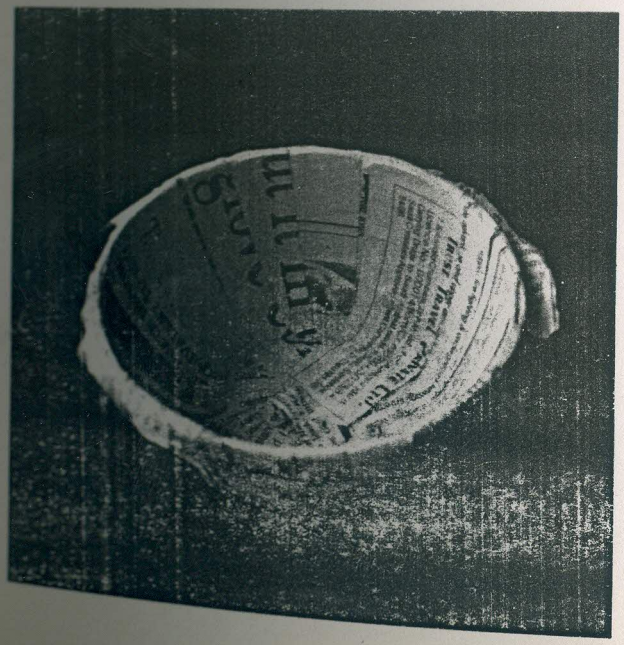
special project

Exploring with Paper mache for Structural Applications



Submitted in partial fulfilment of the requirements for Masters Degree in Industrial Design

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Approval sheet

The Special project entitled " Explorations with Paper Mache for structural applications" by Yogesh S Dandekar is approved in partial fulfilment of the requirement for the Masters Degree in Industrial Design of IIT Bombay.

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Acknowledgement

I express my gratitude and sincere thanks towards my guide Prof. V P Bapat for initiating this project and guiding me through it.

I also would like to thank Mr. Dave of Oasis India Ltd who helped me in knowing the present practices in paper mache and provided me with samples of their material.

My sincere thanks to the faculty and staff of IDC who at times gave suggestions and helped me to carry out my work.

Thanks to my classmates who tolerated the mess I did everyday.

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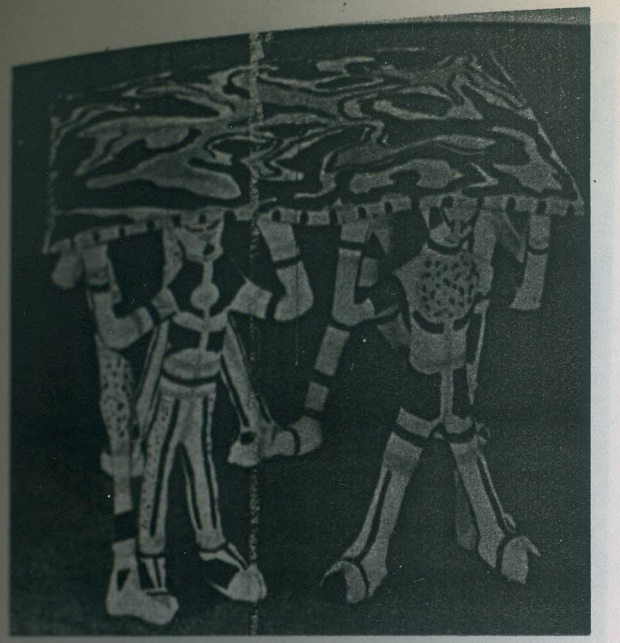


Fig.1 A coffee table in paper mache.

1.Introduction

Man has always needed three dimensional expression and paper mache is cheap and easy material to use and has the advantage of drying naturally to a hard and durable substance without necessarily having to be baked like clay. In IDC some work has already been done on the paper mache and its techniques. This project is a phase of this study towards the research of paper mache in various applicatons in IDC.

Background

By the end of the second century AD the Chinese had invented paper, made from malbery bark, cotton, vegetable fibers and linen rags. Paper making was slow, laborious work and therefore expensive, so it would follow that good was to put to off-cuts and scraps. Two paper mache helmets, toughened by being lacquered, survive from this period are the first example of paper mache.

Paper mache started getting used extensively for elaborately decorated and ornate furnishings that we see in museums. But the decline in the use of this material was revived by French in the 18th century. Paper mache actually means chewed up paper. Trays, boxes and even furniture were made often with inlay in pearls.

Fig.2 A chair in paper mache.

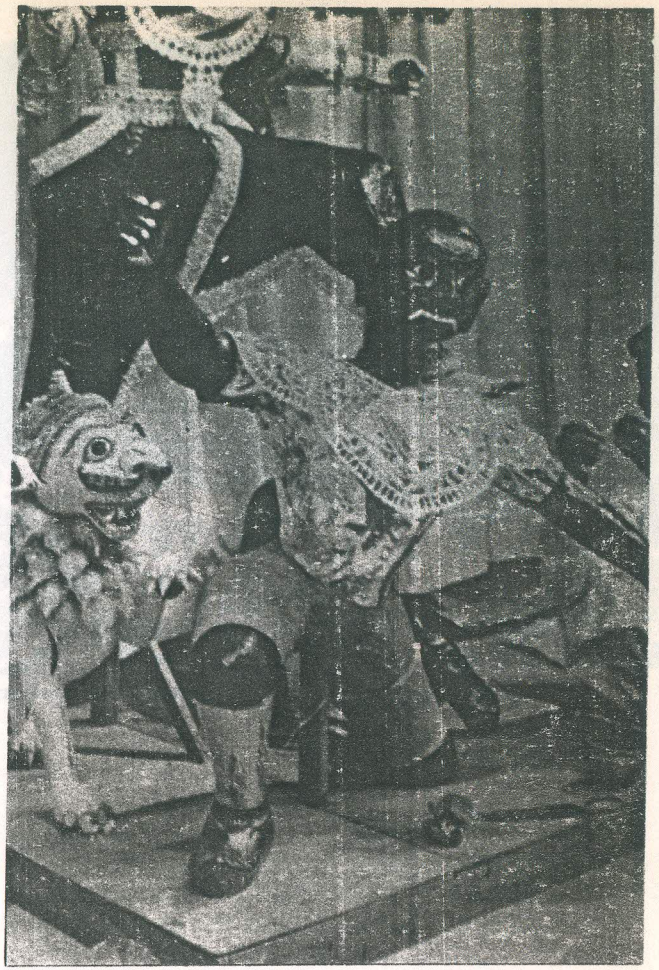


Fig.3 An idol made for the Durga puja in West Bengal.

In America, paper mache is being applied to the existing objects, mostly furniture, giving new life to things which would otherwise be discarded. In 1800 Isaac Weld , an Irishman made a boat in paper mache and actually sailed in it. Charles Frederick built ten prefabricated cottages and a ten-roomed villa for transportation to Australia. Small coffee table (*fig 1*) or chair (*fig 2*) have been made in paper mache but the techniques were different. The chair was made by laminating layers of news papers one over other with binder and then drying them in that position till they get hard. The coffee table is also made by the same technique. The supporting legs were made by paper pulp over a base of rolled tubes. So nowhere there is any reference of using standard sections or fabrication using paper mache parts. Henry Clay, used the material for tray making and for panels for coaches, doors and furniture. He laminated several sheets of paper and dried them in stove by keeping them in two metal plates.Then he rubbed them with Varnish and added further papers till the required thickness was obtained

Fig.6 Workplace of Oasis India Ltd. Working with Mache prepared using powdered paper.

