Elastic Experiment-Analysis of Structural Frames with Panel Wall

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§ 1 Introduction

Shear walls are important elements of building structures. The main role of shear walls is to resist lateral load. Since the lateral loads can become very large, it is necessary to be able to predict the behavior of shear walls in structure.

Up to present time, some of the elastic analyses, such as slope deflection method, of the frames as one dimensional structure have been studied by a great number of investigators. Accordingly it is said that such a structure can be easily and accurately designed. The analyses of the frames with panel walls have not been established enough even in elastic range.

Generally, the walls in the frame cannot be dealt with as line segments very often, because the member width is large as compared with their length. And as the wall itself is a panel, the stress distributions on the boundaries between the wall and beams or columns remarkably complex. Some elastic analyses of shear walls whose stress are complex, have been reported[1)2)3)].

As the stiffness of the panel walls is large as compared with that of the frame, it often interferes with structural design. It is assumed that the stiffness of walls after the shearing crack has not great rigidity and the panel walls resist the lateral force only in the range of its stiffness and the frames resist the rest of it. It remarkably changes according to the walls arrangement, the stiffness of the frame adjacent to the walls and loading conditions.

The studies on analystic solutions of the shear walls after the crack have been reported, but there is no example that the analysis after cracking was applied to the frame with panel wall, and so the further studies are expected.

It is extremely complex and difficult to analyze the frame with the panel which cannot be dealt with as a line segment, but it is very important problem to reexamine the shear wall in consideration of the stiffness of the multistories frame.

It is especially important to know reasonably the stress distribution in the analysis of the frame with walls, although the various lateral force working to the architectural structures, such as earth-quake load or wind load, cannot be estimated in the strict sence. It needs to know easily the approximate stress distribution even if many assumptions are taken into consideration in the process of analysis. There are a few approximate methods to analyze the frame with walls.

1. Truss analogy; The walls are replaced by the truss and the frame is regarded as the assembly of line segments.
2. Classical beam theory; The walls are regarded as the cantilever. Neighboring beams and footing beams give the restrict effect to the walls.
3. Differential equation analysis; For coupled shear walls connected by beams, the beams are replaced by lamina whose stiffness continued in the direction of height is small. This method is analyzed by the differential equation on continuity condition of the defomation of beams.

Truss analogy of walls subjected to shearing force is easy to solve, but the axial force which is transmitted from walls to columns is considered to be concentrated on the top of columns. Since the forces are distributed on the boundary of columns and walls, there are some errors.

The differential equation or the finite difference equation can be treated for frame of special wall arrangement. The slope deflection method which rigid zone and deflection are taken into consideration has been reported. But the definition of the rigid zone is uncertain [7)8)]. As stated above, the further investigations on the frame with walls are necessary.

From these points of view, a few kinds of frames have been analyzed by the photoelastic experiment in order to get a key to the propriety of the practical approximate solution of wall and this research will make a first step toward the practical calculations.

The results of this study do not always applied to the real structure in the strict sence from the following reasons.

1. Poisson's ratio is different from that of reinforced concrete.
2. In general, beams are connected with the floor boards and beams do not deform in the direct of their axes.
3. There are beams meeting at right angles in the joint panel of the beams and the columns.

We cannot help depending on the experiment to prove the propriety of the theory. Photoelastic experiment, which can get the stress in every part of the frame with walls, is superior to the experiment by the reinforced concrete specimen to get the right of the elastic theory.

§ 2 Specimen and Apparatus

Specimen is a frame made of epoxy-resin plate and the frame has three bays and four stories (see Fig. -1). Since the frame has generally the lowest story where columns are fixed, middle stories and the highest story and in order to obtain many kinds of wall arrangement, specimen was made as four stories frame.

All of beam and column dimensions are 6mm thick and 15mm wide. Many files were used in making the specimen, and then we took care that heat stress might not remain as residual stress and that the filed surface might be flat uniformly. Steel panels are pasted on both sides of foundation part of the specimen so as to make base of column fixed. Mechanical properties of material (epoxy-resin) are shown in Fig. -2a and Fig. -2b.

Wall panels are pasted in center span as shown in Figs. 3b~3e. Lateral force was subjected to each story respectively by the apparatus shown in Fig.-4. The photoelastic isochromatic pictures were taken. Tensile force was subjected to one side and compressive force to the other side of frame in order that antimetric load might be acted on the frame.

