

AN INVESTIGATION OF TECHNICAL PROBLEMS THAT OCCUR
DURING CONCRETE SCULPTURE-MAKING, WITH SPECIFIC
EMPHASIS ON THE MODELLING OF CONCRETE OVER LARGE
FRAMEWORKS

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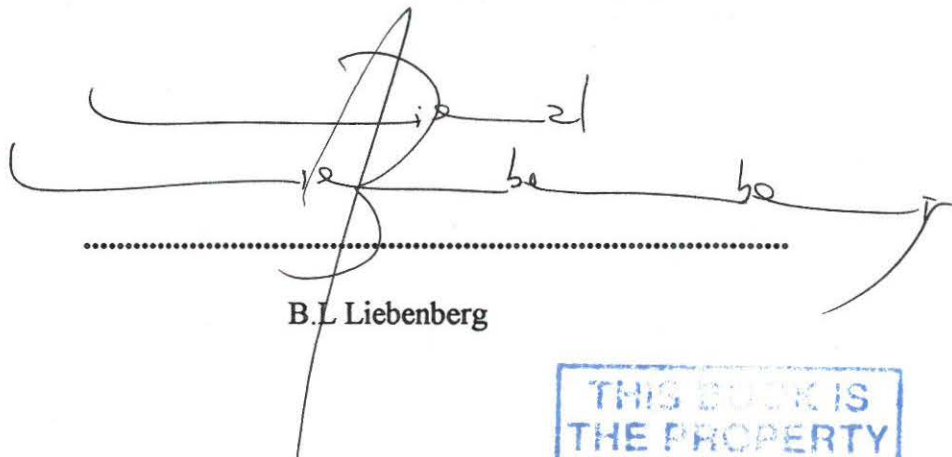
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Here with it is declared that the contents of this dissertation is the candidate's own work and
has not been submitted to any other institution for qualification purposes.



.....

B.L Liebenberg



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BIMBO'S INTERNET CAFE

To God for strength and my parents for their patience.

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CHAPTER ONE

1.1 INTRODUCTION

Concrete has been used throughout history and is one of the direct mediums in which a sculptor can work. Previous research has been done on concrete casting and multiple modelled pieces. However, the lack of satisfactory literature on modelling concrete on large sculptural frameworks has led to the motivation and importance of this research project. Sculptors usually obtained data by relying on published articles and exchanging information by word of mouth with engineers and builders, which is often contradictory, leaving the sculptor confused and more prone to making costly mistakes.

1.2 THE PROBLEM

The researcher proposes to investigate structural and technical problems encountered when modelling concrete on large scale frameworks.

1.3 HYPOTHESIS

The problems encountered during large scale concrete modelling will be solved, by using specific construction methods. These methods include the correct mixing and batching of aggregates, structure and base design.

1.4 THE PURPOSE OF THIS STUDY

- To investigate the lack of substantial information on technical and structural problems, with regard to the usage of cement, aggregates and admixtures.
- To investigate the influence of aggregates and admixtures on concrete sculpture with regard to the following: Structural and base design, scale, proportions, stresses, strains and surface finishes.

1.5 THE IMPORTANCE OF THIS STUDY

Sculptors cannot afford to spend too much time experimenting, as this allows less time to create the sculptural image. With the use of modern technology and available data the sculptor is able to gain time and expertise for further development of his/her creative abilities. Although technology is beneficial, and industrially developed materials are durable and standardised, the artist at times has to ignore industrial methods and explore individual techniques, enabling him/her to arrive at the desired effect. Despite years of continuous experimentation, the sculptor might still not have obtained the correct modelling mixture or have designed an appropriate inner structure for his/her sculptures. This research project aims at reducing this extended time factor by formulating basic guidelines for the modelling of cement on large-scale structures, thereby minimising technical problems that may occur. The increase in technical knowledge will allow room for further development of sculptural ideas in cement as a medium.

1.6 METHOD

Data has been gathered from the following sources

- Cement & Concrete Institute, various books and published articles in South Africa
- Manufacturers and suppliers of admixtures and suppliers in South Africa.
- Various sculptural techniques used at the Cement & Concrete Institute; in order to investigate how these techniques can be applied to the modelling of concrete.

This complex data has been transcribed and presented in an accessible form to make it easier for the reader to understand.

1.7 HISTORICAL OVERVIEW

The first use of concrete dates back to 5600 B.C., when a mixture, consisting of gravel, lime and sand, was used with lime as the main substance. When man started building, he was looking for a bonding agent to use between stones. The Assyrians and Babylonians used clay for this purpose, while the Egyptians used a mixture of lime and plaster (Dalzell, 1955:5). The Greeks had an interesting list of materials which they used. For cement they used lime and resin, to which aggregates like sand and marble dust were added to form concrete. Stucco was used to cover columns when marble was not used (stucco today implies a thin concrete

shell with steel reinforcement). Sometimes a mixture of marble dust and lime was used in a 1:2 ratio as a substitute for sand. According to Dalzell (1955:5) during the second century B.C. the Romans accidentally discovered a stronger building material. Under the impression that it was sand, they mixed pozzolana (volcanic ash that contains silica and alumina) with the lime. However, during the Dark Middle Ages, the art of cement production was lost. The next discovery was in 1824, when an English bricklayer, Joseph Aspin, burned a mixture of lime and clay to produce cement that hardens under water, today known as Portland cement. Portland cement was discovered, after lime and clay was used as natural cement (ibid:5). Today cement can be manufactured according to the needs of the client. These cements are more expensive than those already available on the market, as only a small percentage of clients require such cement. Many products are available today, that can enhance the qualities of the cement, making it stronger and more suitable to work with. Most of the cement and by-products are manufactured for the needs of the builder and small-time client, but a cement that has been specifically designed for the use of the sculptor, has not yet been developed, leaving the sculptor no alternative but to experiment.

A basic background on cement, aggregates and admixtures, and those suitable for use in concrete sculpture, are discussed in Chapter Two. Basic terminology, storage conditions, temperatures and influences on the various materials are dealt with in the discussion.

Further in Chapter Three the researcher discusses the structure, namely what to look for in structure design, as well as the types of structures that are used in modelling concrete sculptures and the harmful effects the materials have on the sculpture itself, for example stresses and strains. The base attachments and the causes of cracks are investigated in Chapter Four. Chapter Five focuses on surface finish, for example sealing, polishing and colouring of the concrete.

All aspects of cement discussed in this document are applied to the type of structures, materials and mixtures the researcher has produced. The final chapter discusses how successful this cumulated data has been applied to the making of individual sculptures.

CHAPTER TWO

CEMENTS, CHEMICAL ADDITIVES, TERMINOLOGY AND CHARACTERISTICS

2.1 INTRODUCTION

This chapter is a brief introduction to the use of cement. Mixing, batching and curing are investigated, as well as water ratios, aggregates and admixtures. The function of the above-mentioned materials are explained, to provide the sculptor with a clearer understanding of their individual characteristics. Each of these materials plays an important role in the successful use of cement, and is needed to ensure that the end product is technically sound. The cement types described in this chapter are Portland cement, Super Sulphated cement and high-alumina cement, of which Portland cement is by far the most widely used.

Cement is a material in powder form with a carefully controlled combination of ingredients such as lime, silica, alumina, iron oxide, and a small amount of other materials, such as gypsum to regulate the setting time of the reluctant cement (Neville & Brooks, 1990:9). According to Everett (1994:112) cement is hydraulic, and is therefore dependent on water rather than air for development of strength. When water is added to cement, an immediate chemical reaction is initiated, which continues while water is still present. Hydraulic cements stiffen at first and develop strength at a later stage. Only a small quantity of water is required to hydrate cement. Additional water evaporates, leaving voids between the particles, and thereby reducing the density, and consequently the strength and durability, of the cement.

The cement paste shrinks during the drying process. Re-wetting of the cement can reverse almost half of the shrinking process. The strength of the cement relies on the water : cement ratio. Excess water increases shrinkage of the cement during drying. The less water one uses, the less shrinkage will occur. The development of strength in cement ceases below freezing-point, and at higher temperatures its rate relates to temperature and age. During the hydration process, cement emits sufficient heat to maintain the temperature of concrete in cold weather. In hot weather exothermic heat may lead to differential stresses, which might be

the cause of cracks in concrete. Because of the different properties of cement, two dissimilar types must never be mixed. Therefore, equipment and tools must be cleaned before switching from one cement to another (ibid:112) .

2.2 TYPES OF CEMENT

2.2.1 PORTLAND CEMENT:

Portland cements are made by calcinating a slurry of clay (silica, alumina and iron oxide) with limestone (calcium carbonate) in a rotating furnace of up to 180 meters in length. The resulting clinker, to which is added a proportion of gypsum to retard the setting of the cement, is ground to a powder, the particle size of which influences the properties of the product (Everett, 1994:114).

2.2.2 ORDINARY PORTLAND CEMENT (OPC)

This is the most widely used type of cement, and it is also the least expensive. It is manufactured using the standard Portland process, without any extra additives, and is used in general applications, where there is no exposure to sulphates in the soil or water (Everett, 1994:114).

2.2.3 RAPID-HARDENING PORTLAND CEMENT (RHPC)

This cement sets at the same rate as ordinary Portland cement (OPC), but because it is finely ground, it develops its strength rapidly and is useful where early strengthening is required. In cold weather, the high rate of heat given off from the cement during the hardening process helps to prevent damage by frost (Neville & Brooks, 1990:25-26).

2.2.4 ULTRA -HIGH EARLY STRENGTH PORTLAND CEMENT

Due to extremely fine particles, concrete made from this cement achieves the three-day strength of rapid-hardening cement within sixteen hours, and its seven-day strength within twenty-four hours. There is, however, little increase in strength after 28 days (Everett, 1994:114).

The early heat emitted during hydration is greater than that of rapid-hardening cement. The growing rate of cracks in concrete, made with ultra-high early strength cement is greater than that of other Portland cements. Shrinkage is similar to that of ordinary Portland cement. With

this type of cement, the cement manufacturer should be consulted before using admixtures (ibid:114).

2.2.5 SULPHATE-RESISTING PORTLAND CEMENT

This cement has a reduced tricalcium aluminate content, and is therefore able to withstand chemical attacks arising in wet conditions from sulphates in industrial waste or clay bricks. It is suitable for use in concrete and appears to have a good quality after curing in ground water that has a concentration of up to 1% sulphur oxide (Everett, 1994:115).

2.2.6 WHITE PORTLAND CEMENT

This cement is manufactured from white china clay and white limestone in a kiln and as a result of this, is white in colour and expensive (Everett, 1994:115). According to Neville (1981:81) white cement is used for architectural purposes, where a pastel or light colour finish is required.

2.2.7 LOW HEAT PORTLAND CEMENT

According to Dalzell (1955:9) this type of cement is used in thick concrete work, where the heat generated by ordinary cement would be excessive and result in serious cracking. Low-heat Portland cement limits the heat produced during hydration. Low-heat Portland cement is a true Portland cement and is not diluted with inner fillers.

2.3 CEMENTS BASED ON PORTLAND CEMENT

2.3.1 WATER-REPELLENT CEMENTS

These cements are used in the finishing of surfaces where water resistance is required. Proportions of ingredients added and the mixing time must be carefully controlled to avoid excess air being entrapped, which might result in the loss of strength and water-resistant properties (Everett, 1994:115).

2.3.2 MASONRY CEMENT

Portland cement-sand mixes are not ideal for bricklaying and external renderings. They are usually too strong, they lack requisite plasticity and water retention, and tend to crack. Masonry cement contains a fine inert filler, and this plasticising agent overcomes these difficulties (Everett, 1994:115).

2.3.3 COLOURED PORTLAND CEMENT

These cements are made by adding coloured pigments to ordinary grey or white cements. They are also very expensive and are only manufactured in small quantities (Neville & Brooks, 1990:31).

2.3.4 PORTLAND BLAST-FURNACE CEMENT

About 30 % of weight blast-furnace slag is added to the ordinary Portland cement clinker before grinding. The requirements for fineness, setting times, soundness and strength are the same as ordinary Portland cement. Due to the hardening rate of 28 days and the limited amount of heat generated, this cement is less suitable for use at low curing temperatures. The strength of the mature concrete, however, is almost the same as that of concrete made with OPC. Portland blast-furnace cement offers good resistance to diluted acids and sulphates, and can therefore be successfully used for constructions in sea water (Everett, 1994:116).

2.3.5 LOW-HEAT BLAST-FURNACE CEMENT

This cement is suitable for use in areas where excessive temperatures may occur. However, its setting is a slower process, the initial set being less than one hour and the final set not more than 15 hours (Everett, 1994:116).

2.3.6 HYDROPHOBIC CEMENT

The particles of this cement are coated with a water-repellent film, and it can therefore be stored in damp conditions for a long time without deterioration. When the cement is mixed with an aggregate, the film is rubbed off and hydration then takes place. Hydrophobic cement has better workability and improved waterproofing properties than OPC cement (Everett, 1994:116).

2.3.7 POZZOLANIC PULVERISED FUEL-ASH CEMENT (PFA)

Pozzolanic pulverised fuel-ash cement contains between 40 and 46% fuel-ash and can generally be used as a low-heat cement, with improved resistance to the action of sulphates and weak acids. The setting time is the same as in the case of OPC. With this cement, lower water contents can be used, which will result in improved durability (Everett, 1994:116).

2.4 STORAGE OF CEMENT

Cement easily absorbs moisture from the air or ground, which results in the deterioration of the cement (Anon., 1995 :10). Due to its sensitivity to atmospherical humidity, it will hydrate or set prematurely if left exposed to moist air. If moisture is absorbed, the cement forms lumps and such damaged cement is not suitable for important work. However, if the lumps are easily breakable between one's fingers, this cement can still be used for non-structural work (Ibid:10).

Cement must be stored as follows:

- The ideal storing place is a closed area or storage room where wind, weather and moisture cannot reach the cement.
- Do not store cement with other materials. Just a small portion of foreign material, for example fertiliser, can result in setting and strength problems.
- The ideal storage time is not longer than three months (ibid:10).
- Once the cement has been opened, it is best to store it in an airtight, light-proof, sealed container.
- Even while working with the cement, it is best to store it in a plastic bag or in a plastic container with a lid.

Damaged cement will negatively influence the results of concrete (Dalzell, 1955:13).

2.5 VOLUME OF A MIXTURE

According to Dalzell, J.R. (1955:13) cement can flow into a smaller space than water. This is illustrated by the fact that a very fine sieve will hold water, but cement granules will easily pass through. Even though the individual grains of sand are very small, there are spaces between the grains where cement can enter. Suppose there are two buckets, one filled with sand and the other with cement. If these two materials are mixed, the resulting mixture will not completely fill the same two buckets, as the cement enters the spaces between the grains of sand and thus reduces the volume of the mixture. This fact should be kept in mind with the batching of cement, aggregates, water and admixtures (ibid:13).

2.6 THE WATER : CEMENT RATIO

Water is not measured, but is slowly mixed into the cement until the desired workable mixture is obtained (Anon., 1995:10). Keep in mind that admixtures reduce the water ratio. According to Schodek (1993:263) the strength of concrete critically depends on the ratio

between the amount of water used during the mixing process and the amount of cement present.

- The drier the mixture, the lower the water : cement ratio, and the stronger and more durable the concrete (Olson, 1988:19).
- Any excess mixing water will reduce the density and strength of the concrete. It will also increase the shrinkage, which will result in cracks (Anon., 1995:10).
- Excess water will also result in a too sloppy mixture, which will not adhere to the framework.
- Always use clean, drinkable water free from chemical substances that might react with the cement (Anon., 1995: 10).

2.7 BATCHING AND MIXING OF THE CEMENT

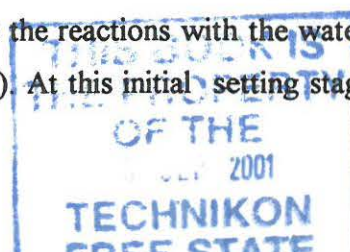
According to Dalzell (1955:32) accurate batching of cement, aggregates and admixtures will result in better consistency control of batches, especially needed when working on large sculptures. In the past it was customary to specify and batch cement and aggregates in proportions by volume, for example one proportion of cement to three proportion of sand. This tended to be inaccurate due to the volume-weight differences between the cement and aggregates. Thus, it is preferable to batch cement and aggregates by weight (ibid:32).

- Cement must preferably be mixed on a clean steel plate or a smooth, clean concrete floor.
- Never mix cement directly on the ground, as this might result in contamination (Addis, 1994:8).
- Smaller mixtures can be mixed in a wheelbarrow, or in a plastic or metal container
- It is preferable to make use of a spade or a mallet-shaped spatula to mix the cement. Never mix cement with a oblong-shaped tool, such as a piece of pipe ,as it will not be properly mixed (ibid:9).

Always make sure that the cement and aggregates are properly mixed.

2.8 SETTING OF CEMENT

After water has been added to cement, the cement paste forms immediately, and for a short period it can still be moulded or shaped. However, as the reactions with the water continue, the concrete begins to stiffen or set (Dalzell, 1955:11). At this initial setting stage, it is still



possible to disturb or reshape the mixture without damaging it. When the setting continues, the mixture loses its plasticity, and if it is then disturbed or reshaped, its strength will be seriously impaired. As more time elapses, a period commences when the mixture reaches a final setting stage. After this period, the mixture cannot be disturbed without seriously affecting its strength and dependability (ibid:11). Once the concrete has set, this hardening action continues, building up a firm internal structure that gains hardness and strength, as long as the cement is kept wet. The duration of this process depends on the type of cement used.

2.9 SHRINKAGE OF CONCRETE

According to Dalzell (1955:12) shrinkage is a natural characteristic of concrete, and is unavoidable. Martin (1995:611) suggests that there is a relationship between drying shrinkage, cement content, water-cement ratio and total water content. Excessive water in concrete increases drying shrinkage and the potential for crack development. If a concrete mass undergoes a relatively mild volume change due to varying conditions of exposure, it will slowly shrink over a period of several months, as the moisture contained in the mass slowly evaporates due to exposure to the atmosphere. Shrinkage occurs rapidly during the initial drying stage. If the concrete is not protected from quick loss of moisture and resulting shrinkage after curing, it may result in serious cracking. Therefore, it is important not to use excess water during the mixing stage. To make sure that excessive shrinking does not occur, it should be kept wet and covered to slow down the evaporation of water in the concrete and to keep it from drying out.

2.10 CURING OF CONCRETE

Schodek says (1993 :263) aluminium powder helps prevent shrinking during the curing stage. To obtain the desired strength in concrete, it must be left undisturbed during the curing process. Curing is a very important stage, and it should be done properly to ensure durable end results. According to Addis (1994:9) water is essential for the hydration of cement, and concrete ceases to develop strength when it dries. If concrete dries before it has developed sufficient strength, the shrinkage of the concrete will result in cracks. Water loss is preventable by covering the concrete form with damp bags, preferably hessian or cloth bags. Plastic bags and sheets do not provide the desired coverage, as they allow too much evaporation to assist the curing process. Addis (ibid:9) suggests that the concrete form be covered for 10 days and kept constantly wet during this period with a moist spray. If the

sculpture is small enough, it should be covered for four days and immersed in water for the remaining days.

