Comparative Study on Different Sand/Binder Mixtures for Suitability in Metal Casting Operations

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ABSTRACT

Sand casting refers to an object produced using the sand casting process. Sand castings are produced in specialized factories called foundries. It is known that over 70% of all metal castings are produced via sand casting process. Molds that are made of sand are relatively cheap, and sufficiently refractory for high temperature use. In addition to the sand, a suitable binder is mixed with the sand. The mixture is moistened, typically with water, but sometimes with other substances, to develop the strength and plasticity of the clay and to make the aggregate suitable for molding.

This research offers a comparative study on the usability and suitability of different local sands and binders for metal casting operations. The aim was to examine three different properties that are necessary for sand casting. Four different types of sands and three binders were combined successfully in different design mixtures. The sands under study were Red sand (Ashkeda), white well sand, red well sand and silica sand (Zallaf). The binders used in the new mixtures were sugar solution, dates extract and local clay.

To achieve the research aim, certain properties concerning sand casting were investigated which are; the mixture strength, thermal collapse temperature and sand texture analysis so that all results can be linked together to support the findings.

The overall conclusion is that each type of our local sand require certain binder to give the best combination of properties required for metal casting operations. The best recommendation for sand/binder mixture for casting is (silica + clay) since this type tolerates a temperature of about 1100 ºc and compression strength of 700 N. The reason for this is that silica contain quartz element that has high melting point of about 1670 ºc. The new second best mixtures was the sample with mixture of (the white well sand + dates extract). This type of sand/binder mixture can endure a temperature as high as 870 ºc, and has a strength of 800 N. The third best choice for metal casting operation will be (Ashkida + dates extract). This type can withstand about 870 ºc and has failure strength of 750 N.
1. Introduction

Sand casting is used to make large parts (typically Iron, but also Bronze, Brass, Aluminum). Molten metal is poured into a mold cavity formed out of sand (natural or synthetic).

The processes of sand casting are discussed in the following, include patterns, sprues and runners, design considerations, and casting allowance[1].

In casting, a smelted alloy or other material fills a mold, then cools and stiffens into a wanted shape. However, a company must plan out post-cast steps to ensure competent outcomes. Proper care should be taken at each step to supply a final product that maintains the right quality and dependability[2].

Casting is one method of metal forming, as there are many other methods, including welding, forging, stamping, extrusion and machining.

Casting has the ability to form advanced geometries since liquid metal facilitates development of intricate designs, in either simple or advanced geometries.

Once the casting tools are in order, very little maintenance and recovery time is necessary. This makes casting an option for mass production applications.

Casting allows for workability of hard metals: Casting is often one of the only solid manufacturing processes for hard metals that are not soft enough for solid state shaping.

Often times, casting can create items in a single and complete step, eliminating the need to assemble multiple pieces.

Minimum sizing restraints: Casting can create really small to quite large parts, even up to 200 tons.

Versatile surface textures: Casting molds can be designed to hand over smooth, semi-smooth or rough area textures [2].

1.1. Types of Casting Techniques

There are several unique casting approaches, each of which requires slight variations in the process. The categorization of the different types of processes are based on the material used to make the molds. Casting options include:
• Fine sand casting
• Plaster casting
• Shell molding
• Wax casting
• Die casting
• Centrifugal casting

While every casting method creates unique challenges and process improvements, all techniques retain the same basic steps. These steps are:

• Patternmaking
• Coremaking
• Molding
• Melting and pouring
• Finishing [2].

Sand casting is a basic industry which is responsible for a great part of the industrial growth of the world. In the beginning the sand caster was also the metal smelter and refiner. At the outset the sand caster made his sand mold, then smelted virgin ore in a wide variety of homemade smelters or blast furnaces and did his casting. As the demand for casting grew the foundry man had to devote more and more time and energy to the actual production of sand casting, thus he had less time to devote to the collection of ore and the smelting end of the business. This gave birth to a new business[2].

The metal smelter who devoted his time and skills to the efficient production of pig iron, brass and bronze ingots which he sold to the ever increasing number of sand foundries. At this point the foundry man became a metal re-melter and caster as it is today. The new born smelting industry released the founder from this chore so he could devote his time to the production of castings and develop his methods to a fine point. There has been much development in sand casting methods but the basic system is the same today as it was at the outset. A sand mold is made into which the liquid metal is cast and when the metal has solidified the mold is broken up (shake out) and you have the casting [2].
In sand casting the development that have taken place, and are taking place, are in improved methods of producing sand molds, mold handling equipment, automatic pouring of molds, automatic conditioning of the sand, automatic shake out and better melting equipment [1].

Automatic computerization have resulted in many highly efficient sand foundries. Nothing brings this into focus more clearly than a visit to a modern automotive foundry works, then a visit to a job shop foundry where men are molding by hand. Even so, it is still sand molds. Ramming up a green sand mold by hand or producing it on an automatic molding machine is still making a sand mold. Ninety-seven percent of the millions of tons of casting produced each year are sand castings with ninety percent of this tonnage being produced in green sand molds [2].
2. Literature Review

2.1. Sand Casting

Sand casting is the most widely used metal casting process in manufacturing. Almost all casting metals can be sand cast. Sand castings can range in size from very small to extremely large. Some examples of items manufactured in modern industry by sand casting processes are engine blocks, machine tool bases, cylinder heads, pump housings, and valves, just to name a few [2].

2.2. Sand

Sand: Product of the disintegration of rocks over long periods of time. Most sand casting operations use silica sand (SiO$_2$). A great advantage of sand in manufacturing applications is that sand is inexpensive. Another advantage of sand to manufacture products by metal casting processes, is that sand is very resistant to elevated temperatures. In fact, sand casting is one of the few processes that can be used for metals with high melting temperatures such as steels, nickel, and titanium. Usually sand used to manufacture a mold for the casting process is held together by a mixture of water and clay. A typical mixture by volume could be 89% sand, 4% water, 7% clay. Control of all aspects of the properties of sand is crucial when manufacturing parts by sand casting, therefore a sand laboratory is usually attached to the foundry [2].

2.3. Use Of Binder In Sand Casting

A mold must have the physical property to keep its shape throughout the casting operation. For this reason, in sand casting, the sand must contain some type of binder that acts to hold the sand particles together. Clay serves an essential purpose in the sand casting manufacturing process, as a binding agent to adhere the molding sand together. In manufacturing industry other agents may be used to bond the molding sand together in place of clay. Organic resins, (such as phenolic resins), and inorganic bonding agents, (such as phosphate and sodium silicate), may also be used to hold the sand together. In addition to sand and bonding agents, the sand mixture to create the
metal casting mold will sometimes have other constituents added to it in order to improve mold properties [2].

2.4. Sand Additives

2.4.1. Kaolinite

This is hydrated aluminum-silicate clay and also known as fire clay. It is one of a family of three distinct mineral having a similar composition, kaolinite, nacrite, and dicite. It is a sedimentary clay of low flux content. It is prime use in molding sands is in facing for very heavy and also in dry sand work when excellent hot strength is required. It comes closer than any other type of bonding clay to producing a sand which approximates the properties of natural bonded sands. It is though and durable and easy to use [4].

2.4.2. Bentonite

Both southern and western bentonites are very useful to the foundry and are closely related chemically. The basic difference in their properties is that southern bentonite will impart less baked, hot and dry strength to a mix. It will collapse quicker and has a shorter life requiring larger and more frequent additions to maintain the sand at a fixed level Than It seems to impart more green strength part for part. Also is beneficial in the shake out due to it is lower hot strength.
Western bentonite is more widely used in steel sands and sands for heavy casting requiring high hot strength to prevent cutting and washing. The smart foundry man uses each to it is best advantage and blends the two together to give him the properties he desires. It is very common use 50 percent western and 50 percent southern as the bonding medium [4].
2.5. Types Of Sand Used In Sand Casting

There are two general types of sand used in the manufacturing process of sand casting[2].

- Naturally Bonded- Naturally bonded sand is less expensive but it includes organic impurities that reduce the fusion temperature of the sand mixture for the casting, lower the binding strength, and require a higher moisture content [2].
- Synthetic Sand- Synthetic sand is mixed in a manufacturing lab starting with a pure (SiO₂) sand base. In this case, the composition can be controlled more accurately, which imparts the casting sand mixture with higher green strength, more permeability, and greater refractory strength. For these reasons, synthetic sand is mostly preferred in sand casting manufacture [2].

2.6. Type And Content Of Binder And Other Additives

The type and content of the sand binder and other additives is the key to controlling the properties of the casting's mold sand mixture [2].

2.6.1. Moisture Content

Moisture content affects the other properties of the mixture such as strength and permeability. Too much moisture can cause steam bubbles to be entrapped in the metal casting [2].

2.6.2. Grain Size

This property represents the size of the individual particles of sand [2].

2.6.3. Shape of Grains

This property evaluates the shape of the individual grains of sand based on how round they are. Less round grains are said to be more irregular[2].
2.7. Properties Of A Sand Casting Mixture

To cast sand, we make a mold around a pattern, open the mold, remove the pattern, close the mold and fill the cavity left in the sand with molten metal. When the metal has solidified, we shake out the mold and have an exact duplicate in metal of our pattern. Anyone who has built sand castles on the beach can attest to how fragile they are. But if we took our beach sand and mixed enough clay with it to give each grain a coating of clay, which when damp is sticky, we would soon realize that we could make great sand castles, not nearly as fragile as our beach castles, which depended upon water alone as a medium to bond the grains together.

With additional experimentation we would find that a mold made of our beach sand, clay and water, could be used to hold molten metal. The next question that would come to mind is why when the mold is filled with hot metal it does not crumble or explode because of the moisture content. Very simple, this is what happens: as the molten metal enters the mold cavity the radiant heat from the metal dries the mold material in advance of the metal flow. The moisture is changed to steam and moves out of the mold through the mold walls because of the porous nature of the molding sand [5].

