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DISCUSSION PRÉPARÉE / VORBEREITETE DISKUSSION / PREPARED DISCUSSION

Light-Gage Steel Floor Systems Provided to Include Utilities – Proposals and Experiments

Systèmes de planchers en dalles orthotropes avec provision de contenir les installations – Propositions et expériences

Leichtstahlbleche mit Berücksichtigung der Installationen – Vorschläge und Versuche

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It is becoming increasingly necessary, when designing structures for buildings, to leave plenty of space under the floor to accomodate air-conditioning, electrical and plumbing installations. Further, reasons of economy drive designers to make the floors cooperate with the steel structures that support them, thus forming, when possible, composite systems.

Many proposals aiming to achieve one or other or even both these results have been put forward and Dr. Scalzi has mentioned them. The author of this paper has also worked on this problem and, together with Dr. Ballio, has started up a series of theoretical and experimental studies at the Polytechnic University of Milan on two types of Floor Systems that he considers of interest.

This research work, sponsored by the Italian National Research Council (CNR), concerns two types of Floor Systems. The first, the "Drawn Floor System", consists of two 1,5 mm sheets with hemispherical deep-drawings, arranged at regular intervals on a 50 cm square mesh and welded together at the contact points (figs. 1 and 2). A 4 cm layer of concrete top and bottom completes the panel, which is then ready to bear the flooring and

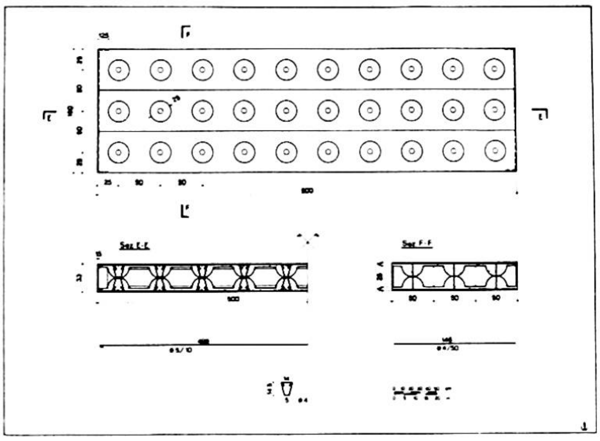

fig. 1

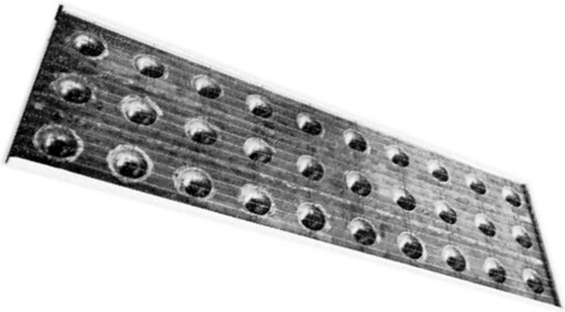

fig. 2

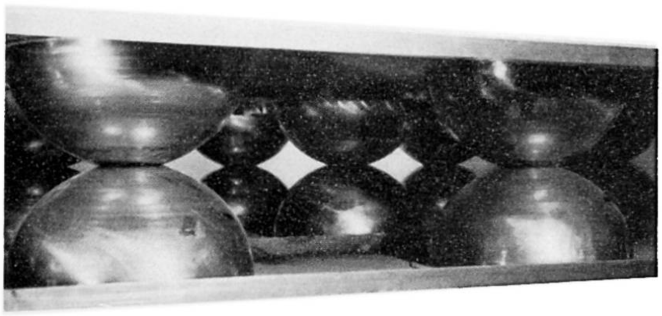

fig. 3

include the utilities (fig.3)

No ceiling is required and the panels are automatically fireproof.

This floor system is particularly suitable because of its twodimensional plate behavior. The drawings are hemispherical simply because dies of that shape were available, but clearly other shapes (for instance, truncated pyramids) should be more suitable.

A floor system with a span of 5 m x 1,50 m has been constructed and subjected to laboratory loads tests (fig. 4).

The loads transmitted by two jacks were distributed so as to achieve as far as possible a uniformly distributed load.

The elastic line due to service loads (fig. 5) and the load-deflection diagram (fig. 6) were plotted with care.

