

BUILDING DIGEST

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WAFFLE UNIT FLOOR/ROOF

Introduction

This digest describes a grid roofing/flooring scheme using precast open box-type units called 'waffle' units. Elimination of the structural deck concrete normally provided above the units and monolithic behaviour of the precast units along with the *insitu* grid beams are the salient features of the scheme. The method of casting the units, design and construction techniques, results of tests carried out on the floor assemblies and the advantages and economics of the scheme are explained.

The Unit

The units may be square or rectangular with sides being 90 - 120 cm and the depth varying according to the span of the roof/floor (Fig. 1). The flange thickness of the units is kept 3.5 in case of 90 cm and 4 cm in case of 120 cm units. Full details of a unit are shown in Fig. 3. A 90 cm square and 30 cm deep unit weighs 140 kg and can be handled by four men. However, a 120 cm square and 40 cm

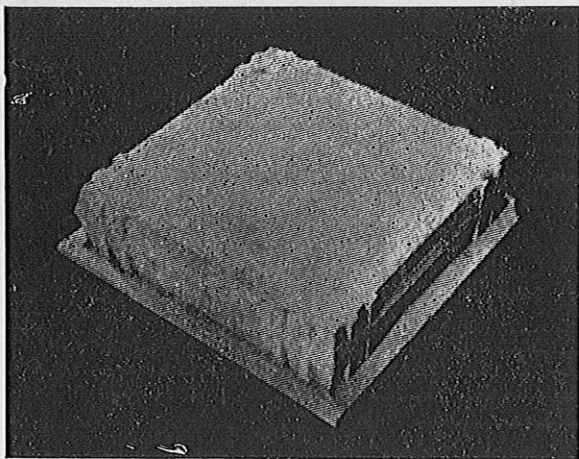


Fig. 1 Waffle unit

deep unit weighs 300 kg and requires light equipment for handling. The larger units are provided with hard-drawn steel wire fabric having 3.15 mm wires at 15 cm c/c in both directions in the flange portion only.

Method of Casting

The units may be cast in timber mould as shown in Fig. 2 and 6. The mould consists of an outer frame and an inner box. The units are cast upside down on a smooth platform over which three coats of a mixture of grease and kerosene oil is applied. The outer frame is assembled and concrete of grade M-150 with 10 mm and below aggregate is laid to the required flange thickness. Next, the inside box is fixed, the sides of the mould are filled with concrete and vibrated with the help of a plate vibrator. After

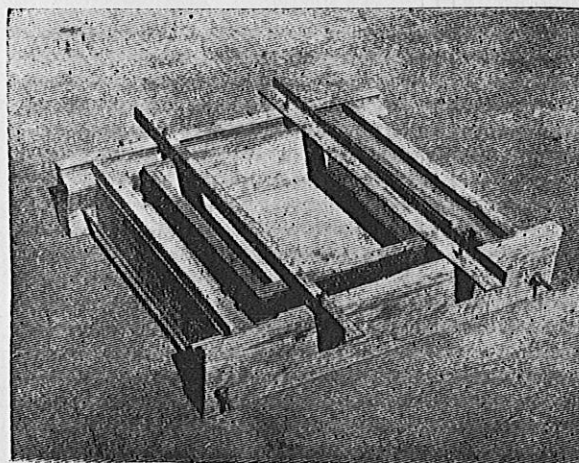


Fig. 2 Mould for waffle unit

about an hour or so, depending upon the weather conditions, the inside box is removed and the faces of the units are finished, where necessary. The next day i.e. twentyfour hours after casting, the outer frame with the unit is pushed slightly to break the bond between the platform and the cast unit. The frame is then dismantled and the unit is subjected to water-curing for 14 days and air-curing for another week before using it in the construction.

Floor/Roof Assembly

After the structure for supporting the grid floor viz. walls/beam is ready, shuttering in strips of 20 cm width is placed in one direction only at a spacing equal to the nominal size of the units. The

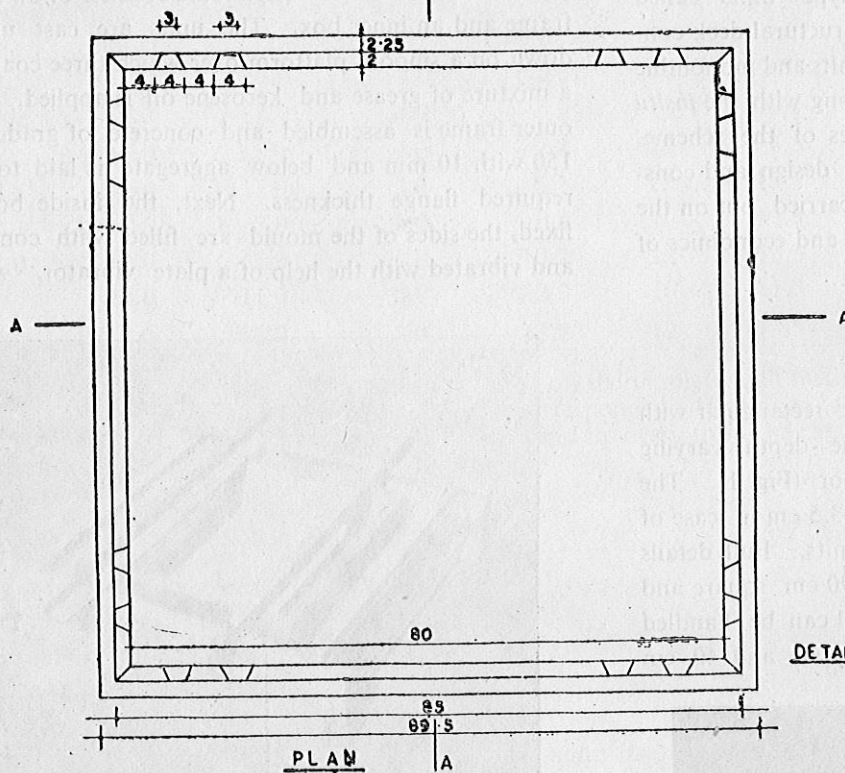
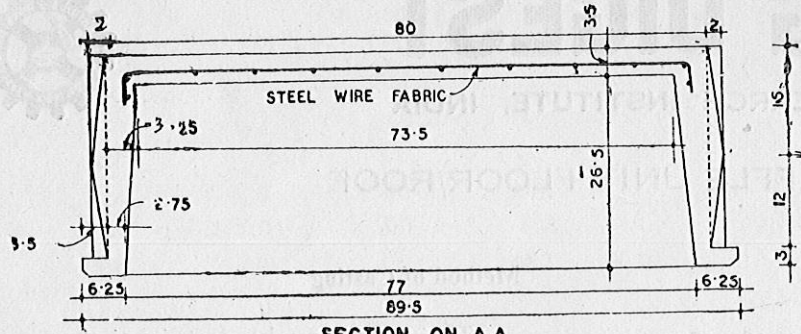


