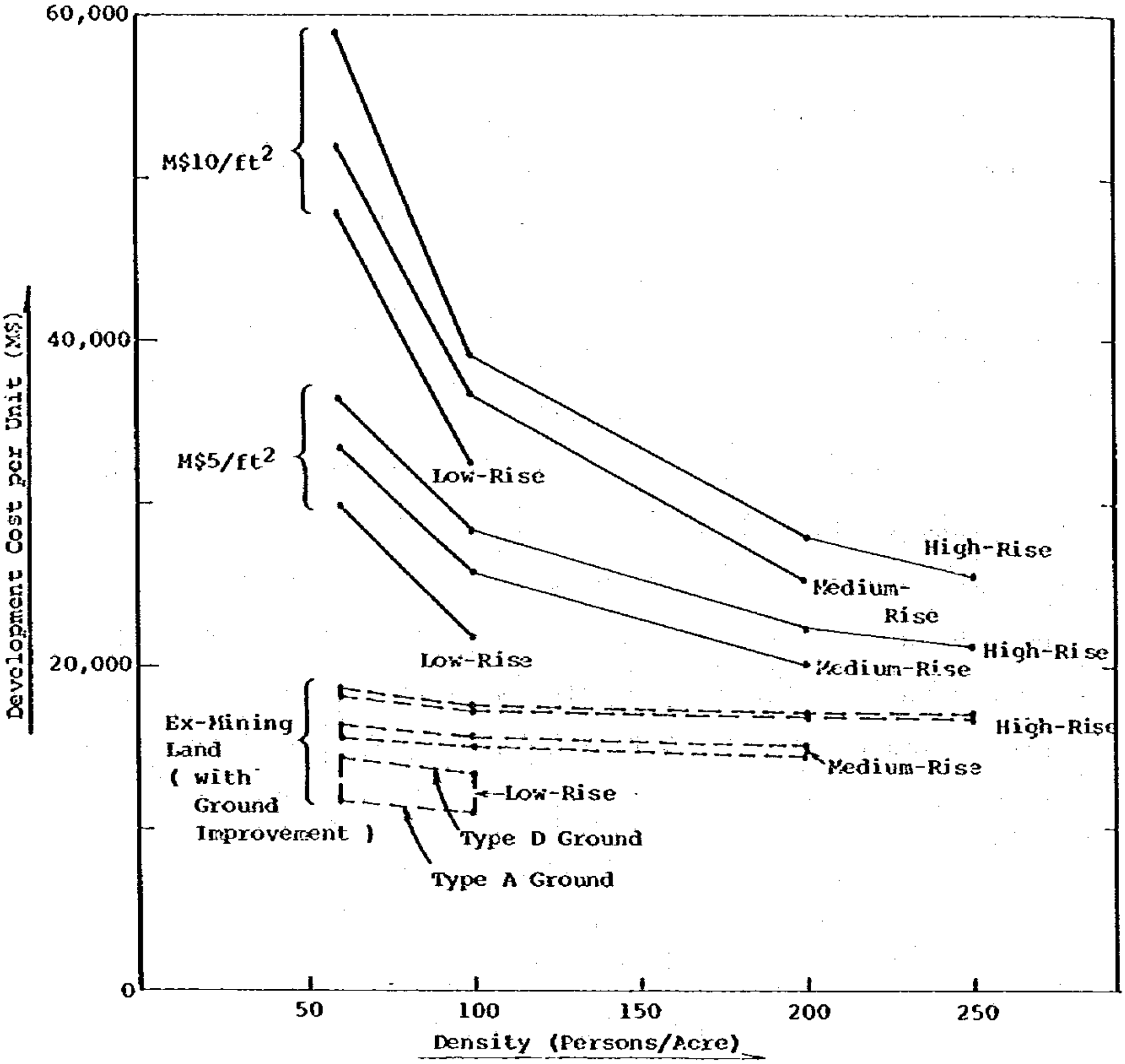
M$

		Using Ex-Mining Land after Ground Improvement	Price of Land		
			M$3/ft²	M$5/ft²	M$10/ft²
Model 13	Cost	10,833∿13,340	17,351	21,707	32,597
	ΔCost	0	4,011∿6,518	8,367∿10,874	19,257∿21,764
Model 26	Cost	14,480∿15,101	17,739	19,917	25,362
	ΔCost	0	2,638∿3,259	4,816∿5,437	10,261∿10,882
Model 34	Cost	16,839∿17,028	19,446	21,188	25,544
	ΔCost	0	2,418∿2,607	4,160∿4,349	8,516∿8,705

ΔCost: Difference between General and Ex-Mining Lands

Fig. 10-14 shows the development cost per unit with respect to development density and structure size for various land costs. For example, curves for a land cost of M$5/ft^2 are prepared by (1) reducing costs of land improvement from housing development costs on ex-mining land, and then (2) adding the land cost of M$5/ft^2.