An analysis of the experimental data supplied the behavior of the floor system, which comprises three

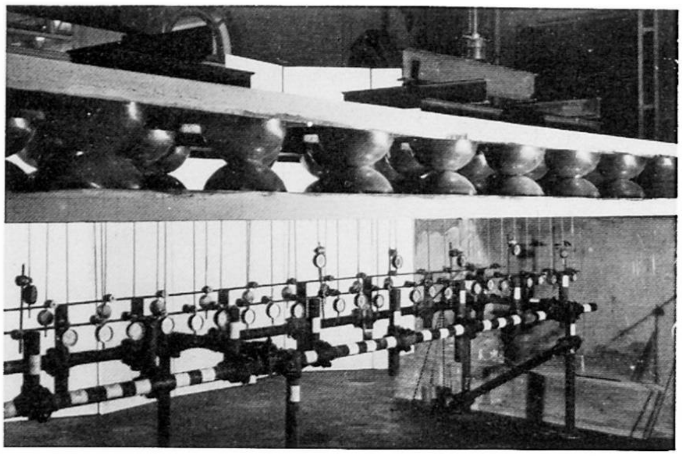

fig. 4

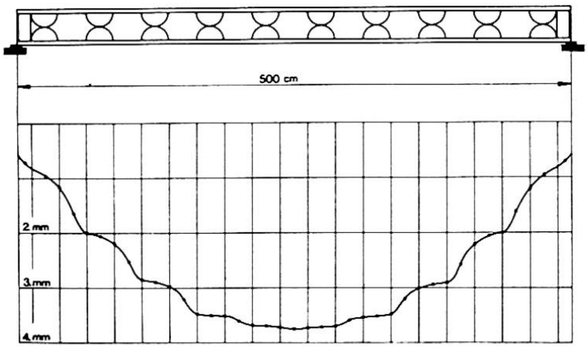

fig. 5

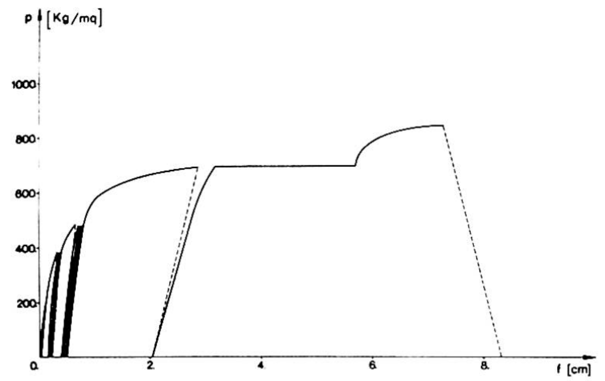

fig. 6

superposed static effects [4]:

a) flexural effect of the floor as a whole

b) shear effect of the floor

c) flexural effect of the top and bottom slabs

The incidence of the three effects may be expressed in the following percentages [5]:

$K_a = 53,5\%$ $K_b = 46,5\%$ $K_c = 0\%$

These values illustrate the importance of the shear effect of the floor. This is confirmed by the mode of failure of the floor.

Fig. 7 shows how failure occurred through piercing of the slab by the hemispherical cups in the zones near supports. Failure occurred at a load of 1.7 times the service load of 500 Kg/m^2.

It is important to emphasise that the behavior of the floor is of rigid plastic type: the initial deflection is little in absolute terms under service loads($f = \frac{L}{1500}$) whereas plastic adaptation under grea-