2.11 TEMPERATURE

CONCRETE IN COLD WEATHER

According to Addis (1994:9) concrete's temperature should never fall below 5°C before and during placing, or below 4°C before it has hardened. Cement ceases to develop strength at freezing point, and is permanently damaged in the process.

2.12 AGGREGATES

An aggregate is the inner-bulk or portion of a concrete or a cast-stone mixture, that gives it its body. Aggregates must not react chemically with the cement, particularly if the finished object will be subjected to the environment (Doran, 1992:16/3). According to Neville (1981:118) the quality of aggregate is of considerable importance. The properties of aggregates greatly affect the durability and structural performance of concrete and may limit the strength of concrete. Therefore it is important to use the highest quality aggregate, because an aggregate can influence the overall performance and strength of the concrete. Aggregates should be: clean; chemically stable; physically strong; aggregate particles should not easily pulverise, and should not possess structural weaknesses such as layers or planes (ibid:118). Aggregates should also be: free from quantities or substances that reduce bondage with aggregates, e.g. clay and oil coatings; expanding, e.g. bituminous coal; decomposable, e.g. organic materials; able to attract moisture, e.g. salt (Everett, 1994:124).

Well-graded aggregates consist of varying sizes of particles that interlock, leaving fewer spaces to be filled by the cement. This results in a more workable mixture, enabling one to use a lower water : cement ratio. According to Neville (1981:193) aggregate particles of a given size form voids. This can be filled by using a smaller particle size. Everett (1994:124) suggests that grading of the aggregates is a process where by aggregates are passed through a sieve. For example particles that pass through a 5mm sieve are graded as fine aggregates, and those that do not pass through are graded as coarse aggregates.

The following list is descriptive of possible aggregates and admixtures that can be used in concrete:

2.13 LIGHTWEIGHT AGGREGATES

2.13.1 CLINKER

Clinker is a thoroughly burned, fused residue obtained from furnaces, and fired with non-pulverised coal. Clinkers may contain free lime nodules. This can result in severe cracking of concrete due to the expansion of the lime (Doran, 1992:16/20).

2.13.2 FURNACE-BOTTOM ASH

Furnace-bottom ash is fused residue from furnaces that have been fired by pulverised coal (Doran, 1992:16/20).

2.13.3 PUMICE

Pumice is volcanic igneous rock that contains air spaces and has an open texture and is used in plaster, lightweight concrete and pozzolanic cement (Brady & Clauser, 1991:670).

2.13.4 EXPANDED CLAY, SHALE OR SLATE

This is produced by pyroprocessing certain argillaceous materials. Rounded pellets with a hard skin and honeycomb interiors are formed during the heating process by evolved gas (Murdock, Brooks & Dewar, 1991:385).

2.13.5 PROCESSED PULVERISED FUEL-ASH

Processed pulverised fuel-ash is produced by pelletising fly ash and stabilising it by means of pyroprocessing or other methods (Doran, 1992:16/20).

2.13.6 OTHER LIGHTWEIGHT AGGREGATES:

exfoliated vermiculite; expanded perlite; expanded slate; chemically treated sawdust; expanded polystyrene beads.

2.14 HEAVYWEIGHT AGGREGATES

2.14.1 Coarse: crushed marble; granite; white quartz; gravel; coarse river sand.

2.14.2 Fine: marble dust; silica flour; fine sand; vermiculite; talc; steel wool fibres.

According to Neville (1981:148) the presence of moisture in aggregates necessitates correction of the actual mix proportions: the weight of water added to the mix has to be

decreased by the weight of the free moisture in the aggregate and the weight of the aggregate must be increased by a like amount.

2.15 THE IMPORTANCE OF WELL-GRADED SAND

The strength and durability of hardened concrete depends on its density. Adding sand, fibres or powders to cement will increase the amount of water required to wet their surfaces, which will cause the ratio of water to cement to rise. According to Olson (1988:19) sand does not shrink, the use of sand confines the shrinkage cracks to the cement paste between the grains of sand. Therefore, it is very important to use well-graded sand (from fine to coarse sand), so that it is densely packed, and thus minimises the spaces between the grains of sand, in order to confine the shrinkage movement.

2.16 ADMIXTURES

Admixtures are intended to modify the properties of concrete. According to Neville (1981:101) admixtures are used primarily on the basis of experience or ad hoc tests, because theoretical information on a scientific basis is generally not available to permit a reliable quantitative prediction of behaviour in concrete under the various possible circumstances. The manufacturer must always be consulted on the use of admixtures, especially if more than one admixture is used simultaneously. Doran (1992:20/4) suggests that admixtures reduce the water ratio, plasticise concrete for improved workability, and also retard the setting of cement. Everett (1994:116) proposes that, negative side-effects can occur if the admixtures are incorrectly used. The following admixtures are suitable for use with ordinary, rapid-hardening Portland cements, but not with other general types of cement:

2.16.1 WATER-REDUCING, SET-RETARDING AGENTS

Water-reducing admixtures generally increase the workability and the adhesiveness of the mixture, and thus the strength of the concrete, as a result of the reduced water : cement ratio. Some water-reducing admixtures also retard the setting of the cement for two to six hours (Doran, 1992:15/12).

2.16.2 FINE POWDERS

Finely ground mineral powders (e.g. chalk and lime kaolin) act as lubricants and improve the cohesiveness by filling the pores in an ordinary cement mixture. If excessive amounts of these

powders are added, it will increase the water : cement ratio, reduce the strength, and increase the shrinkage or cracking tendency (Everett:1994:116).

2.16.3 SURFACE-ACTIVE AGENTS(PLASTICISERS)

“Wetting agents” improve the workability of mixes by reducing the surface tension of water. This allows the water to coat the cement particles more efficiently, and thus improves plasticity. Unfortunately, most of these admixtures reduce the strength of concrete (Everett, 1994:116).

2.16.4 SUPER PLASTICISERS

Super plasticisers exceed the performance of normal plasticisers, and reduce labour in placing and finishing without reducing the durability of the concrete (Everett, 1994:117). According to Olson (1988:19) super plasticisers are very expensive and their use should be monitored. Mixes containing super plasticisers can sag and even cause the shape to change after moulding. This can be controlled by the inclusion of fibres in the mixture and by using less water.

2.16.5 ACCELERATORS

Accelerators increase the rate of setting and strength development of ordinary and rapid-hardening Portland cements by almost 28 days, but they also tend to have side-effects, such as increased heat generation, which may lead to rapid corrosion of reinforcements, and excessive shrinkage. As a result of these side-effects, it would be advisable to first produce a series of test pieces (Everett, 1994:117).

2.16.6 DAMP-PROOFING AND PERMEABILITY-REDUCING ADMIXTURES

These admixtures help to give the cement water-resistant properties. Damp-proofing admixtures prevent water movement by means of capillary action, while permeability-reducing admixtures prevent water passage under pressure. However, no admixtures entirely prevent the passage of water vapour (Everett, 1994:117).

2.16.7 RETARDERS

Admixtures that are based on sugars, starches, zinc oxide or boric oxide retard the setting of cement without significantly affecting its workability and strength (Everett, 1994:117).

According to Neville (1981:107) large quantities of sugar will prevent the setting of cement and can be used when a mixer or agitator has broken down.

2.16.8 SET RETARDERS

Set retarders postpone the setting of cement, and can also extend the workability time. They can prevent setting for many hours or for several days. However, the surface may dry out before curing water is added to a set surface, resulting in a weak concrete. Unfortunately, many set retarders do not extend the plasticity qualities of the fresh mixture, which is important in direct modelling (Olson, 1988:20). According to Neville (1981:107) retarders tend to increase the plastic shrinkage, because the duration of the plastic stage is extended, but the drying shrinkage is not affected.

2.16.9 EVAPORATION RETARDERS

In hot weather with dry winds, a fresh mixture may lose enough water to shrink and develop plastic shrinkage cracks before it sets. This can be prevented by spraying the object with a fine water mist, but that may also cause the ratio of water to cement to increase. An evaporation retardant can be sprayed on to form a mono-molecular film that prevents evaporation without more water having to be added (Olson, 1988:20).

2.16.10 POLYMERS

Polymers in concrete can: increase strength and durability; improve resistance to wear and tear; reduce permeability and water absorption; almost eliminate shrinkage cracks; improve resistance to freeze damage; increase workability and bonding (Doran, 1992:14/8).

According to Olson (1988:20) polymers are either premixed or impregnated into hardened concrete. A polymer is an emulsion of polymer particles suspended in water, which appears as a milky white liquid, thus reducing the water content in cement. However, polymer-modified mixes lose their workability more quickly than ordinary mixes, especially in hot weather. This is counteracted by cooling the polymer in the refrigerator (do not freeze it!). Polymer-modified cement, unlike ordinary cement, should be kept wet for only one or two days after setting. If it is kept wet for more than two days, it loses its strength. Polymers include acrylic and styrene-butadiene (ibid:20).

2.17 CONCLUSION

Data discussed in this chapter gives the sculptor an overview of properties of cement, aggregates and admixtures. These substances and their uses can dramatically influence the results of concrete sculpture. Not all available data was investigated, only that which was applied in the researcher's practical portfolio of work.

CHAPTER THREE

DESIGNING THE STRUCTURE

Usually we think that the larger the sculpture, the heavier, thicker and the more reinforced the inner structure must be. The sculptor is not limited to proportions and dimensions of the work, but the reaction of stresses and strains on the material need to be considered. Only the types of structures that are used in the researcher's practical work are discussed.

3.1 CONSIDERATIONS IN STRUCTURE DESIGN

It is necessary for the sculptor to be aware of factors that can influence the design of the structure. These factors include design parameters; steel and fibre reinforcement and various internal and external forces. The correct use of those enables the sculptor to produce a structure that is technically sound and functional in various conditions. Below follows some considerations for structure design:

- The development of concentrated loads, e.g. people hanging or swinging from the sculpture can be the cause of tension developing inside the sculpture
- The size limit beyond which a particular structure would be unable to carry its own weight.
- Schodek (1993:283) points out the importance of scale in the proportioning of an object. The strength of objects does not vary directly according to their size. For example, doubling the dimensions of an object does not necessarily double its strength.
- Large objects have an increased surface area that can, for example, create larger wind movement on and around the object, e.g. a towering sculpture. As a result of this the type of form and whether the base is detachable or incorporated is determined by the type of structure used.
- If the object is free standing, movability and environmental forces must be considered. This will enable the sculptor to design a sculpture that withstands these conditions (ibid:283).
- The sculpture's own weight can create strain.
- Each force imposed upon a sculpture will create a reaction that is equal in magnitude, and opposite in direction. Forces at top level will push the sculpture in one direction,

while ground forces will push it in the opposite direction (Schodek, 1993:64). These forces creates tensions inside the sculpture. If the wrong type of structure is used, for example a concrete structure with an inner-frame, the tension on the inside will cause the concrete to crack and seriously impair the long livety of the sculpture.

- The weight and proportions of a sculpture limit the transporting capabilities, and should thus be considered when designing.

3.2 DESIGN PARAMETERS

The following lists and explains the different qualities of materials. The influence that the quality of the sculpture can have, is also emphasised.

3.2.1 DUCTILITY

Ductility is the ability of a material to change shape permanently without breaking (Brady & Clauser, 1991:959). According to Olson (1988:101) brittle material like glass will break when deformed - from this we can see that it is not a ductile material. The steel used as reinforcement can yield to stress concentrations by undergoing small permanent changes in shape, and after yielding, it will continue to serve its structural purpose.

3.2.2 ELASTICITY

This is the ability of a material to resume its original form after the removal of the force which has produced a change in form. A substance is highly elastic if it is easily deformed and then able to recover quickly (Brady & Clauser, 1991:959-960).

3.2.3 THERMAL STRESSES

According to Olson (1988:100) thermal stress is stress due to temperature changes in and around an object. This can be due to sun, wind, rain, etc. While the sun warms the outside of a sculpture, the inside remains cool, which causes strain between the inner and outer surfaces. The less material inside the structure, the less stress occurs between the inside and outer surface. Therefore it is advisable to use a hollow-shell whenever possible. To reinforce against such stresses, it is best to place many small gauge-wires close to the surface, covered with just enough cement to prevent corrosion. Several small panels of wire mesh may also be used (ibid:100).

3.2.4 TENSILE STRESS

Tensile stress is the stress a member will experience when subjected to a tensile force (Brady & Clauser, 1991:962). Concrete does not have the ability to endure high tensile stress. This is why reinforcement is used where concrete is subjected to tensile stress.

3.2.5 SHEARING STRESS

Shearing stress is the stress experienced due to a counter force (e.g. stress formed at the shoulder point caused by the weight of the arm) trying to or slide the material planes apart. See (Fig. 3.1). (Olson, 1988:100)

3.2.6 COMPRESSIVE STRESS

According to Olson (1988:100) compressive stress tries to push the material planes together and therefore is a shortening of the material. In (Fig. 3.1) compressive stress is explained through the demonstration of an arm, where the bending stress is pushing the arm down and the compressive stress is pushing the arm upwards.

3.2.7 VIBRATION AND FATIGUE

Large sculptures can easily be subjected to destructive vibrations as a result of strong winds and the vibration of floors. However, it is difficult to compensate for such stresses during the designing process, as the height, weight and many other aspects have to be taken into account. Horizontal vibrations can be eliminated by firmly attaching the sculpture to its base. Vertical vibrations are minimised by adding more support points to the sculpture and the base (Olson, 1988:101).

3.2.8 BENDING STRESSES

According to Olson (1988:21) any linear objects that are subjected to bending, for example, neck, legs, arms, a branch or stem, will be subjected to tensile and compressive stresses. These developed stresses are greatest on the surface. Therefore, steel reinforcement is best placed close to the surface, with only enough cement cover to prevent corrosion (ibid:21). Usually people tend to think that placing heavy steel rods along the central axes inside the framework is the best placing and support that can be obtained. However, this will only lead to tensile and thermal stresses, where the steel on the inside might stretch further than the elastic capacity of the cement, resulting in cracks. Olson (ibid:21) further suggests that the rods or thick wire, used as reinforcement, should run along the length of the member, as near

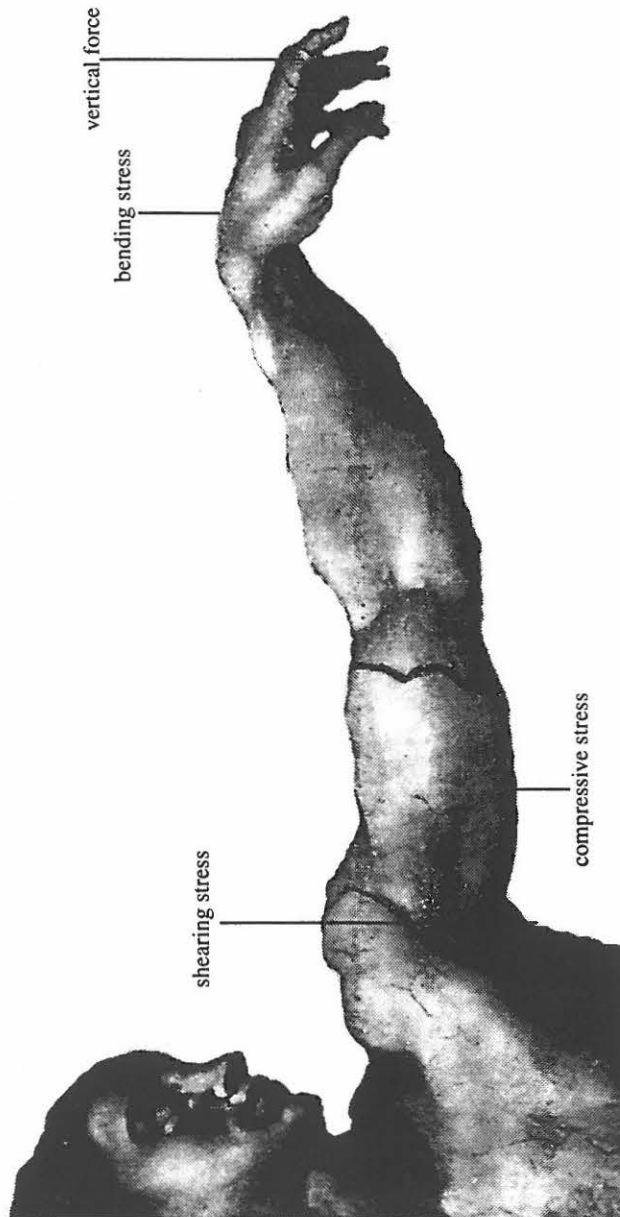


FIG. 3.1

as possible to the surface. Thinner wires should then be spirally wound around them to prevent outward buckling.

3.3 STEEL REINFORCEMENT

According to White (1991:272) concrete reinforced with steel will have an increased tensile strength. Olson (1988:21) suggests when using steel reinforcement, it is important to keep in mind that a matrix of thin rods and wires are more effective than one thick rod. A combination of thick and thin steel rods that are well distributed throughout the cement matrix will enhance strength. According to Olson (1988:39-40) the form is shaped with many steel wires and rods, and the cement mixture is pushed into the gaps. More wires and cement are added as the sculpture develops. This method inclines towards a weighty sculpture. As a result of this, costs accelerate and a solid casting could have been a more financially viable option, although the structure might not be as sound. The amount of reinforcing to be used will depend greatly on the design of the sculpture. Olson (1988:22) further suggests that the reinforcing material must always be free from rust, oil and dirt, to ensure better bonding with the cement. The core structure must be visualised to be of soft material that can sag or bend easily under its own weight. Those sections that will bend most, require the most reinforcement.

3.4 FIBRE REINFORCEMENT

When fibres like steel wool, plastic, bronze and glass are included in the cement mix, it has a twofold function. It will firstly absorb stresses caused by shrinkage and temperature fluctuations. Secondly, fibres can bridge across the tiny beginnings of cracks, preventing them from expanding into larger cracks. When fibres are added, it also increases the tensile strength of the concrete (Olson, 1988: 22).

3.5 VARIOUS STRUCTURES

Three different armatures are discussed. The first armature to be investigated is the shell design, where the cement is applied to a hollow framework. The second design is the reinforced steel armature. This type of structure tends to be the strongest, because of its solid reinforced construction. The third is the polystyrene core-based structure. Here the sculptural form is carved out of polystyrene, which then forms the inner core. These three structure types are applied to the researcher's work and observations and results thereof will be discussed in Chapter Six.

3.5.1 THE SHELL DESIGN

Hurd (1985 : 270) refers to the sculptor Nassoux, who designed and made the sculpture *Isadora* (Fig. 3.2). Nassoux used a shell-shaped design. According to Hurd, the strength of the design depends on the shell, since the cement is applied very thinly.