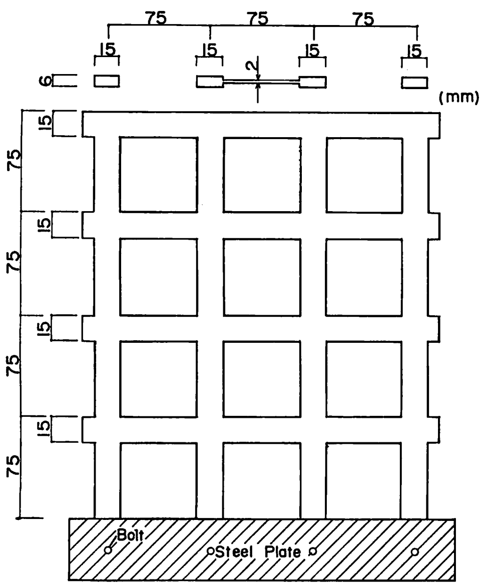

Fig. 1 3 Bays-4 Stories Epoxy Resin Specimen

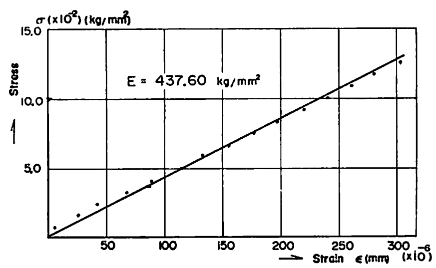

Fig. 2-a Young's Modulus of Epoxy Resin

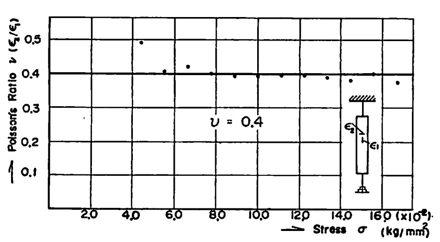

Fig. 2-b Poisson's Ratio of Epoxy Resin

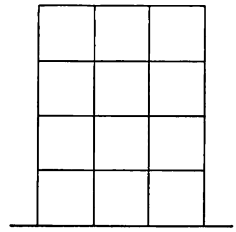

Fig. 3-a Frame without Panel Wall (Specimen-0)

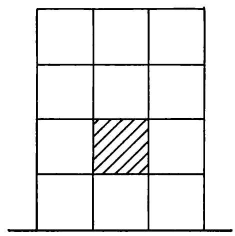

Fig. 3-b Frame with a Panel Wall (Specimen-1)

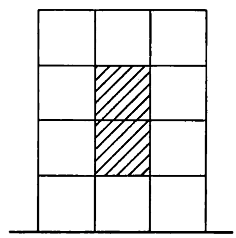

Fig. 3-c Frame with two Panel Walls (Specimen-2)

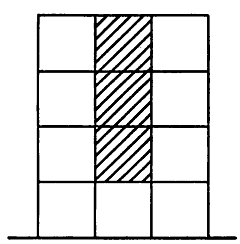

Fig. 3-d Frame with three Panel Walls (Specimen-3)

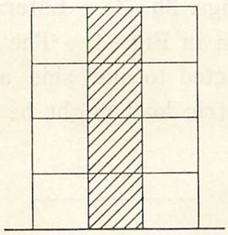

Fig. 3-e Frame with four Panel Walls
(Specimen-4)