2.7.1. Tensile Strength

The explanation of strength is the ability of the sand casting mixture to hold its geometric shape under the conditions of mechanical stress imposed during the sand casting process. Tensile strength is the force that holds the sand up in the cope [6].

As molding sands are many times stronger in compression than tensile strength, the tensile strength must be taken into account. Mold failure is more apt to occur under tensile forces. The tensile strength which is the force required to pull the sample apart, is determined very easily.
2.7.2. Permeability

The ability of the sand mold to permit the escape of air, gases, and steam during the sand casting process[2].

The ability of the mold material to allow the steam to pass through the walls is called permeability. Permeability can be measured with a meter which measures the volume of air that will pass through a test specimen per minute under a standard pressure.

Some instruments are designed to measure a pressure differential which is indicated on a water tube gauge expressed in permeability units. Natural molding sands contain from eight to twenty percent natural clay, the remaining material consists of a refractory aggregate, usually silica grains. Any natural sand containing less than 5 percent natural clay is called a bank sand and is used for cores or as a base for synthetic molding sand [7].

2.7.3. Collapsibility

The ability of the sand mixture to collapse under force. Collapsibility is a very important property in this type of casting manufacture. Collapsibility of the mold will allow the metal casting to shrink freely during the solidification phase of the process. If the molding sand cannot collapse adequately for the casting's shrinkage, hot tearing or cracking will develop in the casting [8].

2.7.4. Flow ability

The ability of the sand mixture to flow over and fill the sand casting pattern during the impression making phase of the manufacturing process, more flow ability is useful for a more detailed casting.

2.7.5. Reusability

The ability of the mold sand mixture to be reused to produce other sand castings in subsequent manufacturing operations [6].
2.7.6. Fineness

This is a measure of the actual grain sizes of a sand mixture. It is made by passing a standard sample, 100 grams, through a series of graded sieves. About ten different sieve are used. As most sands are composed of a mixture of various size grains there is a distribution of sand remaining on the measuring sieves.

The fineness number assigned to the sample is the number of the sieve through which passed the largest amount of sand.

When you fully understand the relationship between the required permeability for a given metal and it is pouring temperature and the relationship of grain fineness to permeability, you will to ably to establish what sand you need for a given metal and casting size. As an example gray iron is poured at a temperature of 2426 cº, and is three times the weight of aluminum which is poured at 1126 cº.

Every sand have their good and bad features and the choice depends upon the class of work and the equipment available.

The basic components of most molding sands are silica and a clay bond. However molding sands can also be made up of other types of refractory material such as zircon, olivine, carbon, manganite, ceramic dolomite and others.

Molding sand is defined as a mixture of sand or gravel with a suitable clay bond. Natural sands are sands found in nature which can be used for producing molds as they are found. Synthetic molding sands are weak or clay free sands to which suitable clay or clays are added to given them the properties needed [9].

2.7.7. Refractoriness

This is the ability of sand to withstand high temperature without fusing or breaking down. For this we can deduce that a sand used for casting steel must be more refractory than one for brass or aluminum because of the greater pouring temperature involved. Also, a sand used to cast large heavy castings must be more refractory than one used for light thin castings of the same metal [10].
2.7.8. Green bond strength

This is the strength of a tempered by it is ability to hold a mold in shape. Sand molds are subjected to compressive, tensile, shearing, and transverse stresses. Which of these stresses is more important to the sands molding properties is a point of controversy [11].

2.7.9. Dry strength

A mold must not only it is shape in the green state, it must also hold it is shape in the dry state. This is an important property and is measured as dry compression by allowing the test specimen to dry out before testing which is then carried out in the same manner as for green strength. A good average is 30 b/s. Dry strength should be no higher than necessary, excessive dry strength results in a critical sand. If the molding sand has too high a dry it will give or break down as the casting shrinks during solidification. This will cause hot tearing of the casting [12].

2.7.10. Durability

This is the measure of the sands ability to withstand repeated usage without losing it is properties and to recover it is bond strength after repeated usage. The sands fineness, the type and amount of clay bond determines the sands durability. The ability of the bonding clay to retain it is moisture is also an important factor [13].

2.7.11. Mold ability

This characteristic is also related to the nature of the bonding clay and the fineness of the sand. Because the base sand determines the resulting finish of the casting, it should be selected with care keeping in mind the type, weight, and class of casting desired. The three or four types of screened sands formerly used for a base has given way to the practice of blending one coarse sand with a fine which results in a better grain distribution. This has been found to produce a better finish and texture. Each of the two sands selected should have a good grain distribution within itself. Contrary to
popular belief, additives of an organic or carbonaceous nature do not improve the finish but only furnish combustibles resulting in better peel [14].

2.8. Types Of Molds Used In Sand Casting

2.8.1. Green Sand Molds

A green sand mold is very typical in sand casting manufacture, it is simple and easy to make, a mixture of sand, clay and water. The term green refers to the fact that the mold will contain moisture during the pouring of the casting [2].

2.8.1.1. Manufacturing Considerations and Properties of Green Sand Molds:

- Has sufficient strength for most sand casting applications
- Good collapsibility
- Good permeability
- Good reusability
- Least expensive of the molds used in sand casting manufacturing processes
- Moisture in sand can cause defects in some castings, dependent upon the type of metal used in the sand casting and the geometry of the part to be cast.

2.8.2. Dry Sand Molds

Dry sand molds are baked in an oven, (at 300F - 650F for 8-48 hours), prior to the sand casting operation, in order to dry the mold. This drying strengthens the mold, and hardens its internal surfaces. Dry sand molds are manufactured using organic binders rather than clay [2].

2.8.2.1. Manufacturing Considerations and Properties of Dry Sand Molds:

- Better dimensional accuracy of sand cast part than green sand molds.
- Better surface finish of sand cast part than green sand molds.
- More expensive manufacturing process than green sand production.
- Manufacturing production rate of castings are reduced due to drying time.
- Distortion of the mold is greater, (during mold manufacture).
• The metal casting is more susceptible to hot tearing because of the lower collapsibility of the mold.
• Dry sand casting is generally limited to the manufacture of medium and large castings.

2.8.3. Skin Dried Molds

When sand casting a part by the skin dried mold process a green sand mold is employed, and its mold cavity surface is dried to a depth of .1-5 inch. Drying is a part of the manufacturing process and is accomplished by use of torches, heating lamps or some other means, such as drying it in air [2].

2.8.3.1. Manufacturing Considerations and Properties of Skin Dried Molds:

• The cast part dimensional and surface finish advantages of dry sand molds are partially achieved
• No large oven is needed
• Special bonding materials must be added to the sand mixture to strengthen the mold cavity surface

2.8.4. Cold Setting Processes

In industrial sand casting manufacture, sometimes non-traditional binders other than those used in the above classifications of sand molds may be used. These binders may be made of a variety of things, such as synthetic liquid resins. Conventional casting binders require heat to cure while these when mixed with the sand, bond chemically at room temperature. Hence the term cold setting processes. Technically advanced, these relatively recent sand casting processes are growing in manufacturing. While more expensive than green sand molds, cold setting processes provide good dimensional accuracy of the casting, and have high production applications [1].
2.9. Mold Setup For Sand Casting

The setup of a sand mold in manufacturing involves using a pattern to create an impression of the part to be sand cast within the mold, removal of the pattern, the placement of cores, (if needed), and the creation of a gating system within the mold. The setup of a mold is covered in detail in metal casting process. A mold setup such as the one shown in figure (2.1) could be typical in a sand casting manufacturing operation [1].

Figure (2.1) Typical Components of a Two-part Sand Casting Mold [1].

2.10. The Pattern

The cavity in the sand is formed by using a pattern (an approximate duplicate of the real part), which are typically made out of wood, sometimes metal. The cavity is contained in an aggregate housed in a box called the flask. Core is a sand shape inserted into the mold to produce the internal features of the part such as holes or internal passages. Cores are placed in the cavity to form holes of the desired shapes. Core print is the region added to the pattern, core, or mold that is used to locate and support the core within the mold. A riser is an extra void created in the mold to contain excessive molten material. The purpose of this is feed the molten metal to the mold cavity as the molten metal solidifies and shrinks, and thereby prevents
voids in the main cast figure (2.2) shown a typical pattern with gating and rising system [16].

![Diagram of a typical pattern with gating and rising system](image)

Figure(2.2) A typical pattern attached with gating and rising system [16].

### 2.10.1. Functions of the Pattern

1. A pattern prepares a mold cavity for the purpose of making a casting.

2. A pattern may contain projections known as core prints if the casting requires a core and need to be made hollow.

3. Runner, gates, and risers used for feeding molten metal in the mold cavity may form a part of the pattern.

4. Patterns properly made and having finished and smooth surfaces reduce casting defects.

5. A properly constructed pattern minimizes the overall cost of the castings [16].

### 2.10.2. Pattern Material

Patterns may be constructed from variety of materials. Each material has its own advantages, limitations, and field of application. Some materials used for making
patterns are: wood, metals and alloys, plastic, plaster of Paris, plastic and rubbers, wax, and resins. To be suitable for use, the pattern material should be:

1. Easily worked, shaped and joined

2. Light in weight

3. Strong, hard and durable

4. Resistant to wear and abrasion

5. Resistant to corrosion, and to chemical reactions

6. Dimensionally stable and unaffected by variations in temperature and humidity

7. Available at low cost.

- The usual pattern materials are wood, metal, and plastics. The most commonly used pattern material is wood, since it is readily available and of low weight. Also, it can be easily shaped and is relatively cheap.
- The main disadvantage of wood is its absorption of moisture, which can cause distortion and dimensional changes.
- Araldite is the new material for pattern making, which is referring to a range of engineering and structural epoxy, acrylic, and polyurethane adhesives [16].

