A Closer Look at Prevailing Civil Engineering Practice – What, Why and How?

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CONTENTS

Preface

It is indeed more than happy to realize that my previous engineering publications have spread to Asia (Hong Kong, Singapore, Japan, Turkey, Philippines, Mongolia, Vietnam, Pakistan, Malaysia), Europe (United Kingdom, Switzerland, Spain, Germany, Bulgaria, Slovakia, Gospodarska Zbornica Slovenije), North America (The United States and Canada), Australia, Barbados and South Africa. I hope that through my writing work I could continue to share my engineering knowledge with the rest of the world in an attempt to achieve simultaneous progress in civil engineering.

It really took countless sleepless nights to complete this book. However, I really enjoyed this writing process because it helped clear up some vague and forgotten engineering knowledge and build up some brand new ones. I intend to write this book in an easy-reading style as in my previous collections so that every reader should be able to pick up some gifts and useful knowledge from it.

Should you have any comments on the book, please feel free to send to my email *askvincentchu @yahoo.com.hk* and discuss.

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Chapter 1. Bridge Works

1. What is the purpose of leveling pad in bridge bearing?

Bridge bearings should be installed to lie horizontally on bridge piers and columns so that it would not induce eccentricity forces on substructure. However, the bridge superstructure requires different longitudinal and transverse level and gradient in order to keep in line with the geometry of the road. As such, it is natural to follow that the superstructure can hardly meet with substructure horizontally so that a leveling pad is introduced at the bottom of the superstructure to join with bridge bearing. Wedge-shaped leveling pad is commonly used for better concrete mobility at the bridge bearings.

2. Central prestressing is normally required during construction in incremental launching method. Why?

The erection condition plays an important role to the structural design of bridges when incremental launching method is adopted.

Each section of superstructure is manufactured directly against the preceding one and after concrete hardens, the whole structure is moved forward by the length of one section. When the superstructure is launched at prefabrication area behind one of the abutments, it is continually subjected to alternating bending moments. Each section of superstructure (about 15m to 25m long) is pushed from a region of positive moment and then to a region of negative moment and this loading cycled is repeated. As such, tensile stresses occur alternately at the bottom and top portion of superstructure section. For steel, it is of equal strength in both compression and tension and it has no difficulty in handling such alternating stress during launching process. However concrete could only resist small tensile stresses and therefore, central prestressing is carried out to reduce the tensile stress to acceptable levels.

Central prestressing means that the prestressing cables are arranged such that the resultant compressive stresses at all points in a given cross section are equal and it does not matter whether tensile stresses occur in upper or lower portion of superstructure during launching process.

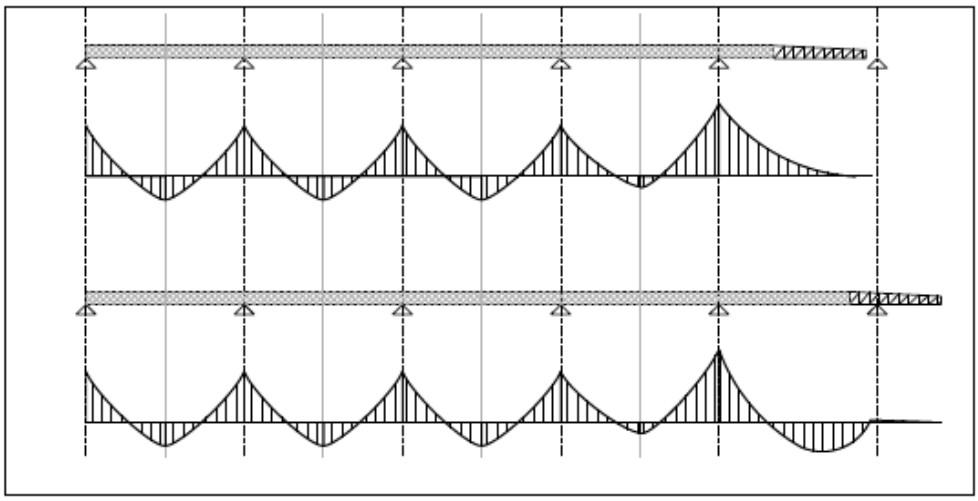


Fig. 1.1 Bending moment envelope in incremental launching

3. Should special design be catered for in bridge piers upon jacking up of superstructure for installation of bearings in incremental launching method?

After the completion of launching process, the superstructure has to be lifted up to allow for installation of bearings. This is usually achieved by means of jacks to raise 5-10mm successively at each pier. In fact, it is anticipated that no special design is necessary for this operation because the effect of differential settlements at support should already be checked in bridge design. Level readings should be checked to ensure that it does not deviate from the designed figure.

4. Can the use of temporary nose in incremental launching method reduce the cantilever moment of superstructure to the value of inner support moment?

When the superstructure is pushed forward, a temporary nose is usually adopted at the front end of the superstructure to reduce the cantilever moment for which the central prestress is designed. The length of temporary nose is about 60-65% of bridge span.

The bending moment of self-weight for internal spans (equal span) of long bridge is $-0.0833WL^2$ at piers and $+0.0417W\ L^2$ at mid-span (W = unit weight of deck and L = span length). However, without the use of temporary nose, the bending moment in the leading pier when the deck has to cantilever from one pier to another would be $-0.5WL^2$, which is 6

times higher than normal values at support.

Theoretically speaking, it is possible to reduce the cantilever moment to the value of inner support moment (i.e. $-0.0833WL^2$) with the use of a long nose. However, from economic point of view, it is would better to adopt temporary additional prestressing instead of longer nose. Hence, in actual site practice, the use of temporary nose would not reduce the cantilever moment of superstructure to the value of inner support moment but only to achieve $-0.105WL^2$.

5. Which of the following methods to reduce cantilever moment is better in incremental launching, (i) temporary nose, (ii) mast or (iii) auxiliary piers?

The use of mast is an alternative to temporary nose. From practical point of view, the use of mast requires continual adjustment of forces in the guys when the superstructure is pushed forward. On the other hand, the implementation of temporary nose system does not require much attention during operation.

For large span lengths (>50m) it is advantageous to adopt auxiliary piers because this helps reduce the central prestress required. However, it may not be economical for auxiliary piers with height more than 40m.

6. What are the main design considerations for temporary nose in incremental launching?

There are two main design considerations for temporary nose:

(i) Maximum sagging moment
The maximum sagging moment at the point of connecting the nose to superstructure occurs when the superstructure is launched far from the pier. It is estimated to occur at about 75% of the span length.

(ii) Maximum bearing pressure at bottom flange of temporary nose

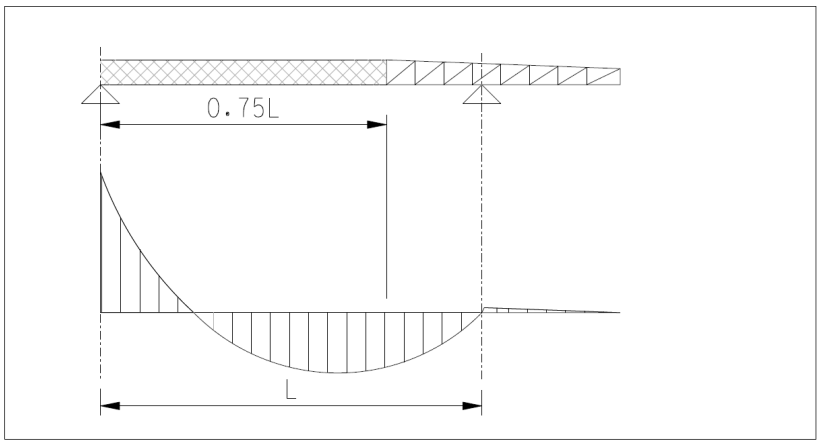


Fig. 1.2 Maximum sagging moment in temporary nose

7. In precast segmental box girder bridges, the bridge segments are usually formed by match casting. It is sometimes observed that a gap is formed between adjacent bridge segments. Why?

To enhance perfect fitting of bridge segments in precast segmental box girder bridges, segments are usually constructed by match casting so that it would not impair the serviceability and load bearing ability of the bridge. The end face of completed segment is adopted as formwork for the new segment. During the concrete hardening process, the hydration effect of new segment induces a temperature rise and develops a temperature gradient in the completed segment. Hence, the completed segment bows temporarily and the new segment sticks to this bowed shape when hardened. After match casting, the completed segment retains its original shape after cooling down while the new segment obtains the profile of bowed shape. Such bowing effect is even more significant for slender segments with large height to width ratio.

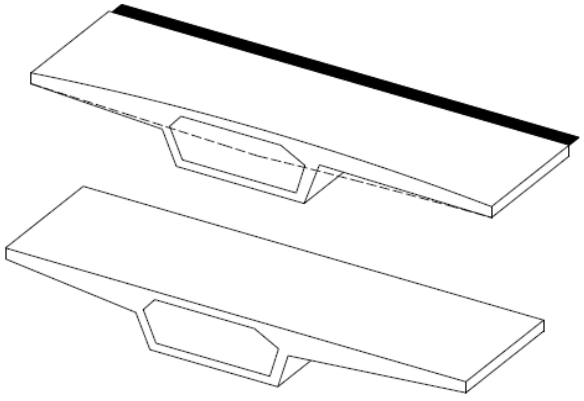


Fig. 1.3 Bowed shape

8. What is the difference between dry joint and wet joint in precast segmental bridges?

Dry joints have been properly used in the past in which the bridge segments are formed by match casting. The prevalence in the past is due to it lower cost and time for construction. There is no gluing material to seal up the joint. As such, leakage through the joint into the box culvert occurs from time to time and this may affect the durability of external post-tensioning tendons. Moreover, owing to the effect of seismic, temperature and creep, the joints are found to open under these conditions. Spalling of top concrete slab at bridge joint was also reported.

Wet joint involves the use of epoxy glue at the mating precast segments. After the application of epoxy glue, a temporary precompression pressure of 0.3MPa is applied by stress bars at top, bottom and the sides of the mating precast segments. The epoxy sets under the applied pressure. The use of epoxy joints provides lubrication to help in the fit-up and alignment of the mating segments and minimizes the effect of hard point contact between segments.

9. Why type of prestressing is better, external prestressing or internal prestressing?

At several locations in the span (i.e. third or quarter points) the tendons are deviated to the correct tendon profile by concrete deviators in external prestressing. The advantages of external prestressing are listed below:

(i) Owing the absence of bond between the tendon and structure, external prestressing allows the removal and replacement of one or two tendon at one time so that the bridge could be retrofitted in the event of deterioration and their capacity could be increased easily. This is essential for bridges in urban areas where traffic disruption is undesirable.
(ii) It usually allows easy access to anchorages and provides the ease of inspection.
(iii) It allows the adjustment and control of tendon forces.
(iv) It permits the designer more freedom in selecting the shape of cross section of bridges.
(v) Webs could be made thinner so that there is a reduction of dead load.
(vi) It enhances a reduction of friction loss because the unintentional angular change like wobble is eliminated. Moreover, the use of

polyethylene sheathing with external prestressing has lower friction coefficient than corrugated metal ducts in internal prestressing.

(vii) Improvement of concrete placing in bridge webs owing to the absence of ducts.

The major distinction between internal prestressing and external prestressing lies in the variation in cable eccentricity. The deflected shape of external tendons is not exactly the same as beams because the displacement of external tendons is controlled by deviators. This is a second order effect at working load and it is very important at ultimate load.

Based on past research, for small span with shallow cross section (i.e. less than 3m deep), the use of internal prestressing requires less steel reinforcement. However, for deeper bridge cross section, the employment of external prestressing results in smaller amount of steel reinforcement.

10. What is the optimum size of cable duct for prestressing?

The cross sectional area of duct is normally 2.5 times that of the area of prestressing steel. The size of ducts should be not designed to be too small because of the followings:

(i) Potential blockage by grout
(ii) Excessive development of friction
(iii) Difficulty in threading prestressing tendon

11. For incremental launching method, the span depth ratio of bridges is normally low. Why?

Bridges constructed by incremental launching method are usually low in span depth ratio and typical values are 14 to17. With low span depth ratio, the bridge segments are stiff in bending and torsion which is essential to cater for the launching process. Such low span depth ratio could tolerate the discrepancy in vertical alignment on supports over which they slide. Such differential settlements may occur owing to the shortening of piers when the superstructure slides over them and the differential deformation of different piers.

12. Why are split piers sometimes used when piers are built directly into the deck?

When the piers are built directly into deck without bearings, the monolithic

construction creates a portal structure which modifies the bending moment envelope in the deck when compared with bridges with bearings. For instance, hogging moments are increased in supports with the decrease in sagging moments in mid-span of bridge deck. On the other hand, the shear stiffness of piers is a major concern because it tends to resist length changes of bridge deck which could not expand and contract readily.

In order to retain the bending stiffness of piers and to destroy the shear stiffness of pier simultaneously, the piers are split into two parts. The split pier act like the flange of an “I beam” which is effective in resist bending moment. The web of the “I beam”, which is responsible for shear stiffness, is purposely removed so that the resulting split piers could deflect readily under length changes.

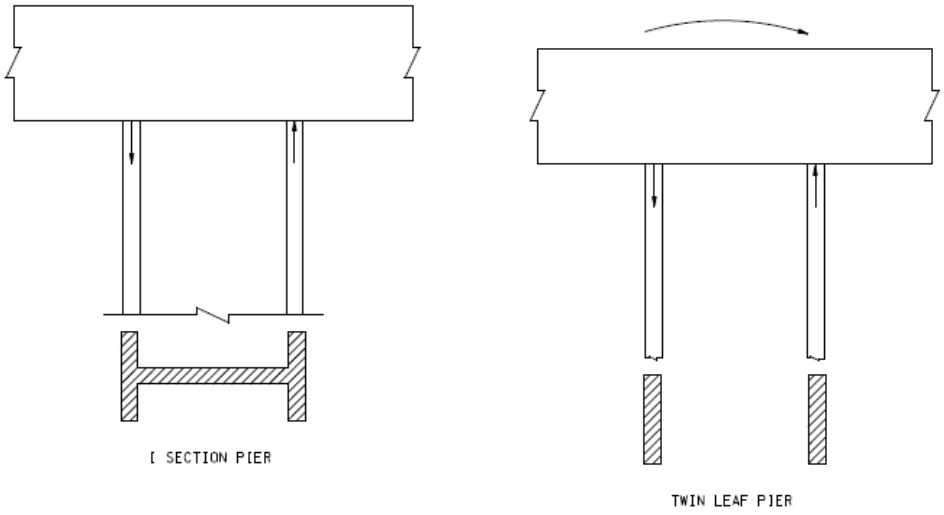


Fig. 1.4 Split pier

13. What is the significance of spacing of split piers?

Live loads on one span tend to cause uplift of outer column of the split piers (twin leaf piers). When the two split piers are designed too close, the uplift may be greater than the dead load reaction of the outer pier so that tension is induced in the outer pier. However, if the two split piers are designed to be adequately far apart, the uplift could hardly overcome the dead load leaving both piers in compression. As such, this allows for the use of pinned bearing. The optimum spacing of twin piers is about 1/25 to 1/13 of adjacent span.

14. What is the significance of null point in bridge deck?

The null point is the position of zero movement in the bridge deck. When the bridge deck is pinned at a single pier, it provides the location of null point with no deck movement. However, when the bridge deck is pinned to more piers, the position of null point has to be calculated. The determination of null point is important because it serves to estimate the forces on the piers by deck length changes and to calculate the sliding movement of sliding and free bearings.

For symmetrical deck founded on two identical fixed piers, the null point should be midway between the two fixed piers. However, if one pier is taller than the other, the null point would be shifted to the shorter stiffer pier.

15. In span-by-span construction, which prestress layout is better (i) single-span coupled cable or (ii) two-span overlapped cable?

For single-span coupled cable, the length of cable is one span and they are coupled at the construction joint which is located at 0.25 of span. The use of single-span coupled cable in span-by-span construction suffers the following drawbacks:

(i) Stressing all tendons in one span is time consuming. Moreover, the construction team has to wait until the concrete has gained enough strength before all tendons in the span to be stressed.
(ii) Extra time is required for coupling of tendons.
(iii) The accommodation of coupler requires the lowering of designed tendon profile. Moreover, the coupler occupies large space in bridge web which is the region of high shear forces. To avoid generating a weak point in web, the web has to be locally thickened to maintain sufficient thickness of concrete.
(iv) Couplers have a higher risk of failure when compared with normal anchorages. The success of such prestress layout is highly dependent on the quality of coupler and workmanship because coupling of all prestressing tendons is carried out at the same point.
(v) The tendon length is only one span long which is economically undesirable.

For two-span overlapped cable, the cable is two-span long. At each construction phase in span-by-span construction, only 50% of tendons are stressed. In most cases, 50% tendons stressing would be sufficient to carry its self weight upon removal of falsework. As such, it allows the use of more

economically longer cable with a reduction in construction time.

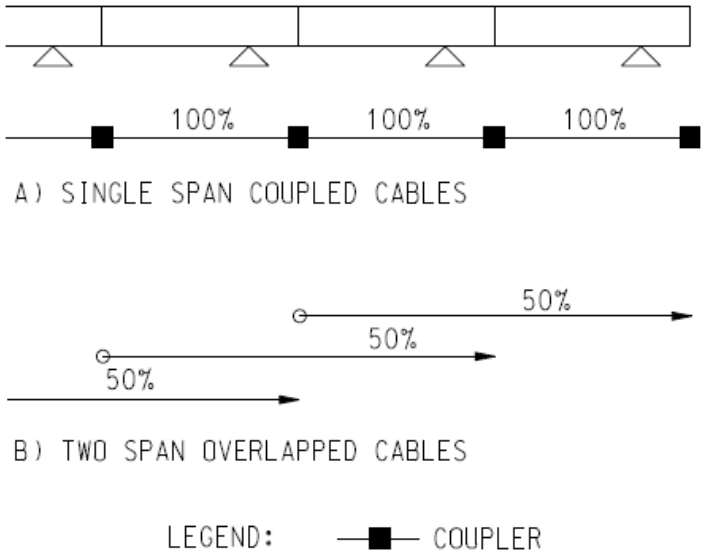


Fig. 1.5 Arrangement of single-span coupled cable and two-span overlapped cable

16. What is the difference between span-by-span construction and progressive placement?

Balanced cantilever construction simply cantilevers segments from a pier in a balanced manner on each side until the mid-span is reached and a closure is made with a previous half span cantilever from the preceding pier.

