CHAPTER II

REVIEW OF LITERATURE

The literature collected from various sources related to this topic is being presented under following subheads:

2.1 Origin and history of batik

2.2 Resist substances used in batik

2.3 Application methods of resist substances in batik

2.4 Fabric, dyeing and paste removal methods in batik

2.5 Traditional motifs and designs in batik

2.6 Wax batik in India

2.7 Plaster of Paris

2.1 Origin and history of batik

A resist method called *katfang* batik was found in Bataliva (Djakarta) employing a paste of groundnuts, lime and water. This is thought to have originated on the central Chinese mainland where, until very recently, the peasant population reserved a white pattern upon a blue dyed ground using a mixture of soyabean cheese (*dou fu*) and lime. The twelfth-century Chinese *in-fa-pu* methods are thought to have been adopted as the basis of the resist paste technique widely used in Japan by home dyers, known as *yuzen*. An unusual technique found in Japan, known as *fukuje*, consisting of blowing the colour through a brass funnel on to the fabric not covered with resist, is said to have originated in Holland where it may have been copied from ancient Chinese techniques. Similar methods are known in Western and Southern regions in India where a clay paste is block printed on the fabric. The methods used in central China, Japan and India all produced more advanced techniques and a considerably more sophisticated standard of design than those used by the West Africa, Batavian and
Southern Chinese tribes. Slovakia is thought to have learnt the secrets of paste resist dyeing from Holland by way of Silesia (Robinson, 1969).

According to Bystrom (1974) the origin of batik is obscure. The work itself comes from the East Indies. Java is most famous for batik work. The art was brought to Europe by the Arabs, initially to Spanish Islands of Majorca. Later the technique was adopted by the silk mills of Switzerland and Lyons.

Batik method of patterning fabric occurs in most counties where the tie and dye techniques are found, predominantly China, Japan, India, Indonesia, the Near and Middle East, and parts of North and West Africa. The method probably originated in Asia early in the Christian era, according to written records and the dating of ancient fabric fragments. However, resist methods could predate written records and existing textile records. Both paste and wax resist techniques have been used in Africa for centuries, although theories of origins are contradictory. Some feel that although fabrics patterned with wax and clay paste dating around the fifth century A.D. have been discovered in Egyptian burial grounds, the fact that there was trade between India and Egypt may well have supported an influence of Indian textiles on Egyptian designs. Some textile authorities believe that resist techniques were introduced to Africa more recently by migrants from Asia. According to Dr. Renee Boser’s early theory on weaving in W. Africa published in 1972, some understanding of resist methods was dispersed among the Fulanis. The fact that the Fulani weaver’s wives are renowned dyers tends to support this theory, while Renee Boser’s inclusion of the Fulani as practitioners of paste resist methods, documented by the Basel Museum’s collection, seems to confirm it. It is equally possible that paste and wax resist techniques were indigenous to local African populations long before the Fulani migrations. The theory of accidental discovery of resist techniques seems more logical when the use of paste resist is considered. Each culture using paste resist makes the paste from its most abundant food staples – cassava root in West
Africa (called *manoic* in French – speaking countries), rice in the Orient, wheat and corn flour elsewhere (*Polakoff, 1982*).

Campbell (2006) informed that the term batik is thought to derive from the Malay *tik*, to drip or drop. Exactly where and when the technique was first practised is uncertain. The earliest known batiks dated to 5th-6th century, were excavated in Egypt and included a linen cloth while patterns showed biblical scenes in blue background. Indigo was specially suitable because its application did not involve heat. Cotton fragments dated to 12th-16th centuries excavated at Fustar, Cairo, may have been imported from India, where batik is believed to have flourished from 5th century AD. Frescos of 6th-7th century AD at Ajanta, Maharashtra show garments decorated with batik patterns. Indian batik export has been documented since 17th century. Excavations in Central Asia at Loulan and Kucha in Xinjiang have yielded many examples of batik textiles. The oldest examples of Japanese wax resist textiles *nikechi* are in Shoso repository of imperial treasures, Nara, and belong to the Nara period (AD 710-94). Some designs appear to have been painted free hand, but other textiles suggest resist application by stamping, block printing or stenciling. Some wax and rice paste resist textiles are still produced in Japan. There is a long and continuous tradition of batik production among the Miao (Hmong) hill people of southern China and Northern Thailand, who draw geometric patterns with wax on to hemp and cotton using pen. This technique probably predates the silk batik trade of the Tang period (AD 618-907), through which the technique and fabrics spread to other parts of world.

According to Eaton (2013) the resist fabrics were often referred to as “indigo resist” or “reserve.” The eighteenth-century American newspaper advertisements indicate that these fabrics were then known as “paste work.” The term refers to the technique most commonly used in Europe to create the designs, which involves block printing a paste, generally made
from pile clay, gum arabic, and copper sulfate, on the parts of the fabric intended to remain white, and dipping the cloth into an indigo dye vat.

2.2 Resist substances used in batik

According to Cockett and Hilton (1955), mixtures of urea formaldehyde resin, starch and pigment like china clay can be used for resist dyeing. The thickening agents in other types of resists are chosen to form a mechanical resist which is precipitated by the dyeing solution. Gum Arabic and sodium alginate are precipitated by acid; locust bean gum by alkali. Salts giving insoluble hydroxides with alkali can be used as mechanical resists under printed vat colours. Examples are manganese chloride and aluminium sulphate. Wax emulsions may be printed as resist, but the subsequent dyeing temperatures must be low. Cationic water proofing agents, printed and baked, give efficient resist as do silicones. In such cases the presence of resisting material in the dyed fabric is not detrimental, as the products have marked softening properties.

An imitation cassava paste can be made by mixing 14g laundry starch, 28g ground plain white flour to a still smooth paste with a little cold water. Hot water (250 ml) is added and stirred to give a smooth paste or cream. It is boiled in a double saucepan for about 15 min., stirring regularly. The mixture is best applied hot to the fabric and left to dry hard before dyeing (Keller, 1966).

Robinson (1969) wrote that the Soninke people of Senegal use as a resist a tough rice paste. In Batavia, a paste of well crushed groundnuts, lime and water is used. The method is called katjang batik. The peasant population in the central Chinese mainland, until recently, used a mixture of dou fu or soyabean cheese and lime. The reserve used in Slovakia consists of Painter’s white clay, gum Arabic, acetate of lead, lead sulphate, blue stone, salve, alum and water.
Robinson and Robinson (1970) suggested that considerable experimenting may be carried out with different pastes for different purposes. A starch paste may be made from equal parts, 1 level tsp of starch, ground rice and plain flour in pint of water. It can be mixed and cooked as with thin custard and painted on the fabric whilst still hot and left to set hard before using dyes with a brush or block. Other paste such as cold water starches, polycell, PVC paste, gum, plain flour on any adhesive, that is not or does not become completely water proof when dry, are also possible starches.

The renovation of old, faded batik in Java involved the use of a rice-paste resist to redefine the design before re-dyeing. But this required boiling in order to remove the resist and old cloths seldom survived the treatment. Cheapest of all was a stencil technique, using lacquered paper and a soyabean paste resist that could be scraped and rubbed off the dyed cloth (Houston, 1975).

Taylor (1978) wrote that special wax printing machines have electrically heated colour boxes to hold resin in place of wax. The resin is naturally dark brown in colour. Resin, unlike paraffin wax or bees wax does not become a liquid on heating, but on application of controlled heat becomes treacle like in consistency.

