Reprinted from "The Indian Concrete Journal", August 1973

Design of concrete floors in factory buildings

S. M. K. Chetty, S. P. Srivastava, Surinder Singh

The paper aims at providing guidelines for the design and construction of concrete floors for industrial buildings, and includes ready-to-use design charts and tables. It discusses also topics such as the effect of sub-base on the floor, the type of joints and their functional requirements, the use of precast slab units, etc.

With the progress of industrialisation in the country, the expenditure incurred on industrial buildings is considerable both in the public and the private sectors. While a great deal of study has been done to find ways and means of reducing the cost of construction of the superstructure, only a limited amount of research has been carried out on floors. No specification for the design of concrete floors in factory buildings is included in the Indian Standard Code of Practice for Plain and Reinforced Concrete, IS : 456–1964.

While examining various avenues for effecting economy in the construction of factory buildings in public sector undertakings, the Bureau of Public Enterprises of the Ministry of Finance, Government of India, collected information from several undertakings with regard to the specifications adopted for factory floorings and the costs thereof under different loading conditions, bearing capacities of the soil under the floors, type and nature of traffic that the floors were subjected to, and the performance of the flooring. The data collected revealed that there was wide variation in specifications and costs for similar conditions of loading and subgrade, thereby indicating the need for evolving a rational procedure for the design of factory floors. At the suggestion of the Bureau, a study was carried out in the Central Building Research Institute, Roorkee, and a procedure for the design of floors was evolved.

Components and the classification of floors

Concrete floor in a factory building is generally made up of three parts, namely, the topping or the wearing course, the base and the sub-base, as shown in *Fig* 1. The function of each of these components is quite distinct and separate. The topping or the wearing course provides a surface which can resist the abrasion and such other effects of the loads. The base acts as a structural member. The sub-base on the one hand provides better drainage, and, on the other, acts as a cushion to distribute the load evenly on the subgrade and to spread it over a larger area. The functional requirements of topping and sub-base are such that no specific design procedure can be evolved for them. They are, therefore, governed by general experience and practice, while the base slab is designed on the basis of the load it is subjected to.

Factory floors can be classified into three broad categories as shown in *Table* 1 depending upon the intended use. In floors of type A and B indicated in *Table* 1, which are subjected to less abrasion, concrete in the base slab and the topping should be laid monolithically. In floors of type C in which the abrasion is severe, the base slab and the topping are laid separately with proper bond. Other relevant information concerning construction technique, the minimum thickness of base course, topping, etc is also given in *Table* 1.

Design of the base slab

When a vehicle moves over the surface of a concrete base, it produces stresses of varying magnitude depending on the position of the load on the floor panel. Three conditions of loading are considered while designing slabs, namely corner loading, edge loading, and interior loading, which may produce maximum stress in the top and bottom fibres of the base. In general, corner and edge loading conditions are the most critical, and they tend to govern the design. However, it may be noted, that a floor designed for these conditions would be very expensive. By providing suitable load transfer joints between different bays, the load can be distributed from the edges or corners of one bay to another. When this is done, the thickness of floor can be designed economically based on the interior loading condition. The stress in slab due to interior loading condition is given by the relation[1]

$$\sigma_t = 0\cdot316\,\frac{P}{h^2}\left[\log_{10} E + \log_{10}\frac{h^3}{k'b^4} - 0\cdot89\right]\,..(1)$$

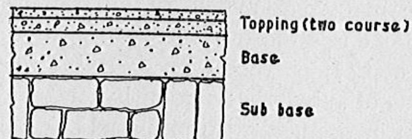


Fig 1 Component parts of a concrete floor

Dr S. M. K. Chetty, Deputy Director and Head of the Building Processes, Plants and Productivity Division, Central Building Research Institute, Roorkee
Dr S. P. Srivastava, Scientist, Central Building Research Institute, Roorkee
Surinder Singh, Scientist, Central Building Research Institute, Roorkee

TABLE 1 Classification of floors

Type	*Use*	*Usual traffic*	*Floor details*	*Minimum thickness*	*Remarks*
A	Light industrial	Foot and pneumatic wheels	Two-course integral topping	Base course (1 : 3 : 6) 12cm topping (1 : 2 : 4) 4cm	Finish of top surface: steel trowel the surface and finish with stiff brush to prevent slipping
B	Medium industrial	Foot and wheels abrasive wear	Two-course integral topping	As per *Figs* 3 to 7 or *Tables* 4 and 5 with minimum base course (1 : 3 : 6) 15cm topping (1 : 2 : 4) 5cm	(*i*) Finish of top surface: steel trowel the surface and finish with stiff brush to prevent slipping (*ii*) For topping use specially hard aggregate
C	Heavy industrial	Foot and steel-tyred vehicles — severe abrasion	Bonded two-course when mineral or metallic surface treatment is given, otherwise two-course integral topping	As per *Figs* 3 to 7 or *Tables* 4 and 5 with minimum base course (1 : 2 : 4) 15cm topping (1 : 1 : 2) 5cm with special aggregate	(*i*) Base — textured surface and bond (*ii*) Topping — special aggregate and/or mineral or metallic surface treatment

where σ_t = allowable tensile stress in concrete
P = the maximum wheel load
h = thickness of the slab
E = modulus of elasticity of concrete
k' = effective modulus of subgrade reaction
b = the equivalent radius of contact of the wheel load

In equation (1), the three factors, allowable tensile stress in concrete, effective modulus of subgrade reaction and the equivalent radius of contact of the wheel load, require some explanation, and they are discussed below.