Progressive placement is similar to span-by-span construction as they both start from one end of structure to another. In progressive placement, precast segments are progressively placed in successive cantilevers on the same side of the same pier. This differs from the span-by-span method in which segments are cast at alternative sides of the same pier such that the hogging moment at the pier is counterbalanced. For progressive placement, temporary stays with temporary tower are placed on the pier to limit the cantilever stresses and deflections.

17. Why is creep a major concern in balanced cantilever method?

In balanced cantilever method, the moment is balanced along the length of the piers. However, along the extended cantilevers only a part of negative bending moment is balanced by prestressing bending moment arising from

normal force induced by prestressing. As such, it results in large deflections induced by concrete creep. These partly unbalanced permanent loads generate creep which produces unexpected and unevaluated hyperstatic effect. In fact, the compressive stresses are very high in lower slab while they are very low in upper slab of bridges.

Chapter 2. Concrete Structure

1. Why is liquid nitrogen added to fresh concrete sometimes instead of ice block/chilled water?

Traditionally, chilled water and ice have been employed to reduce the temperature of concrete mix in hot weather condition. Chilled water has a limitation in its cooling potential. For instance, even if all mixing water has been converted into chilled water, the temperature reduction achieved in concrete mix is only about 2.7 ^{o}C. The complete/partial replacement of mixing water with ice may be a better alternative in terms of cooling potential because ice possesses power from heat of fusion. However, it presents practical difficulty in ensuring homogeneous distribution of ice within concrete mix and the complete melting of ice. Unmelted ice block may be hidden in concrete mix and if it melts before concrete setting it creates high water cement ratio locally. In case unmelted ice block melts after concrete hardening, large voids would be formed which impairs the concrete strength and durability.

Liquid nitrogen is supercooled and has a very high cooling potential. Fresh concrete can be cooled inside a read-mix truck by injection of liquid nitrogen. Liquid nitrogen is kept at a temperature of -196^{o}C in storage tank. Once liquid nitrogen is added to fresh concrete mix, nitrogen in liquid form changes to gaseous state under normal atmospheric pressure in a very short time (e.g. milliseconds).

2. What is the main purpose of chamfers in concrete structures?

Some would suggest aesthetics as the answer of the question. Others may consider safety on the contrary because chamfered edge is less liable to damage to the concrete structure and any objects hitting on it. However, the main reason of the provision of chamfer is to make formworks easier to pull out after concreting operation. It is not uncommon that concrete is getting adhered to formwork and tore away during removal of formwork. In fact, the formation of a sharp nice corner is practically difficult and the concrete at corners is easily chipped and broken into pieces during the removal of formwork. Hence, the provision of chamber could protect the corner from chipping when striking formwork.

3. Some concrete specification requires the testing of compressive strength for both 7 days and 28 days. Why?

7-day compressive strength test results are usually not used for acceptance purpose *but for information only*. Instead, 28-day compressive strength test results are commonly adopted for acceptance purpose.

7-day compressive strength test results are often used to monitor the gain of early strength and they are estimated to be about 64% to 70% of the 28-day strength. As such, it serves as a warning signal to both concrete producers and contractors should the 7-day compressive strength test results are far less than 75% of the 28-day strength. Nowadays, most concrete placement schedule are very tight and it is of paramount importance for contractors to get to know as soon as possible the occurrence of low 7-day compressive strength test results. As such, the contractor could implement suitable measures promptly to get better quality control procedures at construction site and to monitor closely on sampling, molding, and testing of the test cubes so as to avoid the recurrence of the production of low-strength concrete in the coming concrete batches.

4. What is the purpose of adding gypsum in cement?

Gypsum is a mineral and is hydrated calcium sulfate in chemical form. Gypsum plays a very important role in controlling the rate of hardening of the cement. During the cement manufacturing process, upon the cooling of clinker, a small amount of gypsum is introduced during the final grinding process.

Gypsum is added to control the "setting of cement". If not added, the cement will set immediately after mixing of water leaving no time for concrete placing.

5. What is the difference between release agent, form oils, form releaser, demoulding agent?

Release agent, form oils, form releaser and demoulding agent are materials for separating formwork from hardened concrete. Though they generally refer to the same meaning, there are slight differences among these terms.

Release agent: Materials that contain ingredients which are chemically combined with cement.

Form oils: Diesel oils or other oil types.

Form releaser and demoulding agent: General terms to describe materials which perform separation of forms from concrete.

6. How can release agent help to separate formwork from concrete?

There are generally two main types of form releaser: barrier type or chemically active type.

For barrier type (e.g. form oil), it creates a barrier between the form and the fresh concrete. However, the quick evaporation of diesel oils affects clean air.

For chemically active type (e.g. release agent), an active ingredient (e.g. fatty acid) chemically combines with calcium (lime) in the fresh cement paste. This calcium/fatty acid product (grease or metallic soap) is stable and causes the formwork to release from the hardened concrete. It is this slippery, greasy, non-water soluble soap which allows the easy releasing of formwork from hardened concrete.

7. What are the potential problems of excessive application of form oils?

The problems of excessive application of form oils are:

(i) It stains the surface of hardened concrete.
(ii) Excess oils have nowhere to escape and find its way inside the cement paste and form holes subsequently. The oils bead up because of its incompatibility with water in chemical nature.
(iii) Higher cost is associated with increased usage of form oils.
(iv) In a relatively short time essentially most diesel oil evaporates so that it creates environmental problem.

8. Curing time in summer is less than that in winter. Why?

While concrete sets, it gains hardness and strength as the process of hydration slowly spreads the entire body of material. Curing should be

allowed to continue for several days before subjecting the new concrete to significant stress. The period of curing depends on the temperature because the rate of all chemical reactions is dependent on temperature. Therefore, in summer the rate of reaction (hydration) is faster so that a shorter curing time is required. On the contrary, in winter the rate of reaction (hydration) is slower so that a longer curing time is required.

9. How does rain affect the freshly placed concrete?

Rain may affect the water cement ratio at top portion of freshly placed concrete provided that the concrete is not properly protected from rain. To substantially change the water-cement ratio of the concrete at the surface of the slab, *external energy must be supplied* to the system such as troweling passes with excess water on the concrete surface. The energy supplied by the finishing operations pushes the excess water into the slab surface creating a high water cement ratio in the near surface of the concrete so that its strength and durability is reduced. Sometimes, the damage to the concrete surface is apparent since the texture of the surface is easily damaged after the initial curing period. When the surface strength is affected, the long-term durability of the concrete may be reduced. *However, the concrete strength and durability below the surface would not be affected.*

10. What is the purpose of uniform rate of application of water (i.e. 2m depth in 24 hours) in watertightness test of water retaining structures?

In watertightness test of water retaining structures, it normally requires the filling of water at a uniform rate or letting the water pool stand alone for some time before actual measurement is carried out. The reason for such provision in watertightness test is to allow sufficient time for water absorption to take place in concrete. After allowing sufficient time for water absorption to occur, the subsequent measurement of a fall in water level is deemed to be caused by water leakage instead of water absorption provided that adjustment has been made to other external effects such as evaporation.

11. Is curing compound suitable for all concrete?

For concrete structures with low water-cement ratio (i.e. less than 0.4), it may not be suitable to use curing compound for curing. When hydration takes place, the relative humidity of interior concrete drops which leads to

self-desiccation and drying-out. With no external supply of water, the cement paste can self-desiccate in such an extent that the hydration process stops. As such, curing compounds may not be sufficient to retain enough water in the concrete. In this case, wet curing is a better choice which serves to provide an external source of water.

12. What is the difference between curing compound and sealing compound?

Curing compound is primarily used for reducing the loss of moisture from freshly-placed concrete and it is applied once after concrete finishing is completed. Sealing compounds is adopted to retard the entrance of damaging materials into concrete and they are normally applied after the concrete is placed for 28 days. The harmful substances include water, deicing solutions and carbon dioxide which eventually cause freeze-thaw damage, steel corrosion and acid attack respectively.

13. What is the difference between plastic shrinkage cracks and crazing cracks?

Plastic shrinkage cracks are caused by a rapid loss of water from concrete surface before setting of concrete such that the rate of evaporation of surface water is higher than the rate of replacement of upward rising water. Tensile force is developed at concrete surface which forms plastic shrinkage cracks when the concrete starts to stiffen. Plastic shrinkage cracks appear to be parallel to each other with spacing of about 300mm to 1m. The cracks are shallow and generally do not intersect the perimeter of concrete slab.

Crazing is the formation of a network of fine cracks on concrete surface caused by early shrinkage of surface layer. The pattern of crazing cracks is in the form of irregular hexagon. The cause of crazing cracks is the shrinkage of concentrated dense cement paste at concrete surface. A wet mix tends to depress the coarse aggregates and form a highly concentrated cement paste and fines on surface. Hence, the difference between plastic shrinkage cracks and crazing cracks lies in the fact that crazing cracks arise from the shrinkage of weak material such as laitance in concrete surface while plastic shrinkage cracks appear even in normal concrete surface.

14. What is the significance of isolation joints?

Isolation joints isolate slabs or concrete structure from other parts of structure. The presence of isolation joints allows independent vertical or horizontal movement between adjoining parts of the structure. Otherwise, the structure may experience cracking owing to the restrained movement caused by directional connection between adjoining concrete structures.

15. What are the reasons of occurrence of dusting and scaling of concrete surface?

Dusting refers to the formation of loose powder arising from the disintegration of concrete surface. For dusty concrete surface, they can be easily scratched by nails. The cause of dusting can be related to finishing works carried out before completion of concrete bleeding. The working back of bleeding water to concrete surface produces a low strength layer with high water cement ratio. It may also arise owing to inadequate curing and inadequate protection of freshly placed concrete against rain, wind and snow.

Scaling is the occurrence of peeling of hardened concrete surface as a result of freezing and thawing effect. Scaling occurs in non-air-entrained concrete as air entrainment is normally adopted to protect concrete against freezing and thawing. Spaying of sodium chloride deicing salts is also another common cause of scaling.

16. What is the purpose of adding polyethylene film in interior slabs sitting on grade for building structures?

Membrane materials, such as polyethylene film**,** are commonly used to reduce vapour transmission from soils to concrete slab. They are often termed “vapour retarder” and are placed on the underside of concrete slabs sitting directly on soils for building structures. Protection from moisture is essential because floors inside buildings are normally covered with carpet and tiles and penetration of water vapour through concrete slabs could result in the failure of adhesives in tiling, discoloration of flooring products and fungal growth.

17. Should on-site addition of water to fresh concrete be allowed?

The addition of water to fresh concrete in truck mixer upon arrival at the location of concrete is allowed only if some design mixing water is held

back during initial mixing stage. Addition of water in excess of design mixing water would definitely cause an increase of water cement ratio leading to a reduction of concrete strength.

The purpose of adding water to fresh concrete is to increase the workability to facilitate placement of concrete. The use of water-reducing agent or superplasticizer could help resolve the problem but extra attention has to be paid *on the segregation issue*. In case there is some buffer in the amount of water in fresh concrete so that addition of water would not result in exceeding the designed water cement ratio, water could be added based on the following rule of thumb: *5 liters of water per m^3 of concrete gives about 25mm increase in slump*.

18. What are the potential problems of using liquid nitrogen to cool concrete?

Based on the results of past research, there is minimal impact on the properties and performance of concrete by liquid nitrogen (LN). The addition of liquid nitrogen appears to decrease the slump value of fresh concrete. However, the slump loss is not caused by liquid nitrogen but by previous hot concrete mix, i.e. the slump of LN-cooled concrete is the same of original hot concrete. Liquid nitrogen can also be observed to extend the setting time of concrete.

The safety of workers is one of the major concerns when using liquid nitrogen. The extremely low temperature of liquid nitrogen is dangerous to workers as prolonged contact of liquid nitrogen with skin cause severe burns and frostbite. Most concrete mixing drums may not be capable to endure the thermal shock brought about by liquid nitrogen.

19. What is the difference between dry-mix method and wet-mix method in shotcrete?

Shotcrete is not a special product of concrete and it is not a special method of placing concrete.

In dry-mix method the dry cementitious mixture is blown through a hose to the nozzle, where the water is injected immediately. The dry-mix method appears to be better for low volume placements. The nozzleman should pay great attention in adding the necessary amount of water during shooting operation.

Wet-mix method involves the pumping of ready mixed concrete to the nozzle. Compressed air is introduced at the nozzle to impel the mixture onto the receiving surface. The wet-mix method is more favorable for large volume placements. Rebound is less than in the dry-mix method. The nozzleman does not need to be concerned with the control on water addition.

20. What is the difference between no-fines concrete, lightweight concrete and lean concrete?

Pervious concrete is sometimes called "no fines" concrete. It is designed with high porosity and allows water to pass though. It is commonly used in concrete pavement so as to reduce surface runoff and allow the recharging of ground water. The high porosity is achieved by a network of interconnected void. "No fines" concrete has little or no fines and contains just enough cement paste to cover the surface of coarse aggregates while maintaining the interconnectivity of voids.

Lightweight concrete is characterized by low density (1,400kg/m^3 to 1,800 kg/m^3) and is made of lightweight coarse aggregates. In some cases, even the fine aggregates are also lightweight too. The primary use of lightweight concrete is to reduce the dead load of concrete structures.

Lean concrete, which is also known as cement bound material, has low cementitious material content. It has low concrete strength and is commonly used as roadbase material.

21. What is the purpose of applying spatterdash before rendering and plastering?

Spatterdash is a mixture of one part of cement to one and a half parts of coarse sand with enough water. The mixture is thrown forcibly onto the wall so that the impact removes the water film at the interface between spatterdash and the substrate leading to the improvement in adhesion. The spatterdash should cover the substrate surface completely and form a rough texture. Spatterdash serves as *an effective mechanical key* to prevent rendering and plastering material from sliding or sagging. The roughness of spatterdash improves adhesion by providing a positive “key” for plaster to grip. The improper application of spatterdash affects the subsequent bonding of rendering with substrate.

22. What is the significance of Flakiness Index and Elongation Index?

Flakiness Index is the percentage by weight of particles in it, whose least dimension (i.e. thickness) is less than three-fifths of its mean dimension.

Elongation Index is the percentage by weight of particles in it, whose largest dimension (i.e. length) is greater than one and four-fifths times its mean dimension.

Flaky and elongated particles may have adverse effects on concrete and bituminous mix. For instance, flaky and elongated particles tend to lower the workability of concrete mix which may impair the long-term durability. For bituminous mix, flaky particles are liable to break up and disintegrate during the pavement rolling process.

23. What is the difference between carbonation and carbon dioxide attack?

For carbon dioxide attack, carbon dioxide dissolves in water to form a weak acid called carbonic acid. It would dissolve the cement matrix. However, the amount of carbon dioxide from the atmosphere is usually not sufficient to cause harm to concrete structures until additional source of carbon dioxide is available (e.g. decaying vegetable matter).

Carbonation is the process of converting alkaline hydroxides in concrete to carbonates by reaction with carbon dioxide. The significance of carbonation lies in the reduction of pH of pore water in concrete structure from 12-13 to 8-9 so that it drops the protection to steel reinforcement. The process takes place at concrete surface and spreads inwards. The passive nature play an important role in steel corrosion as it prevents corrosion even in the presence of water and oxygen. This passive nature is derived from a stable and thin layer of iron oxide formed at the surface of steel reinforcement. However, if the pH of concrete is dropped, this passive oxide layer becomes unstable and corrosion may start once water and oxygen supply is available.

24. What are the differences in the behavior and properties of recycled-aggregate concrete when compared to normal-aggregate concrete?

Higher porosity of recycled aggregate compared to natural aggregate leads to a higher absorption. Moreover, recycled aggregate has lower specific

gravity than natural aggregate and will make concrete with higher drying shrinkage and creep. Such differences become more significant when there is an increasing amount of recycled fine aggregates. Recycled aggregates also contain more chloride than normal aggregates which may affect the durability of concrete. Moreover, excessive recycled fine aggregates can also generate a harsh concrete mix with low workability.

Chapter 3. Drainage Works

1. What is the importance of uniform support for precast concrete pipes?

Concrete pipes are designed to be uniformly supported along the length to carry vertical loads on its top. They are normally not intended to serve as a beam to carry loads in longitudinal direction under poor ground supports (i.e. high and low spots in bedding). Under cantilever beam action and simply support beam action as shown in the diagram below, circumferential cracks would develop in concrete pipes. Circumferential cracking develops in concrete pipes only when pipe bedding becomes non-uniform. Therefore in unstable ground conditions such as soft spot and hard foundations, care should be taken to provide *firm and even support* to concrete pipes.

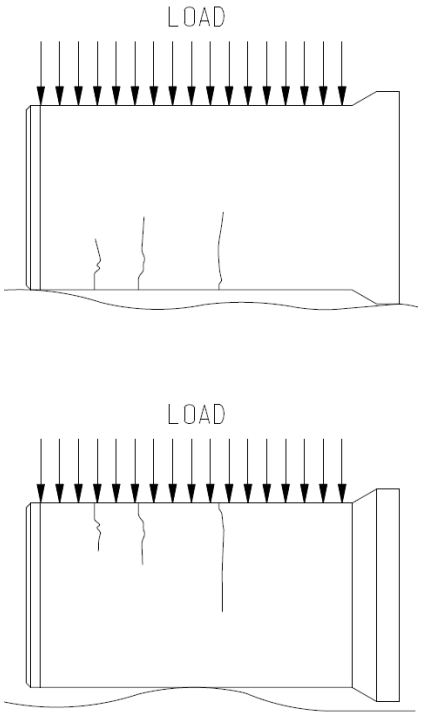


Fig. 3.1 Crack formation in non-uniform support

2. During the time of construction, cracks are likely to develop in small diameter concrete pipes. Why?

During the construction of new pavement, vibratory roller and heavy equipment are needed to compact the filling material and bituminous

material. These heavy equipment could generate very high impact load with short duration on the concrete pipes. It requires an extremely even and uniform support in order to safely support these loads. Therefore, it is not uncommon that construction vehicles are primary source of crack-producer and it usually results in the formation of circumferential cracks.