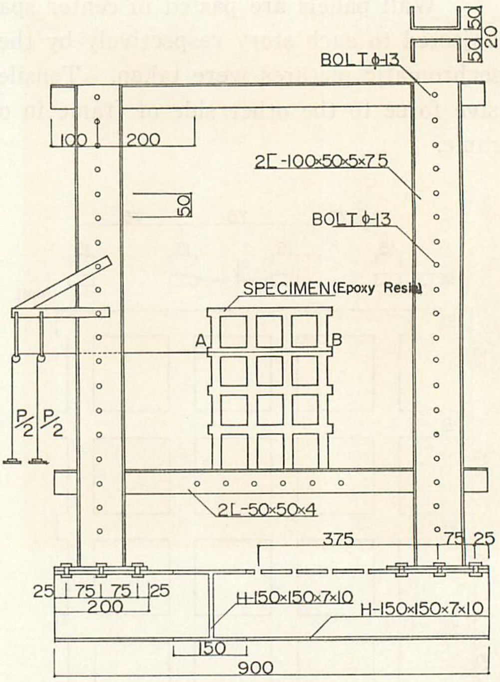

Fig. 4 Test Apparatus

§3 Experimental Results

The specimens No.-0, No.-1 No.-2, No.-3, No.-4 were subjected to lateral forces on each floor respectively and isochromatics pictures were taken. These pictures are shown in photos. 0a～4a in case of the external forces acting on roof floor beam and in photos. 0b～4b in case of fourth floor beam. Many pictures in case of second and third floor beam are shown in Photos. 0c, 1c, 0d, 1d.

Stresses of beams and columns were analyzed by counting fringe orders in these photographs. Stresses shown in Figs. 5a～5e are summed up respective stresses in lateral forces being subjected to each floor. Since there are differences between compressive stresses and tensile stresses inpanel points, average stresses of the two values are shown. There are few photoelastic stripes (Fringe Orders) in both ends columns not being adjacent to wall in the same story, in other words stresses of the columns are small and then there are some errors in counting fringe orders. Accordingly the stresses were introduced from the proportion of bending moments in up and downstairs beams and columns.

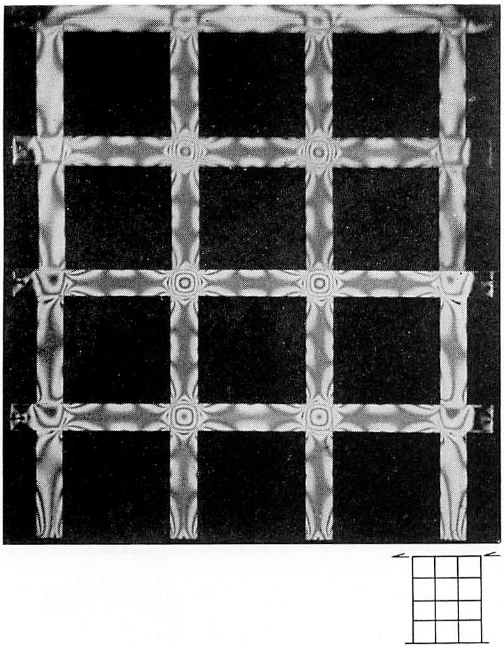

Photo 0-a Isochromatics of Frame without Wall Panel Subjected to Lateral Forces on Roof Beams

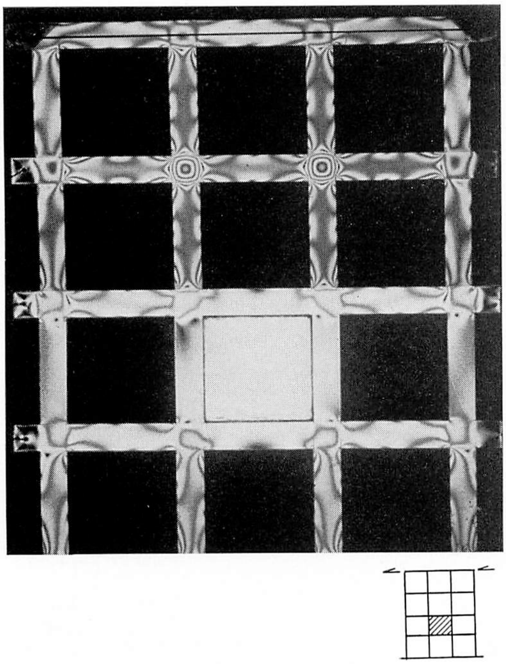

Photo 1-a Isochromatics of Frame with a Wall Panel Subjected to Lateral Forces on Roof Beams

