The Underlying Reasons in Practical Civil Engineering Works

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Preface

To be honest, I never dream of writing four engineering books within 3 years. I sincerely wish that I could write further as a professional writer.

This is my fourth book since my first writing in 2006. Scientists explore the secrets of the universe while engineers simply apply engineering knowledge. Owing to the accustomed way of traditional practice, engineers may exhibit less interest in seeking for the reasons behind engineering practices. However, without knowing the rationale underlying in practical engineering works, it is almost impossible to make advancement in engineering technology. Therefore, this book is purposely written to simulate the interest of engineers in looking for the reasons of various engineering practices.

"Civil Engineering Practical Notes A-Z" and "Ask Vincent Chu (Common FAQ on Practical Civil Engineering Works" are intentionally written for experienced engineers who possess some practical experience in civil engineering. On the contrary, this book is written in the same style and level as "200 Questions and Answers on Practical Civil Engineering Works" which is intended for all engineers, including engineering gradates and young engineers.

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

Vincent T. H. CHU
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Chapter 1. Roadworks

1. In expansion joints why are plastic sleeve normally used in dowel bars instead of debonding agent?

The purpose of plastic sleeve or debonding agent around dowels bars in expansion joints is to minimize the frictional resistance between the bar and its surrounding concrete. This is the reason why plain round bars are usually used instead of deformed bars which provide mechanical interlock with concrete and hence it hinders the free movement of the dowel bar.

Both bituman-based paint (debonding agent) and plastic sleeve could serve the purpose of reducing friction between dowel bar and surrounding concrete. From practical point of view, the use of plastic sleeve (e.g. PVC dowel sleeve) around dowel bars can well prepared off-site and manufactured well in advance, thus saving the time of construction.

2. Why is hot applied thermoplastic road marking normally used instead of cold applied road paint?

Hot applied thermoplastic road marking appears to be more commonly used than cold applied road paint as road marking materials. For hot applied thermoplastic road marking, it allows the addition of solid glass head which enhances reflectorisation effect. This essentially makes great improvement on the visibility of road markings at night time. Moreover, from past experience the durability of thermoplastic road marking is higher than that of road paint.

3. What are the advantages of using rockfill over earthfill to build road embankment?

With the use of rockfill to build embankment, it is not a concern regarding the build-up of pore water pressure during construction so that the embankment can be filled at the faster rate. Moreover, the use of rockfill allows a steeper angle in forming road embankment when compared with earthfill so that it results in a small amount of fill. As such, it helps save the cost of construction.

4. Why are stone mastic asphalt used in heavily trafficked roads?

Stone mastic asphalt (SMA) developed in Germany in late sixties. It is characterized by having a high proportion of coarse aggregates that interlock to form a strong aggregate skeleton. Typical SMA composition consists of 70-80% coarse aggregates, 10% filler and 6% binder. The concept of SMA design is that severe traffic loads is carried by the stone skeleton, and the mastic (a combination of fine aggregates, filler and binder) is introduced in the mix to fill out the remaining void spaces with an aim in achieving durability. To ensure that the course aggregate stone contact function, it is essential to prevent immediate sizes of aggregate to hold course aggregates apart.

Owing to high binder content, drainage inhibitor is added to prevent binder drainage during transport and placing.

In essence, SMA provides a textured, durable and rut resistant wearing course and hence they are commonly used in heavily trafficked roads with high traffic stress.

5. Why is it preferable for SMA layer to be cooled below 40^o before opening to traffic?

SMA contains high binder content and extreme care should be taken during the placing process of SMA. Multi-tyred rollers are not used in paving SMA because of the possible working of binder to the surface of the SMA leading to flushing and pick-up. By the same reason, trafficking of newly-placed hot SMA also produces the same effect of flushing the binder to the surface. As such, it is preferable to have the SMA cooled below 40^o before opening to traffic.

6. Can subsoil drains remove all moisture to protect road formation?

Water control is essential to enhance subgrade to possess good bearing value and strength. Water movement in soils takes place by the action of gravity and capillary actions. Subsoil drains are commonly placed at least 1m below finished subgrade to maintain a lower groundwater table.

A properly constructed subsoil drain could effectively lower groundwater table and control the capillary rise. However, they may not be able to eradicate completely the upward movement of moisture in soils. Therefore, a sand layer or granular sub-base could be placed on sub-grade to remove and intercept the moisture once it starts to accumulate.

7. Can joint sealant provide a perfect watertight seal in joints?

The two main principal functions of joint sealant are to minimize the entry of surface water and prevent the ingress of incompressible material from entering the joint. Other minor function of joint sealant is to reduce the possibility of corrosion of dowel bar by the entrance of de-icing chemicals.

Water entry into joints is undesirable because it leads to the softening of subgrade and pumping of subgrade fines under heavy traffic. However, it is impractical to maintain a completely watertight pavement structure. In fact, vacuum tests show that no sealants could provide 100% watertight seal. The current philosophy to combat water ingress into joints is only to minimize but not to completely prevent water from entering the pavement structure. Instead, a permeable subbase is designed to remove water from the pavement.

8. Which joint sealant is better, acrylic, polysulfide, polyurethane or silicone?

There are four generic types of joint sealant with high performance. Their properties are highlighted in the following table:

Acrylic	Polysulfide	Polyurethane	Silicone
● Accommodate 12% movement. ● Exhibit shrinkage upon curing ● Solvent-based.	● Poor recovery in high cyclic movements ● Exhibit excellent chemical resistance ● Good performance in submerged conditions.	● Accommodate 50% movement. ● Excellent bonding, can be used without primer ● Good UV resistance	● Accommodate 50% movement. ● Excellent low temperature movement capability ● Excellent UV and heat stability

9. Should vehicular parapets be designed to be strong?

Parapets are designed to satisfy different containment levels. The containment level represents the magnitude of impact that the parapet is supposed to uphold.

A parapet designed as low containment level can hardly withstand the impact by large vehicles which may even damage the parapet. On the other hand a parapet designed as high containment level can effectively contain safety large vehicle. However, when it is collided by light vehicles, it is expected that it would cause considerable damage to the light vehicles and its passengers on board. Therefore, strong parapets may not necessarily mean a good parapet.

10. Can vehicular parapets withstand the collision of double-decked bus?

Basically the major problem associated with the collision of double-decked bus lies on the possible overturning of the bus upon collision. The overturning moment is the product of impact force and the difference in the centre of gravity of bus and the height of vehicular parapet. The restoring moment is the product of bus weight and 0.5 times the width of bus.

In fact, owing to the elastic deformation of both the parapet and bus, it is expected that the impact force, and hence the overturning moment may not be larger than the restoring moment for 1.1m high vehicular parapet. Computer simulations have to be conducted to verify if a double-decked bus traveling at a certain speed would roll over the parapet when impacted at a certain angle.

11. In concrete pavement, keyway joint are sometimes adopted in longitudinal joint. Why?

Longitudinal joints are installed in concrete pavement to prevent differential settlement between adjacent concrete panels. Moreover, it serves to control cracking from stresses caused by volumetric changes of concrete owing to moisture and thermal gradients. In essence, the joint contains tie bars to enhance efficient load transfer between adjacent concrete panels.

Sometimes keyway joint are designed in longitudinal joint to improve the performance of the joint. Though the installation of keyway joint does not appear to increase the load transfer efficiency of longitudinal joint, it proves to help reduce the deflection of concrete pavement. Keyways are not recommended for thin slab (less than 250mm thick) because of the difficulty in construction. Moreover, keyways are prone to failure in thin concrete slabs where they are too large or too close to slab surface.

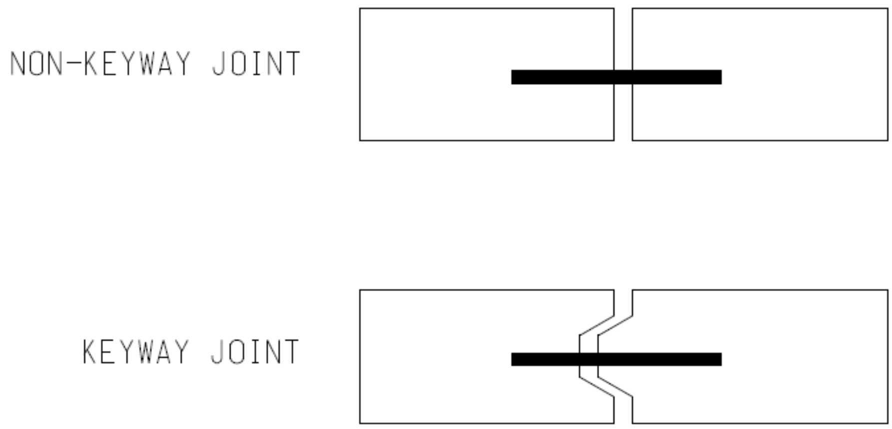


Fig. 1.1 Non-keyway joint and keyway joint

12. For box-out of concrete carriageway, should square box-out or round box-out be adopted?

Isolation joints are introduced where the pavement contains manholes and other structures. The joints allow independent movement of the pavement and roadside structures without any connection which otherwise could result in damage.

Square box-outs are commonly used in pavement and it suffers from the demerit that cracks are observed to appear at the corners of the box-out. Hence, to prevent crack formation at corners, the use of rounded box-outs could eliminate such occurrence. In fact, some form of reinforcement could be introduced to reduce the crack formation in square box-outs. For instance, fillets or reinforcing bars and fabric could be placed at interior corners of square box-outs to hold the cracks together should cracks grow.

13. There is an optimum time to saw contraction joints in new concrete pavement. Why?

There is an optimum time to saw contraction joints in new concrete pavement. Sawing cannot be carried out too early because the saw blade would break out particles from pavement and this results in the formation of jagged and rough edges. Such raveling is undesirable as it would impair the appearance and the ability to seal the joint properly.

Sawing cannot be implemented too late. When the volume of concrete is reduced significantly owing to drying shrinkage or thermal contraction, it induces tensile stress owing to the restraint of such reduction. When the tensile stresses exceed the tensile strength of concrete, cracking would result and form in other locations instead of the planned location of contraction joints.

14. For concrete carriageway, which type of subbase is better, granular subbase or lean concrete (cement-bound material)?

Subbase serves the following functions in a concrete pavement:

(i) Aid in spreading load of road traffic.
(ii) Prevent pumping of fines from subgrade.
(iii) Protect the subgrade from frost.
(iv) Improve drainage of the pavement structure so that the pavement structure is mostly dry with minimum moisture.

Cement-treated bases are easy to construct and provide a stronger and more erosion-resistant platform for the concrete slab when compared with granular subbase. They are normally used for medium to high traffic loads. However, tensile stresses arising from temperature curling would be significantly increased by the presence of lean concrete subbase as compared to granular subbase. Moreover, there is an increase in frictional resistance between concrete slab and subbase.

Granular subbase is susceptible to erosion and it retains moisture for long periods. They are normally used only for roads with low to medium traffic loads.

15. What is the difference between tie bars and dowel bars in concrete carriageway?

Tie bars are deformed rebars or connectors used for holding faces of rigid slabs in contact to maintain aggregate interlock. Tie bars are not load transferring device. For instance, tie bars are used in longitudinal joints in concrete pavement.

Dowel bars are smooth round bars which mainly serve as load transfer device across concrete joints. They are placed across transverse joints of concrete pavement to allow movement to take place. Where movement is purposely designed for longitudinal joints, dowel bars can be adopted.

16. Should lean concrete base and concrete slab be bonded together?

There are two schools of thought regarding the suitability of bonding between lean concrete base and concrete slab. The first one considers it undesirable to bond them together to minimize reflection cracking in the slab. In essence, bonding would cause cracks in lean concrete base to reflect through the concrete slab which may lead to premature cracking. Hence, bond breaking is achieved by applying wax curing compounds on lean concrete bases.

The other school of thought is to promote bonding between lean concrete base and concrete slab by treating the base with a rough texture to promote bonding to the slab. They consider that debonding lessens the lean concrete base's structural contribution to the pavement and increases stresses due to curling and warping.

17. Why is it necessary to ensure cleanliness of bituminous pavement before applying tack coat?

Surface preparation of bituminous pavement is essential in proper application of tack coat. The entire surface has to be cleared of debris, dust and soils. Otherwise, the tack coat would stick to the debris left on the pavement instead of adhering to the pavement. When delivery or placement equipment is driven over tack coat, it tends to stick to the tire's of the equipment instead of pavement.

Chapter 2. Concrete Structure

1. Is waterstop necessary in construction joints of water-retaining structures?

Construction joints are introduced during construction and they are not intended for movement to take place. If the concrete panel on each side of the construction joint has been designed to have maximum crack width of 0.2mm, theoretically this joint would also behave in the same way as its adjoining material. Hence, the design of this part of water-retaining structure such as concrete and steel are identical on both sides of panel. As such, BS8007 makes provision that it is not necessary to incorporate waterstops in properly constructed construction joints based on the above reasoning.

2. For the purpose of defining the serviceability crack width limit state, the maximum design surface crack widths for the exposure conditions defined in BS8007 should be taken to be the following:

> **The maximum design surface crack widths for direct tension and flexure <u>or</u> restrained temperature and moisture effects are:**
> **1) severe or very severe exposure: 0.2 mm;**
> **2) critical aesthetic appearance: 0.1 mm.**

Is the crack width induced by concrete hydration and flexure should be considered individually to satisfy the above maximum crack width requirements?

The crack width induced by concrete hydration and flexure should be considered individually to satisfy the above maximum crack width requirements. For crack width less than 0.2mm, it is assumed that the mechanism of autogenous healing will take place in which the crack will automatically seal up before the structure is brought into service. The crack width induced by hydration, which is checked to be less than 0.2mm, is sealed up first and then it will be subject to flexure for another checking on crack width.

3. What is the difference in functions between internal waterstop and external waterstop?

External waterstops are applied externally on the structures and they proved to be effective when installed on the face with a net clamping pressure. For instance, external waterstops can be placed on the outer face of a basement to guard against water entry into the basement.

