Paper No. 328

Use of Pre-concreted Reinforcement in Slabs

By

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Synopsis.

The paper describes an experimental evidence of the use of pre-concreted reinforcement in slabs. The words "Preconcreted Reinforcement" are coined by the author. Its history is that it was realised that in Pakistan the cheapest slabs are of Reinforced Brickwork. Unfortunately there have been many failures in reinforced brickwork slabs, which can be chiefly attributed to brickwork absorbing moisture and transmitting it to the reinforcement, which very often gets left uncovered by cement concrete. In order to overcome this difficulty and to make sure that reinforcement is properly coated with cement concrete, pre-concreting of the reinforcement was thought of.

Furthermore, it was realised that if pre-concreted reinforcement could be given a certain shape, it might be possible to do away with shuttering, and reduce the cost further. The shape developed is trapezoidal, as shown in plate 2. With separators of bricks in between laid in 1: 3 cement sand mortar, this trapezoidal pre-concreted reinforcment will form tensile portion of a slab. Since the entire dead load cannot be taken by pre-concreted reinforcement, it is necessary to support them at every 5 to 6 ft. The remaining compression portion of the slab is then laid in 1 : 3 cement brick masonry.

A new but well known feature is also introduced i.e., instead of ordinary bars cold twisted bars are used wherein the yield point of the bars is raised by more than 50%, and as such, the working stress of the bars can also be raised 50%. Instead of single twisted bars, the twin twisted bars raise the bond stress considerably and are also helpful for purposes of over-lapping at the joints in spans more than 8 to 10 ft. Three experiments have been carried out which proved highly successful. Since then nearly four dozen buildings have been constructed. The saving in cost, construction time and steel is substantial.

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II. Experimental Procedure and Observations :—

TEST No. 1. Experiment No. 1 was carried out on a slab of 9′ —3″ clear span and 10″ – 3″ width. The trapezoidal pre-concreted reinforcement of twin twisted bars ¼″ diameter is kept 12″ centre to centre by means of bricks laid in 1 : 3 cement sand mortar. On the top of this are laid two layers of brick tiles 12″ × 6″ × 1½″ thick in 1 : 3 cement sand mortar. After properly curing the slab it was tested and the results are shown in plate No. 1.

The load applied was stacks of bricks starting from the middle and going outwards. To prevent arching effect bricks were stacked one over the other with ¼″ between each stack. Deflection was observed for each increment of load on 2 gauges of sensitivity of 1/1000″ which was placed under the roof at mid-span one each side.

The average deflection of guage was plotted against the equivalent per sq. ft. uniformly distributed load. The rise in deflection at 230 lb/sq. ft. is due to sustained load for 10 hours. Similarly the rise in deflection at 275 lb/sq. ft. is due to sustained load for 22 hours. This creep is but to be expected. It is significant that the rate of increase of deflection between 270 lb/sq. ft. and 450 lb/sq. ft. is practically the same as from 170 lb/sq. ft. to 270 lb/sq. ft. After 450 lb/sq. ft. the rate of increase of deflection is very high indicating that the yield point is at 450 lb/sq. ft. The final break occurred at a load of 544 lb/sq. ft. through shear at 18″ from one abutment and where the deflection was shooting up with a slight increment of load.

This experiment was carried out by Mr. Irshad Husain, Research Officer, B & R Lahore, under the author's direction.

TEST NO. 2. Slab No. 2 had 14′ clear span and 3′ width with twin cold twisted 3/8″ dia. bars, 12″ centre to centre. The slab consisted of 3 layers of 12″ × 6″ × 1½″ brcik tiles laid in 1 : 3 cement mortar over the trapezoidal pre-concreted reinforcement with brick separators.

It was also found that a 14 ft. pre-concreted reinforcement offered many problems of handling and as such it was decided to give a central joint so that the pre-concreted reinforcement could be handled conveniently without any danger of breaking. Details of this joint are shown in plate 3. The slab was supported at the joint which was concreted prior to laying of brick tiles.

This slab was tested by stacks of bricks to obtain a uniformly distributed loading condition. In order to eliminate the state of case between the materials, the test specimen was first loaded to an equivalent of 135 lb/sq. ft. and a permanent set of. 2″ was obtained on unloading after 24 hours. The test specimen was reloaded to 90 lb/sq. ft. and

the initial reading was almost reached on unloading after 24 hours. It was again loaded to 120 lb/sq. ft. which on unlooding after 24 hours recovered 78. 8%of the maximum deflection. The slab was then kept under sustained load of 120 lb/sq. ft. for about 6 weeks when a deflection of. 57″ was observed. The observations were later discontinued owing to settlement of one of the boaring walls due to heavy rain fall. Deflection was recorded by cathetometer mounted on a fixed table and the observations were plotted and are shown in plate No. 2.