2.10.3. Pattern Allowances

Pattern allowance is a vital feature as it affects the dimensional characteristics of the casting. Thus, when the pattern is produced, certain allowances must be given on the sizes specified in the finished component drawing so that a casting with the particular specification can be made. The selection of correct allowances greatly helps to reduce machining costs and avoid rejections. The allowances usually considered on patterns and core boxes are as follows:
1. Shrinkage or contraction allowance

2. Draft or taper allowance

3. Machining or finish allowance

4. Distortion or camber allowance

5. Rapping allowance

1) Shrinkage or Contraction Allowance

All most all cast metals shrink or contract volumetrically on cooling. The metal shrinkage is of two types:

i. Liquid Shrinkage: it refers to the reduction in volume when the metal changes from liquid state to solid state at the solidus temperature. To account for this shrinkage; riser, which feed the liquid metal to the casting, are provided in the mold.

ii. Solid Shrinkage: it refers to the reduction in volume caused when metal loses temperature in solid state. To account for this, shrinkage allowance is provided on the patterns.

The rate of contraction with temperature is dependent on the material. For example steel contracts to a higher degree compared to aluminum. To compensate the solid shrinkage, a shrink rule must be used in laying out the measurements for the pattern. A shrink rule for cast iron is 1/20.16 cm longer per meter than a standard rule. If a gear blank of 10.08 cm in diameter was planned to produce out of cast iron, the shrink rule in measuring it 0.03 cm, thus compensating for the shrinkage, Table (2.1) show the rate of contraction of some materials.
Table (2.1) the rate of contraction of some materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Dimension(cm)</th>
<th>Shrinkage allowance (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grey Cast Iron</td>
<td>Up to 60cm</td>
<td>0.315</td>
</tr>
<tr>
<td></td>
<td>60cm to 120cm</td>
<td>0.2646</td>
</tr>
<tr>
<td></td>
<td>Over 120cm</td>
<td>0.20916</td>
</tr>
<tr>
<td>Cast Steel</td>
<td>Up to 60cm</td>
<td>0.63252</td>
</tr>
<tr>
<td></td>
<td>60cm to 180cm</td>
<td>0.48132</td>
</tr>
<tr>
<td></td>
<td>Over 180cm</td>
<td>0.3906</td>
</tr>
<tr>
<td>Aluminum</td>
<td>Up to 120cm</td>
<td>0.3906</td>
</tr>
<tr>
<td></td>
<td>120cm to 180cm</td>
<td>0.36036</td>
</tr>
<tr>
<td></td>
<td>Over 180cm</td>
<td>0.315</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Up to 120cm</td>
<td>0.43596</td>
</tr>
<tr>
<td></td>
<td>Over 120cm</td>
<td>0.3606</td>
</tr>
</tbody>
</table>

In a two-part mold, which is typical of sand castings, the upper half, including the top half of the pattern, flask, and core is called cope and the lower half is called drag. The parting line or the parting surface is line or surface that separates the cope and drag. The drag is first filled partially with sand, and the core print, the cores, and the gating system are placed near the parting line. The cope is then assembled to the drag, and the sand is poured on the cope half, covering the pattern, core and the gating system. The sand is compacted by vibration and mechanical means. Next, the cope is removed from the drag, and the pattern is carefully removed. The object is to remove the pattern without breaking the mold cavity. This is facilitated by designing a draft, a slight angular offset from the vertical to the vertical surfaces of the pattern. This is usually a minimum of $1^\circ$ or 1.5 mm (0.060 in), whichever is greater. The rougher the surface of the pattern, the more the draft to be provided [2].
2) Draft or Taper Allowance:

By draft is meant the taper provided by the pattern maker on all vertical surfaces of the pattern so that it can be removed from the sand without tearing away the sides of the sand mold.

Figure (2.3) shows a pattern having no draft allowance being removed from the pattern. In this case, till the pattern is completely lifted out, its sides will remain in contact with the walls of the mold, thus tending to break it [16].

![Figure (2.3) wrong draft allowance cause failure of pattern [16].](image)

Figure (2.3) wrong draft allowance cause failure of pattern [16].

Figure (2.4) is an illustration of a pattern having proper draft allowance. Here, the moment the pattern lifting commences, all of its surfaces are well away from the sand surface. Thus the pattern can be removed without damaging the mold cavity [16].

![Figure (2.4) a proper allowance [16].](image)

Figure (2.4) a proper allowance [16].

Draft allowance varies with the complexity of the sand job. But in general inner details of the pattern require higher draft than outer surfaces. The amount of draft depends upon the length of the vertical side of the pattern to be extracted; the intricacy of the pattern; the method of molding; and pattern material [16].
3) Machining or Finish Allowance

The finish and accuracy achieved in sand casting are generally poor. When the casting is functionally required to be of good surface finish or dimensionally accurate, it is generally achieved by subsequent machining. Machining or finish allowances are therefore added in the pattern dimension. The amount of machining allowance to be provided for is affected by the method of molding and casting used. Hand molding or machine molding, sand casting or metal mold casting are mostly used. The amount of machining allowance is also affected by the size and shape of the casting; the casting orientation; the metal; and the degree of accuracy and finish required. The machining allowances recommended for different metal is given in Table (2.2). [16].

Table (2.2) machining allowances of various metals

<table>
<thead>
<tr>
<th>Metal</th>
<th>Dimension (cm)</th>
<th>Allowance (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cast iron</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Up to 30.24</td>
<td></td>
<td>0.3</td>
</tr>
<tr>
<td>30.24 to 50.4</td>
<td></td>
<td>0.504</td>
</tr>
<tr>
<td>50.4 to 100.8</td>
<td></td>
<td>0.63</td>
</tr>
<tr>
<td><strong>Cast steel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Up to 15.12</td>
<td></td>
<td>0.3024</td>
</tr>
<tr>
<td>15.12 to 50.4</td>
<td></td>
<td>0.63</td>
</tr>
<tr>
<td>50.4 to 100.8</td>
<td></td>
<td>0.756</td>
</tr>
<tr>
<td><strong>Non ferrous</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Up to 20.16</td>
<td></td>
<td>0.2268</td>
</tr>
<tr>
<td>20.16 to 30.24</td>
<td></td>
<td>0.3024</td>
</tr>
<tr>
<td>30.24 to 100.8</td>
<td></td>
<td>0.4032</td>
</tr>
</tbody>
</table>

4) Distortion or Camber Allowance

Sometimes castings get distorted, during solidification, due to their typical shape. For example, if the casting has the form of the letter U, V, T, or L etc. it will tend to contract at the closed end causing the vertical legs to look slightly inclined. This can be prevented by making the legs of the U, V, T, or L shaped pattern converge slightly (inward) so that the casting after distortion will have its sides vertical [16].
The distortion in casting may occur due to internal stresses. These internal stresses are caused on account of unequal cooling of different section of the casting and hindered contraction.

![Diagram of casting distortion](image)

Figure (2.5) Unequal cooling of different sections [16].

Measure taken to prevent the distortion in casting includes:

i. Modification of casting design

ii. Providing sufficient machining allowance to cover the distortion affect

iii. Providing suitable allowance on the pattern, called camber or distortion allowance (inverse reflection) [16].

5) Rapping Allowance

Before the withdrawal from the sand mold, the pattern is rapped all around the vertical faces to enlarge the mold cavity slightly, which facilitate its removal. Since it enlarges the final casting made, it is desirable that the original pattern dimension should be reduced to account for this increase. There is no sure way of quantifying this allowance, since it is highly dependent on the foundry personnel practice involved [16].

2.11. Pattern Making

In a large foundry there is a close relationship between the pattern maker and the molder. Each is aware of the capabilities and limitation of his own field.
Through the industry, pattern making is a field and an art of its own. The pattern maker is not simply that the pattern cannot make a simple mold or the molder make a simple pattern but each may soon reach a point in the others field beyond his own skill and experience.

Making a pattern is similar to making the piece in wood, with some differences of course. The first difference is that the pattern must be made bigger than the final piece. When the metal melts it expands, and it will contract after being poured into the mold. For aluminum this expansion rate is approximately 1/8” per meter. So a piece 6” long would require a pattern that is 6-1/16” long. On smaller parts the contraction can be ignored though.

Another difference is that any vertical surface, as viewed when the pattern is in the mold, must be tapered. The taper is required to make it easier to remove the pattern from the mold. Once the pattern starts to come out of the mold it will release from the walls of the mold cavity, allowing its removal without scraping sand from the walls. A taper of 4° is usually sufficient [17].

The edges of the pattern also need special consideration. Where the two halves of the mold come together is called the parting line, even though it’s actually a plane. Any edges that are not on the parting line must be rounded. Outside corners must be rounded and inside corners must have a fillet. Rounding outside corners can be as easy as sanding the edges of a wood pattern. Creating the fillets on inside corners requires a filler such as wood putty or auto body filler [17].

Patterns do not have to be made of any particular material. Wood is an easy material to work with, which makes it a good choice. But any material that is rigid enough to hold its shape will work. Some of the patterns that I’ve used are aluminum pieces that my grandfather cast in his foundry before I was born. Patterns can also be made of wax or foam, but the processes used to make castings this way is outside the scope of this project.

After the pattern is made it is sanded smooth and sealed. It is coated with varnish, shellac, or a spray-on clear coat to keep it from absorbing moisture. The green sand
has water in it and an unsealed pattern will absorb the water in the sand. This will lead to a weaker sand mold if too much water is removed from the sand [17].

2.11.1. Solid Pattern

This is a one piece pattern representing the geometry of the casting as shown in figure (2.6). It is an easy pattern to manufacture, but determining the parting line between cope and drag is more difficult for the foundry worker [2].

![Solid Pattern](image1)

Figure (2.6) Solid Pattern [2].

2.11.2. Split Pattern

The split pattern is comprised of two separate parts that when put together will represent the geometry of the casting as shown in figure (2.7). When placed in the mold properly the plane at which the two parts are assembled should coincide with the parting line of the mold. This makes it easier to manufacture a pattern with more complicated geometry. Also mold setup is easier since the patterns placement relative to the parting line of the mold is predetermined [2].