Allowable tensile stress in concrete : The thickness of the floor is governed by the allowable tensile stress of concrete. For normal concrete, the modulus of rupture is about one-fifth to one-sixth of its compressive strength at 28 days. Typical values of the modulus of rupture at the age of 28 days for concrete used in flooring is given in *Table* 2. It is commonly assumed that plain concrete can be subjected to flexural stress almost indefinitely as long as the extreme fibre stress is less than 50 per cent of the modulus of rupture. Hence the allowable tensile stress is taken as 50 per cent of the modulus of rupture.

Effective modulus of subgrade reaction : The effective modulus of subgrade reaction k' of any soil is the pressure exerted by the subgrade and the sub-base jointly on the base. Since the modulus of subgrade reaction depends on many parameters, it is difficult to evolve any analytical relationship correlating all these parameters with it. It is, therefore, desirable to determine the modulus of subgrade reaction by means of a plate-bearing test in the field with proposed sub-base in position. The usual procedure for conducting a plate-bearing test is to record the settlements of a 75-cm diameter plate for different loads. The slope or secant modulus of the pressure-settlement curve taken at the first 1-mm settlement gives the effective modulus of subgrade reaction.

TABLE 2 Modulus of rupture of concrete

Compressive strength, kg/cm²	*Modulus of rupture,* kg/cm²	*Ratio of modulus of rupture to compressive strength,* per cent
100	20	20·0
150	27	18·0
200	33	16·5
250	39	15·5
300	43	14·5
350	47	13·5

In case it is not possible to carry out the field test, the average value of the modulus of subgrade reaction k may be chosen from *Fig* 2, depending on the nature of the subgrade or its CBR value. For properly compacted filled-up soil the value of k is taken as 3 kg/cm³. Due to the presence of sub-base, the modulus of subgrade reaction gets further modified. The effective modulus of subgrade reaction k' can be obtained by multiplying the value of k, *Fig* 2, with the value of α given in *Table* 3 for different specifications of sub-base commonly adopted in practice. The values of α are based on tests conducted at the Central Building Research Institute.

Equivalent radius of contact : The following procedure is adopted to determine the equivalent radius of contact of the wheel load[1,2]. If P is the load per wheel and p the type pressure, then the area of contact $A = \frac{P}{p}$.

In the case of dual wheels, the total area of contact

TABLE 3 Effective modulus of sub-grade reaction, $k' = \alpha k$

α is a constant which depends upon the specification of the sub-base, its value for different specifications being given below, and k is the modulus of subgrade reaction for filled up soil, which may be taken as 3 kg/cm³

Type	Sub base specifications	Factor α
1	Brick soling	1·54
2	Stone ballast	1·33
3	Rubble packing	1·36
4	Lean concrete	3·00
5	Lean concrete over brick soling	3·93
6	Lean concrete over stone ballast	3·56
7	Lean concrete over rubble packing	3·61
8	Water bound macadam over brick soling	2·10
9	Water bound macadam over stone ballast	1·83
10	Water bound macadam over rubble packing	1·87

A = area of contact of two wheels plus the space between them.

The actual dimensions of imprints of tyres are found from the following relations :

$$\text{length of imprint} = \sqrt{\frac{\text{area of contact of one wheel}}{0\cdot523}}$$

$$\text{width of imprint} = 0\cdot6 \times \text{length of imprint}$$

area of space between two wheels = (centre to centre spacing — width of imprint) × length of imprint.

By knowing the total area A, the radius a of an equivalent circular area over which the load is considered to be uniformly applied is found. If h is the thickness of floor, then the equivalent radius of contact in cm is given by

$$b = \sqrt{1\cdot6\,a^2 + h^2} - 0\cdot675\,h,$$

when a is less than $1\cdot724\,h$

or, $= a$, when a is greater than $1\cdot724\,h$.

Design chart for wheel loads

If the maximum wheel load which is expected on the floor, its area of contact and the effective modulus of subgrade reaction are known, equation (1) can be used to determine the thickness. Since equation (1) is of a form making its direct solution difficult, design charts *Figs* 3 to 7 have been prepared to enable the thickness of floor to be determined. The use of the charts is self-explanatory, and it is further illustrated by an example given in the appendix. In case the value of k' or the area of contact is such that it cannot be read directly from the chart, linear interpolation can be done between the plotted values.