Fig. 3
DETAILS OF WAFFLE UNITS

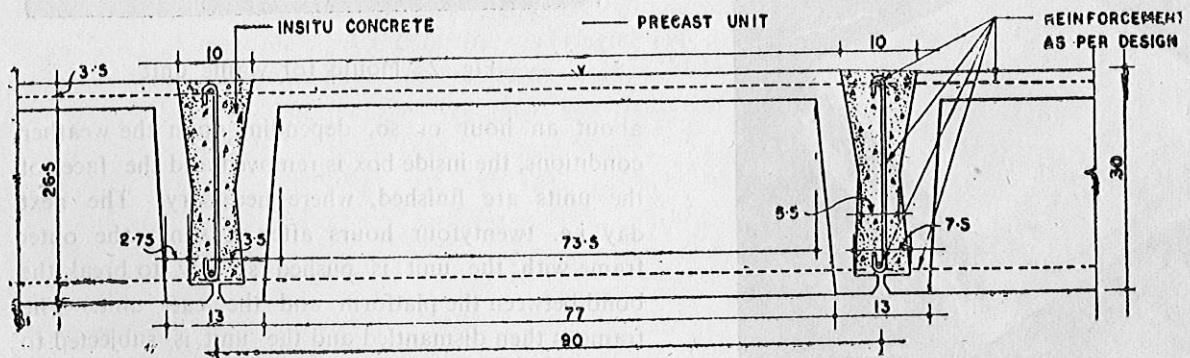


Fig. 4 Section of floor with waffle units

units are arranged over the shuttering in both the directions. Reinforcement, as per design, is provided in the joint between the units and *insitu* concrete is laid upto top level of unit and compacted with a needle vibrator. The *insitu* grid beams are subjected to water-curing for two weeks and the shuttering is struck off after a week or so when the concrete has attained sufficient strength. The cross-sectional details of the floor/roof assembly are shown in Fig. 4. The joint between the units in the ceiling (Fig. 5) is finished by pointing with cement mortar, with a V-groove left between the units. The flooring/weather proof course may be laid above the precast units as is done in the case of traditional construction.



Fig. 5 Ceiling of waffle unit roof

Design

The grid slabs may be analysed by any of the methods of analysis for two-way slabs. The section near mid-span is designed as a Tee section with flanges of the precast units taking compression and the main reinforcement at the bottom in the *insitu* concrete between the units taking the tension. The support section may be designed as doubly-reinforced rectangular beam. The width of the beam may be taken as the thickness of *insitu* concrete plus the thickness of the two precast webs.

Tests

The individual units and the floor assemblies were subjected to load testing of structures as per IS:456-1964 and were found to pass the tests. The floor assembly also withstood the ultimate load specified in the code for which the floor was designed. From

the pattern of cracks developed, it can be said that under ultimate load, the behaviour of the waffle floor is in conformity with the yield-line theory for slabs. Under impact load no damage was observed when 25 kg sand bags were dropped from a height of 1.2 metres.

Advantages of the Scheme

In the case of slabs of large spans, the cost of shuttering may work out to be one-third or even more of the total cost of a slab. Most of the shuttering is eliminated in this scheme, only small strips and centering by props are required. The salient feature of the scheme is that the deck concrete, normally provided above the units in similar schemes in practice, is eliminated as the units are so made that they act monolithically with *insitu* cast beams. Also, the shape of the units has been so worked out that the precast portion acts along with the *insitu* concrete in the joints and ensures load transfer. The horizontal shear keys ensure the vertical transfer of load. The vertical ribs transfer the horizontal stresses from the unit to the beam and prevent the longitudinal separation of the unit from the *insitu* concrete. In this scheme, the loads are distributed on all the four walls or beams on the periphery and hence there is uniform distribution of load. The scheme is economical for two-way spanning slabs of span 6 m and above.

Economics

A comparison of the cost and materials required for the precast waffle unit scheme with those of the traditional Tee beam and slab construction for a roof slab 9.6 m square in size is given in Table 1. The grid spacing has been taken as 1.2 m and the units are 45 cm deep. In both the cases, the design was based on ultimate load theory using deformed bars as the main reinforcement.

Table 1

Comparison of Precast Waffle Unit Scheme with Tee Beam and Slab Construction for a Two-Way Spanning Slab of Large Size

Item	Tee Beam and Slab Construction	Waffle Unit	
	Quantity	Quantity	Saving (%)
Cement (kg/m ²)	49.5	41.5	15
Steel (kg/m ²)	8.8	7.7	10
Cost (Rs./m ²)	48.5	40.5	15