This experiment was carried out by Mr. Shahriar Ahmad, Lecturer, Punjab College of Engineering & Technolgy, under the direction of the author.

TEST NO. 2. In this case the slab had a clear span of 18′-9″and 4′ wide. The preconcreted reinforcement consisted of two 3/8″ bars cold twisted. The distance pieces used in this case were trapezodial section pre-cast concrete units. The compression portion consisted of brick masonry. In this case too, similar joints were used as in experiment No. 2, except that there were 3 joints where it was supported, two at about quarter span and one in the centre. This enabled staggering the joins of eoch pre-concreted reinforcement.

The super-imposed load adopted in this test consisted o cement concrete blocks of 12″×9″×6″ laid side by side to a lyer of 6″ at a time. The average weight of a block was 27 lb each which gave a uniformly distributed load of 59 lb/sq. ft. for each layer. The first layer of blocks even after 24 hours did not show any deflection. It was then decided to test it to destruction and the slab was loaded progressively with one layer of blocks uniformly distributed until failure occured at a load of 236 lb/sq. ft. Deflections were observed mid-span on either side and are tabulated as under :—

Load	59 lb/ sq. ft.	118 lb/ sq. ft.	177 lb/ sq. ft.	236 lb/ sq. ft.
Side 1	0.00	.15″	.31″	.55″
Side 2	0.00	.15″	.32″	gauge removed
Average	0.00	.15″	.315″	.55″

The deflection was measured in this case by a method of exageration due to leverages. This test was carried out by Mr. Qovi of Pakistan PWD under the direction of the author. In this case it will be observed that with even 177 lb/sq. ft. load the deflection was less than 1/600 clear span.

III. Computations and Inferences.

The three slabs tested above for different conditions of loading, are now analysed considering them as simple one-way reinforced slabs. The formulae used are :—

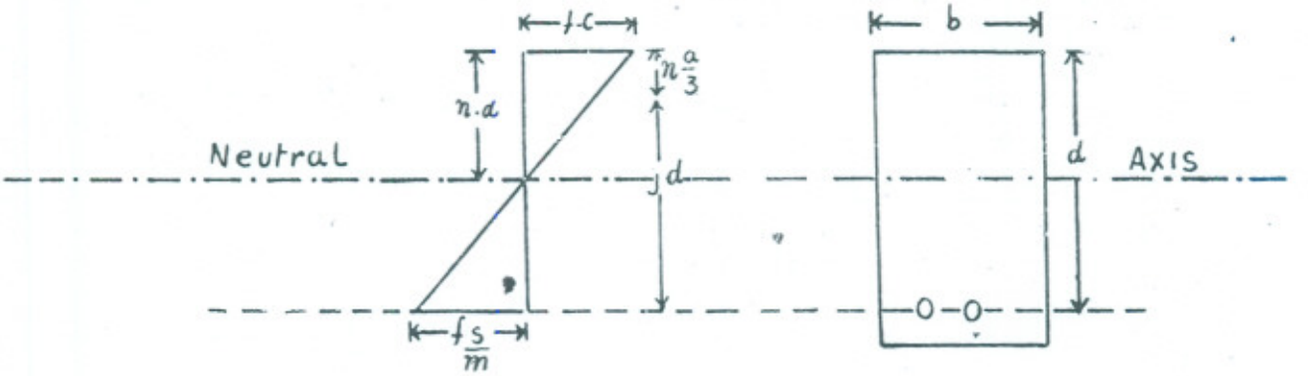
$$ps\ (\%\ \text{of steel}) = \frac{As \times 100}{b \times d} = \frac{50}{m} \times \frac{n^2}{1-n} \quad -(1)$$

$$M = \tfrac{1}{2}\, fc \times b \times nd \times jd$$

$$= \tfrac{1}{2}\, fc\, b \times nd\left(d - \frac{nd}{3}\right) \quad -(2)$$

$$\text{Also } M = As \times fs \times jd$$

$$= \frac{ps \times bd}{100} \times fs \times \left(d - \frac{nd}{3}\right) \quad -(2a)$$



TEST NO. 1.