Fig.4 Boxes and decorative crafts made in Kashmir.

Fig.5 Products made by Oasis India Ltd. Bombay.A photo frame, coasters and towel holder.

In India Kashmir (*fig 4*) is known for a highly skilled and decorative painting work on paper mache articles. Traditionally, in the rural areas, the grain containers that are made with bamboo or cane strips, are sealed with paper mache. This seals the tiny holes in the container and strengthens it. In West Bengal the Durga puja Idols (*fig 3*) are also made in paper mache which is actually paper pulp applied over a frame work of bamboo. In Bombay Oasis India Ltd. (*fig 5,6*) is an NGO which is working in paper mache for last two years. It mainly makes articles like candle stands, bookcanes, hairclips, napkin holders etc.

2. Projects done in the paper mache in IDC

1 Design of packaging in paper mache

2 A special project on paper mache.

This project was done with the aim of explorations in making variety of mache out of waste paper material that is available in IDC. This exploration was to find ways in which this material could be beneficial to the Industrial designer in academics as well as in practice.

Some targeted aims were

It would extend the scope of model making in IDC.

It may possibly result in substitution of hither to conventional model making materials to save time , energy and resources in IDC.

The conclusions of this project were

It can be made in making rough models during concept presentation.

Mache can replace styrene in the vacuum forming in form of cold forming.

Mache mixed with fine silica can be used to minimise shrinkage.

It can even be used in the final models where rough finish is desired.

Can also be used in the ergonomic studies of human body parts.

3. Aim of the project

This project is taken up as the next step towards the research of paper mache in IDC. Research on this material is needed as,

Paper mache is a recycled material which utilises waste paper and thus can be called indirectly environment friendly.

It is biodegradable which makes it directly environment friendly.

The final product becomes very light weight and handy.

It is cheap and economical.

The aim of this phase in the research was

to explore ways in which this material can be utilised in a functional way and thus use its life to the full extent.

to explore the ways in which this material can be utilised in structural applications.

To explore a new verity of mache which is done using the abundantly available shredded paper. This project aims at documenting observations which will help in understanding this material for further experiments. In this phase the following experiments were conducted their observations with their observations given on page 18.

Experiments

* Ways in which standard shapes or sections can be cast in paper mache their process and the limitations.
* To extrapolate the applications of these structural forms and sections.
* To experiment with shredded paper to from paper mache and to check its workability.

4. Process of the project

A small candle stand with an average cross sectional area of 7 sqcm is able to take up a direct load of 40kg (weight of a boy) which shows that the material has a considerable structural strength. If used in products like crafts or decorative articles then the material's strength is under utilised.

This project was conceived in terms of various experiments which were to be carried out in IDC. The first step was to work with the material and get an experience of it. To go for the experiment some considerations were taken as,
The experiments were conducted on the pulp of news paper.

Only binder used was the natural binder in the form of the wheat flour/ Maida as the aim was to create a biodegradable material.

The ways to stop attack of fungus or the mache getting eaten up by the insects or ants was not explored. But Methi powder and Tamarind powder was added in some samples as in also adds to the flow of paste, and incerases its workability.

More emphasis was on the way in which the mache will be molded.

Only the basic ingredients that were necessary were added.
Water repellent and resistant property was not targeted hence in all the samples linseed oil was not added.

If we look at the complete process of paper mache with its ingredients, their proportions, the final object made, its shape and size then it will become difficult to explore in the direction of the aim of the project and the time factor also playing the important role. It can be possible that every year one student shall take up the next phase and the project.

5. Basics of the project

The standard paste made was of news paper (*fig 7 to 10*) . The small pieces were kept soaked in water for a day or two and then it is mashed using a mixer blade to get finer mash. This process won't be able to produce a finer paste as the particle size cannot be reduced by such a way of mashing. If the same paper is passed through a ordinary flour mill then it is converted into powder. This powder when mixed in the vehicle and the binder becomes as fine and workable as clay. Some samples of such past prepared are also taken up for study.

Various Pastes used

News paper pulp mache
-Filler Whiting
Plaster of paris
-Binder Maida
- Methi
Tamarind powder

news paper pulp: whiting : binder
5 : 2 : 2

Shredded paper mache
-Filler Whiting
-Binder Maida

shredding : whiting : binder
5 : 1 : 2

The filler used was whiting and the binder is the ordinary flour / maida. The mash was prepared and stored in the bucket and used whenever required . It showed that this mash can be stored for a considerable amount of time. The use of synthetic glues like Fevicol or any other epoxy resin was avoided because the intention was to concentrate on the biodegradability. The strength of the epoxy resin is already proved in the application in the composite industry.

One other type of mache was created using shredded paper (*fig 16 to 18*). Nowadays paper shredders are becoming more and more popular in offices and there is an enormous amount of shredded paper output that needs to be disposed off. Moreover the binding and printing industry and related paper works are creating paper cuttings which are like shredded papers. An experiment was done to see weather this can form an alternative. The emphasis was to keep the continuity of the shredding as far as possible so that in the final mache they will act as reinforcing members and further strengthen the material.

6. Process and apparatus used in the experiments

All the experiments were done without using any specialised gadgets, instruments or tools. This was done keeping in mind that this could give useful direction in handling the work in smaller scale without much of the investment.

The process of making slab or flats was adopted rather than molding in the molds. The mash was prepared using a mixer blade attached to a drill machine. The fillers and the additives were added in proportions of volume by percentages without giving any exact measurement of the material used.

The various material and things used for the experiment.

Newspaper, shredded paper, whiting, Methi, Linseed oil, Wheat flour/Maida, Plaster of Paris,
cloth pieces , pipes, utensils.

The binder was prepared by mixing Maida in water and heating it to form a paste. Heating of this mixture increases the binding power of the binder many times as compared to the simple mixture.

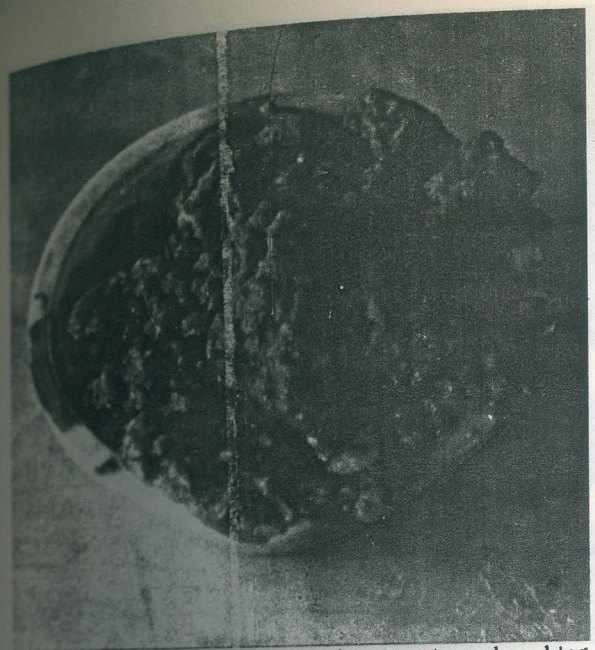


Fig.7 Pulp of news paper after soaking in water and mashing.