3. What is the difference between on-seating and off-seating head in penstock?

A penstock is commonly used to control the flow and water level and for isolation of fluid. It mainly consists of a sliding door which is controlled by mechanical spindle moving through a hole in a frame built onto a structure. Penstock is the term used in UK while sluice gate is more commonly adopted outside UK. In the design of penstock, it is important to identify if it would take on-seating head or off-seating head.

On-seating head refers to the water pressure forcing the penstock into the wall while off-seating head refers to the water pressure forcing the penstock out of the wall as shown below.

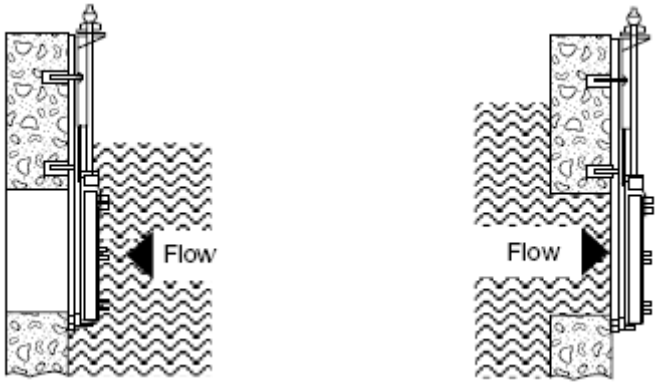


Fig. 3.2 On-seating (left) and off-seating head (right)

4. Should the same freeboard be maintained along a channel?

The freeboard is defined as the vertical distance from water surface to the top of channel bank. The selection of freeboard is dependent on the consequence should overflow out of channel bank occurs. Other than that, consideration should also be given to prevent waves, superelevation and fluctuations in water surface from overflowing the channel banks.

Generally, a 300mm freeboard is generally considered acceptable. For steep channels, it is preferably to have the height of freeboard equal to the flow depth to account for high variations in swift flow induced by waves, surges and splashes.

5. Why is stoplog seldom used in drainage channels?

Stoplog consists of several sets of horizontal beams/logs stacked vertically. For narrow openings, the logs span between support slots at the ends of the openings. For wide openings, intermediate removable support posts may be required. They are prevalent in the past because of its low establishment cost, simple erection and easy operation.

However, there are also several drawbacks of this closure system. Since it requires a long lead time to mobilize workers and equipment for installation, it needs an accurate long-range weather forecast to allow for the long lead time. The situation is even worse for wide stoplogs which requires special lifting equipment for installation of intermediate support posts. When compared with time required to close sluice gates, the installation time of stoplogs is much longer. Moreover, a storage building has to be provided to prevent material loss by theft and damage by vandalism.

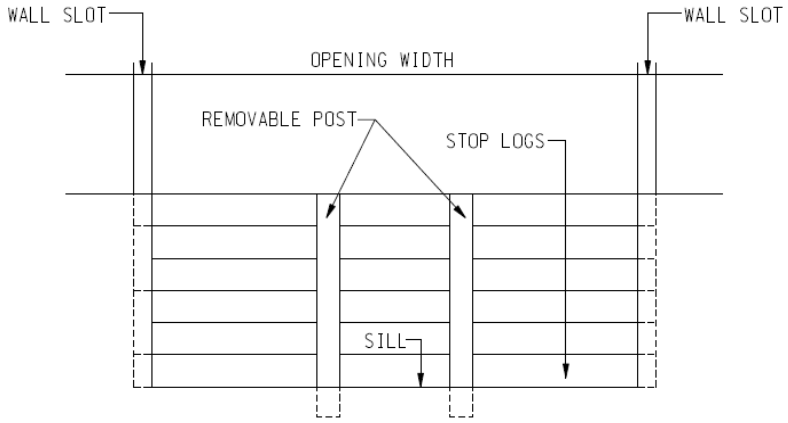


Fig. 3.3 Stoplog system

6. What are the possible causes of longitudinal and circumferential cracking in concrete pipes?

Concrete pipes are designed to crack in tensile zone so that steel reinforcement could take up the tensile stress. Flexural stresses are developed at the top and bottom inside surfaces and on the outside

surface at the sides. As such, they are the potential locations of longitudinal cracks.

Longitudinal cracks are formed as a result of excessive soil and traffic loads or inadequate pipe bedding. Visible longitudinal cracks observed at top and invert inside the pipe should be more severe than those on the outside because tensile stress occur at top and invert portion of the inside of the pipes. On the contrary, longitudinal cracks formed outside the pipe at the sides of concrete pipe should be more severe than those on the inside.

Multiple longitudinal cracks with small crack width (e.g. 0.15mm) is acceptable which indicate effective transfer of stress from concrete to steel. Care should be taken when discovering a single wide longitudinal crack. Circumferential cracks may occur owing to loads imposed during construction and uneven bedding. It may also be caused by the relative movement of another drainage structure connecting to the concrete pipe. Circumferential cracks do not generally affect the load-carrying capacity of concrete pipes.

7. What are the potential problems of high velocity in pipes?

Flow velocity seldom causes abrasion problem for concrete pipes. Instead, the particles carried by effluent in high velocity may create abrasion problem of concrete. The abrasive effect is dependent on the size of particles and velocity. In most circumstances, the problem of abrasion shall be avoided for flow velocities less than 8m/s.

Very high velocity (i.e. more than 10m/s) could also induce significant cavitation problem because air bubbles are formed from low water pressure and they would collapse when entering a region of high water pressure.

8. Why is geotextile filter introduced below the rockfill layer of a typical box culvert?

In a typical box culvert, at the interface between rockfill layer and sub-grade, a layer of geotextile filter is usually added to perform separation function. With the addition of geotextile filter layer, it avoids the intermixing of widely different soil granulations so as to reduce long-term settlement. Moreover, it also prevents interpenetration of rockfill into sub-grade so that the deformed configuration of rockfill may impair its intended function of load spreading.

9. What is the purpose of using riprap in drainage channels?

Riprap is an erosion-resistant ground cover made up of large, angular and loose stones (rock, concrete or other material) with geotextile or granular layer underneath. Riprap is commonly used in drainage channel to provide a stable lining to resist erosion by channel water. It is also used in channels where infiltration is intended but the velocity of flow is too large for vegetation.

A layer of geotextile is normally provided under riprap to perform separation from underlying soils. This prevents the migration of fined-grained soils from sub-grade into riprap and results in settlement and loss of ground.

10. Should riprap be constructed by dumping or by hand-placing?

Riprap by dumping involves the dumping of graded stone by dragline or crane in such a way that segregation would not take place. Dumped riprap is a layer of loose stone so that individual stones independently adjust to shift in or out of the riprap. The dumped riprap is very flexible and would not be damaged or weakened by minor movement of the bank caused by settlement. Moreover, local damage or soil loss can be readily repaired by placement of more rock.

Riprap by hand-placing involves laying of stones by hand and by following a pattern with the voids between the large stones filled with smaller stones and the finished surface is kept even. The interlocking riprap produces a tidy appearance and decreases flow turbulence. Also, owing to the interlocking nature of riprap it allows the formation of riprap on steeper bank slopes. The thickness of riprap can usually be reduced when compared with dumped riprap. However, it requires much labour for installation of riprap. Another drawback is that the interlocking of individual rocks produces a less flexible revetment so that a small movement in the base material of the bank could cause failure of large portions of the revetment.

11. Should angular or rounded stones be used in riprap channel?

Rock used for riprap should be blocky and angular, with sharp edges and flat faces. Angular stones proved to be effective to withstand external forces. Rounded stones have a high tendency to roll and inadequately protect the channel bed and bank. The ratio of length to thickness of

angular stones should be less than 2.

If rounded stones have to be used, they should not be placed not steep embankments. Moreover, the size of rounded stones shall be increased (say 25%) with the corresponding increase in thickness of riprap layer.

12. Should a box culvert be designed as free flow or surcharged flow?

Whenever possible box culverts should be designed for free flow at design flow rate. A box culvert with surcharged flow is similar to inverted siphon which creates maintenance problem. There is a risk of blockage by silt and debris and the inspection and maintenance of submerged culvert is difficult when compared with free flow condition. For long box culverts (more than 20m) it is even more important to design for free flow to decrease the risk of blockage which results in an inaccessible path.

From hydraulic point of view, the change from free flow to submerged condition would cause an increase in head loss leading to a rise in upstream water level.

13. How does lateral pressure of soils affect the drain performance?

The presence of lateral pressure of backfilling sidesoils induces bending moments in the opposite direction from those produced by vertical loads and bedding support reaction. Such bending moment reduces the flexure in pipe wall and as a result this causes an equivalent increase in supporting strength of the pipe.

The lateral pressure of backfilling soils on drains is affected by the deflection of drains. With no occurrence of deflection, lateral pressure induced is in the form of active pressure. If pipe deflection occurs, the drain increases its horizontal dimension so that passive pressure is developed.

Chapter 4. Marine Works

1. Why is larger concrete cover (e.g. 75mm) normally used in marine concrete?

In marine environment, the cover to reinforced concrete in exposure zones is specified to be much larger than normal concrete (e.g. 75mm). Based on past experimental studies, the concrete cover is identified to be directly related to the corrosion failure of marine structures.

In Eurocode 1 under Ultimate Limit State the probability of failure is less than 10^{-4} while under Serviceability Limit State the probability of failure is less than 10^{-2}. For corrosion aspects, it is normally classified under SLS state. For OPC concrete with 50mm cover, the corrosion probability is found to be more than 10^{-2}. However, with the use of 75mm cover, the corrosion probability is about 10^{-3}, which fulfills the Eurocode requirement.

2. In mooring of vessels, wire ropes or fibre ropes are commonly used for tying the vessels to mooring system. It is not recommended to use them together in mooring. Why?

Mooring lines are provided by vessel while the shore provides the mooring points.

Wire ropes provide a more rigid mooring system than fibre ropes. When a high degree elastically is required, fibre ropes would be a better choice. The mixed usage of wire ropes and fibre ropes is not recommended because of the uneven tensioning of ropes. Owing to different material properties associated with wire ropes and fibre ropes, it is almost impossible to allocate uniform tension on both types of wires. As a result, there is possible occurrence of overloading in some ropes.

3. Which configuration is better, finger jetty or T-shaped jetty?

Finger jetty is a more efficient pier structure because it could accommodate vessels at both sides of the jetty. However, there should be sufficient water depth as the berths at finger jetty is relatively close to shoreline when compared with T-shaped jetty so that it is anticipated that vessels are required to berth at shallower water. Moreover, there should be no cross current to enhance berthing at both sides of finger jetty. Also, as mooring points are often located on the jetty, leads are not ideal for larger ships.

T-shaped jetty allows higher water depth for vessels to berth. Moreover, with the installation of breasting dolphins and mooring dolphins, it allows the berthing of larger vessels.

Fig. 4.1 Finger jetty and T-shaped jetty

4. What is the difference in design philosophy between flexible dolphin and rigid dolphin?

(A) Rigid dolphin

The impact energy of vessel is absorbed mainly by fender. As such, the dolphin itself is designed as a rigid structure with a group of piles. The piles serve to transfer the reaction force from fender system to the foundation soils. The design of rigid fender is similar to other structures and the strength and stiffness of rigid dolphin should be sufficient to withstand berthing forces without causing excessive deformations.

(B) Flexible dolphin

The impact energy of vessel is absorbed by lateral deflection of piles. The dolphin itself performs both the functions of *fender and berthing structure*. Flexible dolphin is particular suitable in deep water region because the energy absorption capacity is a function of pile length. The pile stiffness could not be designed to be too low because large deflection of pile may occur so that the pile may touch the jetty or the vessel may touch the pile. On the other hand, pile stiffness could not be designed to be too high because of potential yielding of piles or vessel's hull.

5. What is the difference between breasting dolphin and mooring dolphin?

A dolphin is an isolated marine structure for berthing and mooring of vessels. It is not uncommon that the combination of dolphins with piers could drastically reduce the size of piers.

Dolphins are generally divided into two types, namely breasting dolphins and mooring dolphins. Breasting dolphins serves the following purposes:

(i) Assist in berthing of vessels by taking up some berthing loads.
(ii) Keep the vessel from pressing against the pier structure.
(iii) Serve as mooring points to restrict the longitudinal movement of the berthing vessel.

Mooring dolphins, as the name implies, are used for mooring only and for securing the vessels by using ropes. They are also commonly used near pier structures to control the transverse movement of berthing vessels.

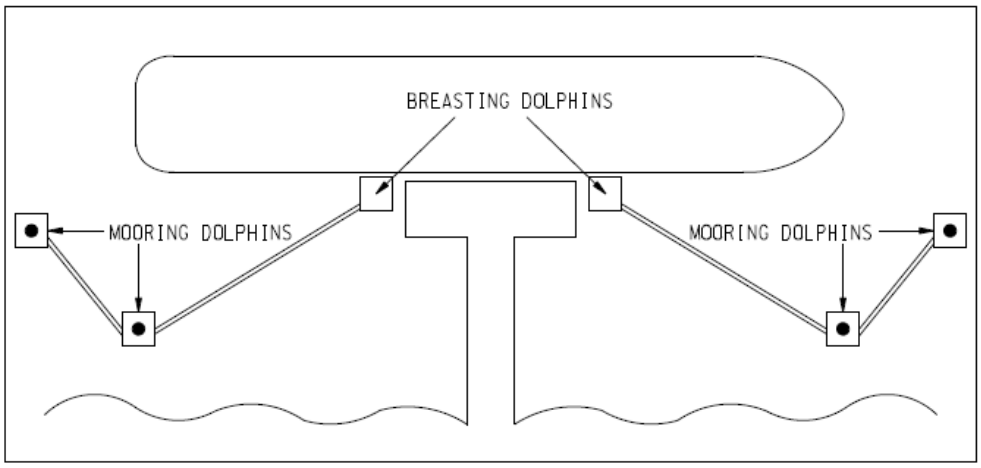


Fig. 4.2 Breasting dolphin and mooring dolphin

6. Why is it desirable to select fenders with low reaction force?

It is always in the interest of engineers to select fenders with high energy absorption with low reaction force. The reaction force is an important factor in the design of quay walls because sufficient savings could be resulted from low reaction force exerted by fenders. In many fender systems such as rubber fender, load-spreading panel is often adopted to cater for high reaction force. Hence, the use of fenders with low reaction force gets rid of

the need of load-spreading panel so that significant economies could be made.

Chapter 5. Piles and Foundation

1. Why are bored piles usually cast higher than the required final level?

It appears to be a common construction practice that bored piles are normally cast up to a piling platform much higher than the formation level of pile caps. Then, the excessive pile length has to be cropped and removed to the correct level for the subsequent construction of pile cap. The reasons of such practice are as follows:

(i) It is technically sound to employ such practice because laitance, impurities and poorly-compacted concrete should have migrated to the top of the piles. Therefore, additional length at the top of piles is constructed to accommodate these sub-standard concrete, which are subsequently removed and cropped to leave high quality concrete over the entire length of piles.
(ii) In actual site practice, the details of construction sequence and access arrangements have potential impact on the possibility of constructing piles to correct level without the need of cropping.

2. What is the purpose of maintaining excess water head during excavation for bored piles?

Excavation of bored piles is usually implemented by a hammer grab. The steel casing will be extended by welding or bolting on additional casing and is installed by hydraulic oscillator. Water is pumped into the casing during excavation and excess water head is required to be maintained to prevent any ingress of material at the bottom of casing. Moreover, for excavation below pile casing, the provision of excess water head is essential to maintain bore stability.

3. What is the widespread usage of 45^o load spread rule?

Under the 45^o load spread rule, when the horizontal distance between the toe level of adjacent piles is smaller than the vertical difference between the piles, additional load is deemed to be added by the pile at lower founding level. Hence, when the pile at lower founding level is within the zone of 45^o spreading from the pile at higher elevation, further load checking is required for the lower pile.

This 45^{o} load spread rule is a common practice of foundation engineers and may not be incorporated in foundation codes. There are some situations where this rule may fail. For instance, when two piles at the same foundation level are situated close to each other, they shall have load effect on each other. However, based on 45^{o} load spread rule, it could not address this concern.

4. There is a general trend that toe defects in bored pile construction have become more serious. Why?

Direct coring method is commonly employed to check the quality and workmanship of bored piles. It is further divided into two main types, namely interface coring (pile/rock interface) and full coring (entire concrete pile length). In the past, the implementation of full-depth coring usually takes place near the pile centre to prevent physical conflicts with reinforcement cage. When placing concrete by tremie method, concrete pouring by tremie pipe is carried out near pile centre and soft and weak materials are usually displaced to the sides of bored piles. As a result, the pile/rock interface at pile centre should indicate the best results. However, with the recent trend of using interface coring through reservation tube attached to the reinforcement cage, there is a high chance that interface coring gives poor results as the reinforcement cage may trap soft and weak materials and they are located far from the pile centre.

5. Some piling contractors incline to use drop hammer instead of hydraulic hammers in setting of piles. Why?

The use of high grade and heavy steel pipes may not warrant the use of drop hammer. For pile driving of Grade 55C steel section, it requires heavier drop hammer with increased drop height so as to comply with penetration resistance at final set. As such, it is possible that such heavy hammer may damage the pile and endangers the worker who takes the final set record.

