# CHAPTER II

## LITERATURE REVIEW AND BASIC THEORY

### 2.1 Literature Review

#### 2.1.1 Concrete

Concrete is a mixture of cement, sand, and gravel which are added enough water to form a chemical action with the Portland cement. This then can be poured into a form smooth outer surface after it has dried. Since 1886, concrete has become one of the most important structural materials. In addition, the concrete material is more resistant to environmental influences, non-flammable, and more resistant to high temperatures. Therefore it is widely used as a protective structure against the effects of fire on buildings. In general, concrete contains air cavities approximately 1% -2%, cement and water about 25% -40%, and aggregates (fine aggregate and coarse aggregate) approximately 60% -75% (Mulyono, 2005).

#### 2.1.2 Drying shrinkage in concrete

The mechanisms involved in the drying process are complex and are often interrelated. This is mainly due to the wide range of the pore size distribution in standard concrete mixes, which determines, to a large extent, the different transport mechanisms during drying. In turn, the pore system evolves in time as a result of hydration and aging. Moisture transport within the porous solid involves liquid water as well as water vapor (Bear & Bachmat, 1991), and mechanisms such as permeation due to a pressure head, diffusion due to a concentration gradient, capillary suction due to surface tension acting in the capillaries, or adsorption-desorption phenomena, involving fixation and liberation of molecules on the solid surface due to mass forces, may act simultaneously within the drying material. Evaporation and condensation within the porous solid is also important for determining the phase in which moisture is transported through the material (Andrade et al., 1999; Mainguy et al., 2001). As stated above, all these phenomena may act simultaneously and be predominant in different regions of the cement paste (aggregates are usually considered to be impervious, with the exception of lightweight concrete). A detailed description of these mechanisms is out of the scope of this thesis and may be found elsewhere, together with an experimental study of the determination of transport properties for modeling purposes (Baroghel-Bouny, 2007).

Different mechanisms for explaining the observed volumetric changes of concrete during drying have been proposed over the years. It is now accepted that in fact the observed behavior is a result of the interaction of all these mechanisms, each of those acting predominantly in a predetermined internal relative humidity range(Bazant, 1988; Soroka, 1993). The aggregates do not affect the shrinkage mechanism as such, but rather exert a restriction to shrinkage, thus provoking only a quantitative change of shrinkage strains.

### 2.1.3 Fiber

Fiber is additive concrete materials that intended to improve the concrete tensile strength and concrete toughness. Fiber are made from metallic (steel) or non metallic materials. S.C.Yaragal (2011) investigated the effects of fibers in concrete for moment-curvature relationship, cracking characteristics and ductility and also confirmed the veracity of the assumptions of elastic and plastic theories of flexure.

Fiber reinforced concrete is an interesting topic discussed in the last two decades. Malagavelli et al (2011), investigated the impact of cement bags on concrete, and found that when the percentage of fiber in concrete was 3.5% it's compressive and tensile strength increased considerably.

### 2.1.4 Steel Fiber Reinforced Concrete (SFRC)

Shende et al (2012) explained that the presence of micro cracks in the mortar-aggregate interface is responsible for the inherent weakness of plain concrete. The weakness can be removed by inclusion of fibers in the mixture. Different types of fibers, such as those used in traditional composite materials can be introduced into the concrete mixture to increase its toughness, or ability to resist crack growth. It is observed that compressive strength, split tensile strength and flexural strength are on higher side for 3% fibers by volume as compared to that produced from 0%, 1% and 2% fibers by volume. By adding steel fibers on concrete, it can increase the compressive strength, flexural strength, and also tensile strength.

Today, steel fiber which is mainly used to reinforce concrete and overcome the problem of brittleness and become the most interesting applications of steel fiber reinforced concretes (SFRC) all over the world. In the ensuing four decades, SFRC has been constantly examined and its technology was continually developed. SFRC is a commercially available and viable construction material (Jacek, 2006).

