CHAPTER IV

EXPERIMENTAL METHOD

In this chapter the experimental work for stress concentration factors is divided into five items as follow:

Objectives

The aim of this experimental study may be stated as follows:

(1) To study the stress distribution in terms of ischromatic fringes in the model made of transparent material by photoelastic method.

(2) To investigate the effect of the parallel - side slit with semi - circular ends centrally placed in a transparent plate on the stress distribution.

(3) To find the point of maximum stress on the edge of the slit or to determine the maximum order of the isochromatic fringe on the edge of the slit.

(4) To calculate the stress concentration factors of each sizes of slit at each angles of inclination.

(5) To investigate the variations of stress concentration factors of a parallel - side slit with semi - circular ends and a narrow slit with circular ends having the same focal length

and the same radius of curvature at their ends by varying their angles of inclination.

(6) To compare the experimental value of stress concentration factors of a parallel - side slit to those values which are calculated by using the equation of stress at the ends of an elliptic hole at various values of c/r and β.

(7) To find the most suitable expressions for k_1 and k_2 in order to satisfy the equation of the stress concentrations factors of a parallel - side slit.

Specimens

The transparent specimens are prepared from epoxy resin sheets of which the optical properties follow the rules stated in chapter II. The original standard size of an epoxy resin sheet is a square plate having nominal dimensions 300 mm x 300 mm in length and 1.5 mm thick. However, the test specimen is considered to be a rectangular plate which its nominal demensions are 80 mm wide, 100 mm long, and 1.5 mm thick as shown in Fig. 4-1, that is, one epoxy resin sheet can be divided into nine pieces of the test specimens by sawing. On each end of a test specimen, 8 mm apart from its rim, eight holes of 3 mm diameters are equally - space drilled so that the external distributed load can be replaced by eight concentrated loads applied at the pins inserted into the holes. In sawing and drilling processes, the care is made so that no stress raiser occurs along the rims of