Though hydraulic hammer is commonly used as standard hammer for driving piles, some piling contractors prefer to employ drop hammers to take final sets. The obvious reason of such practice is that it is convenient for drop hammer to change energy input easily to cater for the range of penetration in final set. On the other hand, the use of hydraulic hammers for setting of piles requires the knowledge of transfer of energy to pile head and hence needs the input from wave equation analysis.

6. In driven piles, the allowable set is limited between 25mm and 50mm per 10 blows. Why?

In final set table it is commonly to limit pile set between 25mm/10 blows and 50mm/10 blows. The reason of the provision for lower limit of set value of 25mm/10 blows is to avoid possible damage at pile toe owing to compressive stress reflected at the bottom of pile. The upper limit of 50mm/10 blows is established principally to avoid very heavy hammer impacting at pile head so that the pile head may be damaged owing to excessive compressive stress. These limitations are believed to be applied originally to precast concrete piles.

7. What are the components in contributing the bearing capacity of shallow foundation?

Based on Terzaghi's bearing capacity equation, there are three components in contribution to the bearing capacity:

(i) Surcharge pressure
Foundations are normally not placed directly on the ground level. Instead, they are installed at a depth below the existing ground level. The soil pressure arising from the depth of soils serves as a surcharge imposing a uniform pressure at foundation level.

(ii) Self-weight of soils
The self-weight of soils contribute to the bearing capacity and is represented by $0.5rBN_r$ (r=density of soils).

(iii) Shear strength
The shear strength of soils contributes to the bearing capacity and is represented by cN_c.

8. What is the difference between pad foundation, strip foundation and raft foundation?

Shallow foundation is commonly accepted as foundation with founding level less than 3m from ground surface. In case surface loads or surface conditions could still affect the bearing capacity, the foundation which sits on it is called shallow foundation.

Pad foundation refers to the foundation which is intended for sustaining concentrated loads from a single point load such as structural columns.

Strip foundation is used to support a line of loads such as load-bearing

walls. For instance, closely-spaced columns render the use of pad foundation inappropriate and strip foundation may be a better alternative.

Raft foundation consists of a concrete slab which extends over the entire loaded area so that loads from entire structure are spread over a large area leading to a reduction of the stress of foundation soils is reduced. Moreover, raft foundation serves to avoid differential settlement which otherwise would occur if pad or strip foundation is adopted.

9. What is the purpose of keeping tremie pipe's tip immersed in freshly-placed concrete for about 1m in underwater concreting?

The size of tremie pipe is about 300mm with sections having flange couplings fitted with gasket to prevent water leakage. The tremie pipe should be closed initially to prevent water from entering the pipe. It should be designed with sufficient thickness and weight so that it would not be buoyant when empty inside water.

The placement of tremie concrete is commenced by putting the closed pipe underwater to the location for concreting, followed by partial filling of tremie pipe with concrete. In order to have tremie concrete flowed out of the pipe, it is necessary to fill the pipe with concrete of sufficient height to overcome the water pressure and frictional head. After that the tremie pipe is raised about 150mm to allow concrete to flow out. To enhance sufficient bonding, each succeeding layer of concrete should be placed before the preceding layer has reached the initial set. The tremie pipe should be kept full of concrete up to the bottom of hopper.

The tip of tremie pipe should always be immersed in freshly-placed concrete for at least 1m *to prevent inflow of water into the tremie pipe and to avoid contact of freshly placed concrete with water*. This serves as the seal against water entry. The loss of seal may result in increased flow rate with fresh concrete affected by seawater. The distance that tremie concrete could be allowed to flow without excessive segregation is about 6-20m.

10. Why shouldn't tremie pipe be left in a position too long without lifting up?

When concrete starts to flow out of tremie pipe, the lifting of tremie pipe should be carried out slowly to avoid disturbance of material surrounding the end of tremie pipe. The mouth of pipe is embedded at least 1m below the concrete surface to maintain the seal.

If a tremie pipe is left in a position too long without lifting up, it would impair the quality of already-placed concrete. The fresh concrete may be placed under the portion of concrete which have set already so that it would raise the mass of already-placed concrete and induce cracks on it.

11. Why is bentonite slurry commonly used in diaphragm wall construction?

Bentonite slurry is one of the most common excavation fluid used in constructing diaphragm wall. Bentonite clay (in powder form) and water are combined in a colloidal mixer and clay particles bond to each other and set to form a gel when left to stand for a period of time. When the bentonite is set in motion, it reverts back to the fluid state rapidly.

Bentonite slurry shores the trench to stabilize the excavation and forms a filter cake on the slurry trench walls that reduces the slurry wall's final soil permeability and to reduce ground water flow. The gel strength and viscosity properties of the bentonite clay allow for cutting suspension and removal.

12. Should high density or low density bentonite slurry be used in diaphragm wall construction?

The use of high density bentonite slurry could improve trench stability. It helps to retain cuttings and particles in suspension and reduce the loss of bentonite slurry into soils of high permeability such as sand. However, the use of low density bentonite slurry is desirable from operation point of view. Low density bentonite slurry tends to be more neatly displaced from soils and reinforcement. Moreover, the pumping of low density bentonite slurry is more easily to be carried out.

13. What is the difference in mechanism in resisting clay and normal soils by bentonite slurry in diaphragm wall construction?

For normal soils, water in bentonite slurry penetrates into the sandy walls and leaves behind a layer of bentonite particles on the surface of the soils. The bentonite particles form the filter cake of low permeability on the excavated faces. The filter would be formed only when slurry pressure is greater than the pore water pressure in excavated soils. The filter cake serves as impermeable layer and allows the application of full hydrostatic pressure of bentonite slurry on the excavated surface of soils.

For soils with low permeability such as clay, there is little water passage from slurry to excavated clay surface so that filter cake would hardly be formed. As a result, slurry pressure simply applies on clay surface.

14. What is the function of introducing cement plug before pouring concrete in bored piles?

It is a common practice in the construction of bored piles by adding a cement plug before concreting of bored piles takes place. One of the possible explanations is that the cement grout serves as a barrier and protects fresh concrete from being washed away by water inside pile bore. The cement grout helps to set aside water when the first batch of concrete is poured down from the tremie pipe. As such, the quality of fresh concrete is anticipated not to be seriously affected by water and this helps to improve toe imperfection problem.

15. What is the purpose of coating driven piles with bitumen?

Coating driven piles with bitumen serves the following purposes:

(ii) It acts as friction reducer and could effective reduce the effect of downdrag.
(iii) It offers protection of steel piles against acid attack from soils.
(iv) It helps to prevent pile corrosion.

16. What are the possible methods to reduce downdrag on piles?

(A) Coating piles with friction reducer such as bitumen.
(B) Predrill a hole firstly, followed by putting in the pile and subsequent filling of annulus with bentonite slurry.
(C) Drive the piles with an oversize shoe and fill the annulus with bentonite slurry.
(D) Adopt double tube method in which the inner pile takes up the structural load and the outer pile carries the downdrag load.
(E) Preload the soils to accelerate settlement.
(F) Use electro-osmosis to enhance water content around the piles and reduce the friction between pile and soils.
(G) Increase the pile capacity by using larger diameter or longer length so that the effect of downdrag is thereby reduced.

17. What is the significance of allowing the usage of combined shaft resistance and end bearing of rock socket to resist loads?

In some design codes, it allows the simultaneous usage of shaft and base resistance of rock sockets to resist loading. Past experience showed that the shaft resistance could be mobilized in rock socket provided that the length of rock socket is less than three times the pile diameter. Such provision eliminates the need for bell-out because higher pile capacity could be derived from the simultaneous usage of shaft and base resistance of rock sockets. Bell-outs are commonly used in piling industry but its effectiveness is doubtful because of some practical issues like the inability of thorough cleaning of pile base.

18. Can dynamic pile test (PDA test) be used to replace pile load test for testing driven pile capacity?

The PDA system consists of two strain transducers and two accelerometers attached to opposite sides of the pile to measure the strain and acceleration in the pile. The force is computed by multiplying the measured signals from a pair of strain transducers attached near the top of the pile by the pile area and modulus. The velocity measurement is obtained by integrating signals from a pair of accelerometers also attached near the top of the pile.

PDA test is commonly used for the following purposes:

(i) Evaluation of driven pile capacity
Soil resistance along the shaft and at the pile toe generates wave reflection that travel to the top of the driven piles. The time the reflections arrive at the pile top is a function of their locations along the pile length. The measured force and velocity at the pile top thus provide necessary information to estimate soil resistance and its distribution.

(ii) Measurement of pile stress during driving
Compressive stress at pile top is measured directly from strain transducers.

(iii) Measurement of hammer energy delivered to the piles
The hammer energy delivered to the pile is directly computed as the work done on the pile from the integral of force times displacement ($\int Fdu$) and this can be calculated as force times velocity integrated

over time (∫Fvdt).

(iv) Determine if pile damage has occurred.
Pile integrity can be checked by inspecting the measurements for early tension returns (caused by pile damage) before the reflection from the pile toe. The lack of such reflections assures a pile with no defects.

There is a growing trend of using PDA test to check driven pile capacity instead of traditional static load test which is more expensive and time-consuming. Some engineers may have reservation on the use of dynamic formula to evaluate driven pile capacity because of the fear of improper selection of quake values and damping factor.

19. What is the difference between Case Method and CAPWAP Analysis?

High Strain Dynamic Testing consists of two main types, namely Dynamic Pile Monitoring and Dynamic Load Testing. Dynamic Pile Monitoring involves the use of PDA to perform real-time evaluation of Case Method pile capacity, hammer energy transfer, driving stresses and pile integrity for every blow count. On the other hand, Dynamic Load Testing is another technique that is evolved from wave equation analysis. CAPWAP Analysis makes use of field measurements obtained by PDA and wave-equation type analytical method to predict pile performance such as static load capacity, pile-soil load transfer characteristics, soil resistance distribution, soil damping and quake values. CAPWAP Analysis is carried out on the PDA data after the test is complete.

Chapter 6. Roadworks

1. What is the importance of glass beads in road markings?

Retroreflectivity refers to the part of incident light from headlights of a vehicle being reflected back to the driver. Retroreflectivity is normally achieved in road marking materials by using glass beads or ceramic beads. These beads are sprayed on the marking materials when the road is marked. The beads are transparent and serve as lenses. When the light passes through the beads, it is refracted through the beads and then reflected back towards the original path of entry. The use of glass beads enhances retroreflectivity which raises the safety level for night driving.

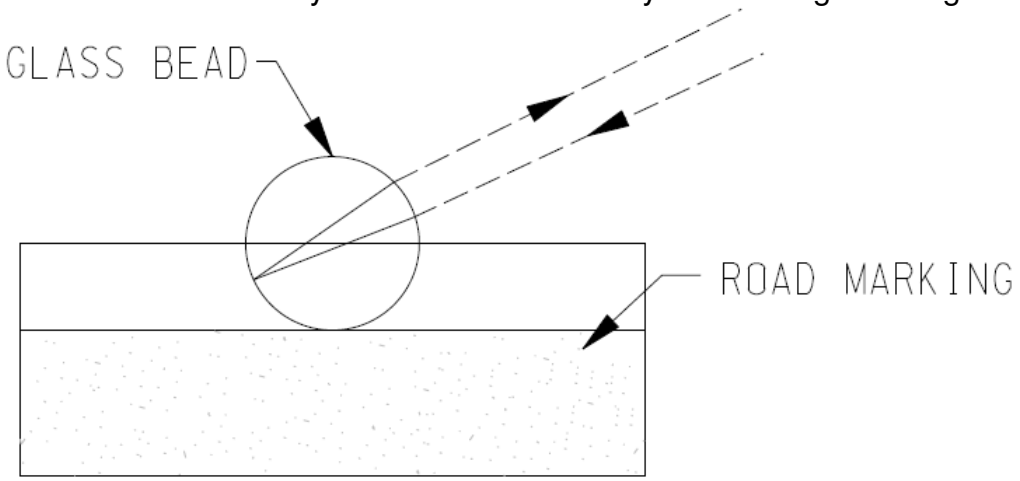


Fig. 6.1 Glass bead in road marking

2. What is the significance of ten percent fines value in testing sub-base material?

Ten percent fines value is a measure of the resistance of aggregate crushing subjected to loading and it is applicable to both weak and strong aggregate. Fine aggregates are defined as those passing 2.36mm sieve. The test aims at looking for the forces required to produce 10% of fine values (i.e. weight of fines aggregates/weight of all aggregates = 10%). This test is very similar to Aggregate Crushing Test in which a standard force 400kN is applied and fines material expressed as a percentage of the original mass is the aggregate crushing value.

Granular sub-base is subjected to repeated loadings from truck types. The stress level at the contact points of aggregate particles is quite high. The

sub-base in pavement is a structural layer used for distribution of traffic loads into larger area. As such, it is of paramount importance that the sub-base material should itself not be disintegrated under severe traffic loads. Ten percent fines value can be used to reveal the aggregate properties when subjected to mechanical degradation.

3. What is Marshall Mix Design for bituminous materials?

The Marshall Mix Design method was originally developed by Bruce Marshall of the Mississippi Highway Department in 1939. The main idea of the Marshall Mix Design method involves the selection of the asphalt binder content with a suitable density which satisfies minimum stability and range of flow values.

The Marshall Mix Design method consists mainly of the following steps:

(i) Determination of physical properties, size and gradation of aggregates.
(ii) Selection of types of asphalt binder.
(iii) Prepare initial samples, each with different asphalt binder content. For example, three samples are made each at 4.5, 5.0, 5.5, 6.0 and 6.5 percent asphalt by dry weight for a total of 15 samples. There should be at least two samples above and two below the estimated optimum asphalt content.
(iv) Plot the following graphs:
  (a) Asphalt binder content vs. density
  (b) Asphalt binder content vs. Marshall stability
  (c) Asphalt binder content vs. flow
  (d) Asphalt binder content vs. air voids
  (e) Asphalt binder content vs. voids in mineral aggregates
  (f) Asphalt binder content vs voids filled with asphalt
(v) Determine the asphalt binder content which corresponds to the air void content of 4 percent
(vi) Determine properties at this optimum asphalt binder content by reference with the graphs. Compare each of these values against design requirements and if all comply with design requirements, then the selected optimum asphalt binder content is acceptable. Otherwise, the mixture should be redesigned.

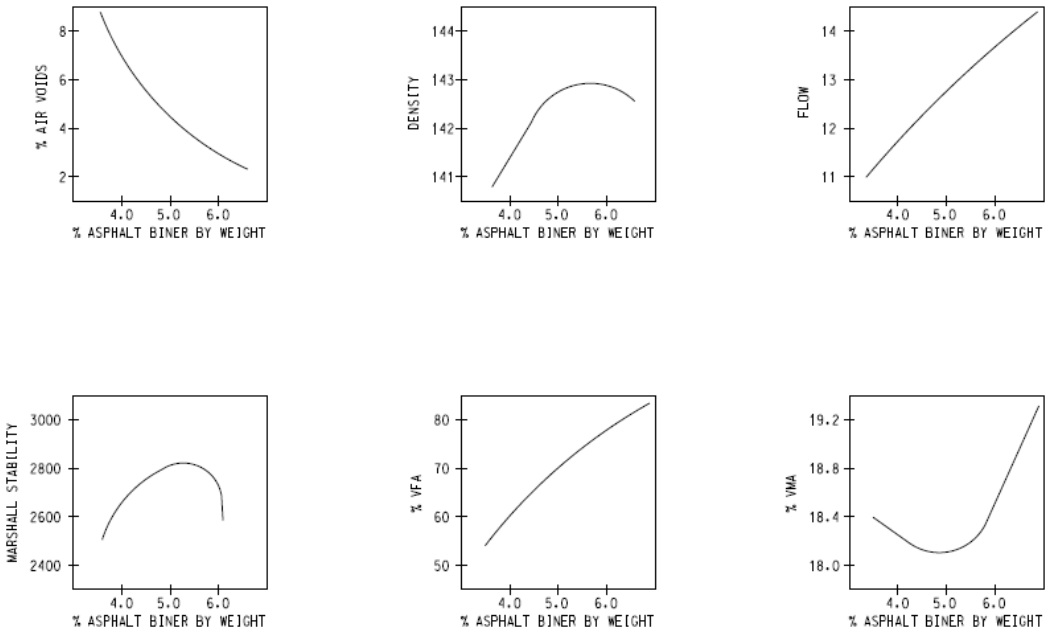


Fig. 6.2 Design graphs for Marshall Mix Design

4. What is the importance of Marshall stability and flow test?

Marshall stability measures the maximum load sustained by the bituminous material at a loading rate of 50.8 mm/minute. The test load is increased until it reaches a maximum. Beyond that, when the load just starts to decrease, the loading is ended and the maximum load (i.e. Marshall stability) is recorded. During the loading test, dial gauge is attached which measures the specimen's plastic flow owing to the applied load. The flow value refers to the vertical deformation when the maximum load is reached.

Marshall stability is related to the resistance of bituminous materials to distortion, displacement, rutting and shearing stresses. The stability is derived mainly from internal friction and cohesion. Cohesion is the binding force of binder material while internal friction is the interlocking and frictional resistance of aggregates. As bituminous pavement is subjected to severe traffic loads from time to time, it is necessary to adopt bituminous material with good stability and flow.

5. Which method of measuring road stiffness is better, Benkelman Beam Test or Falling Weight Deflectometer Test?

Pavement surface deflection measurement is the principal means of

evaluating a flexible pavement structure because the magnitude and shape of pavement deflection is a function of traffic, pavement structure, temperature and moisture affecting the pavement structure. Deflection measurements can be used in back calculation method to determine the stiffness of pavement structural layers.

The Benkelman Beam measures the *static deflection*s and it is operated on the basis of lever arm principle. Measurement is made by placing the tip of the beam between the dual tires and measuring the pavement surface rebound as the truck is moved away. The test is of low cost but it is time consuming and labour intensive in carrying out the test.