DATA:

Slab Dimensions : —		
Clear span	=	9·25 ft.
Total slab thickness	=	6″
Area of steel, (As) (Twin twisted ¼″ dia bars @ 12″ centres)	=	·098 sq. inch
Effective span	=	9·25+0·5 = 9·75 ft.
(Effective) d	=	5″

The position of neutral axis is fixed by the amount of steel provided

$$ps = \frac{As}{bd} \times 100 = \frac{0{\cdot}098}{5 \times 12} \times 100 = 0{\cdot}163\ \%$$

From equation No. 1

$$ps = \frac{50}{m} \times \frac{n^2}{1-n}$$

$$0{\cdot}163 = \frac{50}{30} \times \frac{n^2}{1-n}$$

which gives $n = 0{\cdot}26$

$$jd = \left(d - \frac{nd}{3}\right) = \left(5 - \frac{{\cdot}26 \times 5}{3}\right) = 4{\cdot}57''$$

Calculation of Stresses :—

LOAD NO. 1 = Design Load = 90 lbs. per sq. ft.

$$\therefore M = \frac{90 \times 9{\cdot}75 \times 9{\cdot}75 \times 12}{8} = 12{,}834 \text{ lbs. in.}$$

From equation (2, a), working out fs, we have,

$$M = As \times fs \times jd$$

$$12834 = 0{\cdot}098 \times fs \times 4{\cdot}57$$

$$fs = 28{,}700 \text{ lbs. per sq inch.}$$

From equation No. 2, working out fc, we have,

$$M = \tfrac{1}{2}\, fc\, b \times nd \times jd$$

$$12834 = \tfrac{1}{2}\, fc \times 12 \times {\cdot}26 \times 5 \times 4{\cdot}57$$

$$\therefore fc = 360 \text{ lbs. per sq. inch.}$$

$$\text{Total Shear} = V = \frac{90 \times 9{\cdot}75}{2} = 440 \text{ lbs.}$$

$$\text{Shear Stress} = \frac{V}{bjd} = \frac{440}{12 \times 4{\cdot}57} = 8 \text{ lbs per sq. in.}$$

less than 35 lbs/sq. in.

$$\text{Bond Stress} = \frac{V}{jd \times (\text{Total Perimeter})}$$

$$= \frac{440 \times 4}{4{\cdot}57 \times 2\pi \times 1} = 61{\cdot}4 \text{ lbs/sq. in. less than 200 lbs/ sq. in.}$$

Similarly the Stresses developed in reinforced brickwork for the following conditions of loading have also been calculated and summarised as under :

TEST NO. 1. **Slab size** 9·25′ × 10·25′ Thickness = 6″ **Reinforcement.** Twin twisted bars ¼″ ø placed 12″ c/c.

Total load (lbs per sq. ft) (Self-load + Super-load)	fs (lbs per sq. inch)	fc (lbs per sq. inch)	Bond Stress (lbs. per sq. inch)	Shear Stress (lbs. per sq. inch)	Remark
90	28,700	360	61·4	8·0	
230	73,400	922	157	20·4	
450	1,43,000	1800	307	40·0	Yield point
544	1,71,000	2160	369	48·4	Breaking point

TEST NO. 2.

DATA

Slab Dimensions :—

Clear span = 14·0 ft.

Overall thickness = 7½″

Reinforcement = Twin twisted 3/8″ ø bars placed 12″ c/c

Effective span = 14·0 + 0·75 = 14·75 ft.

(effective) d = 6·5″

Position of neutral axis is fixed by the amount of steel provided As = 0·22 sq. inch.

$$ps = \frac{As}{b \times d} \times 100 = \frac{0{\cdot}22}{12 \times 6{\cdot}5} \times 100 = 0{\cdot}282\ \%$$

For depth of Neutral Axis

$$ps = \frac{50}{m} \times \frac{n^2}{1-n}$$

$$n = 0{\cdot}353$$

$$jd = \left(1 - \frac{n}{3}\right) d = 5{\cdot}78''$$

LOAD NO. 1.

(Self + Super) Load = (75 + 135) = 210 lbs/sq. ft.

$$M = \frac{210 \times 14{\cdot}75 \times 14{\cdot}75 \times 12}{8} = 68{,}500 \text{ lbs. in.}$$

Corresponding Stresses developed in steel and brickwork

fs = 54000 lbs. per sq. inch.

fc = 860 lbs. per sq. inch.

$$\text{Total Shear} = V = \frac{210 \times 14{\cdot}75}{2} = 1550 \text{ lbs.}$$

$$\therefore \text{ Shear Stress} = \frac{1550}{12 \times 5{\cdot}78} = 22{\cdot}4 \text{ lbs. per sq. inch.}$$

$$\therefore \text{ Bond Stress} = \frac{1550 \times 8}{5{\cdot}78 \times 2\pi \times 3} \quad 114 \text{ lbs. per sq. inch.}$$

Similarly the Stresses developed in reinforced brickwork for the following conditions of loading have also been calculated and summarised as under :

TEST NO. 2.