![Split Pattern](image2)

Figure (2.7) Split Pattern [2].
2.11.3. Match Plate Pattern

The match plate pattern is typically used in high production industry runs for sand casting manufacture. A match plate pattern is a two piece pattern representing the casting, divided at the parting line, similar to the split pattern as shown in figure (2.8). In the match plate pattern, however, each of the parts are mounted on a plate. The plates come together to assemble the pattern for the sand casting process. The match plate pattern is more proficient and makes alignment of the pattern in the mold quick and accurate [2].

![Match Plate Pattern](image)

Figure (2.8) Match Plate Pattern [2].

2.11.4. Cope and Drag Pattern

The cope and drag pattern is also typical in sand casting processes for high production industry runs. The cope and drag pattern is the same as the match plate pattern in that it is a two piece pattern representing the casting and divided at the parting line. Each of the two halves are mounted on a plate for easy alignment of the pattern and mold. The difference between the cope and drag pattern and the match plate pattern is that in the match plate pattern the two halves are mounted together, where as in the cope and drag pattern the two halves are separate. The cope and drag pattern enables the cope section of the mold, and the drag section of the mold to be created separately and latter assembled before the pouring of the sand casting [2].
In industrial sand casting processes a gating system, (not shown), is often incorporated as part of the pattern, particularly for a cope and drag pattern. Patterns can be made of different materials, and the geometry of the pattern must be adjusted for shrinkage, machine finish, and distortion. Pattern basics are covered in detail in the patterns section [2].

2.12. Cores

Cores form the internal geometry of the casting. Cores are placed in the mold, and remain there during the pouring phase of the sand casting process. The metal casting will solidify around the core. Core basics are covered in detail in the cores section. Cores are made of the highest quality sand and are subject to extreme conditions during the sand casting operation. Cores must be strong and permeable; also, since the metal casting will shrink onto the core, cores must have sufficient collapsibility. Sometimes a reinforcing material will be placed in a sand casting core to enhance strength. The core may be manufactured with vents to facilitate the removal of gases [1].
2.13. The Sand Casting Operation

The sand casting operation involves the pouring of the molten metal into the sand mold, the solidification of the casting within the mold, and the removal of the casting. The casting operation is covered in detail on the metal casting operation page.

Of specific interest to sand casting would be; the effect and dissipation of heat through the particular sand mold mixture during the casting's solidification, the effect of the flow of liquid metal on the integrity of the mold, (mold sand mixture properties and binder issues), and the escape of gases through the mixture. Sand usually has the ability to withstand extremely high temperature levels, and generally allows the escape of gases quite well. Manufacturing with sand casting allows the creation of castings with complex geometry. Sand casting manufacture, however, only imparts a fair amount of dimensional accuracy to the cast part [2].

After the sand casting is removed from the sand mold it is shaken out, all the sand is otherwise removed from the casting, and the gating system is cut off the part. The part may then undergo further manufacturing processes such as heat treatment, machining, and/or metal forming. Inspection is always carried out on the finished part to evaluate the effectiveness and satisfaction of its manufacture [2].
2.14. Components

2.14.1. Patterns

From the design, provided by an engineer or designer, a skilled pattern maker builds a pattern of the object to be produced, using wood, metal, or a plastic such as expanded polystyrene. Sand can be ground, swept or strike into shape. The metal to be cast will contract during solidification, and this may be non-uniform due to uneven cooling. Therefore, the pattern must be slightly larger than the finished product, a difference known as contraction allowance. Pattern-makers are able to produce
suitable patterns using "Contraction rules" (these are sometimes called "shrink allowance rulers" where the ruled markings are deliberately made to a larger spacing according to the percentage of extra length needed). Different scaled rules are used for different metals, because each metal and alloy contracts by an amount distinct from all others. Patterns also have core prints that create registers within the molds into which are placed sand cores. Such cores, sometimes reinforced by wires, are used to create under-cut profiles and cavities which cannot be molded with the cope and drag, such as the interior passages of valves or cooling passages in engine blocks [6].

Paths for the entrance of metal into the mold cavity constitute the runner system and include the sprue, various feeders which maintain a good metal 'feed', and in-gates which attach the runner system to the casting cavity. Gas and steam generated during casting exit through the permeable sand or via risers, which are added either in the pattern itself, or as separate pieces [6].

2.14.2. Tools

In addition to patterns, the sand molder could also use tools to create the holes.

![Sand Molding tools and books used in Auckland and Nelson New Zealand between approximately 1946 and 1960][1]

2.14.3. Molding Box and Materials

A multi-part molding box (known as a casting flask, the top and bottom halves of which are known respectively as the cope and drag) is prepared to receive the pattern. Molding boxes are made in segments that may be latched to each other and to end closures. For a simple object flat on one side the lower portion of the box, closed at the bottom, will be filled with a molding sand. The sand is packed in through a vibratory process called ramming, and in this case, periodically squared level. The surface of the sand may then be stabilized with a sizing compound. The pattern is
placed on the sand and another molding box segment is added. Additional sand is rammed over and around the pattern. Finally a cover is placed on the box and it is turned and unlatched, so that the halves of the mold may be parted and the pattern with its sprue and vent patterns removed. Additional sizing may be added and any defects introduced by the removal of the pattern are corrected. The box is closed again. This forms a "green" mold which must be dried to receive the hot metal. If the mold is not sufficiently dried a steam explosion can occur that can throw molten metal about. In some cases, the sand may be oiled instead of moistened, which makes casting possible without waiting for the sand to dry. Sand may also be bonded by chemical binders, such as furane resins or amine-hardened resins [18].

2.14.4. Chills

To control the solidification structure of the metal, it is possible to place metal plates, chills, in the mold. The associated rapid local cooling will form a finer-grained structure and may form a somewhat harder metal at these locations. In ferrous castings, the effect is similar to quenching metals in forge work. The inner diameter of an engine cylinder is made hard by a chilling core. In other metals, chills may be used to promote directional solidification of the casting. In controlling the way a casting freezes, it is possible to prevent internal voids or porosity inside castings [18].

2.14.5. Cores

To produce cavities within the casting such as for liquid cooling in engine blocks and cylinder heads negative forms are used to produce cores figure (2.14) shown some parts that require core during casting. Usually sand-molded, cores are inserted into the casting box after removal of the pattern. Whenever possible, designs are made that avoid the use of cores, due to the additional set-up time and thus greater cost [18].
With a completed mold at the appropriate moisture content, the box containing the sand mold is then positional for filling with molten metal typically iron, steel, bronze, brass, aluminum, magnesium alloys, or various pot metal alloys, which often include lead, tin, and zinc. After being filled with liquid metal the box is set aside until the metal is sufficiently cool to be strong. The sand is then removed, revealing a rough casting that, in the case of iron or steel, may still be glowing red. In the case of metals that are significantly heavier than the casting sand, such as iron or lead, the casting flask is often covered with a heavy plate to prevent a problem known as floating the mold. Floating the mold occurs when the pressure of the metal pushes the sand above the mold cavity out of shape, causing the casting to fail [18].

Figure (2.15) Left: Core box, with resulting (wire reinforced) cores directly below. Right: Pattern (used with the core) and the resulting casting below (the wires are from the remains of the core) [18].
After casting, the cores are broken up by rods or shot and removed from the casting. The metal from the sprue and risers is cut from the rough casting. Various heat treatments may be applied to relieve stresses from the initial cooling and to add hardness in the case of steel or iron, by quenching in water or oil. The casting may be further strengthened by surface compression treatment like shot peening that adds resistance to tensile cracking and smooths the rough surface. And when high precision is required, various machining operations (such as milling or boring) are made to finish critical areas of the casting. Examples of this would include the boring of cylinders and milling of the deck on a cast engine block [18].

2.14.6. Design Requirements

The part to be made and its pattern must be designed to accommodate each stage of the process, as it must be possible to remove the pattern without disturbing the molding sand and to have proper locations to receive and position the cores. A slight taper, known as draft, must be used on surfaces perpendicular to the parting line, in order to be able to remove the pattern from the mold. This requirement also applies to cores, as they must be removed from the core box in which they are formed. The sprue and risers must be arranged to allow a proper flow of metal and gasses within the mold in order to avoid an incomplete casting. Should a piece of core or mold become dislodged it may be embedded in the final casting, forming a sand pit, which may render the casting unusable. Gas pockets can cause internal voids. These may be immediately visible or may only be revealed after extensive machining has been performed. For critical applications, or where the cost of wasted effort is a factor, non-destructive testing methods may be applied before further work is performed [18].

2.15. Making The Mold

- (Figure 2.16) shows the patterns made. each one is 1¼” wide, 23/8” long, and 1½” tall. The problem with casting this part is that there will be quite a bit of shrinkage. The shrinkage will be in the center of the top [19].
The mold is made in a box called a flask. A flask is made with two or more interconnecting parts. Figure (2.17) shows a two-part flask. The piece on the left is the bottom and it is called the drag. The piece on the right is the top, and it is called the cope. When the parts are put together the pegs in the cope will fit into the sockets on the drag. This assured the flask goes together the same way each time. The edges of the cope and drag shown in the picture are where the parting line of the mold will be [19].

Since neither the drag nor cope has a bottom, boards must be used to hold the sand in the flask. The two boards in the picture are the molding board and bottom board. All the surfaces of the flask and boards that will touch the molding sand are sealed so they will not absorb moisture [19].
• To start the mold, the drag is placed upside-down on the molding board and the patterns are placed on the board with the parting lines down Figure (2.18). This places all the parting lines on the same plane [19].

![Pattern placement](image)

Figure (2.18) Pattern are placed on the board with parting line [19].