In Falling Weight Deflectometer Test, the falling weight deflectometer is mounted in a vehicle. The sensors are lowered to the pavement surface and the weight is dropped. The test measures the *impact load response* of flexible pavement. It has the potential advantages that it is quick to perform and the impact load can be readily changed. Moreover, the impact action of falling weight appears to be more accurately representing the transient loading of traffic.

6. What is the importance of friction course to expressways and high speed roads?

Friction course, which is known as porous asphalt, is often used as surface material in high speed roads and expressway. It is porous in nature which allows for speedy drainage of surface water. Road safety can be improved because it reduces the chance of hydroplaning/aquaplaning (i.e. there is a layer of water between the tires of the vehicle and the road surface. It may lead to the loss of traction and thus prevent the vehicle from responding to control inputs such as steering, braking or accelerating). It also decreases the splash and spray from vehicles in wet weather. It serves as a drainage channel for water to flow beneath the pavement surface.

Friction course has larger texture depth and this enhance improved skid resistance for vehicles traveling at high speed. It also has other benefits like the reduction of noise generated by vehicle tyres.

7. For a concrete pavement constructed over a box culvert, why is it important to match the location of transverse joints with boundary of box culvert?

When a concrete pavement is constructed over a box culvert, it is important

to match the location of transverse joints with boundary of box culvert. Otherwise, it is likely that full-depth transverse cracks would develop on the pavement slabs just above the location of boundary of box culvert. In case a layer of granular sub-base is introduced to place under the pavement slabs, the sub-base layer serves as crack-arresting layer and the possibility of development of transverse cracks in concrete pavement is reduced.

8. Is the skid resistance of bituminous pavement derived from microtexture of aggregates or texture depth of road surface?

The skid resistance of road surface is of paramount importance in enhancing road safety. The chance of occurrence of skidding is reduced with an increase of skid resistance.

At low traffic speed (i.e. 50km/hr), the skid resistance is mainly controlled by microtexture of bituminous aggregates. For road speed exceeding 50km/hr, the macrotexture of road surface comes into play which is characterized by texture depth of pavement. Hence, surface texture becomes an important parameter when designing high speed roads and expressway. The typical texture depth for concrete carriageway is 0.7mm. However, to maintain skid resistance provided by 0.7mm texture depth of concrete carriageway, 1.5mm texture depth is required for bituminous pavement in high speed road.

9. Why do some countries have reservation on the use of friction course as bituminous surface layers?

Owing to the porous nature of friction course, its deterioration rate is faster than conventional bituminous materials and the durability of friction course is a main concern form users. The service life of friction course is reported to be around 8-10 years.

The main durability problem of friction course is associated with raveling of friction course and stripping of underlying layers. Raveling of friction course occurs as a result of lack of cohesion between aggregates. Stripping of underlying layers is attributed by inadequate drainage of water through the friction course. With the use of polymer in friction course, it permits the use of higher air void (allows for better drainage) and higher binder content.

10. What are the causes of longitudinal cracks and transverse cracks in bituminous pavement?

Longitudinal cracks in bituminous pavement are usually caused by fatigue failure under repeated traffic loading. In thin pavements, cracking starts at the bottom of the bituminous layer where the tensile stress is the highest and then it spreads to the surface as one or more longitudinal cracks. In thick pavements, the cracks usually commence from the top because of high localized tensile stresses from tire-pavement interaction. After repeated loading, the longitudinal cracks develop into a pattern similar to the back of an alligator.

Transverse cracks are usually formed as a result of thermal movement. It may occur because of shrinkage of the bituminous surface due to low temperatures or asphalt binder hardening.

11. Which of the following cause much damage to bituminous pavement?

(a) Low usage by heavy vehicles or frequent usage of light vehicles;

(b) Low speed traffic or high speed traffic

The relationship between axle weight and the associated pavement damage is not linear but exponential. The pavement damage caused by one passage of a fully loaded tractor-semi trailer (80kN) is more than 3,000 passages of private cars (9KN). Hence, heavy trucks and buses are responsible for a majority of pavement damage.

Slow-moving traffic imposes greater damage than fast-moving traffic. Past studies showed that when the speed is increased from 2km/hr to 24km/hr, the stress and pavement deflection is reduced by 40%.

12. What are the differences between tensioned corrugated beam and untensioned corrugated beam?

Tensioned corrugated beam is mainly used in high speed road while untensioned corrugated beam is mainly used in low speed road.

Tensioned corrugated beam is designed mainly for use on central reservation. When a vehicle crashes into tensioned corrugated beam, the beam remains in tension while the post gives way to allow for deformation. Tensioned corrugated beam absorbs impact energy by deflecting as a

whole and helps the vehicle decelerate, and at the same time guide it back towards the carriageway in a gradual and controlled manner. Tensioned corrugated beam is normally not used on curves with radius less than 120m.

Untensioned corrugated beam is commonly used for road bends where radius of curvature is small as the use of untensioned beam does not require tensioning device. It is designed to deform in beams and to re-direct impacting vehicles on a course as close as possible parallel to the barrier.

13. When are the conditions which warrant the installation of safety barriers along roads?

In general there are several main conditions which warrant the installation of safety barriers along roads:

(i) It protects vehicles from hitting a roadside object (e.g. bridge pier, sign post, walls etc). Conversely, it protects the roadside object from damage by collision of vehicles.
(ii) It avoids the crossing over of vehicles over central median.
(iii) It protects the vehicle from falling down a steep slope (more than 3m high)
(iv) A poor record of accidents involving run-off vehicles.

14. How do steel beam barriers (e.g. tension/untensioned beam barrier and open box barrier) function to contain vehicles upon crashing?

Steel beam barrier consists mainly of horizontal rails and vertical posts. When a vehicle hits the steel beam barrier, the kinetic energy is resolved in three components, namely vertical, normal to barrier and parallel to barrier. The vertical and normal components of kinetic energy are dissipated through deformation and bending of beam and supporting posts. As such, the remaining component (i.e. parallel) guides the vehicle back to the carriageway in a direction parallel to the barrier.

15. What is the significance of bleeding in bituminous pavement?

Bleeding occurs in bituminous pavement when a film of asphalt binder appears on road surface. Insufficient air void is a cause of bleeding in which there is insufficient room for asphalt to expand in hot weather and it

forces its way to expand to pavement surface. Too much asphalt binder in bituminous material is also a common cause of bleeding. Bleeding is an irreversible process (the bleeded asphalt on pavement surface would not withdraw in winter) so that the amount of asphalt binder on pavement surface increases with time.

Bleeding forms a sticky and shiny surface which results in the loss of skid resistance for vehicles in wet weather.

16. Why is anti-skid dressing sometimes applied to pavement surface?

Skid resistance of road pavement plays an importance role when vehicles take a bend or brake. The use of anti-skid dressing increases the friction to reduce the possibility of skidding. Anti-skid dressing refers to the road surface treatment which includes high-friction calcined bauxite as the high Polished Stone Value artificial aggregate, together with a resin (epoxy, polyurethane) instead of bitumen to tie the aggregate to the road surface. It is more expensive but is more durable in difficult sites such as crossing and roundabout. Moreover, it also has side benefits of good acoustic quality.

Anti-skid dressing has normally a different colour to the road surface and used to be red in colour. Anti-skid dressing is commonly used in areas which require higher friction values such as approach to roundabouts and traffic lights.

The ability of the road surface to resist skidding is a combination of the surface texture of the road surface and the Polished Stone Value of the aggregate in the road surface. The higher the Polished Stone Value the higher resistance the aggregate has to polished, and hence the greater the capability the aggregate of retaining its own texture. Surface texture of the road surface is often referred to as macrotexture while texture actually on the surface of the aggregate is known as microtexture.

17. What is the purpose of road studs in roads?

In nighttime, car drivers could not see where the road ends and where the alignment of road changes in direction. Without sufficient number of road lightings, it is necessary to provide some means to guide the drivers along dark roads. Hence, in 1933 Percy Shaw invented the cat's eye (i.e. road studs) which is based on the principle of cat's eyes. When a ray of light enters the eyes of a cat, the light shall be reflected back towards to the

emitting source. As such, with the reflection of car's headlights by road studs, it is possible to identify road conditions and alignment in darkness.

However, the provision of cats' eye is not without problem. For instance, there have been reported accidents arising from loosely installed cat's eye. Some new design of cat's eye uses LEDs which flash at about 100 times per second. However, it is claimed to cause epileptic fits of drivers.

18. Why should edge courses of paving blocks sit on concrete bedding?

In pavement made up of paving blocks, the edge courses are normally designed to sit on concrete bedding and haunching. The reason of such provision is to prevent lateral movement of paving blocks when subjected to traffic loads. In essence, the edges formed by edge courses tie the body of the paving blocks as a single unit and they have to rely on concrete bedding and haunching to resist the sideway forces generated by moving traffic.

The concrete bed serves to keep the edge courses in position for surface level and it provides the dead loads in the retaining structure. On the other hand, concrete haunching also holds the edge courses in position from the point of view of lateral movement.

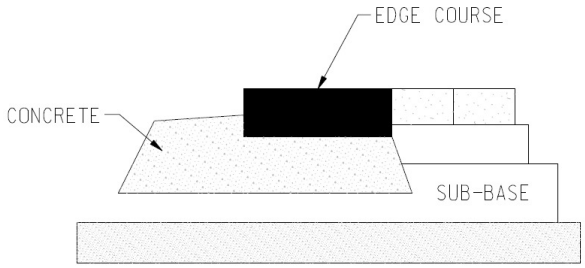


Fig. 6.3 Edge courses in paving blocks

19. What is the purpose of edge courses in paving blocks pavement?

The principal function of edge courses is to form a retaining structure with concrete bedding and haunching to resist sideway movement arising from traffic loads. Other functions of edge courses include:

(i) It serves as level guides when carrying out screeding of sand bedding.

(ii) It aids in the cutting of paving blocks near edge courses because paving blocks could lie over edge courses and the positions of cutting could be marked accurately without any difficulty. However, if a wall instead of edge courses is located adjacent to the pavement, it is practically difficult to position the paving block over the gap because of the physical hindrance of the wall.
(iii) It could be designed as surface drainage channel to convey stormwater to a discharge point.
(iv) It acts as a frame which defines the shape of pavement.

20. For compaction of paving blocks, should the jointing sand be applied before or after the compaction process?

The common practice is to apply jointing sand at the first place followed by subsequent compaction. However, there are several potential problems associated with this method. Firstly, the presence of sand provides support to paving blocks leading to inadequate compaction. Secondly, the excess jointing sand may be crushed during compaction and leaves stains on the surface of paving blocks. Thirdly, damaged paving blocks appear to be difficult for removal owing to frictional grip by jointing sand.

The alternative method is to carry out compaction firstly and then followed by application of joint sand and then re-compaction is carried out again. This method eliminates all the shortcomings of the first method described above. However, it suffers from the demerit of two passes of compaction instead of a single stage of compaction is required. Moreover, the compaction operation tends to be noisier because of the absence of the infilling sand which helps to reduce noise level. The direct contact between individual paving blocks is more vulnerable to spalling during compaction.

21. Can the sand bedding be omitted in paving block pavement?

In the paving block pavement, it normally consists of the following main elements: sub-base, sand bedding and paving blocks. Sub-base is the main structural element to take up traffic load and spread it into larger area so that the traffic stress is small enough for subgrade to sustain. Sand bedding is used for providing correct line and level for paving blocks to lie on. To achieve this, screeding of bedding layer is implemented so that the paving blocks could be laid directly on it without the need of further leveling. The large range of particle sizes associated with sub-base renders it unsuitable to provide a uniform surface with correct level for paving blocks to lie on.

22. What is the difference between safety fence and safety barrier?

A safety fence is intended to absorb some energy caused by hitting vehicles and to realign the vehicles to move parallel to the safety fence.

A safety barrier is intended to provide containment instead of energy absorption upon hit by vehicles. Hence, it is anticipated to have little deflection and deformation only. After crashing, it serves to re-direct the vehicles along the line of barrier.

Chapter 7. Slopes and Excavation

1. In braced excavation, why is Rankine's theory of lateral earth pressure not applicable?

In braced excavation, sheetpiling is constructed at the first place, followed by the installation of struts as excavation proceeds. Following the installation of first row of struts, the depth of excavation is small so that there is no major yielding of soils. However, as further excavation takes place, soils yield before the installation of n^{th} row of struts. The first row of struts prevents yielding near the ground surface. As such, deformation of wall increases with depth with the smallest at the ground level. Owing to the effect of construction method of braced excavation, it differs from the deformation condition of Rankine's theory. This is attributed to arching effects in which there exists upward redistribution of loads. The upper part of braced excavation is in the state of elastic equilibrium while the lower part is in the state of plastic equilibrium.

2. How could counterforts in counterfort retaining wall assist in resisting earth pressure?

Counterforts are used for high walls with height greater than 8 to 12 m. They are also used in situations where there is high lateral pressure, i.e. where the backfill soils are heavily surcharged.

The counterforts tie the base slab and wall stem together and they act as tension bracing which strengthen the connection between wall and base slab. The counterforts help to reduce bending moment and shear forces induced by soil pressure to the retaining wall. Moreover, it also serves to increase the self-weight of the retaining wall which adds stability to the retaining wall.

3. What is the basic mechanism of soil nails in improving soil stability?

Soil nails improve slope stability by:

(i) Partial increase the normal force and shear resistance along potential slip surface in frictional soils.
(ii) Direct reduction of driving force along potential slip surface for cohesive and frictional soils.

(iii) Soil nail head and facing provides containment effect to limit the deformation near slope surface.

Soil nail head serves to provide reaction in mobilizing tensile force in soil nail. Moreover, it provides confinement to soils in active zone behind soil nail head and avoids the occurrence of local failure between adjacent soil nails.

4. What is the purpose of installation of erosion control mat in slopes?

Steep slopes are prone to intermittent high velocity flows during rainstorm and this causes erosion at slope surface which prevents the growth of vegetation.

Erosion control mat is installed to control soil erosion and provide soil stability until vegetation can be established. The principal function of erosion control mat is to prevent pre-vegetated soil loss by stabilizing and protecting soils from rainfall and surface erosion. Moreover, it could provide a long-term artificial erosion control system which would increase the shear resistance of vegetation and provide long-term, tenacious reinforcement of the root system.

5. For Peck's pressure envelope for braced excavation, should total weight or effective weight be used in rectangular and trapezoidal envelope?

The use of active and at-rest theory is not applicable in braced excavation. In essence, upper struts tend to be more heavily loaded while lower struts appear to be less loaded when compared with active pressure theory.

Peck then measured the bracing loads which were converted back to soil pressures. For example, the pressure envelope for non-cohesive soils is $0.65\gamma HK_a$ (γ=soil density, H=height of excavation and K_a=active pressure coefficient).

Some engineers consider γ as total soil weight without applying any water pressure. However, Peck has said "the earth pressures are essentially effective active pressures multiplied by a factor and redistributed as a rectangle or a trapezoid." Hence, effective weight of soils should be used for γ with water pressures added separately.

6. What is the difference between sprigging and turfing?

A sprig is a part of stem with crowns and roots which is cut from a rhizome or stolon. Sprigging is a type of vegetative planting by placing sprigs in spaced intervals in holes. With proper transplantation and maintenance, a sprig is capable of growing as a plant. The cost of sprigging is moderate and vegetation is expected to grow for around six months. However, this method requires high manual input and is labour intensive.

Turfing is the direct application of vegetation with developed roots. The cost of turfing is high when compared with sprigging. However, it is the quickest way to get vegetation. Within a month mature-looking vegetation is ready for use.

7. How can concrete buttress stabilize rock fall?

Sometimes there is a cavity in rock slopes which is caused by previous rock falls. Concrete buttress, together with the use of rock dowels, could help to stabilize the rock slope.

The buttress serves to avoid local toppling of rock face. Moreover, it keeps protects the unstable rock and keep it in place. The presence of buttress also helps hold up the overhang. The size of buttress should be large enough to support the weak rock. In case the surface on which the buttress is founded is not normal to the resultant forces exerting on the buttress, buttress is tied to rock surface by using rock dowels to avoid the occurrence of sliding.

8. Should high preloads be adopted in struts in braced excavation?

Preloading in struts in braced excavation helps eliminate the potential movement. The application of preload decreases the shear stress in soils established previously by excavation. As a result of stiffening of soils, the soil movement is declined accordingly.

However, the use of very high preloads in struts may not be desirable because the local outward movement at struts may cause damage to nearby utilities.

9. What is the significance of free length and fixed length in tiebacks in anchored excavation?

The use of tiebacks in deep excavation allows uninterrupted earth moving within the excavation zone owing to the absence of interior obstructions. The spacing of tieback should not be placed too close as this may impair the capacity of tieback because of the interference between adjacent grouted zones.

A tieback is made first by drilling a hole by a drill rig, followed by placing a bar in the drilled hole. Concrete is then poured in the hole and the connection of tieback with wall is made lastly. A tieback anchor consists of an anchorage located in a bearing layer and the anchor is tensioned at the front face of the wall. The portion of the anchor which transmits the force to the surrounding soil is called the "fixed length". One the other hand, the "free length" of tieback transfers the force from the fixed length through the anchor head to the wall.

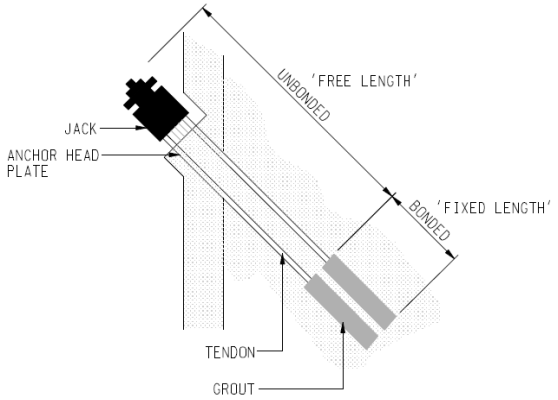


Fig. 7.1 Free length and fixed length in tieback

10. What is the typical proportioning of a retaining wall?

The base slab thickness of a cantilever retaining wall is about 10% of the total height of retaining wall. The length of base slab is about 50-70% of the total height of retaining wall. Generally speaking, the thickness of wall stems may vary along the stem provided that its size should not be less than 300mm to facilitate concrete placement.