### 2.1.5 Sandwich Layer Concept

Layered media, especially the sandwich material with a soft layer subjected to strong impact loading, have attracted much attention since 1970. An investigation conducted by Yonxiang et al (2009) showed that the arch structure composed of foam concrete, SFRC has good blast resistance. The dynamic performance of the foam concrete, SFRC composite structures is studied with different amount of charge. Additionally, coupling relationship of blast resistance and explosion charge is analyzed. Comparison of numerical results with experimental results, show that they are in good agreement and this numerical analysis may provide important guidance for blast resistant design and analysis of underground structures.

The limit strength of sandwich pipes for combined external pressure and longitudinal bending is studied. Steel fiber reinforced concrete (SFRC) is proposed as the core material, since this cementations composite possesses increased extensibility and tensile strength under flexural loading. Steel fiber reinforced concrete (SFRC) can be another choice for the annular material, based on the characteristics of high fracture toughness and good adhesion with metal. On the SFRC property research, the mechanical behaviors of SFRC with different fiber content were simulated using a damaged plasticity model whose parameters were estimated by the tension and compression tests, and the results showed good correlation between the measured and calculated values (Chen et al, 2011).

## 2.2 Basic Theory

### 2.2.1 Concrete

Concretes composite material that uses water, crushed stone, rock sand, also called aggregate, and cement to fills the space among the aggregate particles and glues them together.

Sometimes concrete is referred as brittle material because its behavior under loading is completely different from that of ductile material such as steel. Concrete is not designed to resist direct tension. However, a tensile stress develops in concrete as a result of flexure, shrinkage and temperature changes. Concrete is very weak in tension, the direct tensile strength is only about 7 to 15 percent of its compressive strength.

Concrete has many advantages such as:

- Concrete is economical.
- Concrete's long life and relatively low maintenance requirements increase its economic benefits.
- It is not as likely to rot, corrode, or decay as other building materials.
- Concrete has the ability to be molded or cast into almost any desired shape.
- Building of the molds and casting can be done on the work-site which reduces cost.
- Concrete is a non-combustible material which makes it fire-safe and able to withstand high temperatures.
- It is resistant to wind, water, rodents, and insects. Hence, concrete is often used for storm shelters.

Beside these advantages, also found some problems behind the concrete such as concrete has a relatively low tensile strength, low ductility, low strength-to-weight ratio and concrete is susceptible to cracking.

 


### 2.2.2 Shrinkage in concrete

Changes of pore water content due to drying or wetting processes because significant volume changes of concrete in load-free specimens and it is called shrinkage. shrinkage causes time-dependent cracking, thereby reducing the stiffness of a concrete structure, and is therefore a detrimental factor in all aspects of the design for serviceability.

#### a. Type of Shrinkage in Concrete

There are numerous types of concrete shrinkage, those are:

i. Plastic Shrinkage: this kind of shrinkage occurs soon after the concrete is poured in the forms. The water evaporates and results in a reduction of volume, this causes the concrete on the surface to collapse. It can be reduced by covering the surface with polyethylene sheeting immediately after it is poured.

ii. Drying shrinkage: this is the everlasting process for concrete within drying conditions. The loss of water within the gel pores of the concrete causes the concrete to shrink. The finer the gel within the pores, the more shrinkage.

iii. Autogenously shrinkage: is most prevalent within the concrete in the interior of a dam. When the temperature is constant the shrinkage may occur, especially when there is no moisture movement.

iv. Carbonation shrinkage: is where carbon dioxide penetrates beyond the surface of the concrete. This also depends on the moisture content and the humidity levels. Carbonation shrinkage is caused by the disbanding of calcium hydroxide crystals and the evidence of calcium carbonate.

#### b. Factors affecting drying shrinkage

The factors affecting drying shrinkage in concrete are well-known and written in various text books (see e.g. Soroka, 1993; Mehta & Monteiro, 2006; Neville, 2002). For this reason those factors will only be briefly discussed in this section. They are often interrelated, although they can be grouped into two main categories. On one group, the environmental factors will set up the external conditions, such as humidity level, ambient temperature or wind velocity. The second group involves the characteristic (intrinsic) properties of the concrete material, as may be the aggregate content and their properties, the w/c ratio, the water content and the cement content. The curing and storage conditions are somewhere in the middle of the previous classification, since they consist of the often controlled external conditions which will to a great extent define the quality of the material, i.e. its characteristic properties. Also the influence of additives can be important in some cases, although this is out of the scope of this thesis.

i. Environmental Condition

The environmental conditions will define the severity of the drying process, being more detrimental when there is a combination of dry conditions (low Relative of Humidity), elevated temperatures and a high wind velocity. A low ambient RH will produce strong gradients near the drying surface, thus increasing the drying rate (figure 2.1).

