

Research in Construction – Lab to Land

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Abstract— Construction sector is a down to earth activity. Any industrial research in this sector should end up as results applicable in field are it in design or construction. Author describes a number of products / processes he developed as Researcher at CSIR-SERC and applied extensively in India at projects of technology transfer, from SERC and later in his career as Consultant in the Industry. These were to increase productivity, improve quality and to optimize use of critical materials as also to save construction time.

Keywords — *Funicular Shells; Brick Shells; Lift Slab; Filler Slabs; Concrete Reinforcing Bars; 3 D Steel Structures; Space Frames; Braced Domes; Hyperboloid Shells; Large Panel Prefabrication; Reinforced Earth Design of RCC Elements.*

1. Introduction

In the early sixties and seventies of Indian construction sector emphasis was on saving critical materials like steel and cement, as they were in short supply. Imports of technology were also to be restricted as foreign exchange reserves were meagre. This paper discusses about the development stages of construction field.

2. Materials & Methods

2.1 Funicular Shells

There were two versions of this. One small – about 1 m x 1 m – precast units 25 mm thick deriving its strength from the funicular profile in pure compression with no reinforcement, but bound by a small reinforced edge beam. The other was to construct these shapes over large spans, on form work with minimal ribs or without ribs even in brick masonry 100 – 125 thick. For their use in industry such a proposal to be accepted by the conventional construction people who look to solid previous experience was difficult task, even when laboratory full scale tests are demonstrated. Two major applications came about after strange demonstrations demanded by the clients.

- For a major housing project for the army at Ambala, to build 1500 house for all ranks. The engineer colonel demanded that he will accept it if his 3 tonne truck can safely pass over these shell units. The test was successful and the process was adopted for the entire project in early sixties.
- A long temple corridor was to be built at Tiruchendur, Tamilnadu. The famous film producer Mr. Thevar was the sponsor of the project. He had to be convinced of the product by making his small elephant to stand on 4 legs on a single shell unit. This was also passed and the process adopted. Since then it has been extensively used on several projects across India and a BIS code was also made out. Applications at Chennai,

Hyderabad, Ahmedabad and in Kerala State Nirmithi Centers stand out (Fig.1 & 2).

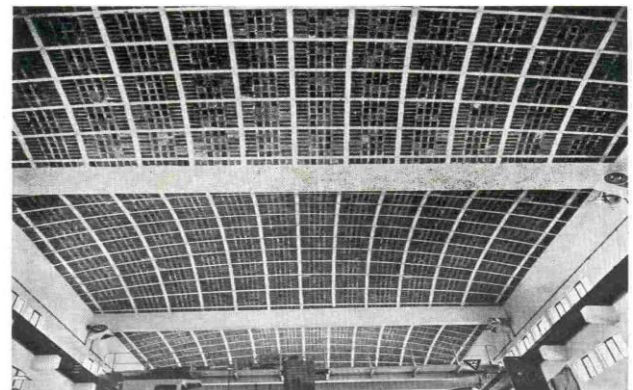


Fig.1: Funicular Shells

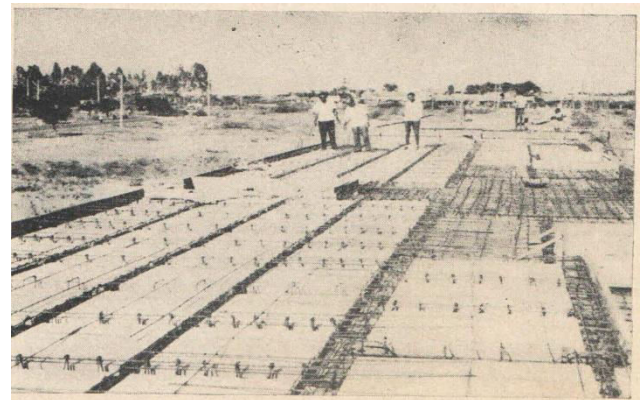


Fig.2: Funicular Shells

2.2 Lift Slab (PT Slabs)

Prestressed concrete has been used extensively in India for bridges, long span industrial buildings and for railway sleepers. Prestressing in slabs was introduced in India very late as PT slabs of spans 6 to 9 m. However, the first prestressed slab as lift slab was demonstrated by SERC as

early as 1960's as part of R & D at Roorkee by the authors team (Fig.3,4).



Fig.3: Lift Slab



Fig.4: PSC Cantilever Truss

2.3 Filler Slabs

Concrete slabs of spans greater than 4,5 m will demand thicknesses above 140 mm. It is well known to designers that 60% of concrete in slab is in tension zone and does not contribute to strength. A better option will be to use a lighter or cheaper material to replace this under-used structural concrete. One such option is to use hollow clay blocks, or light weight cellular concrete blocks in such cases as has been done by the author at several Projects.