	Slab Size	**Reinforcement**
	14′ clear span 3′ wide, Thickness 7½″.	Twin twisted bars 3/8″ ø placed 12″ c/c.

Total load (lbs. per sq. ft) (Self load + Super-load)	fs (lbs per sq. inch)	fc (lbs per sq. inch)	Bond stress (lbs per sq. inch)	Shear Stress (lbs per sq. inch)
(75 + 135)	54,000	860	114	22·4
(75 + 90)	42,400	680	90	17·5
(75 + 120)	50,000	800	106	20·8

TEST NO. 3.

Slab Dimensions.

Clear Span = 18′ — 9″

Overall thickness = 16″

Reinforcement = Twin twisted bars 3/8″ ø 7½″ c/c.

Effective Span = 19·5 ft.

Effective (d) = 14′5″ (1·5″ cover)

Position of neutral axis is fixed by the amount of steel provided

$$As = \frac{0{\cdot}22 \times 12}{7{\cdot}5} = 0{\cdot}352 \text{ sq. inch,}$$

$$ps = \frac{0{\cdot}352}{12 \times 14{\cdot}5} \times 100 = 0{\cdot}2\ \%$$

which gives n = 0.291

nd = 4.22"

jd = 13.1"

LOAD No. 1.

(Self+Super) load = (160+59) = 219 lb per sq. ft.

$$M = \frac{219 \times 19.5 \times 19.5 \times 12}{8}$$

= 1,25,000 lb. in.

Stresses developed.

fs = 27.200 lb. per sq. inch.

fc = 370 lb. per sq. inch.

Total Shear $= V = \frac{219 \times 19.5}{2} = 2140$ lb.

v = Shear Stress $= \frac{2140}{12 \times 13.1} = 13.6$ lb. per sq. inch.

u = Bond Stress $= \frac{2140 \times 8}{13.1 \times 3.2 \times \pi \times 3} = 43.4$ lb. per sq. inch.

Similarly the stresses developed in reinforced brickwork for the following conditions of loading have also been calculated and surmarised as under :—

TEST No. 3.

Slab Size

18' — 9" clear span
4' wide, thickness 16"

Reinforcement.

Twin twisted bars
3/8" ø @ 7½" c/c.

Total Load (lb per sq. ft.) (Self-load+Super load)	fs (lb. per sq. inch.	fc (lb. per sq. inch.	Bond Stress (lb per sq. inch)	Shear Stress (lb per sq. inch)	Remarks
(160+59)	27,200	370	43.4	13.6	
(160+118)	34,500	480	55.1	17.3	
(160+177)	41,700	570	66.9	20.9	Breaking
(160+236)	49,000	682	78 5	24.5	point.

From the above mentioned result it will be seen that for Test No. 1, for a designed load of 90 lb. per sq. ft. fs comes to 28,700 lb per sq. inch and fc comes to 360 lb. per sq. inch clearly indicating that the working strength of steel has been raised by more than 50% as a result of the cold twisting of reinforcement. The result of Test No. 3 also indicate that for a total load of 219 lb. per sq. ft. corresponding to a super-load of 59 lb. per sq. ft. fs comes to 27,200 lb per sq. inch and fc comes to 370 lb. per sq. inch. For intermediate loads fs and fc attain very high values giving a high factor of safety before the yield point is reached.

For Test No. 1, the factor of safety at yield point is 5 when the span is about 10 ft. For the larger span of about 20 ft. the factor of safety is more than 1.5 and for the intermediate span of about 15 ft as in Test No. 2, the factor of safety comes very nearly equal to 3. For residential buildings usually a facror of safety of a little over 2 is recommended. Thus for spans up to 15 ft. Author's Preconcereted Reinforced Brickwork can be adopted with full confidence. Even for larger spans of 20 ft. the slabs are perfectly safe though the factor of safety is less than 2. The slabs showed very little deflection at a super load of 170 lb. per sq. ft, nearly three times as high as the super load corresponding to a value of fs = 27,200 lb. per sq. inch.

The results of all the tests are condensed in plate No. IV and from a careful study of the same it appears that for the author's pre-concreted reinforced brickwork slabs the following values of working stresses should be adopted.

f_s = 27,000 lb. per sq. inch.
f_c = 350 lb. per sq. inch.
m = 30

u (bond strees) = 200 lb. per sq. inch.
v (shear stress) = 35 lb. per sq. inch.

IV. Conclusions:

It would be clear that there could be no objection in using pre-concreted reinforcement for slabs, where cement concrete is more expensive than brickwork. This method certainly will be found economical both from the point of view of cost as well as speed. The author has put up a large number of buildings where he did not have to use shuttering for lintals, canopies and roofs. With preconcreted reinforcement units already pre-cast the speed in completion of buildings was quickened considerably.