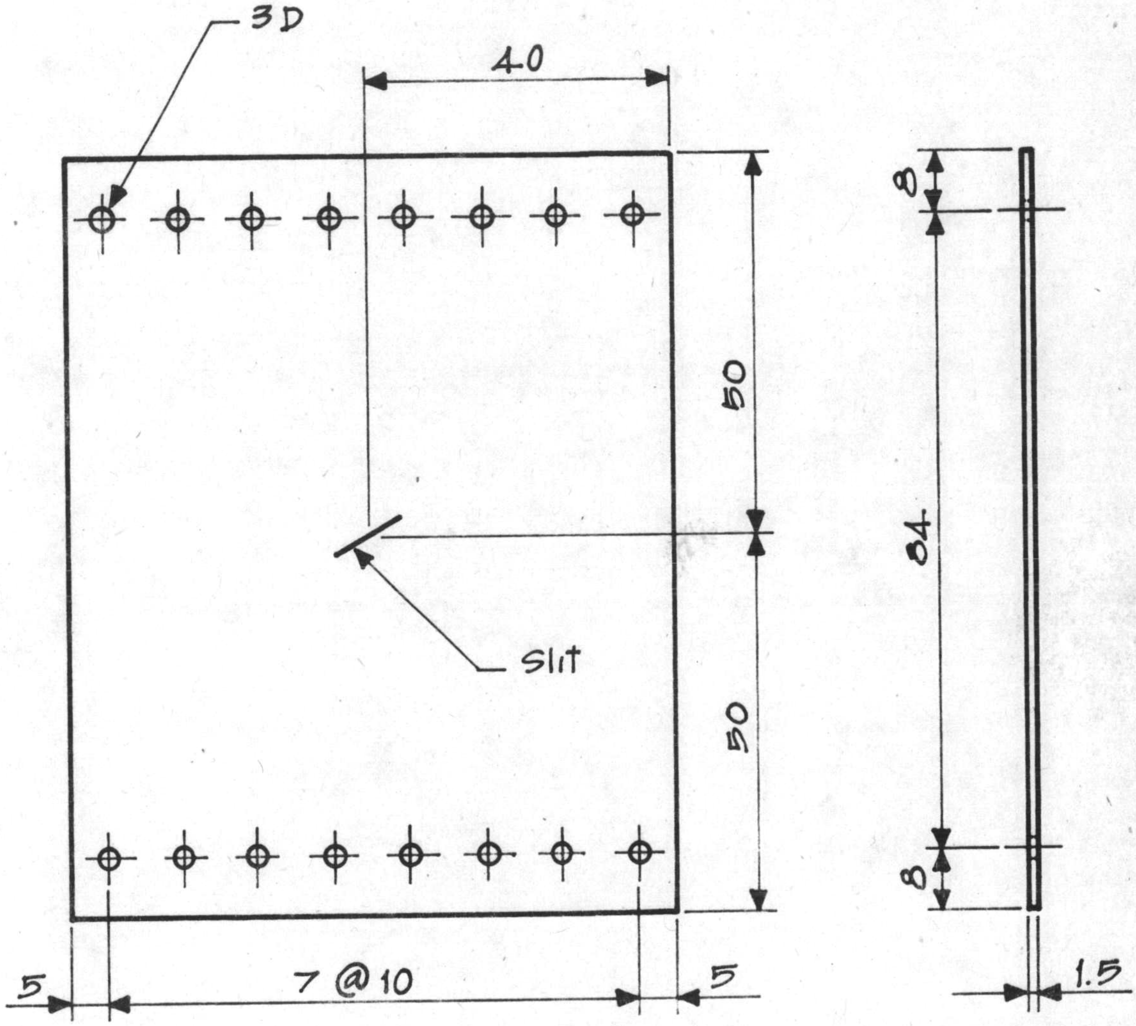


FIG. 4-1 NOMINAL SIZE OF TEST SPECIMEN

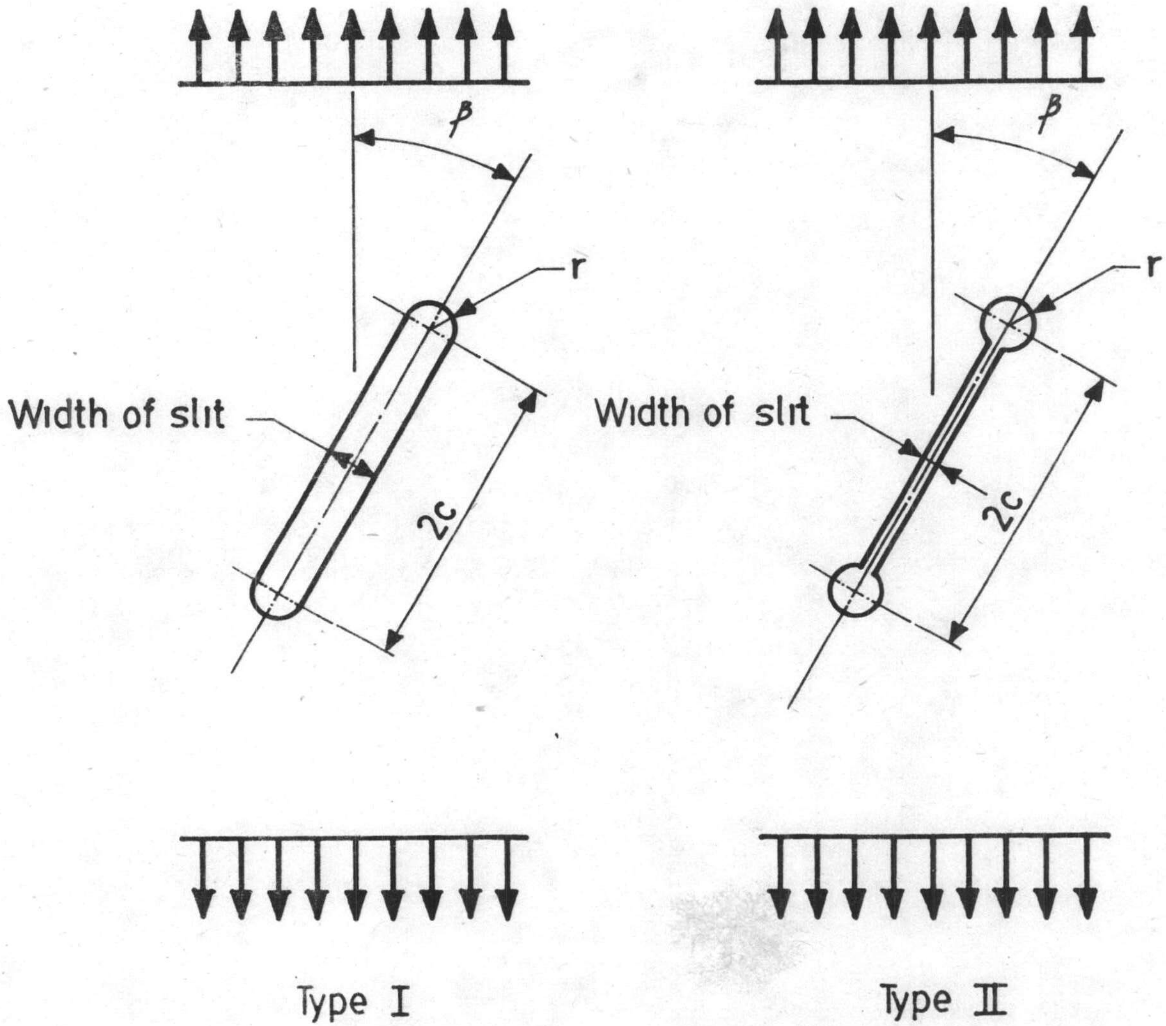


FIG. 4-2 ENLARGED VIEW OF SLITS

the test specimens or at the edges of the holes.

Two types of slits made in the epoxy plate are a parallel-side slit with semi - circular ends, type I, and a narrow slit with circular ends, type II, as shown in Fig. 4-2. Both sides of the slit are parallel and symmetrical with its axis. The processes used for making the slit also involve high speed drilling and hand sawing. First, both ends of the slit are made by drilling with the drill of diameter equal to twice the end's radius of curvature required. Then, two drilled holes are joined by hand sawing. The surface of the slit is neatly made finished by a sand paper. During the rubbing process, heat protection is made by dropping some water on the sand paper.

The final dimensions of the thirty-four test specimens are shown in Table 4-1.

Table 4-1 : Dimensions of Test Specimens

Specimen no.	c (mm)	r (mm)	c/r	β (degree)	Width of Slit(mm)	Width of Plate(mm)	Thickness of Plate (mm)
1	4.0	0.5	8	30	1.0	79.37	1.410
2	4.0	0.5	8	45	1.0	79.62	1.820
3	4.0	0.5	8	60	1.0	79.93	1.375
4	4.0	0.5	8	75	1.0	80.03	1.950
5	4.0	0.5	8	90	1.0	79.80	1.605
6	6.0	0.5	12	30	1.0	79.34	1.730
7	6.0	0.5	12	45	1.0	79.60	1.785

Table 4-1 : (continued)