For retaining wall with a total height exceeding 8-12m, it is recommended to adopt counterfort retaining wall. The counterforts in counterfort retaining wall are normally spaced at about 30% to 70% of the total height. The length of base slab is about 40-70% of the total height of retaining wall.

11. What is the reason of adding steel wire mesh when using erosion control mat in slopes?

It is not uncommon that the use of erosion control mat in slopes is accompanied by the addition of steel wire mesh. The system of erosion control mesh with a steel wire mesh proves to be a more effective method to control surface erosion. In case surface erosion occurs even in the presence of erosion control mat, the soil debris could be trapped between the steel wire mesh and the slope surface. As such, the steel wire mesh essentially serves as an additional protective layer to avoid further occurrence of erosion.

12. What are the applications of diagonal strutting and long flying shores in braced excavation?

Diagonal strutting is sometimes used at the corners of excavation to leave a large working space at excavation level.

Sometimes, raking struts are observed in long flying shores across excavation and these struts serve to decrease the span length of struts.

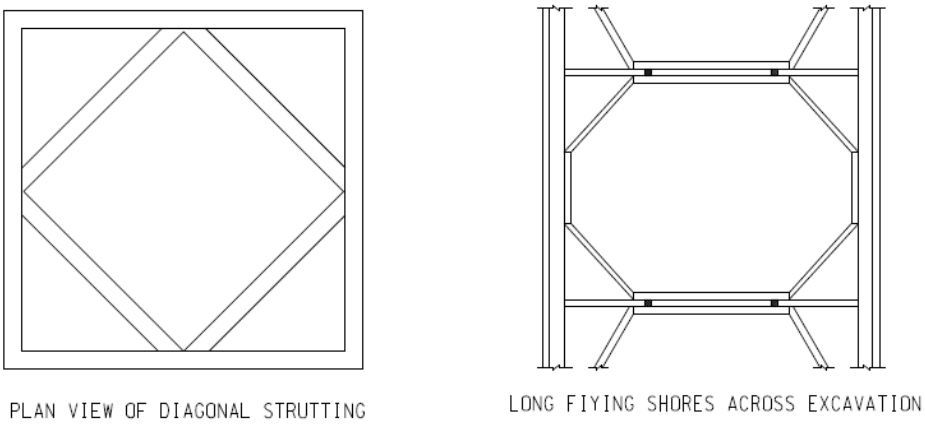


Fig. 7.2 Diagonal strutting and long flying shores in braced excavation

13. Is force and moment equilibrium satisfied by Janbu's method, Bishop's method and Morgenstern-Price method?

Janbu's method and Morgenstern-Price method are non-circular analytical method and they are frequently used for soil slopes while Bishop's method is circular analytical method. Bishop's Simplified method and Janbu's

Simplified method assume that the inter-slice forces are horizontal and inter-slice shear forces are neglected.

Equilibrium Method	Moment Equilibrium	Force Equilibrium	
		Horizontal	Vertical
Janbu's Simplified	No	Yes	Yes
Bishop's Simplified	Yes	No	Yes
Morgenstern-Price	Yes	Yes	Yes

Chapter 8. Tunneling

1. How can Earth Pressure Balance TBM maintain stability of tunnel face?

Earth Pressure Balance (EPB) TBMs are used in excavating and advancing tunnels through any type of soft ground or soil condition, particularly below the water table. The EPB method consists of a cutting chamber located behind the cutterhead. This chamber is used to mix the soil with water foam. It is maintained under pressure by the mucking system. The ground at the cutting face is supported by earth pressure by balancing the advancement of the tunnel with the discharge rate of the excavated soil.

The underlying principle of the EPB method is that the excavated soil itself is used to provide continuous support to the tunnel face by balancing earth pressure against the forward pressure of the machine. The thrust forces generated from rear section of TBM is transferred to the earth in the cutterhead chamber so as to prevent uncontrolled intrusion of excavated materials into the chamber. When the shield advances at the face of excavation, the excavated soil is then mixed together with a special foam material which changes its viscosity or thickness and transforms it into a flowing material. This muck is then stored and is used to provide support and to balance pressure at the tunnel face during the excavation process.

2. Why do Slurry Shield TBMs have difficulty when tunneling in clay?

In Slurry Shield TBMs, the slurry forms a filter cake on the face of excavation which has the following purposes:

(i) It provides the surface for slurry pressure to act on.
(ii) It acts as a seal against the y of groundwater into the tunnel.
(iii) In case the TBM breaks down, this filter cake serves as a sealing membrane at the tunnel face which allows man-entry into the excavation and working chamber upon provision go compressed air.

Slurry Shield TBMs are widely used for non-cohesive soils ranging from fine-grained sand to coarse-grained gravel. It is less suitable when operating in clay because:

(i) Most slurry separation plant could not separate clay from slurry. As

such, the cost of frequent replacement of bentonite slurry is substantially increased.

(ii) Clayey materials to clog and cause blockages in slurry system leading to sudden pressure surges.

3. Should closed-end or open-end pipes be used in pipe ramming?

It is more common to adopt open-end pipes in pipe ramming because it is not readily to undergo surface heaving or pipe deflection when compared with closed-end pipes. Moreover, the use of open-end pipes requires lower ramming force.

Closed-end pipes are only used in the following conditions:

(i) Ground with poor self-support so that inflow of soils inside the pipes would render ground settlement and loss of support to utility services.

(ii) Small size of pipes.

4. What is the difference between "cut-and-cover" method and "cover-and-cut" method in tunnel construction?

"Cut-and-cover" method involves the construction of open cut at the first place, followed by the construction of tunnels under open excavation. Upon completion of the structure, backfilling and reinstatement would be subsequently carried out.

"Cover-and-cut" method involves firstly the construction of cover followed by the second stage in which construction activities are carried out under the cover. As such, the disturbance to the public owing to constructional activities could be reduced to a minimum.

5. Would pipe ramming increase the vertical soil loads on installed pipes?

Consider a certain cross section along the line of pipe ramming. When the pipe is rammed close to the cross section, the horizontal and vertical soil pressure would increase owing to the effect of soil compaction brought about by dynamic ramming operation. Upon reaching the cross section, soil pressure is redistributed around the pipe such that the vertical pressure above the pipes is reduced while the vertical pressure in pipe abutment

locations is increased. When the pipe is advanced further, the load on pipes tend to increase owing to reorientation of soils around pipe wall. Finally, when the pipe is rammed some distance away from the cross section, a stable state is achieved in which there is smaller earth pressure on the pipe's top and higher vertical soil pressure on soils at both sides of the pipe.

6. What are the situations which warrant the use of pipe ramming instead of other trenchless methods?

There are two main distinct advantages of pipe ramming:

(i) Settlement and heaving of existing ground.
Where a pipe have to be installed under an existing railway or heavily-trafficked highway, it is almost impossible to install the pipes by open excavation. In particular, if the pipes to be installed are of shallow depth, the use of some trenchless methods (e.g. pipe jacking and heading) may cause considerable ground settlement because the soil loss within shallow zone would induce larger settlement. As such, the use of pipe ramming could resolve this concern. Pipe ramming is a displacement method which generally would not result in ground loss. For open-ended steel casing, the soils inside the pipe are not removed until the entire casing is installed in place.

(ii) Muck Disposal
For microtunneling, spoils are removed from the excavation face in a slurry so that the spoil are wet. Hence, sufficient space has to be provided to allow for drying of spoils or the wet spoils have to be removed off site immediately. For pipe ramming slurry is not used so that the spoil retains only it natural moisture content. Therefore, it is easier to handle in-situ soils than wet spoils. On the other hand, the amount of spoil produced by pipe ramming is smaller when compared with pipe jacking and microtunneling.

7. What is the difference between close mode, open mode and mixed mode of trenchless methods?

(i) Close mode
It refers to mechanically operated TBM using bulkhead or slurry to balance earth pressure and groundwater. There is no manual access to the face of excavation.

(ii) Open mode
It refers free air hand-dug tunnel or compressed air handing tunneling with manual access to face of excavation.
(iii) Mixed mode
It is similar to close mode except that it allows access to the face of TBM for manual removal of obstructions.

8. Why does settlement occur in microtunneling?

Settlements occur in microtunneling, or other tunnel construction methods in two forms: large settlements and systematic settlements. The cause of large settlements is the over-excavation by microtunneling machine leading to the loss of stability at the tunnel face and the formation of empty space above the tunnel. The occurrence of large settlements is attributed to the improper operation of the tunneling machine or rapid unexpected changes in ground conditions.

Systematic settlements are mainly caused by the collapse of the radial overcut between the jacking pipe and the excavation. The annular space between the jacking pipe and the excavation is essential in microtunneling and pipe jacking for the following purposes:

(i) Reduction of jacking forces
(ii) Injection of the lubrication
(iii)Steering of the microtunneling boring machine

During tunneling, the soils may collapse onto the pipe, resulting in subsidence at the ground surface. Systematic settlements can be controlled by limiting the radial overcut and by filling the annulus with bentonite lubricant during tunneling, and with cement grout after tunneling is completed.

9. How could ground freezing stop ingress of groundwater in excavation?

The concept of ground freezing involves the lowering of temperature of ground near the excavation area. Drillholes with designed spacing are installed so that a chilled brine or liquid nitrogen is introduced into the holes. Brine requires continuous circulation while liquid nitrogen is for rapid freezing and it is unrecoverable. With the addition of a chilled brine or liquid nitrogen, the groundwater is frozen into ice. Upon frozen, soils exhibit higher shear strength and the frozen zone acts as an impermeable barrier

so that water could not enter the excavation zone.

10. Does microtunneling refer to tunnel size less than 1,000mm?

The international definition of microtunneling includes pipe with diameter up to 1,000mm only. However, in the United States, it allows for larger pipe size when defining microtunneling in which pipe with diameters up to 144 inches are also counted within the ambit of microtunneling.

The basic concept of microtunneling has changed gradually owing to recent technological developments and past experience. For instance, the use of alignment control system with advanced surveying techniques allows for longer drives with good control and curved microtunneling. The use of automatic lubrication system enhances lower jacking forces. The employment of gripper in microtunneling machines helps develop adequate loads on cutter discs for cutting rock.

11. What are the situations which warrant the use of microtunneling instead of other trenchless methods?

There are two main advantages of microtunneling:

(i) Difficult ground conditions
Microtunnels could operate under a water head of 30m or more. It is capable of handling a wide range of soils such as cobble, boulders and rock without the need of dewatering.

(ii) Surface settlement
Surface settlement could be minimized by using microtunneling. For example, the use of earth pressure balance method in microtunneling helps balance the external soil loads and groundwater. Moreover, the rate of advancement of machine and the rate of excavation of tunnel face can be readily controlled so that it reduces the occurrence of over-excavation at tunnel face and hence the ground settlement.

12. What is the difference between single shield and double shield tunnel boring machine (TBM)?

In single shield TBM, it extends and moves forward by thrust cylinders on the last segment ring installed.

In double shield TBM, it consists of an extendable front shield which

enhances the cutterhead to be extended. The gripper in the middle section of TBM is mobilized so that it pushes against the tunnel walls to react the boring forces. As these forces are dissipated, it allows the installation of lining segments during tunnel so that it increases the speed of tunneling. Upon completion of a trust stroke, the grippers are retracted and the end portion of TMB is pushed against the front shield by thrust cylinders.

Double shielded TBM is normally used in rock strata with geological fault zones and when a high rate of advancement is required. Single shielded TBM is more suitable to hard rock strata.

13. In Slurry Shield TBMs, should high or low slurry pressure be maintained to support excavated face?

In Slurry Shield TBMs, the slurry supports the wall of tunnel face in a manner similar to diaphragm wall. The bentonite forms a filter cake on the tunnel face on which the slurry exerts its pressure.

The face of a slurry shield tunnel boring machine is stabilized by bentonite slurry, which is kept under pressure. If the slurry pressures provided are too low, instability of the face results with occurrence of large settlements. On the contrary, in case the slurry pressures are kept too high, it leads to an excessive loss of bentonite and significant soil disturbance would occur.

14. Is NATM a tunneling method or a tunneling concept?

In the original version of the New Austrian Tunneling Method, it is a tunneling concept with a set of main principles as follows:

(i) Application of thin-spayed concrete lining
(ii) Closure at invert to form a complete ring as soon as possible
(iii) Measurement of deformation until equilibrium is attained

It is a design concept in which the ground (soil or rock) enclosing the opening becomes a load-bearing element through formation of ring-like body. It uses all available means to develop maximum self-supporting capacity to provide support of the underground opening. In essence, it makes use of geological stress of surrounding soils to stabilize the opening. Therefore, NATM is a tunneling philosophy and concept rather than excavation techniques.

15. What is the difference between NATM and Sprayed Concrete Lining?

The New Austrian Tunneling Method originated from rock tunnels and it requires the use of rockbolts and shotcrete swiftly after blasting. Institution of Civil Engineers has renamed it as Sprayed Concrete Lining for construction of tunneling linings by this method *in soft ground*.

There are some distinct differences in design philosophy between NATM and Sprayed Concrete Lining. In fact, it is not practical to mobilize inherent soil strength through deformation in soft ground. For lower strength of soils in soft ground, there should not be any delay in completing primary support and ground deformation should be reduced as much as possible.

Chapter 9. Site Investigation

1. What is the difference between Dynamic Probing and Standard Penetration test?

Standard Penetration Test (SPT) is an in-situ dynamic penetration test to provide information on the properties of soil. It may also collect a disturbed soil sample for grain-size analysis and soil classification. SPT involves the driving of a standard sampler through a distance of 450mm into the bottom of a borehole using the standard weight of 63.5kg falling through 760mm.

Dynamic Probing Test as per BS1377: Part 9: 1990 involves the driving of a metal cone into the ground through a series of 1-metre length steel rods. These rods are driven from the surface by the hammer system on the rig which drops 63.5 kg weight onto the rods through a fall of 760mm. The number of blows that is required to drive the cone down each 100mm increment is then recorded until a required depth is reached or a refusal is achieved. Dynamic Probing has many applications. For instance, it may be used to estimate the depths of at the interface between hard and soft strata and to trace the outline of objects buried underground.

SPT test is used to provide valuable information on soil properties. However, the main use of dynamic probing is *to interpolate information* between boreholes/trial pits swiftly and to supplement information found from boreholes and trial pits at a low cost. For instance, dynamic probing is carried out close to a borehole where the underground conditions are identified. As such, by using the dynamic probing, the result of borehole can be extended to other areas in between two boreholes.

2. What is the difference between trial pit, trial trench and inspection pit?

A trial pit is used for obtaining information on the subsurface soil conditions. It allows logging of the various soils types and soil sampling. Typical size of trial pits has minimum base plan area of 1.5m^2. Trial trench serves the same purpose of trial pit except that they differ in size and dimension. For instance, the length of a trial trench is normally larger than its width by a certain factor (e.g. 5) to cater for its “trench” shape.

An inspection pit is a pit used for identifying and positioning of underground utilities and structure.

3. When would engineers use Cone Penetration Testing instead of Standard Penetration Test?

(I) Standard Penetration Test is carried out in boreholes at 1.5-2m intervals. However, Cone Penetration Testing allows a continuous record of ground resistance profile.
(II) Disturbance to ground is less by Cone Penetration Testing when compared with Standard Penetration Test.
(III) The use of Cone Penetration Testing is faster and cheaper when compared with the combination of boring, sampling and Standard Penetration Test.

4. How to identify sand and clay from the results of Cone Penetration Testing?

Cone Penetration Testing measures the pressure at the end of cone (end resistance), friction on sleeve and pore water pressure. Friction ratio is defined as the ratio of friction/end resistance.

For clay, typical CPT results exhibit low end resistance, high friction ratio and high pore water pressure.

For sand, typical CPT results exhibit high end resistance, low friction ratio and low pore water pressure.

5. What is the purpose of adding hydrogen peroxide in sedimentation analysis?

There are two major techniques of particle size distribution:

(i) Sieve analysis – for soil particles larger than 60μm they can be separated by this method.
(ii) Sedimentation analysis – for soil particles smaller than 60μm, they are too small to be sieved by sieve analysis. Instead, the particle size distribution is worked out from the rate of settlement of soil particles suspended in water by Stoke's law.

In sedimentation analysis, the soil under testing is firstly boiled with little distilled water to wet and break up the particles. After that, hydrogen peroxide is added *to remove any organic material*. Then the whole mixture is allowed to stand still for a night and then boiled again to remove hydrogen peroxide.

6. How can trial pits be made in slopes?

In slopes, trial pits are transformed into another method called slope surface stripping. It involves the removal of slope surface protection and vegetation to reveal the soil conditions below slope surface for inspection purpose. The strip is about 0.3m to 0.5m wide and 150mm to 300mm deep and it usually extends from the crest to the toe of slopes. Slope surface stripping is commonly used in Hong Kong.

7. Multistage triaxial test may not be preferable for consolidated drained test. Why?

In multistage consolidated drained test, the soil sample is consolidated under all round pressure and then loaded by applying an axial stress. Prior to failure, loading is stopped and the specimen is consolidated under a higher confining pressure. The above steps are repeated for 3 stages to obtain the failure envelope.

The main problem associated with multistage consolidated drained test lies in the practical difficulty in determining the failure state of the soil sample. Judgment has to be made regarding the condition of “immediately prior to failure” on stress strain curves. It is not uncommon that wrong estimation of the failure state occurs when interpreting the stress strain curves. When there is an underestimation of deviator stress at failure, it would result in overestimation of friction angle and underestimation of cohesion. In case actual failure of soil samples occurs before visual recognition, the sample undergoes overstressing so that the deviator stress at failure in later stages is reduced. As such, this leads to overestimation of cohesion and underestimation of friction angle.