This method removes uncertainty of completely covering the reinforcement with cement concrete, and is therefore preferable to reinforced brickwork as at present in use The pre-concreted reinforcement has considerable future in construction of beams and columns and opens a new field in construction method.

Acknowledgment.

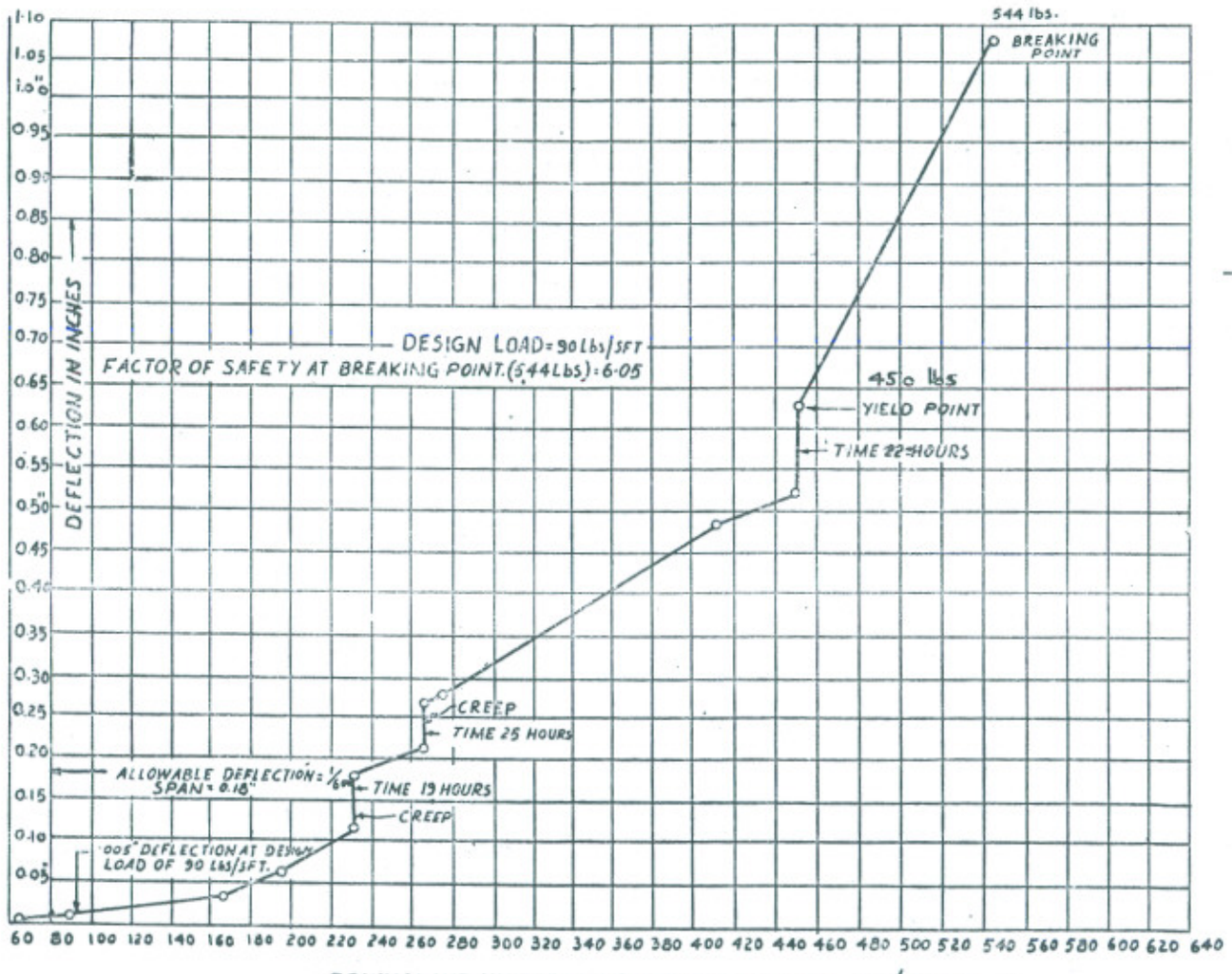
The author is most indebted to Messrs Irshad Hussain, Shahriar Ahmad and Qavi, who carried out experiments for him.

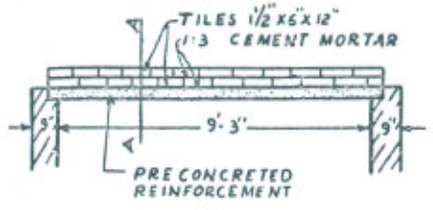
PAPER NO: - 328 — PLATE 1.

