NAVNIRMAN

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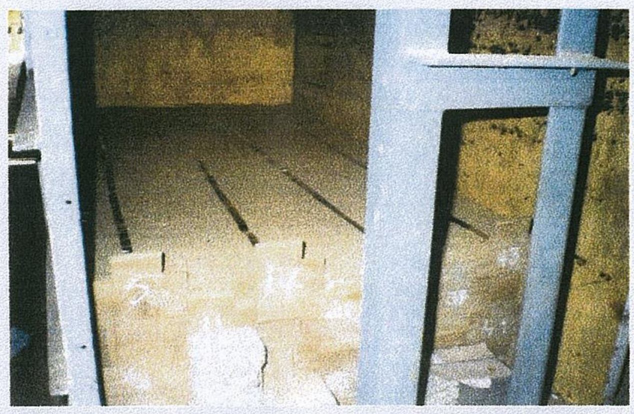
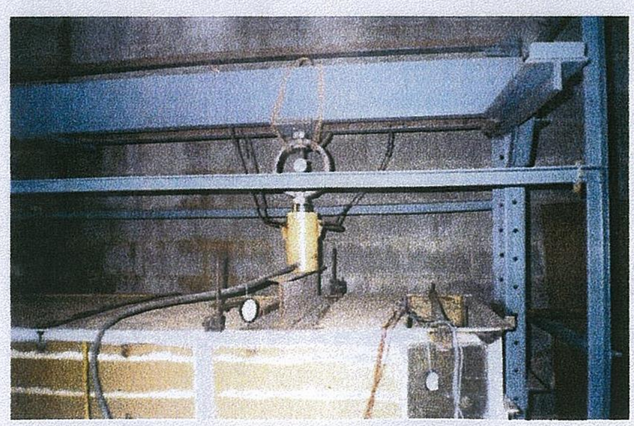


Photograph of Construction of Reinforced Earth Wall model at intermediate stage



Photograph of Reinforced Earth Wall with the strip loading set up

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Gujarat Engineering Research Institute
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&
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Government of Gujarat

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Content

High Performance Concrete: General overview

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Abstract

Based on the compressive strength, concrete is normally classified as normal strength concrete (NSC), high strength concrete (HSC) and high performance concrete (HPC). The advent of pre-stressed concrete techniques has given impetus for making concrete of higher strength. High strength concrete is necessary for the construction of high rise building and long span bridges. To achieve high strength, it is necessary to use high cement content with the lowest possible W/C ratio which invariable affect the workability of the mix. It should be remembered that high cement content may liberate large heat of hydration causing rise in temperature which may affect setting and may result in excessive shrinkage. Active mineral additives like fly ash, silica fume & super plasticizers apart from three basic ingredients i.e.; cement, aggregate & water in conventional concrete incorporated to make highly workable , high strength and durable concrete. Concrete which meets special performance with respect to workability, strength and durability known as" High Performance Concrete". This paperprovides a general overview of the development of HPC. High-performance concrete has been primarily usedin tunnels, bridges, and tall buildings for its strength, durability,and high modulus of elasticity.

Introduction

A high performance concrete is a concrete in which certain characteristics are developed for a particular application and environment. Experience has shown that besides strength, there are other equally important criteria such as durability, workability, ductility are required. HPC invariably contains in addition to high quality OPC, one or more cementious materials such as fly ash, silica fume and a super plasticizer. The main purpose of developing HPC is to enhance the life of structure. Main criteria for HPC are as under:

1. Workability:- HPC should have sufficient workability for proper placing and compaction. As water-cement ratios used in HPC are very low (of the order of 0.3) the use of super plasticizer becomes essential in obtaining the required workability.

2. Strength:- As mentioned earlier, the strength of HPC is invariably higher than the normal mixes. It can range anywhere between 60 Mpa and 150 Mpa (28 days strength).

3. Impermeability:- HPC has to be highly impermeable in order to prevent the ingress of moisture and ions of harmful chemicals. Primarily, three factors influence the permeability of concrete. They are water-cement ratio, compaction and curing.

Water-cement ratio:- As the water-cement ratio reduces, concrete becomes more impermeable. Additionally, certain mineral admixtures also improve impermeability of concrete.

Compaction:- Proper compaction is essential even in case of flowing concrete in order to improve pockets of entrapped air and obtain a uniform distribution of coarse aggregate and water. In general, better the compaction is, more impermeable the resulting concrete will be.

Curing:- As is well known, proper curing of concrete is necessary for gain of required strength and to achieve impermeability.

It is now recognized that with the addition of mineral admixtures high performance concrete (HPC) can be achieved by further lowering water-cement ratio, but without its certain adverse effects on the properties of the material. Hence, it is important to understand how concrete performance is linked to its microstructure and composition. In fact, performance can be related to any properties of concrete. It can mean excellent workability in fresh concrete, or low heat of hydration in case of mass concrete, or very quick setting and hardening of concrete in case of spray concrete which is used to repair roads and airfields, or very low imperviousness of storage vessels. However, from a structural point of view, one understands usually that high strength, high ductility and high durability, which are regarded as the most favorable factors of being a construction material, are the key attributes to HPC.

Objectives :

The main objectives of HPC are as under:

- To put the concrete in to service at much earlier age, for example opening the pavement at 3-days.
- To build high-rise buildings by reducing column sizes and increasing available space.
- To build the superstructures of long-span bridges and to enhance the durability of bridge decks.
- To satisfy the specific needs of special applications such as durability, modulus of elasticity, and flexural strength. Some of these applications include dams, grandstand roofs, marine foundations, parking garages, and heavy industrial floors.

General Characteristics

High-performance concrete characteristics are developed for particular applications and environments. Some of the properties that may be required include:

- High strength
- High early strength
- High modulus of elasticity
- High abrasion resistance
- High durability and long life in severe environments
- Low permeability and diffusion
- Resistance to chemical attack
- High resistance to frost
- Toughness and impact resistance
- Volume stability
- Ease of placement
- Compaction without segregation
- Inhibition of bacterial and mold growth

Microstructure of HPC and NSC

What makes HPC to be different from NSC (normal strength concrete)?

In order to answer this question, the microstructure of the material should be studied. Interrelationships between microstructure and properties of both HPC and NSC need to be established. The microstructure of concrete can be described in three aspects, namely 1) composition of hydrated cement paste, 2) pore structure and 3) interfacial transition zone.

The hydrated cement paste is in fact the hydration products when cement is reacted with water. The pore structure refers to the gel pores, capillary pores and voids, as well as their connections within the hardened concrete. The interfacial transition zone refers to the boundaries between the cement paste, and aggregates or particles of admixtures. The composition of NSC is relatively simple, which consists of cement, aggregate and water.

The hydrated cement paste is referred to as cementious calcium silicate hydrate (C-S-H) gel which is the main product of hydration of cement and water. The hydrated cement paste of NSC is dominated by amorphous C-S-H gel which is intrinsically porous. The porosity in concrete is due to gel pores, capillary pores and voids. Hence, C-S-H gel is low density phase. For concrete with strength below 50MPa, the increase in strength is primarily attained by reducing the capillary porosity alone. However, only reducing the capillary porosity is not enough to generate a concrete strength higher than 50MPa. The gel porosity should also be reduced to gether with the capillary pores so that there is a substantial reduction in the total porosity of concrete.