Specimen no.	c (mm)	r (mm)	c/r	β (degree)	Width of Slit (mm)	Width of Plate (mm)	Thickness of Plate (mm)
8	6.0	0.5	12	60	1.0	79.83	1.730
9	6.0	0.5	12	75	1.0	79.79	1.910
10	6.0	0.5	12	90	1.0	79.30	1.660
11	8.0	0.5	16	30	1.0	79.41	1.510
12	8.0	0.5	16	45	1.0	79.42	1.425
13	8.0	0.5	16	60	1.0	79.43	1.375
14	8.0	0.5	16	75	1.0	79.92	1.585
15	8.0	0.5	16	90	1.0	79.58	1.460
16	10.0	0.5	20	30	1.0	79.71	1.430
17	10.0	0.5	20	45	1.0	79.59	1.900
18	10.0	0.5	20	60	1.0	79.72	1.385
19	10.0	0.5	20	75	1.0	79.53	1.975
20	10.0	0.5	20	90	1.0	79.50	1.455
21	12.0	0.5	24	30	1.0	79.43	1.550
22	12.0	0.5	24	45	1.0	79.08	1.405
23	12.0	0.5	24	60	1.0	79.67	1.445
24	12.0	0.5	24	75	1.0	79.47	1.360
25	12.0	0.5	24	90	1.0	79.71	1.375
26	12.0	0.75	16	30	1.5	79.52	1.410
27	12.0	0.75	16	45	1.5	79.31	1.365
28	12.0	0.75	16	60	1.5	79.67	1.440
29	12.0	0.75	16	75	1.5	79.61	1.345
30	12.0	0.75	16	90	1.5	79.68	1.685
31	12.0	0.75	16	45	0.35	79.52	1.495
32	12.0	0.75	16	60	0.35	79.67	1.615
33	12.0	0.75	16	75	0.35	79.72	1.610
34	12.0	0.75	16	90	0.35	79.94	2.030

Apparatus

The complete unit of a photoelastic bench used to perform an experiment is the polariscope which can be arranged as a plane polariscope or a circular polariscope, its picture is shown in Fig. A 43. The polariscope is composed of the main components as indicated in the figure. They are:

- a monochromatic light source,
- a set of a condensing lens, a polarizer, and a quarter - wave plate,
- a loading frame,
- a set of a quarter - wave plate and an analyzer,
- a focusing unit, and
- a screen or a camera.

The monochromatic light source used throughout the experiment is the yellow light generated by a bulb of Sodium vapor.

The polarizer, analyzer, and two quarter - wave plates attached to the bench are circle - like shapes of 140 mm diameters. This means that the polariscope can be used to inspect the squared specimen of size no larger than 100 mm x 100 mm.