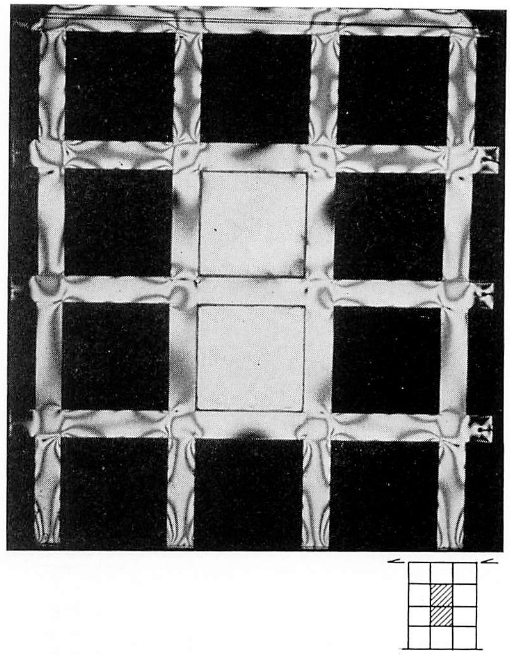

Photo 2-a Isochomatics of Fame with two Wall Panels Subjected to Lateral Forces on Roof Beams

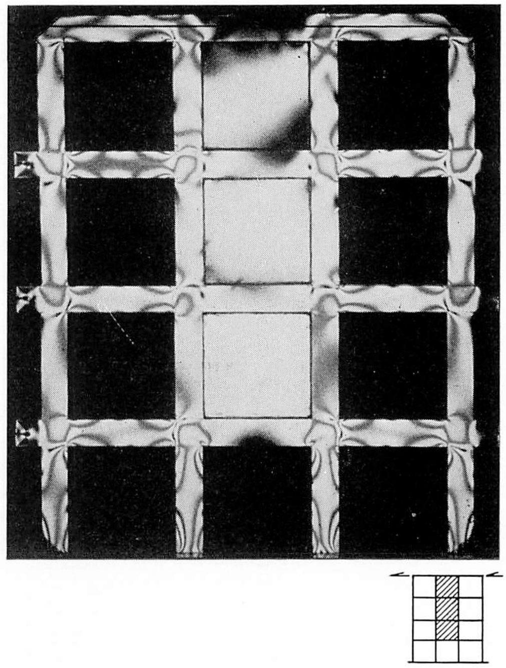

Photo 3-a Isochomatics of Frame with three Wall Panels Subjected to Lateral Forces on Roof Beams

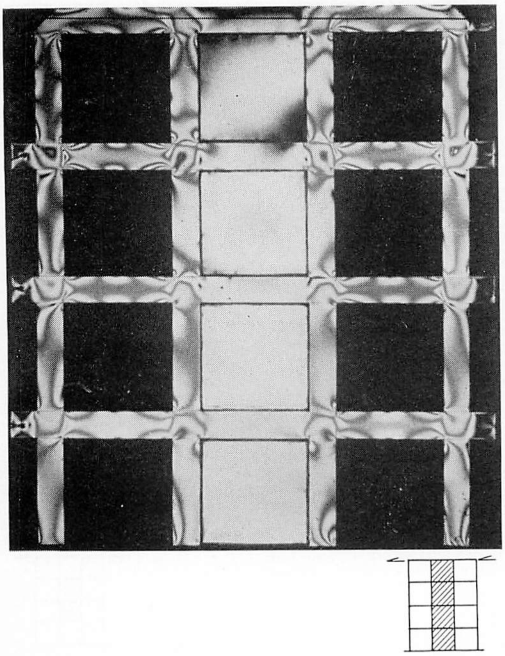

Photo 4-a Isochromatics of Frame with four Wall Panels Subjected to Lateral Forces on Roof Beams

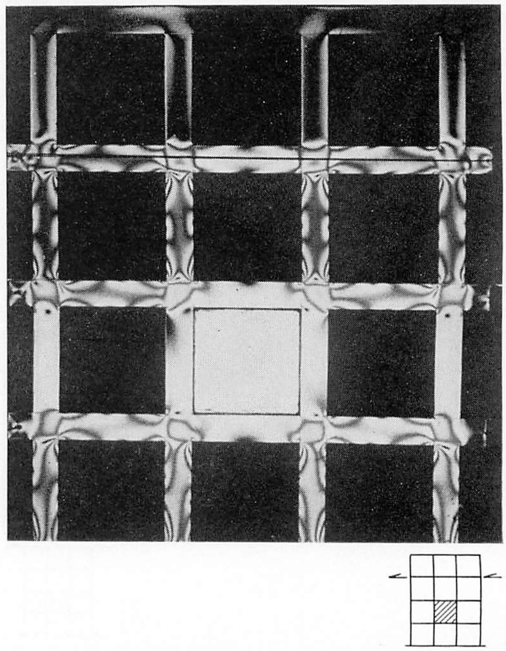

Photo 1-b Isocromatics of Frame with a Wall Panel Subjected to Lateral Forces on fourth Floor Beams