Further reductions in gel porosity require a change in chemistry to convert C-S-H to more crystalline phases, which eventually leads to the production of HPC.

While total porosity of the cement paste matrix has a great influence on the strength of concrete, the pore structure and its connectivity have a significant impact on permeability. A high permeability usually means low durability as the inner part of concrete is more readily to be attacked by surrounding chemicals. The porosity and the pore connectivity of NSC are usually higher than that of HPC due to the absence of fine particles.

In concrete, the zone of cement paste adjacent to the surface of embedded components, like aggregates and steel fibers, has a modified structure when compared to C-S-H gel. This is called the interfacial transition zone, which is about 2-3mm wide on average. This zone is characterized by a higher porosity than the bulk paste matrix as a result of poor packing of cement particles adjacent to the embedment surface. The higher porosity interfacial transition zone is subjected to accumulation of water leading to a locally higher water-cement ratio in these regions. Therefore, the interfacial transition zone in NSC may be weaker than other regions in the concrete system. Various interfacial transition zones may adversely affect the permeability of the bulk material. With prolonged moisture curing, the interfacial transition zone may gradually be filled up with hydration products. This process may improve the bonding between the paste and the embedded materials. However, the strength of the interfacial transition zone is still the lowest after moisture curing. As a result, the interfacial transition zone in normal strength concrete promotes bond cracking along the boundaries of aggregates under external loading.

In order to improve the concrete performance, the following three aspects are considered: (a) the hydrated cement paste should be strengthened, (b) the porosity in concrete should be lowered, and (c) the interfacial transition zone should be toughened. These three aspects are evaluated one by one as follows:

1. The hydrated cement paste can be strengthened by reducing the gel porosity inside the paste. As mentioned previously, the crystalline of C-S-H gel has a lower gel porosity compared to amorphous C-S-H gel. By adding suitable admixture (e.g. silica fume), crystalline C-S-H gel can be achieved.

2. The porosity in concrete can be lowered by adding suitable fine admixture which can fill up the empty space inside concrete. In HPC, very fine admixtures, such as silica fumes or fly ash, is added into the design mix so that the empty space inside concrete can be reduced significantly. Meanwhile, the pore on connectivity is lowered because the very fine particles effectively block the capillary network.

3. The interfacial transition zone can be toughened by lowering the locally high water-cement ratio and by improving the particle packing in this zone. Super plasticizer is added into the concrete mix so that a very low water-cement ratio (less than 0.2) become feasible to be adopted. Fine admixtures, like silica fume or fly ash, is added as well to improve the particle packing in the interfacial transition zone. It is noticed that in order to improve the concrete performance, admixture is a necessary component which must be added into the design mix in order to generate HPC. Hence, its microstructure is quite different from that of NSC.

Three most important admixtures are mentioned here:

(1) Super plasticizer (2) fly ash (3) silica fume

Its properties and impact on the concrete performance are discussed in the following:

Impact of admixtures on concrete

Admixtures are ingredients other than water, aggregates, hydraulic cement, and fibers that are added to the concrete batch immediately before or during mixing, in nominal quantities. A proper use of admixtures offers certain beneficial effects to concrete, including improved quality, acceleration or retardation of setting time, enhanced frost and sulphate resistance, control of strength development, improved workability, and enhanced finish ability.

Admixtures vary widely used in chemical composition, and many perform more than one function. Two basic types of admixtures are available: chemical and mineral. All admixtures to be used in concrete construction should meet specifications, tests should be made to evaluate how the admixture will affect the properties of the concrete to be made with the specified job materials, under the anticipated ambient conditions, and by the anticipated construction procedures. Fly ash, silica fume, or slag are often mandatory in the production of high-strength concrete, the strength gain obtained with these supplementary cementing materials cannot be attained by using additional cement alone. These supplementary cementing materials are usually added at dosage rates of 5% to 20% or higher by mass of cementing material.

(1) Super plasticizer

The use of chemical admixtures such as water reducers, retarders, high-range water reducers or super plasticizers is necessary. Super plasticizer can increase the workability of concrete mix and reduce the amount of water needed. Therefore, it enables the use of very low water-cement ratio and thus produce HPC. The principal active components in super plasticizer are surface active agents. During mixing, these agents are absorbed on the cement particles, giving them a negative charge which leads to repulsion between the particles and results in a more uniform dispersion of cement grains. With the addition of super plasticizers, concrete can be successfully produced and placed with a water-to cement ratio as low as 0.2. However, this value is not the lowest possible value in concrete. Further lowering of water-cement ratio can be achieved by adding other mineral admixtures, like fly ash or silica fume.

(2) Fly ash

Fly ash with suitable spherical morphology can improve the workability and permits lowering the water-cement ratio to 0.3 in favorable cases. Fly ash should have low alkali contents and should not exhibit cementious properties on their own, which means that the early formation of hydrates, leading to a negative impact on flow behavior, can be prohibited. Cement pastes containing fly ashes also develop a finely divided capillary pore system. The super fine fly ash, having a specific surface of 2000-4000 sq.m/kg, was found to have a significant improvement on the compressive strength, tensile strength, permeability, acid resistance and chloride resistance compared with the NSC

[1]. Recently, it has been found that volcanic ash, which is similar to fly ash but is more abundant in volcanic disaster areas, can also be used as partial cement replacement material to manufacture HPC

[2]. In fact, the most important effects on cementious paste microstructure due to these fine particles are changes in pore structure produced by the reduction in the grain size caused by the pozzolanic reactions and the obstruction of pores and voids by the action of the finer grains.

INFLUENCE OF FLY ASH ON PROPERTIES OF FRESH CONCRETE

Concrete Workability:

Use of fly ash increases the absolute volume of cementious materials (cement plus fly ash) compared to non-fly-ash concrete; therefore, the paste volume is increased, leading to a reduction in aggregate particle interference and enhancement in concrete workability.

The spherical particle shape of fly ash also participates in improving workability of fly ash concrete because of the so-called "ball bearing"

Water demand:

For a constant workability, the reduction in the water demand of concrete due to fly ash is usually between 5 and 15 percent by comparison with a Portland –cement –only mix having the same cementations material content, the reduction is larger at higher water/cement ratio.

Bleeding:

A concrete mix containing fly ash is cohesive and has reduced bleeding capacity. The mix can be suitable for pumping and for slip forming; finishing operations of fly ash concrete with relatively high fly ash content will require less water than non-fly-ash concrete of equal slump.

Time of Setting:

All Class F and most Class C fly ashes increase the time of setting of concrete.

Time of setting of fly ash concrete is influenced by the characteristics and amounts of fly ash used in concrete.