If we are to consider a housing development in an area with a land value of M$5/ft^2, the cheapest model is a medium-rise structure with 200 persons/acre, and the 2nd cheapest being a high-rise structure with 250 persons/acre. Table 10-22 shows the three cheapest cases for various land costs. Consideration on the implicit land value is important for the best use of the limited land space even if ex-mining land is acquired cheaply by the public sector.



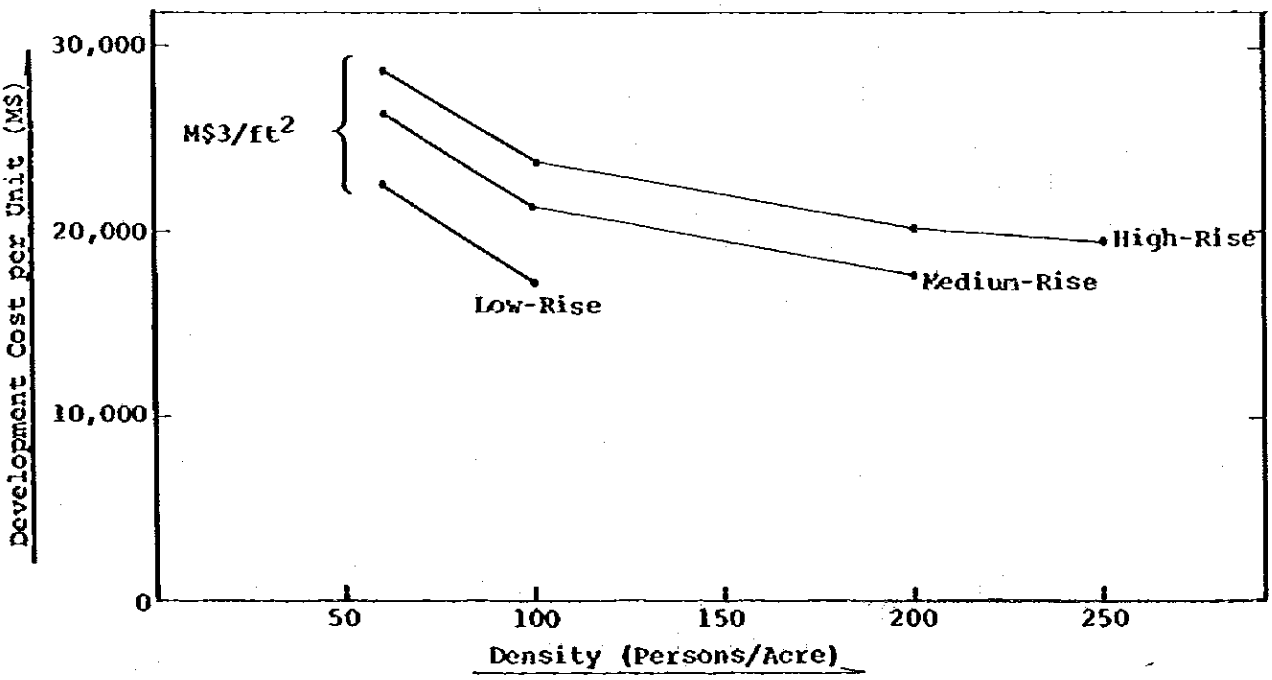


Fig. 10-14 Effect of Land Cost on Development Cost

Table 10-22 Three Cheapest Cases by Land Prices

Land Type		Condition	Cheapest Three		
			1st	2nd	3rd
Ex-Mining Land after Ground Improvement		Density	100 Persons/Acre	60 Persons/Acre	100 Persons/Acre
		Structure	Low-Rise Houses	Low-Rise Houses	Low-Rise Houses
		Ground Condition	Type A	Type A	Type B
		Cost per Unit	M$10,833	M$11,682	M$11,917
General Land (Purchased)	M$3/ft^2	Density	100 Persons/Acre	200 Persons/Acre	250 Persons/Acre
		Structure	Low-Rise Houses	Medium-Rise Houses	High-Rise Houses
		Cost per Unit	M$17,351	M$17,739	M$19,446
	M$5/ft^2	Density	200 Persons/Acre	250 Persons/Acre	100 Persons/Acre
		Structure	Medium-Rise Houses	High-Rise Houses	Low-Rise Houses
		Cost per Unit	M$19,917	M$21,188	M$21,707
	M$10/ft^2	Density	200 Persons/Acre	250 Persons/Acre	200 Persons/Acre
		Structure	Medium-Rise Houses	High-Rise Houses	High-Rise Houses
		Cost per Unit	M$25,362	M$25,544	M$27,820