Since the design charts are for the interior loading condition, it is necessary that there should be continuity in the adjoining panels. The continuity can be achieved by the use of proper load transfer devices which are described. If proper load transfer device is not provided, the slab may fail due to corner or edge loading conditions. It is found that an increase of 50 per cent in the design

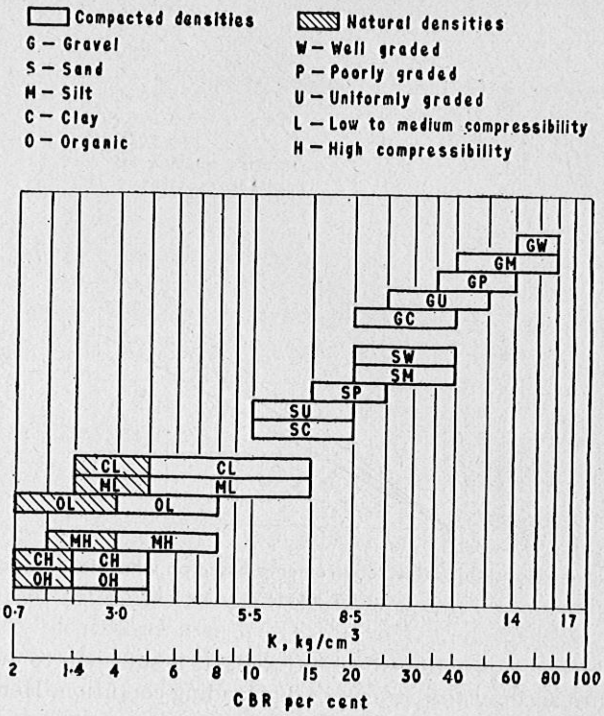


Fig 2 Interrelationship of soil classifications and strength criteria

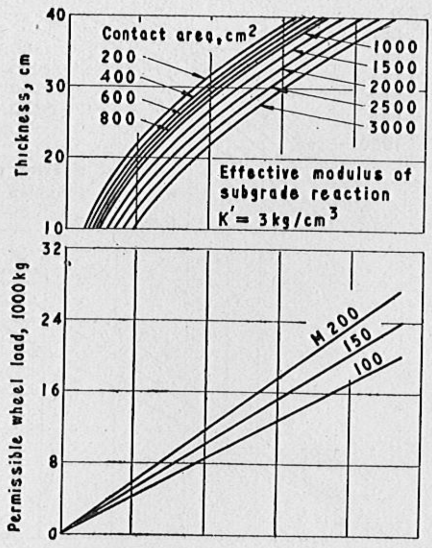


Fig 3 Floor thickness requirements based on wheel-load, contact area and concrete strength (k'= 3 kg/cm³)

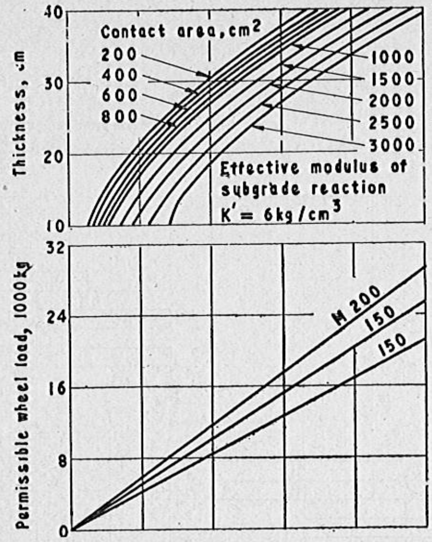


Fig 4 Floor thickness requirements based on wheel-load, contact area and concrete strength ($k' = 6$ kg/cm³)

thickness as obtained from the charts is sufficient to take into account the corner or edge loading condition. Hence it is recommended that where no load transfer device is provided the thickness of the slab should be increased by 50 per cent as shown in *Fig* 8. For ease of construction, the extra thickness may have to be provided throughout the span. This would, however, make the base slab uneconomical. It is, therefore, advisable to provide suitable load transfer devices at all joints.

Design tables for permissible intensity of loading

A survey of the loading data collected by the Bureau showed that often it was not possible to predetermine the design wheel load and its area of contact. In some of the industries, the design of the floor is governed by uniformly distributed load which may occur due to stacking of material. If the complete slab is loaded with a uniform intensity of pressure, theoretically no bending will take place, and the thickness of slab will be independent of the intensity of loading. Hence the slab

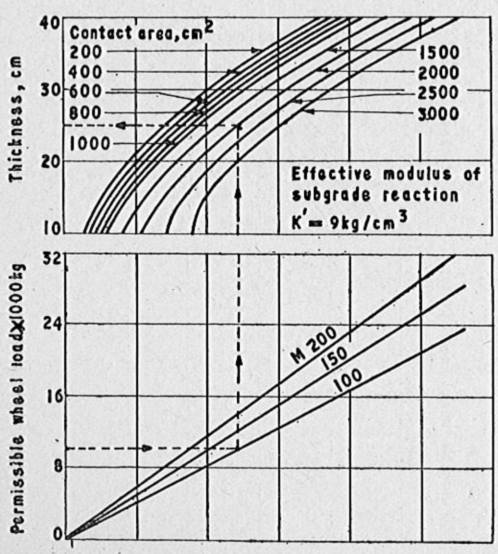


Fig 5 Floor thickness requirements based on wheel-load, contact area and concrete strength ($k' = 9$ kg/cm³)

