Technology Profile

Funicular Shell Roof

South Asia

RESOURCES

Material and labour requirement for construction of funicular roof of size 10' x 12'

Number of Funicular Shells in Roof: 4

Materials	Unit	Quantity
Waste stone pieces	Quintal	3
Bricks	No.	300
Cement	Bags	11
Sand	Cft	31
Aggregate 10/20mm	Cft	50
16mm reinf. Steel	Kg	34
12mm reinf. steel	Kg	13
10mm reinf. Steel	Kg	33
6mm G.I wire	Kg	22
LABOUR		
Mason	Man days	4
Labour	Man days	12
Bar benders	Man days	2

CONCEPT

A Funicular Shell is a 3 dimensional catenary on a rectilinear base. The roofing system consists of doubly curved shells made with materials of good compressive strength such as waste stone pieces and brick tiles and supported on reinforced concrete edge beams. A series of these shells in variable geometric configurations supported on a grid of concrete beams, identical to a coffer slab, provides an attractive roof for small to medium spans.

APPLICATION

Photographs courtesy: Anangpur Building Centre

COMPONENTS

Edge Beam

This is a reinforced concrete beam which supports and distributes the horizontal thrust of the funicular shell. The beam can be conventionally cast along with the funicular shell. As per the span, the beam is designed for a coffer slab or a grid of beams. Alternatively, the beam can be partially precast, in which case a pre-welded reinforcement cage is placed along the grid and cast half. The cage is fabricated as a truss girder *(see overleaf for details)* which improves the load bearing capacity of beam considerably, while simultaneously reducing the beam section.

Funicular Shell

The entire area to be roofed is divided into a grid depending on the size of the funicular shell required or the size / shape of moulds available. The rise to span ratio is 1:6, thus the optimal span of the shell is 3 m though it can span up to 15 m. The mould is supported between the edge beams. Timber planks are used to bridge the gap between the edge of the mould and the edge beam. The shell comprises of the materials – bricks, stone waste – laid in the funicular profile topped with cement-sand mortar and concrete screed.

Concrete In-fill

After the shells have been cast, the valley spaces which are formed between the shells can be filled with light-weight material like brick jelly lime concrete and finished flat. The infill will enable the construction of an intermediate floor which can be used to build above.

KNOW HOW

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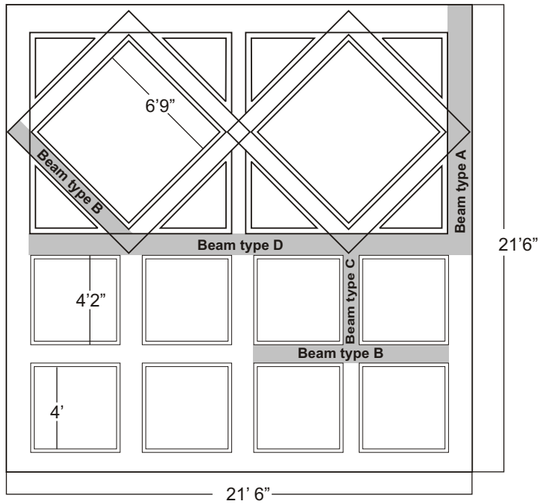
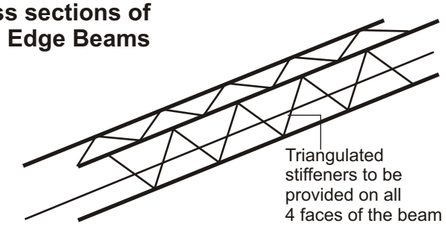
DETAILS

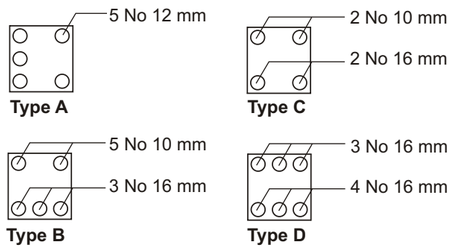
Funicular Shell arrangement for a hall of size 20’ by 20’. The roof has been divided into smaller spans with a grid of beams *(as shown in the sketch).* **3 shapes of funicular shells have been used in the roof**

Plan of the training hall, indicating the grid of Edge Beams

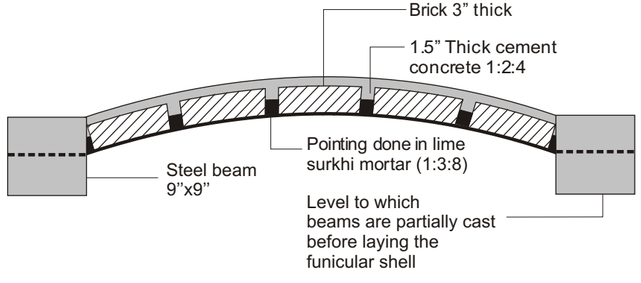


Cross sections of Edge Beams





Section of Funicular Shell



ADVANTAGES

- Allows ample flexibility in design- funicular shells can take any shape – square, rectangular, triangular or trapezoidal
- Uses locally available waste stone, normally available from stone cutting and polishing units
- For construction above the intermediate floor, the funicular roof provides greater flexibility for locating walls since the load distribution is uniform because of arch action of the shell
- Design of the funicular roof can be very well adapted to seismic design requirements
- Finishes like plaster and paint for the roof are not needed
- Being a labour intensive technology, leads to employment generation and integrates craftsmanship
- Simple technology which can easily be adapted by semi-skilled labour with minimum supervision
- The funicular roof is aesthetically much better than other roofs – various artistic patterns can be made using brick and stone

SPECIFICATIONS

Funicular Shell

PROFILE	:	DOUBLY CURVED FOR ANY DESIRED PLAN SHAPE & RISE OF SHELL, ORDINATES ON VARIOUS POINTS CAN BE CALCULATED USING FORMULAE AS PER IS 6332
CLEAR SPAN	:	3’ TO 9’ THIS DEFINES A RANGE OF SPAN FOR NORMAL APPLICATIONS. BIGGER SPANS UPTO 40’ ARE ALSO POSSIBLE, SUBJECT TO STRUCTURAL DESIGN
SHAPE	:	A VARIETY OF SHAPES ARE POSSIBLE-SQUARE, RECTANGULAR, TRIANGULAR TO SUIT THE DIMENSIONS OF THE FLOOR / ROOF
RISE AT CENTRE	:	ONE SIXTH OF THE CLEAR SPAN 6” TO 18” (FOR 3’-9’ SPANS)
SHELL MATERIAL (FOR A MASONRY SHELL)	:	BROKEN STONE PIECES OF 1”-2” THICKNESS BRICK TILES (1.5”-2”) OF AT LEAST 50 KG/ CM^2 COMPRESSIVE STRENGTH
REINFORCEMENT	:	NO REINFORCEMENT IS NEEDED IN A MASONRY FUNICULAR SHELL
TOPPING MORTAR	:	RICH CEMENT-SAND MORTAR OF 1:2 RATIO OVER THE MASONRY SHELL

Edge Beam (cast as a grid of beams)

REINFORCEMENT:		A PRE-WELDED BEAM WITH TRIANGULATED STIFFENERS ON ALL SIDES WITH 6 MM BARS (AS SHOWN IN THE FIGURE).THE BEAM IS TO BE DESIGNED AS PER SPAN
CROSS SECTION	:	9” X 9” (FOR A 9” THICK MASONRY) CAN BE COMMONLY USED
CONCRETE MIX	:	M 20 IN-SITU CONCRETE FOR THE BEAM AS WELL AS IN THE VALLEY BETWEEN ADJACENT SHELLS

CONSTRUCTION