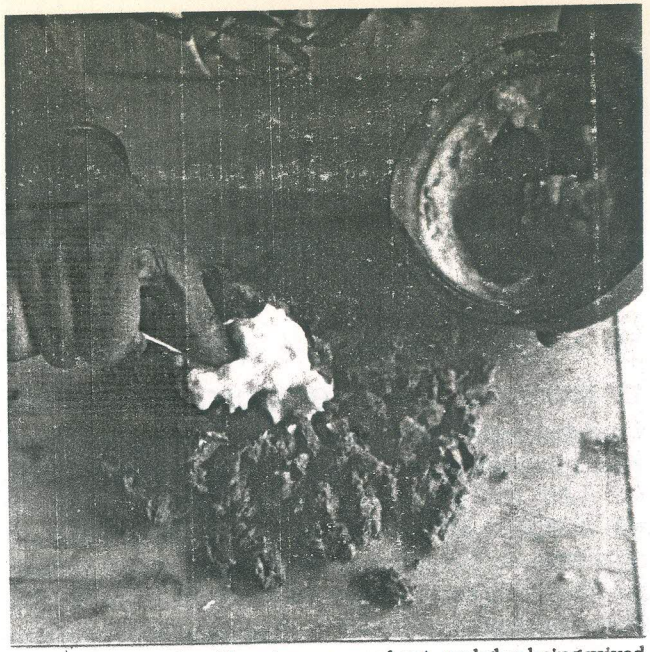


Fig.8 Paper pulp with water squeezed out, and glue being mixed.

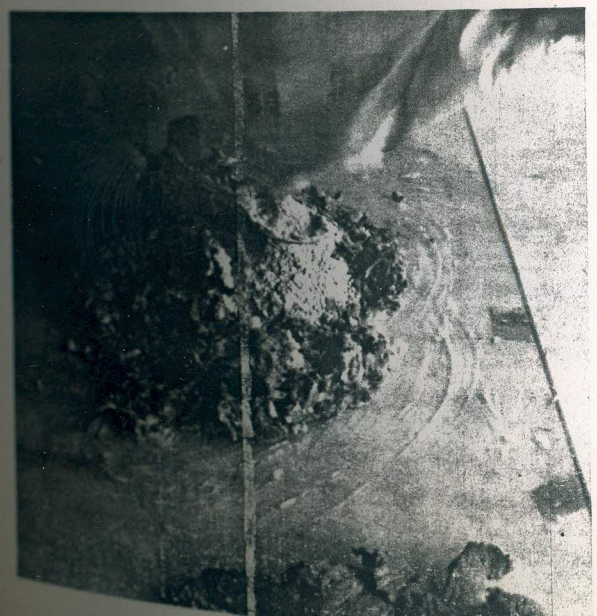


Fig.9 Whiting as a filler being added.

Fig.10 Rolling the prepared paste in cloth.

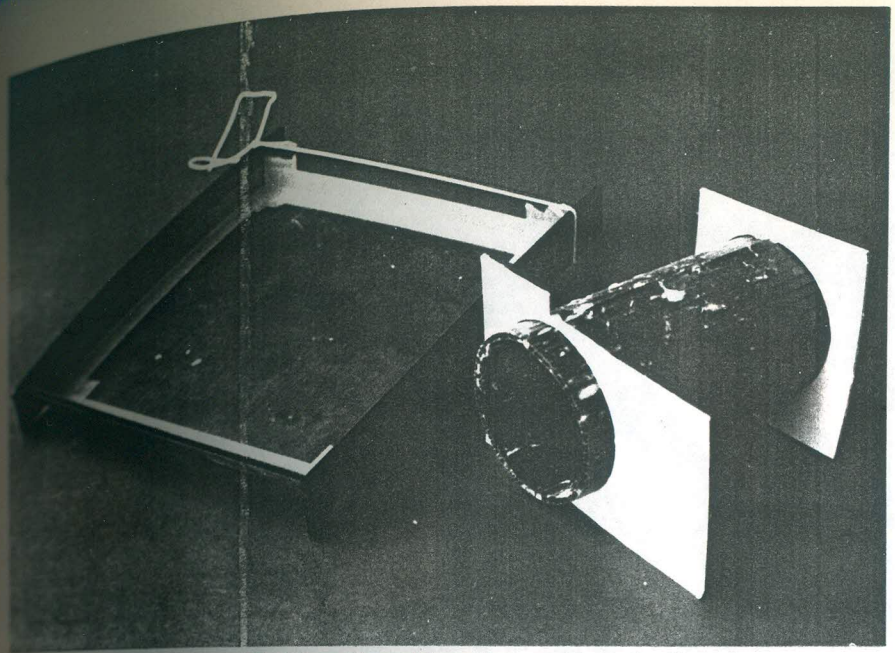


Fig.11 Molds made in corugated PVC board for molding. These molds are flexible and open.

7. Experiments done

7.1 Ways in which standard shapes or sections can be cast in paper mache. Their process and limitations.

As a first stage the rolled mache plates were laid over standard sections to obtain the profiles of those in paper mache. These sections showed considerable strength if they are made of considerable thickness (*fig 12 & 13*).

Flexible molds(*fig 11 & drg 1a*) can be made to obtain the standard sections. These flexible molds were made from the PVC sheets by pasting them together using adhesive PVC tape. These molds were closed and tied in position using strings or cardboard cutouts. Various aspects of using these flexible molds are

The sections will have to me manufactured in smaller lengths as they need support of the mold till they dry.

If the molds are made in a material that is not water absorbent then the drying of the mache takes more time. So the molds should be made of a material which will absorb the water out of the mache and thus speed up the process of drying (*drg 1c*).

The mold should have parts moving towards each other on the side in which the mache is laid (*drg 1b*). Because if the mache is turned in opposite direction then the cross section at the edge becomes less and there are chances of the breaking of the section.

Hollow sections can also be molded using flexible molds but their lengths will be restricted (*fig 15*).

If the molds provide depressions or ribs in the larger surfaces then the mache part will get more rigidity and also to reduce the warping due to the shrinkage the surface need to be broken down into more undulations so as to keep the warping minimum (*fig14*).

Even lamination can be done to attain the rigidity required. The corrugations in the corrugated sheet can be replaced at the larger scale by corrugated paper mache forms.

The sections tried and the molds are shown in the photographs and sketches. These sections can be utilisd to make small products, boxes, containers, school bags, packaging trays. If we see at the composition of the paper mache then it is kind of composite like FRP other composites of epoxy and polyster resins. These sections are slowly replacing structural steel in some areas. Similarly the paper mache sections can be used for the lesser load applications. These applications could range from Architecture and even in Aerospace application, being a light and versatile material.