(3) **Silica Fume** Silica fume, which has a similar function as fly ash, is very effective in lowering the water-cement ratio needed for workable concrete in conjunction with super plasticizers because it is sub-micron particle size allows it to pack between the cement grains. The spaces between cement grains that would normally have to be occupied by water are now partially filled with other solid particles. This is the basis of castable densified with small particle (DSP) systems, which can have a water-cement ratio as low as 0.16 with a compressive strength more than 150MPa. In such a high strength concrete, the C-S-H gel formed by conventional hydration reacts with silica fume at high temperature to form crystalline hydrate which is a dense phase without intrinsic porosity. It is found that the workability of high strength concrete can be maintained when 6% of the cement (by weight) is replaced by silica fume. In pastes with higher water- cement ratios, silica fume is adept at subdividing the pore system Very fine silica fume is effective in eliminating the inter facial transition zone because of its good particle packing characteristics. It is found that the silica fume, in combination with super plasticizers, improves the bonding between paste and aggregate due to the formation of a dense microstructure in the interfacial transition zone .Hence, there is little or no interfacial porosity resulting in a

strong paste-aggregate bond in HPC. It is noticed that the admixtures and the sand present in HPC are all very fine. The small sizes of these particles are essential in generating HPC. The basic concept of adding fine particles into the concrete mix is based on packing theory. It is found that packing density of concrete governs the performance of concrete to a large extent. Effective particle packing depends on the relative size of particles and the number of different sizes.

STRENGTH DEVELOPMENT OF SILICA FUME CONCRET

Early Strength

The early strength development is probably through improvement in packing and improvement of the interface zone with aggregate.

High Strength Concrete:

Silica Fume has been successfully used to produce very high-strength, low-permeability, and chemically resistant concrete. Addition of Silica Fume by itself, with other factors being constant, increases the concrete strength.

Modulus of Elasticity:

The modulus of elasticity of concrete containing silica fume is somewhat higher than is the case with Portland cement only. Concretes of similar strength it has been reported that concrete containing silica fume is more brittle.

Permeability of concrete:

The permeability of concrete also reduces.

Advantages of High Performance Concrete

The advantages of using high performance concretes often balance the increase in material cost. The following are the major advantages that can be accomplished.

- Reduction in member size, resulting in increase in plinth area/useable area and direct savings in the concrete volume saved.
- Reduction in the self-weight and super-imposed dead load with the accompanying saving due to smaller foundations.
- Reduction in form-work area and cost with the accompanying reduction in shoring and stripping time due to high early-age gain in strength.
- Construction of High –rise buildings with the accompanying savings in real-estate costs in congested areas.
- Longer spans and fewer beams for the same magnitude of loading.
- Reduced axial shortening of compression supporting members.
- Reduction in the number of supports and the supporting foundations due to the increase in spans.
- Reduction in the thickness of floor slabs and supporting beam sections which are a

major component of the weight and cost of the majority of structures.

- Superior long-term service performance under static, dynamic and fatigue loading.
- Low creep and shrinkage.
- Greater stiffness as a result of a higher modulus of elasticity
- Higher resistance to freezing and thawing, chemical attack, and significantly improved long-term durability and crack propagation.
- Reduced maintenance and repairs.
- Smaller depreciation as a fixed cost.

Limitations

Followings are the limitations of HPC:

- High Performance Concrete has to be manufactured and placed much more carefully than normal concrete.
- An extended quality control is required
- In concrete plant and at delivery site, additional tests are required leads to increases cost
- Some special constituents are required which may not be available in the ready mix concrete plants.

Conclusion

This paper provides an overview of the fundamentals of high performance concrete (HPC) and its various applications. The microstructure of HPC and its influence on concrete performance is presented. The three key attributes of HPC: strength, ductility and durability are discussed. Fly ash, silica fume and super plasticizer are important ingredients to manufacture high performance concrete. In order to produce HPC with high ductility, fiber is a critical element which should be present in the design mix.. It is suggested that three criteria should b considered to produce durable concrete. These criteria are strength, permeability and cracking resistance. Because of its advantageous characteristics, HPC is now widely used in tunnels, bridges, and tall buildings**.**

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PUMPABLE CONCRETE AND MIX DESIGN

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1.0 Introduction:

Pumped concrete may be defined as concrete that is conveyed by pressure through either rigid pipe or flexible hose & discharged directly into the desired area. Pumping may be used for most of all concrete construction, but is especially useful where space or access for construction equipment is limited. Pumping of concrete is universally accepted as one of the main methods of concrete transportation and placing. Adoption of pumping is increasing throughout the world as pumps become more reliable and also the concrete mixes that enable the concrete to be pumped are also better understood.

Development of Concrete Pump: The first patent for a concrete pump was taken in USA in the year 1913. By about 1930 several countries developed and manufactured concrete pump with sliding plate valves. By about 1950s and 1960s concrete pumping became widely used method in Germany. Forty per cent of their concrete was placed by pumping. The keen rivalry between the leading German manufacturers, namely, Schwing, Putzmesister and Elba, has boosted the development of concrete pump and in particular the valve design which is the most important part of the whole system.

2.0 Concrete Pumps: Pumping equipment consists of pumps which are three types. (a) Piston type concrete pumps (b) Pneumatic type concrete pump (c) Squeeze pressure type concrete pump. Other accessories are rigid pipe lines, flexible hose & couplings etc.

The modern concrete pumps are a sophisticated, reliable and robust machine. In the past a simple two – stroke mechanical pump consisted of a receiving hopper, an inlet and an outlet valve, a piston and a cylinder. The pump was powered by a diesel engine. The pumping action starts with the suction stroke drawing concrete into the cylinder as the piston moves backwards. During this operation the outlet value is closed. On the forward stroke, the inlet valve closes and the outlet valve opens to allow concrete to the pushed into the delivery pipe.

3.0 Pumpable Concrete: A concrete which can be pushed through a pipeline is called a pumpable concrete. Pumpable concrete can be pushed under pressure through a pipeline system that may include flexible hose as well as steel pipe line. In a pipe line, concrete moves in the form of a cylinder or slug separated from the pipe line wall by a lubricating layer of mortar. The concrete mix must be such that the concrete slug can pass through reducer and go around bends in the line, which are normal pipe line setups that cause the aggregate in the mix to rearrange their position. For this to happen, the mix must be dense, cohesive and have sufficient mortar. The mortar required depends on the size of line being used, on the efficiency of the valve, on the concrete pump and on the pressure available to push the concrete. If the mix is harsh or lacks mortar and does not deform readily, particle interference and high friction will result and a blockage will occur. It is made in such a manner that its friction at the inner wall of the pipeline does not become very high and that it does not wedge while flowing through the pipeline. When concrete is pumped, free water in the mix transmits the pump pressure to the concrete slug. But if the spaces or voids between the aggregates are not filled with mortar, or the mortar is too thin and runny, the pump pressure can cause segregation forcing the water through the mix. When this happens, the lubricating layer is lost, the coarse particles interlock, friction between the particles and the pipeline increases and the concrete stops moving in the pipeline. To prevent this, the voids between the aggregate particles must be filled with smaller aggregate particles so that the pressure at which segregation occurs is greater than pressure needed to pump the concrete. Voids between aggregate particles are reduced in size by using a range of particles sizes from coarse to fine (proper gradation) and by using an adequate amount of cement and fine fines to create enough mortar to sufficiently coat all the particle surfaces. Concrete mixes that have too many fines may also be difficult to pump. Here, the problem is not segregation. The mix is cohesive but friction between the concrete and the line may be so great that pump pressure is not high enough to move the concrete. This type of pumping problem is more common with high strength concretes or with concretes containing a high proportion of very fine materials such as rock dust. These concretes are sticky and additional pressure is needed to overcome adhesion between the mortar and the pipe walls. Increasing the amount of well-graded coarse aggregate in these mixes will help to reduce the fines content and improve pumpability. A clear understanding of what happens to concrete when it is pumped through pipe line is fundamental to any study of concrete pumping. Pumpable concrete emerging from a pipeline flows in the form of a plug which is separated from the pipe wall by a thin lubricating layer consisting of cement paste. The water in the paste is hydraulically linked with the inter particle water layer in the plug.