Although wax printing with tampons is a dominant medium in Senegalese design techniques, the hand-applied paste resist tradition is still an active one. A paste is made of okra – a small green vegetable often used as a design theme throughout West African particularly in the hand-printed adinkra cloths of Ghana. Boxes of commercial starch are also used to make resist. The okra gombo, the paste mixture, is easily made. The dried okra flour, mixed with water, is heated. Once this gombo starch mixture is thick like cornstarch pudding and cooled, it is ready. Whereas traditionally okra powder was used, now they buy little boxes of starch and use that (Polakoff, 1982).
White resist on indigosol ground is produced by combined mechanical and chemical effect. Glue, starch, British gum, etc are used along with zinc oxide and titanium oxide to give the thickener mechanical resist effect. Sodium thiosulphate (hypo) is the best resisting chemical under indigosol ground. Maize starch, british gum, Thickening containing titanium dioxide is used for white resist under azoic ground (Shah et al, 1982).

The Yoruba people of the Niger area of West Africa practice adire alek dyeing in which they use a starch resist paste made from Cassava tubers (Proud, 1965, Jameson, 1973 and Flower, 1986). It is used as a liquid like wax but it doesn’t dry so quickly as wax, time can be spent considering its effects while it is actually being used. The obvious cracking seen in batik doesn’t occur with adire, as the paste is more elastic. However, when wet paste dries, it contracts and puckers the cloth. Cracks can be formed to some extent by gently pulling the cloth (Flower, 1986).

According to Flower (1986) gutta resist is a latex- derived resist which has recently become available from a limited number of suppliers. It takes the from of a thick, colourless, slightly rubbery liquid that will penetrate a fine fabrics and stick to it, forming a resist which is soft and pliable even when dry. It can be painted or applied through a forcing bag or pipette. It can and should in some instances – be thinned with a proprietary thinner, and in this form the finest of lines can be drawn with it which are nevertheless strong enough to act as a resist. Unlike wax resist, it can be used cold, yet unlike starch resist it actually penetrates the cloth, forming a seal on both sides. It can itself be coloured with any paint for which white spirit is the solvent. Gold, silver, and black gutta is sold by suppliers and this can be used to form a deliberate outline to shapes that are part of the design and are not removed.

Ahmed and Lomas (1996) used waxes with higher melting points than the traditional products in applying batik style to polyester fabrics to permit a higher dyeing temperature of
around 70 degrees Celsius. A process was developed that gave effective resist prints with a pale/medium range of over dye shades.

**Francis and Sundara (1998)** found that 100% paraffin wax samples had more whiteness while 100% bees wax samples had better sharpness of design than their blends.

**Shahidulla et al. (1994)** developed a resist printing technique of jute fabrics using a natural thickener, guar gum. The padding and exhaust methods of printing were used with different amounts of guar gum, and the best results were obtained with the padding method using 2.5 percent thickener.

**Gogoi et al. (1998)** conducted a study to see the effect of different resist substances that can be used for batik work. Fevicol, refined wheat flour paste, sago paste, rice flour paste and bee’s wax were used as resist substances and naphthol dyes were used to dye cotton and silk fabrics. It was concluded that fevicol, refined wheat flour, waxy rice flour and bee’s wax offered maximum resistance to dye penetration. Waxy rice flour resist was found to be easier and quicker to remove.

In a study, **Parul (2002)** tried six types of pastes (starches, plaster of Paris and clays). The samples were dried and dyed with naphthol dyes. The resist materials were removed by scratching, rubbing, brushing, peeling off and washing. The dyed samples were examined to evaluate the resist materials in terms of their power to resist the dye penetration. The resist materials were also evaluated in terms of ease of application and removal. Among paste resists best results were obtained with POP.

Solvent based *gutta* (resist, works like wax but is liquid), water based *gutta* (applied straight from a tube), potato dextrin paste resist (not for immersion dye baths), corn dextrin resist (not suited for immersion dye baths) are also available in market (Anonymous).
Gill et al (2004) in her research on Plaster of Paris found that POP was easier to remove and was less expensive than wax with the crack effects similar to waxed samples. It also required less time in the whole process than wax.

Gill et al (2005) compared various types of adhesive tapes in resist dyeing. Out of the four types of tapes tried in the study the PVC electrical insulation tape was found to be most effective and suitable resist tape. The fabric base medicated tape could not withstand contact with water and separated from fabric as soon as it came in contact with water. The edge binding tape and the surgical tapes did not detach but could not resist satisfactorily.

Traditional batik requires application of wax. In place of wax almost any type of flour can be used to make paste resists (finer the better) – rice, cassava, soya, corn whatever is available. One of the best paste resists is a mixture of gum Arabic and Kaolin, sometimes also containing little alum. This should be left to cure for couple of weeks and it works better with cold dyes (Flint, 2008).

Gill et.al. (2008) compared the aesthetic appeal of the prints obtained from different paste resists. It was found that kuttu flour paste produced coarse crack effect and Bengal gram flour paste brought medium crack effect as compared to the fine crack effect of wax.

Maiwa Handprints Ltd. offers presist a water based resist that combines the crisp line look of hot wax and convenience of starch paste resist. Presist works well with hand applications of dye or discharge agents. It will not withstand immersion dyeing. It may be applied to silks and other fine fabrics for a strong resist line or to heavier cottons etc. for interesting textile effects. Japanese nori paste consisting of rice flour, rice bran, salt, water and calx. It has the advantage of being extremely strong, withstanding short, cool dye bath immersions like indigo or hand applications. Potato Dextrin is a starch resist that can produce lace like patterns and crackle lines similar to batik. Most often it is used to resist an overall area but printing and painting the paste also have unique results. The tendency of this resist is
to crack in the drying process and it is this breaking of the resist that causes the unique dye textures (Anonymous 2013).

Wax is one of the oldest forms of textile resist and is perhaps the strongest. It is possible to use it in long, cool, immersion dyebaths and in hand painting projects. Natural beeswax, microcrystalline wax and paraffin wax can all be used in numerous combinations for a variety of effects. Natural beeswax is malleable and tacky and when mixed to a ratio of one to one with paraffin creates a strong resist and the characteristic crackle that defines batik. It may also be used at a ratio of 70% beeswax to 30% paraffin to create concise detail with little crackle. Microcrystalline wax is also known as synthetic beeswax, it is a strong batik wax that when used alone gives a light crackle effect. It can withstand the alkali of a typical dyebath well and is most often used to strengthen beeswax and paraffin mixture (Anonymous 2013).

2.2.1 Consistency of resist pastes

An easily made paste that satisfactorily resists cold dye and wash out after dyeing can be made from plain flour with tap-water to the consistency of thick batter. Consistency can be varied according to the cracks required (Keller, 1966).

According to Robinson and Robinson (1970), the consistency of thick plain flour paste can be varied according to the type of crackle required thick paste gives a large crackle, thinner paste gives a finer crackle.