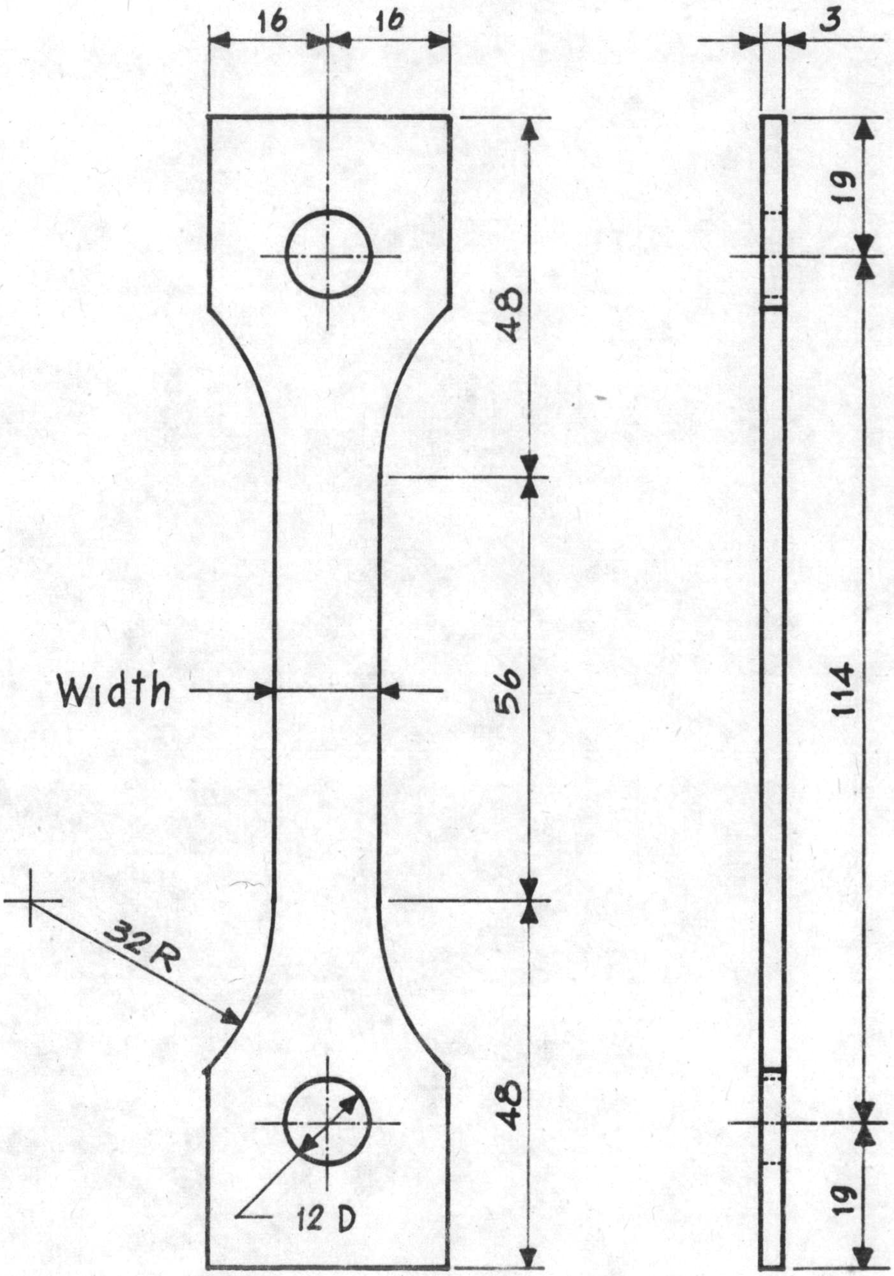
The loading frame prepared is vertically and horizantally adjusted. It is also able to rotate about a vertical axis so that the plane of a test specimen is made perpendicular to the traversing light. The useful space of the loading frame is within 240 mm wide and 340 mm high. Load applied to a test specimen was acted by a weight on the hanging disk at the end of a lever hinged at another end. The weight can be increased or decreased by a step of 0.1 pound force.

The interference of two light waves will be recorded as an image on the screen or on the film of a camera. The eye - side section of the focusing unit is so small that the camera used has to be a single lens reflex type. A camera with a standard sized film of 35 mm can be attached to the photoelastic bench.

Calibration of Material Used

There are many methods to calibrate the material used for preparing the test specimen.(9) The most common method is a tensile test, and it is considered to be used for this calibration. The dimensions of a selected specimen for calibration are shown in Fig. 4-3, it is made of a 3.2 mm thick epoxy resin sheet. This calibration is performed to determine the fringe constant of the material. In two drilled holes at both ends of the specimen shown in the figure, two brass bushes are inserted so that they will be able to be adjusted to make the uniaxial load applied to the specimen collinear.

Consider the specimen when it is subjected to the load P. It is evident that at any right section on the specimen the



AVERAGE WIDTH = 14.12 mm

FIG. 4—3 SPECIMEN FOR CALIBRATION

internal force is uniformly distributed over the surface and its direction parallel to the direction of the load P. If the two forces P applied at both ends is kept collinear, there is also no shear stress on that right section. This means, if an element of the specimen is considered, it can be concluded that one of its principal stress axes coincides with the direction of the load P, and normal stress and shear stress diminish in the perpendicular direction, consequently;

$$\sigma_1 = \frac{P}{dh}, \quad \sigma_2 = 0 \tag{37}$$

where d and h are representatives of the width and the thickness of the calibrated specimen.