2.4 Reinforcing Bars

A good percentage of cost of concrete construction is for the reinforcing bars used in concrete (often 25 to 50% of cost of RCC). In the sixties, only MS bars of smooth surface with yield strength of 26 N/mm² was used in India. R & D at SERC by the authors' team developed bars of

higher strength and increased bond strength by cold working of the bars, essentially by twisting. This was a 2 stage operation having to handle each bar for twisting. But in India of sixties could not afford to import alloying materials or twisting process / machines.

The bars developed and patented by the authors' team was licensed to Tata Steel and several million tonnes of this steel was produced as Grip bars (TISCON) and used in India. As an import substitution work this received GOI inventions award. As the economy progressed and imports liberalized, higher grades of steel were produced and reinforcing bars of single operation (TMT) were made out of it. Today these bars of grade 500 and above are universally used in India. (Fig 5 - cold twisted / TMT bars).

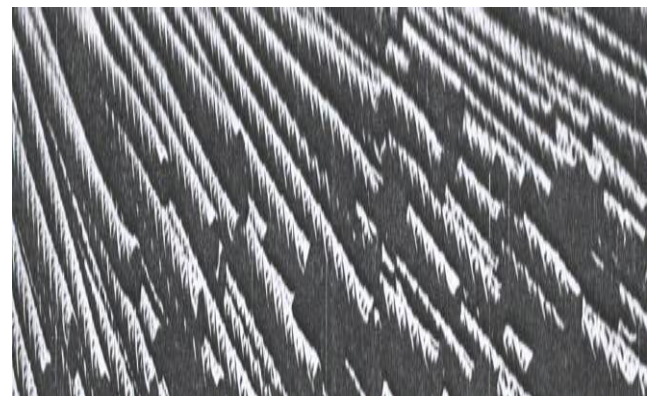


Fig.5: Reinforcement - TISCON BARS

2.5 Space Frames / 3D Structures

Covering large column free areas for assembly, sports and some industrial activities and hangars or Airport structures is a major problem in construction sector. Its design, manufacture and erection are equally difficult. The author had attempted to do this on a number of projects. His R & D has also resulted in a patented process of braced domes (Fig 6,7).



Fig.6: Steel Structures

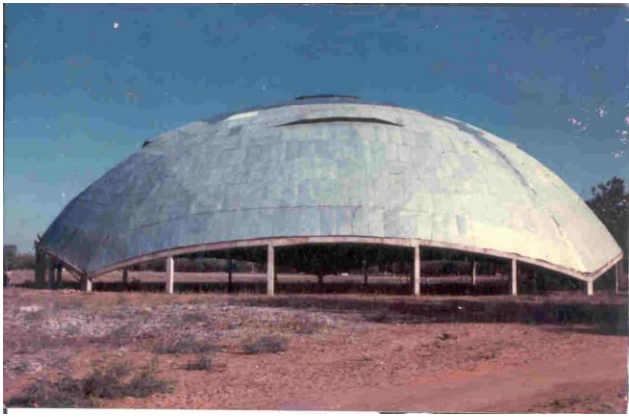


Fig.7: Steel Structures – Braided Dome

2.6 HP Shells

Precast thin concrete shells of 6 – 8 mm thickness, in plain RCC or by pretension concrete have been developed. These were used on a number of projects designed by the author. Precast elements of 2 – 2.50 m width in hyperboloid geometry can be formed of straight lines, shaped as a doubly curved surface. These are ideal for use for large spans. Notable applications are on the CSIR campus. (Air India, Chennai Airport, NIOT labs at Chennai and Tirupathi Q Complex (Fig. 8, 9)).



Fig.8: Pre Cast Hyperboloid Shells



Fig.9: Pre Cast Hyperboloid Shells

2.7 Large Panel Prefabrication

Post War Europe adopted this technology for large scale construction for housing. Here concrete bonded room size panels are prefabricated in factories, brought to site and erected using tall tower cranes. India did not adopt this widely as we had no big highways, no tower cranes till the late eighties. However, attempts were made in Mumbai and Delhi to adopt these but with limited success. The author as part of his R & D work at CSIR did a pilot project of constructing 144 medium flats (< 100 m²) in four storeyed configurations. The walls were made of concrete bonded hollow clay blocks and slabs were made of waffle shaped shells all fabricated on on-site casting. A tower crane available with CSIR – SERC was used on the Tamilnadu Housing Board Project at Chennai (Fig 10). Like in other parts of India this technique also did not find favour with builders.