For continuous plug movement, the pressure generated by the flow resistance must not be greater than the pump pressure rating. However, if the concrete is too saturated at higher w/c ratio, the concrete at certain pump pressures may be such that water is forced out of the mix creating an increase in flow resistance and a possible blockage. In other words, a very stiff concrete is not pumpable and also a concrete with high w/c ratio is also not pumpable. It is interesting to note that if a concrete is pumpable, it is implied that it is a good concrete. For the successful pumping of a concrete through a pipeline it is essential that the pressure in the pipe line is transmitted through the concrete via the water in the mix and not via the aggregate. In effect, this ensures the pipe line is lubricated. If pressure is applied via the aggregate it is highly likely that the aggregate particles will compact together and against the inside of the pipe to form a blockage, the force required to move concrete under these conditions is several hundred times that required for a lubricated mix. If however, pressure is to be applied via the water, then it is important that the water is not blown through the solid constituents of the mix; experience shows that water is relatively easily pushed through the particles larger than about 600 microns in diameter and is substantially held by particles smaller than this. In the same way, the mixture of cement, water and very fine aggregate particles should not be blown through the voids in the coarse aggregate. This can be achieved by ensuring that the aggregate grading does not have a complete absence of material in to consecutive sieve sizes for example between 10 mm and 2.36 mm. In effect, any size of particle must act as a filter to prevent excessive movement of the next smaller size of material.

3.0 Properties of fresh pumpable concrete:

Concrete contains cement, water, fine aggregate or sand & coarse aggregate. (Usually gravel or crushed stone). Admixtures such as air entraining agents, fly ash or water reducing agents may also be added. How the fresh concrete behaves depends on properties & proportions of the materials used. Some of the factors that affect pumpability are as under:

(1) **Slump:** The slump test measures the ability of a concrete to flow. Higher

slump concretes that are still cohesive, flow more readily & are easier to pump. However excessively high slump concrete can separate & cause plugs in the pump or in the line. To obtain the higher slump more water can be added to the mix. Adding water to increase the slump will also decrease concrete strength if no additional cement is added. And alternative method to increase slump is to add a water reducing admixture. However, you must maintain adequate free water in the mix to transmit the energy of the pump to the concrete, and you must maintain adequate cement content to provide sufficient mortar for lubrication in the pipe line.

(2) **Trowelability :** A concrete that is easy to finish will generally also be easier to pump. Trowelability is affected primarily by the amount of fine sand, cement and other fines such as fly ash in the mix. Up to a point the more fines and the higher the mortar volume, the lower the line pressure will be, if slump is held constant.

(3) **Segregation:** Segregation is separation of coarse aggregate from mortar or separation of cement paste from aggregate in freshly mixed concrete. Mixes that segregate easily will be harder to pump.

(4) **Harshness:** Harsh concrete mixes do not have sufficient mortar to adequately coat the surface of the aggregate and to fill the voids between the aggregate. Because of this, they lack cohesion. They are more likely to segregate and are more difficult to finish or pump than mixes with sufficient mortar. If in a slump test the slumped concrete breaks off or falls apart when lightly tapped with the tamping rod. The mix lacks cohesion and probably won't be pumpable.

(5) **Bleeding:** Bleeding is movement of water to the tip surface of concrete as heavier materials settle. This is caused by poorly graded sand which does not properly fill all the voids, and allows the water to bleed through the very small open channels. Mixes that bleed excessively are difficult to pump. Even on jobs where the concrete is not pumped, the use of these mixes should be avoided because finishing will be delayed, flatwork surfaces will be less durable, secondary flooring such as tile may not adhere properly, and sand streaking will occur on vertical surfaces.

A pumpable concrete, like conventional concrete mixes, requires good quality control i.e. properly graded aggregate and aggregate constantly batched and mixed thoroughly. Depending on the equipment, pumping range will vary from 8 to 70 m^3 of concrete per hour. Effective pumping range will vary from 400 to 1900 m horizontally, or 100 to 600 m vertically.

4.0 Design Considerations for Pumpable Concrete:

The mix is proportioned in such a way that it is able to bind all the constituent materials together under pressure from the pump and thereby avoiding segregation and bleeding. The mix must also facilitate the radial movement of sufficient grout to maintain the lubricating film initially placed on the pipeline wall. The mix should also be able to deform while flowing through bends. To achieve this, the proportion of fines i.e. cements and fine particles below 0.25 mm size (particles below 300 microns) are of prime importance. The quantities of fine particles between 350 to 400 kg/m^3 are considered necessary for pumpable concrete. The above quantities are not only found necessary for maintaining the lubricating film, but it is important for quality and workability and to cover individual grains.

There are two main reasons why blockages occur and that the plug of concrete will not move:

- Water is being forced out of the mix creating bleeding and blockage by jamming , or
- There is too much frictional resistance due to the nature of the ingredients of the mix.

5.0 Basic consideration:

5.1 Cement content: Concrete without admixtures and of high cement content, over about 460kg/$m^3$is liable to prove difficult to pump, because of high friction between the concrete and the pipe line. Cement contents below 270 to 320 kg/m^3depending upon the proportion of the aggregate may also prove difficult to pump because of segregation within the pipeline.

5.2 Workability: The workability of pumped concrete in general hasan average slump between 75 mm to 100 mm. A concrete less than 50 mm slumps are impractical for pumping and slump above 125 mm should be avoided. In mixtures with high slump, the aggregate will segregate from the mortar and paste and may cause blocking in the pump lines.The mixing water requirement varies from different maximum sizes and type of aggregates. In high strength concrete due to lower water-cement ratio and high cement, concrete workability is reduced with the given quantity of water per cu.m.of concrete. In such cases water reducing admixtures (super plasticizer) are useful. A loss of slump during pumping is normal and should be taken into consideration when proportioning the concrete mixes. A slump loss of 25 mm per 300 meters of conduit length is not unusual, the amount depending upon the ambient temperature, length of line, pressure used to move the concrete, moisture content of aggregate at the time of mixing, truck haulage distance, whether mix is kept agitated during haulage etc. A slump loss of approximately 80 mm per hour for truck haulage distance, whether mix is kept agitated during haulage is not unusual.