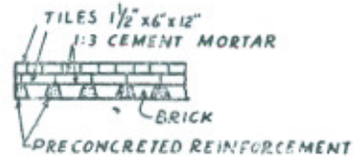
USE OF PRE-CONCRETED REINFORCEMENT IN SLABS

TEST NO. 1

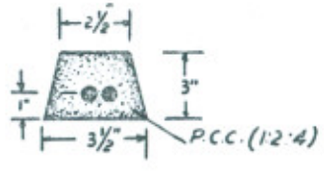
CURVES SHOWING DEFLECTION OF THE SLAB OF 9'-3" SPAN 10'-3" BREADTH







CROSS SECTION AT A.A.



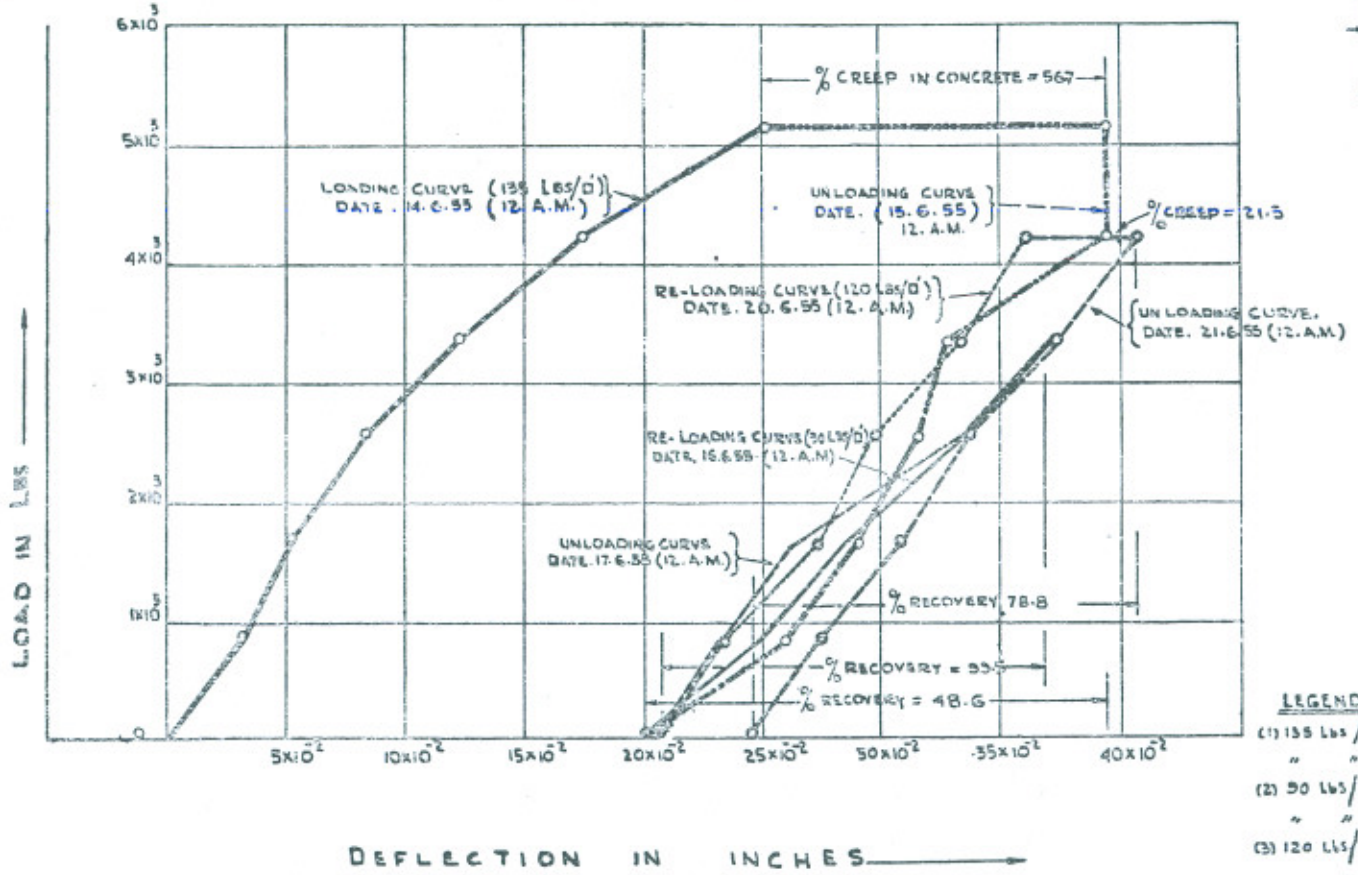
SECTION OF PRECONCRETED REINFORCEMENT 2 NO. ¼" TWISTED BARS.