• Sand is then shoveled into the flask with a trowel and is rammed firmly with a rammer (Figure 2.19). The sand is built up in layers until the drag is filled. After filling the drag the bottom (which is the top at this point) is leveled off and the mold is vented. A wire is poked into the sand to make holes that will allow the air and steam in the mold to escape when the metal is poured into the mold( Figure 2.20) [19].

![Ramming the Sand](image)

Figure (2.19) Ramming the Sand [19].
Figure (2.20) create the vents [19].

- After venting the sand some loose sand is sprinkled on the mold and the bottom board is rubbed into the sand. The object is to have solid contact between the sand in the drag and the bottom board. If the sand does not have adequate support it will break when the cope is rammed up. This will result in a distorted casing [19].

When the bottom board is in place the drag is rolled over. Since the halves of a mold can easily weigh 40 to 60 pounds each this has to be done carefully. The molding board is removed to reveal the parting line of the drag (Figure 2.21)

Figure (2.21) The Parting Line [21]

At this point provisions have to be made for the metal to enter the mold (Figure 2.22). The hole that the metal is poured into is called the sprue, and it is made by placing a sprue pin in the mold. The halves of the mold also have to be isolated from each other so the mold will come apart cleanly. In (Figure 2.22) parting dust is being sprinkled on the face of the sand. Parting dust will not absorb moisture, so it creates a barrier that keeps the sand in the cope from adhering to the sand in the drag [19].
After the parting dust is applied the cope is placed on the drag. The cope is filled with sand, rammed, and vented just like the drag. The next step is to cut a funnel shape around the sprue pin as shown in (Figure 2.23). The funnel shape provides a larger target when pouring the metal [19].

Then the mold is opened and the cope is placed behind the drag (Figure 2.24). The patterns now have to be removed from the mold. This is done by screwing an eyescrew into the pattern and rapping against the screw with a rapper (Figure 2.25). I use a 1” box-end wrench for a rapper. Rapping the pattern makes the cavity a fuzz larger to help remove the pattern, and it also strengthens the walls of the cavity. When the pattern is loose it is pulled out of the sand [19].
Figure (2.24) The Open Mold [19].

Figure (2.25) Rapping the Pattern [19].

The final step in creating the mold is to cut gates from the sprue to the cavities (Figure 2.26). The gates complete the path that the metal will follow from outside of the mold to the cavities [19].

Figure (2.26) Cutting the Gates [19].

The mold is then moved to the casting area and reassembled.
2.16. Furnaces

The central piece of equipment in a foundry is the furnace. A furnace has a lining of refractory that holds in the heat while the fuel heats the crucible and metal being melted. There are commercial blends of refractory available, but the linings can also be made from homebrewed mixes of sand, fire clay, and cement. Some people have even used fire brick as a lining with success. Refractory linings can incorporate fillers such as sawdust or Perlite that will burn out of the lining to leave a void. The voids will increase the insulating ability of the lining [19].

The biggest difference in furnaces is the fuel used. The fuels can be separated into three general classes: solid, gas, and electricity. Solid fuels include charcoal, coal, coke, and wood. Gas fuels include natural gas (methane) and propane. Of course, electricity uses electricity [19].

Each type of fuel has its advantages and disadvantages. Solid and gaseous fuels require an air source to burn the fuel fast enough to release enough heat to melt the metal, but a hair dryer can be used for this. Solid fuels leave a lot of ash after they are burned, so the furnace has to be cleaned out after it has cooled. Gaseous fuels require piping and regulators, and the fuel source must be isolated from the heat of the furnace. The biggest disadvantage to electricity is the possibility of electric shock, so the heating elements must be shut off before entering the heating chamber with any tools or scrap. One advantage that electricity has over both solid and gaseous fuels is that it is quiet since no air source is required. But this can also be a disadvantage since you could leave the furnace on without noticing or, more importantly, you can be lulled into feeling it’s completely safe [20].

The construction of a furnace depends on the type of fuel used.

2.16.1. Melting the Metal

The first thing is to fill the crucible with scrap (Figure 2.27). The important thing to remember is to not jam the scrap in the crucible. When the metal expands it could damage the crucible [20].
Figure (2.27) Crucible Filled with Scrap [20].

(Figure 2.28) shows the crucible in the furnace. Notice that the entire area is covered by a 2½” thick layer of sand. The sand will protect the concrete floor in case of a spill.

Figure (2.28) Furnace

a torch can be used to light the furnace (Figure 2.29). The blower is turned on and placed in the air stream. Then the furnace is closed to allow things to heat up.

Figure (2.29) Lighting the Furnace
When the metal starts to melt it will settle in the crucible. This leaves room on top for more scrap. The lid of the furnace can be opened, as shown in (Figure 2.30), to allow scrap to be placed in the crucible. But the scrap can’t be dropped in. It has to be held above the furnace for a short period of time to dry it out. If a piece of scrap, like a beer or pop can, has moisture in it and is pushed into the molten metal, the moisture can turn to steam and blow the metal out of the furnace [20].

![Figure 2.30 Opening the Furnace](image)

When the crucible has enough metal for the casting, it is removed from the furnace. At this point the temperature of aluminum will be in the 1127°C to 1327°C range, even though aluminum melts at 927°C. The metal has to be superheated so it won’t freeze before it is in the mold [20].

After the crucible is removed it is placed on some bricks next to the furnace (Figure 2.31). Any impurities that were on the metal have floated to the top of the metal and formed a mass called dross. The dross is skimmed off with a skimmer and discarded so the impurities won’t be poured into the mold [20].

![Figure 2.31 Skimming the Dross](image)
Now the metal is poured into the mold (Figure 2.32). The metal has to be poured quickly, but steadily. If the flow is stopped for any reason, the metal that is in the mold could freeze before the pour starts again. After the mold is full, the excess metal is poured into an ingot mold (Figure 2.33).

Figure (2.32) Pouring into the Mold [20].

Figure (2.33) Pouring into an Ingot Mold [20].

The casting is now allowed to cool for a while. Thin castings don’t require much cooling time, but heavier castings should cool for up to an hour. This cooling period is a good time to wipe off all the sweat and replenish bodily fluids. Once the casting has cooled the mold is destroyed (Figure 2.34). The sand is broken up and put back in the bin. Some of the water has been boiled off, so more is added and the sand is mixed so it will be ready for the next time. (Figure 2.35) shows the caps as they came out of the mold, ready for machining. The picture also shows the shrinkage on each cap [20].
2.17. Soil Texture Determination

2.17.1 Hydrometers:

It is a hollow cavity with a quantity of lead that has a graduated leg and is designed on the basis that if placed in a suspension floating vertically and the intersection of the suspended surface with the grading is the suspension concentration in grams / liter. The Biocas Hydrometer was designed and calibrated on the basis that it measures the focus at an effective depth [21].

The hydrometer is a device for measuring the density of fluids and solids. The construction of a hydrometer is based on the Law of Archimedes, from which it follows that the weight of a liquid that is displaced by a suspended substance (in this case, a hydrometer) is equal to the weight of the suspended substance. The density of
the fluid under investigation can be determined by the depth of the hydrometer’s immersion in the fluid (the volume of liquid displaced by it) and the weight of the hydrometer. In practice hydrometers are of two types: constant-weight hydrometers (most widely used) and constant-volume hydrometers [21].

2.17.2 Soil Texture:

The soil texture expresses the softness or roughness of the soil granules and is estimated by rubbing or rubbing a wet sample between the fingers of the hand where it is possible to sense its softness or roughness as well as determine the degree of adhesion by hand and its ability to form, and accordingly determines the strength Is it sandy or basket or mud Or any degree between them.

The individual earth granules are divided according to their diameter and according to the international division system to:

- **Gravel**: Granular diameter greater than 2 mm.
- **Sand**: Granular diameter ranges from 0.02 to 2 mm.
- **Celt**: Granular diameter ranges from 0.002 to 0.02 mm.
- **Clay**: The diameter of the granule is less than 0.002 mm [21].

The following is a brief description of textures

- **Sandy texture**:

The soil contains more than 85% sand, and is characterized by loose dislocated, dry, does not stick to the hand and does not form, which is wet, and may be sandy, rough, medium or soft[21].

- **Texture loamy**:

The soil contains sand less than 52%, Salts 28-50% and clay from 7-27% and is characterized as cohesive with a greasy, good adhesion and is moist [21].

- **Texture silt**:

The soil contains more than 80% salt and less than 12% clay and has a soft soapy feel- not coherent and does not stick to the hand [21].
• Texture clay:

The soil contains more than 40% clay and the ratio of sand and salts is less than 40%. In the wet case, it is soft and has a great ability to form and bond. When rubbed between the hands or on the surface. [21].

2.17.3 Soil texture Triangle determination:

Determine the percentage of any component on the side of the triangle representing it and then draw a straight line corresponding to the base corresponding to the head representing 100% of this component. We repeat this for the other two components. The three rectangles meet at a point located in a particular area of the triangle of textures, each of which represents a name or a degree of strength. As shown in figure (2.36) [21].

Figure (2.36) Soil texture determination [21]
3. Experimental Work

In this project, four different types of sands were collected from difference areas of Libya's southern regions (Sebha and Shati cities) and were selected for the present study. The aim was to provide a comparative investigation of these types of sands in terms of their suitability for metals casting operations.

In sand casting the mold must have certain properties to be applicable for metals casting, some of which are listed below:

1. Strength.
2. Collapsibility
4. Permeability.

Due to the lack of casting laboratories, only two properties were tested in the present work, which were:

1. Strength.
2. Collapsibility

3.1. Materials

Which are as follow:

1. Red sand (Ashkida)
2. Silica sand (Zallaf)
3. Wells sand (white)
4. Wells sand (red)

The binders that were used as link between sand boundaries are:

1. Clay
2. Sugar Solution
3. dates Extract
The mixtures (type of sand + type of binder) that were designed in this work are shown in table 3.1. Three (3) samples were made from each mix design, two (2) samples were used for strength measurement and one (1) sample was used for thermal collapse test.