5.3 Aggregate: The important properties of coarse aggregates that affect pumpability are maximum size, shape and surface texture and most importantly, gradation of particle sizes present. If the porosity of the aggregate is exceptionally high, water absorption can also affect pumpability. Maximum size of the coarse aggregate is considered when choosing line diameter. Generally speaking, the line diameter must be 3.5 to 4 times greater than the maximum aggregate size. The hose size required is also affected by the coarseness of the mix and the angularity of the aggregate. When using mixes with 25 to 40 mm aggregate, it is recommended to use 125 mm line. A 100 mm line is suitable for mixes using 19 to 25 mm aggregate and 75 mm line should be used when placing 19 mm and smaller aggregates. As the hose gets smaller, the mortar requirement increases. The maximum size of crushed aggregate is limited to one-third of the smallest inside diameter of the hose or pipe based on simple geometry of cubical shape aggregates. For rounded aggregates, the maximum size should be limited to 40 percent of the pipe or hose diameter. The shape of the coarse aggregate, whether crushed or rounded has an influence on the mix proportions, although both shapes can be pumped satisfactorily. The crushed pieces have a larger surface area per unit volume as compared to uncrushed pieces and thus require relatively more mortar to coat the surface. Coarse aggregate of a very bad particles shape should be avoided. The grading of coarse aggregate should be as per IS: 383. If they are nominal single sized, then 10 mm and 20 mm shall be combined in suitable proportion to get a graded coarse aggregate. Fine aggregate properties have a greater effect on pumpability than do coarse aggregate properties. Fine aggregate of Zone II as per IS: 383 is generally suitable for pumped concrete provided 15 to 30 percent sand should pass the 300 micron sieve and 5 to 10 percent should pass the 150 micron sieve. In practice it is difficult to get fine and coarse of a particular grading. If available sands are deficient in the finer sizes they can be blended with selected finer sand or stone dust or fly ash to make up the deficiency in fines. In absence of fine aggregate of required grading they should be blended with selected sands to produced desired grading and then combine with coarse aggregates to required grading(All in Aggregate). Too many fines can also cause problems. Finer materials have more surface area that has to coat with the cement –water paste. So if, there is too much fine sand or stone dust in a mix, more water will be needed to get the required slump. The extra water has several harmful effects: (a) It reduces the strength (b) It increases shrinkage (C) It makes concrete less watertight.

5.4 Admixture for Pumped Concrete: Admixtures are commonly used in most concrete, regardless of how the concrete is to be placed. However, many of the admixtures will affect pumpability as described below.

5.4.1 Air-entraining admixtures incorporate a large number of very small bubbles in the concrete. The main reason for putting entrained air in the mix is to improve resistance to deterioration caused by the freezing and thawing. However, up to a point, the air also increases pumpability because of improved plasticity, less bleeding and less segregation. About 3 to 5 percent air by volume of the concrete is the best amount for pumping purpose. Too much air, in excess of 7 to 8 percent, can decrease pumping efficiency by absorbing some of the pump stroke energy as the air compresses.

5.4.2 Water-reducing admixtures can be used to increase slump without adding water or they can be used to reduce the amount of water needed to get a desired slump. High range water reducers or super plasticizers can increase the slump of a concrete by as much as 150 mm without increasing the chance that segregation will occur. They have been used successfully on many pump jobs, especially for high rise construction. However, water reducers will not by themselves make an unpumpable concrete pumpable.

5.4.3 Fly ash is a fine material which can be added to concrete either as an admixture or as a partial cement replacement. The additional fines reduce the void content of the solid material and make the mix more pumpable. Because of their smooth surface and rounded shape, fly ash particles also reduce bleeding and internal friction without increasing the water required to keep the slump constant. Fly ash may make concrete set more slowly, this can delay finishing and increase the time period during which vertical forms must withstand maximum form pressures. Pumping aids are admixtures with the sole function of improving pumpability. They do this by making the water in the concrete thicker or more viscous. This makes the water less likely to be forced out of the concrete under pressure.

5.4.4 Accelerators are added to concrete to make it set and gain strength faster. If accelerators are used in pumped concrete, delays are a problem to be avoided because the concrete may lose slump faster or even set up in the lines. If pumping lines are exposed to freezing temperature, the concrete will freeze regardless of whether accelerator has been added to it.

5.4.5 Retarders make concrete set more slowly. They may help the pumping operation under hot weather conditions, when very long pipe lines are used or when the placing rate is very slow.

6.0 Pumping: Before the pumping of concrete is started, the conduit should be primed by pumping a batch of mortar through the line to lubricate it. A rule of thumb is to pump 25 liters of mortar for each 15 meter length of 100 mm diameter hose. Using smaller amounts for smaller sizes of hose or pipe. Dump concrete into the pump-loading chamber, pump at slow speed until concrete comes out at the end of discharge hose and then speed up to normal pumping speed. Once pumping has started, it should not be interrupted as concrete standing idle in the line is liable to cause a plug. Of great importance is to always ensure some concrete in the pump receiving hopper at all times during operation, which makes necessary the careful dispatching and spacing of ready-mix truck.

7.0 Testing for pumpability: There is no recognized laboratory apparatus or precise piece of equipment available to test the pumpability of mix in the laboratory. The pumpability of the mix therefore is checked at site under field conditions.

8.0 Field practice: The pump should be as near the placing area as practicable and the entire surrounding area must have adequate strength to support the concrete delivery trucks, thus assuring a continuous supply of concrete. Lines from the pump to the placing area should be laid out with a minimum of bends. For large placing areas, alternate lines should be installed for rapid connection when required. When pumping downward 15 m or more, it is desirable to provide an air release valve at the middle of the top bend to prevent vacuum or air buildup. When pumping upward it is desirable to have a valve near pump to prevent the reverse flow of concrete during the fitting of clean up equipment or when working on the pump.

9.0 Common Problems in Pumping Concrete: The most common problem in pumping concrete is blockage. If concrete fails to emerge at the end of pipeline, if pump is mechanically sound, it would mean that there is blockage somewhere in the system. This will be indicated by an increase in the pressure shown on the pressure gauge. Most blockages occur at tapered sections at the pump end.

Blockages take place generally due to the unsuitability of concrete mix, pipeline and joint deficiencies and operator's error or careless use of hose end.

It has been already discussed regarding the quality of pumpable concrete. A concrete of right consistency which forms a concrete plug surrounded by lubricating slurry formed inside the wall of pipe line with right amount of water, well proportioned, homogeneously mixed concrete can only be pumped. It can be rightly said that a pumpable concrete is a good concrete. Sometimes, high temperature, use of admixtures, particularly, accelerating admixtures and use of high grade cement may cause blockages. Chances of blockage are more if continuous pumping is not done.

A pipe line which is not well cleaned after the previous operation, unclean worn-out hoses, too many and too sharp bends, use of worn out joints are also other reasons for blockages.

Operators must realize and use sufficient quantity of lubricating grout to cover the complete length of pipeline before pumping of concrete. The hose must be well lubricated. Extreme care should be taken in handling the flexible rubber end hose. Careless bending can cause blockages.

9.1 Clearing Blockages:

A minor blockage may be cleared by forward and reverse pumping. Excess pressure should not be blindly exerted. It may make the problem worse.

Sometime shortening the pipeline will reduce pressure and on restarting pumping the blockage gets cleared off.

Tapping the pipe line with hammer and observing the sound one can often locate a blockage.

Blockage could be cleared by rodding or by using sponge ball pushed by compressed air or water at high pressure.

9.2 Placing Concrete.

It is not enough that a concrete mix correctly designed, batched, mixed and transported; it is of utmost importance that the concrete must be placed in systematic manner to yield optimum results. The precautions to be taken and methods adopted while placing concrete in the under-mentioned situations is as under.