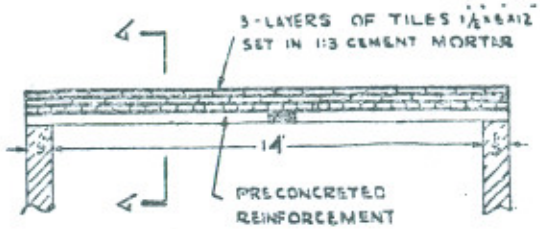
PAPER NO 328 PLATE II

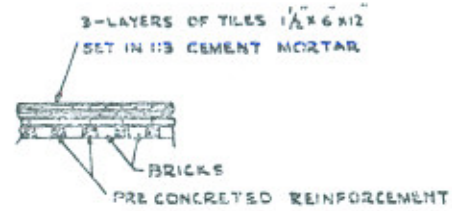
USE OF PRECONCRETED REINFORCEMENT IN SLAB.

TEST NO 2

CURVES SHOWING DEFLECTION OF THE SLAB OF 14' SPAN 3' BREADTH







CROSS SECTION AT "A-A"



SECTION OF PRECONCRETED REINFORCEMENT

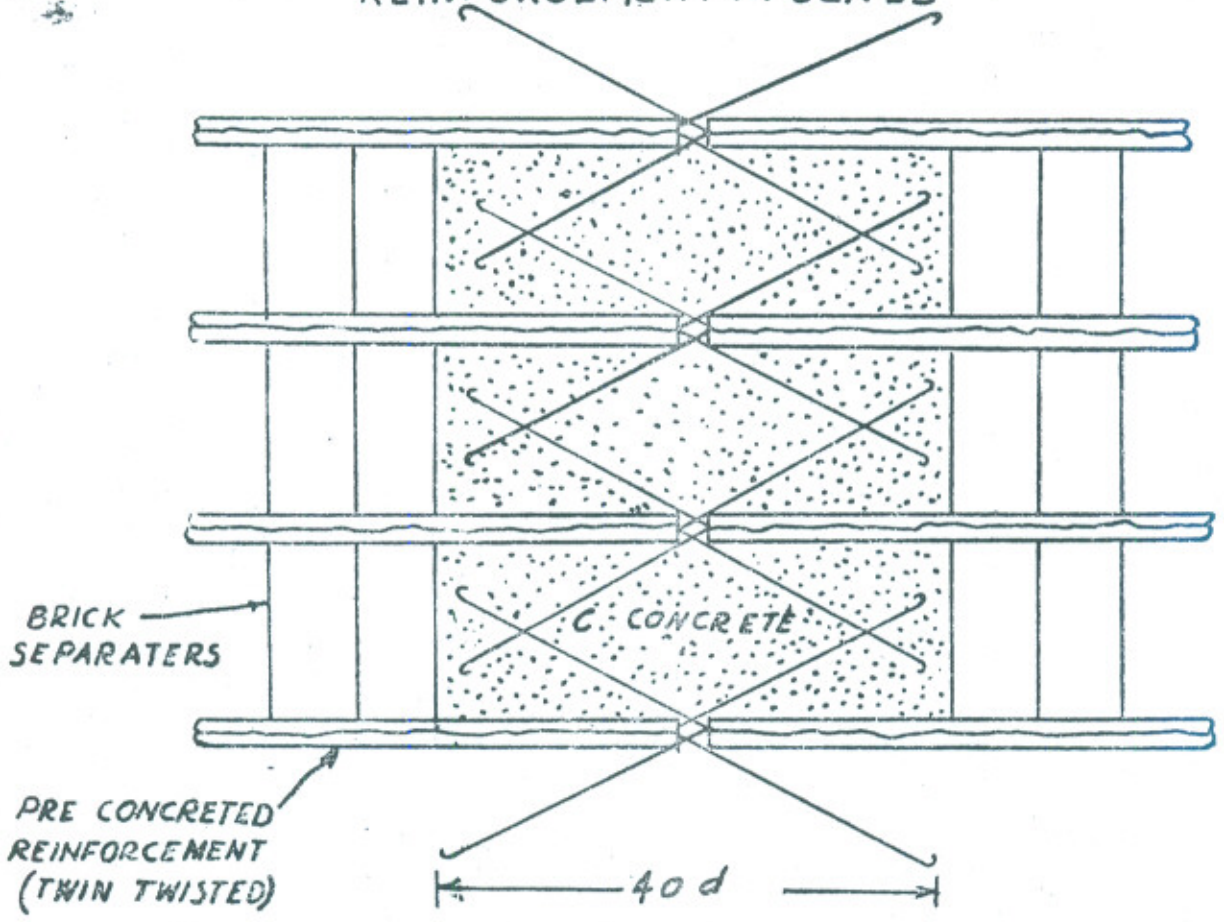
LEGEND:-

(1) 135 Lbs/D' ——— LOADING CURVE
" " ——— UNLOADING CURVE
(2) 90 Lbs/D' ——— LOADING CURVE
" " ——— UNLOADING CURVE
(3) 120 Lbs/D' ——— LOADING CURVE
" " ——— UNLOADING CURVE