Internal waterstops are applied internally within the thickness of concrete and it is usually adopted when water pressure can act in both ways. They proved to be effective measures to guard against water flow in both directions but its success lies on the proper installation of waterstops inside the concrete structure. For instance, the installation of waterstops inside concrete slab encounters the problem of improper compaction of concrete around the waterstops.

4. Can rapid-hardening cement be used in water-retaining structures?

Normal Portland cement is usually adopted in water retaining structures. Where sulphates or chemical agents are anticipated in groundwater, sulphate-resisting cement may be used to guard against sulphate and chemical attack. However, it is normally not advisable to use rapid-hardening cement in water-retaining structures because it involves greater evolution of heat during hydration process, leading to increased shrinkage cracks which form the location of potential leakage in the structure. It is only applicable in cold weather condition where the rate of hydration is low.

5. What are the reasons in setting maximum and minimum time for concreting successive lift in water-retaining structures?

Maximum time for concreting successive lifts is required for concrete structures to reduce the potential differential strains. However, minimum time is needed to allow for possible shrinkage and thermal contraction to take place in the event of alternative bay construction before concreting to alternate bays. Otherwise, cracking may result which is undesirable in water retaining structure.

6. Is slump test a good test for measuring workability?

Though slump test is originally designed as a measure of workability, it turns out to be an indicator of excessive water content in concrete only.

Slump test is not considered as a measure of workability because:

(i) There is no connection between the test results of slump test and workability;

(ii) The test results exhibit large random variations which is greater than that due to observed differences in workability;

(iii) Concrete of different workability may have the same slump.

7. How can permeable formwork improve the quality of concrete?

Permeable formwork serves as a filter that allows excess water and trapped air to escape from concrete surface. During compaction by vibrators, the fluid movement through permeable formwork drives out air and water, leaving behind a denser and stronger concrete. The movement of water results in a decrease in water in fresh concrete and fines cement particles from interior concrete shall be carried towards the formwork. Hence, it lowers the water cement ratio at concrete surface and enhances a higher strength near concrete surface.

In traditional formwork, during concrete compaction process the vibration tends to force water to the surface of concrete mass owing to the rearrangement of solid particles in concrete. As such, the concrete in concrete/formwork interface possess more water than the interior concrete. Consequently, the higher water cement ratio at concrete surface would lower the surface strength. Permeable formwork functions and solves this problem by allowing excess water to pass through.

8. Can the depth exceed the width of joint sealant in concrete joints?

The shape of joint sealant affects its ability to stretch with movement. For instance, for rectangular joint sealant if the depth exceeds the width it tends to resist stretching of sealant in thermal movement. Moreover, block shape, when compared with concave shape, appears to be more resistant to stretching.

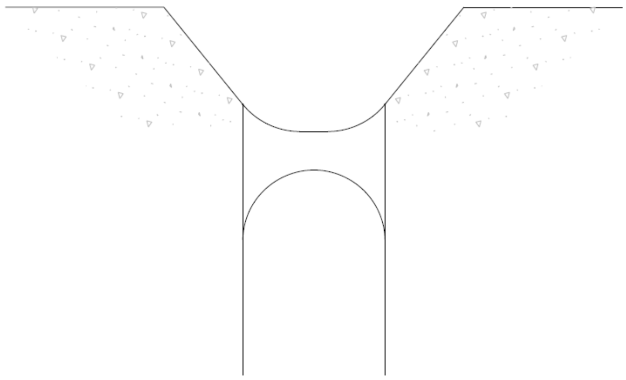


Fig. 2.1 Concave shape sealant

9. What is the function of cladding in concrete buildings?

Cladding refers to the external layer of the building which provides the aesthetic effect. Apart from the external appearance of the building, the main use of cladding is to protect the building structure from weather in one of the following ways:

(i) Cladding is made of impermeable materials so that rain water could only access the building through joints. However, properly designed joints with sealant could completely keep out the rain infiltration.
(ii) Cladding is made up of porous material (bricks) which absorbs rain during rainfall and subsequently dries out. Water could hardly penetrate into the building given that the cladding is of sufficient thickness with low permeability.

10. Is Schmidt hammer test a standard test for testing concrete strength?

The Schmidt hammer test involves hitting the in-situ concrete with a spring-driven pin at a defined energy, and then the rebound is measured. The rebound depends on the surface hardness of the concrete and is measured by test equipment. By referring to the some conversion tables, the rebound result of the test can be used to determine the compressive strength of the concrete. Although past investigations showed that there is a general relationship between compressive strength of concrete and the rebound number, there is a wide range of disagreement among various research workers regarding the accuracy of estimation of strength from Schmidt hammer. In fact, there is about a variation of 15-20% in concrete strength measured by the method.

Schmidt hammer is in not a standard test for acceptance testing of concrete strength. It is only a test used for estimating the strength of concrete in structure and it can hardly be considered as a substitute for compressive strength test.

11. Is shrinkage in concrete a totally reversible process?

In drying shrinkage, the excessive water which has not taken part in hydration process would migrate from interior of concrete core to the concrete surface. As a result of evaporation of the water moisture, the volume of concrete shrinks. The reduction in volume owing to moisture loss is termed shrinkage. In fact, aggregates in concrete would not cause shrinkage and helps to resist the deformation.

Stress would be generated owing to the occurrence of shrinkage. For instance, concrete at surface tends to dry more rapidly than the interior, leading to differential shrinkage. This results in the formation of internal balancing forces in which there is tension on concrete surface with compression in the interior concrete. About 90% of ultimate concrete strain occurs in the first year.

When the water is allowed to absorb water, only part of shrinkage is reversible. Water loss from gel pore with C-S-H and capillary pres can be readily replenished. However, water loss from the space between C-S-H layers cannot be easily replaced with water. Once water is lost from the space between C-S-H layers at the first place, the bond between the layers becomes stronger and the layers would get closer together, thus making it difficult for water to re-enter into the reduced space.

12. What is the difference between “High strength concrete” and “High performance concrete”?

There is common confusion about the terms “High strength concrete” and “High performance concrete” and it appears that they refer to the same thing. In fact, “High performance concrete” refers to the concrete which has been specially designed to achieve a certain particular characteristics such as high abrasion assistance and compaction without segregation. It may turn out that the designed concrete would possess a high strength but this is obviously not the original intention.

"High strength concrete" is designed to have concrete strength of 70MPa and more.

13. Why are recycled aggregates and recycled concrete aggregates not suitable for "High strength concrete"?

Not all aggregates are suitable for producing "High strength concrete" because the strength of aggregates may control the ultimate strength of concrete once they are crushed apart before the failure of cement paste.

Recycled aggregates and recycled concrete aggregates are normally not recommended in producing "High strength concrete". Owing to their intrinsic effect of reduced compressive strength, it requires increased cement content to counterbalance this effect in normal concrete situation. However, in the case of "High strength concrete", the very high cement level has already been adopted which offers little scope for further increase in cement content.

14. In "High strength concrete" in buildings, 56 or 91-day compression test results are sometimes adopted instead of 28-day compression test results. Why?

In normal concrete structures, 28-day test results are often adopted. However, in the construction of high-rise buildings using "High strength concrete", compressive strengths based on 56 or 91-day compression test results are commonly used instead. Since the process of construction of high-rise buildings involves the construction of lower levels firstly in which they are not loaded for a period of a year and more. Substantial material savings shall be resulted from using 56 or 91-day compression test results. Moreover, with later ages of test results used, other cementing materials can be incorporated into the concrete mixture which improves the durability of concrete in terms of heat generation in hydration and other aspects.

15. Why shouldn't internal vibrators be forced down into fresh concrete?

Internal vibrators operate by generating impulses which liquefy the fresh paste so that the internal friction between aggregates is reduced. As a result of vibration effect, the mix become unstable and trapped air would rise to the top while aggregates would settle to the bottom.

Internal vibrators should be allowed to fall in fresh concrete under its own weight and should not be forced to drag down into concrete. The reason behind this is that the use of force to push down internal vibrators would leave a mortar channel in fresh concrete and this result in the formation of weak concrete along this channel.

16. Should large-diameter or small-diameter vibrators be used in compacting concrete?

There is a general rule regarding the size of vibrators in compacting concrete. The diameter of the vibrator should be a quarter of the wall thickness of the concrete being cast. In general, large-diameter internal vibrators have higher amplitude with lower frequency while small-diameter internal vibrators have lower amplitude with higher frequency. In particular, small-diameter internal vibrators with high frequency are normally used in compacting high slump concrete.

17. Why does plastic sheet cause discolouration to freshly placed concrete?

Plastic sheets are commonly used in curing to prevent moisture loss from concrete surface. However, it is not uncommon that discolouration occurs on the concrete surface. When plastic sheeting is spread over concrete surface and in direct contact with concrete, it tends to leave colour streaks on concrete surface. The problem of discolouration becomes even worse when calcium chloride is used in concrete mixes.

18. What the preferable size of cover blocks?

The purpose of cover blocks are:

(i) Maintain the required cover.
(ii) Prevent steel bars from getting exposed to the atmosphere so that steel corrosion may result.
(iii) Place and fix reinforcement based on design drawings.

As cover blocks after concreting shall form part of concrete structure, it is preferably that the cover blocks shall possess similar strength to the concrete structure. Moreover, the size of cover block should be minimized so that the chances of water penetration to the periphery would be reduced.

Chapter 3. Drainage Works

1. Two contraction joints and one expansion joints are usually adopted for drainage channels. Why?

In the life cycle of a concrete structure (not prestressed concrete), it will generally undergo the following process of contraction and expansion:

Contraction: (a) Early thermal movement
(b) Seasonal contraction owing to drop in temperature
(c) Shrinkage
Expansion: (a) Seasonal expansion owing to drop in temperature

The order of magnitude for items (a) to (c) is more or less the same. Hence, qualitatively speaking, for a given length of concrete structure, the number of contraction joints should be more than the number of expansion joints and they are roughly in the order of 3:1 to 2:1 based on the number of expansion and contraction process above. Of course, the actual spacing and number of contraction joints and expansion joints should be determined case by case.

2. What are the potential problems of channels to carry supercritical flow?

Supercritical flow involves shallow water flowing in high velocity. The shallow water depth results in higher velocity head when compared with subcritical flow. The fast flow of water causes erosion to channel linings and beddings. When the channel slope becomes flat, the flow can become subcritical causing the formation of hydraulic jump which further causes erosion to channel bed.

Owing to swift flow of water in channels accommodating supercritical flow, there is considerable safety risk in the event of passengers falling into the channel and washed away to downstream. Moreover, it poses difficulty in carrying out maintenance operation of the channel owing to its high water flow.

3. Why is Manning's formula more often used than Chezy formula in open channel flows?

Manning's formula was proposed by Robert Manning (an Irish engineer) to calculate uniform flow in open channel. It is probably the most widely used uniform-flow formula around the world. Its extensive usage is due to the following reasons:

(i) The majority of open channel flows lies in rough turbulent region;
(ii) It is simple in form and the formula is well proven by much practical experience.

Manning's formula shall not be applied in situations where Reynolds number effect is predominant. For Chezy formula, it is less commonly used owing to insufficient information to find out equivalent roughness and it is not backed by sufficient experimental and field data. However, in smooth boundaries, Chezy formula shall be adopted instead of Manning's formula.

4. Should screens (trash or security) be always placed at culvert inlet?

Screens are provided at culvert inlet owing to one of the following reasons:

(i) To trap trash or debris which might otherwise accumulate in the culvert and block the flow subsequently;
(ii) To prevent access into the culvert by children.

However, screens are not always placed at culvert inlet and they should be determined case by case. For trash or security screens installed in place, it would inevitably trap floating debris and rubbish. Unless they are regularly removed, it would eventually lead to rise in upstream water level leading to local flooding.

For new culvert, there is a trend that the use of trash screens is declining. Trash screens are only placed in culvert inlet where there is a high risk of blockage history. Instead the need of trash screen can be eliminated by adopting the following design features:

(i) There are fewer changes of cross section, fewer bends and smooth transitions into the culvert. As such, it would provide fewer locations to trap debris and trash.
(ii) Provision of good access to the culvert to facilitate regular inspection.
(iii) The culvert should be not designed too long to enhance easy access to clear a blockage.

5. Can dowel bars be omitted in the joints of box culvert?

Dowel bars in joint normally serve to maintain structural continuity by transmitting shear forces between adjacent concrete structures. For box culvert, the use of dowel bars in joints is essential owing to the following reasons:

(i) Without dowel bars, differential settlement would result and it leads to the formation of steps in the box culvert. As a result the flow capacity of box culvert would be reduced.
(ii) The steps in the box culvert would also provide locations to trap rubbish and debris.

6. In scale models, should Froude Number or Reynolds Number be adopted to obtain similarity between model and prototype?

Froude number is used when gravitation forces is predominant in the channel flow. Reynolds number is adopted when viscous forces are predominant in the channel flow. It is almost impossible to make Froude number and Reynolds number identical in model and prototype. Therefore, the use of these numbers should be judged case by case. For instance, in open channel flow Froude Number is used in the scale models as gravitation forces is predominant.

7. How can manholes be adapted to the final height of the pavement?

Theoretically speaking, the whole manhole structures can be constructed as a whole instead of splitting into two stages of construction. With detailed calculation of longitudinal fall and cross fall of road pavement, it is possible to place and construct the manhole cover and frame in accurate levels and falls so that the whole manhole can be constructed in a single stage.

However, in actual practice it may not always be possible to accurately predict the inclination and levels of future manhole cover. As such, it is not uncommon that the construction of manholes is split into two stages:

(i) 1st Stage: The lower part of manholes is constructed up to the access shaft (about the level of sub-base). Then a rigid cover is placed over the access opening of the manholes and bituminous materials are placed on its top to construct the pavement.

(ii) 2nd Stage: The bituminous material around the rigid cover is removed and several courses of brickwork are normally placed on the access shaft to adjust the level of manhole cover and frame to fit with the final height of the pavement. Finally, manhole cover and frame are installed in position as shown in the sketch below.