(a) Placing concrete within earth mould (example: Foundation concrete for a wall or column).

(b) Placing concrete within large earth mould or timber plank formwork (example: Road slab and Airfield slab).

(c) Placing concrete in layers within timber or steel shutters. (Example: Mass concrete in dam construction or construction of concrete abutment or pier).

(d) Placing concrete within usual from work (Example: Columns, beams and floors).

(e) Placing concrete under water.

Concrete is invariably laid as foundation bed below the walls or columns. Before placing the concrete in the foundation, all the loose earth must be removed from the bed. Any root of trees passing through the foundation must be cut, charred or tarred effectively to prevent its further growth and piercing the concrete at a later date. The surface of the earth, if dry, must be just made damp so that the earth does not absorb water from concrete. On the other hand if the foundation bed is too wet and rain-soaked, the water and slush must be removed completely to expose firm bed before placing concrete, if there is any seepage of water taking place into the foundation trench, effective method for diverting the flow of water must be adopted before concrete is placed in the trench or pit.

For the construction of road slabs, airfield slabs and ground floor slabs in buildings, concrete is placed in bays. The ground surface on which the concrete is placed must be free from loose earth, pool of water and other organic matters like grass, roots, leaves etc. The earth must be properly compacted and made sufficiently damp to prevent the absorption of water from concrete. If this is not done, the bottom portion of concrete is likely to become weak. Sometimes, to prevent absorption of moisture from concrete by the large surface of earth, in case of thin road slabs, use of polyethylene film is used in between concrete and ground. Concrete is laid in alternative bays giving enough scope for the concrete to undergo sufficient shrinkage. Provisions for contraction joints and dummy joints are given. It must be remembered that the concrete must be dumped and not poured. It is also to be ensured the concrete must be placed in just required thickness. The practice of placing concrete in a heap at once place and then dragging it should be avoided.

When concrete is laid in great thickness, as in the case of concrete raft for a high rise building or in the construction of concrete pier or abutment or in the construction of mass concrete dam, concrete is placed in layers. The thickness of layers depends upon the mode of compaction. In reinforced concrete, it is a good practice to place concrete in layers of about 15 to 30 cm thick and in mass concrete, the thickness of layer may vary anything between 35 to 45 cm. Several such layers may be placed in succession to form one lift, provided they follow one another quickly enough to avoid cold joints. The thickness of layer is limited by the method of compaction and size and frequency of vibrator used.

Before placing the concrete, the surface of the previous lift is cleaned thoroughly with water jet and scrubbing by wire brush. In case of dam, even sand blasting is also adopted. The old surface is sometimes hacked and made rough by removing all the laitance and loose material. The surface is wetted. Sometimes, neat cement slurry or a very thin layer of rich mortar with fine sand is dashed against the old surface, and then the fresh concrete is placed. The whole operation must be progressed and arranged in such a way that, cold joints are avoided as far as possible. When concrete is laid in layers, it is better to leave the top of the layer rough, so that the succeeding layer can have a good bond with the previous layer. Where the concrete is subjected to horizontal thrust, bond bars, bond rails or bond stones are provided to obtain a good bond between the successive layers. Of course, such arrangements are required for placing mass concrete in layers, but not for reinforced concrete.

Certain good rules should be observed while placing concrete within the formwork, as in the case of beams and columns. Firstly, it must be checked and the reinforcement is correctly tied, placed and is having appropriate cover. The joints between planks, plywood or sheets must be properly and effectively plugged so that matrix will not escape when the concrete is vibrated. The inside of the formwork should be applied with mould releasing agents for easy stripping. Such purpose made mould releasing agents is separately available for steel or timber shuttering. The reinforcement should be clean and free from oil. Where reinforcement is placed in a congested manner, the concrete must be placed very carefully, in small quantity at a time so that it does not block the entry of subsequent concrete. The above situation often takes place in heavily reinforced concrete columns with close lateral ties, at the junction of column and beam and in deep beams. Generally, difficulties are experienced for placing concrete in the column. Often concrete is required to be poured from a greater height. When the concrete is poured from a height, against reinforcement and lateral ties, it is likely to segregate or block the space to prevent further entry of concrete. To avoid this concrete is directed by tremie, drop chute or by any other means to direct the concrete within the reinforcement and ties. Sometimes, when the formwork is too narrow, or reinforcement is too congested to allow the use of tremie or drop chute, a small opening in one of the sides is made and the concrete is introduced from this opening instead of pouring from the top. It is advisable that care must be taken at the stage of detailing of reinforcement for the difficulty in pouring concrete. In log span bridges, the depth of prestressed concrete girders may be of the order of even 4–5 meters involving congested reinforcement. In such situations planning for placing concrete in one operation requires serious considerations on the part of designer.

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GEOSYNTHETICS REINFORCED BRIDGE APPROCH FOR HIGHWAY – A MODEL STUDY

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SYNOPSIS :

This paper presents the results and comparisons of different tests conducted on the Model Geosynthetics Reinforced Earth Retaining Wall for different positions of wheel loading on bridge approach for highway . The stresses in reinforcing strips were calculated using strain gauges and maximum tension line located. The earth pressure distribution was studied using earth pressure cells.

1.0 INTRODUCTION

Originally a French Engineer, Henri Vidal, had published his investigation on soil reinforcement in 1966 and started the use of the term "Reinforced Earth". Later on Schlosser (1969), Bell et. Al. (1971), Lee et. Al.(1973), Jones (1978),Holtz (1978), etc. were the major research workers who had derived critical length of strips to govern the cutoff failure and evaluated the critical height of retaining structures.

In present paper, the model study of an instrumented Reinforced Earth Wall is carried out. Rankine's active pressure theory and Laba and Kennedy's theory are used to calculate active earth pressure on facing wall and to determine total length of Reinforcing strips.

2.0 SCOPE AND OBJECTIVES

It is desired to study fully instrumented model reinforced earth wall of 1.2 m height Using aluminum foil strips of 2 cm width as reinforcement, natural Banadarpur sand as backfill and regular cross shaped wooden facing panels as facing elements.

The main objectives of present investigation are:

- To study load settlement characteristics of footings.
- To study lateral displacement characteristics of wall.
- To measure the tensile forces in reinforcing strips and to locate maximum tension line using strain gauges attached to reinforcing strips.
- To study the failure pattern of reinforcing strips and strips rupture locations.

- To study the earth pressure distribution using earth pressure cells.
- To study the mode of failure and failure wedge.