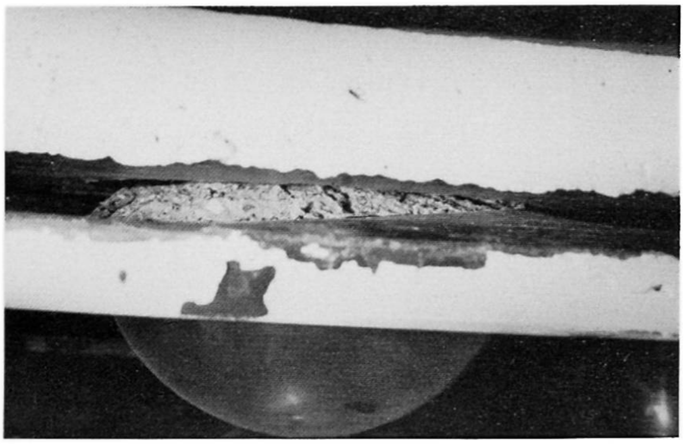

fig. 7

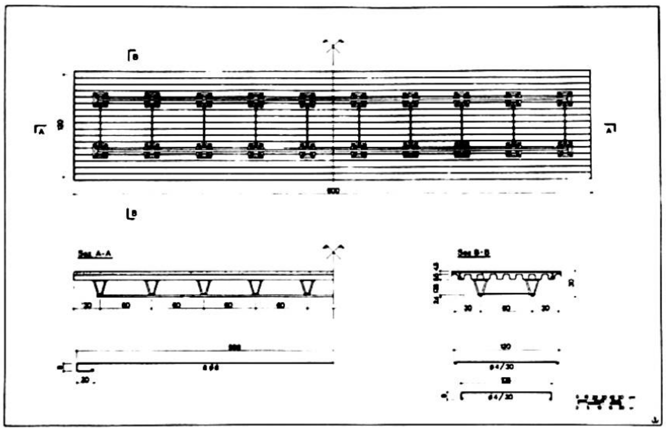

fig. 8

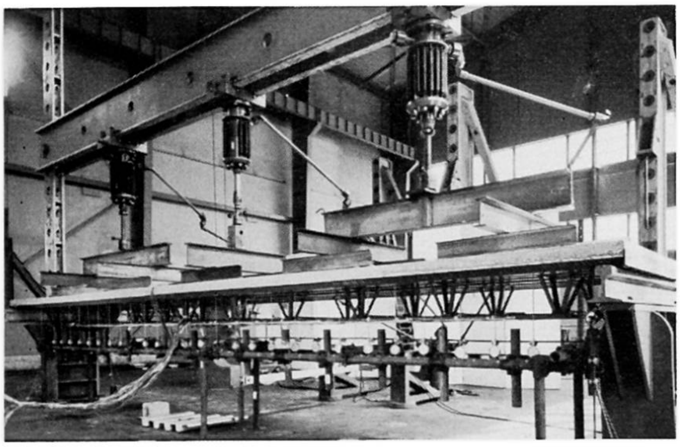

fig. 9

ter loads is considerable as proved by a ductility factor of 17. This, in the author's wiew, suggests that this type of floor system is particularly suitable for plate behavior where the redistribution of moments can favorably operate according to limit design methods.

For this reason experiments on a Drawn Floor System of 5 metres square are being arranged.

The second type of floor system that has been devised and tested (figs. 8 and 9) is an Open Type Floor System consisting of two plane parts with shear connectors between. The upper part is a cold-formed ribbed panel 1 mm thick with small drawings to act as shear connectors between the concrete casting and the steel sheet.

The total thickness of the composite slab ranges from 10 to 4.5 cm. On top there is a mesh of steel rods Ø 8 mm every 15 cm lengthwise and Ø 4 mm every 15 cm. crosswise.

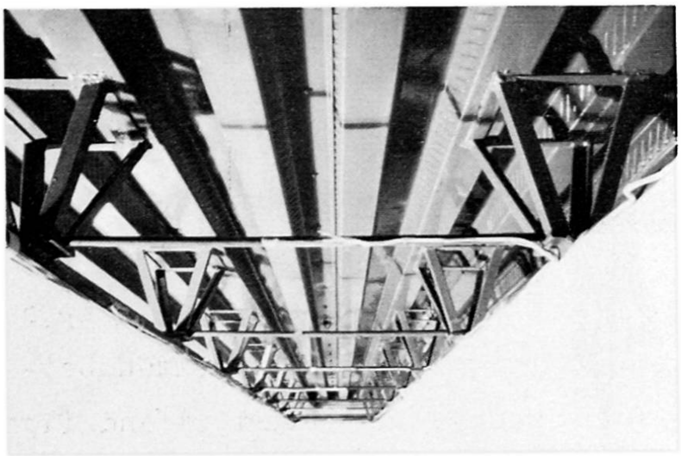

fig. 10

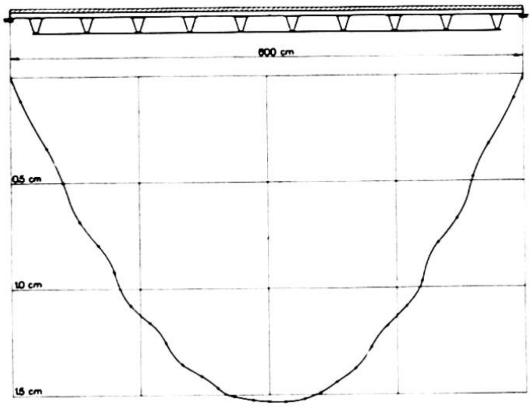

fig. 11

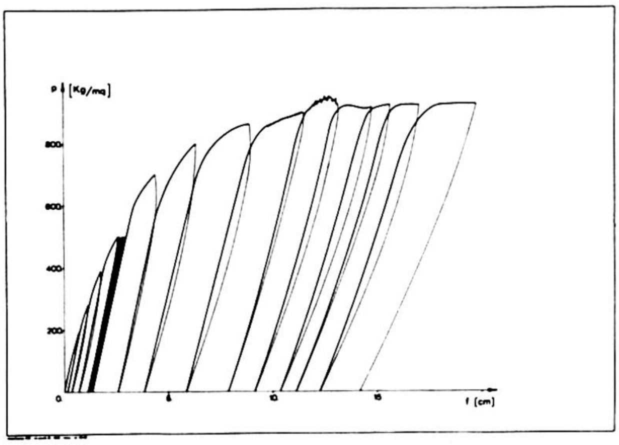

fig. 12

The lower part consists of a square mesh of steel rods Ø 24 mm lengthwise and Ø 12 mm crosswise.