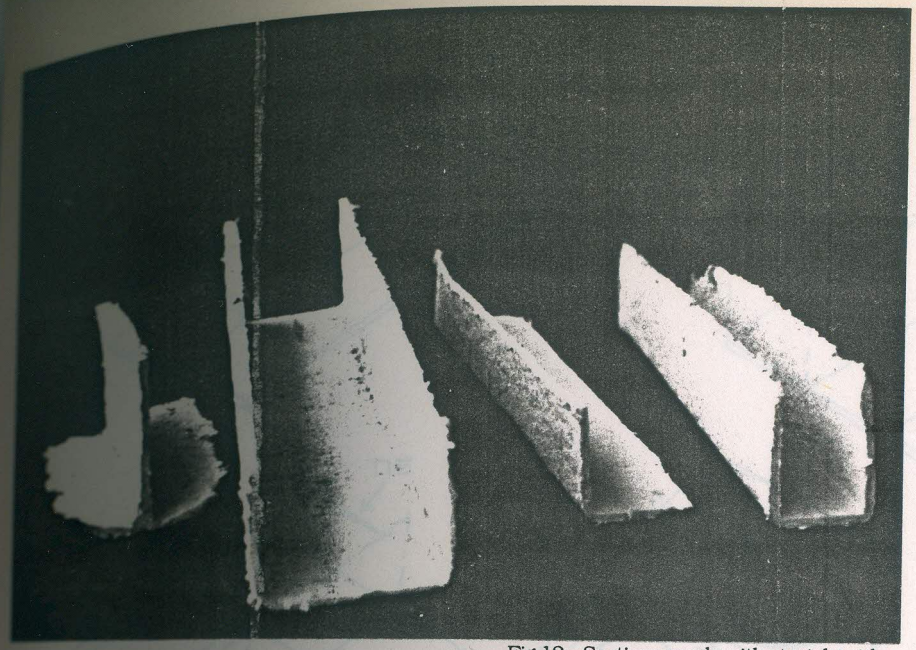


Fig. 12 Sections made with straight sides.

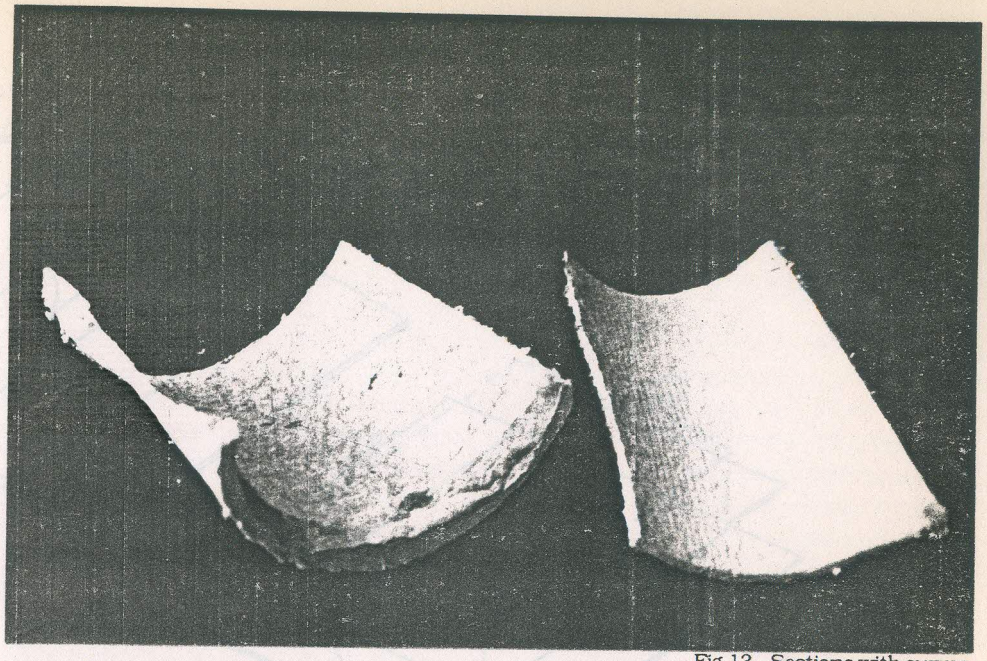


Fig. 13 Sections with curves.

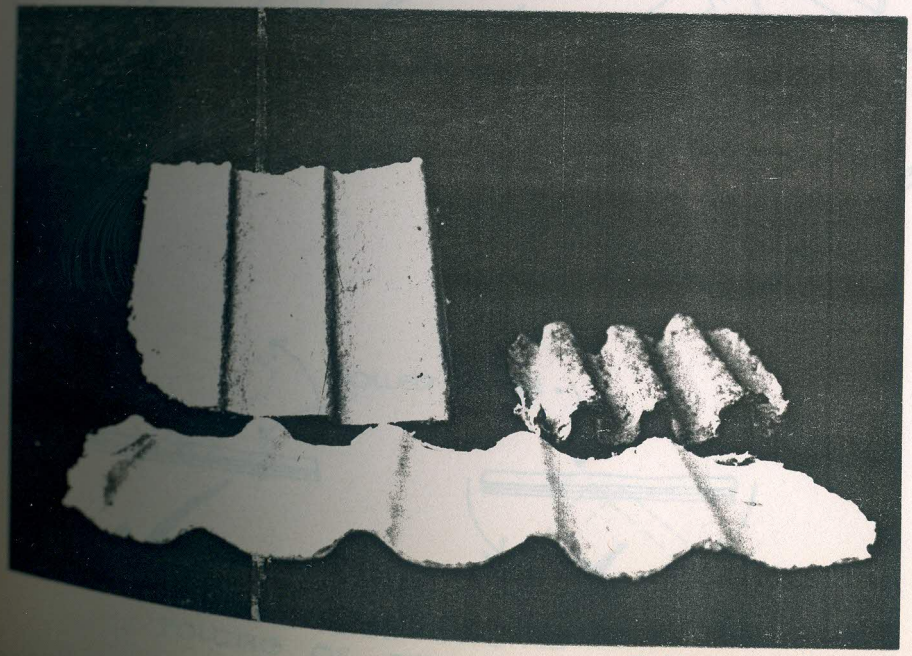


Fig. 14 Corrugated sections.