Flower (1986) recommended that the pastes should be of different thickness for different purposes. A paste which is too thick can’t be forced through a syringe and one that is too thin will seep underneath a stencil. For general use, the paste should not be too runny, but should be thick enough to drop freely (like thick batter). When making the paste, the water should be added to the flour gradually and lumps must be dispersed. A blender can be used if available. The paste should then be cooked.
The consistency of *gutta* is very important. It should be thin enough to penetrate the cloth but enough to seal it and form a resist. If *gutta* prove to be too thick it can be diluted with pure surgical spirit or thinner. It should be diluted very slowly, drop by drop, to prevent it from becoming too thin. The mixture should be tested on cloth while it is being diluted. The final mixture should have a consistency of thick single cream or thin honey and should dry on the cloth in about ten minutes. If during experiments, a *gutta* line doesn’t hold back the dye it may be necessary to regutta over the *gutta* that can be seen on the back of the cloth. If on the other hand the *gutta* doesn’t dry within 15 minutes, making it impossible even to apply the dye this means the *gutta* is too thick and should be removed. It can be removed by soaking the silk in clean white spirit. Small blobs can be removed by rubbing silk between to pads of cotton wool, one soaked in white spirit, one dry (Flower, 1986).

**Chauhan and Gill (2007)** studied the performance of different consistencies of the resist paste. They found that the medium consistency was found to be the best as its application and removal were easier. Application and removal of the thick consistency were little difficult than the medium consistency. The thin consistency was ranked least satisfactory as its application and removal both were difficult than the other two. The resist effect was found to be the same with all the consistencies.

**2.2.2 Traditional non-wax resists used in India**

**Robinson (1969)** informed that in parts of South India a clay paste compounded of a sticky clay, gum, crude sugar and water is block printed on the fabric to act as a resist for indigo dye.

There is a *saree* used by the Bhil women in M.P., called *neela lugda*, as indigo blue is its main back ground. This is printed in the clay resist process only at Bhairongarh (Chattopadhyay, 1975).
Krishna (1977) reported that in Rajasthan the printing is done with special type of clay. When the small water pools start drying up in summer a kind of insect starts growing in them. As the pools dry up, these worms die and form a layer on the bed of the pool. After the mud has dried up it looks like a sponge. This spongy clay is dug up and mixed with a bit of lime soap and gum and made into a sort of paste to be used as resist.

Mohanty and Mohanty (1983) described the resist paste used in Bagru printing of Rajasthan. Dabu is the local name of the resist paste. The three kinds of dabu in use are the Kaligar dabu, dolidar dabu and gawanrbali dabu.

Kaligar dabu is the commonly used resist. It has least adhesive strength among the three kinds of dabu. It can withstand processing liquor only once. Its ingredients are kalimitti, gothan ka chuna, bidhan wheat flour and gum. Kali mitti has appreciable percent of clay which is gelatinous and has a fair adhesive property. Bidhan wheat flour is the flour of wheat spoil by worms and is unsuitable for human food. Five kg of kalimitti, 2 kgs of lime, 1 kg of bidhan and 250g of gum are mixed together with water to form a semi thick paste. The kalimitti is wetted for 12 hours. To this bidhan, lime and gum are added. The whole mass is then trampled by foot for two hours. Then water is added to this mass in an earthen vessel to form a semi thick paste and it is left overnight. In the morning the paste is strained through a cloth to remove grit.

Dolidar dabu is also commonly used. The ingredients of this are bidhan wheat flour, lime and gum. 1 kg of bidhan 500 of lime and 50g of gum are mixed together in water to a semi thick paste. This is kept overnight and is strained through a layer of cloth. It has a better adhesive strength than the kaligar dabu and is employed where more than one wet treatment is required.

Gawanrbali dabu is used rarely. Its ingredients are gawanr seed powder, limemolasses, oil and kali mitti. 1 kg of roasted gawanr seed powder is boiled to a thick paste
water in a copper or brass vessel and kept aside. 5kg powdered lime, 250g of molasses and 250g of *meetha tel* cooked in water are spread in the sun so as to form a dry thin sheet of material. This sheet is then ground to a fine powder. To this 1 kg of *kali mitti* and water are added and the whole mass is mixed to a paste. The cooked *gawanr* paste, along with water, is added to the lime paste and the whole thing is mixed to form a semi thick paste. It has best adhesive strength among the three and is used where a number of wet treatments are required (Mohanty and Mohanty, 1983).

Hiremath (1985) stated that starch resist in an age old method used in India for textile designing. Rice flour paste is used as substitute of wax. The rice flour is mixed with sufficient amount of water to make a thick paste and cooked in a double boiler, until the paste is glossy.

Dabu or mud-resist is a special printing technique of central Rajasthan, done in Jaipur district, in villages of Bagru, Kaladera, Jairampura and Badagaon Jahota. Dabu is a thick viscous paste made of clay, lime, tree gum and insect eaten wheat. It was used as the last print in the print process to save the "booti" or motif from the dyeing colours. The outline print known as "rekh" was either left empty or printed with another colour "datta" and then developed in alizerene dye in copper vessels. Later the dabu was done before the dyeing. Sawdust is thrown on dabu to dry it faster (Anonymous, 2009).

Though Bagru remains the chief centre of block printing, *Kaladera* has made its own name in the practice of this craft of natural dyeing and mud-resist. The process of the mud resist printing is fairly elaborate. A viscous paste of clay, lime, tree gum and insect eaten wheat is made and is called 'Dabu'. The block, which is made of wood, is dipped into *dabu* and imprinted on the cloth, depending upon the design. The outline print known as "rekh" is
either left empty or printed with another color "datta" and then developed in alizarin dye in copper vessels (Mohanty and Mohanty, 1983).

Sawdust is thrown on dabu to dry it faster. Once it dries, the cloth is then dyed in the required color and then washed with ample water to remove the impurities (Anonymous, 2013).

2.3 Application methods of resist substances in batik

Keller (1966) suggested that flour paste can be applied with a brush, a potter’s slip trailer, or icing bag, or a syringe with a fine nozzle directly on to the fabric, which is either stretched over a batik frame or laid on newspaper on the working area. It can also be applied through stencil cut from oil stencil paper can be also printed with very simple blocks from a pad, or by painting or rolling the paste on to the block. The fabric is dried thoroughly. This is most important and can take longer than appears, as the surface of the paste dries out first. The fabric becomes puckered as the paste shrinks in drying. Where a crackle is required the fabric is pulled so that the flour paste cracks.

A typical west African technique which involves painting or rolling a medium-thick starch resist on plain, patterned or coloured cloth in striped, regular shaped or all over. While it is still wet, a comb of metal, rubber, plastic or card is used to make patterns in the starch. The comb must be pressed hard on to the fabric to clear away as much as possible of the resist in the pattern shapes to allow dye penetration. Then fabric is dried, cracked if required and dyed (Keller, 1966).

Traditionally metal or leather stencils have been used to make paste resist designs on fabrics in Nigeria. The paste is pushed through the openings cut into the stencil. These stenciled designs are repeated over the entire fabric, usually alternating various motifs in an attractive juxtaposition (Polakoff, 1982 and Keller, 1966).
The stencils are cut out of a thin sheet of Zinc or the metal lining of an old packing-case. The stencil is placed on the undyed fabric and the starch spread on the exposed parts with a piece of wood (Robinson and Robinson, 1970).

According to Robinson and Robinson (1970), the flour paste can be painted on to the fabric with a brush which is washed out in cold water immediately after use. On drying thoroughly, the material will be puckered. The fabric is pulled so that the flour paste cracks.

Taylor (1978) informed that thermostats are fitted in colour boxes of wax printing machines. As the cloth comes out of the machine it is sprayed with cold water to cool the printed resin. Crackling is produced by cracking the resin before dyeing. It may be done by hand or by passing the fabric through a round narrow opening.