Substitute eq. (37) into eq. (21) or eq. (34), give

$$P = 2dh\,Fn$$

Referring to eq. (22), it is remembered that f = hF, then

$$P = 2dfn \tag{38}$$

This equation is capable of determining the material fringe value f by varying an applied load P and recording the corresponding isochromatic fringe order n. The relation between P and n are recorded as shown in Table 4-2. As shown by eq. (38), the graph plotted P against n is linear and slope of the graph will be equal to 2 df, and d is known variable, 14.12 mm, thus f will be determined.

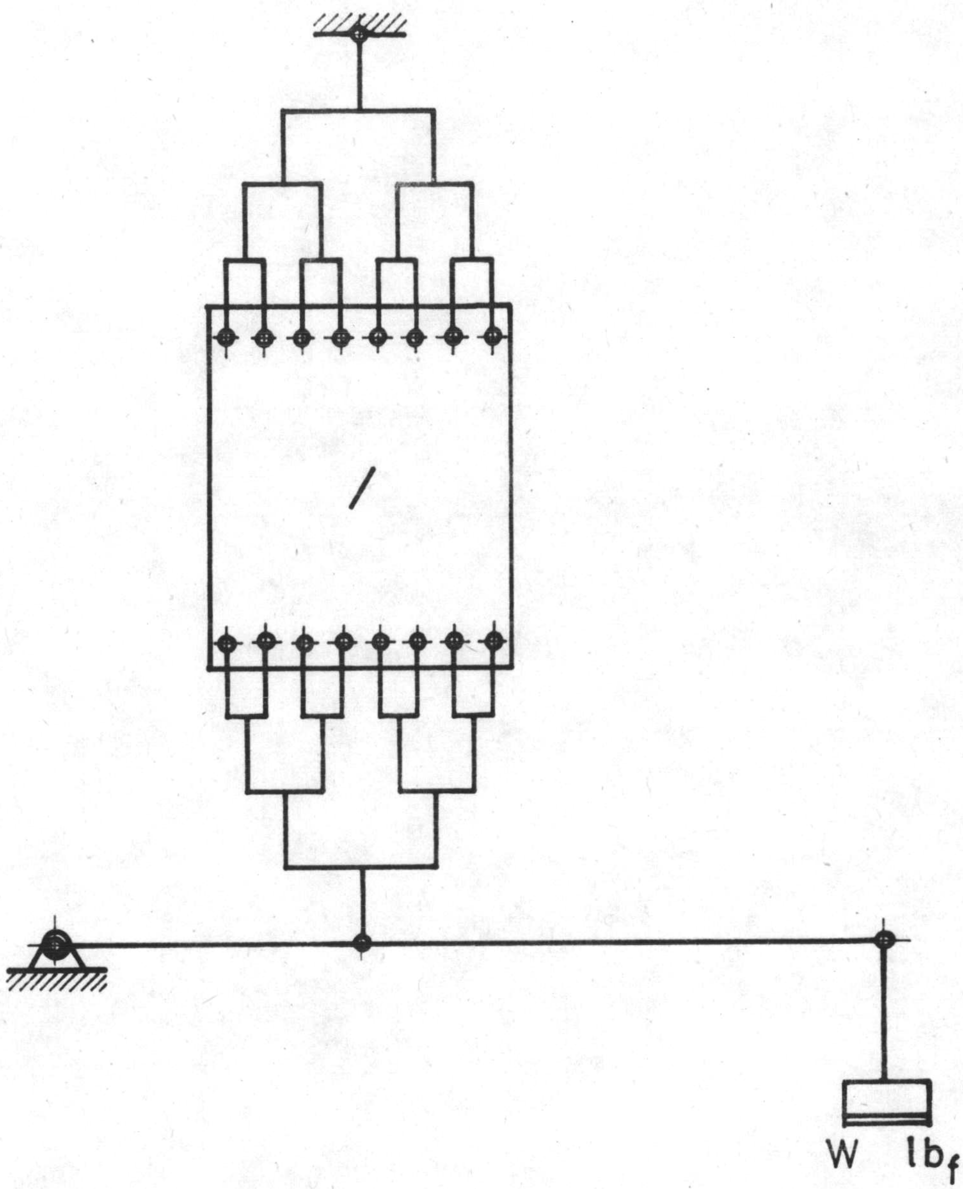
Table 4-2 : Load and Fringe Order of Calibrated Specimen