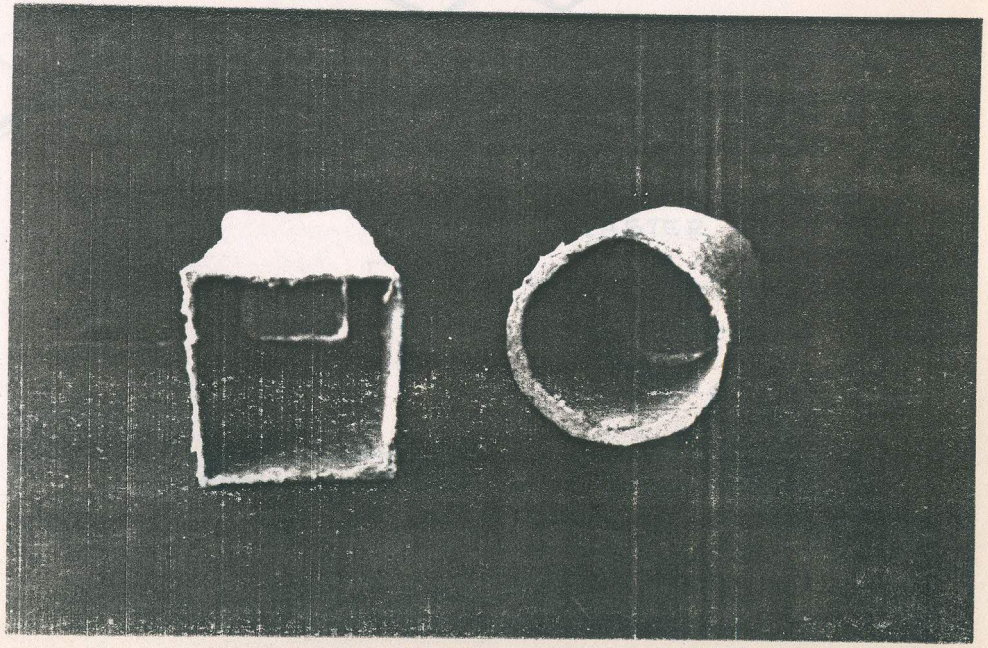
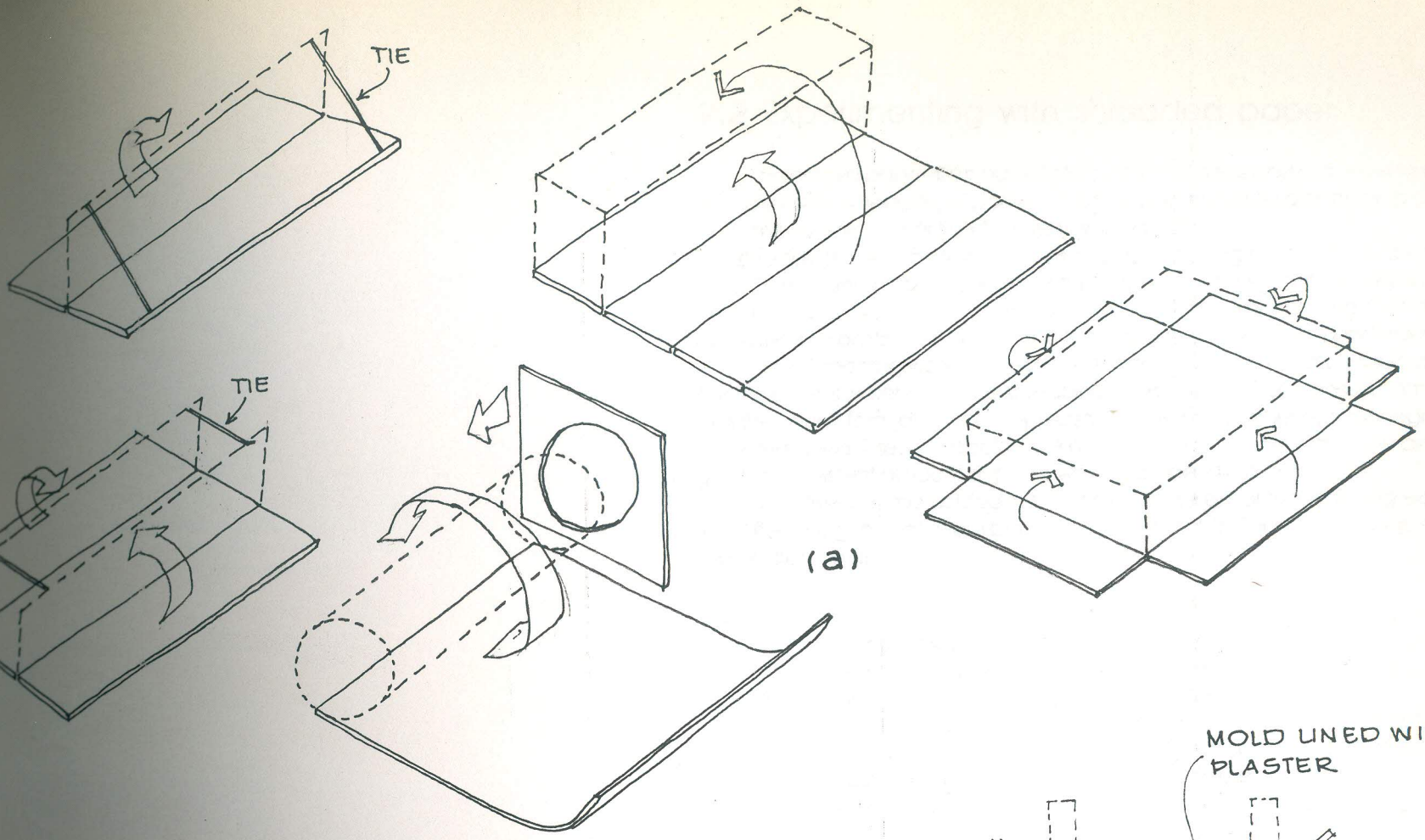
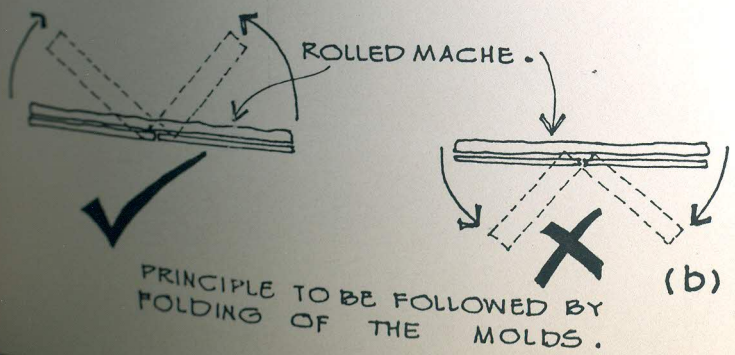
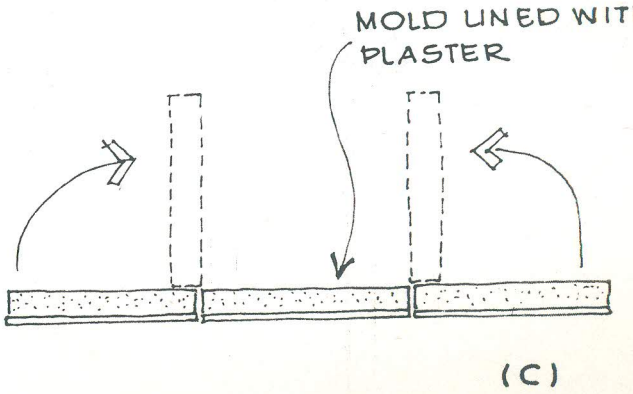


Fig. 15 Hollow core sections.





PRINCIPLE TO BE FOLLOWED BY FOLDING OF THE MOLDS.



DRG 1

7.2 Experimenting with shredded paper.

Shredded paper is an output of any printing press and, offices where paper shredders are used. Shredding of paper is advised and preferred over burning of the important documents. This stands true for every wasted paper.
The shredding are in the form of strips of paper ranging from 2mm to a width of 10 to 15 mm. Depending upon the width of the shredding the strength may vary. The principle here is simple that if the continuity of these strips is maintained then there will be a considerable amount of increase in the strength of the mache and the shrinkage.

The shredding were soaked in water and then immediately used after squeezing out the excess water out of the shredding. These are then separated from each other so that they don't form a lump of dry mash. Any plastic or other non biodegradable material is removed. These shredding are only wet not soaked in water. The binder mixed in it gives a consistent amount of paste which can be rolled.

Any filler can be added in the mash. In the experiment whiting was added as a filler After rolling the flats were put in the flexible molds. For making the tiles they were put into plaster molds.

Observations

* The process is Quick and fast.
* The mache dries faster than the mache made from pulp.
* This experiences less surface shrinkage.
* Even if the final mache is not homogenous it will not affect the strength.
* The mache does not give a good surface finish no matter how much you press it against the mold. But at higher pressure this material might get a good surface finish.