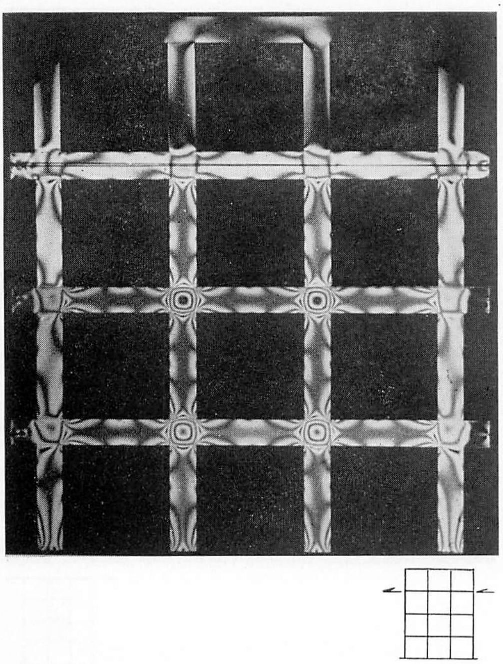

Photo 0-b Isochromatics of Frame without Wall panel Subjected to Lateral Forces on fourth Floor Beams

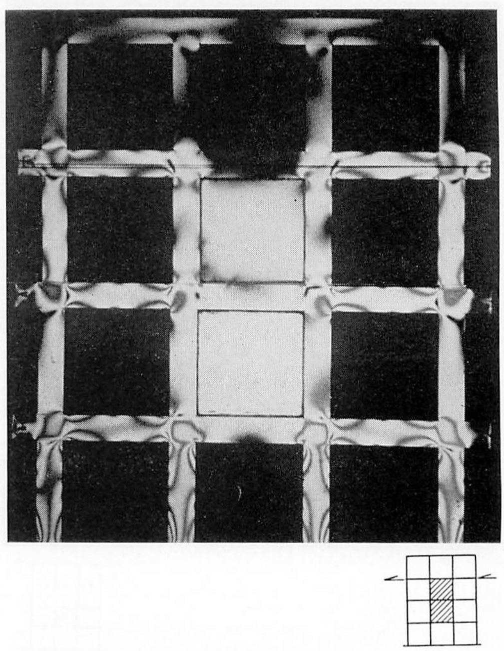

Photo 2-b Isochromatics of Frame with two Wall Panels Subjected to Lateral Forces on fourth Floor Beams

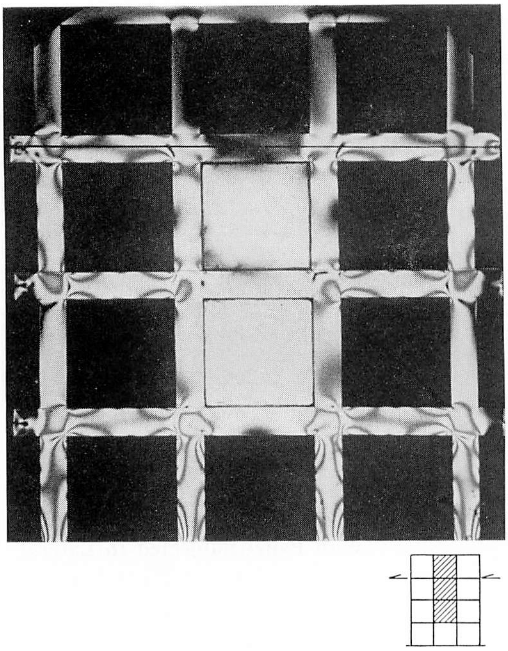

Photo 3-b Isochromatics of Frame with three Wall Panels Subjected to Lateral Forces on fourth Floor Beams