Paste resists are also applied by hand with a chicken feather, broomstick or knife edge in Nigeria. Fingers, carved calabash combs, and broom twigs are used to incise designs on paste-covered fabrics in Senegal. De Zeltner mentions the use of a “small tooth comb” as an instrument for incising designs into the paste resist used on fabrics in Senegal. This method still exists for resist techniques in Africa and Indonesia. According to MS Anderson-Bauer, in Senegal, various methods exist for application of Okra paste. They use their fingers or a piece of calabash- a piece of gourd- that looks like a comb, or else they take ten to fifteen pieces of a broomstick, tie them together, and make swirling designs on the cloth. It’s a typical Guinean sarakole technique (Polakoff, 1982).

A plastic bottle with a nozzle can be used for the application of rice flour resist. This paste is filled in the bottle and pressed slowly over the design and is left to dry completely (Hiremath, 1985).

Flower (1986) suggested many application tools and methods for paste resists. Stencils of various kinds can be used. Traditional stencils are cut from thin metal sheet. When parts of the stencils break away causing the past to settle in large pools, the comb is used to
break up the pools into swirling patterned areas. Stencils can be cut from thin lino tiles or sheets of thin plastic. Card can be used, but has a tendency to become soggy after several applications of resists. When delicate parts of a design are to be drawn the native Nigerian craftsmen use a single chicken feather dipped in the starch. One can also use fine old brush if chicken feather is not available. Large ones are unsuitable, as glutinous flour paste clogs them too quickly. For larger coverage paste is spooned on to the cloth and spread with the fingers. A tool used in the decoration of ceramics, known as a slip trailer has been found to be useful. The bulb can be squeezed to suck up liquid and squeeze again to release it. The liquid oozes out forming lines. Squeeze detergent bottles and icing syringes can be used in the same way. A forcing bag can be made from a polythene bag with one corner cut off, the size of the hole determining the amount of paste that comes out. Combs can also be made out of card, or teeth can be pulled out of plastic combs to give fine uneven swirls. Designs can be drawn into the pools of paste using a fine-pointed object such as a nail.

For application of gutta resist the fabric is usually fixed to a frame. This ensures that the gutta fully penetrates the cloth and doesn’t stick it to a flat surface. A gutta line like wax line start and finish with a blob. This can be avoided by beginning the line on a piece of paper and drawing it off on to the work. If pipette is lifted quickly at the end of the line no blobs should occur there either. The gutta can even be screen printed on to silk and by this method replicas can be produced. They can be painted or dyed in the same or different colourways (Flower, 1986).

In Rajasthan a special clay resist is applied on cloth with the help of wooden blocks (Krishna, 1977).

In Bagru the traditional printer always performs the dabu printing of cloth on a pathiya. Dabu paste is taken in a handi filled to half of its depth by the paste. It is kept on his right side and with the selected dabu data suited to the particular motif of the print. Then
resist print is imposed on the motif in the same manner as in *syahi* and *begar* printed, with the exception that a soft beating is given only once on the handle of the block. The printer lightly dips the date block in the resist paste, just enough to smear the surface thinly and evenly with the paste which needs experience and any excess of paste would spread to other parts of the motif. The *dolidar* and *gawanrabi* resist paste dry up quickly but *kaligardabu* don’t, so a specially made dust, composed of thin roots and soil under the wheat seedings, properly sieved, is sprinkled over the portions covered by the *dabu* prints. The cloth is then spread and dried. Tender care is taken while moving the cloth from place to place or form operation to operation not to damage the *dabu* prints by harsh handling (Mohanty and Mohanty, 1983).

Das (1991) informed that in West African batik a continuous roll of silk fabric is fed into a duplex roller printing machine. The colour boxes containing the wax are heated so that the wax remains molten. Both sides of the fabric are thus coated with wax in a patterned design in one operation. The waxed silk cloth, usually after several days of storage to harden the wax, is then submitted to a cracking operation, followed by dyeing.

Hoiberg (2000) wrote that the traditional way to design with natural indigo has been to print, paint or tie the resist and then dye. Though both the mechanical and chemical resists exist, traditionally, mechanical resist were mainly used. In India, wax and mud were used as resist. *Nori* a sticky paste prepared from rice is used in Japan. For printing *nori* is applied over a *kata* (stencil). In India wooden blocks are used for application.

According to Srivastava (1998) there are many ways of applying wax to cloth. It can be done by using brush, kalamkari pen, tjantings or tjaps (blocks). The new methods used today are splash method, stencil and scratch method. In the splash method the molten wax is poured from a cup or sprinkled from a brush. In the scratch method the whole cloth is covered with wax which is then spread on a glass sheet illuminated from underneath so that
outlines can be seen clearly. The lines of the design are redrawn with a blunt nail and the material is then dyed.

The resist can be applied with a paint brush, printed using blocks or silk screens or applied with wee paper cone. Interesting effects can be obtained by applying the resist quite thickly, allowing it time to dry thoroughly and then cracking the paste carefully. Paste resists have long been applied with wooden blocks. Lino sponge, brush and stick applications also work well. The paste must be perfectly smooth and consistency such that the block can pick up without details becoming clogged (Flint, 2008).

2.4 Fabrics, dyeing and paste removal methods in batik

2.4.1 Fabrics used in batik

Fairly substantial cotton is normally used for adire, as the dye which is painted on, must not be allowed to penetrate the cloth. Fine fabrics such as silk are unsuitable, as they are easily penetrated, even by the thickest dye (Flower, 1986). Sometimes, imported Manchester cotton goods in brilliantly coloured patterns or self stripes or floral patterns are over printed locally with most unusual results (Polakoff, 1982).

Gillow and Barnard (1991) informed that in western India the resist substances are applied on rather coarsely woven cloth unlike the tradition of south-east India which uses a wax resist, on finely woven cloth.

Ahmed and Lomas (1996) explored an ultrasonic dyeing method for wax batik on polyester in which the use of appropriate pre-swelling of the substrate had been reported to give acceptable shade depths at 50 degrees Celsius.

In Bagru (Rajasthan), fabrics used for clay resist dyeing include khaddar, mulmul, latha, dosuti and other handloom cotton fabrics (Mathur 1997).
Gogoi et al (1998) found that cotton and silk fabrics were equally suitable for batik printing with pastes like fevicol, refined wheat flour paste sago, paste, rice flour paste and bee’s wax.

Gupta et al (2008) stated that the fabrics suitable for batik should be smooth and thin in order to get a good effect. Silk is perhaps the easiest fabric of all to use. Other fabrics suitable for this are soft cotton and organdie. Heavy, coarse and thick fabrics are not much used. Any fabric for making batik should be thoroughly washed and ironed before use. Cotton which have starch should be boiled in soapy water to remove the starch. Dyes will not be taken up properly if the fabric is not absorbent.

Chauhan and Gill (2009) studied the performance of resist paste on different cotton fabrics. It was found that application of the resist paste was easiest on the sheer fabrics i.e. organdy, mulmul and voiles followed by the fabrics with medium weight i.e. banner, cambric, casement, poplin, flannelette and khadi. Application of resist paste on corduroy and terry fabric was difficult because of the uneven surfaces. Removal of the resist paste was found to be easy in all the fabrics except corduroy and terry fabric. The outlines were found to be sharpest in voile fabric, followed by mulmul and organdy. Banner, corduroy and cambric scored next to organdy. The outlines on terry fabric were the least sharp, followed by flannelette, casement, poplin, khadi and rib knit. The resist effect was found to be the best on voile fabric followed by, organdy, cambric, mulmul, poplin, casement, rib knit and banner cloth. Terry fabric got the last rank for resist effect, followed by corduroy, khadi and flannelette. It was concluded that the use of pop resist is suitable for smooth surface fabrics of light and medium weight.