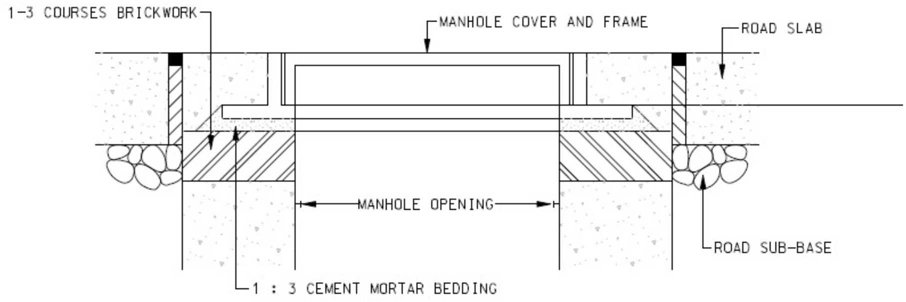


Fig. 3.1 Typical details of manhole cover and frame

8. What is the purpose in providing beveled edge in the inlet of box culvert?

The bevel is sometimes introduced at the inlet of box culvert to decrease the flow contraction at the inlet. In fact, the outlook of bevel is similar to a chamfer except that a chamfer is smaller in size and it is mainly used to prevent damage to sharp edges of concrete during construction. The bevels can be designed as plane or round edges.

The addition of bevels to the inlet of box culverts could increase the capacity of box culvert by about 5-10%. In fact, the socket end of precast concrete pipes serves the same function as the bevels in the box culvert.

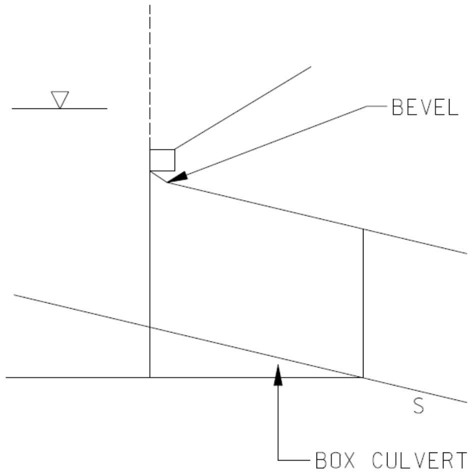


Fig. 3.2 Beveled edge in inlet

9. What is the difference between inlet control and outlet control in hydraulic design of box culvert?

In the hydraulic design of box culvert, there are two flow controls, namely inlet control and outlet control. In inlet control, the entrance characteristics of the box culvert (e.g. headwater depth and entrance configuration) determine the hydraulic capacity of the box culvert, and the culvert is actually capable of conveying a greater flow than the inlet would allow. Barrel shapes and tailwater depth are of no significance in determining the hydraulic capacity. Inlet control usually takes place for culverts lying on steep slopes.

For outlet control, the inlet could accept more flow than the box culvert could carry and the hydraulic capacity of the box culvert is dependent on all hydraulic factors upstream from outlet tailwater.

10. Which shape of drains is better, elliptical or circular?

Horizontal elliptical pipes are commonly used where vertical clearance is hindered by some existing structures. Moreover, horizontal elliptical pipes possess higher flow capacity for the same flow depth than most other structures with equivalent full capacity.

For vertical elliptical pipes, it requires less excavation during trench installation owing to its narrow span. Moreover, backfill loads on the pipe is reduced when compared with circular pipes. Also, owing to its geometric shape, it is mostly used where there is limitation of horizontal clearance. From hydraulic point of view, vertical elliptical pipes allow higher self-cleansing velocity under dry season.

11. What is the significance of critical slope in hydraulic design of box culvert?

Critical slope is the minimum slope in which maximum discharge shall occur without requiring the box culvert to flow full. For box culverts with slope less than critical slope, at low headwater it tends to flow full and eventually requires a higher headwater depth to convey the same amount of water required for culverts with slopes greater than critical slope.

12. Why is air test considered for checking leakage in pipes though there is no direct relation between air loss and water leakage?

There is no correlation between air loss and water leakage owing to the physical difference between air and water and the difference in behaviour of air and water under pressure conditions. Someone may doubt the philosophy in using air leakage to test for water leakage in pipes.

For cracks and openings of capillary tube size, surface tension may hinder the flow of water while air would still pass through the minute cracks. Based on past experience, for pipes passing air test is deemed to have satisfied water test (infiltration or exfiltration). For pipes which fail air test, it should also be subjected to water test before considering any replacement or rehabilitation.

13. Should the outer side of drainage channel at a bend be elevated to cater for superelevation?

Flow around a bend results in a rise of water surface on the outside of the bend and it is natural to consider that extra height of channel wall on the outside of bend to prevent overflow of water.

However, for supercritical flow in channel, owing to the effect of superelevation extra height of channel wall should be provided on both sides of the bend. This is because supercritical flow around a bend would make water level go up alternatively on the outside and inside of the bend owing to cross waves. This cross wave pattern may continue for some distance downstream. As such, both sides of bend shall be lengthened to cater for this effect.

14. Should precast concrete pipes be laid with spigot pointing downstream direction when fitted into sockets?

There is a general rule of laying precast concrete pipes: *the precast concrete pipes should be laid from downstream end to upstream end*. Moreover, *precast concrete pipes should preferably be laid with spigot end pointing downstream direction when fitted into sockets*.

The reason of laying pipes from downstream to upstream is that any rainfall occurs during construction can be drained off the site without flooding the pipe trench. Moreover, gravity and other forces applied to the pipes during installation of pipe joints help tighten the joint and eliminate any remaining joint gap. On the other hand, for pipe laying with spigot point downstream direction, this prevents the joints from opening up arising from pipeline movement. The concrete pipe joints are also protected from the entry of foreign materials.

15. Does autogenous healing make the concrete pipe even stronger than original?

Autogenous healing is common in underground drainage pipes because of the presence of water on either side of the pipes. The non-moving cracks in concrete pipes are sealed by calcium carbonate crystals from carbon dioxide in air and calcium hydroxide in concrete in the process called autogenous healing. The healed cracks are impermeable and behave even stronger than the original.

Autogenous healing can also be adopted to combat corrosion. The presence of water provides the basic conditions for both corrosion and autogenous healing. Corrosion shall take place with rusting of steel. At the same time, calcium carbonate from autogenous healing would be deposited on the cracks and the location of rusting. At last, the two processes compete i.e. disruption by volume expansion of rusting and the isolation of steel surface.

16. Sometimes, "TOP' are observed on the surface of concrete pipes. What does it mean?

It is obvious that pipes should lifted up and laid with "TOP" up. Otherwise, cracking may occur in the portion labeled "TOP" because they are not supposed to take up significant loads on the sides of the pipe.

In fact, the reinforcing cage in concrete pipes can be circular or elliptical. For pipes with elliptical reinforcing cage, it may contain the label "TOP" on its top. Elliptical reinforcing cage is more effective to resist loads because the reinforcement is mainly placed on the tension side of the concrete pipe. As such, the use of elliptical reinforcement needs less steel than circular ones for the same loading carrying capacity.

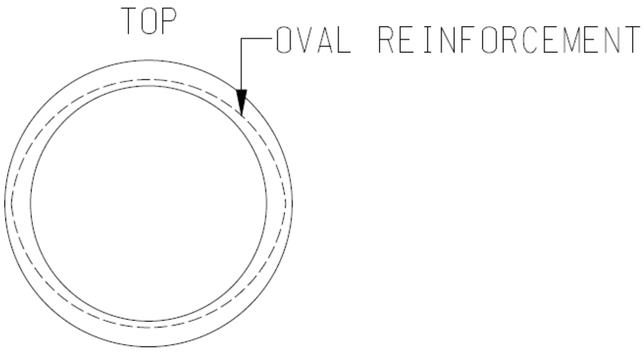


Fig. 3.3 Oval reinforcement in concrete pipes

17. Why is it preferable to have backfilling partly-completed before carrying out water test?

Water test is not intended to reassess the individual pipe performance because this should have been done in the manufacturing process. Instead, it serves to check the occurrence of faults during pipe laying process and to ensure that the pipeline can resist the internal hydrostatic service pressure it will be subjected to.

After adding water to the pipeline, 24 hours are usually specified before actual measurement. This stabilization time is required because both the escape of air trapped at pipe joints and water absorption take time to complete.

It is recommended that backfilling to pipes shall be partly-completed before the conducting of water test to cater for possible floating of pipelines in the event of accidental filling of pipe trench with water. Moreover, it is recommended to place adequate sidefill to restrain the pipeline to prevent movement of pipeline during water test. Otherwise, excessive movement of pipeline from water pressure may result in failure at joints.

18. Why are coupling system usually used for drains constructed in reclamation areas?

Pipes used in drainage works are normally of spigot and socket type which is flexibly jointed. For this kind of pipe connections, it allows small amount of rotation and hence it could withstand certain degree of uneven ground settlement. Owing to uncertain nature of settlement in reclamation area where differential settlement is anticipated to occur, coupling system is usually provided for drains installed in reclamation area which provides a higher degree of resistance to differential settlement. Otherwise, it may cause cracking of pipelines leading to washing in of soil inside the pipelines. In the worst scenario, significant loss of soil may result in ground subsidence.

19. Why is gabion apron necessary for gabion retaining wall to retain river embankment?

Gabion aprons are provided at gabion walls to protect its toe from scouring due to river flow. The scouring would eventually lead to undermining of the gabion structure and affects its structural stability. The length of gabion apron should be long enough such that it reaches beyond the limit where scouring may form. A layer of getextile filter is normally placed at the base of gabion structures to prevent leaching out of foundation soils.

Chapter 4. Marine Works and Safety

1. In reclamation by filling sand, what is the effect of filling operations below mean sea level?

Filling below mean sea level usually has a low density. The settling sand in standing water would form a loose skeleton leading to a low density. However, as the sand level is rising, the increased load causes reallocation of sand grains in lower layers. As such, after dissipation of excess pore water pressure, it results in increased density.

2. How does soil plug in open-ended tubular piles affect its loading carrying capacity?

In marine piles, the tubular piles are sometimes purposely designed to be open-ended to facilitate deeper penetration. In this mode of pile formation, soil plug is formed inside the piles.

The plugging ratio (the ratio of length of soil plug to the length of pile penetration) affects the load carrying capacity of piles. It was demonstrated by experiments that the end bearing capacity decreases with an increase in the plugging ratio. Moreover, close-ended piles display a higher end bearing capacity than open-ended piles as close-ended piles prevent soil from entering the piles and force them around the pile tip leading to a higher stress state in this region.

3. Why are sleeves often installed inside the lower part of open-ended driven piles?

In marine piles, open-ended piles are more often used than close-ended piles to enhance longer length of piles installed. This is essential to provide better lateral resistance against berthing loads and other lateral loads in marine structures.

To enhance longer length of driven piles installed, sleeves can be employed inside the lower part of open-ended driven piles. The sleeves lead to improved drivability with more soil entering the pile to from soil plug. The longer is the sleeves, the higher is the plugged length. This is because there is higher stress release experienced by soils flowing past the sleeves.

4. How does safety helmet function?

The main principle of safety helmet is to protect workers against impact by falling objects or struck by swinging object *by energy absorption*. Upon hitting by an object, the helmet dissipates some of the energy in the following mechanisms:

(i) Stretching of harness inside the helmet;
(ii) Partial damage of outer shell of helmet.

The remaining energy is then evenly spread around the head to reduce the hitting stress on worker's head.

5. Working at height is commonly defined in many countries as falling more than 2m. Why?

For more than 2 metres, it is commonly defined as high level fall in which most injuries are resulted from. However, there is an increasing trend that there has been similar number of injuries from low level falls (i.e. less than 2 metres) and from high level falls. As such, some countries have deleted the *"2 metre rule"* as the definition of falling at height. Instead, it is newly defined as working at a place from which a person could be injured by falling from it, regardless of whether it is above, at or below ground level without stating the level of fall.

6. In fender design, when calculating the berthing energy absorbed by fenders, should engineers take into account energy absorbed by piers?

The design of a fender system is based on the principle of conservation of energy. The amount of energy brought about by berthing vessels into the system must be determined, and then the fender system is devised to absorb the energy within the force and stress limitations of the ship's hull, the fender, and the pier.
Firstly, the energy released by the largest/heaviest vessel allowed to use on the pier is determined to be delivered to the pier by first impact. Then, the energy that can be absorbed by the pier would be calculated. For pier structures that are linearly elastic, the energy is one-half the maximum static load times the amount of deflection. However, in case the structure is extremely rigid, it can be assumed to absorb no energy.

The energy to be absorbed by fender system should be the total energy of *berthing vessels deducting the energy absorption by pier structures.* Finally, a fender system capable of absorbing the amount of energy without exceeding the maximum allowable force in the pier should be chosen from fender product catalogue.

7. Why do vessel operators choose to contact the fender system at its bow instead of mid-ship location during berthing operation?

When calculating berthing energy of vessels, there is a factor called "eccentricity factor" which accounts for different berthing energy when the vessel contact the fender system at different locations of the vessel.

For instance, for mid-point berthing the eccentricity factor is unity which means there is no loss of berthing energy. For third-point berthing and quarter-point berthing, the eccentricity factor is 0.7 and 0.5 respectively. In fact, engineers always attempt to reduce the amount of berthing energy to be absorbed by fender system and pier structures. As such, it is recommended for vessels to contact fender system at its bow or stern because the reaction force would produce a rotational moment to the vessel which dissipates part of vessel's energy.

8. Can water help dissipate part of berthing energy?

Depending on the configuration of pier, water could help dissipate part of berthing energy. For instance, for closed docks in which there is a solid wall going down directly to the bottom of seabed, the quay wall will push back all the water that is being moved by the vessel and creates a cushion effect which dissipates part of berthing energy (10-20%). On the contrary, for open dock in with piles beneath and water can flow through the underside of piers, there shall be no cushion effect of water.

Similarly, the larger is the draft of vessels, the less trapped water can escape under the vessel so that the cushion effect of water can be enhanced to dissipate part of berthing energy.