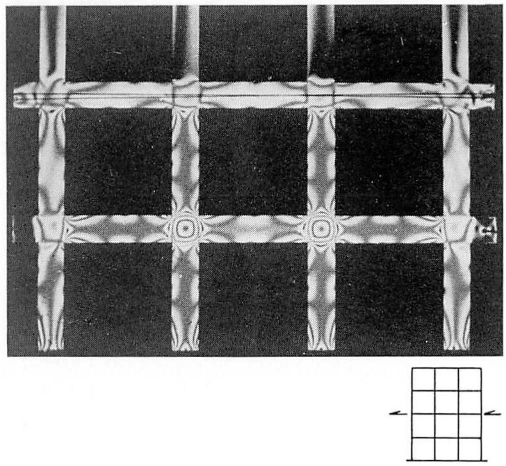

Photo 0-c Isochromatics of Frame without Wall Panel Subjected to Lateral Forces on third Floor Beams

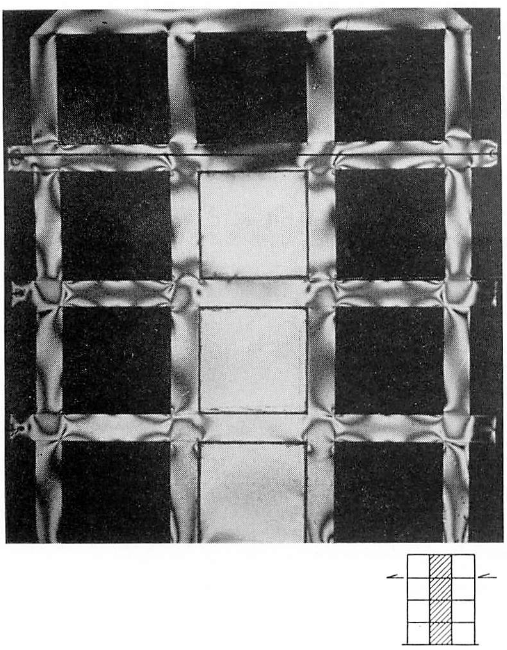

Photo 4-b Isochromatics of Frame with four Wall Panels Subjected to Lateral Forces on fourth Floor Beams

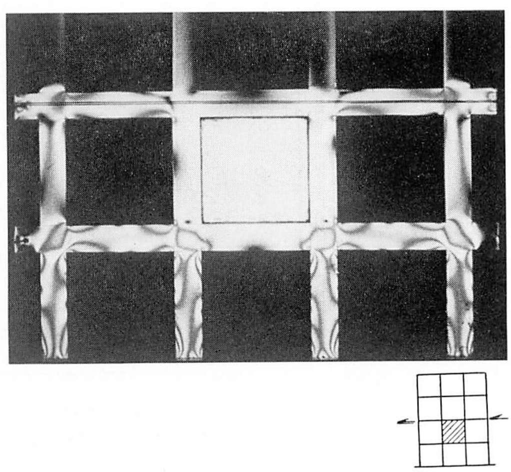

Photo 1-c Isochromatics of Frame with a Wall Panel Subjected to Lateral Forces on third Floor Beams

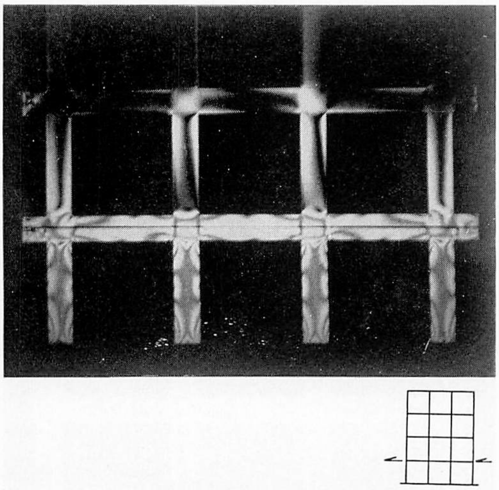

Photo 0-d Isochromatics of Frame without Wall Panel Subjected to Lateral Forces on second Floor Beams

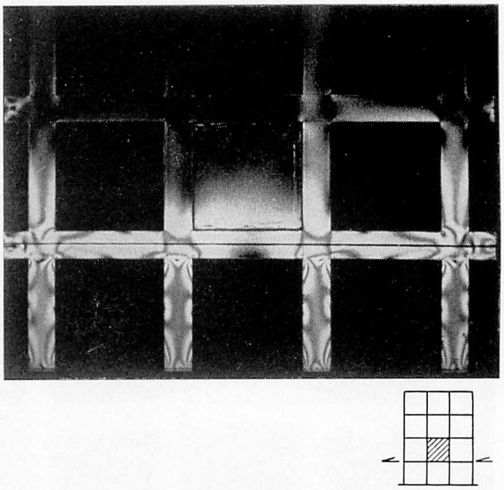

Photo 1-d Isochromatics of Frame with a Wall Panel Subjected to Lateral Forces on second Floor Beams