3.2. Preparation of the Materials for Testing:

Specimen of sand with 92% of the total mixture, with 8% as content of binder, the sand should be garbled before using, see figure (3.1).

Figure (3.1) Types of sands
Table (3.1) Samples made from mixing different sands and binders. Diameters of each sample is measured for strength measurement

<table>
<thead>
<tr>
<th>No. of sample</th>
<th>Type of sample + binder</th>
<th>Diameter of sample cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Red sand (Ashkida 1) + sugar solution</td>
<td>5.3</td>
</tr>
<tr>
<td>2</td>
<td>Red sand (Ashkida 2) + sugar solution</td>
<td>5.3</td>
</tr>
<tr>
<td>3</td>
<td>Red sand (Ashkida 1) + clay</td>
<td>5.2</td>
</tr>
<tr>
<td>4</td>
<td>Red sand (Ashkida 2) + clay</td>
<td>5.1</td>
</tr>
<tr>
<td>5</td>
<td>Red sand (Ashkida 1) + dates extract</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>Red sand (Ashkida 2) + dates extract</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>Silica sand 1( Zallaf )+ sugar solution</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>Silica sand 2( Zallaf )+ sugar solution</td>
<td>6</td>
</tr>
<tr>
<td>9</td>
<td>Silica sand 1( Zallaf )+ dates extract</td>
<td>6</td>
</tr>
<tr>
<td>10</td>
<td>Silica sand 2( Zallaf)+ dates extract</td>
<td>6</td>
</tr>
<tr>
<td>11</td>
<td>Silica sand 1 ( Zallaf ) + clay</td>
<td>5.2</td>
</tr>
<tr>
<td>12</td>
<td>Silica sand 2( Zallaf ) + clay</td>
<td>5.2</td>
</tr>
<tr>
<td>13</td>
<td>Wells sand 1 (red color)+clay</td>
<td>5.3</td>
</tr>
<tr>
<td>14</td>
<td>Wells sand 2 (red color)+clay</td>
<td>5.2</td>
</tr>
<tr>
<td>15</td>
<td>Wells sand 1(red color)+ dates extract</td>
<td>5.3</td>
</tr>
<tr>
<td>16</td>
<td>Wells sand 2(red color)+ dates extract</td>
<td>5.4</td>
</tr>
<tr>
<td>17</td>
<td>Wells sand 1(red color )+ sugar solution</td>
<td>5.3</td>
</tr>
<tr>
<td>18</td>
<td>Wells sand 2(red color )+ sugar solution</td>
<td>5.3</td>
</tr>
<tr>
<td>19</td>
<td>wells sand 1(white color )+ sugar solution</td>
<td>5.2</td>
</tr>
<tr>
<td>20</td>
<td>wells sand 2(white color)+ sugar solution</td>
<td>5.2</td>
</tr>
<tr>
<td>21</td>
<td>Wells sand 1(white color)+ dates extract</td>
<td>5.3</td>
</tr>
<tr>
<td>22</td>
<td>Wells sand 2(white color ) + dates extract</td>
<td>5.4</td>
</tr>
<tr>
<td>23</td>
<td>Wells sand 1(white color )+clay</td>
<td>5.2</td>
</tr>
<tr>
<td>24</td>
<td>Wells sand 2(white color )+clay</td>
<td>5.2</td>
</tr>
</tbody>
</table>
The samples that were prepared for compressive strength tests were made in cylindrical shape, with the dimensions as shown in table 3.1. These samples were made from the different (sand/binder) mixtures which were planned in this work. Plastics molds were used for casting these sand mixtures to obtain cylindrical sand/binder samples as shown in figure (3.2).

![Figure (3.2) - The samples after drying](image)

### 3.2.1. The process of Mixing

The selected sand and binder are added together and then mixed mechanically. After complete mixing, the mixture is then left to dry, see figure 3.3. The duration of dryness of each sample vary dramatically, some of which took days and the other took weeks to dry, depending on the type of binder.

![Figure (3.3) The dimensions of the specimens](image)
3.3. Testing and Equipment's

3.3.1. Strength of the Mold (Compression Test)

Compressive strength is a limit state of compressive stress that leads to failure in a material in the manner of ductile failure (infinite theoretical yield) or brittle failure (rupture as the result of crack propagation) [22]. The strength of the sand mold in the green and dry states are explained in details in Chapter 2, 2.7.9 and 2.7.10 sub-sections. In this work, the samples were compressed using ELE international machine model shown in figure 3.4.

Figure (3.4) Compression test machine

3.3.2. Thermal Collapse Test:

In this test, all the different samples were heated up and monitored frequently to find out the temperature at which each sample collapse. The furnace containing sand samples at high temperature is shown in figure 3.5.
3.3.3. Soil Texture Determination by Mechanical and Chemical Analysis

Mechanical analysis aims at separating the soil granules in mechanical and chemical ways so that we obtain a homogeneous suspension from the individual primary granules, then find the particle distribution and determine the soil texture [21]. Figure (3.6) illustrate soil texture triangle determination to determine the class of soil.
3.3.3.1. Steps of work:

Several steps were followed in this part of the experimental work, which are as follow:

1) Prepare 50 or 100g of specimen depending on rate of clay, which that has high percent of clay it should be 50g.

![Figure (3.7) The weight of sand prepared](image1)

2) Add 100 ml of distilled water to each sample.

3) Add 5 drops of hydrogen peroxide + 5 drops of dilute hydrochloride + 50 ml of Calgon solution.

![Figure (3.8) Soil solutions before extraction](image2)
4) Transfer the solution to the mechanical mixing device for five minutes.

5) The solution is transferred in full to a 1000 ml filtered filter and then supplemented by distilled water.

![Image of soil solutions in a 1 liter littered tester](Image)

Figure (3.9) Soil solutions in a 1 liter littered tester

6) Measure the density of the liquid using the hydrometer after leaving it in the laboratory for 45 seconds, then measured the temperature using the thermometer.

3.3.3.2. Determination of the ratio

Salinity and clay ratio

\[
\text{Salinity and clay ratio} = \frac{\text{Calgon reading solution} - \text{thermal coefficient} + 45 \text{ s after hydrometer reading}}{\text{dry soil weight}} \times 100 \text{ } (1)
\]

Mud ratio

\[
\text{Mud ratio} = \frac{\text{Calgon reading solution} - \text{thermal coefficient} + \text{two hours after hydrometer reading}}{\text{dry soil weight}} \times 100 \text{ } (2)
\]

Sand Ratio

\[
\text{Sand Ratio} = 100\% - \text{Salt and Clay Ratio} \text{ equation } \text{ equation } (3)
\]

Thermal coefficient = reading temperature for solution - (20 \times 0.36) \text{ } (4)

Where:

- 20 = the constant temperature at which the device is designed
• 0.36 = Thermal coefficient measurement constant

4. Results and Discussion

In this part of the project, analysis of the data from the experimental work is explained. Data includes strength measurement for the different sand/binder mixtures and thermal collapse temperature for each type of sand/binder mixture, as well as soil texture classification. As indicated in the previous chapter, the new designed sand/binder mixtures were made from different sands and binder materials.

4.1. Strength (Compression Resistance of Mixtures)

In this part of the project, samples of cylindrical shape were examined under compression to find out their failure strength. The results will provide direct indications into the resistance of these types of sand/binder mixtures to loads and forces, which are expected during casting operations. Two samples of each type were tested in compression and Table 4.1 shows the failure strength of each of them.
Table (4.1) Strength of sand samples related to its dimensions