9. Should small vessels be considered in the design of fenders?

Smallest vessel should also be taken into consideration when designing fender system. In vertical orientation of fender system, the types and sizes of all vessels should be considered taking into account the tidal effect at that region. To conduct proper design of fender system, engineers must consider the height and draft of both the smallest and largest vessels to determine the point of contact on the fender. It is not uncommon that design of fender system considers only the largest vessels berthing in the pier which should be avoided as it might not function for smaller vessels berthing in dock.

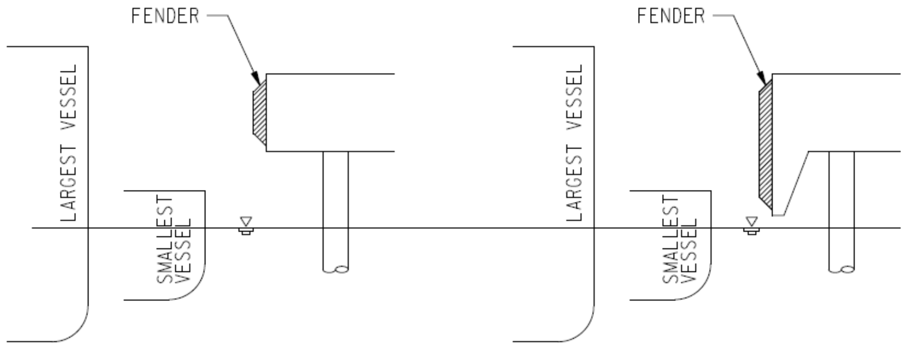


Fig. 4.1 Effect of smallest vessels in fender design

10. What is the difference between weight chain, shear chain and tension chain in fender system?

The weight chain is used to sustain the weight of face and frontal panel. Shear chain help protect the fender from damage while the fender is in shear deformation and they are orientated at 20 - 30° to the horizontal. Tension chain serves to guard the fender against damage when the fender is under compression.

Chapter 5. Piles and Foundation

1. What are the reasons in observed settlements in rockfill foundation?

Compression of rockfill is normally caused by a reduction in dimension of fill and by rearrangement of particles into closer packing.

When the rockfill are saturated, the strength of rock would be reduced accordingly. In fact, wetting of rock surfaces does not reduce the coefficient of sliding friction between rockfills. Considerable settlement may result not from the lubricating effect of water but from a reduction of rock strength at its point of contact. The contact points would then be crushed under intergranular force and the contact area increases until contact pressure is less than the strength of rockfill.

Rockfill with sharp corners proved to be more liable to settlement than those of well-rounded.

To minimize settlement of rockfill, the intergranular force should be reduced and this is achieved by grading the size of rock particles such that there is minimum amount of voids and hence a maximum amount of particle contacts. To avoid particle rearrangement under future loading, the rockfill should be properly compacted with earth-moving machinery.

2. How can piles be driven through steeply dipping karst surfaces?

The steep dipping and variable nature of karst surfaces poses problems for installation of driven piles. Very often, the consequences of hard driving piles over steeply-inclined karst are slipping and buckling of piles. To tackle these problems, the following two options are mostly adopted:

(i) Pre-boring is carried out in steep dipping karst surface as this method could penetrate hard layers;
(ii) Reinforcing the end section of driven piles by welding stiffening plates

3. When are prestressed tiebacks used in sheet piling works?

The use of prestressed tiebacks gets rid of the need of interior bracing. Prestressed tiebacks are anchored into rock or granular soils and excavation can be conducted by using powerful shovel instead of using hand excavation or other small excavators. It provides less restraint and allows free movement for excavation.

4. What is the difference between free earth support method and fixed earth support method?

For free earth support method, the soils at the lower part of piling is incapable of inducing effective restraint so that it would not result in negative bending moments. In essence, the passive pressures in front of the sheet piles are insufficient to prevent lateral deflection and rotations at the lower end of piling. No passive resistance is developed on the backside of the piling below the line of excavation.

For fixed earth support method, the piling is driven deep enough so that the soil under the line of excavation provides the required restraint against deformations and rotations. In short, the lower end of piling is essentially fixed.

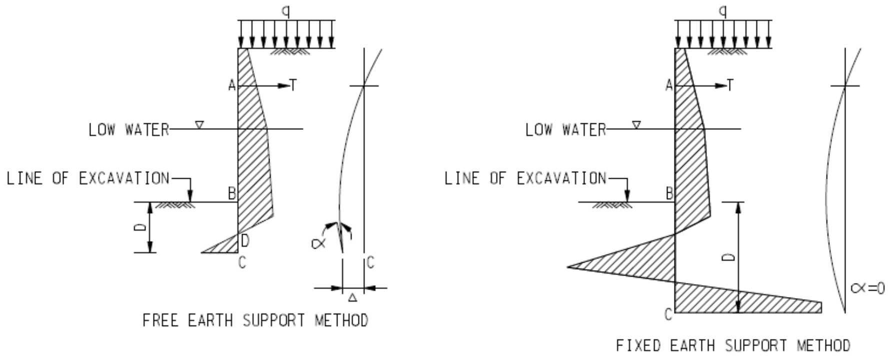


Fig. 5.1 Free earth support method and fixed earth support method

5. What are the limitations of plate load test?

Plate load test is carried out to check the bearing capacity of foundation soils. The limitations of plate load test are:

(i) It has limited depth of influence. It could only give the bearing capacity of soils with depth up to two times the diameter of plate.
(ii) It may not provide information on the potential for long term consolidation of foundation soils.
(iii) There is scale effect as the size of test plate is smaller than actual

foundation.

(iv) To gain access to test position, excavation is carried out which causes significant ground disturbance. The change in ground stress leads to the change of soil properties which the test is planned to investigate.

6. In pile driving operation, would soils always exhibit an increase in pore water pressure?

The change in pore water pressure varies in different soils. In loose sands and sandy silts, the pore water pressure increases during pile driving owing to soil densification. The increase in pore water pressure reduces the soil strength. However, after piling operation ceases for a certain period of time, upon dissipation of pore water pressure the soils would result in increased strength by soil "set-up".

For dense sands, the piling operation cause dilation and increases the pore volume. As such, water may not be fast enough to infiltrate to equalize the pore pressure and this results in a reduction of pore water pressure. Therefore, the apparent increased soil strength is temporary only and it would be reverted back when soil relaxation takes place soon.

7. Which one is better in driven piles, high hammer/pile weight ratio or low hammer/pile weight ratio?

Boussinesq's closed form solution for a rod fixed at its end and hit on its top by a mass shows that compressive stress in the rod increases with the mass of hammer. On the other hand, a larger relative mass of hammer leads to lower tension stress. When an impact is made on friction pile, the compressive stresses are highest at pile top. When an impact is made on end-bearing pile, the compressive stresses may be highest at the top or the bottom of the pile.

To achieve optimal pile driving operation, the piles should be installed quickly with low blow counts. This can be achieved by heavy hammer but it is uneconomical as it requires higher lifting equipment cost and transportation cost. A lighter hammer appears to be more economical but for the same impact energy as heavy hammer, it requires a greater stroke and impact velocity which may cause damage to pile.

In fact, low hammer/pile weight ratio leads to damage at pile top or cracks along the pile. High hammer/pile weight ratio may cause compressive overstressing at the pile bottom.

8. What is the value of micropiles when compared with bored piles and driven piles?

Micropiles are defined as bored piles with diameters not exceeding 250mm. Micropiles were first constructed in Italy in 1950s and were given the name "root piles".

Whenever bored piles (larger diameter) and driven piles are considered feasible, they should be more economic than micropiles. Owing to the small size of piles, only small dimension of equipment is needed for construction. Moreover, it can be used to drill through any type of soils, boulders and hard materials.

Micropiles have extensive applications under the following situations:

(i) Underpinning and retrofitting existing structures;
(ii) Locations of limited vertical clearance and small working areas.

9. In seismic liquefaction, what is the difference of pile failures mechanism between lateral spreading and buckling?

Most of design codes assume that pile fails during strong earthquake by lateral spreading. Lateral spreading is based on bending mechanism where the inertia and slope movement causes bending in piles. In essence, piles are considered as beams which are subjected to lateral loads such as slope movement leading to pile failure.

Piles are slender columns with lateral support from foundation soils. When the length of pile increases, the buckling loads decrease with the square of pile length. For buckling failure, soils around the piles lose the confining stress during earthquake and can hardly provide lateral support to piles. As such, the pile serves as an unsupported column with axial instability. It will buckle sideways in the direction of least bending stiffness under axial load.

10. In press-in piling, how can driving shoes help to reduce jacking loads?

Press-in piling involves the use of hydraulic rams to provide the force to jack the pile into ground. The hydraulic ram is part of machine called "Silent

Piler" which uses jacked pile to provide reaction force for jacking.

The use of driving shoes could reduce the jacking load. The presence of driving shoes change the flow of soils around pile tip and this leads to reduced effective horizontal stress on internal pile shaft. As a result, this enhances a reduction in shaft friction which is the major element for making up the jacking load.

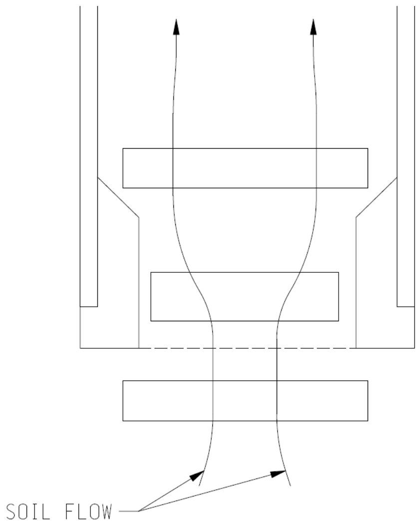


Fig. 5.2 Soil flow along driving shoes

11. What is the difference between compaction grouting and fracture grouting?

Grouting can be implemented in two common modes, namely compaction grouting and fracture grouting. For compaction grouting, high viscosity grout is commonly used for injection into soils. Upon reaching the soils, the grout would not penetrate into soil spaces. Instead it forms a spherical bulb and remains as a homogeneous mass. The formation of bulb displaces the nearby soils.

Fracture grouting involves the use of low viscosity grout. Upon injection, the grout would split open the ground by hydraulic fracturing and penetrate into the fractures. Similarly, soils are displaced during the process.

12. Should thin or thick bitumen layer be used to reduce negative skin friction in driven piles?

When piles are driven through an upper layer of granular soils, thick

(10mm) bitumen layer would be scrapped off during the driving process. A thin coat of 1mm to 2 mm thick is not likely to flow in storage and to peel off during pie driving. The bitumen can be applied by brushing or sprinkling after heated to a liquid state. In cold weather conditions, it may be difficult to handle hot bitumen. As such, the bitumen could be mixed with solvent to soften the bitumen which should be able to cure rapidly to ensure that the bitumen coat stays on the piles.

For precast piles, a primer could be added to achieve better cohesion of bitumen to the piles.

13. Is critical depth of piles a fallacy?

The critical depth of piles are normally assumed as 10-20 pile diameter deep and is the depth beyond which the resistance is constant and is equal to respective value at critical depth.

The critical depth is a fallacy which comes from the failure to interpret the results of full and model-scale pile tests. In full-scale test, the neglect of presence of residual loads renders a measured load distribution to be linear below the so called “critical depth”. Residual loads refer to loads that are induced in piles during and after installation of piles.

14. There is an old rule that *“the area of a follower should be one-fifth of precast concrete pile”*. Why?

The rules of wave mechanics suggested that to avoid reflection of stress wave caused by different impedance values, acoustic impedance should be the same for the follower and precast concrete piles. As such, it enhances smoothest driving and prevent follower from bouncing on the head of piles which is undesirable as it may damage the piles and lowers the efficiency of driving.

Acoustic impedance = Elastic Modulus (E) x Area of Pile / wave velocity

Wave velocity (c) = Elastic Modulus / Density of Pile

For normal steel, E=205GPa, c=5,100m/s
For normal concrete, E=30GPa, c=3,800m/s

For same acoustic impedance,

Area of concrete/Area of steel = (205/5,100)/(30/3,800) = 5

Chapter 6. Bridge Works

1. Why do most elastomers used in pot bearing are usually contained?

To specify space requirements, most pot bearings are designed for high contact pressures with small contact area with bridges. This also enhances lower friction values. Under the free state, most elastomers in pot bearings can hardly sustain this high pressure and hence they are most contained to prevent overstraining. When properly constrained, the elastomer behaves like semi-viscous fluid and can safely accommodate angular displacement.

2. Why do some engineers prefer to use neoprene instead of natural rubber in elastomeric bearings?

Some engineers may choose to design elastomeric bearings to sit on the piers without a connection. The bearing is held in place by frictional resistance only. Paraffin used in natural rubber would bleed out and result in significant decrease in friction. As such, elastomeric bearings would slip away and walk out from their original locations. To solve this problem, neoprene, instead of natural rubber, is used as elastomer because paraffin is absent in neoprene bearings.

3. For elastomeric bearings, which shape is better, rectangular or circular?

Circular bearings have the advantage for standardization because only one dimension can vary in plan. They are suitable for use in curved and large skewed bridge as they could accommodate movement and rotations in multiple directions.

Rectangular bearings are suitable for low skewed bridges. In particular, it is best suited in bridges with large rotations and movements.

4. In wind tunnel test, why are similarity of Reynolds Number between real bridge and model is often neglected?

Wind tunnel test is often conducted to check aerodynamic stability of long-span bridges. To properly conduct wind tunnel test, aerodynamic similarity conditions should be made equal between the proposed bridge and the model. Reynolds Number is one of these conditions and is defined as ratio of inertial force to viscous force of wind fluid. With equality of Froude Number, it is difficult to achieve equality in Reynolds Number.

For instance, for a model scale of 1/40 to 1/150, the ratio of Reynolds Number between the bridge and the model varies from 252 to 1837 with a difference of order from 100 to 1000. As such, similarity of Reynolds Number between real bridge and model is often neglected.

5. How does the shape of bridge deck affect the aerodynamic behaviour?

Two types of bridge vibration that are of special concern are:

(i) Flutter, which is self-induced vibration characterized by occurrence of vertical and torsional motion at high wind speeds.
(ii) Vortex shedding, which is the vibration induced by turbulence alternating above and below the bridge deck at low wind speeds.