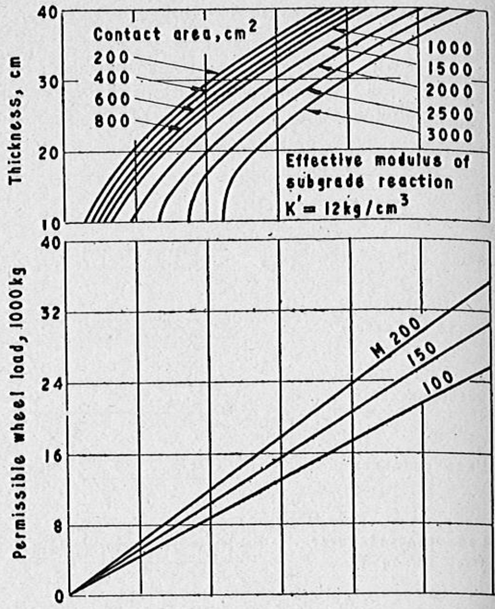


Fig 6 Floor thickness requirements based on wheel-load, contact area and concrete strength ($k' = 12$ kg/cm³)

will be designed for partially loaded condition with load on the optimum area of contact which produces the maximum bending moment. The optimum area of contact can be determined as follows.

Let A be the area of contact and p the intensity of loading. Then equation (1) can be rewritten as

$$\sigma_t = 0\cdot316 \frac{pA}{h^2}\left[\log_{10}\frac{Eh^3}{k'\,b^4} - 0\cdot89\right] \quad \ldots\ldots\ldots(2)$$

Also, $b^4 = (\sqrt{(1\cdot6\,a^2 + h^2)} - 0\cdot675\,h)^4$ when a is less than $1\cdot724\,h$

$$= \left(\sqrt{\left(1\cdot6\,\frac{A}{\pi} + h^2\right)} - 0\cdot675\,h\right)^4 \quad \ldots\ldots(3a)$$

or, $b^4 = a^4$, when a is greater than $1\cdot724\,h$

$$= \frac{A^2}{\pi^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3b)$$

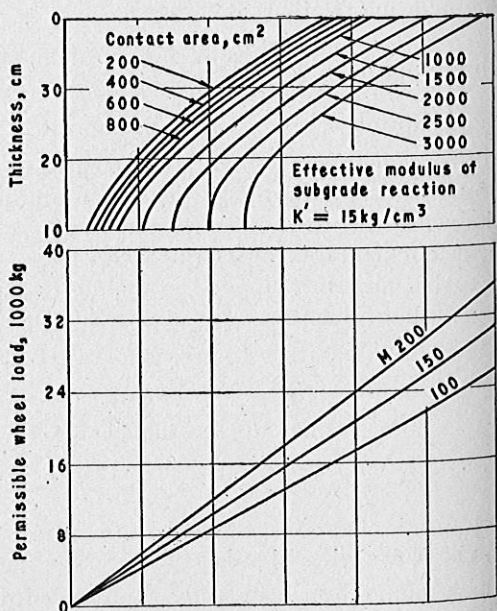


Fig 7 Floor thickness requirements based on wheel-load, contact area and concrete strength ($k' = 15$ kg/cm³)

Assuming that $a > 1\cdot724\ h$, substituting for b^4 in equation (2) and replacing $0\cdot89$ by $\log_{10}7\cdot762$,

$$\frac{\sigma_t}{p} = \frac{0\cdot316\,A}{h^2}\left[\log_{10}\frac{\pi^2 E h^3}{7\cdot762\,k' A^2}\right]$$

$$= \frac{A}{7\cdot35\,h^2}\left[\log_e \frac{\pi^2 E\,h^3}{7\cdot762\,k' A^2}\right] \quad \ldots\ldots\ldots\ldots\ldots(4)$$

Differentiating with respect to A, and

putting $\dfrac{d\left(\frac{\sigma_t}{p}\right)}{d_A} = 0,$

$$\log_e \frac{\pi^2 E\,h^3}{7\cdot762\,k' A^2} = 2 \text{ or, } \log_{10}\frac{\pi^2 E\,h^3}{7\cdot762\,k' A^2} = 0\cdot8684 \quad ..(5)$$

Therefore, $A = 0\cdot4149\sqrt{\dfrac{E\,h^3}{k'}}$ ....(6)

Thus A is the optimum area of contact which will produce the maximum moment. It may be noted that for a given thickness and subgrade modulus, the optimum area of contact is unique. The design thickness of slab for a given intensity of loading can be determined by using the values from equations (5) and (6) in equation (4).