<table>
<thead>
<tr>
<th>No. of sample</th>
<th>Type of sample + binder</th>
<th>Diameter of sample (Cm)</th>
<th>Force (KN)</th>
<th>Average force (N)</th>
<th>Stress (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Red sand (Ashkida 1) + mix of sugar solution</td>
<td>5.3</td>
<td>0.6</td>
<td>700</td>
<td>0.11</td>
</tr>
<tr>
<td>2</td>
<td>Red sand (Ashkida 2) + mix of sugar solution</td>
<td>5.3</td>
<td>0.8</td>
<td>750</td>
<td>0.15</td>
</tr>
<tr>
<td>3</td>
<td>Red sand (Ashkida 1) + clay</td>
<td>5.2</td>
<td>0.7</td>
<td>900</td>
<td>0.13</td>
</tr>
<tr>
<td>4</td>
<td>Red sand (Ashkida 2) + clay</td>
<td>5.1</td>
<td>1.1</td>
<td>900</td>
<td>0.22</td>
</tr>
<tr>
<td>5</td>
<td>Red sand (Ashkida 1) + dates Extract</td>
<td>6</td>
<td>0.7</td>
<td>750</td>
<td>0.12</td>
</tr>
<tr>
<td>6</td>
<td>Red sand (Ashkida 2) + dates Extract</td>
<td>6</td>
<td>0.8</td>
<td>750</td>
<td>0.13</td>
</tr>
<tr>
<td>7</td>
<td>Silica sand 1 (Zallaf) + mix of sugar solution</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>Silica sand 2 (Zallaf) + mix of sugar solution</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>Silica sand 1 (Zallaf) + dates Extract</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>Silica sand 2 (Zallaf) + dates Extract</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>Silica sand 1 (Zallaf) + clay</td>
<td>5.2</td>
<td>0.5</td>
<td>700</td>
<td>0.1</td>
</tr>
<tr>
<td>12</td>
<td>Silica sand 2 (Zallaf) + clay</td>
<td>5.2</td>
<td>0.9</td>
<td>700</td>
<td>0.17</td>
</tr>
<tr>
<td>13</td>
<td>Wells sand 1 (red color) + clay</td>
<td>5.3</td>
<td>0.4</td>
<td>450</td>
<td>0.08</td>
</tr>
<tr>
<td>14</td>
<td>Wells sand 2 (red color) + clay</td>
<td>5.2</td>
<td>0.5</td>
<td>750</td>
<td>0.1</td>
</tr>
<tr>
<td>15</td>
<td>Wells sand 1 (red color) + dates Extract</td>
<td>5.3</td>
<td>0.7</td>
<td>750</td>
<td>0.13</td>
</tr>
<tr>
<td>16</td>
<td>Wells sand 2 (red color) + dates Extract</td>
<td>5.4</td>
<td>0.8</td>
<td>750</td>
<td>0.15</td>
</tr>
<tr>
<td>17</td>
<td>Wells sand 1 (red color) + mix of sugar solution</td>
<td>5.3</td>
<td>3.2</td>
<td>3050</td>
<td>0.6</td>
</tr>
<tr>
<td>18</td>
<td>Wells sand 2 (red color) + mix of sugar solution</td>
<td>5.3</td>
<td>2.9</td>
<td>1650</td>
<td>0.55</td>
</tr>
<tr>
<td>19</td>
<td>Wells sand 1 (white color) + mix of sugar solution</td>
<td>5.2</td>
<td>1.9</td>
<td>1650</td>
<td>0.36</td>
</tr>
<tr>
<td>20</td>
<td>Wells sand 2 (white color) + mix of sugar solution</td>
<td>5.2</td>
<td>1.4</td>
<td>800</td>
<td>0.27</td>
</tr>
<tr>
<td>21</td>
<td>Wells sand 1 (white color) + dates Extract</td>
<td>5.3</td>
<td>0.8</td>
<td>800</td>
<td>0.15</td>
</tr>
<tr>
<td>22</td>
<td>Wells sand 2 (white color) + dates Extract</td>
<td>5.4</td>
<td>0.8</td>
<td>800</td>
<td>0.15</td>
</tr>
<tr>
<td>23</td>
<td>Wells sand 1 (white color) + clay</td>
<td>5.2</td>
<td>0.6</td>
<td>750</td>
<td>0.12</td>
</tr>
<tr>
<td>24</td>
<td>Wells sand 2 (white color) + clay</td>
<td>5.2</td>
<td>0.9</td>
<td>750</td>
<td>0.17</td>
</tr>
</tbody>
</table>
The average results for failure strength are included in table (4.1). The highest strength resistance were red sand (Ashkida) plus clay 1.1KN, Silica sand (Zallaf) plus clay 0.9KN, wells sand (red color) plus sugar solution 3.2KN and wells sand (white color) plus sugar solution 1.4KN, although there are several high strength results for some samples but only the highest were chosen for each sand type.

4.2. Thermal Collapse Temperatures

In this part of the project, one sample of each type of sand/binder mixture was tested thermally in a furnace. The samples had cylindrical shape were examined to find out the highest temperature (°C) each type can withstand before collapsing. The results will provide direct indications into the resistance of these types of sand/binder mixtures to high temperatures, which are expected during casting operations. Table 4.2 shows the thermal collapse temperature for each of them.
### Table (4.2) Results of Collapse testing

<table>
<thead>
<tr>
<th>No. Of sample</th>
<th>Name of specimen + its binder</th>
<th>Notes during heating</th>
<th>Degree of collapse °</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Red sand (Ashkida) + sugar solution</td>
<td>Surface cracking With the rise of the combustion fumes</td>
<td>300</td>
</tr>
<tr>
<td>2</td>
<td>Red sand (Ashkida) + dates extract</td>
<td>Cracks on the surface</td>
<td>870</td>
</tr>
<tr>
<td>3</td>
<td>Red sand (Ashkida) + clay</td>
<td>Surface cracking , increase brittleness</td>
<td>650</td>
</tr>
<tr>
<td>4</td>
<td>Wells sand (red color ) + sugar solution</td>
<td>Cracks on the surface, brittle</td>
<td>300</td>
</tr>
<tr>
<td>5</td>
<td>Well sand (red color ) + dates extract</td>
<td>Combustion</td>
<td>400</td>
</tr>
<tr>
<td>6</td>
<td>Well sand (red color ) + clay</td>
<td>Crack due to elevated temperature</td>
<td>500</td>
</tr>
<tr>
<td>7</td>
<td>Wells sand (white color ) + dates extract</td>
<td>Cracking during solidification</td>
<td>870</td>
</tr>
<tr>
<td>8</td>
<td>Wells sand (white color ) + sugar solution</td>
<td>Burning start at 390c, with rise of fumes</td>
<td>390</td>
</tr>
<tr>
<td>9</td>
<td>Wells sand (white color ) + clay</td>
<td>Burning start at 350c</td>
<td>350</td>
</tr>
<tr>
<td>10</td>
<td>Silica sand + clay</td>
<td>It withstand up to 1000c</td>
<td>1100</td>
</tr>
<tr>
<td>11</td>
<td>Silica sand + dates extract</td>
<td>Combustion</td>
<td>150</td>
</tr>
<tr>
<td>12</td>
<td>Silica sand + sugar solution</td>
<td>Combustion</td>
<td>200</td>
</tr>
</tbody>
</table>

For this test each class of sand with the three different binder were heated up at the furnace, three samples registered the highest temperature resistance which were Red sand (Ashkida) + dates extract at 870c°, Wells sand (white color ) + dates extract at 870c° and Silica sand + clay at 1100c°. Notes during heating process were listed in the table.
4.3. Results of Soil Texture Determination

In this part of the project, sample of each type of sand and clay binder were further investigated by mechanical analysis (texture determination). This was necessary to understand the reason behind the variation of the results from compression resistance and thermal collapse temperature tests. The mechanical and chemical analysis of the soil will determine its texture by using the equations no.(1,2,3) from the previous chapter and triangle determination method, see figure (2,36). Table 4.3 shows the results from calculation of mud, soil ratio and soil texture.

Table (4.3) Calculation of soil texture

<table>
<thead>
<tr>
<th>Nu.</th>
<th>Sample Name</th>
<th>Soil Weight Dry</th>
<th>Thermal Factor</th>
<th>Constant Calgon Solution</th>
<th>Reading Hydrometer After 45 Second</th>
<th>Hydrometer Reading After 2 Hours</th>
<th>Silt Ratio</th>
<th>clay Ratio %</th>
<th>Sand Ratio %</th>
<th>Soil texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ashkida sand (red color)</td>
<td>50</td>
<td>14.8</td>
<td>0.9</td>
<td>32</td>
<td>24</td>
<td>91.8</td>
<td>0</td>
<td>8.2</td>
<td>Clay texture</td>
</tr>
<tr>
<td>2</td>
<td>Well sand (white color)</td>
<td>100</td>
<td>14.8</td>
<td>0.9</td>
<td>10</td>
<td>4</td>
<td>10</td>
<td>37.8</td>
<td>62.2</td>
<td>Sandy clay</td>
</tr>
<tr>
<td>3</td>
<td>Well sand (red color)</td>
<td>100</td>
<td>14.8</td>
<td>0.9</td>
<td>21</td>
<td>13</td>
<td>7</td>
<td>27.9</td>
<td>72.1</td>
<td>Sandy clay loam</td>
</tr>
<tr>
<td>4</td>
<td>Silica sand (zllaf)</td>
<td>100</td>
<td>14.8</td>
<td>0.9</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>13.9</td>
<td>85.1</td>
<td>Loamy sand</td>
</tr>
</tbody>
</table>


5. **Discussions and Analysis of Data**

Further analysis of the project data is essential for providing more insights into the suitability of the different types of sand and binder under study. Table 5.1 provide a summary of the different tests results.

Table 5.1- Summary of the different tests results

<table>
<thead>
<tr>
<th>No. Of sample</th>
<th>Name of specimen + its binder</th>
<th>Texture</th>
<th>Compression Resistance (N)</th>
<th>Degree of Collapse c°</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Red sand (Ashkeda) + sugar solution</td>
<td>Sandy clay</td>
<td>700</td>
<td>300</td>
</tr>
<tr>
<td>2</td>
<td>Red sand (Ashkeda) + dates extract</td>
<td>Sandy clay</td>
<td>750</td>
<td>870</td>
</tr>
<tr>
<td>3</td>
<td>Red sand (Ashkeda) + clay</td>
<td>Sandy clay</td>
<td>900</td>
<td>650</td>
</tr>
<tr>
<td>4</td>
<td>Wells sand (red color ) + sugar solution</td>
<td>Sandy clay loam</td>
<td>3050</td>
<td>300</td>
</tr>
<tr>
<td>5</td>
<td>Well sand (red color)+ dates extract</td>
<td>Sandy clay loam</td>
<td>750</td>
<td>400</td>
</tr>
<tr>
<td>6</td>
<td>Well sand (red color)+ clay</td>
<td>Sandy clay loam</td>
<td>450</td>
<td>500</td>
</tr>
<tr>
<td>7</td>
<td>Wells sand (white color ) + dates extract</td>
<td>Sandy clay loam</td>
<td>800</td>
<td>870</td>
</tr>
<tr>
<td>8</td>
<td>Wells sand (white color ) + sugar solution</td>
<td>Sandy clay loam</td>
<td>1650</td>
<td>390</td>
</tr>
<tr>
<td>9</td>
<td>Wells sand (white color ) + clay</td>
<td>Sandy clay loam</td>
<td>750</td>
<td>350</td>
</tr>
<tr>
<td>10</td>
<td>Silica sand + clay</td>
<td>Sandy</td>
<td>700</td>
<td>1100</td>
</tr>
<tr>
<td>11</td>
<td>Silica sand + dates extract</td>
<td>Sandy</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>12</td>
<td>Silica sand + sugar solution</td>
<td>Sandy</td>
<td>0</td>
<td>200</td>
</tr>
</tbody>
</table>
It can be clearly seen that each type of our local sand require certain binder to give the best combination of properties required for metal casting operations. For instance, it is noticed that the sample made from wells (Red color) sand/ sugar solution binder have the highest strength resistance with a value reaching 3050 N. However, this type of mixture can not withstand high temperatures because it failed at a very low temperature of 300 C and the cause may be refer to that the melting sugar temperature is lower than that of sand. Therefore, this type will be neglected for casting consideration.