3.0 EXPERIMENTAL STUDY

The model tank of size 2.3 m x 1.2 m x 1.2 m was used in construction of reinforced Earth Wall which is made of iron with one side made of transparent Perspex sheet for observation. Plane cross-shaped facing panels of size 20 cm x 20 cm and 1.5 cm thickness were used. In order to align the facing panels vertically, vertical holes of diameter 3 mm were drilled in the flanges of each panel. Alignment rods of 2.5 mm thickness were inserted through these holes. The sand was filled and compacted in 10 cm layers. In all the tests, electric motor vibrator is used to get required density of sand. The obtained experimental density of sand was 1.58 gm/cc. The relative density obtained was 66.2%. The angle of internal friction of sand and the angle of interface friction between sand and reinforcing strip were 38.07◦ and 29.745◦ respectively. Strain gauges were attached on three central panel strips at different vertical levels 3 predetermined spacing. Strain gauges were having gauges resistance 120 Ω, gauge length 10 mm and gauge factor 2. Integrated diaphragm type stainless steel pressure cells having body diameter 25 mm and of capacity 5kg/cm² were used for the measurement of horizontal stress kept at the back of the facing panels. To measure the vertical settlement of the footing, two dial gauges were used and to measure the lateral deflection of the facing wall, three dial gauges were used. Figure 1 shows typical section of RE wall for strip loading wheel load is considered analogous to strip load M.S. plate of size I 2 m x 0.28 m and weight 16.7 kg was used made to resemble a strip footing. Static load was applied with hydraulic jack in the increment of 3.174kpa. After each load increment the settlement time of about 10 minutes was given and then the reading of all 5 dial gauges. 9 strain gauges and 4 earth pressure cells were taken Refer photographs of construction of Reinforced Earth wall model at intermediate stage and loading set up.

4.0 RESULTS :

4.1 Load – settlement characteristics :

Figure 2, Figure 3 and Figure 4 show the load – settlement characteristics of RE wall subject to strip load at 18 cm, 36 cm, and 48 cm from facing wall respectively.

Figure 5 shows when the distance of strip footing was changed from 0.15 H to 0.3 H from facing, failure load increased by 23.17 % and when the distance of strip footing was changed from 0.15 H to 0.4 H from facing failure load increase by 29.79 % .

4.2 Lateral displacement characteristics

Figure 6, Figure 7 and Figure 8 shows the lateral displacement characteristics of RE wall subject to strip load at 18 cm, 36 cm, and 48 cm from facing wall respectively. Figure 9 shows the graph of Lateral displacement vs Distance of loading at intermediate constant loading intensity. It can be seen that the lateral displacement of facing wall at 90 cm height is maximum for all the position of loading. This shows that for any position of strip loading, maximum lateral displacement of facing occurs at the height of 0.75 H in the RE wall.

4.3 Maximum tensile Stress Characteristics

A) Strain gauge results :

Figure 10 shows the tensile stresses at different location along the length of the reinforcing strips. The points on the reinforcing strips having maximum tensile stress were joined to get maximum tension line. The maximum tension line touches the top of RE wall at 45 cm (0.375 H) from facing wall.

B) Strips breakage results :

Figure 11 shows the maximum tension lines drawn from the distance of breakage of reinforcing strips from facing. The points of breakage of reinforcing strip were joined to get maximum tension line. It can be observed from the graphs that the maximum tension line touches the top of RE wall in between 40 cm to 50 cm from facing.

4.4 Earth pressure distribution

Figure 12 shows the earth pressure distribution along the height of facing wall. It can be observed that the earth pressure increases as the height increases up to approximately 70 cm and then again decreases.

5.0 CONCLUSIONS

- As the distance of strip loading from facing increases, the strength of RE wall Increases.
- For strip loading at any distance from the facing wall, maximum lateral Displacement of facing occurs at the height of 0.75 H.
- From the strain gauge reading and observed values of breakage of reinforce strips, it can be concluded that the maximum tension line starts from base of facing wall and touches the top at the distance of 45 cm (0.375 H) from the facing.
- For strip footing tensile, failure of reinforcing strips is predominant than pull out Failure of reinforcing strips for all positions of loading.
- The maximum lateral earth pressure occurs at the height of 0.58 H to 0.66 H from the base of RE wall.
- The failure surface becomes stable at an angle of 27◦ with the horizon

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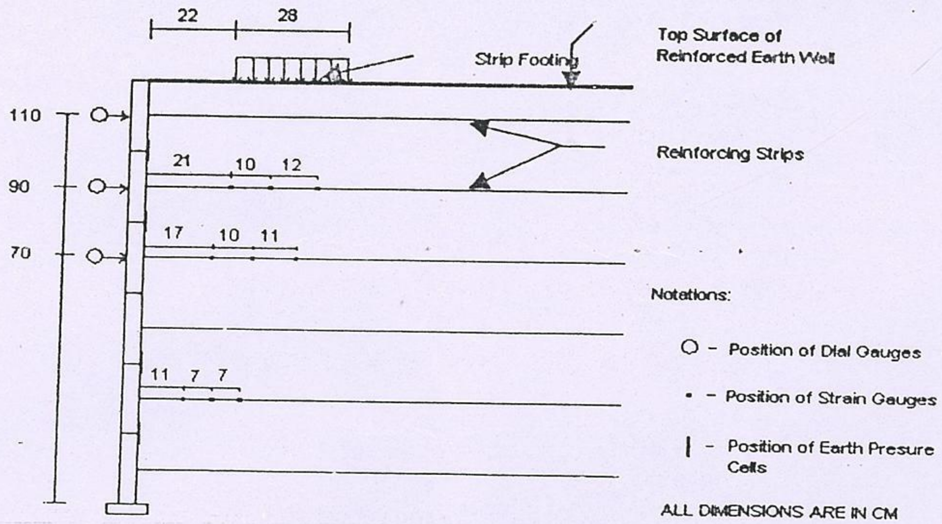


Figure 1. Typical section of Reinforced Earth Wall
(Centre of Strip Footing is at 36 cm from Facing)