Then $\dfrac{\sigma_t}{p} = 0\cdot1201\sqrt{\dfrac{E}{k'\,h}}$ ....(7)

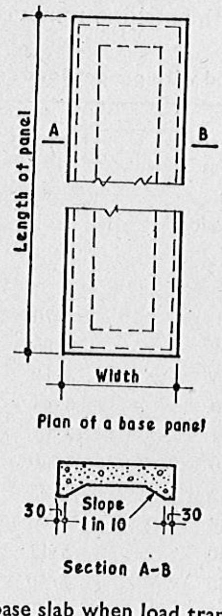
or $p = \sqrt{\dfrac{k'\,h}{E}}\ \delta_t\ \dfrac{1}{0\cdot1201}$

σ_t, kg/cm² $= 1\cdot04\sqrt{\sigma cu}$

and $\sqrt{E} = \sqrt{10^3\,\sigma cu}$

Hence p, kg/cm² $= 0\cdot26\sqrt{kh}$ ....(8)

Hence, if intensity of loading and the modulus of subgrade reaction are known, the thickness of slab can be determined. It is interesting to note that the thickness of slab is independent of the quality of concrete, for a given intensity of loading. However, the area of contact, corresponding to optimum intensity of loading, as given in equation (6), is not independent of the quality of concrete. A plot showing $\frac{\sigma_t}{p}$ versus area of contact, *Fig* 9, indicates that for a particular quality of concrete, the critical area of contact increases with thickness of slab.



8 Thickening of base slab when load transfer devices are not provided

Tables 4 and 5 which are based on equation (8) give the permissible intensity of pressure on a slab of given thickness resting on a subgrade with sub-base having known effective modulus of subgrade reaction for the two cases: when the load transfer devices are not provided and when they are provided.

Effect of impact

In the case of a flooring with a perfectly levelled surface, the passage of wheels will be smooth and there will be no impact effect to cause additional stresses[3,4]. In practice, however, irregularities do occur due to imperfections in workmanship or other causes. Studies made on pavements have revealed that impact at construction joints is not greater than at any other place provided the joints are properly constructed. The impact allowance that may be applied as an increased percentage in the static loads is specified as follows:

	Impact allowance
(*i*) in the case where transverse joints are adequately dowelled or are provided with other effective load transfer devices	nil
(*ii*) in the absence of load transfer devices	25 per cent

If the slab is not designed for wheel loading and is mostly subjected to static loads only, there is no need to make any impact allowance. In the case of flooring subjected to regular and repetitive loads due to loading and unloading of factory material, a certain allowance should be made for impact depending upon the use. As no experimental data are available to establish the exact impact factor in such cases, it may be taken as varying between 0 to 25 per cent of the static load. If the impounding load is restricted to a particular area of the floor it is recommended that such portions alone may be adequately strengthened with reinforcement.

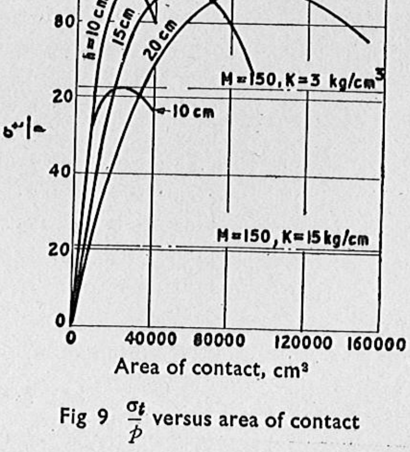


Fig 9 $\frac{\sigma_t}{p}$ versus area of contact

TABLE 4 Permissible intensity of load in kg/cm² (where the slab is provided with proper load transfer device)

Subgrade modulus k, kg/cm³	*3*	*6*	*9*	*12*	*15*	*20*
Thickness, h, of the slab, cm			*Permissible intensity of load,* kg/cm²			
10	1·48	2·07	2·56	2·96	3·30	3·81
12	1·62	2·28	2·80	3·24	3·61	4·19
14	1·75	2·46	3·03	3·50	3·90	4·55
16	1·87	2·64	3·24	3·74	4·18	4·82
18	1·98	2·79	3·42	3·96	4·42	5·10
20	2·09	2·95	3·61	4·18	4·65	5·40
25	2·34	3·29	4·05	4·68	5·20	6·01
30	2·55	3·60	4·41	5·10	5·70	6·60
35	2·81	3·95	4·87	5·62	6·29	7·25
40	2·96	4·19	5·13	5·92	6·60	7·65
50	3·31	4·70	5·72	6·62	7·41	8·55

Joints — location and design

From practical considerations the width of the base is generally kept at 4 to 5m. Concrete flooring can, however, be laid in long stretches lengthwise, say in lengths of 25 to 30m between expansion joints. In between control joints should be provided in such a way that the resulting panels are approximately square. The various types of joints normally used in factory floors are shown in *Fig* 10 and are discussed below.