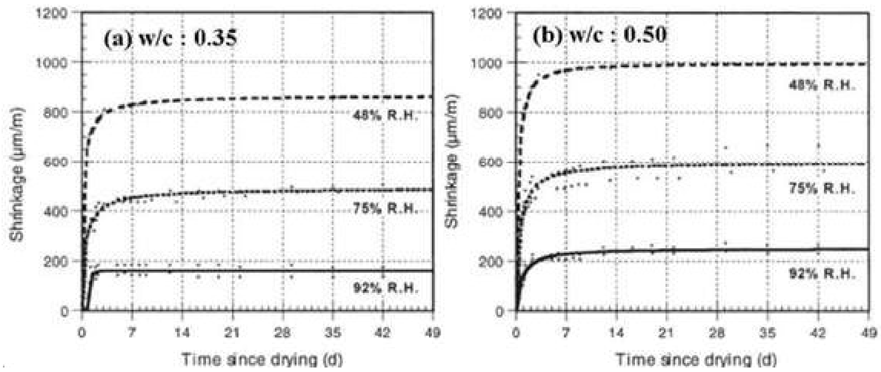


Figure 2.1 Effect of ambient (constant) relative humidity of exposure on the drying shrinkage rate for 4 x 8x 32mm mortar specimens with two different w/c ratios (a) 0.35 (b) 0.50 (from Bissonnette et al., 1999).

 


ii. Aggregate concentration and stiffness

The presence of aggregates in concrete restrict the overall deformations, as regular aggregates do not generally show appreciable creep when subjected to stresses, nor they are subjected to drying due to the low permeability as opposed to the cement paste. Table 2.1 shows the influence of aggregate to cement ratioon drying shrinkage (Neville, 2002). It can be clearly noticed that the higher the aggregate/cement ratio, the lower the shrinkage strains, due to the mentioned restraining effect, but most of all because the shrinking volume fraction of the composite material in concrete decreases.as shown in the table 2

Table 2.1 Typical values of shrinkage strains in mortar and concrete samples with a squared cross section of 127mm2, exposed to a 50% RH environment at 21ºC (Neville, 2002).

| **aggr./cem. Ratio** | **Shrinkage at 6 months ($x10^{-6}$) for w/c ratio of:** | | | |
|---|---|---|---|---|
| | **0,4** | **0,5** | **0,6** | **0,7** |
| **3** | **800** | **1200** | **----** | **----** |
| **4** | **550** | **850** | **1050** | **----** |
| **5** | **400** | **600** | **750** | **850** |
| **6** | **300** | **400** | **550** | **650** |
| **7** | **200** | **300** | **400** | **500** |

The stiffness of the aggregates has also important consequences on shrinkage, since the restraining effect highly depends on this parameter. As a general rule it can be stated that the lower the stiffness of the aggregate the higher the shrinkage strains. The elastic modulus of the aggregates obviously affects that of the concrete material, for example when comparing normal and lightweight concrete made with the same cement paste. In Figure 2.2 (b) the effect of the stiffness of the aggregates on the shrinkage strains is shown in terms of the secant modulus of the concrete. However, it should be noted that in the case of lightweight concrete, the drying process is rather different, as water may diffuse through aggregates and migrate out of them (since they are much more porous than normal aggregates), which may in turn crack due to hygral gradients (Lura & Bisschop, 2004) of aggregate rigidity by fitting the exponent n, which should depend on the elastic properties of the aggregates.as shown in the figure 2.2.