One of the important features affecting the aerodynamic behaviour of a bridge is the shape of bridge deck. The shape which provides maximum stability against wind effects is that of an airplane wing, on which the wind flows smoothly without creating turbulence and there is no separation of boundary layers. To improve the aerodynamic behaviour of a bridge, addition of wind fairings and baffle plates could be considered.

6. In grillage analysis of skew bridge, should a skew mesh be adopted or the transverse members are set orthogonal to the main members?

For skew deck, the transverse members are set orthogonal to the main members to find out the correct moment and deflections. Skew decks develop twisting moments which is more severe for higher skew angles. The most economical way of designing reinforcing steel is to place the reinforcement along the direction of principal moment.

For skew angle less than 35^o, it may not be practical to adopt this approach in the skew region. Instead, the transverse members are kept parallel to the support line so that a skewed mesh is adopted. The use of skew mesh suffers from the demerit that it would slightly overestimate the output of moment and deflections.

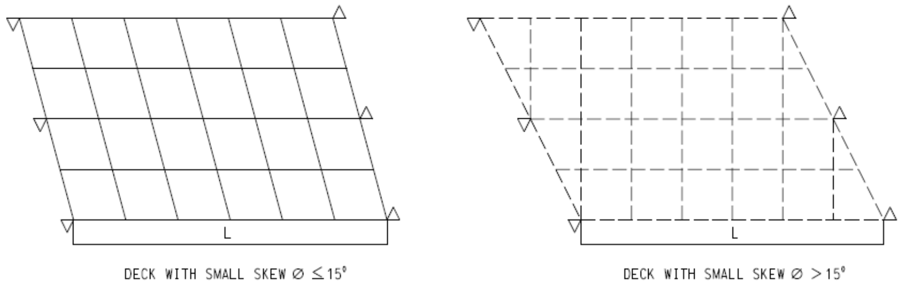


Fig. 6.1 Different reinforcing arrangement in skewed bridge

7. What is the purpose of installation of shear keys in bridge abutment?

In small and medium sized bridges, shear keys are often designed in bridge abutments to provide transverse support to the bridge superstructure under lateral loads. They are not intended to carry vertical loads and they have important applications in resisting seismic loads.

Shear keys in bridge abutment are divided into two types, exterior or interior. Exterior shear keys have the demerit of the ease of inspection and repair. The shear keys are designed as sacrificial and it is assumed that once their capacity has been exceeded, the shear keys would not provide further support. As such, the bridge columns should be designed to provide transverse support once the shear keys fail to function.

8. In bridge columns, why are stirrups be placed around the vertical reinforcement?

In uniaxial compression test of concrete, upon reaching the ultimate load failure of concrete occurs where major cracks line up in the vertical direction and the concrete cube would be split up. The development of vertical cracks involves the expansion of concrete in lateral directions. In case the concrete is confined in lateral directions, it was observed that the formation of vertical cracks would be hindered as indicated in past experiments. As a result, the concrete strength is increased with also a rise in failure strain.

The above theory is often used in the design of bridge columns. Steel stirrups are installed at around the vertical main reinforcement. Other than the function of shear reinforcement, it helps to avoid the lateral deformation of interior concrete core so that the strength of concrete column is increased.

9. Should at-rest, active or passive soil pressure be used in the design of abutment?

At-rest soil pressure is developed during the construction of bridge abutment. Active soil pressure are developed when the abutment are pushed forward by backfilled soils at the back of abutment wall. A state of equilibrium shall be reached when the at-rest pressure is reduced to active earth pressure. Hence, at-rest pressure is considered when assessing the stability of abutment while active pressure is adopted when assessing the adequacy of structural elements of abutment.

Passive pressure is only considered in integral abutment which experiences passive pressure when the deck expands under thermal other effects.

Passive pressures are developed when the abutment wall pushes the soils at the front of abutment. Given that larger movements is required to mobilize passive pressure than active pressure and the abutment is designed not to slide under active pressure, it is normally assumed that passive pressure does not develop at the front of abutment. Moreover, there is a possibility that soils may be removed temporarily owing to utility diversion; it is normally assumed that stability contribution by soils in front of abutment is ignored.

10. What is the exact coverage of HA loading?

Type HA loads first appeared in 1945 and the concept of HB load was introduced in BS 153 in 1954. Type HA loads is the normal loading for United Kingdom and covers vehicles up to 44 ton. HA loads are represented by a uniformly distributed load with a knife edge load. HA loads have covered the following situations:

(i) More than one vehicle occupying the width of a lane;
(ii) Overloading in normal vehicles;
(iii) Impact load induced when car wheel bounce when traveling crossing potholes.

11. Which bridge parapet is better, steel parapet or aluminum parapet?

Steel parapets normal requires painting or pre-treatment with hot-dip galvanizing as they are prone to corrosion and they are normally the cheapest choice for normal containment level of vehicles.

The initial material and setup cost of aluminum parapet is high. They are free of the problem of corrosion and the design of aluminum parapets does not require surface protection. However, owing to their high material price, care should be taken on the design to prevent stolen of parts of parapet. Moreover, aluminum parapet is lighter than steel and has weight savings over steel parapets.

12. When would torsional stiffness of members be considered in analyzing a bridge?

If a box-girder type bridge is purposely chosen because of its torsional strength, then the torsional stiffness and resistance should be considered in design. However, it is commonly accepted to assume that torsional stiffness of a beam to be negligible so that it saves the complexity to provide reinforcement to resist torsion. As such, this would result in higher bending moments induced in the beam.

If the torsional stiffness has been incorporated in computer model during the structural analysis, then it is necessary to check the torsional resistance of the beam.

13. Are there any problems associated with Integral Abutment Bridge?

Integral Abutment Bridges are bridges without expansion joints in bridge deck. The superstructure is cast integrally with their superstructure. The flexibility and stiffness of supports are designed to take up thermal and braking loads.

The design of Integral Abutment Bridges is simple as it may be considered as a continuous fame with a single horizontal member with two or more vertical members. The main advantage of this bridge form is jointless construction which saves the cost of installation and maintenance of expansion joints and bearings. It also enhances better vehicular riding quality. Moreover, uplift resistance at end span is increased because the integral abutment serves as counterweight. As such, a shorter end span could be achieved without the provision of holding down to expansion joints. The overall design efficiency is increased too as the longitudinal and transverse loads on superstructure are distributed over more supports.

However, there are potential problems regarding the settlement and heaving of backfill in bridge abutment. For instance, "granular flow" occurs in backfill materials and it is a form of on-going consolidation. Settlement of backfill continues with daily temperature cycles and it does not stabilize. Active failure of upper part of backfilling material also occurs with wall rotations. This leads to backfill densification and can aggravate settlement behind the abutment.

14. What is the purpose of providing a barrier around the bridge piers?

Accidental collision of heavy vehicles such as tractor-trailer with bridge piers is not uncommon around the world. The consequence of such collision is catastrophic which may involve the collapse of bridges and loss of human lives. As such, suitable provisions are made to protect bridge piers against these accidental collisions. The most common way is to install a crashworthy barrier which should be designed to be capable of resisting the impact of heavy vehicles. Alternatively, in some countries such as the United States, they tend to revise the design of bridge barriers by requiring the bridge piers to be able to resist the collision of 1,800kN static force at 1.35m above ground.

15. Why are precast concrete piers seldom used in seismic region?

The use of precast concrete elements enhances faster construction when compared with cast-in-situ method. Moreover, it enhances high quality of piers because of stringent control at fabrication yards. The environmental impact is reduced especially for bridges constructed near waterways. In particular, for emergency repair of bridges owing to bridge collapse by earthquake and vehicular collision, fast construction of damaged bridge is of utmost importance to reduce the economic cost of bridge users.

The precast bridge piers are mostly used in non-seismic region but not in seismic region because of the potential difficulties in creating moment connections between precast members and this is essential for structures in seismic region.

16. Other than load transfer, what are the functions of diaphragm?

Diaphragm is a member that resists lateral forces and transfers loads to support. Some of the diaphragms are post-tensioned and some contain normal reinforcement. It is needed for lateral stability during erection and for resisting and transferring earthquake loads. Based on past research, diaphragms are ineffective in controlling deflections and reducing member stresses. Moreover, it is commonly accepted that diaphragms aided in the overall distribution of live loads in bridges.

17. How does deck equipment (median dividers and parapets) affect the aerodynamic response of long-span bridges?

Bridge parapets raise the overall level of bluffness of long-span bridges. When the solidity ratio of barriers increases, the effect of increasing the bluffness also becomes more significant. The principal effects of deck equipment such as median dividers and parapets is that it enhances an increase in drag forces and a reduction in average value of lift force.

Chapter 7. Slopes and Earthwork

1. Why are fill slopes compacted to dense state instead of loose state?

In rainstorm, the runoff from rainfall infiltrate into the top layer of fill slopes. It may result in saturation of this layer of fills leading to the decrease in soil suction. Consequently shallow slope failure may occur.

If the fill slope is in a loose state, the soils would tend to decrease in volume during deformation. As a result this induces a rise in pore-water pressure which triggers slope failure in form of mud-avalanche.

If the fill slope is in a dense state, the soils would tend in increase in volume during deformation and it only fails like a mud slump.

2. Is soil nail head an essential feature of soil nails?

Soil nail head is an essential feature of soil nails which help prevent active zone failure. Active zone failure involves shallow failure in the outer part of slope within active zone and it fails by separating and sliding down the slopes and sols nails remain in place.

Soils nail heads also enhances the mobilization of tensile resistance of soil nails and increases the factor of safety of slopes.

3. How can vegetation improve soil shear strength and slope stability?

Vegetation in slopes could modify the soil moisture condition in two ways:

(i) Soil moisture is absorbed by roots of vegetation and the water is transpired to its root;
(ii) It intercepts the rainfall by reducing the amount of rainwater penetrating into the slope.

Both processes, i.e. evapotranspiration and interception effected by the presence of vegetation contribute to dry soil conditions. Moreover, evapotranspiration results in soil suction in unsaturated soil slopes, which further improves the shear strength of soil. As such, it tends to delay the time of saturation in slopes and this essentially improves the slope stability.

4. Why are steeply inclined soil nails not commonly used in stabilizing slopes?

Based on stress-strain relations, when the angle of soil nails below the horizontal (angle b in the figure below) is small, the soil nails intersect the normal to the potential slope failure surface at a relatively large angle. Tensile stresses can be readily developed in the soils nails. However, if the angle of soil nails below the horizontal is large, the soil nails intersect the normal to the potential slope failure surface at a small angle and little or no tensile stress would be mobilized in the soil nails. In this case, it is ineffective in utilizing its tensile strength to prevent slope failure. In the worst scenario, the soils nail would under the state of compression for even steeper soil nails.

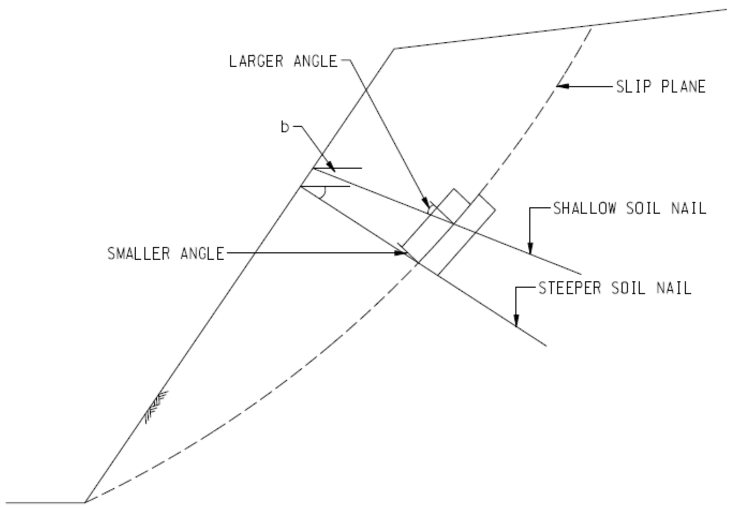


Fig. 7.1 Different inclination of soil nails

5. Can grout be utilized in providing tensile resistance of soil nails?

The passive nature of soils nails requires a small movement for the nails to take up loading. During this process, it is understood that the grout annulus around the nail would crack to allow for these small displacements. Therefore, the tensile capacity of grout is normally ignored in design and only compressive capacity might be considered.

6. Can sheets or geo-grids replace reinforcing elements in soil nails?

Where soil nails are intended for improving the slope stability of existing ground, sheets or geo-grids can hardly replace reinforcing elements in soil nails. Practically speaking, the reinforcing of existing slopes limits the types of reinforcing elements to be adopted. For instance, sheets or geo-grids do not have sufficient bending stiffness to be inserted into exiting slope and they are usually placed in soils as soil layers are built up. The reinforcing element of exiting ground requires steel bars with good tensile strength.

7. What is arching effect in soils?

Arching occurs when there is a difference of the stiffness between the installed structure and the surrounding soil. If the structure is stiffer than the soil then load arches onto the structure. Otherwise, if the structure is less stiff than the soil then load arches away from the structure.

For instance, if part of a rigid support of soil mass yields, the adjoining particles move with respect to the remainder of the soil mass. This movement is resisted by shearing stresses which reduce the pressure on the yielding portion of the support while increasing the pressure on the adjacent rigid zones. This phenomenon is called the arching effect.

The principle of soil arching can be easily illustrated by buried pipes. If a rigid pipe is installed in soils, soil columns on both sides of the rigid pipe are more compressive than the soil columns on top of the rigid pipe because of the higher stiffness of rigid pipes when compared with soils. As such, soil columns on both sides tend to settle more than the soils on top of the rigid pipe and this differential settlement causes a downward shear force acting along the sides of soil columns on top of the rigid pipe. As such, the load on the rigid pipes becomes larger than the sole weight of soil columns on its top. Similarly, if a flexible pipe is adopted instead, the above phenomenon shall be reversed.