2.4.2 Dyes and dying for batik

According to Keller (1966) for starch paste, the most satisfactory are the pigment colours, these will not substantially affect the paste. After preparing these are painted all over
the pasted side of the fabric with a large paint brush or felt or a foam roller. The reverses of the fabric is checked that the dye has penetrated the cracks in the paste. The dye is allowed to dry thoroughly before fixing (right side down on clean paper, back cover with more clean paper and ironed at the correct fabric temperature). Then the fabric is rinsed in cold water and left to soak for a few minutes to soften the paste. Dylon cold water dyes, Dylon Ultra Batik dyes, certain reactive dyes and indigo can also be used. Care should be taken—not to leave the paste resist in dye bath for a long period. It may soften the paste resist leading to penetration. The paste fabric is immersed in dye bath for few moments, removed and while it is still wet placed on a plastic sheet and left overnight. Then it is rinsed, soaked, scraped, rinsed and ironed.

In India Indigo dye is used with clay resist to obtain a light pattern on blue ground (Chattopadhyay, 1975 and Robinson, 1969). Krishna (1977) informed that in past vegetable colours were used with clay resist but later modern dyeing methods started to be used involving synthetic dyes.

According to Robinson and Robinson (1970) flour paste resist can be used with Procion M dyestuff, but it can be thickened with Manutex R S. The is fixed by the leaving the fabric in the room overnight, followed by rinsing, scraping off resist material rinsing thoroughly and ironing on reverse side on top of paper. Porocion H, Cibacron and other Reactive dyestuff thickened with Minutax can also be used and reasonable fixation can be achieved by steam ironing when the dye is dry especially if the catalyst recipe is used. Another option is to use polyprint. One part polyprint colour and nine parts of polyprint binder are mixed. This polyprint may be painted over the paste. The brush should be washed out immediately after use. The application is than dried thoroughly. For fixing, the paste side of fabric, the fabric is placed on a pad of several sheets of newspaper and covered with one
sheet of newspaper, and ironed for three minutes at appropriate heat for the fabric used. Then the fabric should be rinsed in cold water.

Once the paste resist design has been completed and dried. The fabric is ready for dyeing. In larger compounds, such as those found in Abeokuta, the dyeing may be done on the premises, while in Ibadan, where the production is on a smaller scale, the fabric is usually taken to a dyer-aloro. In Nigeria today, a combination of natural and synthetic indigo is used to achieve the many blues so popular among the Yoruba. The fabrics require several days of dipping to achieve the deep midnight-blue background tones. Once the dark rich blue is acquired, the paste is scraped off, revealing the designs preserved in the original white fabric, to which some pale blue has inevitably penetrated. In order to deepen this blue slightly and eliminate the white, contrasting areas, the fabric is passed through a final dye bath after the starch has been removed (Polakoff, 1982).

Mohanty and Mohanty (1983) explained the Indigo dyeing (Nila karna) process for Bagru resist prints. This is a process of cold dyeing. The cloth previously dyed with alizarine and subsequently printed with the resist paste is taken, piece by piece and treated in the stock indigo math. The operation consists of opening out the folds of the cloth, dipped vertically inside the math, so that it is completely immersed in the liquor and then taking it out. This takes about two minutes. The cloth inside the vat takes at once a rich green colour. After this, the cloth exposed to air where rapid oxidation takes place and the green colour turns to a deep blue shade in minutes. The same operation is repeated to give depth and uniformity to the colour. Next to nila karna is the tapana process. In this process the cloth piece is immersed in a paundhi containing the liquor of mingan for bleaching. The cloth pieces may undergo this processing either before printing or after completion of the printing operations. For processing 36 m of cloth, about 1 ½ kgs of dried minganis mixed in cold water. The pieces are kept immersed in this for 12 hours, taken out thereafter and dried in the sun. Water is
sprinkled on the cloth at intervals during drying not to allow the cloth to dry out completely. After 8 hours, the cloth pieces are washed in clean water and again immersed in the mingan solution for night, followed by wetting and drying. This whole process is repeated once more, after which the cloth pieces are thoroughly washed and dried. This process makes the ground of the cloth sparkling white.

According to Hiremath (1985) starch resist can be used safely for a single dye only.

According to Flower (1986) the thickened domestic dyes and reactive dyes are the most suitable types of dye for use with a starch resist paste. If a purpose built baker is available, pigments can be used. Reactive dyes are, as usual the most successful, giving intensity of colour and softenss of handle. Methods of fixing that involve the application of damp heat will adversely affect the starch resist. Ironing is also sometimes impractical, owing to the thickness of the flour paste. If pigments have been used they can be fixed by baking, as can procions. However although procion-dyed fabric can be baked in a domestic a oven, pigment coloured fabric must only be baked in a purpose built baker, as dangerous fumes are given off. Domestic dyes often incorporate their own fixing agents, and don’t require further fixing after dyeing.

Traditionally the adire resist fabric of Nigeria consists of two colours only, the white back ground colour and the indigo. The final depth of colour of the blue dye is determined by the amount of times the fabric is dyed. The simplicity of the technique, combined with the power of the colour, made these adire cloths very striking. The best results are achieved when the dye is painted on, and doesn’t fully penetrate the fabric (Flower, 1986).

Special alcohol/water based dyes are recommended by suppliers for use with gutta resist. As most gutta work is done on silk or wool, Acid or Procion dyes can be used. The choice of dyes is very important for several reasons: the gutta line, if it is fine, doesn’t necessarily need to be removed; as it is so pliable it doesn’t affect the feel of the cloth. With
dyes such as Procion which can be fixed simply by air hanging, the *gutta* line need not be affected at all. Acid yes and the special, recommended dye do, however, require streaming to fix them. This process might affect *gutta*, making it stick to the paper that is used to roll the cloth in during printing. Samples should be produced first to determine which dyes and fixing methods are most suitable for use with *gutta* (Flower, 1986).

Gogoi et al. (1998) and Parul (2002) used Napthol dyes with various starches. These don’t require a heating of the dye bath. Parul (2002) reported that Bengal gram flour paste could resist satisfactorily three dyeings if completely dried before each dyeing, while *kuttu* flour paste could resist two dyeings only. Plaster of Paris could resist many more dyeings than starch pastes and wax, without reapplication.

2.4.3 Removal of resist pastes

The fabric is placed on newspaper and the starch paste is scrapped off with the back of a kitchen knife or plastic knife. The fabric is then rinsed thoroughly to remove last traces of starch and reverse side is ironed on top of clean paper (Keller, 1966 and Robinson and Robinson, 1970).

In Rajasthan, after the cloth is dried it is rubbed to remove the dried clay resist paste (Krishna, 1977).

According to Hiremath (1985) removing the starch paste from the fabric is much simpler and quicker than the wax. She suggested to scrape the dry rice flour paste with a knife and to wash the fabric till all the starch is removed.