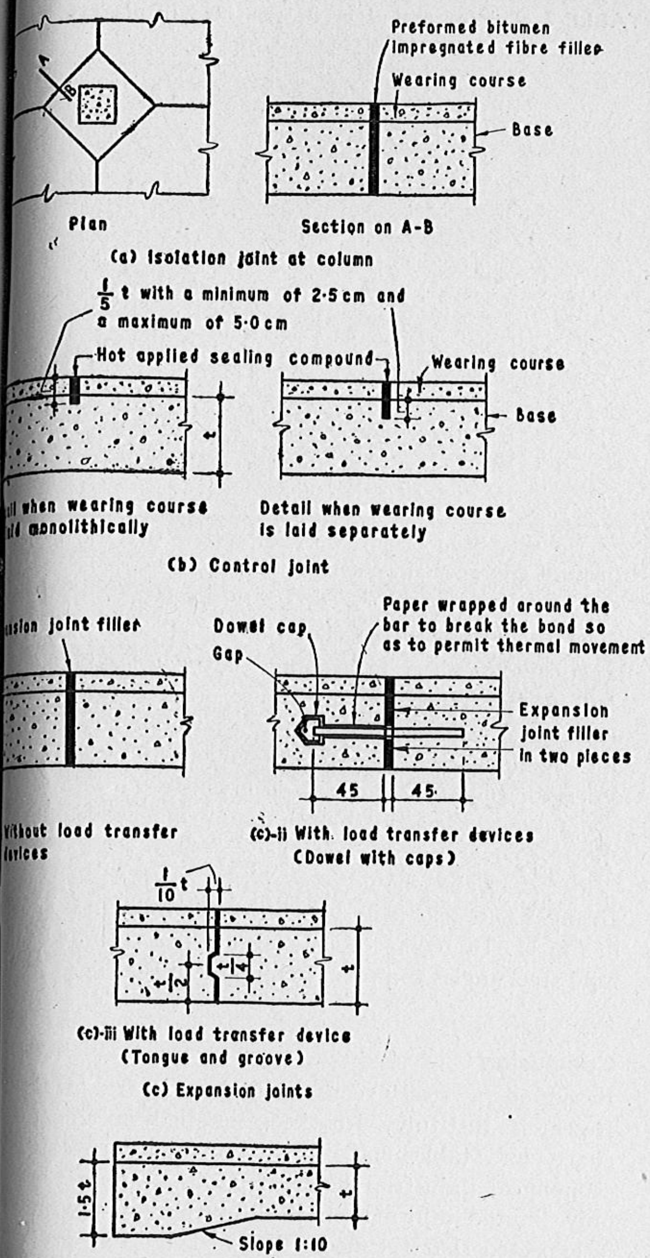
Isolation joints : These joints, *Fig* 10(a), are used where the flooring has to be separated structurally from the other building elements in order to allow for differential horizontal and vertical movements. Isolation joints must be used at junctions with walls, columns, machine foundations and footings or other points of restraint. These joints are filled up with preformed bitumen impregnated fibres conforming with the Indian Standard Specification for Preformed Fillers for Expansion Joints in Concrete — Non-extruding and Resilient Type, IS : 1838-1961. The joint fillers may be of the required height to serve as screeds during concreting operations.

Control joints : Control joints, *Fig* 10(b), are provided for accommodating differential movements in the plane of the slab caused by drying shrinkage and thermal gradient across the thickness. These joints are spaced at 5 to 6m intervals and are formed by providing a continuous dummy groove or saw cut in the top portion of the base. The groove reduces the slab thickness just sufficiently to allow the formation of cracks within it. If the joints are sawed, the depth of the saw cut should not be less than the diameter of the largest size coarse aggregate. Otherwise, the cracks may go around pieces of large aggregate near the pavement surface instead of following the saw cut. The result may be unsightly spalls in warm weather when the concrete is expanding and is in compression. The width of the groove is 8 to 10mm, and depth one-fifth of the thickness of slab with a minimum of 2·5cm and maximum of 5cm. The depth should be measured from the top of the wearing course in case it is laid monolithically and from the top of the base when the wearing course is laid separately.

Control joints may be formed either by sawing or by pressing a T-section of mild steel while the concrete is still in the plastic state. Alternatively, it can also be formed by inserting a metallic strip into the slab during the concreting operations. After the concrete has sufficiently hardened, the strip is removed, taking care not

TABLE 5 Permissible intensity of load in kg/cm² (where the slab is not provided with proper load transfer device)

Subgrade modulus k, kg/cm³	*3*	*6*	*9*	*12*	*15*	*20*
Thickness h of the slab, cm			*Permissible intensity of load,* kg/cm²			
10	1·21	1·69	2·10	2·41	2·70	3·11
12	1·32	1·86	2·28	2·64	2·95	3·41
14	1·43	2·01	2·47	2·85	3·19	3·71
16	1·53	2·15	2·64	3·05	3·41	3·95
18	1·62	2·27	2·80	3·24	3·61	4·16
20	1·70	2·40	2·95	3·40	3·80	5·41
25	1·91	2·69	3·30	3·82	4·25	4·91
30	2·08	2·94	3·60	4·16	4·65	5·40
35	2·30	3·22	3·97	4·60	5·11	5·91
40	2·41	3·41	4·20	4·85	5·40	6·24
50	2·71	3·84	4·69	5·41	6·09	6·72



(d) Thickening of base slab at the entrance

Fig 10 Joints and load transfer devices

o break the edges of the newly formed gap. These joints re filled with hot-applied sealing compounds complying ith the Indian Standard Specification for Hot-applied ealing Compounds for Joints in Concrete, IS : 1834–961.

xpansion joints : These joints, *Fig* 10(c), are meant to ccommodate the expansion and hence are provided ith a clear gap for the full depth between adjacent abs. They are spaced at intervals of 25 to 30m along e length and are filled with expansion joint filler which compressible enough to accommodate the expansion adjacent parts. Preformed bitumen impregnated fibre er complying with the Indian Standard specification, : 1838–1961, may be used for this purpose.