- The form of the sculpture is constructed with mild steel rods, leaving the inner volume of the structure hollow. More round bar is used in this armature than in the others. This is to create as well as reinforce a surface for the attaching of the wire mesh.
- Wire mesh is placed over the structure, and secured with wire to the structure. Three to five layers of wire mesh can be applied. It is preferable to use small pieces of mesh that overlap each other rather than one large piece. This creates a firmer surface to which the first layer of concrete can be applied (ibid:270).
- When designing a one, two or four-legged sculpture, it is advisable to use thicker rods at the bottom, which interconnect with the upper part of the body. The framework is covered with wire or steel mesh, which is further reinforced by winding steel wire around the structure.
- When this type of framework is used, it is advisable to use a fibre-rich mix in the first layer of cement, for better adherence to the framework. Depending on how simple, intricate or large the framework is, it might take multiple-layered applications of concrete to cover the framework.
- The concrete surface is roughened for better bonding with the second layer.
- When the work is done in stages, the finished parts should be kept moist and covered. The first part might be in its curing stages at the beginning of the next session. If it is not kept sufficiently moist, the sculpture will not cure properly, resulting in reduced strength and crack formation creating a poor bonding surface for the next layer of concrete. When moist cement is applied, the dry concrete will retain moisture from the fresh batch, causing cracks. These cracks will appear on the attached section, which might lead to serious concrete failure.

3.5.2 REINFORCED STEEL STRUCTURE

With this type of structure, it is possible to work quite finely and delicately. Depending on the scale used, steel rods or wire are used to form the sculpture. The artist may use the linear quality of the metal rods as a tool with which to draw. (Fig. 3.3) shows the various steps to follow when manufacturing a reinforced steel structure.



FIG. 3.2 Isadora

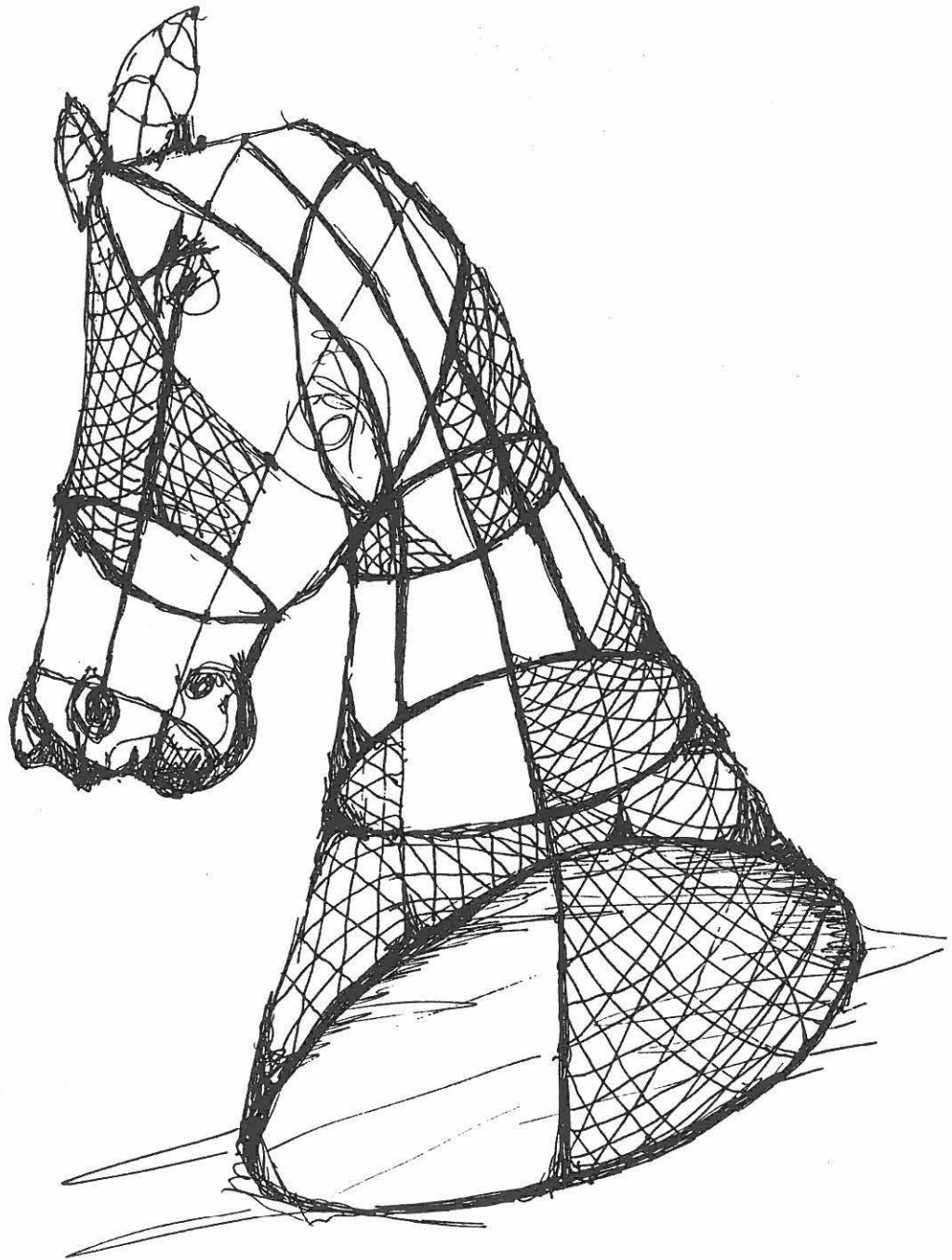


FIG. 3.2.a The shell design.

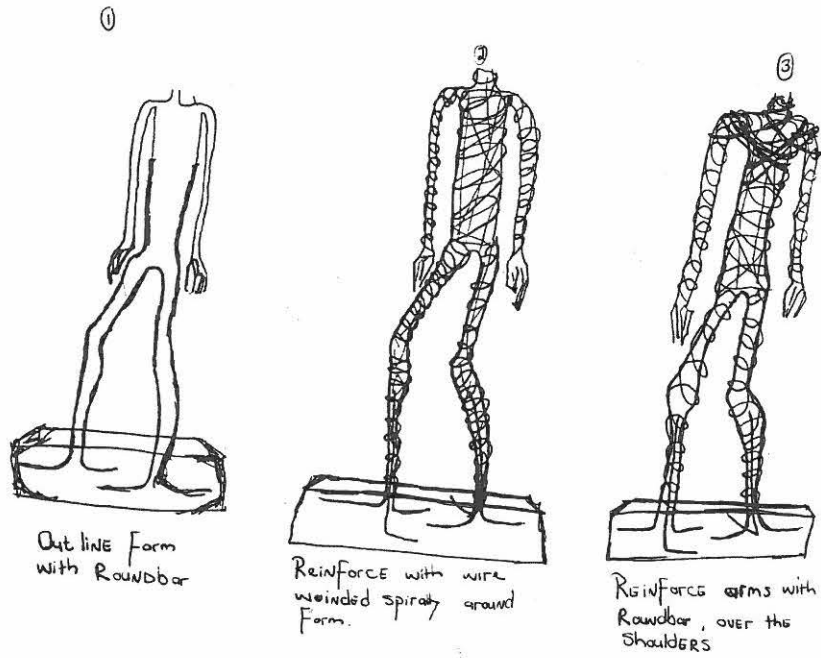


FIG. 3.3 Steps on how to do the Steel reinforced framework.

- An inner framework that runs down the axis of the sculptural form should never be used, as this builds up tension forces inside the sculpture, especially if the central axis is connected to a base (Olson, 1988:52). In (Fig. 3.4) the incorrect and correct frameworks are demonstrated.
- The form is outlined with steel rods or wire. Thereafter, wire is spirally wound around the form so that the cement can be pushed between the wires to form a cement core. More wires are attached around the form, close to the next layer of cement. The more fine wires used for reinforcement, the better. By doing so, one will gradually build up the form.
- For a more elaborate work with one, two, three or four legs, the heaviest rods are placed from the bottom up. Olson (1988:39) also suggests that, if one forms a leg, for example, one must use two of the heaviest rods to shape it, spaced as far from each other as possible, with one rod close to the front and back of each leg. Thinner rods are applied generously at the top. Olson (1988:40) further suggests that those sections that bear the most stress, like ankles, neck and the places where the arms connect to the body or any other bend, must be properly reinforced with the wire spirally wound around the form, to prevent buckling of the rods.
- The base forms an important part of this structure, especially the connection of form to the base. This type of structure results in a heavier sculpture. If a base is required, Olson (1988:40) suggests that one should make it in two parts, with the smaller part attached to the feet, provided with holes for bolting it to a larger section. With this type of structure, one can produce a design that does not need a base and which is supported by its own weight.
- Depending on the intricacy of the design, and whether it should be moved to another location, for example, the reinforced steel structure is not recommended for a sculpture with a large inner volume. If the sculpture does have a large inner volume, it will be quite heavy and not easy to move. Problems might arise with the different concrete layers, if the batching of aggregates and admixtures is not consistent. The result is different curing and setting times that cause surface cracks. If the surface is not properly moistened between layers, the dry layer will absorb moisture from the fresh concrete, which will cause premature drying of the concrete before the curing stage has started. This will have a serious effect on the development of strength in the concrete. As a result of this, it is important to be consistent in the batching, mixing and curing of concrete.

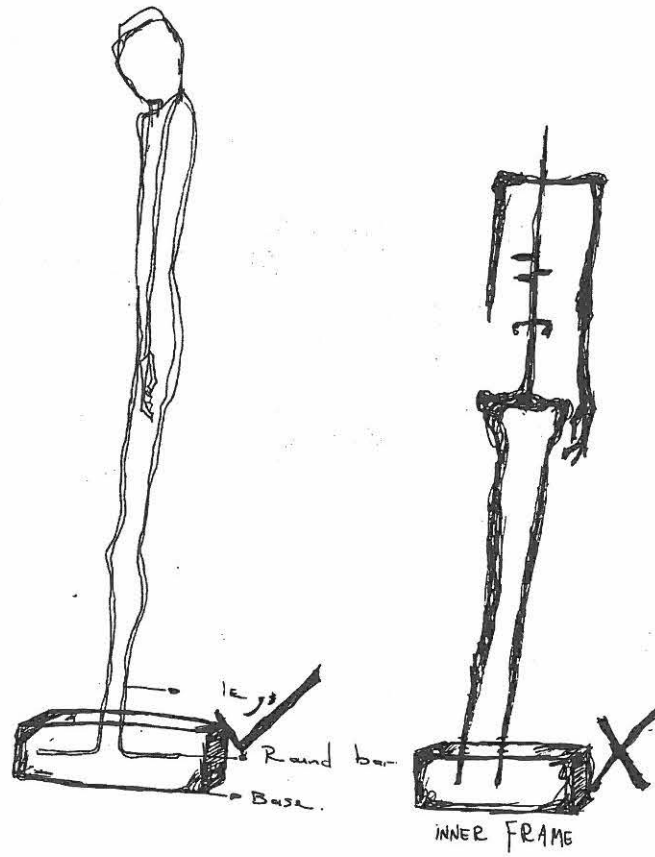


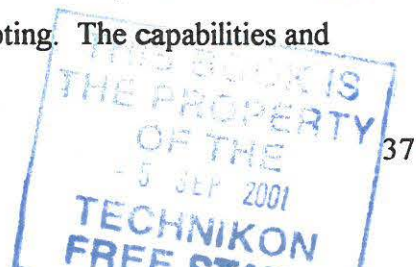
FIG. 3.4. The inner frame.

3.5.3 THE POLYSTYRENE CORE STRUCTURE

This type of structure is ideal for a sculpture that requires a large inner volume. It is light in weight and by carving the desired form prior to concrete application, one is able to have a clearer idea of what the end result will look like.

- Polystyrene is available in large blocks, but smaller pieces can also be glued together. The form is achieved by cutting the polystyrene with a saw, bread-knife or NT cutter, depending on how much is to be cut away. The form can also be shaped with a gas flame or with heated wire.
- Considering the amount of concrete to be applied, an overall layer of 2 cm is taken off the final polystyrene form using a rasp (Addis, 1994:44).
- The polystyrene surface should always be sealed. PVA paint is suitable for this purpose. According to Addis (1994:44) it prevents loose, polystyrene particles from contaminating the concrete.
- Nails are pushed into the polystyrene surface to allow better adherence of the concrete to the surface. Steel rods are placed around the form for reinforcement purposes (Addis, 1994:45).
- Polystyrene is not as strong as steel, and is merely a way of achieving the form and filling up the inner core. If this type of structure is not properly reinforced, it collapses under its own weight. It is suitable for a design that would otherwise require too much inner volume (Fig. 3.5), and the polystyrene fills up the inner space, resulting in a lightweight sculpture. How to shape and reinforce this structure is shown in (Fig. 3.6).
- The work should not be too thin when the inner core is shaped. The polystyrene tends to break under the weight of the concrete while it is still wet, whereas in the case of the reinforced steel structure, the work can be relatively thin, e.g. a ribcage.

In this study, the three identified structures are examples of successful structures previously used, and bear close relation to the type of structures suitable for this research. The researcher's experience gained with these structures has been included in this chapter. A minimum of two sculptures were made using each of the three structure types. Additional sculptures were produced using an experimental structure. Previously researched structures have been modified to suit the researcher's own style of sculpting. The capabilities and



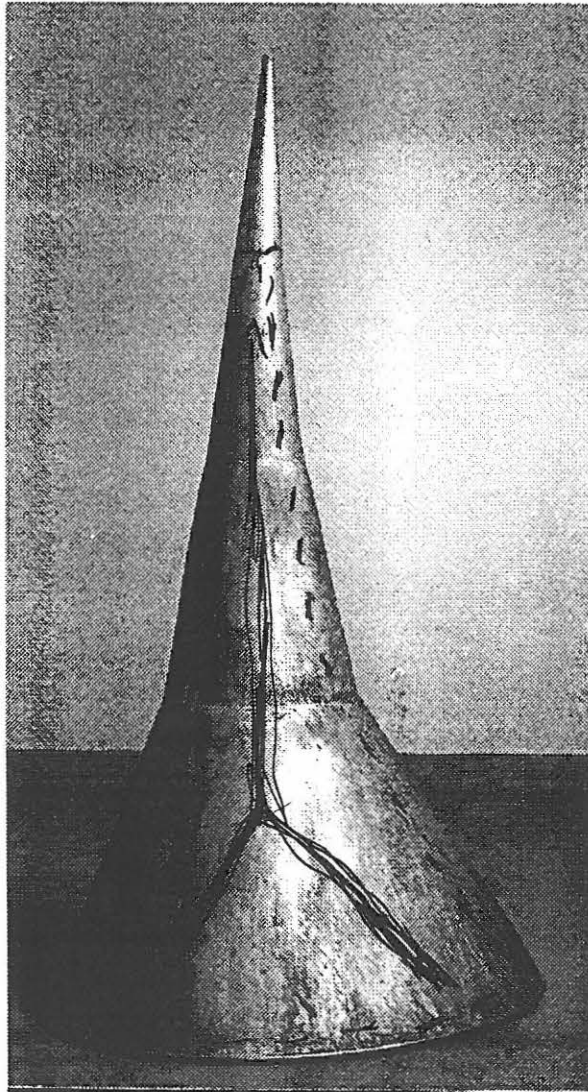


FIG. 3.5 Inner volume

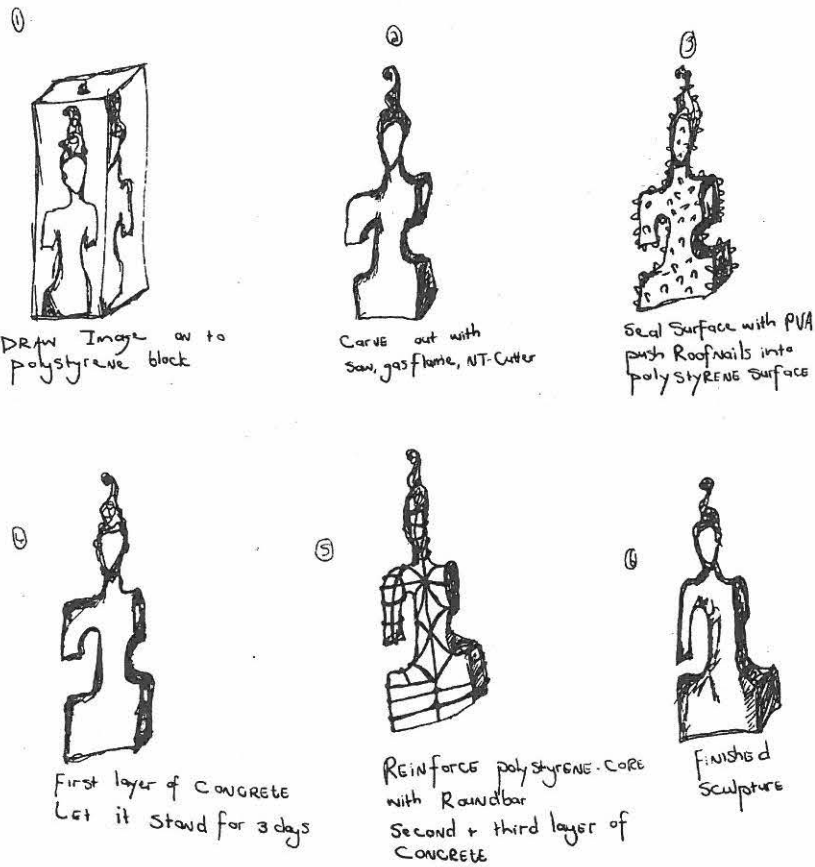


FIG. 3.6. How to shape the polystyrene structure.

restrictions of each structure will be discussed in Chapter Six. The practical work attempts to explore the boundaries of each structure type.

**THE IMPORTANCE OF THE BASE, AND THE DETERIORATION
OF CONCRETE****4.1 THE IMPORTANCE AND FUNCTION OF THE BASE**

Generally the main function of a sculpture's base is physical stability. According to Schodek (1993:58) one of the most important aspects of a sculpture is that it should not topple over in any situation. Because the base acts as a stabilising factor, the following should be taken into account: where the sculpture is placed, how the base and sculpture are secured to each other, and how the base is attached to the sculpture's surface. All these aspects influence the longevity of a sculpture. According to Schodek (1993:66) if a sculpture were attached to the base, by connecting bolts, the work would be stable. But if a wind force were sufficiently strong to overcome the balancing moment of the sculpture, the force would create tension in the connecting bolts. The sculpture will not overturn as long as the bolts can resist the tension force. This applied to types of sculpture in both steel and concrete. (Fig. 4.1) shows an example of connecting bolts stabilising the sculpture to its base. The following points on the base and attachment therefore should be considered:

- Sculptures can be stabilised by: their own weight, distributed support points and the base attachment. These should be taken into account when designing the structure.
- Indoors: The display environment and location is of importance to the work, as well as considering factors such as people traffic and installation (Schodek, 1993:303). These factors might cause the sculpture to become unsafe if not taken into account.
- Outdoors: Laterally acting forces that act primarily in a horizontal direction, such as winds, should be considered. In larger works, overturning due to laterally acting loads can be life threatening (Schodek, 1993:61). When these forces are taken into consideration the sculptor is able to construct a sculpture that will function in these conditions.
- Initial ground movements: Ground movements due to earth tremors or the ground shifting over the years, sets the mass object in motion. Once in motion, the initial



FIG 4.1

tendency of the mass is to remain in motion in the direction first taken. Soon the mass might be moving in one direction, while the shift of the ground might suddenly reverse its direction. The sculpture is then pulled in one direction while the pedestal beneath it moves in the opposite direction. The sculpture could topple over or slide (Schodek, 1993:69). Therefore the sculptor should not use a type of base that has to be embedded in the ground or a base that's attached rigidly to the sculpture itself. A base that allows for movement with the earth surface is most suited. (See Fig. 4.2).