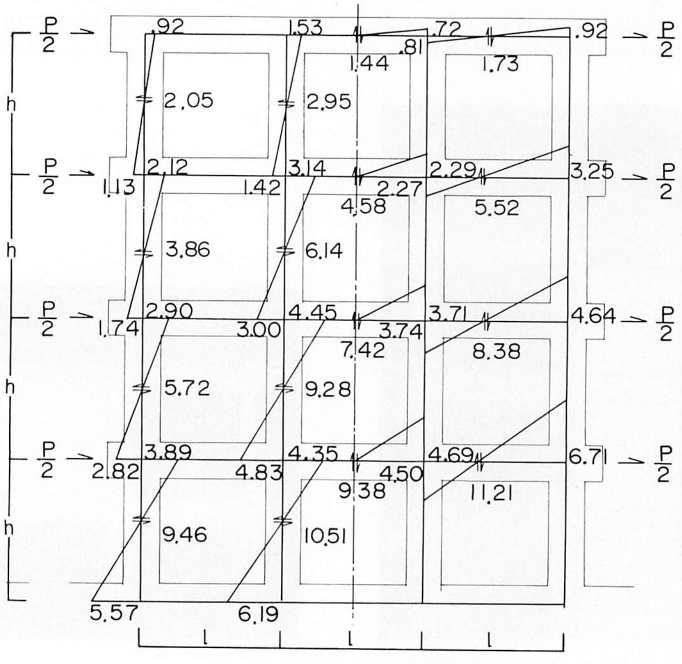

Fig. 5-a Bending Moments (10×Ph) and Shearing Forces (10×P) in the Specimen-0 (h=ℓ)

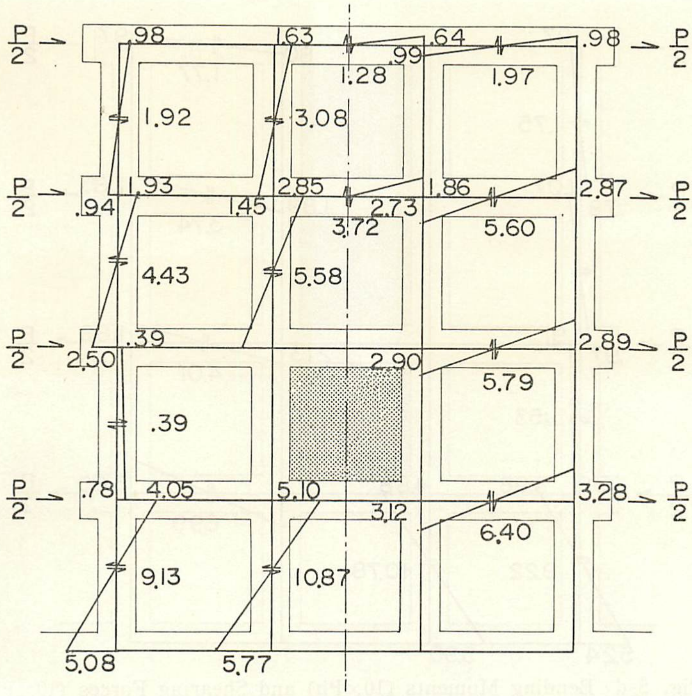

Fig. 5-b Bending Moments (10×Ph) and Shearing Forces (10×P) in the Specimen-1 (h=ℓ)