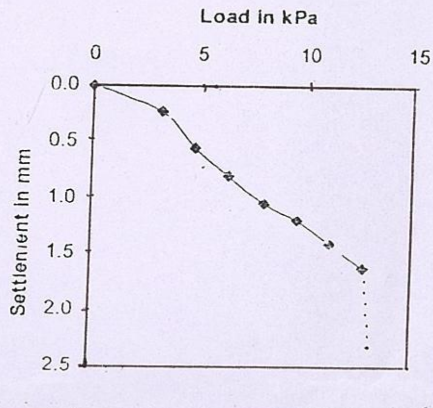


Figure 2

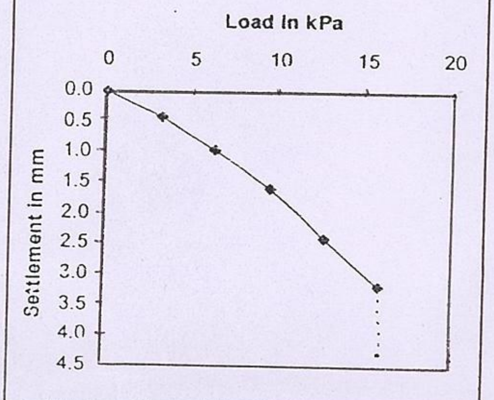


Figure 3

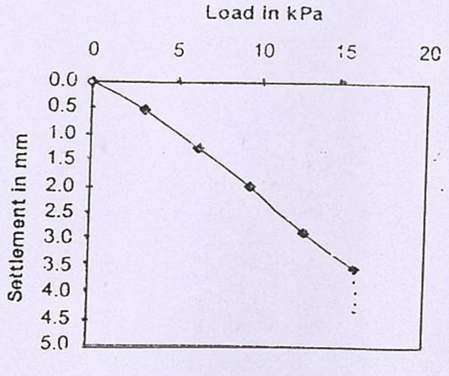


Figure 4

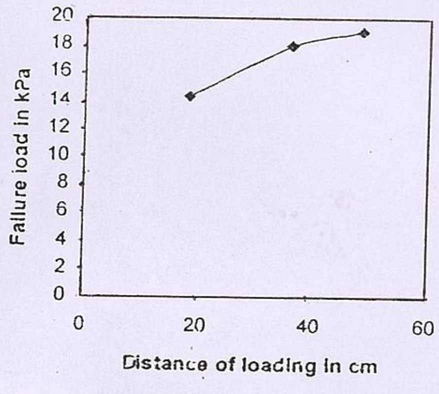


Figure 5

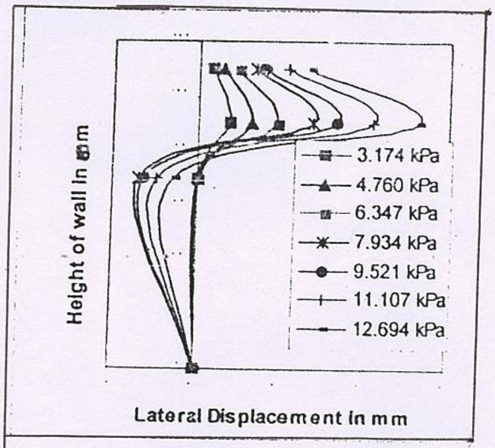


Figure 6

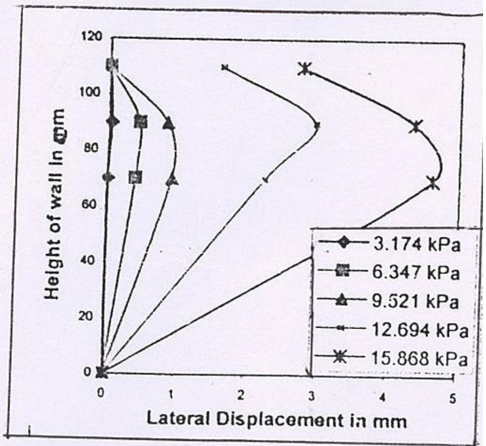


Figure 7

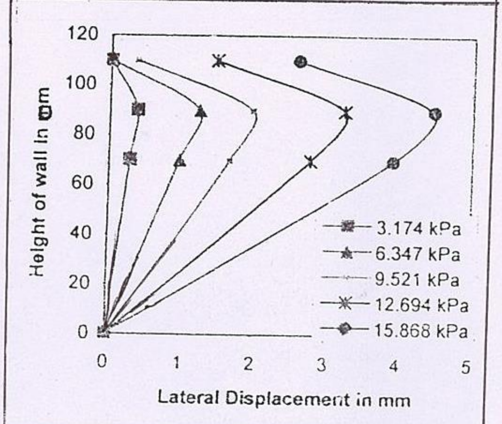


Figure 8

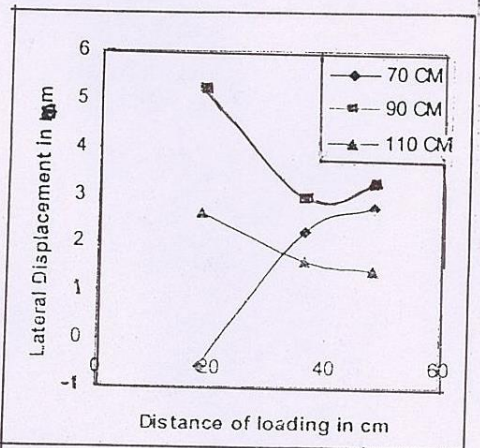


Figure 9

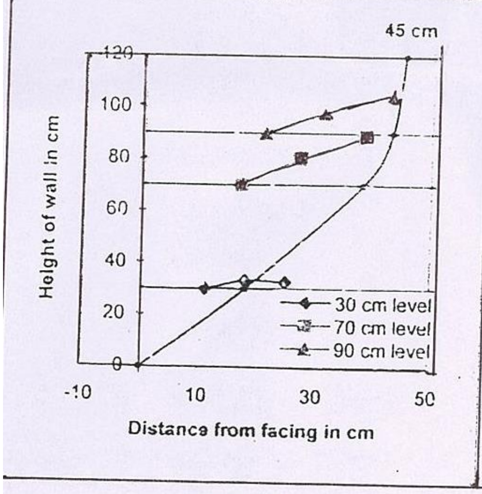


Figure 10

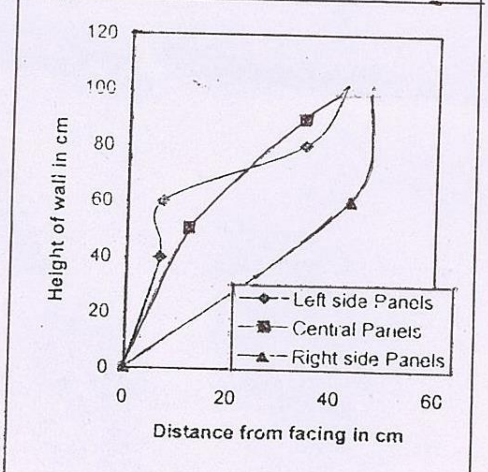


Figure 11

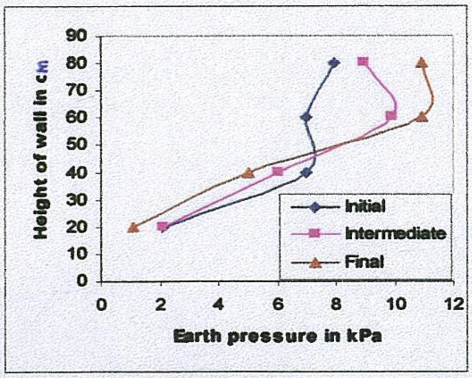
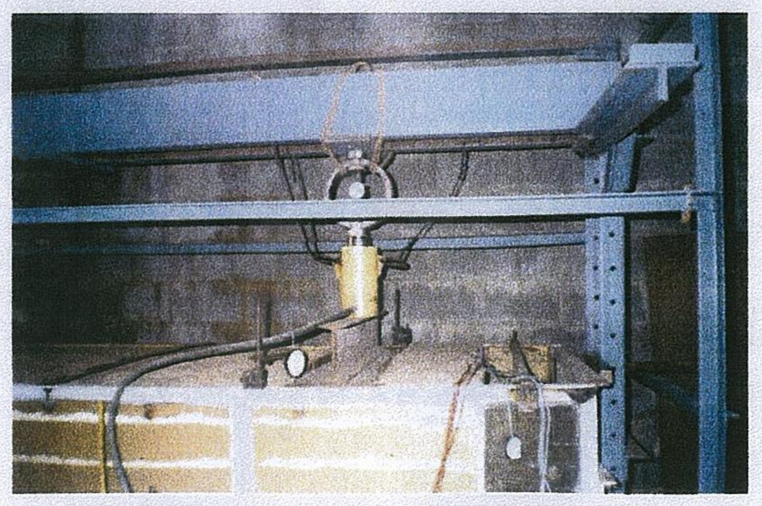


Figure 12

Photograph of Construction of Reinforced Earth Wall model at intermediate stage



Photograph of Reinforced Earth Wall with the strip loading set up