- The size, height and weight of the sculpture.
- The temporary or permanent location of the sculpture, will indicate what type of base is to be used. In a temporary location a base that is easy to dismantle and move should be used (ibid:69).

The importance of the base in concrete sculpture cannot be overlooked, especially where base attachments can cause structural stress inside the sculpture, resulting in cracks. It is crucial when designing the structure to consider the requirements for the base. More common designs are either a sculpture standing on a base or a free-standing sculpture. Below lists a discussion of the basic points to consider in the three base constructions.

4.1.1 THE HEAVY BASE

According to Schodek (1993:58) in the case of large sculptures, the heavier the base the less likely the sculpture will overturn. Stability can be increased by widening the base of the sculpture (Fig.4.3). However, the heavier the base in relation to the upper part of the sculpture, the closer the centre of gravity will be to the base. Schodek (1993:60) suggests that the lowering of the overall centre of gravity tends to improve stability, and sculptures are much less likely to overturn under their own weight, whether the base is attached to the surface or not (See Fig. 4.4). Large and heavy bases tend to create problems if the base is very high or has to be portable. Lateral tension forces, the stability of the surface and the attachment of the base, must be considered (ibid:61). One solution is to incorporate the base in the structural design as part of the sculpture. Giacometti's *Tall Figure* (Fig. 4.5) is an example of how the sculptor can incorporate the base and the sculpture. However, this will result in a very heavy piece of sculpture (especially if it is large), that will make movability difficult, but might decrease the possibility of structural tension inside the work. Another possibility is to incorporate a lightweight base, which is attached to a heavier, stable base,

FIG. 42

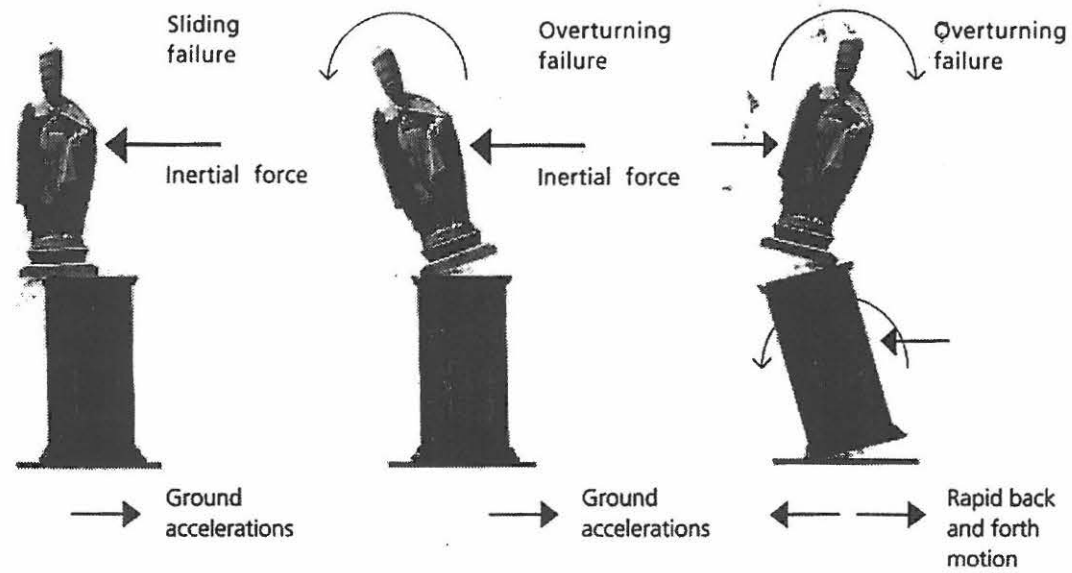




FIG. 4.3 Widening of the base.



FIG. 4.4



FIG. 4.5

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making the sculpture more portable (ibid:63). However, the method used for attaching the two bases to one other can cause force and structural tensions, and should be carefully considered. This aspect will be discussed later in this chapter.

4.1.2 THE SCULPTURE'S OWN WEIGHT

A sculpture that balances on its own weight either has a wide base or multiple support points. The base becomes an extension of the sculpture. When a base or pedestal is not desired as part of the sculptural design, the sculptor can use distributed support points to introduce stability. According to Schodek (1993:64) the number of support points are crucial. Two support points are unstable. Where a triangle is formed, the sculpture is positioned with two points touching the ground and a third acts as a counter balance, see (Fig.4.4). Three points are needed for stability, and are most suitable for keeping the sculpture upright (Fig.4.6). Four points in a sculpture tend to wobble, due to the difficulty in equally balancing the four points (ibid:64). Three points are the most stable due to the triangular formation, where the centre of gravity of the weight lies above the triangle formed by the support points. This will ensure that the sculpture will not overturn. However, when the upper mass causes the centre of gravity to fall outside the triangle formed by the support points, the sculpture is inclined to topple (Fig. 4.7). Balance is a crucial factor in the designing of a structure. According to Schodek (1993:61) it is better to keep the larger mass (thus the centre of gravity) near to the ground and the lighter mass at the top.

4.2 FUNCTIONAL BASES FOR CONCRETE SCULPTURE

It has become imperative for the sculptor to consider technological developments when producing work. The discussion on functional bases is to make the sculptor aware of certain bases which can be used in the design. The focus falls on three types of bases that co-operate with the structures discussed in Chapter Three. Note that the following only serves as a guideline:

4.2.1 BASE INCORPORATED DESIGNS

When designing the base within the structure, the following points deserve attention:

- The proportions, design and scale.
- The influence of balance on the type of design.
- Environmental forces, e.g., wind, sun, etc.

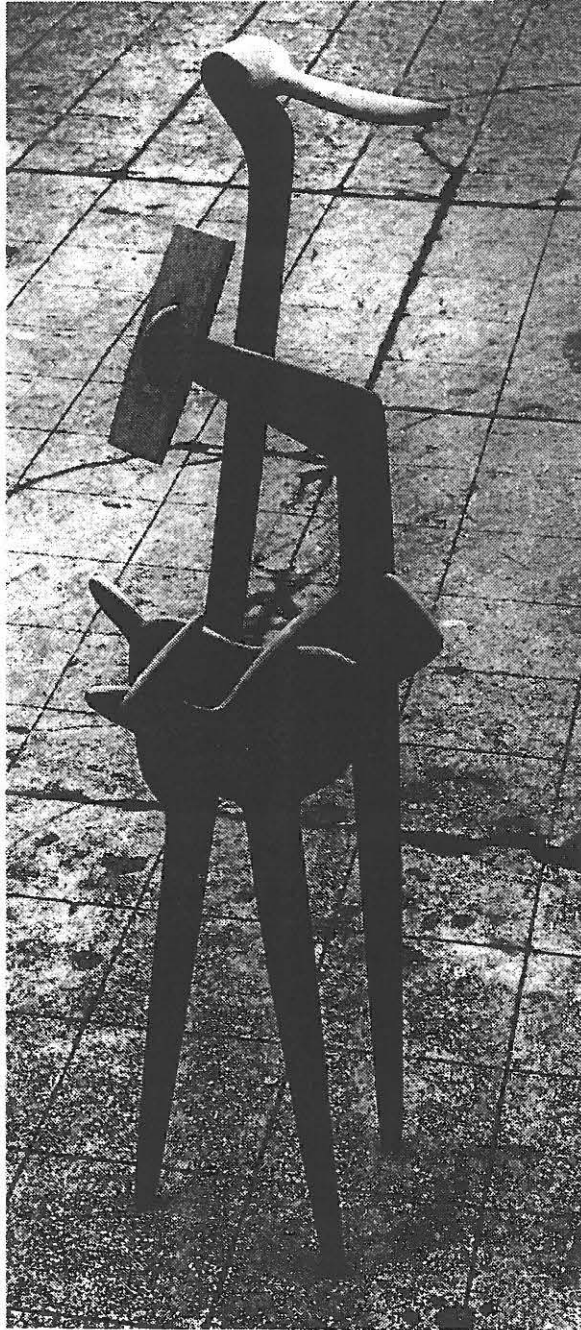


FIG.4.6 Three distribution points

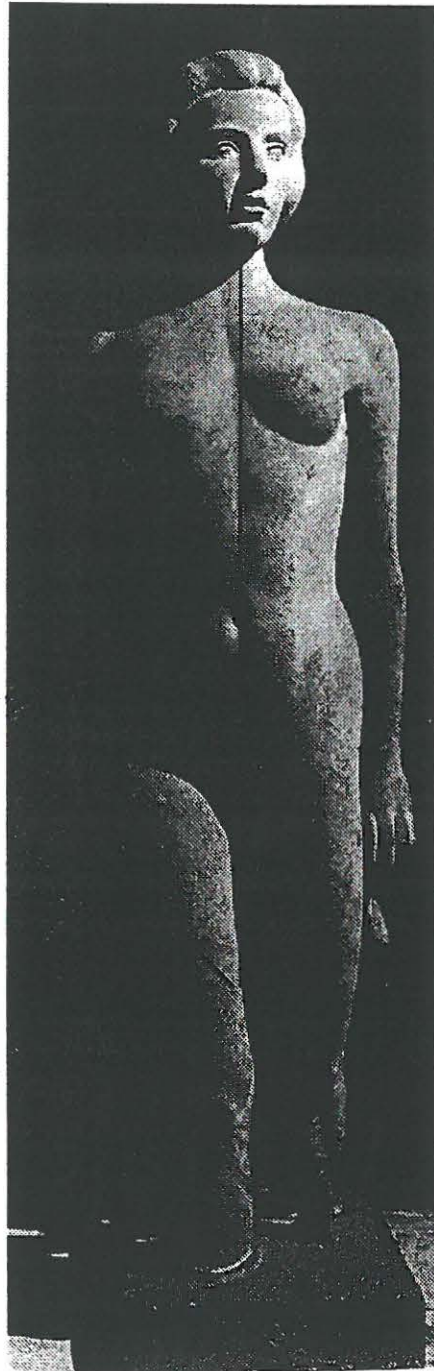


FIG. 4.7 The center of gravity

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This kind of base is not attached to a heavier base or the surface to prevent it toppling. If this is not properly balanced the sculpture will overturn. The bottom part of the sculpture should balance the top. With this base one can create functional as well as aesthetically pleasing sculptural works, because the base is part of the sculptural form itself (Fig. 4.8 and Fig. 4.9).

4.2.2 BASE ATTACHED TO A POLYSTYRENE CORE

With a large sculpture, a smaller base is incorporated in the structure and attached to a larger and heavier base. This makes the sculpture more portable. Addis (1994:50) uses a temporary wooden base, fixed to the bottom of the polystyrene surface. He also suggests that one can use wooden plugs glued into holes in the polystyrene to receive screws.

4.2.3 BASE ATTACHED TO THE SHELL AND STEEL STRUCTURE

Heavy metal bars or concrete slabs can be used as bases. Again the type and weight of base will depend on the function, movability and structure of the sculpture. One can create functional and creative bases, that will complement the sculpture. The base is attached to these structures in many ways. Holes can be drilled into the concrete while it is still wet, to receive the base, which can have screws or a steel pipe inserted (Olson, 1988:76-84). The sculpture can either be shifted onto the base or screwed on. With the shell structure it might be more functional to shift the base and structure onto each other.

4.3 POSSIBLE CAUSES OF CRACKS IN CONCRETE

Cracks in concrete can seriously jeopardise the longevity of the sculpture. This is why it is important to be aware of what contributes to crack formation. Below follows a list of elements that could influence the causes of cracks in concrete:

4.3.1 WATER

Water must be free from substances that can react with the cement or admixtures. Water suitable for drinking can be used. Too much water used in a mixture, will intensify the shrinkage movement causing cracks. The driest possible mix must be used.



998

436

FIG. 4.8. Base Incorporated.

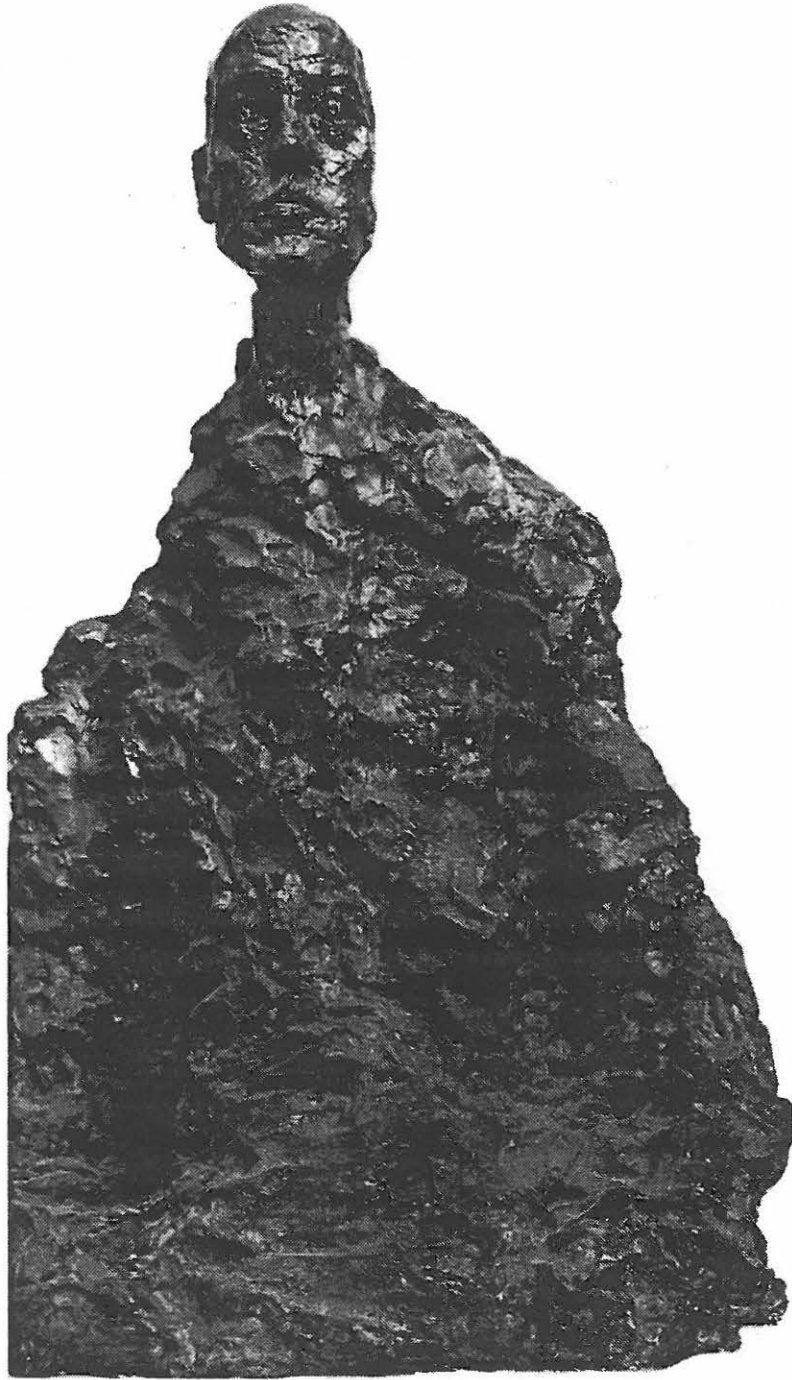


FIG. 4.9

4.3.2 ADMIXTURES

The manufacturer must be consulted before admixtures are used and instructions must be followed carefully. Be certain which admixtures can be used together. Some admixtures, when combined, can alter the properties of each other and the cement. Too much admixture in a mix will alter the properties of the cement. The result is concrete that might be brittle and reduced in strength. Always make trial batches to ensure the correct amount added and the span of time the cement can be applied, in order not to damage the strength and properties of the cement. Refer to admixtures discussed in Chapter Two.

4.3.3 CURING

Curing is the most important stage in concrete sculpture making. According to White (1991:109) rapid drying of the concrete causes strength reduction and plastic shrinkage cracks, and if too much water evaporates, hydration of the concrete will not be completed. Always keep the sculpture moist and covered during the curing period. Moisture tends to reverse some of the natural shrinkage in concrete, causing fewer cracks.

4.3.4 GRADING OF AGGREGATES

A batch consists of aggregates ranging from fine to coarse, results in a dense mixture that reduces the voids between aggregates that can be filled with water. This reduces the shrinkage movement, and by adding fibres, even more so. Aggregates must be clean from substances that can react with the cement or admixtures. Sand must be thoroughly graded. Not using the full range of graded aggregates enhances the tendency for cracks to occur. Refer to Chapter Two.

4.3.5 STORAGE

Cement must be properly stored to prevent moisture contamination, which might cause the formation of lumps. This can alter the properties of the cement. If the lumps cannot be easily crushed with the fingers, it is not suitable for use. Damaged cement should never be used (Anon., 1995:10).

4.3.6 STRUCTURES

There is usually a film of oil or grease on metal bars and wire, which might make cement adherence to the metal difficult. Make sure that the metal bars are clean. The surface can also be roughened for better adherence. In designing the structure, look out for stress points.

Such points should be sufficiently strengthened. However, over-reinforcement of the design with thick rods might result in cracks.

4.3.7 CEMENT : WATER : AGGREGATE RATIO

The volume of the material strength must be considered when batching cement, water and aggregate. Too much cement will make the concrete brittle and weak. If too many aggregates are used to the cement ratio, there will not be enough cement to cover the surface of the aggregates, making the cement unable to bind the materials together. The amount of water added, must allow for a workable mixture. Too much water will increase the shrinkage movement. A good volume of mix is one part cement to two or three parts aggregates. Refer to Chapter Two.

4.4 CONCLUSION

It is important to be aware of the technical aspects when working with concrete. Understanding these could eliminate possible dangers that might result in technically unsound work. Corrosion destroying the inner support system or using the incorrect type of structure are the main aspects to be avoided. The understanding and correct application of data discussed in this chapter allowed for further experimentation with the limitations of the structure.

CHAPTER 5

THE SURFACE FINISH

5.1 APPLICATION IN FRESH CONCRETE

Intricate patterns and textures can be obtained by pushing objects or stencils onto the surface or the dragging and raking of objects across the surface. The use of either wooden or metal stencils can produce an interesting patterned surface. Textures can also be obtained by using brushes, forks and sticks (Olson, 1988:24) Objects such as shells, glass, wood, metal and bones can be pushed into the wet cement for embellishment.

5.2 WORKING THE HARDENED CONCRETE SURFACE

According to Addis (1994:47) on hardened concrete, detail and subtle surface modelling is achieved by means of using a number of tools, including stone-carving chisels and engraving tools which are suitable for fine work. Excess material can be removed, or intricate shapes can be cut into the concrete's surface with a grinder. A masonry disc must be used.

As a safety precaution the eyes, nose and mouth should be protected from dust. The work should be done in a well-ventilated area and a respirator should be worn to prevent the inhalation of concrete dust. Cement, whether wet or dry, should never be allowed to come into contact with any part of the body (ibid:48).