Expansion joints may be of different types with or thout load transfer devices. Expansion joint without ad transfer device is shown in *Fig* 10(c)-*i*.

Load transfer devices : To achieve the transfer of load from one panel to the other at the expansion joint, dowels with caps are provided as shown in *Fig* 10(c)-*ii*. There are many references which deal with the detailed design of dowel bars[1,2,5]. The design is based on the assumption that the dowel acts as a cantilever. The bending stress of dowel or the bearing stress of concrete, whichever is greater, governs the size of the dowel bar. *Table* 6 gives the length, diameter and spacing of dowel bars for different thicknesses of the concrete base. An alternate method of load transfer device is the tongue and groove joint shown in *Fig* 10(c)-*iii*.

As load transfer device cannot be provided at the entrance, the thickness of the base slab may be locally increased by 50 per cent as shown in *Fig* 10(d). This, however, need not be done where the thickness of the base slab has already been augmented due to non-provision of load transfer device as stated earlier.

TABLE 6 Size and spacing of dowel bars for different thicknesses of concrete base

Base thickness, cm	10	15	20	25	30	35	40
Dowel diameter, mm	12	12	12	12	20	20	20
Spacing, cm	45	45	37·5	30	45	37·5	30

Note : length of dowel = 45cm on either side.

To make the slab continuous transversely, dowels can be provided as indicated in *Table* 6. However, dowel caps need not be provided in this case as sufficient space will be available for expansion due to shrinkage of the concrete. In all types of joints, the edges should be made round with the help of an edging tool after the concrete has been laid, and levelled and finished in order to avoid any damage at these locations.

Reinforcement

In locations where cracking due to temperature and shrinkage stresses are to be controlled, it is desirable to provide reinforcement. Also, where there is likelihood of appreciable bulking of the subgrade due to fluctuations in water-table, reinforcement must be provided as this helps to transfer the load evenly over the subgrade.

The amount of reinforcement to be provided depends upon the coefficient of friction at the interface of base and sub-base, the length of the panel and the weight of the slab. It is inversely proportional to the permissible tensile stress. Taking into considerations these factors, the percentage cross-sectional area A_s of the steel required is given by the formulae :

(*i*) $A_s = 0{\cdot}0020L$ per cent for plain mild steel bars

(*ii*) $A_s = 0{\cdot}0013L$ per cent for high strength deformed bars

being the length of panel in metres between expansion joints where provision has been made for movement of the panel.

The same steel is provided along the width as well. In either case there should be a minimum of 6mm bars at 20cm centres. Instead of mild steel bars it will be advantageous to use welded mesh reinforcement as the latter can be easily spread over green concrete, thus avoiding the time and labour involved in tying mild steel bars.

The reinforcement should be placed at a depth of 5cm from the top surface of the wearing course when it is laid monolithically and from the top of base course when wearing course is laid separately. It should be kept continuous through the control joints.

Use of precast reinforced concrete slabs

Where deep excavations have been made for machine and column foundations, particular care should be taken to back-fill in layers and to compact each layer to the maximum density. Use of pneumatic tampers would be of help in obtaining greater compaction than by manual methods. In spite of these precautions settlements may still occur; in such locations therefore, as well as in locations where proper compaction cannot be quickly obtained, precast reinforced concrete slabs should be used. The use of precast slabs is also recommended when the lay-out for machine foundations has not yet been decided, or changes in lay-out are likely in future. The following suggestions are made with regard to the size and the thickness of the precast slab and the reinforcement to be used:

(*i*) the thickness of the base slab may be designed in accordance with the procedure already indicated for in situ concrete slab without load transfer device

(*ii*) if the designed thickness is 15cm or less, the size of the precast unit should be equal to 80cm × 80cm × 10cm; for thickness between 15cm and 25cm, a size of 60cm × 60cm × 15cm is recommended.

These sizes are convenient for manual handling. Where the designed thickness is greater than 25cm, the quantity of steel required is quite high and there are practical difficulties in accommodating this amount of steel in the slab. Hence the use of precast slabs corresponding to a designed thickness greater than 25cm is not recommended. The reinforcement for the various designed thicknesses of slab is given in *Table* 7. It is preferable to use welded mesh reinforcement keeping an effective cover of 2cm.

Precast slabs should invariably be provided with arrangements for lifting. A typical arrangement is shown in *Fig* 11. The edges of the slab may be provided with mild steel angles to prevent chipping of the edges.