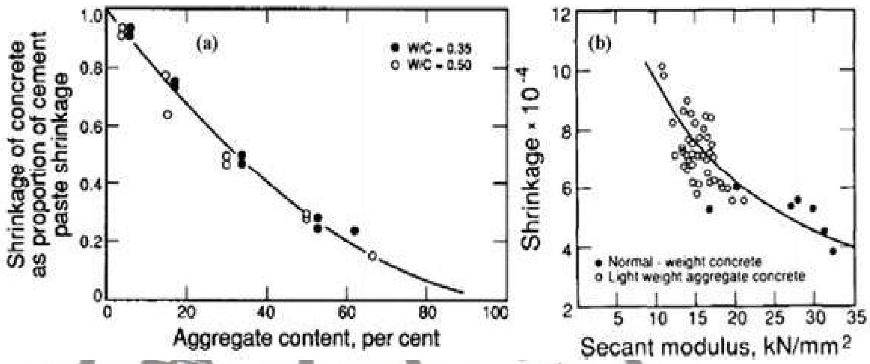


Figure 2.2 (a) Effect of aggregate concentration on shrinkage of concrete: theoretical vs. experimental results by Pickett (from Soroka, 1993). (b) Relation between shrinkage strains and concrete secant modulus of elasticity, data by Richard (from Soroka, 1993).

iii. Water to cement ratio (w/c), water content and cement content

The w/c ratio and the contents of water and cement are three interrelated factors, since by fixing any pair of them the third one can be immediately determined. Starting with the effect of the concentration of these two components (water and cement), it can be shown that the greater the concentration, the greater the shrinkage deformations. In the case of water, increasing its content will lead to increasing the amount of evaporable water, and thus the potentiality to suffer shrinkage strains. On the other hand, the cement content determines the fraction of cement paste in concrete. Obviously, shrinkage will be greater the higher the cement paste content, which represents the shrinking phase of the material (since aggregates are generally inert).

The w/c ratio determines how much water exist in the cement paste. It is often used to empirically determine concrete strength and other properties of concrete. The porosity will be higher (and thus its durability will be poor and the strength will be lower) as this ratio increases its value. Accordingly, reducing the w/c ratio will lead to a considerable decrease in the shrinkage strains and the porosity of the cement paste. This is shown in figure 2.3, where shrinkage strains for mortars and concretes with different w/c ratios are compared.

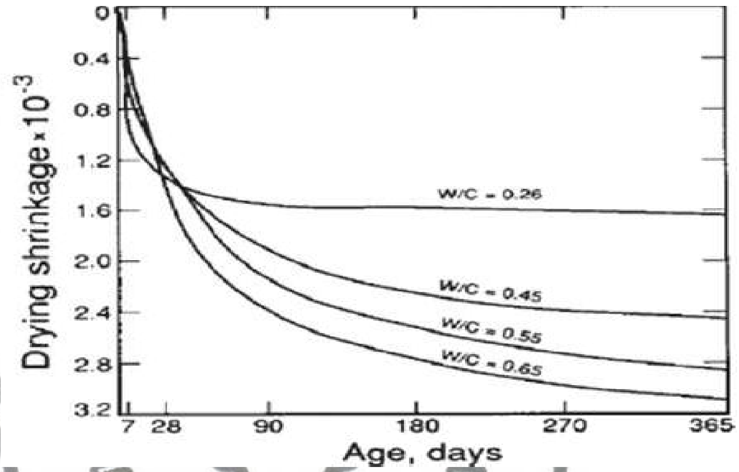


Figure 2.3 Effect of w/c ratio on the drying shrinkage of concrete as a function of time, data by Haller (from Soroka, 1993).

iv. Addition of admixtures

The effect of mineral admixtures on the shrinkage strains and mechanisms is diverse. Their addition produces changes in the microstructure of the cement paste, as well as modifications of the pore structure.