Fig.10: Large Panel Prefab (TNHB Chennai)

2.8 Retaining Walls

Traditionally to retain earth along the roads or plots in sloping terrains, the mass of the retaining wall is considered as the resisting force. Hence, roughly a retaining wall should have a base width of 0.4 to 0.50 of the height of earth retained. This is because the retained earth and the mass of retaining wall are considered as to separate elements.

Modern designs now try to integrate this by combining the two masses and reducing the wall to minimum thickness. This combination is possible by anchoring the thin facial wall into the soil by anchorages. The mass at the back should be of cohesive soil. The author has adopted this technique on a number of projects (Fig.11). The reinforced earth concept can now be seen on all the high way projects of elevated passages. On stable soil like laterite the walls may stand by itself but a grid can stabilise it from falling down.



Fig.11: Reinforced Earth Retaining Wall

2.9 Design of RCC Elements

A lot of time is spent by designers for design of various RCC elements for buildings. Most Civil Engineers in construction go by what is given by the designer. It is necessary to check at least on a first cycle basis the designs they have received. A few design tables are presented here for reference.

- Slabs for given span / moments.
- Beams for given loadings / spans
- Columns for given P_u / M_u .

Computer aided designs are available for the design office. Yet the sites may not have the skills and infrastructure to verify this (Refer tables).

Table 1 : (M_u) Slab Moments – Interior Panels
kNm at 10 kN/m² Factored 1.5 x 1.15

Panel Size	Slab Thickness $M_x / WCx^2 \times$ Coeff	.045	.034	.032	.024
4m x 5m 276X	140 mm	12.42 +A'	9.38 (A)	8.83 A	6.62 A
		.065	.049	.032	.024
3.5m x 7m 212X	125mm	13.78 +C	10.39 (C)	6.78 A	5.09 A
		.032	.024	.032	.024
6m x 6m 360 x	175mm	19.87 +C'	14.90 (C)	19.87 +C'	14.90 (C)
To be matched by resisting moment of Slabs (RMU) - kNm					

Thic kness	→Bar Spacing					
	Y8@ 275 2.22	Y8@ 175 2.85	Y8@ 150 3.33	Y10@ 200 3.93	Y10@ 175 4.49	Y10 @ 150 5.23
125	9.49	12.18	14.24	16.80	19.19	-
140	11.99	15.39	17.99	21.22	24.24	28.24
175	13.99	17.95	20.99	24.76	28.28	36.61
Select Bars for +ve moment and add extra for -ve moment at support						

Table 2: Resisting Moments

Ast. cm ²	Resisting Moments M_u CAPACITY OF BEAMS - (kN-m)				
	DEPTH OF BEAMS				
	300	450	600	750	900
2.24	20	33			
4.08	37	60			
6.12	57	90	118	150	190
7.22	61	106	140	178	226
9.42		139	183	233	295
11.17		164	216	275	345
12.94		200	250	319	400
14.67		226	286	365	460
19.56			381	486	615
24.09			469	598	755
29.34				728	920
Arrive at Design Moments (M_u)		Look for nearest RM for given d			

Table 3: Column Section (Area of Steel - 4% Max)

Concrete M25		COLUMN SECTION (AREA OF STEEL - 4% MAX)									
Pu	Mu	300 x 300	230 x 375	230 x 450	300 x 450	300 x 600	375 x 375	450 x 450	300 x 750	600 x 600	
500	30	8cm ²	8cm ²	9cm ²							
1000	60	18cm ²	16cm ²	11cm ²	11cm ²		12cm ²				

1500	90		32cm ²	26cm ²	26cm ²	15cm ²	21cm ²	15cm ²						
2000	120			39cm ²	34cm ²	18cm ²	36cm ²	23cm ²		18cm ² (Min)				
	200					54cm ²	32cm ²	57cm ²	36cm ²					
2500	150					54cm ²	32cm ²	53cm ²	36cm ²	18cm ²		29cm ² (Min.)		
3000	180						45cm ²	57cm ²	51cm ²	29cm ²		29cm ² (Min.)		
	300						63cm ²			56cm ²		40cm ²		
3500	210								63cm ²	45cm ²		29cm ²		
4000	240									60cm ²		36cm ²		
	400											74cm ²		57cm ²
5000	300									84cm ²		81cm ²		
6000	360											90cm ²		
	600													126cm ²

3. Conclusion

Today we have all these in plenty. R & D in those days concentrated on these aspects. Some of these efforts and their results as application in industry are described here credits are due to Prof. Late G S Ramaswamy, Director SERC for guidance in these project to the author.

Acknowledgement

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