Fig. 16 Mixing of the shredding with glue. The shredding are only wet not soaked in water.

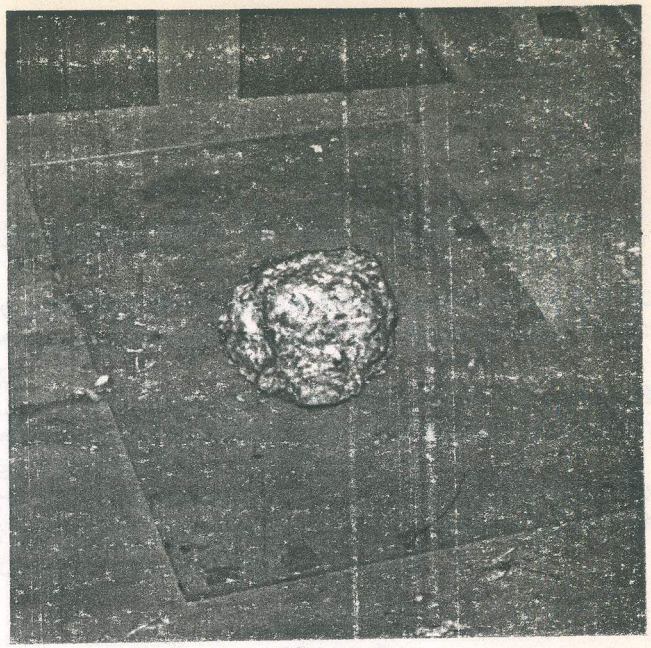


Fig. 17 The paste of paper shredding.

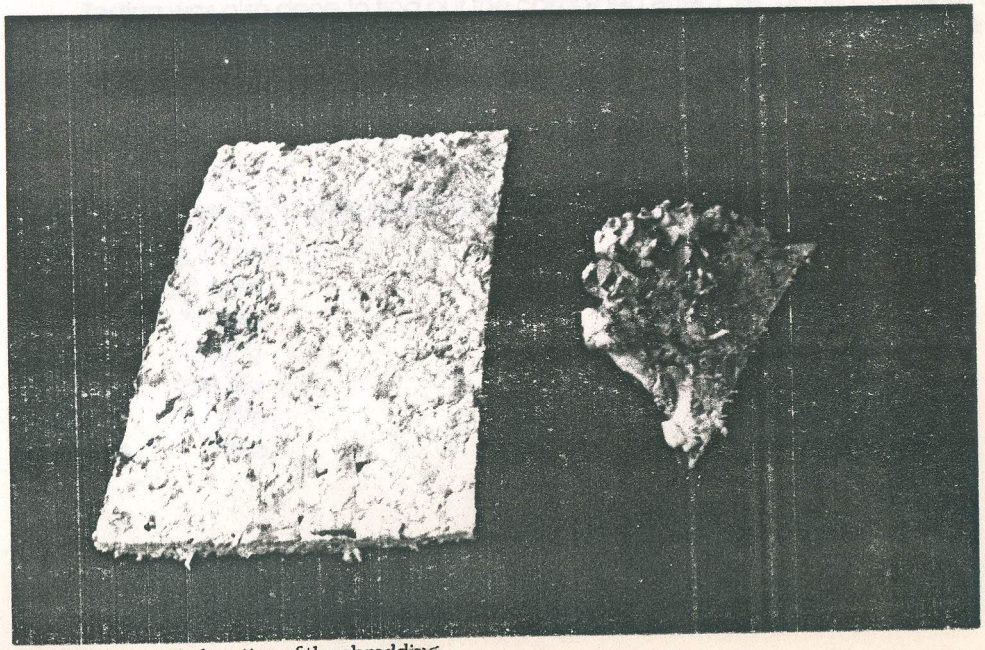


Fig. 18 The rolled section of the shredding.

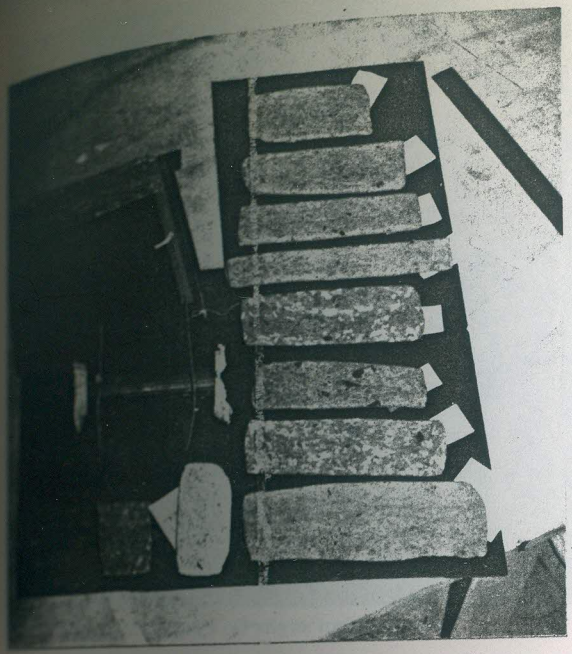


Fig.19 Samples made for the testing. These are yet to be cut as per the sizes recommended for testing.

Table 1

Mache type	Stress MPa = N/m^2
News paper pulp mache	1.26 MPa
Shreaded Papre mache	1.30 MPa
Powdered paper mache	2.34 MPa
News paper + 30% Shredding	1.26 MPa
News paper + 50% shredding	1.56 MPa

7.3 To find structural strength of the paper mache.

This experiment was conducted to find out the structural strength of the mache. The direct stresses of compression and tension are found out and the testing machines in the Mechanical Eng. Dept.

Tests were carried out on basic three type of samples. The IS codes give basic tests for such types of material as Tension and Brusting strength. The samples were made from the material and trimed in required sizes for testing (*fig 19*).

Tension is basically the test carried out to find out the direct tensile stress on the material. Brusting is the test carried out to find out the Impact strength of the material.

The basic types of paper formats used were,
Newsprint mache
Shredding
Mache of paste made by grinding in a small flour mill.
(paste obtained from Oasis India ltd).

Testing was also done to find out the combined effect ,i.e. of the combination of newspaper mache and shredding at different percentages. The results are given in the table (*table no.1*)

Direct Tensile stresses of some other materials

wood	8-13 MPa
ABS	41 MPa
Acrylic	72 MPa
Melamine	41 MPa
TFE	23 MPa
Plaster	MPa
Asbestoes	MPa