**c. Measuring shrinkage strain**

A brief reference should be made to some practical aspects of shrinkage strain measurements in concrete specimens, as another important factor when analyzing shrinkage tests. The position of the points of measurement of the (longitudinal) shrinkage strains plays an important role in the determination of the coupled hygro mechanical behavior of concrete (figure 2.4). Due to the fact that drying is a diffusion process, internal RH will not in general be at equilibrium with the environment. Thus, nonlinear shrinkage strains distributions within the thickness of a concrete sample will develop. The use slender specimens for drying shrinkage tests and to perform the measurement of longitudinal strains far from the sample ends (approximately at 1.5 times the diameter or edge of the specimen, as a general rule). as shown in the figure 2.4

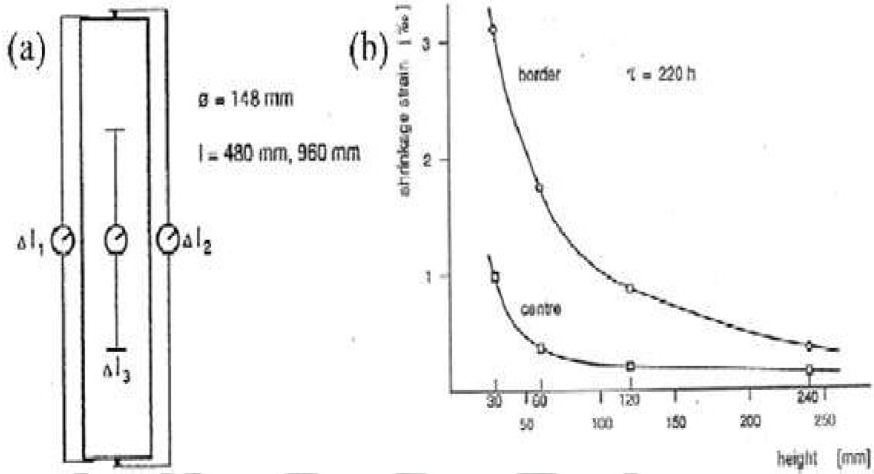


Figure 2.4 (a) Different possibilities of strain measurement in a drying shrinkage test. (b) Relation between the height of concrete specimens of constant diameter and the measured longitudinal strains at the border and at the centre of the samples (from Wittmann, 1993).

**d. Shrinkage induced microcracking and Its detrimental effect**

During the drying process, whether it is due to internal or external restrictions, self-equilibrated stresses are usually generated within a specimen cross-section. The moisture gradients are responsible for a differential drying (and thus shrinkage) of the specimen, causing tensile stresses near the exposed surface and compressive stresses in the inner layers (due to compatibility of strains and equilibrium considerations). When the induced-tensile stresses exceed the tensile strength of concrete (which is an age-dependent property) cracking will irremediably occur. At the beginning of drying, micro cracks will mainly develop perpendicular to the drying surface. Cracks with a width smaller than 50 microns which is typically of maximum crack opening for drying shrinkage induced cracks, in accordance with Shiotani et al, 2003. It should be noticed that a RILEM state of the art report on microcracking suggests that this limit should be 10 microns (Damgaard & Chatterji, 1996),

### 2.2.3 Fiber

Fiber is a rope or string used as a component of composite materials, or matted into sheets to make products. Fibers are often used in the manufacture of other materials. Fibers have been used in construction materials for many centuries. The last three decades have seen a growing interest in the use of fibers in ready-mixed concrete, precast concrete, and concrete.

Fibers made from steel, plastic, glass, and natural materials (such as wood cellulose) are available in a variety of shapes, sizes, and thicknesses; they may be round, flat, crimped, and deformed with typical lengths of 6 mm to 150 mm (0.25 in. to 6 in.) and thicknesses ranging from 0.005 mm to 0.75 mm (0.0002 in. to 0.03 in.). Figure 2.5 shows the various steel fiber form.