8. Do soil compaction test results over 100% mean over-compaction?

Soils can experience over-compaction if the compactor makes too many passes over it. In fact, relative soil compaction test results over 100% do not necessarily mean over-compaction because the relative compaction is based on the maximum dry density of the soil obtained by the Proctor test and this does not necessarily refer to *absolute* maximum dry density.

Over-compaction is considered undesirable because it may eventually create cracks in the underlying compacted material so that it results in a decrease in density. Moreover, it causes waste of machine power and manpower which is undesirable.

9. Vertical drains can be installed in square and triangular patterns. Which pattern is better?

Vertical drains are commonly installed in square and triangular patterns. The zone of influence of vertical drains (R) is a function of drain spacing (S).

For drains in square pattern: R = 0.546S
For drains in triangular pattern: R = 0.525S

The advantages of square pattern are that it is more convenient to lay out and manage on site. However, triangular pattern is the most popular one because it provides a more uniform consolidation between drains than square pattern.

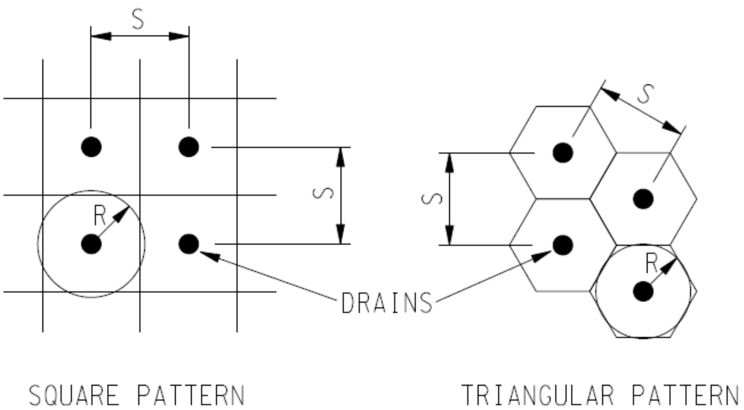


Fig. 7.2 Square pattern and triangular pattern of vertical drains

10. What is the difference between hydroseeding and turfing on slopes?

Hydroseeding is the provision of grass seed mixed with fertilizer and nutrient by spraying. The grass seed shall grow and the root of grass serves as reinforcing fiber to hold tightly the surface soils.

Turfing is the direct application of grass with developed roots on slope surface. The already-developed grass is expected to grow easier when compared with hydroseeding. The roots of grass shall extend onto soils to strength the overall surface.

11. Do inclined rock bolts perform better than rock bolts normal to joints?

The use of rock bolts can be dated back to Roman Empire and it was commonly believed that rock bolts pin surface rock (bedded rock strata or individual rocks) to more stable rock. With the insertion of rock bolt into rock slope, it increases the rock mass's stiffness and strength with respect to shear and tensile loads. Axial force in rock bolts consist of a force component normal to joint plane which contributes frictional resistance, and a force component parallel to joint plane which contributes to dowel action.

Inclined rock bolts helps to stiffen shear and results in an increase in shear strength at smaller displacements. Rock bolts perpendicular to shear planes provide the lowest shear resistance. The optimal inclination of rock bolt is 30^o to 60^o based on past experimental works.

12. What are the differences between rock dowels and rock bolts?

Rock dowels are passive reinforcing elements which need some ground displacement for activation. In installation of rock dowels, a hole is drilled and untensioned steel bars are inserted into the hole. When displacements along joints occur, rock dowels are subject to both shear and tensile stresses. The level and ratio of shear and tensile stress depends on the properties of the surrounding ground, the grout material filling the annular gap between the dowel and the ground and the strength and ductility parameters of the rock dowel itself. Moreover, the degree of dilation during shear displacement affects the level of stress acting within the dowel.

Rock bolts are tensioned once the anchorage is attained to actively set up a compressive force into the surrounding rock. This axial force increases the shear capacity and is generated by pre-tensioning of the bolt. The system requires a bond length to enable the bolt to be tensioned. In essence, rock bolts start to support the rock as soon as they are tensioned and the rock does not have time to start to move before the rock bolt becomes effective.

13. Other than liquefaction, what are the possible causes of failure of loose fill slopes?

Other than static liquefaction, slow-moving slips driven by transient pore water pressure leading to high speed landslide are the other possible cause of failure of loose fill slopes.

For loose fill lying on low permeability soil layers, there is potential storage of infiltrating water when the slope of underlying low-permeability soil layer is mild. As such, there is a localized zone of high transient pore water pressure induced within the fill material. Flowslides normally start with a local slip caused by transient pore water pressure by soil layering or flow restriction. Then, the nature of slow-moving soil debris and the geometry of slip result in a fast landslide.

Chapter 8. Tunneling

1. Is thrust wall an essential element in pipe jacking? Can it be omitted if there is insufficient depth for constructing normal thrust wall?

Thrust wall is an essential element in pipe jacking and it provides the reaction against the pipe jacking operation. In poor ground, consideration may be given to using piling or other methods to increase the stiffness of thrust wall. When there is insufficient depth to construct thrust wall (e.g. jacking through an embankment), a structure has still be constructed to provide the reaction to pipe jacking. In this case, the resistance to horizontal jacking loads is resisted by piles, ground anchors or other methods to reinforce the structure.

2. Packers are normally introduced in pipe joints in pipe jacking. Why should packers be kept 20mm back from the edge of concrete?

Joint stress is induced in pipe joints during pipe jacking. Packers are normally installed in pipe joints to avoid localized stressing of joints leading to concrete crushing. In essence, packers should be elastic enough to take the reloading jacking force. Moreover, it should be thick enough to take the compression of maximum joint stress. Theoretically speaking, packers should be provided in all of the joint area except 20 mm back from the edge of concrete. The reason of such provision is to reduce the risk of local spalling of side edges.

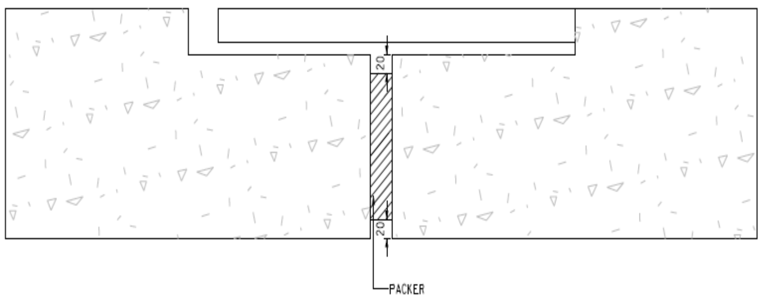


Fig. 8.1 Packer in pipe joint

3. Can pipe jacking be implemented in a fast manner?

Energy is a function of load and speed. Damage may occur on the jacking pipes if it is incapable of absorbing the energy. Pipe jacking requires large energy in the process. Jacking pipes are low speed energy absorbers. To cater for the low-speed-energy absorbing characteristics of jacking pipes, hydraulic jacks should be designed to provide high loads with low speeds. Otherwise the excessive high speed generated by hydraulic jacks would cause kinetic damage to the pipes.

4. Why are aqueous lubricants considered inappropriate for cohesive soils in pipe jacking?

Lubrication performs effectively in pipe jacking by maintaining a layer of lubricant between the outside surface of jacking pipes and the adjacent soil. However, once the ground has collapsed onto the jacking pipe, the effect of lubrication would be greatly reduced. Hence, it is important to maintain sufficient pressure to avoid these occurrences.

Bentonite slurries are commonly used in silty, sandy and granular soils but it is not recommended to use in clayey soils because it may cause swelling in clays by absorption of water and this results in increased contact between the jacking pipe and soils. Hence, non-aqueous lubricants should be considered for cohesive soils.

5. In pipe jacking, can engineers roughly estimate the order of stress concentration in pipe joints?

Theoretical line and level of pipelines can hardly be achieved in pipe jacking. As such, the provision of angular deflection is made at pipe joints to accommodate such deviation. Normally, maximum allowable angular deflection at pipe joints in pipe jacking is 0.5^{o}.

As a rule of thumb, the stress concentration at a pipe joint is about 3 times the joint stress resulting from uniform distribution of stress. As such, for grade 50MPa precast concrete pipe, the allowable uniform joint stress is expected to be one-third of its compressive strength, i.e. 16.67MPa.

6. Why is sharp-edges shield normally used in pipe jacking with manual excavation?

The shield connected to lead pipe is normally sharp-edged in design because:

(i) It helps to reduce the resistance when the shield enters into soils;
(ii) It reduces the amount of soil dropping into the shield.

Sometimes the shield is equipped with jacks so that it allows tilting of the shield and adjustment could be made to the direction of pipe jacking.

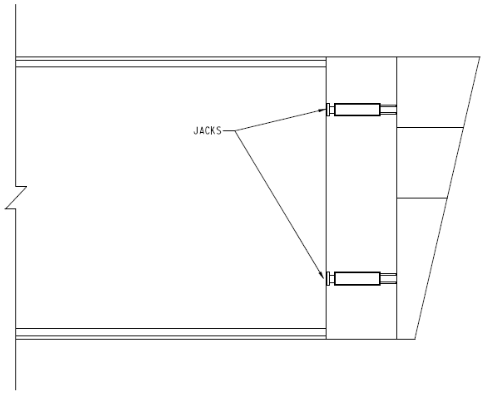


Fig. 8.2 Sharp-edged shield

7. How can lubricants reduce the jacking forces?

The lubricating fluid serves to reduce the jacking force in the following ways:

(i) It saturates the overcut leading to partial and complete buoyancy of the jacking pipe in the cavity. As such, the contact surface area between the jacking pipe and soils is decreased.
(ii) It stabilizes the cavity by limiting the radial effective stress acting on the jacking pipe.
(iii) The interface friction angle between the soils and the jacking pipe are reduced by the lubricants.

8. In concrete pipe joint for pipe jacking, butt end type with mild steel band and socketed in-wall rubber ring type are commonly used. Which one is better?

Butt end type with mild steel band is commonly used for stormwater application. The mild steel band serves to prevent lateral displacement if pipe joint during pipe jacking.

Socketed in-wall rubber ring type is normally used for sewer and pressure pipe situation and for pipe size exceeding 1200mm in diameter. The rubber ring is designed to provide a seal to pipe joint to ensure watertightness, which is essential in sewage pipelines.

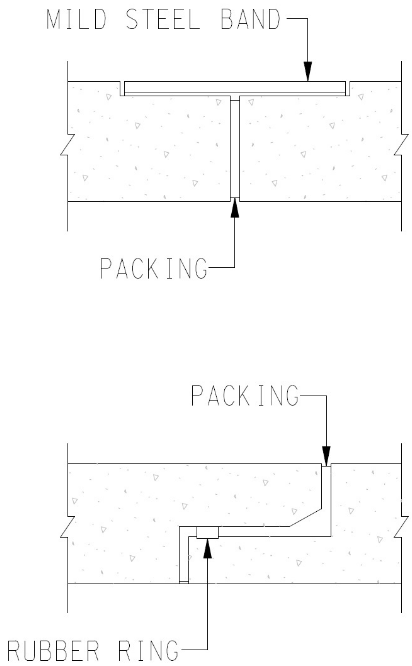


Fig. 8.3 Butt end type with mild steel band and socketed in-wall rubber ring type

9. Swelling of clay develops significant stresses on pipe and its effect is even magnified by the use of lubricant. How can swelling inhibitors help to resolve this problem?

Lubricants are introduced in pipe jacking to reduce the jacking loads. However, for pipe jacking in clay the swelling of clay is accelerated by water-based lubricant as the free water in the lubricant is readily absorbed by clay. To address the problem, swelling inhibitors are added to lubricants which enhance a reduction of free swelling for clays. In essence, the ability of swelling inhibitors to reduce free swelling of clay is achieved by the alternation of clay properties and formation of barrier on cavity surface.

10. What are the functions of lattice girder in tunneling?

Lattice girders are supporting elements in tunnels and they normally consist of steel bars laced together in triangular pattern. They are made to suit the shape of the tunnel. Owing to their small steel reinforcing area, they are not expected to contribute much to the overall support of tunnel. Instead, they are designed and provided for the following reasons:

(i) They have similar spacing with rock bolts and they are intended to

provide temporary support to rock which is readily to loosen and fall.
(ii) Their presence provide an indication if sufficient thickness of shotcrete is applied.

11. What is the difference in two common approaches in tunnel support, i.e. support approach and reinforcement approach?

For *support approach* it involves the application of reaction force at the face of excavation by using heavy structures, primarily ribs and lagging. For *reinforcement approach*, it involves the overall improvement of rock mass performance by techniques such as rock dowels, rock bolts and ground anchors. The target of reinforcement approach is to keep the rock and blocks from moving and loosening so that a large dead load of rock would not be exerted onto the support system. In fact, it holds the rock together and causes the ground around the opening to form a self-supporting ground arch around the opening.

There is a trend of tunneling industry to move from support approach to reinforcement approach because it requires less amount of structural steel support.

12. How can shotcrete stabilize tunnels?

When shotcrete is sprayed on a rough ground surface, it fills small openings and cracks. It serves as initial support and also immediate support after excavation. It decreases the possibility of relative movement of rock bodies or soil particles and, therefore, controls the loosening of the exposed ground surrounding the tunnel.

Shotcrete lining could take up significant loads though it forms a flexible support system. In fact, shotcrete lining is expected to undergo large deformations which enable the intrinsic strength and self-supporting properties of the ground to be mobilized as well to re-distribute stresses between the lining and ground. During the deformation of lining, stresses within the shotcrete lining are relocated to the surrounding ground. As such, this mechanism of load transfer in turn generates subgrade reaction of the ground which gives support to the shotcrete lining.

Friction between shotcrete and the ground also reduces the differential movement of the ground. Even though shotcrete may not form a complete ring, the frictional forces between shotcrete and the ground could provide support to the ground.

13. What is the difference between compensation grouting and normal grouting?

Compensation grouting is a technique to offset settlement induced during tunneling and underground excavation. The main idea of compensation grouting is to inject grouts into the zone between tunnel and overlying building to compensate for ground loss and stress relieve owing to underground excavation. The injection of grout changes the in-situ stress state and influences the soil deformation.