According to Olson (1988:24) rasps and files are used to work off the final concrete surface, and these range from coarse, medium and fine. A dull rasp should be used when concrete has just set, before it acquires enough strength to securely hold the sand grains. Bronze, glass, plastic and steel fibres are softer than the rasp and can be worked as the concrete hardens. When the cement is firm enough to hold the fibre (but still soft) a coarse rasp should be used. Finer rasps or files are used as the concrete hardens. Files tend to wear down quickly, so second-hand files rather than new should be used. Rasps leave a gauged mark, which can be removed with a fine file, or be left to create texture. Silicone carbide paper can be used wet or dry, and will remove small granules of hardened concrete, creating a smooth surface. If fibre is used in the concrete, textures of the fibre grain can be revealed by using this paper.

The surface should be wet to avoid airborne dust. This paper is not as durable as a rasp and tends to wear down quickly (ibid;224).

5.3 BURNISHING

According to Olson (1988:25) when the surface is dry and hard it can be burnished to a glossy appearance. A steel wire brush, inserted in an electric drill, can be used on a rough surface. The brush should be tested on the cement surface at different curing stages, to determine optimum hardness for burnishing. Burnished surfaces need a protective coating, e.g. (ibid:25)

Cemcrete`s Concrete sealer is a non yellowing clear polymer emulsion that seals the concrete surface against corrosion caused by carbonation.

5.4 ACID WASHING THE CONCRETE SURFACE

According to Addis (1994:48) acid washing removes a thin film of cement paste from the surface. The concrete surface should be properly wet, before an acid wash can be applied. The surface should be washed with water afterwards. The acid wash can be applied with a broom or just poured over the surface. After the acid wash has been washed off, the concrete surface should be allowed to dry out slowly. Depending on the effect one requires, repeated acid washings may sometimes be necessary to obtain the optimum results.

Safety precautions: When working with acid, waterproof rubber gloves and splash-proof eye protection should always be worn. The acid should never be applied to a dry concrete surface and should never be allowed to dry on the concrete (Addis, 1994:48).

5.5 COLOURING CONCRETE

Concrete sculptures can be coloured with the following: white and coloured cements; coloured admixtures; mineral oxide pigments; chemical stains; dry-shake colour hardeners; acrylic paint washes; oil-paint; decorative paints;

Since there are many possible ways of achieving the desired appearance, there should be one major concern: to minimise maintenance. In applying the final surface finish, factors that have an effect on the final result must be considered. These include not only cement and aggregates, but also finishing textures and methods of curing. Methods for colouring concrete are described below.

5.5.1 WHITE AND COLOURED CEMENTS

Coloured Cements

According to Dabney (1982:21) there are four general types of cement, other than standard grey Portland, that affect colour. All of these types can be used to produce integrally coloured concrete. The costs vary considerably, owing to the different pigments that are used. Some pigments are made of more expensive materials than others, especially the colour green.

White Portland Cement

This is manufactured with minimum quantities of iron and manganese oxide. It is generally used for architectural concrete structures and is mixed into mortar, cement paints and other types of decorative concrete, where white or a bright colour is desired. For an opaque white appearance more pigment is added to decrease the transparency (Dabney, 1982:21).

Standard Portland Cement with a Light Tint

This type of cement is lighter than normal grey, or a slight tan shade. The colour results naturally from the particular raw materials used to manufacture cement (Dabney, 1982:21).

Special Coloured Cement

This cement is specifically manufactured in various shades of tan. Some of the tan shades are quite bright, but tend to lose intensity with age (Dabney, 1982:21).

Pigmented Cement

In this cement, the manufacturer blends pigments with Portland cement (generally white). Excellent results can be obtained by combining coloured cements with coloured mixtures. This is more expensive, but often an exact desired colour cannot be obtained in other ways (Dabney, 1982:21).

5.5.2 COLOURED ADMIXTURES

According to Barker (1983:2) admixtures are added to concrete during mixing. These are termed admixtures rather than aggregates. According to Dabney (1982:21) colouring concrete by using a coloured admixture is suitable for both flat-work and vertical concrete. Coloured admixtures increase strength and durability, and improve the workability of the

cement. Admixtures reduce the water requirement for concrete, hence there is less colour bleeding, latency and efflorescence (ibid:21).

5.5.3 PIGMENTS

According to Dabney (1982:23) pigments are usually a colouring agent, in powder form, that are directly added to the cement in the mixing process. Technically these must be considered admixtures by virtue of the way in which they are added to concrete, but they are not in the category of chemical admixtures. Pigments must be carefully selected and proportioned. The advantage of using pigments rather than pigmented admixtures, is that pigments are usually less expensive and more easily available. However, the colour tends to fade in the sun (ibid:23).

5.5.4 CHEMICAL STAINS

A different method of colouring concrete is by chemically staining the cured concrete. Interesting effects can be achieved. Stains have enhanced special formed concrete in zoo displays, fountains and other decorative projects (Dabney, 1982:23). According to Taylor (1994:46), chemical stains are water solutions of metallic salts that penetrate and react with the concrete to produce insoluble, abrasion-resistant colour deposits in the pores of the concrete. Stains will not hide surface defects or existing discolourations and are available in black, green, reddish brown and various shades of tan. Concrete stain colours are limited by the chemicals used. The colour produced is not merely a surface coating; it penetrates to a limited depth (ibid:46). Dabney (1982:23) suggests that stained surfaces require maintenance by applying coloured wax or coloured sealers. The colours of the stained surface vary in shade, as do stone and other natural materials, unless the surface is subsequently treated with coloured wax or coloured sealers. For weathered or badly worn concrete, brown or black stains usually give the best results.

5.5.5 DRY-SHAKE COLOURS

Taylor (1994:45) states that dry-shake colours are basically dust-on colours, that can achieve vibrant colours, ranging from pastels to sharp blues. The more dry-shake colour one uses, the brighter the colour will be. Costs vary according to brightness of colour. An intense colour requires more pigment than a pastel shade.

5.5.6 ACRYLIC PAINT WASHES

These require a mixture of acrylic paint: artist colours or wall-paint mixed with water. The volume of paint to water will depend on the result the sculptor wants to achieve. If more paint is used in the volume of mix, the wash and colour will be intensified. Several repetitions are necessary before the required results are achieved. The surface should be allowed to dry before the second wash is applied. Washes of different colours can be applied over one another (Addis, 1994:49).

5.5.7 OIL-PAINT

Artist's oil-paint can also be used to colour concrete. Oil-paint can be diluted with linseed oil or ordinary cooking oil. Linseed oil also acts as a sealant. Coloured oil washes can also be applied to the surface. The surface must be dry before the next wash is applied .

5.5.8 DECORATIVE PAINTS

Different painting techniques can be used to make a concrete sculpture look old or resemble rusted metal. Patterns can also be painted on. The sculpture should be properly cured and dried before applying paint. The surface should also be made dust free by pre-washing the sculpture with water. Different effects can be achieved by applying paint to either a dry or a wet surface.

5.6 CURING

According to Dabney (1982:25) curing is the most important of all these procedures. Great care must be taken to select the proper curing method. The use of water-mist is suitable for uncoloured concrete, but not for coloured concrete. Dry-shake colour lies on top of the surface, so the use of water mist can dispense the colour unevenly over the surface.

The right surface cover for curing must be considered. Burlap or other wet covering is the same as water fog mist and is totally unsatisfactory. Plastic sheets and waterproof paper can cause uneven moisture distribution over the top surface, resulting in a blotchy surface appearance (ibid:25). In general, coloured concrete should be cured with material recommended by the manufacturer of the dry-shake hardener or colouring admixture. The most popular method is to use a colour-matched curing wax, which will enhance the beauty as well as improve the structural integrity.

5.7 SEALERS AND PROTECTIVE COATINGS

According to Olson (1988:23) sealers protect the concrete against waterborne contamination and freeze-damage. The sealer should be applied to a cured and dried concrete surface. The most effective sealers penetrate the pores to prevent water from entering, but still allow water vapour to pass through the pores. Excess water inside the cement matrix after curing should be allowed to evaporate, to prevent freeze-damage (ibid:23).

Protective coatings, sometimes also called sealers, produce a film that adheres to the surface. Some of these may also penetrate the pores. The most effective coatings are those based on methyl methacrylate. They do not yellow with time. Methyl Methacrylate: protects against chemical fumes, airborne pollution, acids and alkalis; repels water, but allows water vapour to pass.

Other sealers and protective coatings are :

Siliconates, silicates, urethanes, butadiene's, chlorinated, rubber and linseed oil. Clear Cobra wax polish can be used, but several applications of the wax are necessary.

5.8 REPAIRS

Cracks, air pockets and soft spots can be filled with cement paste of a contrasting colour or value to enhance decorative surface patterns. According to Olson (1988:25) the cracks are widened with a sharp knife before filling. The surface is refinished with silicon carbide paper. Big cracks and holes are filled with a foaming agent, e.g. Purefoam. This is an insulation and construction foam that expands (because of a propellant) into the cracks, filling them up. This is ideal for big cracks, because of its expandability. There are many filling and repairing agents available on the market. Bonding agents and glues are also available for pieces that have broken off.

5.9 CONCLUSION

Data discussed in this chapter gives the sculptor an overview of different types of surface finishes. This also creates an awareness of what type of equipment is suitable for the working of a concrete surface, giving the sculptor a choice of final texture surface and colouring of the sculpture. Colouring methods and the use of pigments and colour admixtures must be used with caution as they can influence the properties of the cement.

CHAPTER 6

DISCUSSION OF INDIVIDUAL WORKS

In this chapter the researcher's works as well as problems encountered are discussed. The sculptures are categorised under the following four categories: metal armature; polystyrene-core structure; steel-reinforced armature; combination armature. A minimum of three sculptures were made in each category. The three types of structures discussed in Chapter Three, have already been successfully used by other sculptors. The aim of reworking these structure types was to explore what the structural limits of each structure were: To selecting the correct type of structure for each sculptural form. For example if the sculptural form is thin, long and delicate, it will require a structure that enables an easy manipulation of form, yet also gives the necessary support and strength. The results of the applied data will now be discussed in detail.

6.1 THE SHELL ARMATURE

The first three sculptures were based on the shell design discussed in Chapter Three. (See Fig. 6.1.1, 6.1.2 and 6.1.3). During the manufacturing process certain questions arose that served as a catalyst for this research project. The materials used in all three sculptures are listed below:

MATERIALS

6 mm metal round bar: 8 mm metal round bar: 6 mm metal wire mesh: Crete stone: newspaper: river sand: OPC Portland cement; Ponel wood glue: water.

6.1.1 MIXING AND BATCHING

The concrete mixture used in these sculptures consisted of three parts sand to one part OPC Portland cement. Batches were small and were made up as they were needed, to prevent premature setting. If a batch was too wet, more sand was added. The moisture content of some batches was more than that of others. This caused uneven curing between layers of concrete, with one layer drying out faster than the other, creating tension between the layers



FIG. 6.1.1 Silence. 1993
Concrete Sculpture. Shell armature.
Height: 2 m

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FIG. 6.1.2 Scream. 1993.
Concrete Sculpture. Shell armature.
Height: 2 m



FIG. 6.1.3 Contemplating. 1993.
Concrete Sculpture. Shell armature.
Height: 2 m

and causing cracks. Clean tin cans were used to measure ingredients. The mixing was done in a wheelbarrow, and wood glue was used as an admixture to improve the plasticity of the mix.

6.1.2 THE WORKING METHOD

All three sculptures consisted of two parts. The sculpture consisted of female forms attached to long and wide bases. The armatures of these sculptures were constructed out of 6mm and 8mm metal round bar (see Fig 6.2.1, 6.2.2 and 6.2.3). The 8mm round bar was used for the base, to make it sturdy, and the 6mm round bar for the figure, because it was easier to manipulate the thinner round bar to achieve the desired form. The established armature was then covered in 6mm wire mesh to prepare a suitable surface to which the concrete could be applied. Because the wire mesh holes were too big, newspaper dipped in crete stone was then smeared over the surface to cover the holes. This was then followed by layers of concrete, at which time the armatures were tilted at an angle to make concrete application easier. Each day one side of the armature would be covered in concrete, moistened, covered in black plastic bags and left to stand for the rest of the day. This was repeated on all the sides until the armature was completely covered in concrete.

6.1.3 CURING

Because the sculptures were moved outside during their curing stage, they were exposed to sunlight and wind, which rapidly dried the concrete out. The sculptures were not kept sufficiently wet or covered. The concrete's strength was reduced, which led to cracks on the surface of the sculpture.

6.1.4 COLOURING

The sculptures were left to dry out completely, before colouring took place. The sculptures were coloured in the same way. White PVA colour washes were used and allowed to dry on the surface. Green and brown oil-paint was mixed with ordinary cooking oil and the resultant mixture was then applied several times. Each coat was left to dry, before the next one was applied. All oils generally tend to seal the surface, but unfortunately, cooking oil did not seal the surface for an indefinite time, so the surface had to be sealed again after some time. The oil-paint was applied to the surface in very light washes and after being exposed to external conditions the colour has not yet faded.

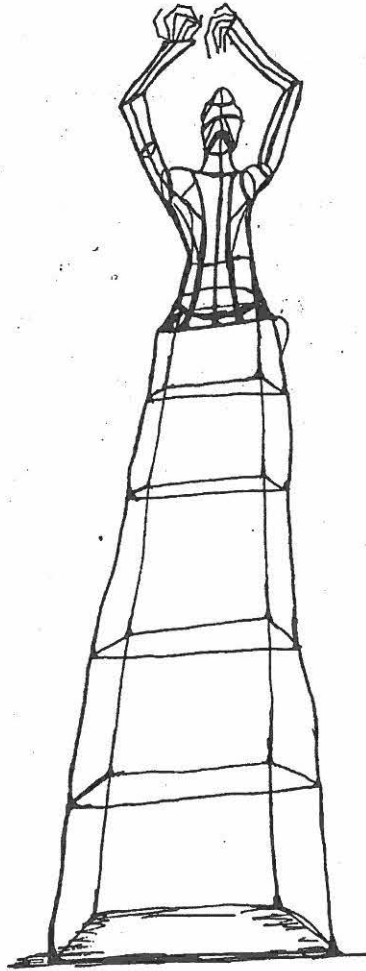


FIG. 6.2.1 Sketch for shell armature: Scream

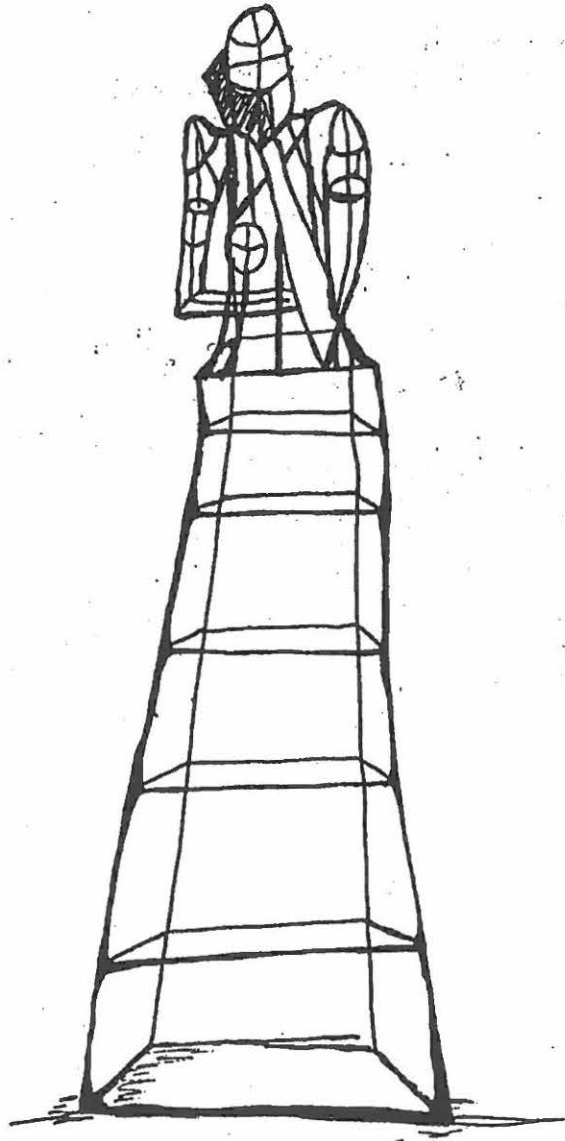


FIG. 6.2.2 Sketch for shell armature: Contemplating

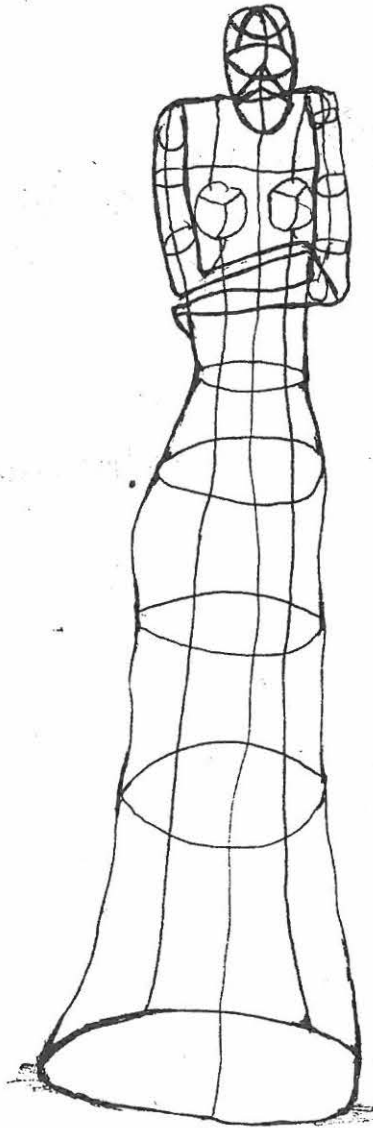


FIG. 6.2.3 Sketch for shell armature: Silence

6.1.5 CONCLUSION

When starting with this structure, there was no prior knowledge as to the amount of steel and wire mesh that should be used, the proper way of reinforcing as well as stresses and strains that had to be taken into account, with the construction of a steel armature. Owing to this inexperience the three initial sculptures are deteriorating. The following incorrect steps were taken:

- The cement and sand were not sifted and the sand was not thoroughly graded. This resulted in a mix with insufficient volume and plasticity. Because the batches were not consistent in their moisture content, tension between the layers, occurred producing uneven shrinkage resulting in cracks.
- The base of the sculpture was not sufficiently reinforced, leaving large spaces between round bars. So when the wire mesh was attached to the armature, there was not enough attachment surface available. This left no option but to use large pieces of wire mesh, which could not be properly stretched over the armature. The surface was too flexible. Each time concrete was applied to the surface, it would put stress on the previous layer, due to movement, as there was nothing to hold the previous surface in place.
- When applying the concrete, the bottom of the armature was not sealed with concrete. Corrosion of the round bar and wire mesh took place, weakening the support structure resulting in severe grazing and cracking of the surface. (See Fig. 6.3.)
- The newspaper dipped in crete stone should have been attached to the surface with wire, so that it could not pull away from the wire mesh surface.
- The breast and head of the armature were too big. This was discovered after concrete application. The fault was making the armature exactly the same as the final dimensions and not taking into consideration the several centimetres of concrete that were to be applied to the armature. This created several visual disproportions, once the concrete had been applied. As a result of this the following two options were experimented with on the other two armatures:
 - 1) The proportions of the final sculpture were taken into account, and then several centimetres were deducted from the final armature.
 - 2) The breasts were not included in the framework, but modelled on afterwards. By modelling the breast without an inner framework the form could be



FIG. 6.3 Scream. 1993.
Example of deterioration of sculpture.

manipulated with greater ease. The breast was slowly built up, leaving a day between each application to allow the concrete to set. This was more time consuming than the first option.