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DETAIL OF THE JOINT

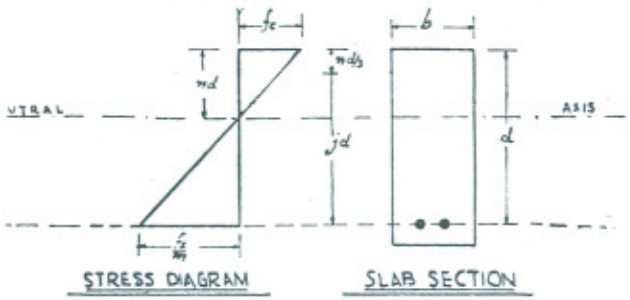
USE OF PRE-CONCRETED REINFORCEMENT IN SLABS



PLAN

SCALE 1"=1'

Experimental Observations & Computed Data.



STRESS DIAGRAM SLAB SECTION

Allowable Working Stresses for Azam's Preconcreted Reinforced Brickwork As Derived from experiments 1 to 3 :—

fs , (Stress in Steel)	= 27,000	lbs/□"
fc , (Stress in R.B. work)	= 350	lbs/□"
u , (Bond Stress)	= 200	lbs/□"
v , (Shear Stress)	= 35	lbs/□"
m , (Modular Ratio)	= 30	

. of t	Steel Provided area sq. inches	'ps' %age of steel	Overall Slab Thickness (inches)	Effective Depth 'd' (inches)	'nd' (inches)	'jd' Lever Arm (inches)	'L' Effective Span (Feet)	Super-Imposed Load (lbs/□')	'W' Total load= Supper load+ Self load of Slab (lbs/□')	Bending Moment 'M' (lbs inches)	'fc' Developed. lbs/□"	'fs' Developed lbs/□"	'u' Bond Stress lbs/□"	'v' Shears Stress lbs/□"	Experimental Conditions & Observations: Allowable Deflection (span/600) (inches)	Observed Deflection (inches)	CONDITION OF LOADING	REMARKS.
T 1 n 10'	TWIN Twisted Bars ½ Dia. @12" centres as= (0·098□")	0·163	6"	5"	1·3"	4·57"	9.75'	40lbs/□'	90 lbs/□'	12,834	360	28,700	614	8·0	0·18"	0·005"	Designed Load	1. Loading—Progressively increasing. 2. Factor of safety at yield point = 5·00. 3. Factor of safety at Breaking point = 6·05
								180	230	32,800	922	73,400	157	20·4		0·12	Intermediate Loading	
								400	450	64,200	1,800	1,43,000	307	40·0		0·52	Yield Point	
								494	544	76,500	2,160	1,71,000	369	48·4		over 1·05	Breaking Point	
T 2 n 15')	TWIN Twisted Bars ⅜" dia. @ 12" centres as= (0·22□")	0·282	7·5	6·5	2·3	5·78	14.75	135	210	68,500	860	54,000	114	22·4	0·28	0·20	Gradually loaded upto 135 lbs/□' then unloaded after 24 hours. Reloaded to 90 lbs/□' and unloaded after 24 hours. Reloaded to 120lbs/□' and unloaded after 24 hours.	1. Loading—alternate loading and unloading. 2. Creep took place at 135 lbs/□' & percentage recovery was 48·6 ; & also at 120lbs/□' with percentage recovery = 78·8.
								90	165	54,000	680	42,400	90	17·5		0·20		
								120	195	63,500	800	50,000	106	20·8		0·57		
r 3 20')	TWIN Twisted Bars ½" dia. @7½" centres.	0·20	16	14·5	4·22	13·1	19·5	59	219	1,25,000	370	27,200	43·4	13·6	0·38	0·00	Loading-close to the designed load.	1. Progressively increasing loading. 2. Factor of safety at breaking point = 1·8
								118	278	1,59,000	480	34,500	55.1	17·3		0·15	Intermediate loading	
								177	337	1,92,200	570	41,700	66.9	20·9		0·315	Intermediate loading	
								296	396	2,26,000	682	49,000	78·3	24·5		0·55	Breaking point.	