8. Why is multiple packer test instead of single packer test sometimes adopted in testing permeability of rock?

Packer test is used in unlined drillholes in rock to test the permeability. In single packer test, the hole is drilled to the bottom of first test section and the top of the test section is sealed off by a packer. Water is then delivered to the test section and it is kept at constant pressure and the flow is measured.

In highly fractured rock there is a high chance that water tends to leak around the packer which gives inaccurate result. As such, multiple packers are adopted instead in which three sections of the drillhole are sealed up

and water is pumped to them at equal pressure. This eliminates the tendency for water to flow around the packers from the middle section. Hence, a more accurate result could be obtained by measuring flow from the middle section alone.

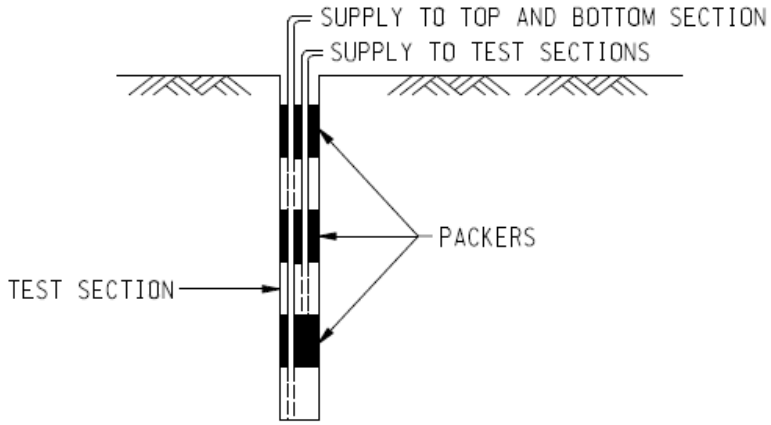


Fig. 9.1 Illustration of multiple packer test

9. Why is shear box test not a better alternative to triaxial test in determining shear strengths of soils?

The test procedure is simpler for shear box test. However, it suffers from the demerit that drainage conditions are not easily controlled and pore water pressure cannot be measured. Moreover, the plane of failure is governed by the test itself rather than the properties of soil. It is likely that shear stress distribution across the soil sample is not uniform. The above limitations may affect the accuracy and reliability of test results.

One of the advantages of shear box is that the test could be continued to large strains so that residue shear strength could be determined. In fact, triaxial test has mostly replaced shear box test for normal application.

Chapter 10. Sewage and Waterworks

1. Why are some ductile iron pipes cement-mortar lined?

Cement mortar lining provides a high pH in the inner surface of ductile iron pipes and it serves as a physical barrier to water to guard against corrosion of iron from acidic water. Moreover, owing to smooth nature of cement lining, it results in the provision of high flow.

For cement-mortar lined ductile iron pipes to convey water, water infiltrates the pores of lining and releases some calcium hydrate. The freed calcium hydrate form calcium carbonate with calcium bicarbonate in water so that it serves to clog the pores of linings and avoid further permeation of water. Moreover, iron also reacts with lime to precipitate iron hydroxide which also seals the pores of linings. As such, the lining provides both chemical and physical barrier to aggressive water.

2. In some countries like the United States, asphaltic seal-coat is used in cement mortar lining of ductile iron pipes. Why?

The original intention of adding a thin asphaltic seal-coat on freshly placed cement-mortar lining is to reduce water loss during hydration so as to achieve better curing of the linings. In fact, it also helps hinder the leaching of cement by corrosive water. Otherwise, leachates from cement linings may cause a rise in pH in water.

However, asphaltic seal-coat is considered undesirable from environmental point of view. The seal-coat material is solvent-based which contains volatile organic compounds, which is an air pollutant.

3. What is the purpose of polyethylene encasement for ductile iron pipes?

The provision of polyethylene encasement avoids the direct contact of ductile iron pipes with surrounding aggressive environment. However, polyethylene encasement is not intended as a water-tight system. Initially moisture between ductile iron pipes and polyethylene encasement contains some oxygen which shall be ultimately depleted and this would put a stop to the oxidation reaction. This process leads to a stable and stagnant environment near the pipe and it provides a protective environment.

4. What is the purpose of bolt tightening sequence in flanged joints?

Bolted flange joint is widely used in watermains. In essence, a bolt axial tension is applied by the torque control method. The preload values are recommended by gasket suppliers to control gasket crushing and to achieve proper gasket seating stress. A proper bolt tightening sequence in flanged joints is essential to control stress variation in flange joint components. Otherwise, leakage occurs at flanged pipe joints during operating conditions.

Most joint surface of joints is not completely flat. The sequence of bolt tightening exerts a huge effect on the resulting preloads. Since joints containing gaskets have a comparatively low compressive stiffness, bolt preloads in such joints are particularly sensitive to the tightening sequence. Owing to the compression of joint surfaces, tightening one bolt close to another pre-loaded bolt will affect the preload generated by the firstly-tightened bolt. A proper bolt tightening sequence ensures that an even preload distribution is achieved in the flanged joint.

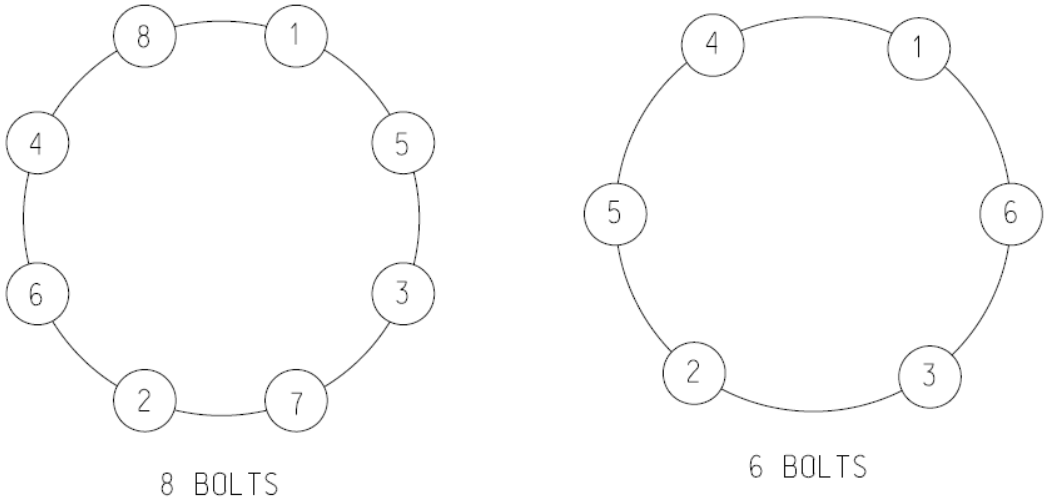


Fig. 10.1 Bolt tightening sequence in flanged joints

5. What is the reason of retightening in flanged joints?

Traditional gaskets are non-elastic in nature. As such, this property of gasket results in a reduction in the bolt's preload as time goes by. In fact, this phenomenon usually takes place shortly after installation leading to bolt relaxation. To reduce the effect of bolt relaxation which may cause subsequent water leakage during operation, retightening the bolts is

carried out some time latter after initial tightening.

6. What are the limitations of CCTV regarding the inspection of sewers?

CCTV is a well-established and prevalent method for pipe inspection. However, there are several limitations of CCTV technology:

(i) It could only provide the view of pipe internal surface above waterline.
(ii) It does not provide the view of soil conditions surrounding the pipe.
(iii) Most CCTV system is incapable of measuring pipe gradient.
(iv) It does not provide any structural data on the integrity of pipe wall.

7. What is the difference between ductile iron pipes and steel pipes in resisting external loads?

Ductile iron pipes normally possess thicker pipe walls and are generally stiffer than steel pipes. As such, it replies less on side fill soils to support external loads. Hence, it is not necessary to achieve highly-compacted soils for ductile iron pipes for sustaining external loads.

For steel pipes, owing to less stiffness associated with thinner pipe walls, it relies heavily on the stiffness of backfill soils in resisting external loads. Hence, to enhance the external load-carrying capacity of steel pipes, the most convenient methods are to improve the quality of backfill materials and to increase the level of soil compaction.

8. What does the pipe thickness of ductile iron pipes generally larger than that of steel pipes?

Both steel pipes and ductile iron pipes use hoop stress equation to model internal pressure design. The difference in pipe thickness arises as a result of more conservative approach in DI pipes.

For ductile iron pipes, surge pressure is considered as part of design pressure and they are added together before applying a safety factor of 2 as follows:

$$t = \frac{F(P+S)D}{2Y}$$

where t = Pipe thickness
F = Factor of Safety of 2
P = Working pressure
S = Surge pressure
Y = Yield strength of ductile iron

For steel pipes the design of working pressure is based on 50% of steel yield strength (i.e. a factor of safety of 2). The presence of surges could be allowed to increase the stress in pipe to 75% of yield strength. The design is based on the following steps:

(A) If surge pressure is less than or equal to one-half of working pressure, the pipe shall be designed using working pressure only with 50% yield strength as allowable stress.

$$t = \frac{PD}{2Y}$$ where Y = 50% of yield strength

(B) If surge pressure is more than or equal to one-half of working pressure, the pipe shall be designed using working pressure and surge pressure only with 75% yield strength as allowable stress.

$$t = \frac{(P+S)D}{2Y}$$ where Y = 75% of yield strength

For case A**,** the use of 50% yield strength is essentially the same of adopting a safety factor of 2 in DI pipe design. However, as surge pressure is not considered, the thickness calculated is smaller than that in DI pipe design.

For case B, the use of 75% yield strength is essentially the same of adopting a safety factor of 1.33 in DI pipe design. As such, the thickness calculated is smaller than that in DI pipe design.

9. What are the controversial health issues of using asbestos cement pipes for watermain?

There are suspected health hazard for using asbestos cement pipes for watermain. In drinking water the gastrointestinal tract cancer risk depends on the amount of asbestos swallowed. When asbestos cement pipes are in good condition, there should be little safety problem. However, when the

pipes become aged so that some may break down, it then become a great hazard. When someone takes a little asbestos which are distributed to other parts of the body so that no single parts of the body have excessive amount of asbestos, the risk should be theoretically on the low side. The harmful effect of asbestos is its ability to accumulate in human body. The microscopic fibers lodged in tissues can act like time bombs and cause cancer years later. Since asbestos exposure is cumulative, adults have three or four decades to develop cancer after exposure while youngsters have six or seven.

However, according to the findings of WHO, asbestos fibres are too large to be absorbed during the digestion. Therefore, the chance of significant transmission of asbestos fibres would seem to be low. Some evidence suggests that high density asbestos-cement products pose no detectable risk to the public because asbestos fibres are carcinogenic only when inhaled but not ingested.

10. In road opening, it is sometimes noted that asbestos cement pipes are broken up into pieces. Why?

Asbestos cement is mainly a mixture of cement and asbestos fibres with density greater than 1000kg/m^3. It contains about 10% asbestos fibres and it is a light grey hard material. The fibres are tightly held in cement mixture and they shall be discharged if asbestos cement undergoes significant disturbance such as drilling and sawing.

However, one of the important characteristics of asbestos cement is the relative brittleness. As such, asbestos cement pipes can be broken easily when falling at height or driven over by heavy vehicles. Hence, it is not uncommon that asbestos cement pipes are observed to break up into pieces in inspection pits.

11. What is the difference between "linear characteristic" and "equal percentage characteristic" in controlling butterfly valves?

For "linear characteristic", the flow rate is directly proportional to the amount of travel of butterfly disk. For example, at 25% open of butterfly disk, the flow rate of 25% of maximum flow.

For "equal percentage characteristic", equal increment of opening of butterfly disk leads to equal percentage change in flow rate. For example, when butterfly disc open from 30% to 40%, it generates a change in flow

rate of 50%. Therefore, when butterfly disc open from 40% to 50%, it also generates a change in flow rate of 50%. If the flow rate at 30% is 200m^3/s, then the flow rate of 40% and 50% open are 300m^3/s and 450m^3/s respectively.

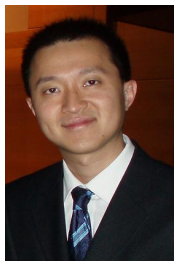
The use of different characteristics depends on the amount of pressure drop available to the butterfly value. Should more than 25% of system pressure drop is available to the butterfly value, then the employment of linear characteristic would provide the best results. On the contrary, if less than 25% of system pressure drop is available to the butterfly value, then the employment of equal percentage characteristic would be a better choice.

12. Why is partial PVC lining instead of full lining adopted in concrete pipes?

The main function of PVC lining is to protect concrete surface against hydrogen sulfide attack. Moreover, it also guards against attack by a wide range of acids and alkalis. Hydrogen sulfide generated in sewerage by bacterial action under anaerobic (absence of oxygen) conditions is converted to sulphuric acid by aerobic bacteria growing on wet sewer walls. This acid reacts with the lime in the concrete, causing breakdown of the concrete pipes. The addition of lining could also improve the flow capacity.

Only the concrete above the line of minimum flow shall be attacked by hydrogen sulfide and therefore PVC lining is needed above this flow line. For medium to large pipe sizes, partial lining of 300 degree with 60 degree pipe invert exposed proves to be effective against attack. Small diameter pipe may warrant complete linings of pipes.

About the Author



Vincent T. H. CHU (朱敦瀚) obtained the degree of civil and structural engineering in the University of Hong Kong. He is the author of the monthly column "The Civil FAQ" in the Hong Kong Engineer published by the Hong Kong Institution of Engineers and is the author of the civil engineering monthly columns "The Civil Q&A" and "The Civil Corner" on the websites on World Federation of Engineering Organization and the University of Science and Technology (American Society of Civil Engineers – International Student Group) respectively. He is the recipient of the Ombudsman's Award 2007 under complaint-related category and Young Engineer of the Year Award 2008 (Merit) organized by the Hong Kong Institution of Engineers. He is also the author of the engineering book "200 Question and Answers on Practical Civil Engineering Works", "Civil Engineering Practical Notes A-Z" , "Ask Vincent Chu (Common FAQ on Practical Civil Engineering Works)" and "The Underlying Reasons in Practical Civil Engineering Works".

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The author has established a free Civil FAQ email service called "Ask Vincent Chu" (email: askvincentchu@yahoo.com.hk) in which he would answer civil engineering queries raised from engineers (especially young engineers).

Interested readers could refer to the personal interview of the author regarding his further background information:

(i) South China Morning Post on 13 March 2008

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Hong Kong Faces

After a slow start in primary school, Vincent Chu Tun-hon met a teacher who inspired him to work hard and become an award-winning civil engineer. Now he is doing his best to repay this faith by helping young people taking their first steps in the profession

It was not the high pay and prestige of the profession, but the mysteries of the Egyptian pyramids that got him into civil engineering.

Money was certainly a concern when Vincent Chu Tun-hon, a 31-year-old civil engineer who now works for the government, was puzzling over his career path in high school, but it was his science teacher who gave him the biggest clue.

"He asked the class if we had ever thought about how the pyramids in Egypt were built," he recalls.

Years later, Mr Chu is still searching for the answer. "There are many theories, but one with a higher possibility is that they were built on ramps with rocks all the way to the top."

There is a myth that the people who built the pyramids were trapped inside after their work was completed, but Mr Chu quickly rejects the idea.

"There would be openings left in there, the same as with all other buildings (and people could have escaped through them). All buildings have spaces or openings for transporting material and emergency purposes."

Many people might think that other fields, like computer and mechanical engineering, offer better prospects than civil engineering, but Mr Chu says his interests were always in one direction.

"My parents asked if I wanted to study for a profession like doctor or lawyer, but I had spent a lot of time reading books and already had a very strong interest in maths and civil engineering."

He also recognised that he had no talent for arts and design. "I was a science student, so perhaps I was more interested in knowing how roads and bridges were built."

He was also inspired by local structures that were known internationally, like the Tsing Ma Bridge and the international airport; they inspired him and strengthened his desire to be a civil engineer.

The profession overlaps with architecture, but Mr Chu liked the fact that it extended beyond buildings to include airports, bridges and reclamation work.

Mr Chu's devotion to his profession have paid off with two awards – the Ombudsman's Award 2007 and Young Engineer of the Year 2008.

His success at such a young age is not just the result of hard work, he says, but also of the encouragement he received from his mother and his teacher at primary school.

Mr Chu said he was a poor student in his first year at primary school. "Not that I didn't study, but maybe I wasn't the teachers' favourite." Being a rather quiet student, he was deeply impressed by one experience in particular, at the school's Christmas party.

"The cutest students, or those who could talk very well or were the teachers' favourites got the biggest presents but I was just left out in the corner."

His mother then realised he was not very happy at school, and decided to help him switch to another school – and it was there that he met his mentor, an experience that completely changed his life.

"I was small and thin, but when I was in Primary Three [after switching schools], one of the teachers there picked me as a prefect, and that brought my confidence back," he says, explaining that it was usually the big and active students who were chosen.

His performance at school improved dramatically and he entered the University of Hong Kong to study

> One of the teachers there picked me as a prefect, and that brought my confidence back

for a degree in civil and structural engineering, graduating in 1998. The influence of his mentor at primary school gave him the inspiration to help others to learn and do better in school.

Mr Chu has set up a free e-mail inquiry service called "Ask Vincent Chu" for all civil engineers, to mainly focus and help graduates and assistant engineers raise any civil engineering problems that they have experienced in their everyday work.

Other than investigating how the pyramids were built, Mr Chu is planning to continue postgraduate education later and would love to explore the possibilities of teaching in future.

"If there's a chance, I'd love to help them [students], but first I need to see if there's anyone who will hire me."