- The concrete was not sufficiently cured. The sculpture was left standing outside in the sun and covered up in black plastic bags to prevent loss of surface moisture, but the wind blew underneath the coverage. The surface moisture of the concrete was drying out too fast, which led to concrete that was brittle and weak.

The following procedures should be considered while constructing this armature:

- There should be sufficient reinforcement on the armature.
- The use of smaller strips of wire mesh to cover the armature and a minimum of three layers of such strips should be applied. This is to create a dense surface on which to apply the concrete.
- The amount of concrete to be applied, thereby designing the armature a few sizes smaller.
- Concrete must always be applied to the bottom of the armature, so that the entire armature is sealed in concrete, to prevent corrosion.
- If the concrete cannot be cured indoors, an evaporation retarder must be used to prevent loss of surface moisture.
- After colouring, the concrete sculpture must be sealed with a surface sealer to prevent abrasion of the surface.

6.2 THE POLYSTYRENE CORE STRUCTURE

After the Shell armature, a framework was sought after which would allow for large inner volumes and a form that could be easily manipulated. This structure was more suited to the previous type of sculptured forms. The method of Addis (1994:44) was used. Addis used polystyrene as an inner core structure and was able to create large sculptures by using this structure. Addis's sculptural forms were not complicated. After realising this, the type of forms explored with the researcher's sculpture making changed. The aim was to see if thin and delicate forms could be created with this type of structure. The following materials were used for the making of this type of structure.

MATERIALS

Polystyrene ; Polygum glue; 6mm round bar ; PVA; PCFA 15 cement ; river sand; Water; Duralatex; Drikon.

6.2.1 MIXING AND BATCHING

The mixture consisted of two parts sand to one part PCFA 15 cement for the first two layers. The third and final layer of concrete consisted of a mixture containing three parts sand to one part PCFA 15 cement. Batches were small and controlled. Drikon was added as an admixture to provide plasticity and to waterproof the concrete. This was a drier mixture than the one used for the previous sculpture, because the admixture reduces the amount of water required in the concrete.

6.2.2 THE WORKING METHOD

All three structures were formed out of polystyrene. The form was established by gluing pieces of large polystyrene together with polygum glue. The form was then cut out of the polystyrene with a bread knife and wood saw. Finer pieces and detail were shaped with an NT cutter and a gas flame. When the polystyrene form was finished, 2 cm of thickness was taken off with a rasp, allowing for an amount of concrete to be applied. Because polystyrene has a porous surface and consisted of loose particles, the surface was then sealed with white PVA to prevent the particles from contaminating the concrete mixture. Roof nails were then pushed into the polystyrene surface to allow the concrete better adherence to the surface (see Fig. 6.4). The prepared structures were then placed horizontally on the floor to make the concrete application easier. The concrete was smoothed onto the structure by hand working from the bottom up and then pressure was applied to ensure compacting of the concrete. Three layers of concrete were applied to all the structures, with three days left in between each layer to allow the concrete to set. After the first layer of concrete, round bar was shaped around the form for reinforcement. The structures were properly covered and kept moist between layers.

6.2.3 CURING

The sculptures were properly moistened and kept covered throughout the curing stage and then left to dry. This time they were cured indoors.



FIG. 6.4 Horse 1. 1997
Reinforcement of the head.

6.2.4 COLOURING

After the surface had been left to dry, the sculptures were coloured with a PVA wash, giving a white appearance to the surface, with parts of the concrete left to show through. The dark colours were brown oil-paint mixed with cooking oil. Brown oil-paint washes were applied to the surface. Each surface was left to dry out before the second coat was applied. The surfaces were sealed with Cobra wax polish and then later with Nova stone sealer. After six months the colour has not yet faded.

6.2.5 CONCLUSION

This type of structure worked quite satisfactorily. Alterations to the structure were easily executed, by merely cutting off or gluing on polystyrene. This structure is ideal for a form that requires a large inner volume. The following incorrect steps were taken:

- The polystyrene structure was not sufficiently reinforced before concrete application. While concrete was being applied the structure broke into pieces, because the thin polystyrene form could not support the weight of the concrete.
- To reinforce the sculptural form, metal rods were applied close to the polystyrene surface (see Fig. 6.5). Unfortunately, the gas flame was used to manipulate the round bar around the form, causing the polystyrene to melt under the concrete. The heat of the flame robbed the first layer of concrete of its surface moisture, damaging the concrete surface and reducing it to a low-strength concrete. As a result when the second layer of concrete was applied, the surface was already damaged.
- The admixture differed from batch to batch, because of inconsistent measurements.

Procedures considered while constructing this structure:

- This type of structure is not suitable for too fine or thin work.
- This structure must be reinforced, especially in the hollows. The structure can be reinforced with wire mesh, round bar and wire, depending on the size of the structure.
- The polystyrene surface must always be sealed.
- Surface attachment for the concrete is provided by pushing roof nails or other nails into the polystyrene.
- The reinforcement should be done before the cement is applied, especially when reinforcing with round bar.

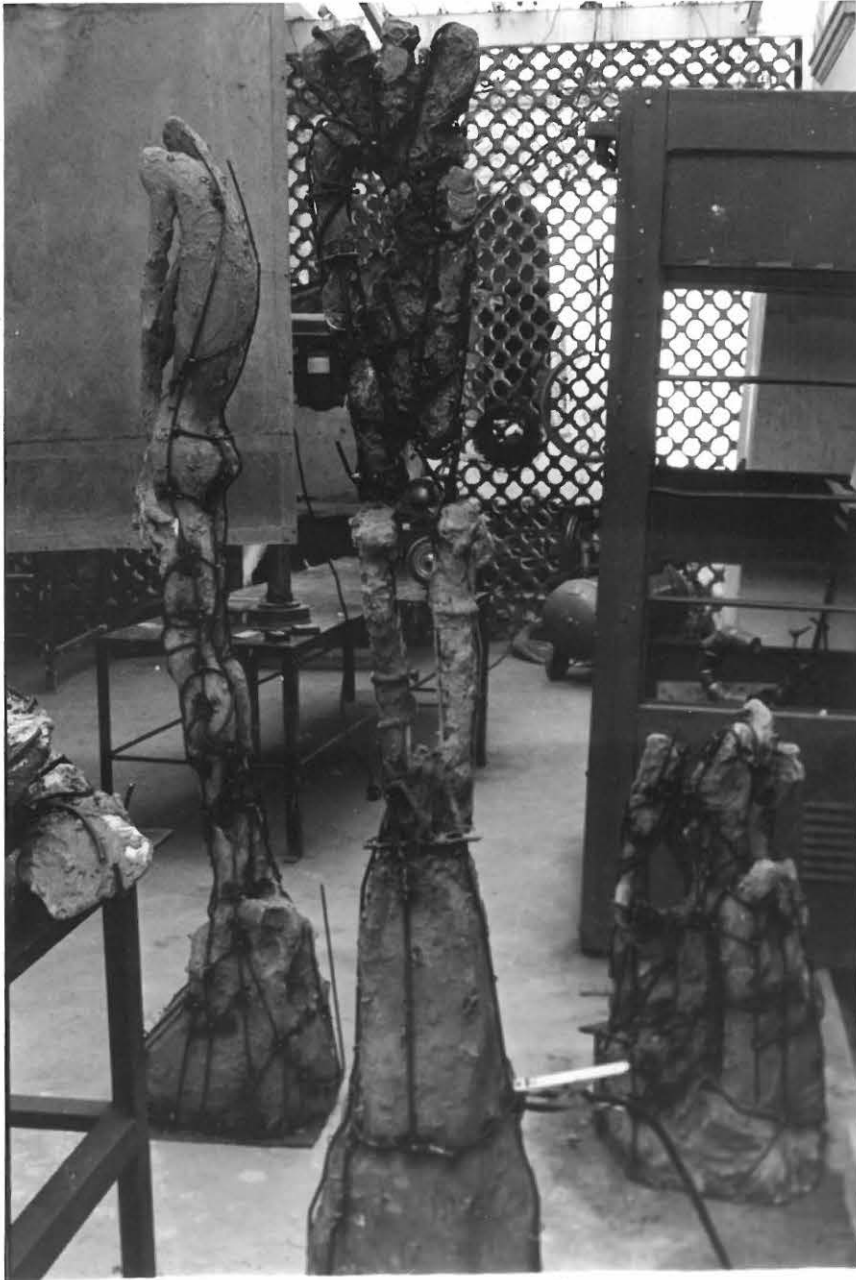


FIG. 6.5 Steel reinforcement of a polystyrene core structure.

- After each layer the surface can be reinforced with wire or wire mesh, because the layers are applied thinly. The surface can be roughened to provide better adherence for the next layer
- The completed polystyrene core sculptures are shown in Fig.6.6.1, 6.6.2, 6.6.3.

6.3 THE STEEL-REINFORCED STRUCTURE

This structure was more suitable to the way in which the sculpture form was progressing. The more confident a sculptor becomes, the more willing the sculptor is to experiment with form and structure. Initially the researcher started out making sculptures that required a structure which would give suitable support, for large inner volumes, and progressed to making forms more shapely and delicate. This was why Olson's (1988:39-40) type of structure was more suitable for the researcher's work (see Chapter Three), which again led to considering the limitations imposed on this structure. Olson (1988:39) discusses a two-legged figure, that stands up straight with the feet slightly apart, this though doesn't leave room for the depiction of movement or a more complex figures. All the possible stresses and strains that such a form will impose on the structure need to be considered.

The reason the two-legged figure was made, was because all sculptures consisted of a form extending into a base or platform that broadened at the bottom, creating a very stable support system for the sculpture with minimum stress. Throughout history the two-legged figure was usually supported by a third stabilising point, e.g. a tree stump or a dress, etc. Stabilising a non-flexible material like concrete or marble with just two points, such as the feet and ankles, which carry the entire weight of the figure is difficult to construct. Even attaching these two points to a base will create enormous stress at the ankles. The figure usually tends to break at the ankles. The problem with this structure was to overcome how stress was to be deducted from the ankles, without the use of a third support point. Concrete is not a ductile material. Below follows a list of materials used in this structure:

MATERIALS:

OPC Portland cement; Nitabond; river sand; plaster sand; bandage ; steel wool ; 0.6mm wire; 0.8mm wire; 6mm round bar; 10mm round bar; lime; ISO-Resin Foam.

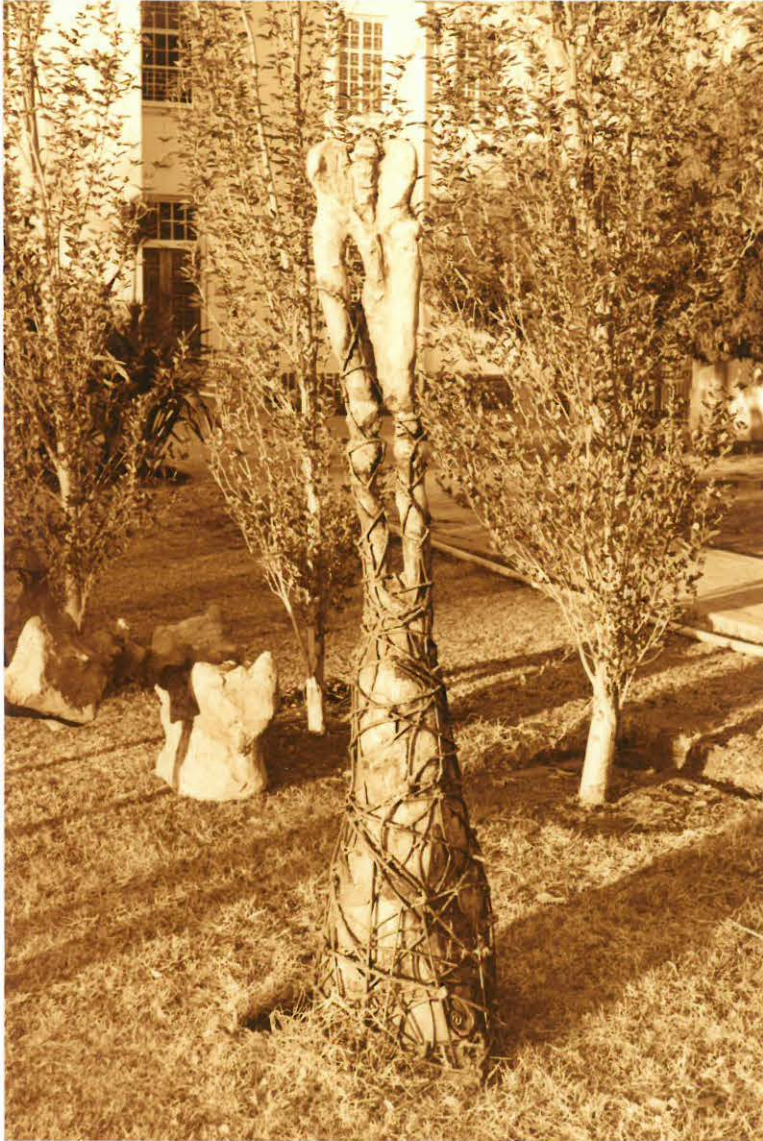


FIG. 6.6.1 Pelvis. 1997
Concrete sculpture. Polystyrene core structure.
Height: 1,7 m



FIG. 6.6.2 Horse 1. 1997.
Concrete sculpture. Polystyrene core structure.
Height: 2,5 m



FIG. 6.6.3 The Maiden. 1997
Concrete sculpture. Polystyrene core structure
Height: 2 m

6.3.1 MIXING AND BATCHING

The mixture consisted of three parts sand to one part OPC cement. The batches were small and consistent. Nitabond was used as an admixture. The first layer consisted of steel wool dipped into a concrete mix of one part cement to two parts sand. No admixtures were used in the first coat.

6.3.2 THE WORKING METHOD

The structure was constructed from the feet up to the upper part of the body with 10mm round bar for reinforcement. The upper body was formed out of 6mm round bar, because of the intricate manipulation of the form. The structure was then reinforced and spaces were filled up with 0.8mm wire, entwined around the figure (see Fig. 6.7.1 and 6.7.2). The structure for the base was attached to the figure at this stage, before concrete application. This type of structure has no surface to which the concrete can be applied. The concrete was applied to fill the voids of the structure and a final thin layer of concrete was applied over the entire surface. Concrete was first applied to the base to stabilise the structure, then to the arms and body. Lastly the legs were filled up with concrete to minimise stress on the ankles. Steel wool dipped in concrete was entwined in and around the structure and left to stand for three days so that the concrete could set. The steel wool created a surface for the next application of concrete. The second layer of concrete applied was to fill in the structure, and was reinforced with 0.6mm of wire entwined around the structure. A specific surface finish was created by dipping bandages in a watery concrete solution, then entwining them around the figure. The surface texture was then softened by applying a layer of concrete. The layers were kept moist and covered.

6.3.3 CURING

The sculptures were regularly moistened and covered in black plastic bags, during the curing stage.

6.3.4 COLOURING

The colour was applied with PVA paint washes, which were allowed to dry after each stage. Detail was painted on with a mixture of oil-paint and cooking oil.

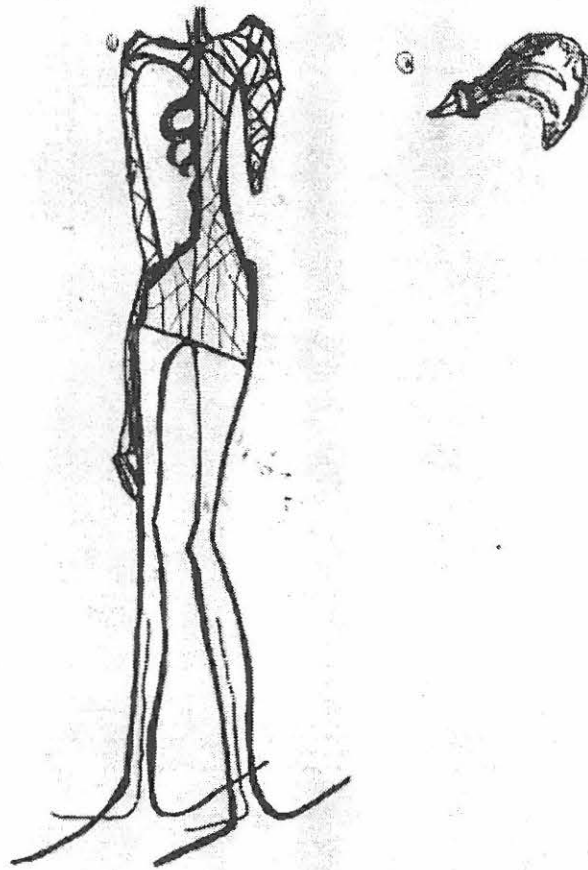


FIG. 6.7.1 Sketch of framework for steel reinforced armature

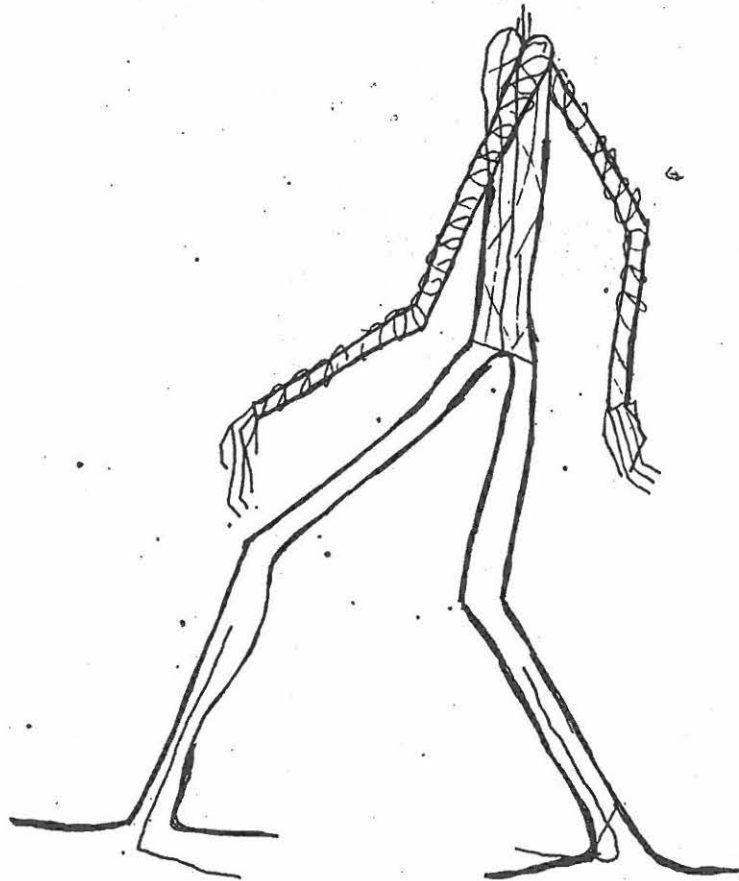


FIG. 6.7.2 Sketch for steel reinforced armature: The walking dude

6.3.5 CONCLUSION

With this type of structure, it is possible to work relatively thin. There were limitations with regard to the two-legged figure. The type of pose in which the figure is positioned can put too much stress on the structure, in other words, the figural limitations of the structure must be kept in mind. All the possibilities and limitations of this structure were not tested, because only the two-legged figure was focused upon (see Fig. 6.8.1 and 6.8.2). The following incorrect steps were taken (also illustrated in Fig. 8.1 a):