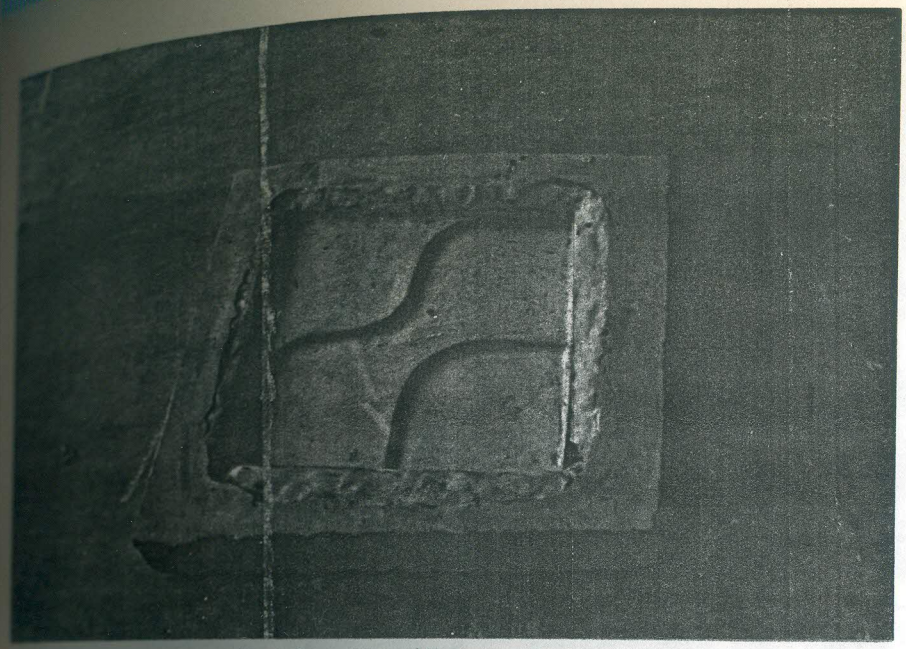


Fig:20 Mold made in Plaster of Paris for molding of tiles.

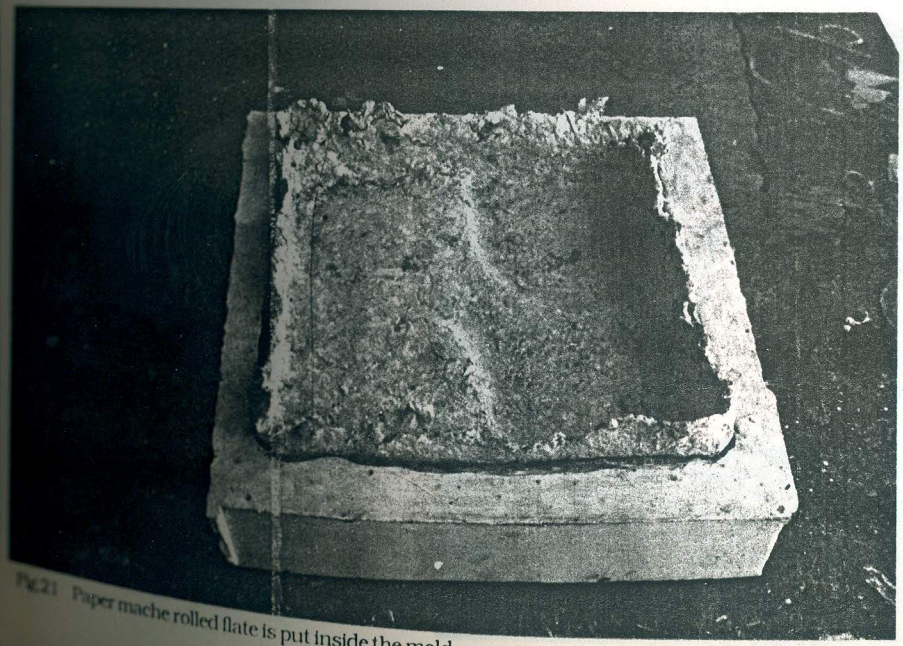


Fig:21 Paper mache rolled flate is put inside the mold.

7.4 Trial of making tiles out of paper mache.

A tile of 25cm x25cm was selected. Molds of this tiles were perpared in plaster of paris (*fig 20,21*). In these molds the Paper mache tiles were molded (*fig 22 to 23*).

The Plaster molds helped in faster drying of the mache.

The initial tiles shrinked a lot. This was due to less thickness of the mache. It suffered excessive warping. Then the next trial was to increase the thickness so that the warping will be less. This worked better than the first trial. The third trial was done bye giving ribs in the mold so that the surface of the final tile will be having ribs and thus the surface of the tile will be broken. This also helped in reducing the shrinkage. As another try Silica sand was added to the paste in a ratio of 1: 6 (silica:sand) this worked with the tile but not so much with the ordinary sample.

If continuous work is done in this, then it is possible to arrive at a ratio of thickness to the surface area which will have least warping.

Some observations while molding and drying.

* Such a tile should have a opening type mold lined with water absorptive material.
* Shrinkage can be reduced, if for intitial evaporation of water the part is kept in direct sun, and then the final drying takes place in the shade under pressure.
* The ribs on one side arrested the warping in that direction but it experienced warping in the other direction. The panel without any ribs and a thinner section experienced warping in both the planes.

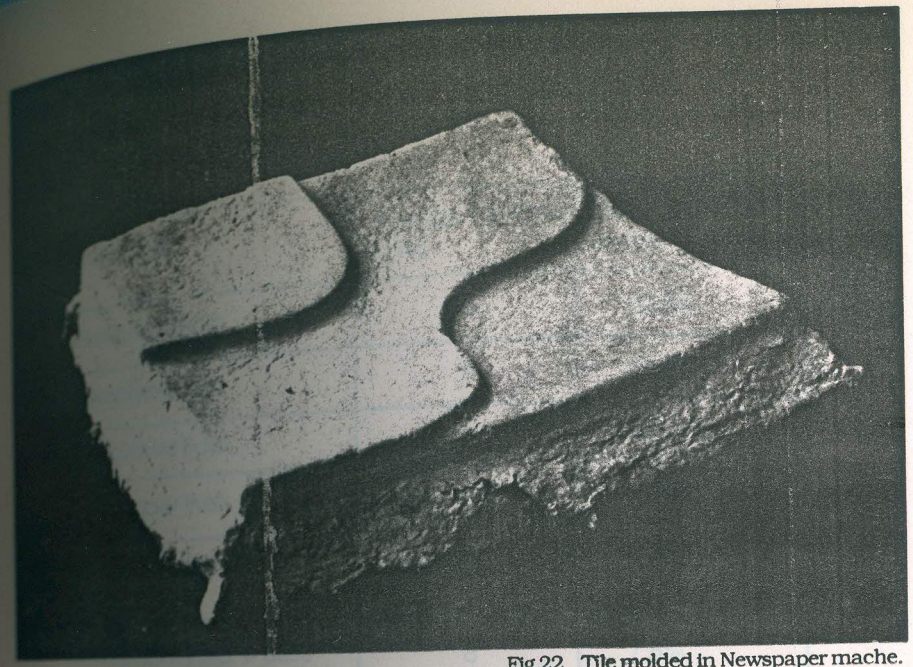


Fig.22 Tile molded in Newspaper mache.