Compensation grouting could be implemented by fracture grouting and compaction grouting. Normal grouting can be carried out in situations such as post-grouting of mini-piles and filling of voids without the effect of compensation of ground loss and stress relieve.

Chapter 9. Steelwork

1. What is the reason of grouping several reinforcement bars in concrete structure?

For too much reinforcement to be incorporated in concrete structures, the reinforcement bars are sometimes groups because:

(i) It facilitates placing of fresh concrete with more space available;
(ii) It tends to limit segregation , which otherwise caused by close spacing of bars;
(iii) It ensures good cover.

2. Why does square hollow section become more popular than circular hollow section in steelworks?

Circular hollow section was available for many years until in 1960s for the approval of square hollows section and rectangular hollow section. From technical point of view, circular hollow section is the most efficient form of strut when compared with square hollows section and rectangular hollow section. However, nowadays, the use of square hollows section and rectangular hollow section is ever on the rise because of the ease of connections between individual struts.

3. There is a general rule in fillet weld that *"the leg should be equal to the thickness of metals."* Why?

Let's take an example of 6mm thick plates to illustrate the rule. In case 12mm leg is adopted in the fillet weld, the weld volume would be 3-4 times more than required. It would result in waste of weld metal and welder's time. Worse still, over-welding may weaken the structure and result in distortion owing to the formation of residue stress. As such, the resulting weld could support less stress than fillet weld with "the leg equal to the thickness of metals."

On the other hand, for welding the same 6mm thick plates, if 3mm leg is used instead, it is under-welded. The resulting weld may break through the leg of the weld.

4. Convex fillet welds are sometimes used in welding. Why?

There are three types of fillet weld cross section profile, namely, flat, convex and concave. The convexity in convex fillet welds serve as reinforcement, which is believed to provide additional strength. However, care should be taken in not introducing excessive convexity to fillet welds. Excess convexity leads to an increase in stress in weld toes which may subsequently fails by cracking.

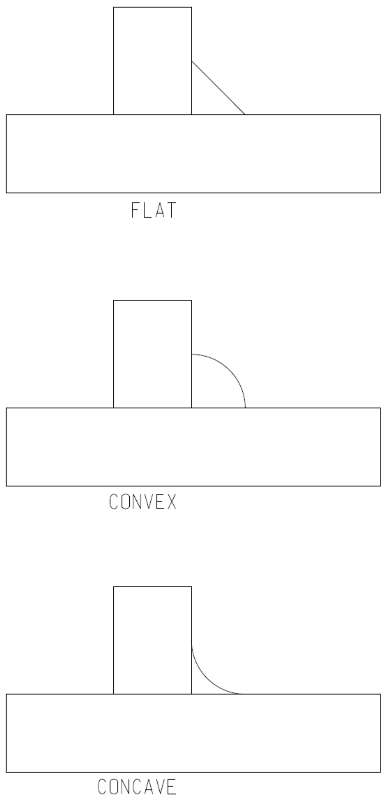


Fig. 9.1 Different types of fillet welds

5. In welding design what are the different applications of square-groove, V-groove, U-groove and J-groove?

When the base metal is thin (i.e. 0.125” to 0.25”), square-groove can be adopted. Where welding is carried out from one side of the joint, a temporary backup strip can be used to ensure proper joint penetration and to avoid excessive leakage of metal though the joint.

V-groove is commonly used for medium to thick metals (i.e. 0.25” to 0.375”).

For even thicker metal plates, U-groove and J-groove can be adopted to provide good penetration of welded metal. One demerit of U-groove and J-groove is the preparation of the metal plates. For instance, air carbon arc and special mechanical cutting tools are required for preparing the joints.

6. What is the vibration mechanism caused by driving sheetpiles?

There are generally three main vibration mechanisms caused by driving sheetpiles:

(i) When the sheetpiles are impacted by a hammer, a compressive wave would be formed and it travels down to the toe of sheetpiles. A large amount of energy would be used to cause downward movement of sheetpiles while some of the energy would be reflected back up to the sheetpiles. The remaining energy would be transmitted to soils which expand outward as a spherical wavefront called “P” waves.
(ii) The impact action of hammer causes temporary lateral deformation of sheetpiles. A surface wave is then established which travels outward from pile shaft circumferentially.
(iii) The downward motion of sheetpiles arising from hammering action induces vertically polarized shear waves which propagate outward in cylindrical wavefront.

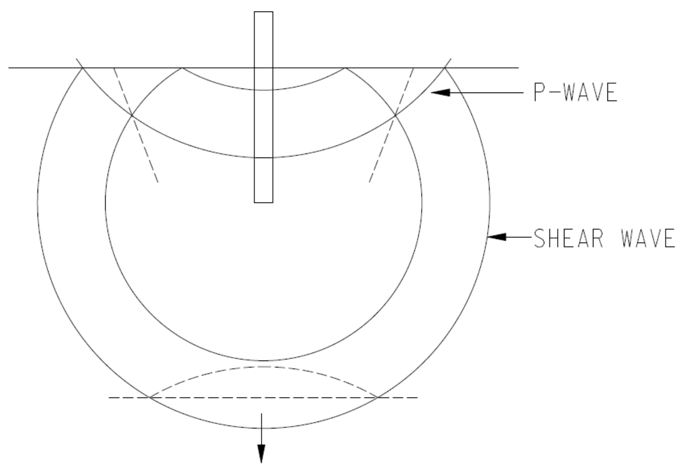


Fig. 9.2 Vibration waves by driving

7. Should wide or narrow sheetpiles be adopted in temporary work?

In general, wide and deep sheetpiles tend to be more cost-effective than narrow sections because they provide the same bending strength with a lower weight per square foot. As such, with increasing width of sheetpiles sections, fewer sheetpiles are required to cover a certain length of piling operation. Hence, the cost of installation can be reduced accordingly.

However, consideration should also be given to the drivability of steel sections. The larger the surface area of piling sections, the higher the driving force is required. Therefore, the drivability of wide sheetpiles appears to be lower than that of narrow sheetpiles.

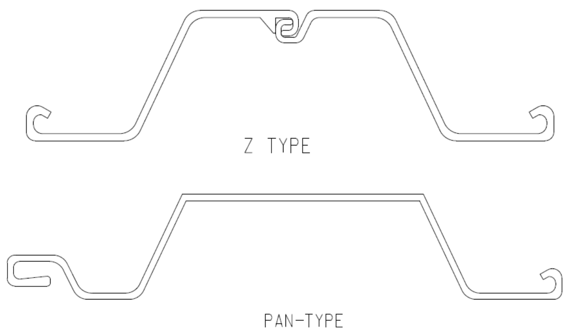
8. What is the difference of the following types of sheetpiles (Z-type, U-type, flat web and Pan-type)?

Z-type: The interlocks are situated as far away from the neutral axis as possible to facilitate good shear transfer and to enhance higher strength to weight ratio. This is the most common type of sheetpiles used in many countries.

U-type: U-type sheetpiles perform in similar manner as Z-type sheetpiles. The major difference between them lies on the location of interlocks. For U-type sheetpiles, the interlocks are located at neutral axis which reduces the efficiency of the section. The properties of U-type shall be decreased owing to the problem of shear transmission.

Flat web: The mechanism in resisting load differs from other types of sheetpiles. Flat web are usually installed in circles and the sheetpiles are held together by tensile strength of the interlock.

Pan-type: Pan-type sheetpiles are smaller in size than most other sheetpiles. Owing to their smaller size, they are commonly used for resisting short and light loaded structures.



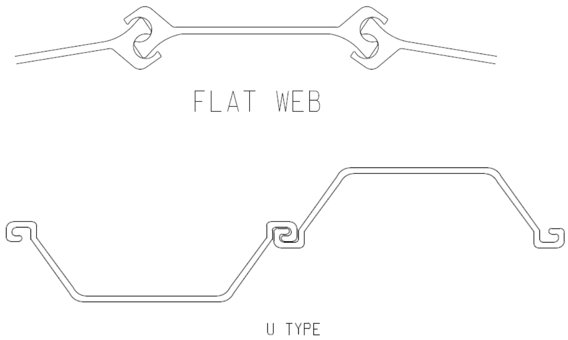


Fig. 9.3 Different types of sheetpiles

9. What is the purpose of conducting bend test of reinforcement?

It is not uncommon that steel reinforcement is bent prior to installation into concrete structure. However, upon bending process steel reinforcement may fracture owing to the following reasons:

(i) The ribs on steel bars serve as location of stress concentration which is a potential weak point for fracturing.
(ii) Owing to their intrinsic high strength, large force is required during the bending process.
(iii) The radius of bending is too tight.

Temperature is also an important factor for controlling the risk of steel fracture. The risk of fracture is increased when there is a drop of temperature because steel has lower toughness at low temperatures.

Therefore, bend test are carried out for reinforcing steel to testify their bending performance.

10. What is the purpose of conducting re-bend test of steel reinforcement?

In BS4449:1997 it species a re-bend test of steel reinforcement where reinforcing steel is bent 45^{o} at 100^{o}C for an hour and then bent back by 23^{o}. The purpose of re-bend test is to measure the effect of strain ageing on steel. Strain ageing has embrittlement effect which takes place after cold deformation by diffusion of nitrogen in steel. Hence, there is limitation stated in some design codes to restrict the nitrogen content of steel to 0.012%.

11. Is fatigue more serious in large-diameter reinforcing steel?

Indeed past research showed that large-diameter reinforcing steel appeared to be weaker under fatigue loading conditions. Therefore, in some standards the stress range for testing fatigue of steel bars are reduced for increasing bar size for the same reason.

Moreover, fatigue performance of steel bars is also governed by stress concentrations at the root of ribs. Bar failure usually initiates from the root of ribs under fatigue loading. In this connection, any damage to ribs during bending process can lead to failure by fatigue.

12. How can heating assist in rebending of steel reinforcement?

It is not uncommon that starter bars are bent up within the formwork as a measure of temporary protection. Later, after the concrete is placed and formwork is removed, the steel bar reinforcement would be pulled out and straightened.

For rebending of bars, it is preferably be implemented for small diameter bars with mild steel. Moreover, rebending of steel bars should not be carried out below 5°C owing to brittle fracture. Heating could be adopted to assist rebending process. However, heating should be applied to a good length of a bar instead of a concentrated location because of the possible occurrence of overheating. Moreover, after heating the cooler adjacent part of the steel bar may experience fracture when the bars are stressed in case concentrated heating is applied to steel bars.

Chapter 10. Sewage and Waterworks

1. In the design of dry well pumping stations, which arrangement is better, "turned-down" bellmouth or horizontal intake?

Pumps can be installed as dry well or wet well. The wet well is commonly used because of its simplicity and low cost. However, this type of pump arrangement has the potential problem of maintenance. For instance, it requires the de-watering of sump and removal of pumps out of the sump, which is suitable for stormwater pumping station which does not require pumping for most of the time. For dry well, the pumps could be assessed and maintained all of the time.

In general "turned-down" bellmouth of pump inlet is more popular because of the following two reasons:

(i) It is less susceptible to vortex action with similar water height.
(ii) It accommodates a lower water cover.

2. What is the purpose of bellmouth entry to a circular pipe for pumps?

If sharp edged inlet to pipes connecting to a pump is adopted, flow separation will occur. Flow separates from sharp edges and a recirculation zone is formed. Moreover, turbulence shall form at downstream when the flow at vena contracta subsequently expands to fill up the unfilled void. Flow separation leads to significant head loss.

The design of bellmouth entry is to ensure that the flow is uniform over the entire intake section and the head loss induced at inlet section is minimized.

3. What are possible causes of manhole explosions?

It is not uncommon that manhole explosion occurs nowadays. Manhole covers are dislodged from the frames which is associated with a release of energy. Manhole explosion occurs mostly owing to the ignition and combustion of flammable gas. Sources of flammable gas include the followings:

(i) Natural gas as a result of leakage of nearby gas line;
(ii) In sewer manholes, it is rich in methane which tends to accumulate inside manhole;
(iii) Gas generated by degradation of cable insulation.

4. Should sewer manholes be designed as watertight?

Sewer manholes should preferably be designed to be watertight owing to the following reasons:

(i) Water-tightness is important in sewer system. Otherwise, leakage of sewage from manholes would seriously contaminate the environment.
(ii) In the event of high water table, water would infiltrate into sewer manholes. Therefore, a higher volume of sewage would be delivered to sewage treatment plant for treatment and this essentially increases the cost for treating this additional volume of water.

5. Is vitrified clay pipes chemically resistant against all aggressive materials in sewage?

In the manufacturing process of vitrified clay pipe, the clay material particles are fused into an inert and chemically stable compound. It is capable of carrying a wide range of commercial, industrial and domestic sewage. In fact, it is chemically resistant against sulfuric acid induced by hydrogen sulfide. Moreover, it is reported to be unaffected by the presence of solvents.

However, there are still some chemicals which are known to cause damage to vitrified clay pipe. For instance, vitrified clay pipe is not immune to attack by hydrofluoric acid and hot concentrated caustic wastes.

6. Do extreme temperatures damage vitrified clay pipes?

Vitrified clay pipe is capable of withstanding extreme temperatures. However, vitrified clay pipe is liable to damage by thermal shock – a swift change of temperature. Such rapid temperature variation induces thermal gradients inside the pipe wall which produces stresses which damage the pipe. To guard against possible damage of vitrified clay pipe by thermal shock, engineers should check in design about the temperature of sewage to be carried, rate of flow, temperature of pipe and soils and the wall thickness of clay pipes.

7. How can thrust blocks resist unbalanced force in horizontal bends in watermain?

Thrust block resists the unbalanced force in two common approaches. In the first approach, thrust block serves as gravity block which makes use of its own dead weight to resist the thrust forces. An example of this application is vertical down bends.'

The second approach of thrust block to resist unbalanced forces in watermain involves providing a larger bearing area so that the resulting pressure against the soils does not exceed the bearing capacity of soils. Therefore, the function of thrust block in this case is to make use of stiffness of concrete to spread the thrust force into larger area. An example of this application is horizontal bends in watermain.