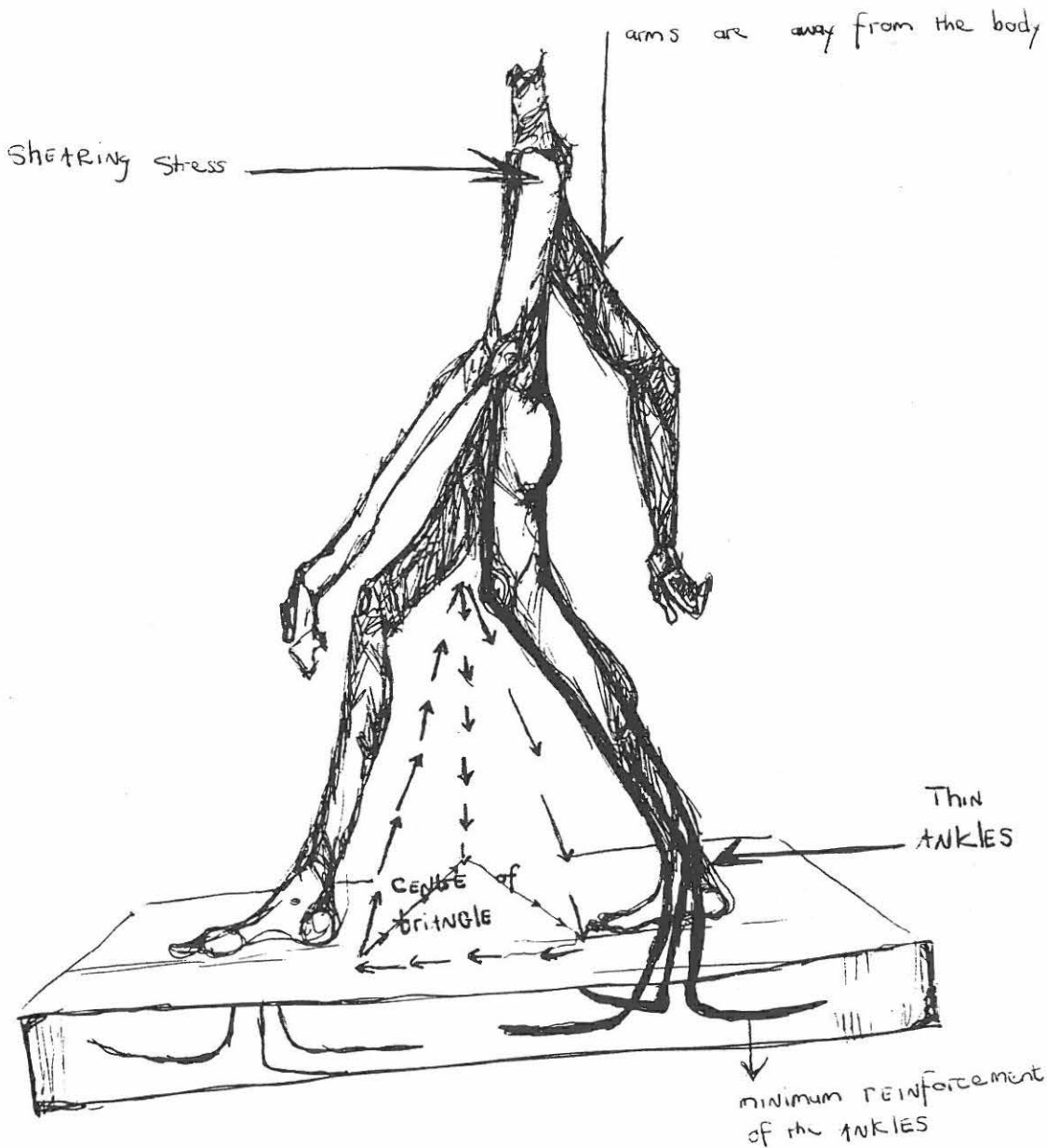


FIG. 8.1.a



FIG. 6.8.1 Walking Dude. 1997
Concrete sculpture. Steel reinforced structure.
Height: 2 m



FIG. 6.8.2 Escape Delayed. 1997
Concrete sculpture. Steel reinforced structure.
Height: 2 m

- The batches were too moist.
- As part of the structural experiment, the ankles were not over-reinforced.
- The arms were deliberately designed far from the body, to see whether the structure would survive the stress and strains of time to come.
- The concrete covering on the structure was too thin.
- When working in a solid material, the two-legged figure's legs and ankles are made thicker, creating a more visually weighty figure. This was done so that the legs would be able too sustain the weight of the figure. The idea was to limit the thickening of the ankles without attaching a third point.
- The legs, which carry the entire weight of the body, were attached to the base by the ankles and feet. The area of attachment was limited, making this a very unsteady solution for stabilising the body to the surface.

The consideration's that have to be considered with this type of structure:

- When designing a figural structure, the weight of the figure must fall in the centre of the triangle, so as not to create an unbalanced disturbance on the structure, causing stress and strains.
- The centre of gravity must be kept near to the ground. This will put less stress on the structure.
- A central axis as a structure must not be used when there are just two points that will connect to the base.
- The arms can be used to balance the figure.
- If the arms are away from the body, they must be reinforced across the shoulders and around the upper part of the body.
- The first layer of concrete for this structure is much more moist than in other structures, and so fibre must be included as well as properly graded sand ranging from fine to coarse in order to ensure a mix that is more clay-like.
- This type of structure is suitable for the two-legged figure, if the structure type and pose of the figure are properly calculated.

6.4 COMBINATION ARMATURE

This type of armature was carried out with great success. A combination of the polystyrene core structure and the steel-reinforced structure were used. In the areas where a larger inner volume was required, polystyrene was used, with metal reinforcement around it. For thinner

parts like the legs, round bar was used. If an overall thin sculpture was required, the form was achieved with round bar and then reinforced with wire (see Fig. 6.9.1[a], 6.9.1[b], 6.9.2). Iso-Resin Foam was then injected into the steel-reinforced structure, making it solid. This was a better option than using polystyrene that was unable to support the weight of the concrete when worked too thinly. Below lists the materials used:

MATERIALS

OPC Portland Cement; river sand; plaster sand; crusher dust; lime; Iso-Resin Foam; 0.6mm wire; 0.8mm wire; bandages ; 8mm round bar; 6mm round bar; Nitabond.

6.4.1 THE WORKING METHOD

The form was constructed out of 6mm and 8mm round bar. More round bar was used than in the steel-reinforced structure, especially at the legs and the body. Polystyrene was used where a large inner volume was required, and foam for the thinner parts where the voids needed filling in. The structure was then reinforced with 0.6mm wire entwined around the form. Bandages dipped in a watery concrete mix were attached to the legs and smoothed over with concrete. The rest of the concrete was applied by hand, working from the bottom up. The base and arms were first covered in concrete to eliminate stress at the ankles, and then the body and the legs were covered. The sculptures were left to stand for three days. A small amount of Nitabond as admixture was used, but not in all the batches. Crusher dust and lime were used as part of the aggregates to achieve a more clay-like mixture. The fine particles in the crusher dust and lime filled in the voids between the usual range of sand graded from fine to course, making the mixture more dense.

6.4.2 CURING

Moistening the sculptures proved difficult, because of their complicated form. They were kept covered throughout in black plastic bags. The *Horse* was covered in cling wrap, with the last application of concrete as this produced a texture similar to wrinkled flesh.

6.4.3 COLOURING

After the surface had been left to dry the sculptures were stained in some areas with woodstain and covered entirely with brown oil-paint washes.

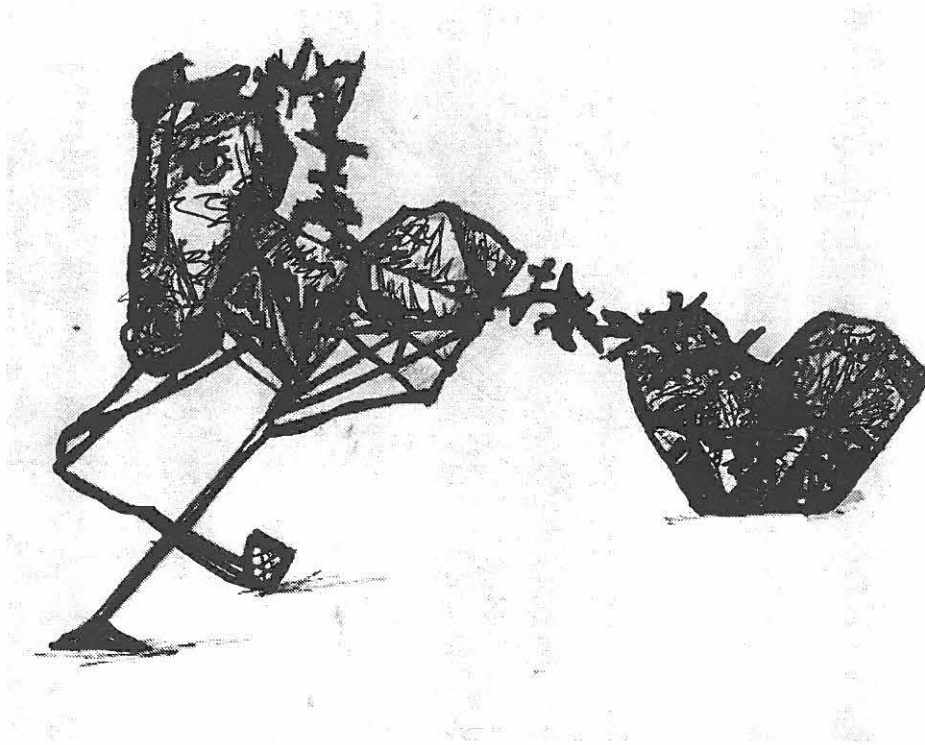


FIG. 6.9.1 a Sketch of HORSE 2`S framework: The complete frame.

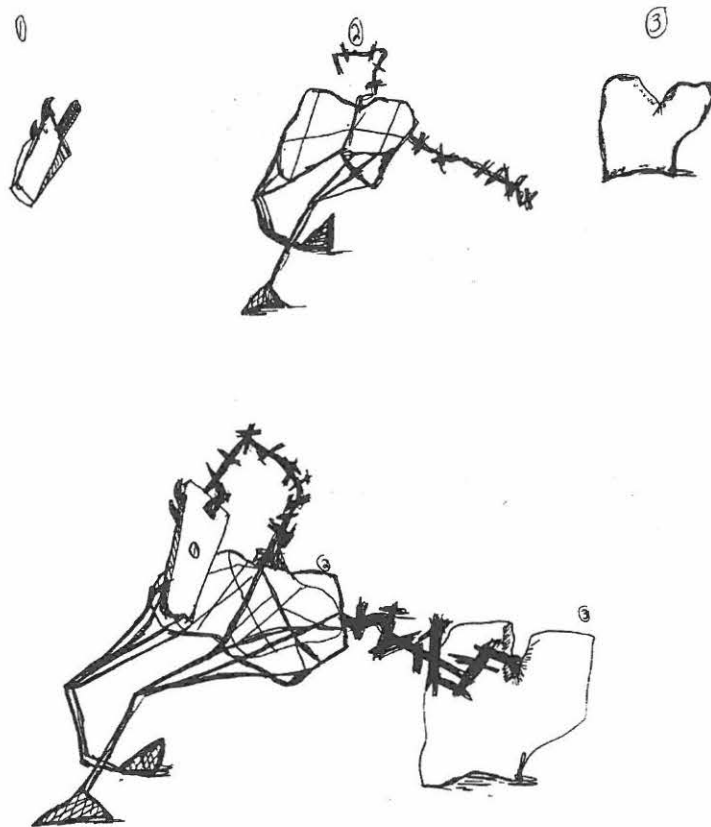


FIG. 6.9.1 b Sketch of HORSE 2'S framework: The three pieces

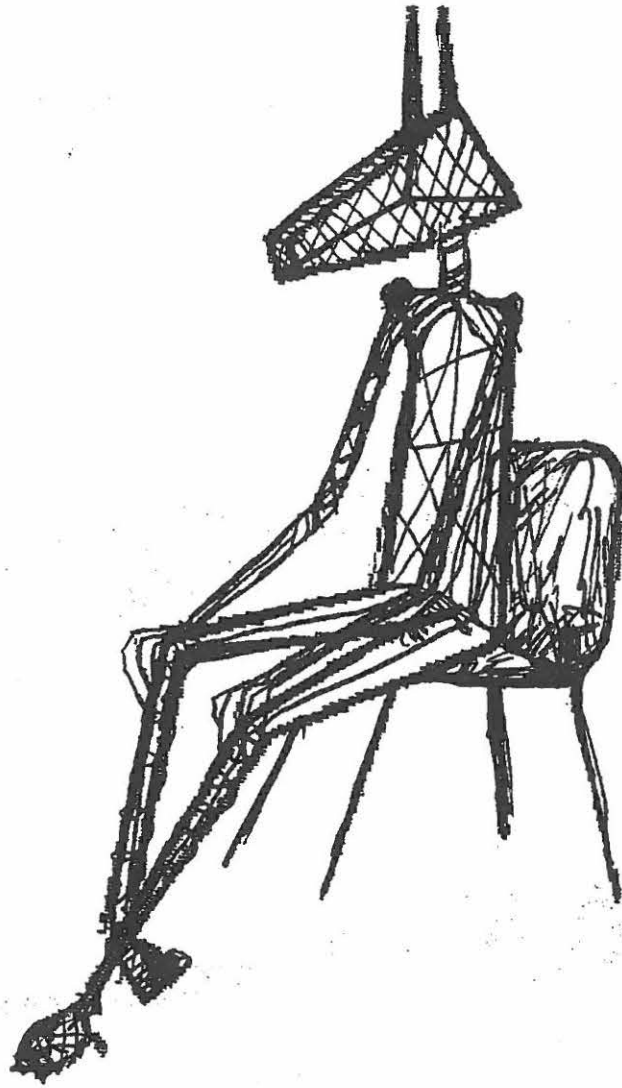


FIG. 6.9.2 Sketch of The maiden transformed

6.4.4 CONCLUSION

This type of armature was very successful. Large shapes were successfully combined with relatively thin ones. The weight of the *Horse* was positioned low to the ground and a triangular formation created between the forelegs and the back strengthened the design of the structure. The larger part of the weight and stress were carried by the backbone and the hips, but still distributed evenly between the back and front of the *Horse*. The *Horse* can be dismantled into three sections for portability (see Fig. 6.10.2). *The Maiden*, on the other hand, a sitting figure, representing a cross between a jackal and a donkey was the least stress-related of all the sculptures, because of her seated position (see Fig. 6.10.1).

6.5 FINAL CONCLUSION

The researcher tested all the varying structures discussed in Chapter Three. The same type of base was incorporated in all three types of structures. This was the best option for the type of sculptures produced. For the last two sculptures a combination armature was used, and there was no need for a base to be attached. Although the first structures were not totally successful, the researcher was still able to use the data gained to provide basic guidelines for further development. Out of the wide variety of admixtures, the researcher only used Drikon, Durulutex and Nitabond.

The evaluation of the researcher's practical projects clearly revealed that following the relevant processes and construction methods are imperative to the success of the works. Problems encountered with previous concrete sculptures required the need for additional technical knowledge to overcome these problems. General problems encountered in this study include the lack of information on structural problems, batching and curing, which were successfully overcome in the researcher's combination structure. The design of this structure was finally reached by experimenting and testing the structures mentioned in Chapter Three. Positive aspects gained from these tests allowed the researcher to establish basic guidelines for working on large concrete frameworks. This data has left the researcher with a clearer understanding of the abilities of concrete and structure types. The result of the researcher's practical works show that technical problems were successfully overcome.



FIG. 6.10.1 The Maiden Transformed. 1997
Concrete sculpture. Combination armature.
Height: 1,20 x 0,40 m



FIG. 6.10.2 Horse 2. 1997
Concrete sculpture. Combination armature.
Height: 0,70 m x 2 m

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GLOSSARY and TERMINOLOGY

The following terminology is used in today's building industry and will help the sculptor to better understand what cement and concrete are all about. The chemicals which are used in the cement, concrete and admixtures are also explained:

ABRASIVE

A material used for rubbing, grinding down or smoothing a surface, such as emery cloth or paper, a grinding wheel and glass paper (Brett, 1989:230).

ABSORBENCY

The ability of a substance to take in something else, normally water, or to reduce the intensity of something else, such as heat, sound and light (Brett, 1989:230).

ACCELERATOR

A substance which increases the rate of a chemical reaction (Brett, 1989:230).

ACID

A substance containing hydrogen which can be replaced by a metal to form a salt. This is used in concrete to remove excess cement during the acid-washing colouring process (Brett, 1989:230).

ACRYLIC

A group of plastics used mainly as transparent roof sheeting or glazing. May also be used for baths and basins (Brett, 1989:230).

ADHESION

The sticking together of materials by chemical or mechanical bonds (Brett, 1989:230)

ADMIXTURE

A material added to the basic constituents of a mix to alter one or more of its properties (Brett, 1989:232).

AGGREGATE

A filler material used in mortar and concrete mixes. Various named according to their source or particle size (Brett, 1989:232).

AGGREGATE : CEMENT RATIO

The relationship between the amounts of aggregate and cement in a concrete mix (Brett, 1989:232).

AIR SET

The partial hydration of cement and plaster prior to use, due to absorption of water vapour from the air. Also termed bag set (Brett, 1989:232).

ALL-IN AGGREGATE

A graded mixture of fine and coarse aggregates used in concrete. Also termed ballast (Brett, 1989:233).

ALUMINA

The oxide of aluminium, Al_2O_3 . The natural crystalline mineral is called corundum, but the synthetic crystals used for abrasives are designated usually as aluminium oxide. For other uses and as a powder, it is generally called alumina. It is widely distributed in nature in combination with silica and other minerals, and is an important constituent of the clays for making porcelain, bricks, pottery and refractories. Different types of alumina are used in ceramics and catalysts, and as a filler in plastics, glass and vitreous enamels and cosmetics (Brady & Clauser, 1991:34).

ALUMINIUM CHLORIDE

$AlCl_3$ is normally encountered as gray granular crystals which sublime at $950^\circ C$, and is used as a catalyst for high-octane gasoline and synthetic rubber and in the synthesis of dyes and pharmaceuticals (Brady & Clauser, 1991:168).