According to Flower (1986) the flour paste should be carefully peeled and scraped off. It might be helpful to immerse the fabric in warm water while resist is being removed. The *gutta* line can be removed permanently by soaking the fabric in white spirit, when the dye is fixed. This should be done outdoors if possible to avoid inhaling fumes. The fabric can also be dry cleaned. This removes any traces of the *gutta*. 
Francis and Sundara (1988) found that bees wax was easier to remove as compared to paraffin wax. Soap solution and soda ash treatment for 30 minutes was found to be the best and quickest for wax removal.

The wax is removed by boiling, sometimes the process must be repeated several times. It was suggested never to tip the hot waxy water down a sink, as when solution cools there may be plumbing disasters. Wax is difficult to remove completely without employing aggressive solvents so is best avoided in an eco friendly practice. Colour of many cold dyes is compromised when wax is removed by boiling. Hot dyeing adversely affects wax patterning. I suggest limiting the use of wax resist to indigo, woad, cold eucalyptus and mud dyes (Flint, 2008).

2.5 Motifs and designs in batik

2.5.1 Motifs and designs in Nigeria

Among the many squares of typical Ibadadun designs are stylized birds, snakes, frogs and scorpions; designs inspired by nature include different leaves, kola nuts and stars; items from everyday life include umbrellas and watches. Much lesser used are purely decorative designs, not inspired by real objects. However, distinguishing the Ibadabun design from other adire elekois the unmistakable design known as the “pillars of Mapo Hall, alternating with spoons”. It is a traditional pattern, probably forty or fifty years old. The number of spoons alternating with the pillars is a guide to the quality of the cloth. The more numerous the spoons, the more valuable that fabric is judged. Another extremely popular Yoruba design, olokun, which means “goddess of the sea”, has a greater use of purely decorative design motifs, but also includes stylization of wire, snakes, birds, leaves, combs, and the popular “OK OK” (Polakoff, 1982).

An infinite variety of traditional themes is found in hand applied cassava resist cloths. The popular design, “My head is together”, is enriched by the addition of the artist’s name
and profession. Within the tradition of repeated and alternating designs enclosed within a designated number of squares and rectangles – techniques of hand painted \textit{adire eleko} are used on fabrics designed to be worn by Yoruba woman in their conventional wrappers. When old, damaged stencils are copied, distortions caused by broken areas are incorporated into the new designs. Combining the paste into a cloudlike pattern is common (Polakoff, 1982).

The Soninke people of Senegal use as a resist a tough rice paste, with which they cover the cloth spread out on a mat. According to the movement of the comb the resulting design, which becomes indigo blue in the dyeing, consists of straight lines or zigzag (Polakoff, 1982 and Robinson, 1969).

2.5.2 Motifs and designs in Madhya Pradesh

The most popular design is called \textit{gamla} which represents the wheat grain enclosed in a diamond shape of slanting dots. Where the ground colour is changed from the normal indigo, only the \textit{lahariya} (waves) are depicted; where the ground is black, only border is printed, nothing on the body. The borders carry the \textit{janjira} design which consists of two white-dotted parallel rows with semi-circles or incomplete circles in between, so inter-locked as to form a pattern. The elaborate \textit{pallu} starts with a black border, after which comes a white line, followed by a green band delineated by two black lines, anteriority and posteriorily. On this is a continuous leaf and star repeat motif linked like a creeper, the leaves inclining towards the right. In the middle of the black band is an arch like repeat of tree motif with branches, leaves, flowers and birds. Prominent are two leaves and a star shaped flower in yellow, and a tree with leaves, flowers fruits and birds. The stem and leaves are in green, fruits and birds in white with black dots inside. After the blue band the earlier order is repeated in reverse. Then comes a complicated pattern called \textit{gabra} made up of four thick black lines, the intervening space being coloured orange, on which are printed convex and concave geometric motifs in repeat and white dots on the black lines. There is again a thick
black band, the intervening space being coloured green with the repeat of star and leaves. Then is the second complex pattern called *banwala gabla*, which has two new innovations, five petal flowers instead of the star shaped and a cluster of birds that become visible quite suddenly to give a surprise. The rest is a repeat of the earlier patterns (*Chattopadhyay, 1975*).

2.5.3 Motifs and designs in Bagru

The Bagru motifs may be arranged in five distinct groups. In floral group there are either flowers with petals and spikes arranged in a circular form around a centre or a spray of the floral design with buds, leaves, shoots and stem. The buds have pointed oval shapes. The leaves may be saw-edged. The shoots or broken twigs emanate form the stem with or without leaves, flower or buds. The stem is the central cylindrical core supporting the entire arrangement. The class of tendrils comprises spiraling or intertwined stems with flowers, leaves or buds. When repeated end to end, they give a continuous flowering pattern. Apart from the vegetative ornamentation, forms of birds, particularly that of *mayur* (Peacock) are also to be found. Motifs of trellis designs, popularly called *jals* in Bagru, form definitely indicate Persian influence. Such motifs cover the entire body of the cloth. They are without borders. Figurative designs include animals, bird and human figure motifs. *Hathi* (elephant), *hiran* (deer), *sher* (tiger), *mayor* (peacock), *kabutar* (pigeon) and *sua* (parrot) are among the common animal and bird figure. Human forms are *pari* (fairy), man and women are also used. The geometrical motifs are *laharia, choupad, kangura, sidhi line ki dhar, bindi, choubindi, chatai, chhedani, chundri sona* etc. The ornamentations are straight lines, circles, squares and triangles and are used either separated or in combination (*Mohanty and Mohanty, 1983*).

2.5.4 Motifs and designs in Andhra Pradesh
Motifs of Kalamkari include floral, birds, animals, Persian derived buttis and Mihrabs. The designs were made according to use. On canopies, mythological designs were made according to use. On Prayer mats, Mihrabs were made which depicted tree of life motif with birds in its branches and animals under it. Earth is shown as a triangle and rivers as lines. On pillow covers, bed sheets etc. rural and sport scenes were made (Chattopadhyay, 1975).

2.6 Wax resist printing in India

Hiremath (1985) stated that resist dyeing is an age old method used in India for textile designing. Gillow and Barnard (1991) recorded that evidence of Gujrat’s block printed wares have been excavated at Fostat near Cairo, the oldest of which have been dated as 15th century or earlier. These textile fragments are resist printed with unsophisticated yet pleasing design typical of hand-printed textiles of the region today.

Batik is an ancient art which originally traveled from India to Indonesia and when it died in India, was brought back from that country. The original Indian technique in which textiles were covered with clay, gum, wax or resin before dyeing the fabric was elaborated by the Indonesians, giving the cloth a very distinctive character. This art was first revived in Santiniketan in India but has now spread and there are a few centres where batik is done (Chattopadhyay, 1963).

2.6.1 Wax resist printing in Madhya Pradesh

Umedpura and Tarapur are two villages on either banks of the river Gamber, In Madhya Pradesh. Best known are the nanana pieces used by Bhil women for skirts which are printed using mordant, alizarin and resist techniques. The cloth is first softened by caster oil and an alkali. The outline for the printing is done in Ochre, and block printed with alum paste which turns like area red. This colour is blocked off by a mixture of wax, linseed oil and resin. The rest is dyed in indigo and a solution applied of gum paste and alum to make it resist the rest and white parts of the design. The dyeing is done in alizarin and the local
Sakkur print to stop colours running. It is finally immersed in a pomegranate rind solution which turns the white into yellow and the blue into a greenish black. Another traditional product printed in these two villages is the borderless neela kisaree, printed in wax resist process and used by the Bhil women (Chattopadhyay, 1975).