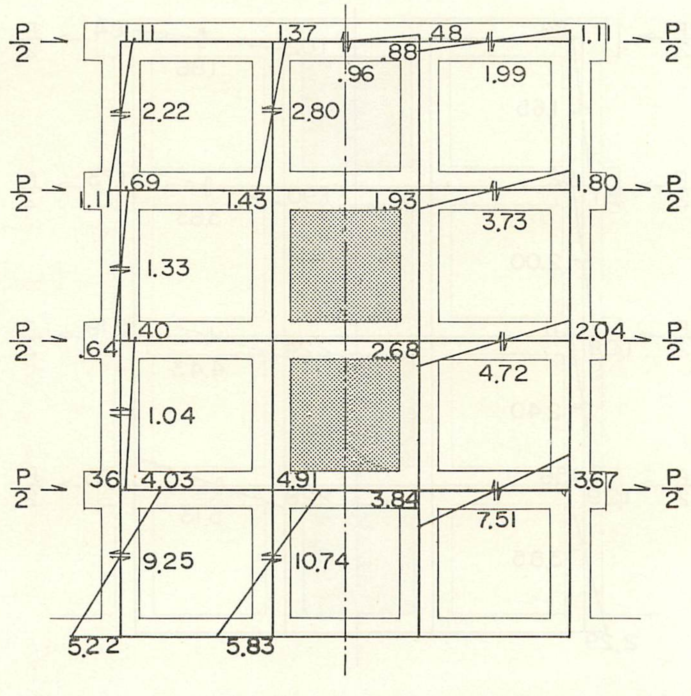

Fig. 5-c Bending Moments (10×Ph) and Shearing Forces (10×P) in the Specimen-2 (h=ℓ)

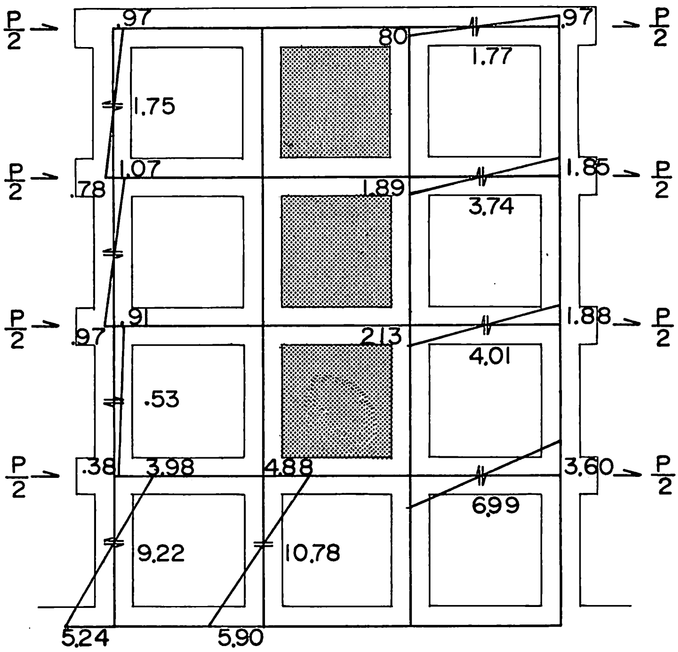

Fig. 5-d Bending Moments (10×Ph) and Shearing Forces (10×P) in the Specimen-3 (h=ℓ)

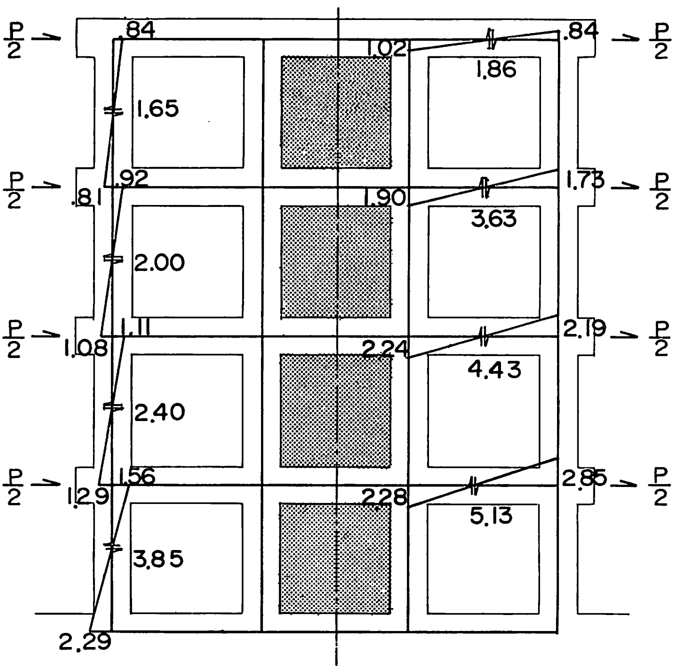

Fig. 5-e Bending Moments (10×Ph) and Shearing Forces (10×P) in the Specimen-4 (h=ℓ)

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