The connexion elements are lattice, square-base pyramids with the apex located at the knots of the net forming the lower frame.

In this floor system, unlike the one previously described, the concrete was cast on the metal structure supported only at the ends, without need for propping at the other points.

A sample of this system with a span of 6 by 1.20 m (fig. 10) was tested. The loads applied simulated as closely as possible a uniformly distributed load. Here again the elastic line due the service loads (fig. 11) and the load-deflection diagram (fig. 12) were determined with care. The center line deflection and the load were recorded with displacement transducers and a dynamometer respectively, and plotted direct by an Hewlett Packard 7005 X,Y recorder.

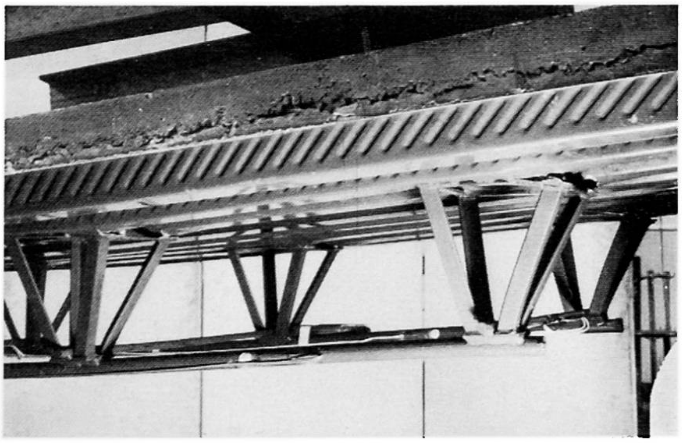

fig. 13

The behavior of the open type floor system is qualitatively similar to that of the drawn floor system but the performace is definitely superior, as is apparent from a comparison between figs. 5 and 11 and figs. 6 and 12.

In particular, the overall flexural static behavior and the effects due to shear and to upper layer work out as follows:

$$K_a = 61\% \qquad K_b = 24\% \qquad K_c = 15\%$$

Here again, the shear effect is important and its importance is confirmed by the mode of failure (fig. 13), which shows how collapse occurred through tearing of ribbed sheet away from the upper connexion of pyramids. However, the safety coefficient of the floor proved to be considerable (s = 1,95) and the deflection due to accidental service loads of 500 Kg/m^2 ($f = \frac{L}{420}$) were within quite normal limits.

For this latter floor system too the plastic adaptation was considerable: ductility factor = 7. It must be noted however that the collapse did not occur in the overall but the structure adapted herself to support a load a bit lower than the collapse one even after the crack of the connections of some pyramidal spacers from ribbed sheet. There are then good reasons for believing that also this floor system is suitable for plate behavior according to limit design methods. It must be admitted that the upper plate of mixed ribbed sheet and concrete is orthotropic and certainly more flexible and less resistant in the direction at right angles to the one tested. On the other hand, it is possible to gauge the most suitable diameter for the steel rods that constitute the bottom layer or even lay some in the diagonal direction where they would be used to best effect.

The weakest point, to wich future research must certainly be directed, is in this case too the point of connexion of the elements involved in shear effect to the slab. Before going on the further tests on floor systems it is intended to investigate this subject further, partly because on this point the problem is not only one statics but of technology and economics.

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SUMMARY

This contribution presents a study of two floor-systems using cold-rolled or cold-drawn steel sheets.

Exeperimental investigation were conducted on both floor-systems to determine the load-deflection diagram, elastic line and failure load. The results are reported and the principles of design and construction of the prototypes are outlined.

RÉSUMÉ

On présent une étude concernant deux prototypes des planchers réalisées avec tôle formée à froid. On a effectué des recherches expérimentales pour determiner la liaison entre la charge et la flèche, la ligne élastique et la charge limite.

On donne ici des renseignements sur les résultats de l'étude en soulignant les principes suivis dans le projet et la réalisation des prototypes.

ZUSAMMENFASSUNG

Dieser Bericht erläutert zwei Decken-Prototypen aus kaltgerollten oder -gereckten Stahlblechen. Experimentelle Versuche haben den Zusammenhang zwischen Belastung und Biegung einerseits sowie Biegelinie und Traglast gezeigt. Es werden die Ergebnisse, Entwurfsprinzipien sowie der Aufbau der Prototypen mitgeteilt.