ANHYDROUS

Applied to a substance containing no water. The term is the opposite of hydrated and hydrous. It is also a type of gypsum plaster used for finishing (Brett, 1989:233).

ASBESTOS FIBRE

A general name for several varieties of fibrous minerals, the fibres of which are valued for their heat-resistant and chemical-resistant properties. Asbestos is made into fabrics, paper, insulating boards and insulating cements. The original source of asbestos was the mineral actinolite, but the variety of serpentine, known as chrysotile, now furnishes most of the commercial asbestos. The fibre have been used as reinforcement with cement, lime and plastics (Everett, 1994:185).

BALLAST

See all-in aggregate.

BATCHING

The process of proportioning the constituent materials for a concrete mix, either by weight or volume (Brett, 1989:236).

BLAST FURNACE

A furnace used for the melting of iron(Brett, 1989:237).

BLAST-FURNACE SLAG

Is one of the hardest concrete aggregates available. It has a porous structure and, when crushed, is angular. It is also crushed and used for making pozzolana and other cements. Slag contains about 32% silica, 14% alumina, 47% lime, 2% magnesia and small amounts of other elements. It is crushed, screened and graded for marketing (Brady & Clauser, 1991:756).

BLEEDING

Excess water rising to the surface of freshly placed concrete. This leaves behind a network of interconnected voids which reduce both the strength and durability of the concrete (Brett, 1989:237).

BLOWHOLE

A small hole or cavity in the concrete face due to air pockets trapped against the form faces, excessive application of release agents, or use of neat oil as a release agent (Brett, 1989:237).

BONDING AGENT

An adhesive material normally applied to a smooth surface to increase adhesion (Brett, 1989:237).

BRITTLENESS

The property of breaking without perceptible warning or without visible deformation (Brady & Clauser, 1991:959).

BULKING

The increase in the volume of damp aggregate due to the film of liquid separating the particles (Brett, 1989:239).

BUTADIENNE

Also called divinyl, vinyl, ethylene, enythrene and pytrolylene. A colourless gas used in the production of neoprene, nylon, latex paints and resins. Butadienne has a boiling point of -3°C , and a specific gravity of 0.6272. Commercial butadienne is at least 98% pure.

Butadienne is primarily obtained as an ethylene co-product during the steam cracking of Naptha or gas oil. It is also made by oxidation dehydrogenation of n-butenes, the dehydrogenation of butanes, and the conversion of ethyl alcohol. The largest use for butadienne is the production of elastomers, such as polybutacliene, styriene-butadienne, polychloroprenne and acrylonitrite, butadiene, or nitrite rubbers. The rubbers have less resilience and a higher heat build-up than natural rubber, but they also give much greater wear life, low temperature flexibility and increased groove cracking resistance in side walls (Brady & Clauser, 1991:127).

CALCINATION

The extreme heating of a substance during the manufacture of cement, lime and plaster (Brett, 1989:239).

CALCIUM

A soft white metal that tarnishes rapidly in the atmosphere. Its main compounds are calcium carbonate, calcium hydroxide, calcium silicate and calcium sulphate (Brett, 1989:239). A metallic element. Symbol Ca, belonging to the group of alkaline earths. It is one of the most abundant materials, occurring in combination in limestones and calcareous clays (Brady & Clauser, 1991:132).

CALCIUM CARBONATE

Occurs naturally as chalk, limestone and marble. Used in the manufacturing of lime and cement (Brett, 1989:239).

CALCIUM CHLORIDE

A white, crystalline, lumpy or flaky material of the composition CaCl_2 . The specific gravity is 2.15, the melting point is 772°C and it is highly hygroscopic and deliquescent, with rapid solubility in water. The commercial product contains 75% to 80% CaCl_2 . Calcium chloride is obtained from natural brines and dry lake beds, after the extraction of sodium chloride, bromide and other products. One of its uses is for accelerating the settling of mortars, but more than 4% in concrete will decrease the strength of the concrete (Brady & Clauser, 1991:134).

CALCIUM FLUORIDE

Ca_2F_6 is a colourless crystalline powder used for etching glass, in enamels, and for reducing friction in machine bearings. It is also used to produce ceramic parts resistant to hydrofluoric acid and most other acids (Brady & Clauser, 1991:347).

CALCIUM HYDROXIDE

Slaked lime used in cement, plaster and mortar (Brett, 1989:239).

CALCIUM SILICATE

A clear crystalline substance used in the manufacturing of bricks, cement and glass (Brett, 1989:239). $\text{CaO}\cdot\text{SiO}_2$ is a white powder used as a reinforcing agent in rubber, as an absorbent to control the viscosity of liquids, and as filler in paints and coatings. It reduces the sheen in coatings (Brady & Clauser, 1991:133).

CALCIUM SULPHATE

Also known as anhydrite or gypsum. May be heated (Brett, 1989:240).

CARBON

A non-metallic element, with the symbol C, existing naturally in several allotropic forms and in combination, as one of the most widely distributed of all elements. It is quadrivalent and has the property of forming chain and ring compounds. Carbon occurs as hydrocarbons in petroleum and as

carbohydrates in coal and plant life, and from these natural basic groupings an infinite number of carbon compounds can be made synthetically. Carbon is available in a large number of different grades, sizes and shapes (Brady & Clauser, 1991:141).

CEMENT

A material, generally in powder form, that can be made into paste, usually by addition of water, and when moulded or poured, will set into a solid mass. Numerous organic compounds used for adhering, or fastening materials are called cements, but these are classified as adhesives, and the term alone means a construction material. The most widely used cements

are Portland cements. It is a bluish-grey powder, obtained by finely grinding the clinker made by strongly heating an intimate mixture of calcareous and argillaceous minerals. The chief raw material is a mixture of high-calcium limestone, known as cement rock, and clay or shale. Blast furnace slag may also be used in some cements.

The colour of the cement is due chiefly to iron oxide. In the absence of impurities, the colour would be white, but neither the colour, nor the specific gravity, is a test of quality. The specific gravity is at least 3.10. Good cement is always finely ground, with 98.5% passing through a 200 mesh screen (Brady & Clauser, 1991:178).

CEMENT-SAND PLASTER

Used for external rendering, internal undercoats and water-resistant finishing coats (Brett, 1989:241).

CHEMICAL CHANGE

A change in substance, in which a new substance is formed with different properties. Normally accompanied by heat (Brett, 1989:242).

CHEMICAL REACTION

A chemical change that takes place when two or more substances are combined. This results in a rearrangement of the bonding of atoms or ions, and a new substance is formed (Brett, 1989: 242).

CHLORINATED RUBBER

An ivory or white powder produced by the reaction of chlorine and rubber. Approximately 67% of its weight is made up by rubber, and it is represented by the empirical formula $(C_{10}H_{13}Cl_7)_x$, although it is a mixture of two products - one having a CH_2 linkage instead of a $CHCl$. Chlorinated rubber is used in acid-resistant and corrosion-resistant paints, in adhesives and in plastic.

The uncompanied film is brittle, and for paints, chlorinated rubber is plasticised to produce a hard, tough, adhesive coating, resistant to oils, acids and alkalies. Betacote 95, of Essex Chemical Corp., is a maintenance paint for chemical-processing plants, which is based on chlorinated rubber. It adheres to metals, cements and wood, and is rapid drying. The coating is resistant to acids, alkalis and solvents (Brady & Clauser, 1991:192).

COARSE AGGREGATE

Consist of particles mainly greater than 5mm in size (Brett, 1989:243).

COMPRESSION

Stress in a structural member that causes squashing and crushing. It has a shortening effect, the opposite of tension (Brett, 1989:243).

CONCRETE

A construction material composed of Portland cement and water combined with gravel, crushed stone or other inert materials such as expanded slag or vermiculite.

The cement and water form a paste which hardens by means of chemical reaction into strong stonelike mass. The inert materials are called aggregates, and for economy more cement paste is used than is necessary to coat all the aggregate surfaces and fill all the voids. The concrete paste is plastic and easily moulded into any form, or trowelled to produce a smooth surface. Hardening begins immediately, but precautions are taken, usually by covering, to avoid rapid loss of moisture, since the presence of water is necessary to continue the chemical reaction and increase the strength. Too much water, however, produces a concrete that is more porous and weaker. The quality of the paste formed by the cement and water largely determines the character of the concrete.

Proportioning of the ingredient of concrete is referred to as designing the mixture, and for most structural work, the concrete is designed to give comprehensive strengths of 2,500 to 5,000 lb/in² (16 to 34 MPa). A mixture may be proportioned 1 volume of cement to 1 volume of sand and 3 volumes of stone, or a more lean mixture will be 1:3:6.

Concrete may be produced as a dense mass which is partially artificial rock. Chemicals may be added to make it waterproof. Air-entraining chemicals may be added to produce minute bubbles for porosity or light weight. Normally the full hardening period for concrete is at least 7 days. The gradual increase in strength is due to the hydration of the tricalcium aluminates and silicates. Concrete is stronger in compression than in tension. Steel bars or mesh are embedded in structural members to increase the tensile and flexural strengths (Brady & Clauser, 1991:225-226).

COPOLYMERS

A mixture of polymers termed homopolymers, copolymers and terpolymers (Brady & Clauser, 1991:638).

CORROSION

A surface chemical reaction. This applies to metals which can be corroded by the action of water, air and chemicals (Brett, 1989:245).

CRAZING

A point or plaster defect where the surface has cracked or split in drying (Brett, 1989:294).

CURED

A substance that has completed the curing process (Brett, 1989: 245).

CURING

The process of changing from a liquid to a solid by chemical reaction. Applied to the hardening process of adhesives, cement, concrete, plastics, plaster, etc. (Brett, 1989:245) .

DEHYDRATION

The removal or elimination of water (Brett, 1989:246).

DENSE

A substance which is heavy for its volume; in other words a substance with a high density (Brett, 1989:246).

DENSITY

The mass of a unit volume of a substance. The smaller the space into which the mass is concentrated, the greater the density (Brett, 1989:246).

EMULSION

A water-thinned paint for use on walls and ceilings (Brett, 1989:249).

EVAPORATE

The loss of a liquid's surface molecules into the air by evaporation (Brett, 1989:249).

FINE AGGREGATE

Aggregates having particles mainly less than 5mm in size, e.g. sand (Brett. 1989:251).

FINISHING COAT

The paint coat that seals the surface, gives the final colour and provides the desired surface finish. Also the final coat of plaster (Brett, 1989:251).

FOAMED CONCRETE

This is made from a mixture of sand, lime, cement and gypsum with aluminium powder, which reacts to produce $3\text{CaO} \cdot \text{Al}_2\text{O}_3$ and free hydrogen which generate tiny bubbles. The set

material contains about 80% cells and has only about one-third of the weight of ordinary concrete, with a compressive strength of 1,000 lb/in² (6MPa) (Brady & Clauser, 1991:226).

FOAMED SLAG

This is a name used in England for honeycomb slag, used for making lightweight, heat-insulating blocks. A super phosphate cement is made in Belgium from a mixture of basic slag, slaked lime and gypsum (Brady & Clauser, 1991:757).

FUMED SILICA

This is a fine translucent powder of the simple amorphous silica formula made by calcinating ethyl silicate. It is used instead of carbon black in rubber compounding to make light-coloured products, and to coagulate oil slicks on water so that it can be burned off (Brady & Clauser, 1991:739).

GRADING

The selection or classification of materials for quality, strength or particle size (Brett, 1989:254).

GROUT LOSS

The leakage of cement and water at form work joints, bolt positions, etc. Causes a surface defect, having a sand-textured appearance lacking in cement paste (Brett, 1989:254).

GYPSUM PLASTER

For internal use different grades of gypsum plaster are used according to the surface and coat. Undercoats use browning for general use, and bonding for concrete, finishing coats, use-finish on an undercoat or board-finish for plasterboard (Brett, 1989:254).

HEMIHYDRATE

A gypsum plaster that has been heated to drive off some of its water, and is therefore quick setting (Brett, 1989:255).

HIGH-ALUMINA CEMENT

This uses bauxite (aluminium oxide) instead of clay. It develops very early strength which is much higher than OPC, although in the long term it has been found unstable due to conversion, and is therefore now rarely favoured for structural work (Brett, 1989:255).

HYDRATED LIME

It is made by grinding quicklime, slaking the powder with water and sifting it to a fine powder. It is easier to handle and is a more reliable product than ordinary lime (Brady & Clauser, 1991:474).

HYDRATION

The chemical reaction of a substance combining with water, as in the setting and curing of concrete, mortar and plaster (Brett, 1989:256).

HYDRAULIC CEMENT

A cement, such as Portland cement, which will set and cure under water (Brett, 1989:256).

LEAN CONCRETE

A mix having a high aggregate : cement ratio (Brett, 1989:260).

LIME

A calcium oxide, CaO, chemically known as calcia, occurring abundantly in nature, chiefly in combination with carbon dioxide as calcium carbonate, in limestone, marble, chalk, mortars and cement (Brady & Clauser, 1991:473).

LIME MORTAR

This is made from a mixture of hydrated lime, sand and water, and will have a compressive strength up to 400 lb/in² (3MPa) (Brady & Clauser, 1991:474).

LIME-SAND PLASTER

Used for both undercoats and finishing-coats (rarely), although lime can be added to other plasters to improve their workability (Brett, 1989:60).

LINSEED OIL

This is the most common of the drying and is widely used for paints, varnishes, linoleum, printing inks and soaps. It is obtained by pressing the seeds of the flax plant, *linum usitatissimum*, which is cultivated for oil perosis (Brady & Clauser, 1991:477).

MASS

A measure of the quantity of a material or substance (Brett, 1989:261).

MIXTURE

A material created by mixing two or more substances together with no chemical change. They can be in any proportion and can be easily separated by physical means. Each substance also retains its own properties (Brett, 1989:263).

MORTAR

The gap-filling adhesive that holds bricks, blocks or stonework together to form a wall. It takes up the slight difference in shape and provides a uniform bend to transfer the loads from one component to the next. Made with Portland cement, sand and water and sometimes lime, to aid spreading (Brett, 1989:264).

NATURAL AGGREGATE

Naturally occurring materials, e.g. gravel, sand and crushed rock (Brett, 1989:265).

PLAIN CONCRETE

A concrete mix without any admixtures or reinforcement (Brett, 1989:268).

PLASTER

The material applied on internal walls and ceilings to provide a jointless, smooth surface, which can be easily decorated. External plastering is usually called rendering. The plaster is a mixture that hardens after application. It is based on a binder (gypsum, cement or lime) and water, with or without the addition of aggregate (Brett, 1989:268).

PLASTICITY

The property in a material of being deformed under the action of a force and not returning to its original shape upon the removal of the force (Brady & Clauser, 1991:961).

PLASTICISER

A solution added to the mixing water of concrete, plaster and mortar mixes to lower the surface tension. This improves dispersion of the cement particles and lubricates the cement paste (Brett, 1989:269).

PRE-STRESSED CONCRETE

A structural concrete unit that has been given a high tensile strength by embedding tensioned wires or cables into it. In pre-tensioned concrete the wires are stretched before the concrete is cast, whereas in post-tensioned concrete the wires are tensioned after the concrete has hardened (Brett, 1989:270).

REINFORCED CONCRETE

Plain concrete embedded with steel reinforcement to increase its tensile strength (Brett, 1989:272).

RETARDER

A substance that slows down a chemical reaction. Sometimes added to adhesives, concrete and mortar to slow down the rate of curing or hydration (Brett, 1989:273).

SHRINKAGE

The diminution in dimensions and mass of a material (Brady & Clauser, 1991:961).

SILANE (Sealers)

Formed by silicon and hydrogen, corresponding to methane, CH_4 , it is also a gas as is methane, and has the formula SiH_4 . But in general, the silicones do not have the SiH radicals, but contain CH radicals as in the organic plastics. Basically, silicon is treated with methyl chloride and a catalyst to

produce a gas mixture of silanes, $(\text{CH}_3)_x (\text{SiCl})_{4-x}$. After condensing, three silanes, methyl chlorosilane, dimethyl dichlorosilane and trimethyl trichlorosilane, are fractionated. These are the common building blocks of the siloxane chains, and by hydrolysing them, cyclic linear polymers can be

produced with acid or alkali catalysts to give fluids, resins and rubbers (Brady & Clauser, 1991:747).

SILICA

A mineral of the general composition SiO_2 , silicon dioxide, which is the most common of all materials, and in combined and non-combined states, is estimated to form 60% of the earth's crust. Many sands, clays and rocks are largely composed of small silica crystals. When pure, silica is colourless to white. The unit crystal or molecule of ordinary silica has the formula SiO_2 and the single crystal grains are thus molecularly cryptocrystalline with no electron-bonded lattice. But the chemical formula of fused silica and quartz is given as Si_2O_7 which is the pattern of a continuous lattice in which each silicon atom is surrounded by four silicon atoms (Brady & Clauser, 1991:737).

SILICA FLOUR

Made by grinding sand, it is used in paints as a facing for sand moulds, and for making flooring blocks (Brady & Clauser, 1991:738).

SLAG

The molten material that is drawn from the surface of iron in the blast furnace, slag is formed from the earthy materials in the ore and from the flux. Slags are produced through the melting of other metals, but the term usually means iron blast-furnace slag. Slag is used in cements and concrete for rooting, and as ballast for roads and railways (Brady & Clauser, 1991:756).

STRAIN

The distortion set-up in a material by the action of an external force (Brady & Clauser, 1991:961).

STRENGTH

The ability to resist physical forces imposed upon a material (Brady & Clauser, 1991:961).

STRESS

Internal forces set up in a material by the action of an external force (Brady & Clauser, 1991:962).

TALC

A soft friable mineral of fine colloidal particles with a soapy feel. It is a hydrated magnesium silicate, $4\text{SiO}_2 \cdot 3\text{MgO}$, with a specific gravity of 2.8 and a hardness of 1 mohs.

Talc is now used for cosmetics and paper coatings, as a filler for paints and plastics, and for moulding into electrical insulators, heaters, parts and chemical ware. Talc of specified purity and particle size is marketed under trade names. Asbestine, of C.K. Williams & Co., is a talc powder of 325 mesh for use as a filler. Ceramitalc, of the International Talc Co. Inc., is a talc powder used as a source of magnesia and to prevent crazing in ceramics. The hydrous aluminium silicate pyrophyllite, found in California, is similar to talc, but with magnesium replaced by aluminium. In mixtures with talc for wall tiles, the aluminium eliminates crazing. It is also substituted for talc as a filler for paints and paper (Brady & Clauser, 1991:825).

TENSILE STRENGTH

The maximum tensile load per square unit of original cross-section that a material is able to withstand. Tensile strength is the most common measure of the strength and ductility of metals (Brady & Clauser, 1991:962).

VERMICULITE

A foliated mineral employed in making plasters and board for heat, cold and sound insulation, as a filler in calking compounds, and for plastic mortars and refractory concrete. The mineral is an alteration product of biotite and other micas. It occurs in crystalline plates. Also used as a light aggregate in concrete (Brady & Clauser, 1991:884).

WATER : CEMENT RATIO

The relationship between the amounts of water and cement in a concrete mix (Brett, 1989:283).

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