2.6.2 Wax Resist Printing in Rajasthan

The wax resist method used in Sanganer (Near Jaipur) is called main ki chhapai. In this method chir juice, desighee and bee’s wax were used to make the resist paste which also left good smell in the fabric. Such prints were in great demand 150 years ago. This was printers trade secret which was learnt only by daughter-in-law not by daughters (Kothari, 1949).

According to Mathur (1997) chir juice, til oil and wax in mixed for this kind of dabu in Sanganer. The til oil helps in bringing brightness in the printing. The prints appear same on both the sides of the fabrics.

Jaisalmer in the border desert of Rajasthan has a special style of resist print done only in winter and that too at night, as it needs very low temperature. The printing table is covered with sand sprinkled with water and covered by a wet cloth. A special block with raised surface and deep grooves is dipped in liquid wax and pressed over the cloth and when it comes into contact with the cool surface, solidifies the wax. The whole material is next dyed in dark red colour and then dipped in hot water to melt the wax. The piece presents interesting tonal effects. The local ritual saree called jarribhat has an elaborate design built up of squares against an unusual background of black, red and pink (Verma, 2002).

2.6.3 Kalamkari of Masulipatnam

The coromandel coast of India, from Masulipatnam (to the north down) to Napatnam in the south, was historically the source of some of the most beautifully hand painted cotton fabrics. Resists and mordants were traditionally applied with a brush or pen. These painted
fabrics were known as Kalamkari fabrics due to Persian influence. “Kalam“ is a Persian word which means “pen“ and “kari“ means “work“(Chattopadhyay, 1975).

The printing process involves a series of long complicated operations. Cotton cloth is used which is first bleached by repeated immersion in a solution of goat or buffalo dung and frequent rinsing in river or canal. In the next stage, mordanting of the bleached cloth is done in the myrobalan (harda) solution containing fresh buffalo milk the cloth is uniformly soaked and dried. Then outlines are printed either in black or in red or in combination. The cloth is allowed to dry in the sun. After two or three days it is taken and cleaned in running water and dried. The next stage is scalding which gives permanent red colour to the outlines printed. It also helps to remove the gum and myrobalan. Then bleaching is done as done earlier. Except the areas where black and red outlines are printed the rest of the area is rendered white. Next, Rice starch is prepared and applied, and dried by spreading on the grass. For wax application the most important requirement is an earthen pot, which is half broken forming a shallow basin. The fire is kept going without the flame. The pot is put on this hearth with bee wax in it. The hearth keeps the wax in a molten state without unduly raising its temperature. The kalam is dipped in the molten wax. The pad absorbs the liquid wax. The workers exerting gentle pressure on the pad make the wax run down the points of the kalam and thus apply it to the cloth over the required areas leaving those portions which have to be dyed blue. The cloth is then put in the sun for a little while till the wax film shows signs of melting so that any gaps not effectively covered by the kalam may get automatically filled (Gillow and Bernard, 1991).

The wax covered cloth is dipped in the natural indigo dye solution and is kept for a few minutes and then taken out and hung on a bamboo pole. For uniform dyeing either cloth is dipped again or is applied by using soft brush. Then the cloth is spread out resting it on pegs. The cloth is put in a big copper vessel and boiled to remove wax. The cloth is then
dried. All traces of wax on the cloth, with the help of spoon made up of coconut shell. Then cleaning and bleaching of the cloth is done. The cloth is once again starched. While starching, buffalo milk is also added, which prevents the colour from spreading out when dyeing. The remaining colours that are usually applied designs are yellow and green. The yellow colouring material is also a vegetable dye and is applied by spreading cloth on the low work benches by means of a small kalam. The areas to be coloured green are already dyed blow and the yellow myrobalan colour is applied on these portions so that a green colour is evolved at the required places. In the finishing stage alum solution is applied (colours become permanent) then dried in the sun for a day. The cloth is then dipped in water for about half an hour and then soaked in cow dung solution, tied up into a bundle and kept for a night. Then it is repeated washed and dried. Ultimately it is boiled and washed with soap (Pannu, 2007).

It takes about two months for a piece of cloth to undergo all these processes (Mehta, 1970 and Sharma, 2002).

2.7 Plaster of Paris

Plaster means a plastic mixture of solids and water that sets to a hard, coherent solid and that is used to line the interiors of buildings. A similar material of different composition, used to line the exteriors of building is known as stucco. The term plaster is also used in the industry to designate POP (Anonymous, 1992).

POP is quick setting gypsum plaster consisting of a fine, white powder, calcium sulfate hemihydrate or semihydrates (CaSO$_4$.1/2H$_2$O), which hardens (hydrates) when moistened and allowed to dry. POP is prepared by heating calcium sulfate dehydrate (CaSO$_4$.1/2H$_2$O) to $120^\circ$-$180^\circ$C. With an additive to retard the set, it is called wall or hardwall plaster. Used since ancient times, POP is so called because gypsum was earlier used near Paris to make plaster and cement (Anonymous, 1978b).
POP is a white hygroscopic powder having a chemical formula, CaSO$_4$.½H$_2$O. It can be manufactured from gypsum containing at least 94% CaSO$_4$. 2H$_2$O. The gypsum is first powdered to 90 mesh size and then calcined in pans at about 100°C - 140°C, as a result of which 1.5 parts of water molecules are removed from gypsum CaSO$_4$. 2H$_2$O and ordinary POP CaSO$_4$.½H$_2$O is obtained (Sharma, 1998).

2.7.1 Gypsum-The raw material for POP

Calcium is fifth most abundant element on earth. It occurs as carbonate (chalk, limestone, marble, calcite) sulfate (anhydrite gypsum) fluoride (fluorite or fluorspar) and phosphate (apatite) (Anonymous, 1978a).

Gypsum in a non-metallic natural mineral of great economic importance. It is the most common sulphate mineral. It is anhydrous sulphate of calcium characterized by the chemical formula CaSO$_4$. 2H$_2$O. It shows a little variation from its composition. Gypsum is one of the several evaporate minerals. These precipitate in seas, lakes, caves and salt Flats due to concentration of ions by evaporation (Anonymous, 1992).

Gypsum is usually found in beds or bands in the sedimentary rocks such as limestone, sandstone and shales. Sometimes they are also found as scattered crystals and grains in clays. Gypsum is also obtained as a byproduct during the manufacture of salt from brines and sea water by direct solar evaporation method. Gypsum is found in various forms. Albesteris massive dense and crystalline variety of gypsum. It is generally translucent and pure variety of gypsum. Being soft, dense and fine textured, it is used for carving images and other art pieces. Seleniteis another pure form of gypsum. It has mono clinical crystal structure and occurs in the form of sheets or plates. This is used in the laboratory equipment for the polarization of light, because thin sheets of selenite polarize light. Anhydriteis the anhydrous variety of gypsum. It occurs sometimes as dense mass and sometimes shows tints of blue and pink. Finely crystalline gypsum mixed with loams, clays, sands and humus is called gypsitein
which gypsum content varies from 60 – 90%. Satinspar gypsumvaris pure form of gypsum having monoclonical crystals and occurs in the form of parallel threads. It is translucent, when densely formed. Deposits of pure gypsum in the form of white snad are known as gypsum sands (Sharma, 1998).