8. How can restrained joints resist thrust forces in pressurized pipelines?

The unbalanced thrust forces in pressurized pipelines cause the line to move and joints to separate unless the unbalanced force is counterbalanced by some means such as thrust blocks.

Restrained joints can be adopted to resist the thrust forces. The mechanism of restrain joint involves gripping and locking the pipe joints together to avoid axial movement and joint separation. For the unbalanced thrust forces, they are distributed to the surrounding soils in such as way that the bearing area is assumed to decrease linearly from the location of thrust forces to the end of restrained pipes. The soil bearing against the pipelines and soil friction provide resistance to movement of pipelines.

9. Why are hydrodynamic forces not considered in the design of thrust blocks?

Liquids in motion produce forces whenever the velocity or flow direction changes. The forces produced by changes in direction of fluid is called hydrodynamic forces and is equal to (density of fluid x discharge x change in flow velocity).

In underground pressurized pipelines, the configuration of pipelines causes unbalanced forces of hydrostatic and hydrodynamic and joint separation shall result if these forces are not properly balanced. In general, the unbalanced hydrostatic and hydrodynamic forces are called thrust forces. In normal applications of pressurized pipelines in wastewater works and waterworks, it is observed that the range of fluid velocity and discharge is quite limited. As such, the resulting unbalanced hydrodynamic forces induced are insignificant when compared with unbalanced hydrostatic forces and they are often neglected in the design of thrust blocks.

10. What are the effects of sediment deposition in sewers?

There are mainly three major effects of sediment deposition in sewers:

(i) The deposited sediment may cause initiate small blockage of flow. Later when larger solid builds up it may result in total blockage of sewers.
(ii) The deposited sewer restricts flows leading to the drop in hydraulic capacity.
(iii) The deposited sediment serves as a point of pollutant storage or generator. The pollutants are stored temporarily and be discharged in high flow conditions. Moreover, biomedical change in sediment deposition releases gases which are corrosive to sewers.

11. What is the difference of movement of solids in large sewers and small sewers?

For solids in large sewers, forces on solids position them at different flow heights depending on their specific gravity.

There are generally two modes of movement of solids in small sewers, namely, *floating and sliding dam*. The floating mechanism operates when the size of solid is small when compared with the diameter of sewer. Solids move with the wave of sewage. On the other hand, the sliding mechanism functions when the size of solid is large when compared with the diameter of sewer. The sewage waves build up behind the solids which act as a barrier at the base of sewer. When the waves store sufficient energy to overcome the friction between solids and sewer invert, the solid would move along the sewer.

12. Should engineers consider embankment condition and trench conditions when considering flexible pipes?

The structural capacity of flexible pipes (e.g. plastics and metals) is derived from ring bending stiffness. Owing to creep or relaxation the ring bending stiffness decreases with time. Flexible pipes are liable to failure by excessive vertical deflections, ring bending strain and buckling.

For rigid pipes, the shape of embedment determines the amount of loads on pipes. For trench condition, the side walls of the trench provide frictional support to resist the filling material on top of pipes. For embankment condition, the fill materials on either sides of the pipe settle more than the soils on top of the pipe leading to increased loads on the pipe. However, for flexible pipes, it distort in the vertical direction at least as much as the embedment. The friction effects can hardly be developed to increase the loads on the pipes more than the loads on soil on its top. Hence, the shape of embedment is generally not considered when determining the loads on flexible pipes.

13. Proper installation is essential for flexible pipes. Why?

Flexible pipes are pipes that can deflect at least 2% of the pipe diameter without any damage. When compared with rigid pipes such as precast concrete pipes, flexible pipes are comparatively weak and they count predominantly on the composite action between pipe deflection and backfilled soils to achieve structural stability. On the other hand, rigid pipes rely mainly on their inherent structural strength to carry imposed earth and traffic loads. Hence, improper installation of flexible pipes would compromise structural performance and results in risk failure.

The design of flexible pipes is complex as the soil boundary conditions include not only the backfilling trench but also the envelope of original soils outside the trench. It requires detailed assessment of theoretical pipe deflection, long-term bending strain and buckling pressure.

14. What is the importance of trench width for the installation of flexible pipes?

Granular bedding is commonly used as bedding for flexible pipes. Granular material is self-compacting and it helps to reduce the pressure acting on the wall of pipe trench. Granular materials have higher modulus of soil reaction than adjacent in-situ soils and this allows it to carry higher loads than in-situ soils without deformation.

However, for poor in-situ soil conditions, the in-situ soils may not provide adequate lateral support when the flexible bends deform vertically and push the sides of pipe outwards the wall of pipe trench. As such, additional trench width is required so that thicker granular bedding on the sides of trench can be backfilled. As such, the thicker layer of granular bedding enhances the spreading of the force over a larger area so that the strength of poor soils is adequate to support it without failure.

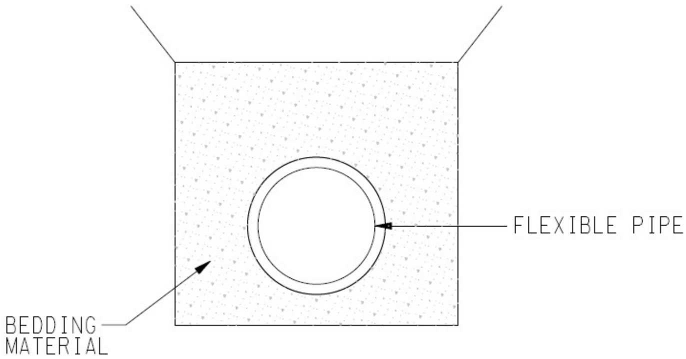


Fig. 10.1 Bedding material of flexible pipes

15. Does pipe deflection affect its flow capacity?

When excessive pipe deformation occurs, it may impair the joint performance and affect the strain in pipes. Based on the information by PIPA, there is a 5% reduction of flow capacity when the pipe is deflected by 15%. Hence, pipe deflection has impact on flow capacity but its effect is not significant.

16. Does sunlight impair the structural performance of PVC pipes?

Sunlight contains ultraviolet which transform PVC particles to a complex structures with brownish discoloration. The effect of discoloration can be reduced with addition of UV absorbers such as titanium dioxide.

Based on past research results, the impact resistance is affected by sunlight exposure for two years on PVC pipes while there is no effect on tensile strength and pipe modulus. As flexible pipes resist loadings by deformation of pipe, there shall be no impact on the pipe's load-carrying capacity owing to sunlight exposure. In general, smaller pipes with thin wall are more likely to be affected by sunlight than larger pipes with thick wall. For storage of PVC pipes for a long period, it is recommended to protect them against sunlight by tarpaulin or by painting. For painting PVC pipe, oil and solvent-based paint should not be used as this would dissolve the PVC pipe. Water-based paint should be adopted instead.

17. What are the functions of different layers in the trench of flexible pipes?

A typical pipe trench for flexible pipes is divided into the following layers:

(i) Final backfill
This region has little influence on the performance of pipes. However, as it is close to existing road surface, it highly affects functioning of roads and structures.

(ii) Initial backfill
This zone provides some assistance in supporting pipe loads. It mainly serves to prevent the flexible pipe from damage upon placement of final backfill. It is beneficial to increase the depth of this region.

(iii) Haunching
This zone provides the resistance to pipe deflection and support pipe loads.

(iv) Bedding
This zone is commonly made up of compacted fill materials. It serves to provide even support for pipe laying and to maintain the pipe with correct line and level.

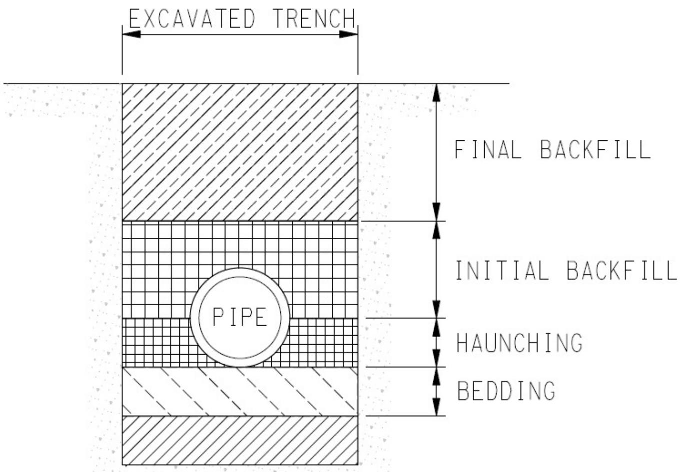


Fig. 10.2 Different bedding layers of flexible pipes

About the Author

Vincent T. H. CHU (朱敦瀚), famed as *walking encyclopedia of civil engineering* (有 Civil 百科全書的外號), 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" and "Ask Vincent Chu (Common FAQ on Practical Civil Engineering Works)".

The book "200 Question and Answers on Practical Civil Engineering Works" is widely publicized and posted on the websites of following engineering organizations and universities around the world:

EUROPE

Posted on Engineering Websites

- European Council of Civil Engineers ECCE
  http://www.ecceengineers.eu/papers/index.php

- Institution of Civil Engineer (United Kingdom)
  http://www.ice.org.uk/knowledge/document_details.asp?Docu_id=171

5&intPage=4&faculty

- German Federation of Technical and Scientific Organisations DVT
http://www.dvt-net.de/intern.html

- Slovak Chamber of Civil Engineers (斯洛伐克共和國)
http://www.sksi.sk/buxus/generate_page.php?page_id=1

- Hemsley Orrell Partnership (Consulting Civil & Structural Engineers)
http://www.hop.uk.com/information.html

- Imperial College London
http://civeselib.wordpress.com/ (posted on 30 June 2008)

- Chamber of Commerce and Industry of Slovenia (Gospodarska zbornica Slovenije) (斯洛文尼亞)
http://www.gzs.si/slo/panoge/zbornica_gradbenistva_in_industrije_gradbenega_materiala/strokovna_literatura_zbir_/druge_strokovne_publikacije

- Colegio de Ingenieros de Caminos, Canales y Puertos (CICCP) (Spain)
http://www.ciccp.es/default.asp?dem=6

Distribution to Members

- Schweizerischer Ingenieur- und Architektenverein (SIA - Switzerland)

- The Federation of the Scientific - Engineering Unions in Bulgaria

ASIA

Posted on Engineering Websites

- Japan Society of Civil Engineers
http://jsce.jp/index.pl?section=bookReview

- Turkish Chamber of Civil Engineers
http://e-imo.imo.org.tr/Portal/Web/IMO.aspx?WebSayfaKey=815

- Japan Federation of Engineering Societies
  JFES-IAC E-News No. 5 (7/2008)
  http://www.jfes.or.jp/activitie/iac_news/jfes-iac_e-news_005.pdf

- Philippine Institute of Civil Engineers
  http://www.pice.org.ph/console.htm

- Mongolian Association of Civil Engineers
  http://www.mace.org.mn/index.php

- The University of Science and Technology (American Society of Civil Engineers – International Student Group)
  http://ihome.ust.hk/~asce/

- The Alumni Newsletter of the University of Santo Tomas Civil Engineering Department (Philippines)
  http://lab6report.wordpress.com/2007/05/09/a-weblog-devoted-to-ust-civil-engineers/

- The University of Hong Kong (Civil Society)
  http://web.hku.hk/~civilsoc/

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- Institution of Engineers, Pakistan

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- City University of Hong Kong

- University of Science, Malaysia

- Vietnam Society for Soil Mechanics and Geotechnical Engineering (VSSMGE)

NORTH AMERICA

Posted on Engineering Websites

- Deep Foundations Institute
  http://www.dfi.org/

- The CivilEngineer.org
  http://www.thecivilengineer.org/general_civil/library_general_civil.html

Distribution to Members

- Structural Engineers Association of California (SEAOC)

- Arup –Washington DC Office

OCEANIA

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- Engineer Australia (Informit e-library)
  http://www.informit.com.au/elibrary_ieleng.html

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- Monash University (Australia)

- Giffith University (Australia)

AFRICA

Posted on Engineering Websites

- Institute of Professional Engineering Technologists (South Africa)
  http://www.ipet.co.za/news/OctFinalPDF2008.pdf

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- South African Institution of Civil Engineering

ISLANDS OR OTHERS

Posted on Engineering Websites

- World Federation of Engineering Organizations
  http://www.wfeo.org/

- The Barbados Association of Professional Engineers
  http://www.bape.org/

- International Association for Bridge and Structural Engineering (IABSE)
  www.iabse.org/elearning

- World Council of Civil Engineers (WCCE)
  http://www.wcce.net/resources.htm

The book "Civil Engineering Practical Notes A-Z" can be obtained by filling in a questionnaire which can be downloaded on the following websites:

- Institution of Civil Engineer (United Kingdom) website
  http://www.ice.org.uk/knowledge/document_details.asp?Docu_id=2371&faculty=

- German Federation of Technical and Scientific Organisations DVT
  http://www.dvt-net.de/intern.html

- The CivilEngineer.org
  http://www.thecivilengineer.org/general_civil/library_general_civil.html

- European Council of Civil Engineers ECCE
  http://www.ecceengineers.eu/papers/index.php

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- Vietnam Society for Soil Mechanics and Geotechnical Engineering (VSSMGE)

The book "Ask Vincent Chu (Common FAQ on Practical Civil Engineering Works)" can be downloaded on the following websites:

- World Council of Civil Engineers (WCCE)
  http://www.wcce.net/resources.htm

- The CivilEngineer.org
  http://www.thecivilengineer.org/general_civil/library_general_civil.html

- The University of Hong Kong (Civil Society)
  http://web.hku.hk/~civilsoc/

- Institution of Civil Engineer (United Kingdom) website
  http://www.ice.org.uk/knowledge/document_details.asp?Docu_id=2370&faculty=

- European Council of Civil Engineers ECCE
  http://www.ecceengineers.eu/papers/index.php

- South African Institution of Civil Engineering
  http://www.civils.org.za/Publications/Otherpublicationsofinterest/tabid/94/Default.aspx

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- Giffith University (Australia)

- University of Science, Malaysia

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) Face Magazine on 2 December 2008

http://education.atnext.com/index.php?fuseaction=Article.View&articleID=11925677&issueID=20081203

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