Weight, W lbf	Load, P N	Fringe Order n
0.0	74.73	0.5
2.0	128.10	1.0
5.5	221.51	1.5
8.0	288.23	2.0
11.0	368.29	2.5
14.0	448.36	3.0
16.9	525.75	3.5
20.0	608.49	4.0
23.0	688.55	4.5
26.0	768.61	5.0
28.5	835.33	5.5
31.5	915.40	6.0
34.0	982.12	6.5
37.0	1062.18	7.0
39.5	1128.90	7.5
42.5	1208.97	8.0
45.0	1275.69	8.5
47.5	1342.41	9.0
50.0	1409.13	9.5
52.5	1475.85	10.0
55.0	1542.57	10.5

Experimental Precedure

Thirty-four pieces of the test specimens were tested in the polariscope one at a time. The orientation of the polarizer, the analyzer, and the quarter - wave plates were set in order that the bright field was obtained. If the isochromatic fringe pattern appearing on the test specimen was to be recorded by photographing, the bright field was necessarily introduced. On the other hand, if the bright field was not needed the polariscope could be manually operated to form a dark field on the screen. It should be noticed that the intensity of light on the camera's film had to be sufficient to photograph a desired stress pattern.

The positions of the optic axes of the polarizer, the analyzer, and the quarter - wave plates were set as shown in Fig. 2-2.A in order to give the bright field. The optic axis of the polarizer was perpendicular to that of the analyzer which was the same as the optic axes of the two quarter - wave plates. The first quarter - wave plate made an angle to the polarizer of 45 degrees leading. The test specimen placed in the loading frame was perpendicular to the rays of light as shown in Fig. A 46 and Fig. A 47. The load applied to the test specimen was transmitted by the loading lever which was hinged at one end and the disk subjected to a weight was suspended at another end. The loading diagram of a test specimen was clearly shown in



Load Applied to Test Specimen = [16.8 + 6W] 4.448 N

FIG. 4—4 LOADING DIAGRAM OF TEST SPECIMEN

Fig. 4-4. The total force acted on the test specimen was given by an equation

$$P = (16.8 + 6\ W)\ 4.448 \qquad (39)$$

where W was the weight on the disk in pounds (lb_f) and

P was the load acted on the test specimen in newtons (N).

The method used to determine the order of an isochromatic fringe was a simple one. First, no load applied to the specimen, all points on the specimen had a white band of isochromatic order equal to zero. As the load gradually increased, the isochromatic band changed from white to black and to white again white the load still increased. If a particular point on the test specimen was observed and its isochromatic fringe changed as above, this meant, the isochromatic orders were 0, 0.5, and 1.0 respectively. It was the fact that if the test began with the bright field, the white band of a isochromatic fringe had an integral order of 0, 1, 2, 3, ... and so on whereas the dark band had a half order of 0.5, 1.5, 2.5 ... etc.

This experiment was to find the stress concentration at the edge of the slit and to show the distribution of isochromatic lines, so two methods of recording data were employed.

The first method : an observation was made by eyes looking through a telescope for an isochromatic fringe of order 4.5 at the edge of the slit while the applied load was gradually increased. The weights, W, for the test specimen which the fringes of order 4.5 appeared on their edges were shown in Talbe A 1.

The second method : load was applied to the test specimen as much as possible so that many isochromatic lines appeared on it. The isochromatic pattern from this method were recorded by photographing as shown in Fig. A 8 to Fig. A 41.