2.7.1.3 Mining and uses of gypsum

Gypsum deposits are mined throughout the world. In India the recoverable reserves of gypsum are estimated at 238 million tones. Out of this, 0.344 million tones are of surgical/plaster grade, 39.7 million tones of fertilizer/pottery grade, 34.33 million tones of cement/paint grade, 5.5 million tones of soil reclamation grade and the rest is unclassified. The production of gypsum is confined to Rajasthan, Tamil Nadu, Jammu and Kashmir and Gujrat. Rajasthan is the main producer of gypsum, followed by Jammu and Kashmir. Gypsum is used for a variety of purposes but chiefly in the manufacture of POP, in agriculture to loosen clay rich soil and in manufacture of fertilizer (Anonymous, 1992).

Gypsum is also used in the preparation of chalk pencils or crayons, tiles, plasters, baking powder, cement (to prevent rapid setting), paints, pharmaceuticals, paper filling, insecticides, water treatment, etc. because it is tasteless, non-abrasive and chemically inert. It is used to lower the pH of water brewery (Sharma, 1998).

2.7.2 Manufacture of POP

\[
\begin{align*}
120^\circ C & \quad \quad 200^\circ C \\
2(\text{CaSO}_4 \cdot 2\text{H}_2\text{O}) & \quad \quad (\text{CaSO}_4)_2\text{H}_2\text{O} & \quad \quad \text{CaSO}_4 \\
\text{Gypsum} & \quad \quad \text{Plaster of Paris} \\
\end{align*}
\]

POP is made from gypsum by heating gypsum in powdered form in a vertical kettle or a rotary kiln (Ebrel and Ingam, 1949). The kettle is fired by gas, fuel oil or coal. A screw
conveyor kettle transfers the powdered gypsum into the vertical kettle and dehydration starts with 15-20 minutes. The mass is heated to 120°C by rising the temperature gradually. During the heating 1.5 molecules of water are expelled out of gypsum and the product formed is hemihydrate (CaSO$_4$.½H$_2$O). After the conversion of whole mass into hemidydrate the boiling stops and the turbulence is also stopped. Now temperature increase rapidly to 160°C. At this temperature the charge is thrown out and the product is cooled and stored as POP. If instead of dumping down the charge at 160°C, the temperature is further increased to about 190°C, the charge again starts boiling and it will continue till the ½ molecule of water present in hemihydrate is also expelled out and the charge settles down. Heating is continued upto 220°C. This charge is known as second strength when made into castings and structural products. However, with storage ageing, it absorbs moisture and gets converted into ordinary hemihydrate (Sharma, 1998).

For good quality POP, gypsum with more than 94% (Ca SO$_4$. 2H$_2$O) is crushed in jaw crushers, washed, dried and finely ground. It is calcined at 130°C-150°C. The water content is checked from time to time by drawing samples. A product of uniform size is obtained by adjusting the moisture contents. After cooling for 24 hours, the product is mixed with potassiumbisulphate(2 kg per tonne of POP) to regulate the time of setting POP. It is then packed in polyethene lined jute bags (Sharma, 1998).

According to Singh (2006) the production cycle in Bhutanese plants comprised crushing, pulverization and calcination. Optimum temperature of calcination was 120-165 degrees Celsius. Duration of calcinations was 5 hours per charge. The calcined material is finely ground before bagging.

2.7.3 Setting POP

When made into thin pastes with water POP makes a plastic mass and then quickly sets to a hard mass. When water is added, rehydration occurs the interlockery finely
crystalline texture, that results forms a uniform hardened mass. The slightly increased volume of the set plaster serves to fill the mold into which it has been poured (Anonymous, 1992).

This process is exothermic (heat is evolved). The setting takes place in two stages.

<table>
<thead>
<tr>
<th>Setting</th>
<th>Hardening</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaSO₄.½H₂O</td>
<td>CaSO₄. 2H₂O</td>
</tr>
<tr>
<td>POP</td>
<td>H₂O</td>
</tr>
</tbody>
</table>

Orthorhombic Monorhombic gypsum

The setting is due to reformation of the dehydrate which forms interlacing needles. When mixed with the POP powder forms a paste, which quickly hardens and a slight expansion takes. As a result, closely packed crystalline gypsum CaSO₄. 2H₂O is obtained. The process of setting POP can be accelerated by adding alkali sulphates such as Na₂SO₄. K₂SO₄. The latter initiate as well as accelerate the process of crystallisation (Sharma, 1998).

When the powdered hemihydrate is mixed with water to form a paste or slurry the calcining reaction (dehydration of gypsum) is reversed and a solid mass of interlocking gypsum crystals with moderate strength is formed. The chemical reaction of hydration requires 18.6 lb of water for each 100 lb of plaster of Paris, any water in excess of this makes the mixture more fluid and it eventually evaporates, leaving a porous structure. In general the greater the porosity the lower the strength of the set plaster. Plaster of Paris molds for ceramic casting must have a certain minimum porosity in order to absorb water added represents a compromise between the conflicting properties of high strength and high porosity.

Diverse type of plasters, varying in the time taken to set, the amount of water needed to make a pourable slip and the final hardness are made for different uses. These characteristics are controlled by the calcination condition (temperature and pressure) and by addition to the plaster. For example, hydrated calcium sulphate (CaSO₄. 2H₂O) greatly
accelerates setting time and therefore the use of utensils contaminated with set plasters is to be avoided (Anonymous, 1992).

2.7.4 Uses of POP

There is very widespread use of the plaster of Paris in bandage in hospital and dispensary for purposes of fixation and immobilization of fractured bones and diseased joints (Ware, 1906).

POP (sulphate of lime) is especially useful for the production of mold cast, and preliminary models and when mixed with POP will in a short time re-crystallize or set (that becomes hard and inert and its volume will increase slightly). When set it is relatively fragile and lacking in character and is of limited use for finished work. Plaster can be poured as a liquid modeled directly when of suitable consistency. Other materials can be added to retard its setting to increase its hardness or resistance to heat, to change its colour or to reinforce it (Anonymous, 1978a).

Molds of POP were in common use in the 18th century to cast pottery vessels in slip, a creamy mixture of clay and water washed over earthenware before firing (heat hardening). When the slip was poured into the mold, the plaster absorbed the water from it and thus deposited a layer of clay on the surface of the mold. When this layer was strong and thick enough, the surplus slip was poured off, the cast was removed and fired, and the mold was used again. This method was still in common use in the 1970’s. POP is also used to precast and hold parts of ornamental plaster work placed on ceiling and cornices and in medical use to make plaster casts. Some modern sculptors work directly in POP. The speed at which plaster sets gives the work a sense of immediacy and enables the sculptor to achieve his original idea quickly. POP can be carved as well as modeled in the final stages if the pieces is to be cast in bronze, the process of plaster casing is eliminated (Anonymous, 1978b).
POP is used in surgery for plastering fractured parts of the body. In laboratory it is used for making apparatus air tight. It is also used in making moulds, statues and for making black board chalk. It also finds use in plastering the walls, interior ceilings and decorations, etc. (Harvey 1996 and Sharma, 1998).

To meet specific requirements in the finishing coats, special finishing materials like plaster of Paris is used in building construction. It is used for repair of holes and cracks in plastered surfaces. It is very effectively used for ornamental works. It is used in combination with ordinary lime for building interior works (Gopi, 2009).

Plaster of Paris is a great material to use for basic sculptures and craft projects because it is easy to prepare and sets in a few minutes (Anonymous, 2013).