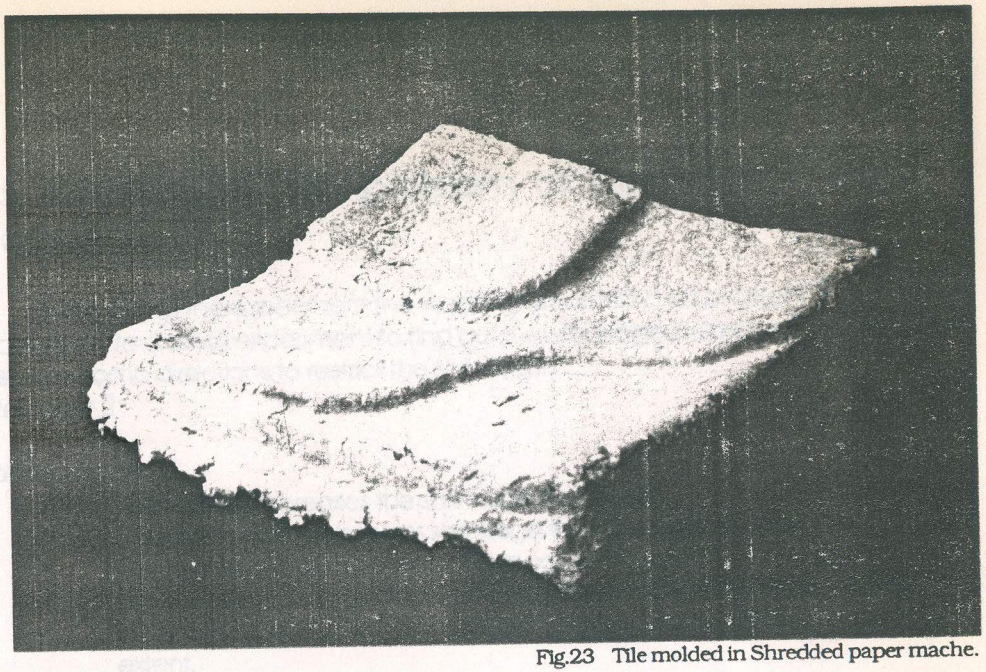


Fig.23 Tile molded in Shredded paper mache.

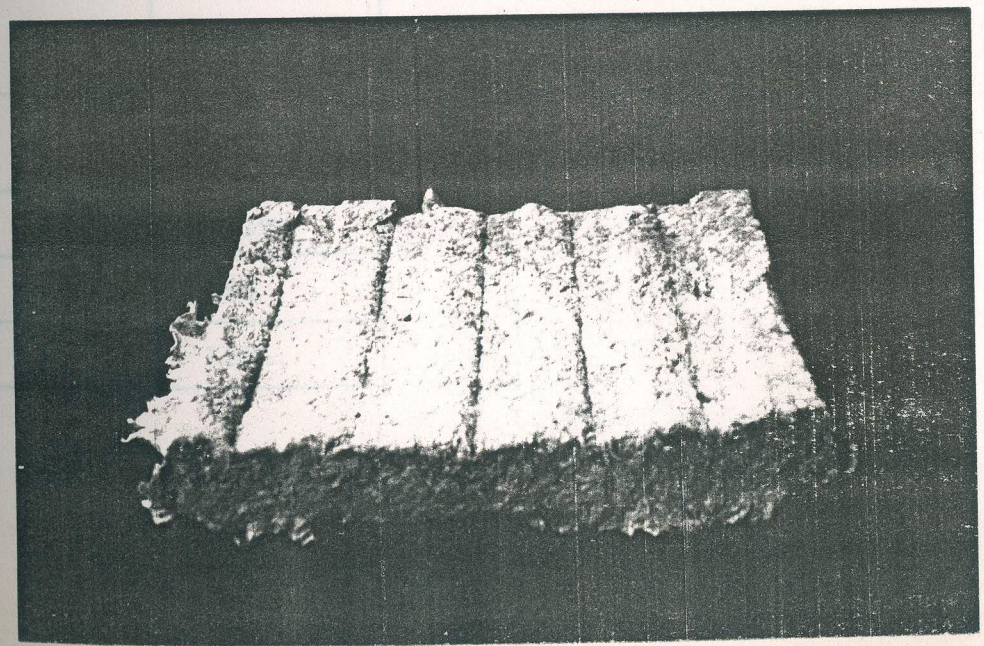


Fig.24 Tile molded with corrugations on the surface in shredded paper mache.

Table 2

Mache type	Average Thickness (mm)	Shrinkage in % of original length
News paper Pulp	5	12.8%
News paper Pulp	5	12.9%
News paper Pulp	5	10.93%
News paper Pulp	6.5	9.3%
News paper Pulp + 30%shredding	6	9.7%
News paper Pulp + 50% shredding	6	7.8%
News paper Pulp+ Cloth strips	6	8.81%
News paper Pulp + 40% starch	4	7.0%
Shredding mache	4	10.03%
Shredding mache	5.5	8.5%
Shredding mache	6	7.56%

7.5 Experiments with problem of shrinkage in paper mache.

While doing the experiment the warping attracted a lot of attention. So it was decided to do a small experiment to find out the shrinkage in various maches and to postulate some directions to restrict the shrinkage.
Refer table 2

Conclusions

* As thickness increases the shrinkage decreases.
* Shredding mache has less shrinkage than the pulp mache.
* Mixing shredding with pulp in the mache reduces the shrinkages.
* Drying the molding under perssure between water absorbing molds.
* Initial drying in sun and final drying in shade controls shrinkage to some extent.

8. Observations

This project was done to observe the material and the experiments were not enough to come out with the final conclusions. This phase has taken the study further and has raised a need to do further experiments.

* It is possible to make paper mache into structural forms for low load applications. Paper mache panels single or laminated can be very well used in the doors, partitions, shelves, and even in applications like false ceiling tiles. So that the life of the recycled material is used to the fullest.

* To ensure simplicity in molding the molds should be of flexible and folding type. It means that the actual surface which will be giving the shape to the mache will be flexible and it will have a backing of a rigid support.

* If the molds are lined with absorptive material like plaster then the drying process takes less time and less possibility of shrinkage.

* Paper mache can be applied in acoustical rooms also if they are made into panels as the material if made porous has a higher coefficient of absorption.

* After the experiments it shows that the only problem that was stopping the use of this material into larger applications is the shrinkage and warping experienced in this material. The material experiences shrinkage in two forms
    * Shrinkage in dimension/overall size.
    * Surface shrinkage.

* Ways in which this can be kept under control are — Increase in the thickness and give more ribs. But apart from this for paper mache we can conclude that to some extent shrinkage can be controlled by
* Breaking the surface area into smaller areas by undulations.
* Molding considerably dry mache into water absorbing molds under high pressure, which is similar to the way in which the tiles are manufactured.
* Adding silica sand into the paste to a ratio of 1:6 (silica sand : paste) This was tried out but further experiment could be done to find the optimum ratio.
* The corrugated sections cast show very less amount of shrinkage.
* The paste made from Powder of paper showed less shrinkage on drying.

* The shredded papers if used act as a good alternative for the paper mache. with similar properties.
* The final the final preparation of shredded paper dries very fast as compared to the mache prepared from the pulp. As the shredding are not soaked in water but only made wet.
* If the strength is compared. The direct stresses are more or less the same but the mache out of the shredding show more resistance to torsional stresses.
* In terms of shrinkage the shredding mache behaves similar to pulp mache but the has more surface shrinkage .
* The sections if made in shredded mache show good resistance to bending.

* The strength testing shows that this material can be applied in only in low load applications. But it can definitely be used as filler panels.

Some experiments that have come up which need to be done with further detailed planning and fully dedicated experimentation are

1 Control of shrinkage
Through ingradients.
Through Form explorations.
2 Process to manufacture the sections.
3 Surface finishing of the Mache products.
4 Further exploration in using the shreaded paper and its applications. This phase of experimentation has proved shreaded paper to be a good alternative to make paper mache.

9.Glossary

9.1 List of Figures

9.2 Drawings

9.2 List of tables

10. References

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