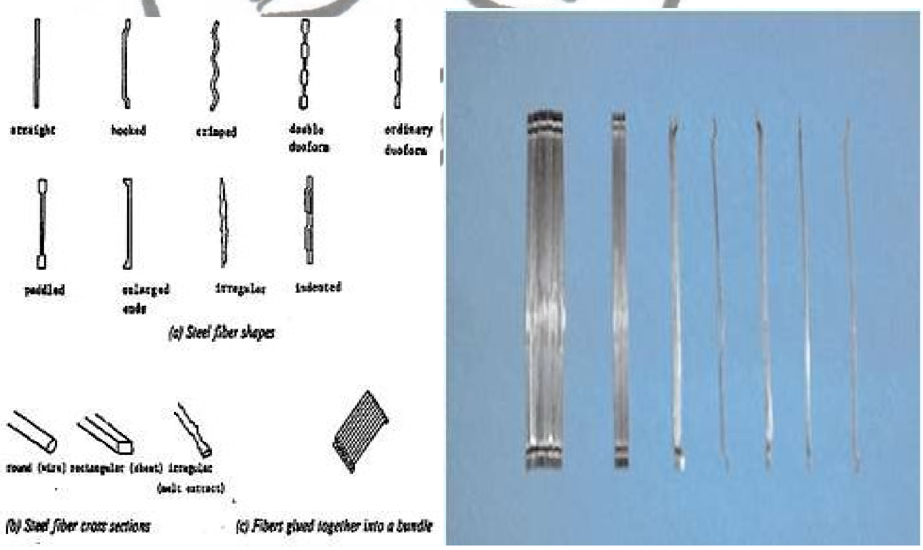


Figure 2.5 Various types of steel fiber form (Soroushian and Bayasi, 1991)

Steel fibers are short, discrete lengths of steel with an aspect ratio (ratio of length to diameter) from about 20 to 100, and with any of several cross sections. Some steel fibers have hooked ends to improve resistance to pullout from a cement-based matrix (Figure 2.5). ASTM A820 classifies four different types based on their manufacture. Type I Cold-drawn wire fibers are the most commercially available, manufactured from drawn steel wire. Type II Cut sheet fibers are manufactured as the name implies: steel fibers are laterally sheared off steel sheets. Type III Melt-extracted fibers are manufactured with a relatively complicated technique where a rotating wheel is used to lift liquid metal from a molten metal surface by capillary action. The extracted molten metal is then rapidly frozen into fibers and thrown off the wheel by centrifugal force. The resulting fibers have a crescent-shaped cross section. Type IV is other fiber that has been mentioned before. For tolerances for length, diameter, and aspect ratio, as well as minimum tensile strength and bending requirement, see ASTM A820.

Steel Fiber Reinforced Concrete (SFRC) includes steel fiber into concrete in order to make up for the brittle properties compared to the general concrete, various characteristics such as tensile strength, bending strength, bending toughness.

SFRC, which is gained by mixing steel fiber into the short length within the concrete in random directions, can control the micro crack extension and local crack growth within the section as the concrete is under tensile stress. This can be done through its role as a bridge. By doing so, ductility within the area increases after the occurrence of the crack along with the tensile strength.

Through the mixture of steel fiber, the increase of tensile strength within the concrete as well as improved ductility can bring improvements in behavior for concrete structures that have the tendencies of destruction. The increase in bridging function for the steel fiber becomes is influenced on the fiber dispersion, and fiber dispersion plays an important role in fiber dispersion.

The main factors that control the performance of the composite material are:

a. Physical properties of fibers and matrix
b. Strength of bond between fibers and matrix

 


Although the basic governing principles are the same, there are several characteristic differences between conventional reinforcement and fiber systems:

a. Fibers are generally distributed throughout a given cross section whereas reinforcing bars or wires are placed only where required
b. Most fibers are relatively short and closely spaced as compared with continuous reinforcing bars or wires
c. It is generally not possible to achieve the same area of reinforcement to area of concrete using fibers as compared to using a network of reinforcing bars or wires

Fibers are typically added to concrete in low volume dosages (often less than 1% by volume), and have been shown to be effective in reducing plastic shrinkage cracking. Fibers typically do not significantly alter free shrinkage of concrete, however at high enough dosages they can increase the resistance to cracking and decrease crack width (Shah et al, 1998). Steel-fiber volumes used in concrete typically range from 0.25% to 2%. Volumes of more than 2% generally reduce workability and fiber dispersion and require special mix design or concrete placement techniques.