Zoe Mak

Seen

Gals worship at al of fashion prieste

Lane Crawford's Café Costa in IF overrun on Tuesday night as Ho fashion gals couldn't wait to wo the altar of Nina Garcia (right), t priestess of fashion for *Elle* mag more widely recognised nowad of the sartorial judges on reality *Project Runway*.

The congregation was backe length of the restaurant as ever wanted to have his or her copy *The Little Black Book of Style* sig

For her part, the New Yorke lapping up the attention, happil pictures and giving hugs.

"Everything's great. The pla great. The people are great," G gushed, despite having to stand place in heels and autograph bo most of the two-hour event.

One of her book's messages follow brand names and trends However, most women did keer out what she was wearing. For t her beaded black ensemble wa Lanvin and the heels were Chris Louboutin. After the book signi Crawford took Garcia to the Chi for dinner, and she spent yester sightseeing before leaving toda Beijing to continue the book tou

Thursday Thinktan

Five things we're all wondering about

1. David Beckham visit l 2003's frenzy ... Los A Galaxy is not exactly L Galacticos.
2. MTR rail link from Sha Central approved ... th to diversify to transpo case the property thin doesn't work out.
3. YouTube clip shows te fighting student ... for mother tongue, this is you really teach some lesson.
4. Hong Kong and Shenz conduct study over ov and future of border z isn't it 50-50 split now *divorces?*
5. Plans to raise housing Discovery Bay ... the to force all

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(ii) Jiu Jik 招職 on 30 September 2008
http://www.jiujik.com/jsarticle.php?lcid=HK.B5&artid=3000022089&arttype=LEISU&artsection=CAREER

B16 職業特攻 文 職君

年輕工程師撰寫工程問答書籍

要成為工程師，在大學修讀工程科目後，
還要累積在職工作經驗及參加公開試。
一般來說須要三至四年時間。
現職政府渠務署工程師的朱敦瀚，
在考取工程師資格時對不少土木工程的應用問題產生興趣及疑問，
完成考試後還把問題，以及經過考究及工程師學會審議的答案結集成書，
希望將問題提出，幫助新手上路之餘，
也望能助長業界討論氣氛。

出書想幫人

朱敦瀚於香港大學修畢土木工程後，跟其他同學一樣，找到實習工程師的工作，然後成為助理工程師，完成工程師的專業試後，成為正式的工程師。在 27 歲之年，他卻一心把自己在考試期間的學習重點及提問結集成書。「自己對土木工程好有興趣，但在準備應考工程師試時，發現有很多跟實務環境相關的問題，並不能從大學的書本內找到答案，加上當時經已任職助理，累積了一些實際工作經驗，於是把這些問題及從各方面找到的答案寫下來。完成後便成為《實務土木工程問與答二百題》。希望這些答案能幫助日後應考的人士。」

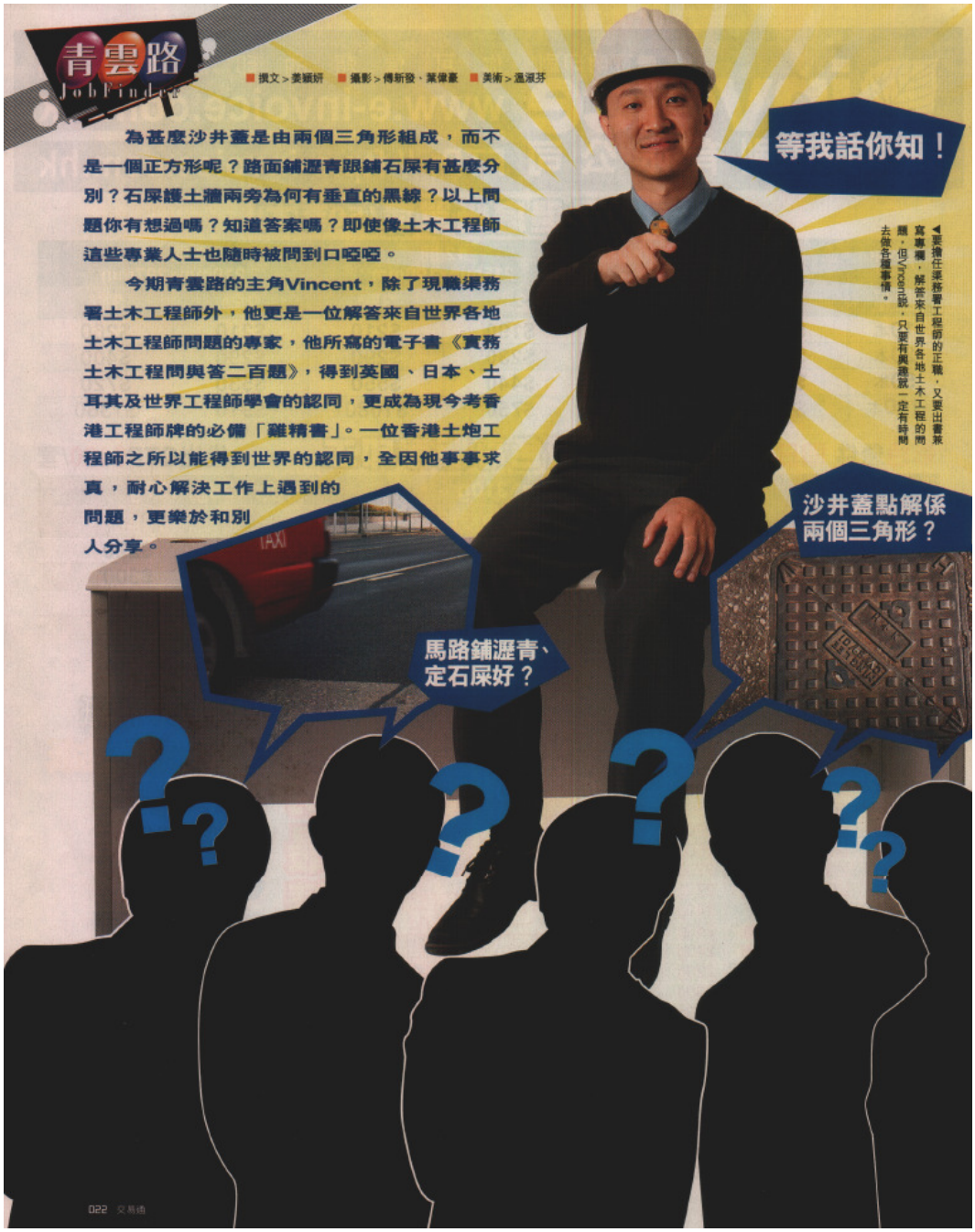
他表示這本《實務土木工程問與答二百題》是首本香港土木工程的書籍上載於英國土木工程師學會、日本土木工程師學會、世界工程師學會及土耳其土木工程師學會的網上作免費瀏覽。書籍面世後，他亦不時收到香港及外地的土木工程師發電郵給他討論當中的答案及提出新的問題，這樣亦觸發他出版另一本與土木工程有關書籍的《土木工程知識 A-Z》。

現在，朱敦瀚於香港工程月刊《The Hong Kong Engineer》撰寫工程專欄 'The Civil FAQ'，他希望日後亦能將這個專欄的答問結集成書，給業界人士參考。

朱敦瀚現職渠務署工程師，剛剛獲得「2007 申訴專員嘉許獎」—— 投訴處理組別及 2008 年度「傑出青年工程師獎」優異獎。

朱敦瀚表示，根據英國土木工程師學會的統計，其著作於該網站的下載次數已經超過一萬次，圖為其另一本著作《土木工程知識 A-Z》。

(iii) Face Magazine on 2 December 2008
http://education.atnext.com/index.php?fuseaction=Article.View&articleID=11925677&issueID=20081203



土炮土木工程師 成世界解謎專家

馬路上的沙井蓋多由兩個三角形組成，因為任何一個平面只需3個支撐點，由兩個三角形組成可以避免蓋面矮起；如果用一個正方或長方形蓋面來代替，4個角會比三角形多了一個支撐點，多出來的一隻角很容易會矮起，當汽車駛過時，碰到沙井蓋凸起的部分會發出嚨嚨的聲響，亦令車震動使乘客坐得不舒服。路面鋪瀝青或石屎各有好壞處，鋪瀝青的好處就是只需等6小時，路面便會乾涸，能再次行車，而行車時會較流暢及發出較少噪音，但壞處就是道路的設計壽命只有約20年；鋪石屎則不方便維修，因為每次維修完畢也要等大約最少7天路面才會乾涸（快乾石屎例外，只需15小時），但路的設計壽命卻可長達40年。石屎護土牆每隔約10至15米就會有一條約20毫米粗的垂直黑線，黑線是用作預留空隙，令石屎護土牆有空間膨脹或收縮，避免產生裂縫損壞牆身結構及影響外觀。

▲每次實施工程前，Vincent必定要現場視察環境，檢查現場與設計圖是否有差距，平時亦會檢查路邊渠口有否缺塞。

實際工作疑難多

以上有關工程界的常見問題和詳盡答案，皆由現職渠務署土木工程師的Vincent提供，他可說是解謎專家，現時他在《都市日報》、世界工程組織聯盟、香港科技大學的土木及環境工程學系等網站寫專欄，解答來自世各地工程師的疑問。別以為以上問題只有行外人才會發問，這些問題全是Vincent現實中曾為行內見習或現職土木工程師解答過的問題。其實，木土工程師的工作範圍很廣，小至建設渠道、馬路，大至起橋、水塘和機場，所以不同範疇的土木工程師未必知道所有行內知識，而初入行的見習工程師及助理工程師需要邊做邊學，很多實際工作情形未必會知道。

現年32歲的Vincent，入行10年，由見習工程師做起，只花了4年，便成功考政府的牌照，正式成為土木工程師，先後於渠務署、土木工程拓展署及路政署工作。「我初初畢業出嚟做見習工程師，發覺喺大學上堂學嘅嘢太理論化，到實際工作時發覺好多嘢都唔識。好似原來起馬路可以唔使鋪鋼筋，路面只需每隔約5米預留3毫米嘅空隙，熱脹冷縮產生裂痕只會出現喺空隙嘅底部，唔會妨礙馬路運作。而鋼筋生銹亦有好處，嗰啲有花紋嘅石屎牆鋼筋本身好滑，如果生咗銹，反而可以增加摩擦力，同啲石屎會黐得實啲。呢啲嘢除咗問上司，自己仲成日去土木工程署個圖書館搵書搵答案。」

Vincent由見習時開始不斷去找尋答案，當發掘的答案愈多，就愈想和別人分享，「學識咗嘅嘢好想話畀人知，等其他人唔使好似我初入行咁徬徨。咁啱喺03年同啲同事傾開，沙士爆發令經濟差咗好多，工程少亦令新入職嘅畢業生少咗，又眼見好多見習土木工程師做做吓就放棄。我知道土木工程其實係好多嘢學好得意，我相信出番本書解答工程界常見嘅問題，

會令多啲人對土木工程感興趣，多啲新人同舊人繼續留番喺行內工作。」

出書獲世界認同

Vincent為了推出了他第一本英文電子書《200 Questions and Answers on Practical Civil Engineering Works》(《實務土木工程問與答二百題》)，只是籌備工作已花了年半的時間，結集以往遇到的問題及答案，完成後他給了英國工程師學會核實書本，認為內容無誤，有參考作用，便把該書放在他們的網站供人免費下載，結果大受歡迎，得到世界各地工程師的欣賞。期後日本、土耳其及世界工程師學會均一致認同Vincent的著作內容真實無誤，分別放在其網站讓人免費下載，截止今年5月，單是英國土木工程師學會網站便已經有過萬人下載書本，而《實務土木工程問與答二百題》更成為現時考香港工程師牌的必備「雞精書」。

最初寫電子書的動機只是分享，雖然沒錢賺，但得到了來自世界各地的認同，更搖身一變成為解答有關工程謎團的專家，「估唔到本書出咗之後，有好多見習工程師同世界各地嘅工程師都send email畀我，問我問題或者同我討論啲新技術，例如會傾吓起碼頭用乜形樁去支撐會好啲？因為圓形樁較能承受嚟自各方向嘅巨大撞擊，比起方形樁會冇咁易彎。而香港地少填海多，填海嘅技術會先進啲，外國就地大，起大型建築就會拿手啲，咁大家交換吓意見，就會易啲進步。之後，仲開始有人搵我寫專欄添。」他自05年起，陸續在世界工程組織聯盟、香港科技大學的土木及環境工程學系等網站均設有專欄，解答工程學的問題，最近連《都市日報》也找到他的筆跡。在跟不同工程師討論問題後，啟發到Vincent於07年再推出第二本著作《土木工程知識A-Z》，在各大書局發售。

愛上金字塔入行

在香港土木工程不算是熱門科目，當初Vincent為甚麼會對土木工程感興趣呢？「父母好想我做醫生，但係我自細就畀金字塔迷住，好記得小學時，老師問我有冇諗過金字塔係點起嘅，雖然到啲家都未有答案，但引起我對土木工程嘅興趣。中學嘅時候已經不斷咁自己去睇相關嘅書，其實讀建築都可以起樓，但係我同樣鍾意填海，所以大學諗都冇諗就揀咗土木工程。」興趣是最好的推動力，Vincent從此向着自己的理想進發。

Vincent中五會考有8A，但沒想過他小學時考第尾很自卑，「讀小學二年級嘅時候，我又瘦又細粒，讀書成績又唔好，考全班第尾，經常畀老師鬧又成日見家長，嗰時對自己好冇自信，覺得自己咩都做唔好。阿媽冇鬧我，佢見到我咁，覺得間學校可能唔啱我，幫我轉校。轉咗校之後，遇到某老師，我以前以為要高大同主動先至有資格做風紀，但估唔到佢揀我做風紀，仲要係做風紀隊長，我好感激佢，因為佢，我先知道自己有能力，有咗信心就

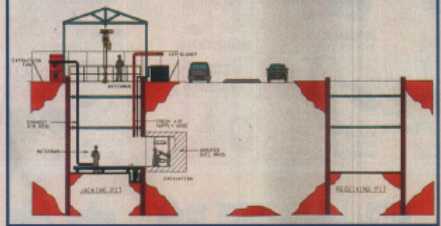
▲Vincent在獻主會小學遇到恩師葉老師，他就如了Vincent當風紀時，令Vincent感覺信心大增更名列前茅。

肯畀心機讀書，之後英文考試我係全班最高分嘅個。」

出色表現獲大獎

Vincent很感激葉老師的知遇之恩，令他認清自己的能力，自此，讀書很用功，更名列前茅。葉老師幫助Vincent重拾自信，亦教會他要樂於助人，像葉老師找出他成績差是因為欠缺動力才能對症下藥，所以他知道要真正幫助人就應耐心探索事情。除了解答問題外，在日常工作裏，Vincent的耐心求知性格也表露無遺，在他處理皇后大道中工程的時候，不但會先花時間實地了解工地範圍的情況，亦諮詢工地附近居民，和參加了中西區區議會聽取意見，他更在皇后大道中擺放圍欄，模擬施工時的地盤範圍，邀請區議員、居民及業主去實地了解情況，然後再向他們解釋工程的需要及好處。

「我哋最後決定用成本較貴嘅無坑挖掘法，無坑挖掘法即係唔掘起晒條街，掘個洞入去地底度做渠務工程，好開心件事好圓滿，因為我哋成功限制咗承建商嘅施工時間，咁就唔會喺繁忙時間阻到居民同商舖嘅生意。」這種不斷尋求最佳方案的精神，令Vincent的工作得到讚賞，他先後得到2007申訴專員嘉許獎和08年香港工程師學會的傑出青年工程師優異獎，表揚他對香港工程界的貢獻。「我喺家一路進修緊土木工程知識，成日做research同留意工程界嘅新消息，希望將來可以從世界各地引進一啲新技術，令到香港嘅工程會做得愈嚟愈好。」



▲Vincent提議在皇后大道中的渠務工程以無坑挖掘法來進行，因為工程會於地底進行，可減少對附近商舖和市民的影響。此乃無坑挖掘法模擬圖片。

土木工程師點入行？

政府每年都會招聘見習土木工程師，安排在不同部門工作，累積經驗。今年特首曾蔭權更承諾致力發展十大基建，相信未來土木工程師會更吃香。而坊間不少私人機構需要聘請有關職位，如利基控股有限公司旗下的利達建築集團及基利承建有限公司現在均聘請見習工程師。無論政府或私人機構，見習土木工程入職資格需擁有土木工程學位，新入職者人工約1萬，一般在職累積約3年經驗便可升至助理工程師，期間要自行投考牌照，得到牌照後就有機會成為工程師。如果想知道招聘詳情，可瀏覽下列網址：

政府網址：
hkucsb.hku.hk:8080/advertsys/allvacancyC.html
（如有空缺，會在此公布）
利達建築集團網址：
www.buildking.hk/cms/GetFile.aspx?File=../Files/Reports/21_1.htm
基利承建有限公司網址：
www.buildking.hk/cms/GetFile.aspx?File=../Files/Reports/22_1.htm

土木工程師晉升階梯：

高級工程師（人工約$40,000至$70,000）

約5年

工程師（人工約$30,000至$46,000）

約2年

助理工程師（人工約$20,000至$25,000）

約3年

見習工程師（人工約$10,000）

後記 冷知識有人識？

當記者知道沙井蓋為什麼由兩個三個形組成時，回到公司急不及待要認叻向同事發問，這條冷知識問題，如我所料，他們一個都不懂得回答，在我說出答案時，看見他們點頭的樣子，我已禁不住流露出驕傲的神情。

但回想Vincent不厭其煩為我解答了多條，對我來說是冷知識的問題時，他面上只掛上一個傻傻的笑容，一點驕傲也沒有，給人只有謙遜的感覺……蘇格拉底講過，如果想要拓展知識，必須接受自己的無知，謙卑的人才能成為聰明的人，Vincent擁有智者的特質，難怪能成為工程界的解謎專家。

想問Vincent問題，可電郵至askvincentchu@yahoo.com.hk