The two mixtures of (silica sand /sugar solution) and (silica sand/ dates extract) failed at zero force, which means that sample of these types of mixtures are weak and has no strength resistant at all. This can be related to weak bonding between the constituent's materials. Contrary to this, and based on the above analysis, the best recommendation for sand/binder mixture for casting is (silica + clay) since this type tolerates a temperature of about 1100 ºc and compression strength of 700 N. This can be explained by the fact that silica contains sandy texture (see table 4.3 and 5.1). Sandy texture originally is a quartz contains SIO 2 of about 50-90 % and clay of about 2-8 % [21]. Quartz is well known of tolerating high temperature and has high melting point of about 1670 C [23], the clay is a strong binder.

The new second best mixtures was the sample with mixture of (the white well sand + dates extract). This type of sand/binder mixture can endure a temperature as high as 870 C, and has a strength of 800 N. This can be related to the strong chemical bond that may be formed between both sand and binder.

The third best choice for metal casting operation will be (Ashkida + dates extract). This type can withstand about 870 ºc and has failure strength of 750 N. Again, dates extract is the best choice for being binder in this type of sand. The reason may be similar to second best mixture, which due to the stronger chemical bond between sand/binder mixtures.

It is well established that aluminum is used largely in sand casting operations and because the melting point of aluminum is 660 C [24], any mixture of sand/binder that failed at low temperature during thermal collapse test will be ignored as recommendation in the present work.

Further analysis was carried out to determine the type of chemical bond, for each sample. However due to lack of some instruments the analysis was not finished.

Appendixes indicates all the experimental work conducted.
6. Conclusions

This work aims to provide a comparative study on the usability and suitability of different local sands and binders for metal casting operations. The aim was to focus on investigating certain properties that are of great importance for sand casting. The findings can be summarized as follows:

1. Four different types of sands and three binders were combined successfully in different design mixtures.

2. The sands under study were Red sand (Ashkedah), white well sand, red well sand and silica sand (Zalaf). The binders used in the new mixtures were sugar solution, dates extract and local clay.

3. The investigated properties concerning sand casting were the mixture strength and thermal collapse temperature. These were followed by another test to study the texture of each type of sand to link all results together to support the findings.

4. Based on the above analysis, the best recommendation for sand/binder mixture for casting is (silica + clay) since this type tolerates a temperature of about 1100 ºc and compression strength of 700 N. The reason for this is that silica contain quartz element that has high melting point of about 1670 c°.

5. The new second best mixtures was the sample with mixture of (the white well sand + dates extract). This type of sand/binder mixture can endure a temperature as high as 870 c°, and has a strength of 800 N.

6. The third best choice for metal casting operation will be (Ashkida + dates extract). This type can withstand about 870 ºc and has failure strength of 750 N.

7. The overall conclusion is that each type of our local sand require certain binder to give the best combination of properties required for metal casting operations.
7- References


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Appendix
8. Appendix

-Extracting of soil

-Measured the PH value

-Experience Tools:

1- 0.25gm of soil

2. distilled water

3 cups of size 50 ms

4. Paper nomination

5. Shake the device (IKA RH-KT / C)

6. magnet

7. flasks distillery

8. flasks distillation holder

9. Balance

-Steps calculate the PH and conductivity:

1- 0.25gm of soil +25 ml of distilled water is placed inside the cup 50 ml

Figure (3.1) Sand solution
2. placed on a shaking machine at speeds of 400 rpm using a magnet, which is placed inside the cup Amoatis with the sample at room temperature for one hour

![Figure (3.2) sand solution on shaking device](image)

3. The sample filtration using filter paper

![Figure (3.3) refining a solution from the precipitation sand](image)

4. then placed in a 50 ml cups and the account is adjusted by way of reference ASTMD7100-11

![Figure (3.4) measured the PH value](image)
- Account humidity:

- Experience Tools

1. Buttery dishes

2. Dryer

3. Balance

4. The sample of soil to cover the surface of the dish

- Steps account humidity

1. The crucible are placed in an empty, dried at a temperature of 105°C temperature for an hour, to remove moisture

2. The Crucible weight after drying

3. calculate the sample weight before drying with dish

4. calculate the sample weight after drying for 3 hours in the dryer at a temperature of 105°C heat

5. calculate the weight of the moisture stop the process if the difference between the sample weight before drying became subtracted from the sample weight after drying \( \leq 0.002 \), by way of reference amended ASTM D4959-16

\[ \% M_c = \frac{w_1 - w_2}{w_1} \times 100 \]

- Digestion by garbling:

- Experience Tools:

1. concentrated sulfuric acid \( \text{H}_2\text{SO}_4 \)

2. concentrated nitric acid \( \text{HNO}_3 \)

3. concentrated hydrochloric acid \( \text{HCL} \)
4. hydrogen peroxide
5. sandy swimming
6. water free of minerals
7. graduated cylinder 10 mms
8. flasks record 100 mms
9. flasks intensify (round base)
10. sieve measuring 0.25 meters mms
11. preheated (BI) Barnstead Electro thermal

**Action Steps:**

1. 0.5 of sample +25 ml of $\text{H}_2\text{O}$ + 2ml of $\text{HNO}_3$ concentration then putted on heating to drying as shown in figure below

![Figure (3.5) sand solution on Heating device](image)

2. Then add 3 drops of $\text{H}_2\text{SO}_4$ (concentration) +10ml of $\text{HCl}$ (concentration) and is placed on the bathroom sand and raise temperature gradually reach to 200c, and leaves evaporates degree drought.
3. Add 5ml of HNO₃+2ml of H₂SO₄+5ml of HCLO₄, then heated until rise fumes white of (SO₃), the solution become clear.

7. Cooling the solution at room temperature and transferred to standard flask 50ml then complemented by water free ions.
Table (3.1) to calculate the results of the PH and conductivity

<table>
<thead>
<tr>
<th>Nu. Of specimen</th>
<th>Name of sample</th>
<th>TEMP</th>
<th>TDS Mg/l</th>
<th>Conductivity μs/cm</th>
<th>Salinity Ppt</th>
<th>MΩ/cm</th>
<th>PH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Clay</td>
<td>17.8</td>
<td>455</td>
<td>928</td>
<td>0.5</td>
<td>0.0011</td>
<td>5.81</td>
</tr>
<tr>
<td>2</td>
<td>Ashkeda sand (red color)</td>
<td>18</td>
<td>21</td>
<td>42.3</td>
<td>0</td>
<td>0.024</td>
<td>6.11</td>
</tr>
<tr>
<td>3</td>
<td>Wheel sand (white color)</td>
<td>18.1</td>
<td>22</td>
<td>44.4</td>
<td>0</td>
<td>0.023</td>
<td>6.66</td>
</tr>
<tr>
<td>4</td>
<td>Wheel sand (red color)</td>
<td>18.1</td>
<td>51</td>
<td>104.5</td>
<td>0.1</td>
<td>0.0096</td>
<td>6.51</td>
</tr>
<tr>
<td>5</td>
<td>Silica sand (zllaf)</td>
<td>18.1</td>
<td>16</td>
<td>32.2</td>
<td>0</td>
<td>0.031</td>
<td>6.70</td>
</tr>
<tr>
<td>6</td>
<td>Silica sand (zllaf)</td>
<td>18.1</td>
<td>15</td>
<td>30.4</td>
<td>0</td>
<td>0.033</td>
<td>6.51</td>
</tr>
<tr>
<td>7</td>
<td>Agricultural sand</td>
<td>18.1</td>
<td>22</td>
<td>44.4</td>
<td>0</td>
<td>0.023</td>
<td>6.40</td>
</tr>
</tbody>
</table>

Table (3.2) to calculate the percentage of moisture

<table>
<thead>
<tr>
<th>Nu. of the sample</th>
<th>Name of sample</th>
<th>The weight of the dish is empty after drying</th>
<th>The weight of the sample by drying with dish</th>
<th>The weight of the dish and has a sample after drying</th>
<th>The weight of moisture</th>
<th>The percent of moisture%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Clay</td>
<td>8.5464g</td>
<td>9.5221g</td>
<td>9.5082g</td>
<td>0.0139g</td>
<td>1.4261%</td>
</tr>
<tr>
<td>2</td>
<td>Ashkeda sand (red color)</td>
<td>8.6073g</td>
<td>1.3770g</td>
<td>9.9744g</td>
<td>0.0099g</td>
<td>0.7189%</td>
</tr>
<tr>
<td>3</td>
<td>Wheel sand (white color)</td>
<td>8.5808g</td>
<td>1.9982g</td>
<td>9.6715g</td>
<td>0.0075g</td>
<td>0.6829%</td>
</tr>
<tr>
<td>4</td>
<td>Wheel sand (red color)</td>
<td>8.5513g</td>
<td>2.0828g</td>
<td>10.6324g</td>
<td>0.0017g</td>
<td>0.0816%</td>
</tr>
<tr>
<td>5</td>
<td>Silica sand (zllaf)</td>
<td>8.5229g</td>
<td>2.0318g</td>
<td>10.5501g</td>
<td>0.0046g</td>
<td>0.0226%</td>
</tr>
<tr>
<td>6</td>
<td>Silica sand (zllaf)</td>
<td>8.5199g</td>
<td>1.5683g</td>
<td>10.0859g</td>
<td>0.0023g</td>
<td>0.1466%</td>
</tr>
<tr>
<td>7</td>
<td>Agricultural sand</td>
<td>8.5495g</td>
<td>1.1071g</td>
<td>9.6541g</td>
<td>0.0025g</td>
<td>0.2258%</td>
</tr>
</tbody>
</table>