As the advantage of fiber reinforced concrete compared to normal concrete, reinforced concrete has more strength and durability. Because the concrete is fabricated with steel fiber that can withstand high pressure before it becomes damaged or weakened. Much of the stress in a building is transferred to the steel, which takes the pressure off the concrete. This allows reinforced concrete to carry much more weight than regular concrete. In addition to having additional strength, reinforced concrete is also flexible. During the construction process, the flexibility in reinforced concrete helps the structure take shape and decreases the tension in the foundation.

One of the major disadvantages of reinforced concrete is the cost involved in the fabrication process. Incorporting steel fibers into a cement mix are very labor intensive, which makes it much more expensive than regular concrete. When compared to steel, reinforced concrete has a low rate of compressive strength. The low rate of compressive strength may cause cracks to develop within the foundation of a building. Cracks are often caused by moisture, which causes the material to expand and shrink, and leads to major problems down the road.

### 2.2.4 Steel Fiber Reinforced Concrete (SFRC)

Porter first put the idea that concrete can be strengthened by fiber inclusion forward in 1910, but little progress was made in its development until 1963, when Roumaldi and Batson carried out extensive laboratory investigations and published their classical paper on the subject. Since then, there has been a great wave of interest in and applications of SFRC in many parts of the world. While steel fibers improve the compressive strength of concrete only marginally by about 10% to 30%.

The efficiency of steel fibers as concrete macro-reinforcement is in proportion to increasing fiber content, fiber strength, aspect ratio and bonding efficiency of the fibers in the concrete matrix. The efficiency is further improved by deforming the fibers and by resorting to advanced production techniques. Any improvement in the mechanical bond ensures that the failure of a SFRC specimen is due mainly to fibers reaching their ultimate strength, and not due to their pullout.

Steel fiber reinforced provided about the ductility and tensile strength for a concrete. In this case (concrete shrinkage), the steel fiber reinforced concrete has some effect such as the strain distribution spread more average, slackening the occurring of crack and restraining or dispersing crack on lining.

The efficiency of steel fiber as concrete in proportion is to increase fiber content, strength, aspect ratio in the concrete matrix. For further improved by deforming the fiber and resorting to advanced production technique. As we know that the steel fiber provide a resistance to impact and high fatigue, shrinkage control of concrete, very high flexural, shear and tensile strength and high thermal resistance.

The compressive strength of concrete is only slightly affected by the presence of fibers. The addition of 1.5% by volume of steel fibers can increase the direct tensile strength by up to 40% and the flexural strength up to 150%. Steel fibers do not affect free shrinkage. Steel fibers delay the fracture of restrained concrete during shrinkage and they improve stress relaxation by creep mechanisms (Altoubat and Lange 2001).

The durability of steel-fiber concrete is contingent on the same factors as conventional concrete. Freeze-thaw durability is not diminished by the addition of steel fibers provided the mix is adjusted to accommodate the fibers, the concrete is properly consolidated during placement, and is air-entrained. With properly designed and placed concrete, little or no corrosion of the fibers occurs. Any surface corrosion of fibers is cosmetic as opposed to a structural condition.

Steel fibers have a relatively high modulus of elasticity about 210,000 MPa. Their bond to the cement matrix can be enhanced by mechanical anchorage or surface roughness and they are protected from corrosion by the alkaline environment in the cement matrix (ACI 544.1R-96).

Steel fibers are most commonly used in airport pavements and runway/taxi overlays. They are also used in bridge decks, industrial floors, and highway pavements. Structures exposed to high-velocity water flow have been shown to last about three times longer than conventional concrete alternatives. Steel fiber concrete is also used for many precast concrete applications that make use of the improved impact resistance or toughness imparted by the fibers. In utility boxes and septic tanks, steel fibers replace conventional reinforcement. Figure 2.6 shows the example of steel fiber usage on bridge deck.

Figure 2.6 Bridge deck with steel fibers.

Steel fibers are also widely used with concrete in thin-layer applications, especially rock-slope stabilization and tunnel linings. Silica fume and accelerators have enabled concrete to be placed in thicker layers. Silica fume also reduces the permeability of the concrete material (Morgan 1987). Steel-fiber concrete has been successfully applied with fiber volumes up to 2% by volume.