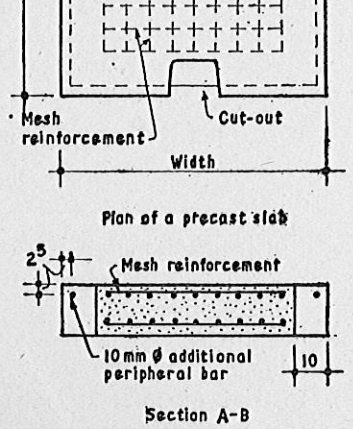


Fig 11 Typical arrangement for lifting precast slab

TABLE 7 Reinforcement to be provided in precast reinforced concrete slabs

Designed thickness, cm	*Size of precast slab,* cm × cm × cm	*Area in cm² of plain mild steel bars in either direction both at top and bottom**	
		for concrete of grade M100	*for concrete of grade M150*
10	80 × 80 × 10	1·73	2·12
12	80 × 80 × 10	2·49	3·06
14	80 × 80 × 10	3·38	4·15
16	60 × 60 × 15	1·83	2·22
18	60 × 60 × 15	2·29	2·62
20	60 × 60 × 15	2·83	3·47
25	60 × 60 × 15	4·32	5·42

* The total reinforcement in each precast slab will be four times the area given in column 3 or 4.

Conclusion

Based on a study conducted by Central Building Research Institute, Roorkee, detailed specifications, charts and tables have been prepared for designing economical industrial floors, regarding which there is only limited information in literature at present. It is expected that the floors designed by the proposed procedure will be economical and will give trouble-free service.

Acknowledgments

The authors are grateful to the Bureau of Public Enterprises, Ministry of Finance, Government of India, and in particular to Mr L. G. Selvam who suggested the topic for study and took very keen interest during all stages of the work. They would also like to convey their thanks to Mr V. S. Agarwal and Mr D. S. Tolia who helped in carrying out the field tests. The study forms a part of the research work being carried out at the Central Building Research Institute, and is published here by kind permission of the Director.

References

1. YODER, E. J. *Principles of pavement design.* John Wiley and Sons Inc, New York, USA, 1959.
2. —— *Concrete roads: design and construction.* Road Research Laboratory, Department of Scientific and Industrial Research. Published by Her Majesty's Stationery Office, London, 1955.

3. —— Recommended practice of concrete floor and slab construction. Reported by ACI Committee 302. *Journal of the American Concrete Institute*, January 1966. Proc Vol 63, pp 1–58.

4. —— Recommended practice of concrete floor and slab construction. Reported by ACI Committee 302. *Journal of the American Concrete Institute*, August 1968. Proc Vol 65, pp. 577–610.

5. FRIBERG, B. Design of dowels in transverse joints of concrete pavement. *Proceedings of the American Society of Civil Engineers*, 1938. Vol 64, pp. 1809–28.

Appendix

Illustrative example : Design of a base slab for carrying Euclid dumper given following data —

Front tyres	2 nos, size 30cm × 60cm
Load on front axle	6,850kg
Rear tyres	4 nos, size 35cm × 60cm
Load on rear axle	20,400kg
Tyre pressure	6kg/cm²
Assume centre to centre distance between pair of wheels	= 35cm
Impact factor (assumed)	0

The area of contact of the wheel is determined by the same method as followed in pavement design.

Case A — front axle

Load on each wheel $\frac{6,850}{2} = 3,425\text{kg}$

Area of contact of each wheel $\frac{3,425}{6} = 570 \cdot 84\text{cm}^2$, say 570cm^2

Case B — rear axle

Load per pair of wheel $\frac{20,400}{2} = 10,200\text{kg}$

Area of contact per wheel $\frac{10,200}{2 \times 6} = 850\text{cm}^2$

Length of imprint $= \sqrt{\frac{\text{Area of contact per wheel}}{0 \cdot 523}}$

$= \sqrt{\frac{850}{0 \cdot 523}}$

$= 40 \cdot 3\text{cm}$

Width of imprint $= 0 \cdot 6 \times$ length of imprint

$= 0 \cdot 6 \times 40 \cdot 3$

$= 24 \cdot 18\text{cm}$

Centre to centre distance between pairs of wheels $= 35\text{cm}$

Area of surface between two wheels $= (35 - 24 \cdot 18) \times 40 \cdot 3$

$= 10 \cdot 82 \times 40 \cdot 3$

$= 436\text{cm}^2$

Total area of contact under a pair of wheels $= 2 \times 850 + 436\text{cm}^2$

$= 2,136\text{cm}^2$, say, $2,000\text{cm}^2$

Assuming that the subgrade is of the filled up type, the modulus of subgrade reaction k is equal to 3kg/cm^3. If sub-base of type 4 is chosen, the factor α from *Table* 3 is $3 \cdot 00$, and therefore, the effective modulus of subgrade reaction k' is $3 \cdot 00 \times 3 = 9\text{kg/cm}^3$.

Knowing the load, contact area and effective k' value, the designed thickness can be arrived at by referring to *Fig* 5. For concrete of M100 grade the thickness is 25cm for rear axle load. Similarly, the thickness required for the base in loading case A or the front axle has got to be computed. The thickness which is greater is to be adopted. In this case, however, case B governs the design, and hence computation in respect of case A is not shown. Assuming load transfer devices will be provided between adjacent panels, the designed thickness will be 25cm.

Printed and published by Col C. L. Proudfoot (Retd.) for The Concrete Association of India, a Division of The Associated Cement Companies, Limited, at 'Cement House', 121, Maharshi Karve Road, Bombay 400 020 and printed at The Times of India Press, Bombay, India.