Slurry-infiltrated concrete (SIFCON) with fiber volumes up to 20% has been used since the late 1970s. Slurry infiltrated concrete can be used to produce a component or structure with strength and ductility that far exceeds that of conventionally mixed or sprayed fiber concrete. SIFCON is not inexpensive and needs fine-tuning, but it holds potential for applications exposed to severe conditions and requiring very high strength and toughness. These applications include impact and blast-resistant structures, refractoriness, protective revetment, and taxiway and pavement repairs. Figure 2.7 shows the example of slurry-infiltrated steel-fiber concrete application.

 


Figure 2.7 Tightly bunched steel fibers are placed in a form, before cement slurry is poured into this application of slurry-infiltrated steel-fiber concrete (SIFCON).

Table 2.2 shows the mix design of Slurry infiltrated concrete with fiber that can be used to produce a component or structure with strength and ductility that far exceeds that of conventionally mixed or sprayed fiber concrete.

Table 2.2 SIFCON mix design.

| | |
|---|---|
| Cement | 1000 kg/m$^3$ (1686 lb/yd$^3$) |
| Water | 330 kg/m$^3$ (556 lb/yd$^3$) |
| Siliceous sand $\leq$ 0.7 ($\leq$ 0.028 in.) | 860 kg/m$^3$ (1450 lb/yd$^3$) |
| Silica Slury | 13 kg/m$^3$ (1.3 lb/yd$^3$) |
| High-range water reduction | 35 kg/m$^3$ (3.7 lb/yd$^3$) |
| Steel fiber (about 10 vol.-%) | 800 kg/m$^3$ (384 lb/yd$^3$) |

### 2.2.5 Sandwich layer concept

The concrete that made by sandwich concept is divided into two part, upper and bottom side. The upper side is plain concrete and the bottom side (same concrete) contain of steel fiber. The sandwich concrete slab and beam is an attempt on utilizing factors that have a favorable effect on mechanical properties of steel fiber concrete structure, also the casting method has proved to be favorable in order to align the fiber in the direction of stress.

  

In practice, there are many surfaces of concrete slabs which are disintegrated due to different actions and because those damages have near surface, underlies remain undamaged and they are still proper for further use. Therefore, damaged layer has to be removed and replace by new overlay with the same thickness. High quality bond between old and new layers has to be achieved. The new overlay and old concrete underlay have to make unified monolith, which is able to bear loads.

Surface preparation has the greatest impact on the long-term performance of bonded overlays. Two main steps of surface preparation have been performed rough planning with milling, and before the fresh SFRC was placed, grout had been applied over the cleaned rough area. Such workability of fresh SFRC was proper for pumping and placement into the overlay. SFRC with low content of short fibers will have higher crack opening resistance. High-range super plasticizer is an admixture which has significant effect, not only on increase in strength, but also on improvement in the crack opening resistance. It seems that such super plasticizer improves deneseness of cement paste, as well as distribution of fibers. Fibers become more efficient and therefore increase crack-opening resistance of SFRC.

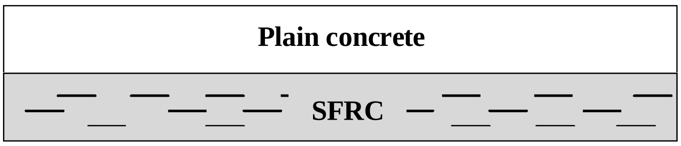


Figure 2.8 Sketch of sandwich layer concrete.

Sandwich layer concept shows great promise which can saves 30 to 40 % of the usage of steel. It is very light with wet, demoulding density of less than 1000 $kg/m^3$. It also seems clear that the sandwich concept may offer important advantages when it comes to safety, design life and operational prformance.

## 2.3 The difference between this research and previous researches

The previous researches used bio-waste fiber namely oil palm trunk fiber and in this research used steel fiber reinforced concrete. Limit strength of sandwich and SFRC and produced the sandwich concrete and SFRC with different fiber content dosage. Increase the compressive strength of SFRC and Increase the mechanical properties of SFRC with different steel fiber content.

## 2.4 Hypothesis

The hypothesis of this research is:

Ho: Steel fiber decrease the drying shrinkage on steel fiber reinforced concrete and sandwich concrete