FIRST LIGHT PAVILION - CONCRETE SHELL

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The First Light Pavilion is to be a concrete shell structure that contains a new visitor centre at Jodrell Bank Centre for Astrophysics outside Manchester. The shell roof is to be covered in soil and to be accessible to the public. The First Light Pavilion is designed by Hassell Architects and I was working on the structural design up to stage 4 as part of Atelier One.

The first light pavilion is a 200 mm thick, 50 m diameter reinforced concrete shell roof. The shell is made more complicated by its loading, the size, the thickness and the shallow curvature. It is the first large scale shell structure to be built in UK in the last 25 years and very few precedents are present of this scale around the world.

Figure 1. Render (Image credit: Hassell Architects)

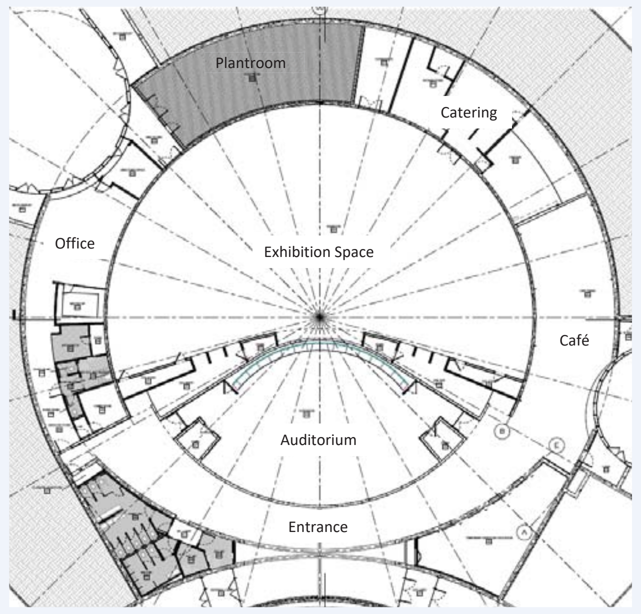


Figure 2. Floor plan

Figure 3. Photo from site

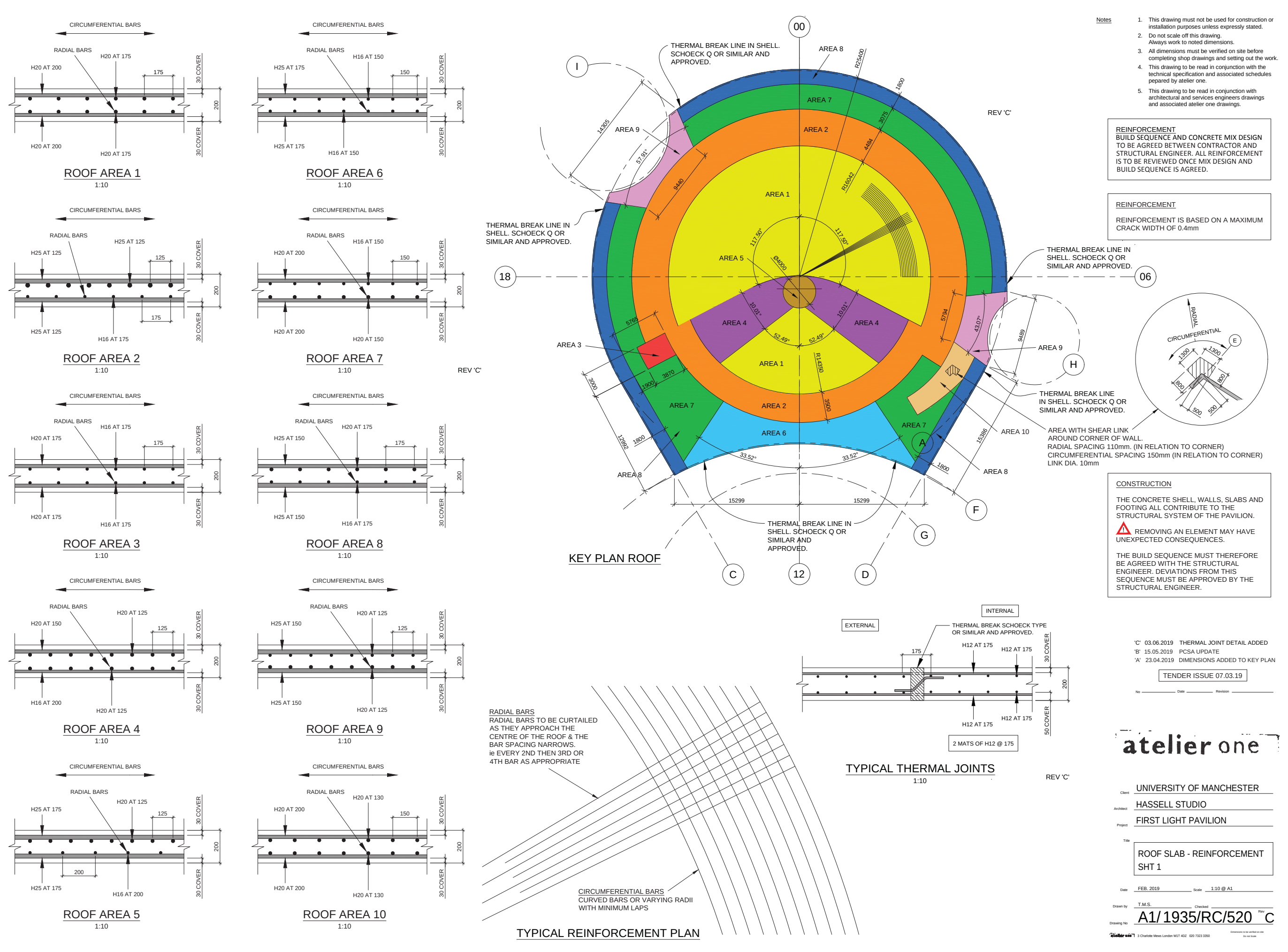


Figure 4. Reinforcement zones

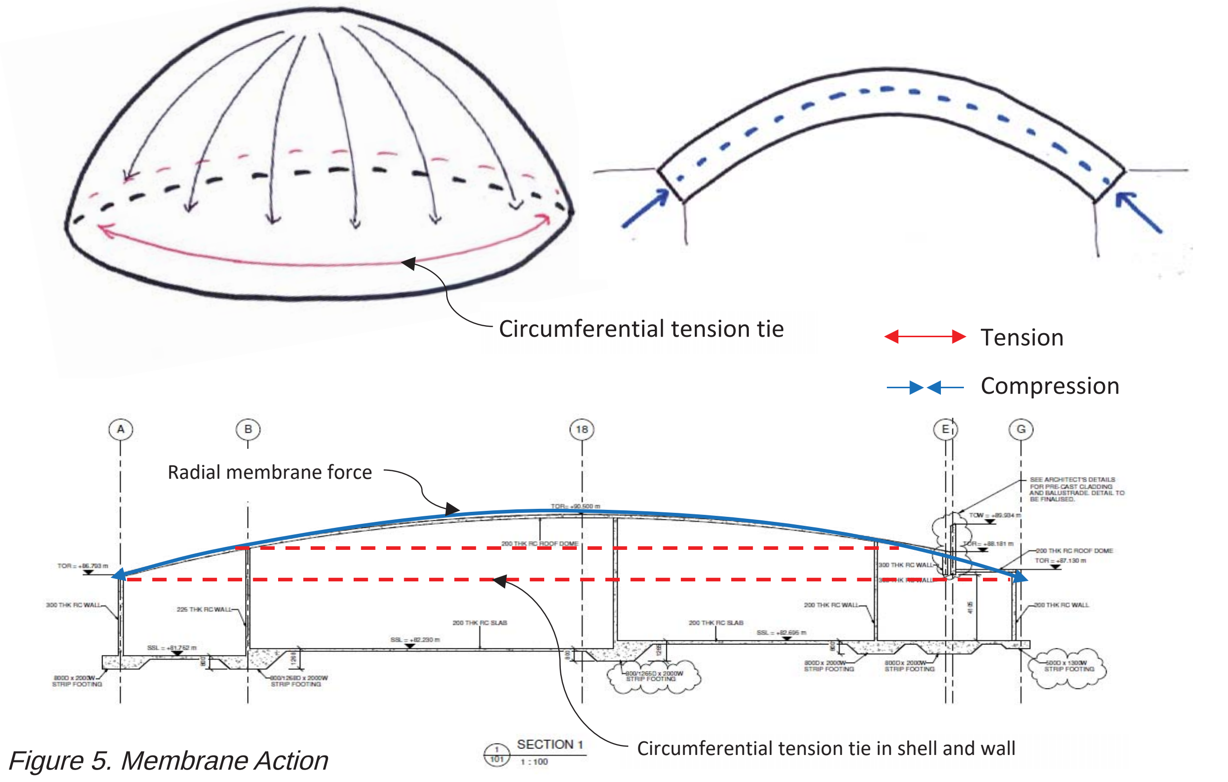


Figure 5. Membrane Action

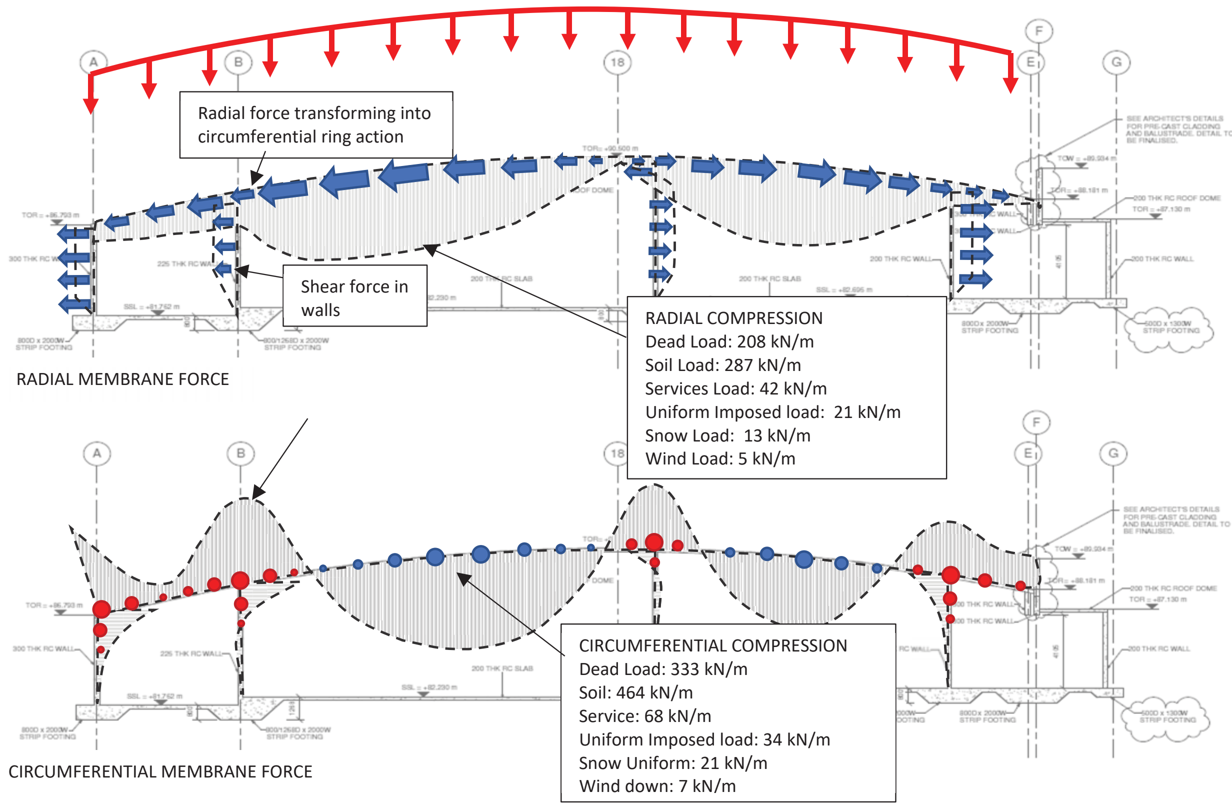


Figure 6. Magnitude of Membrane Forces

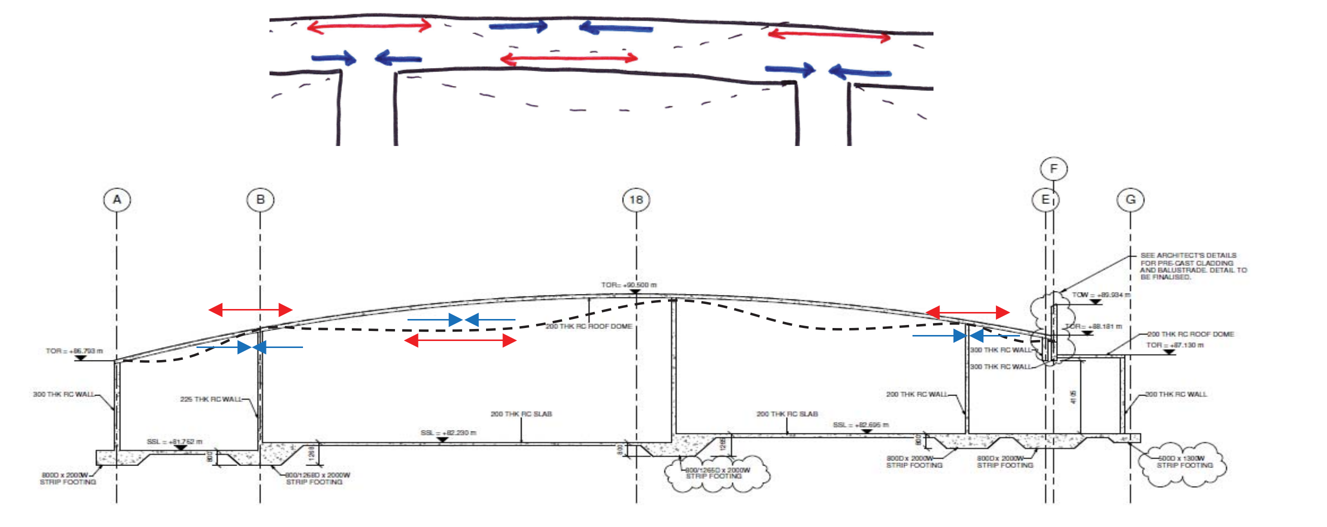


Figure 7. Slab Action

A bespoke analysis and strategy of load paths and structural behaviour was required for this project since the structure is one of a kind. The low curvature of the shell structure was a major challenge since it resulted in the structure partly working as a shell in membrane action and partly as a slab in bending. To understand the exact behaviour of the structure, and the proportion of slab action versus shell action and how this is affected by the cracking behaviour and non-linearity of the material, a complex non-linear material behaviour analysis was required. The shallow dome also causes large thrust forces which do not occur in a standard project. The circumferential reinforcement in the shell as well as in the circular walls was designed to deal with these forces and tie the structure together.

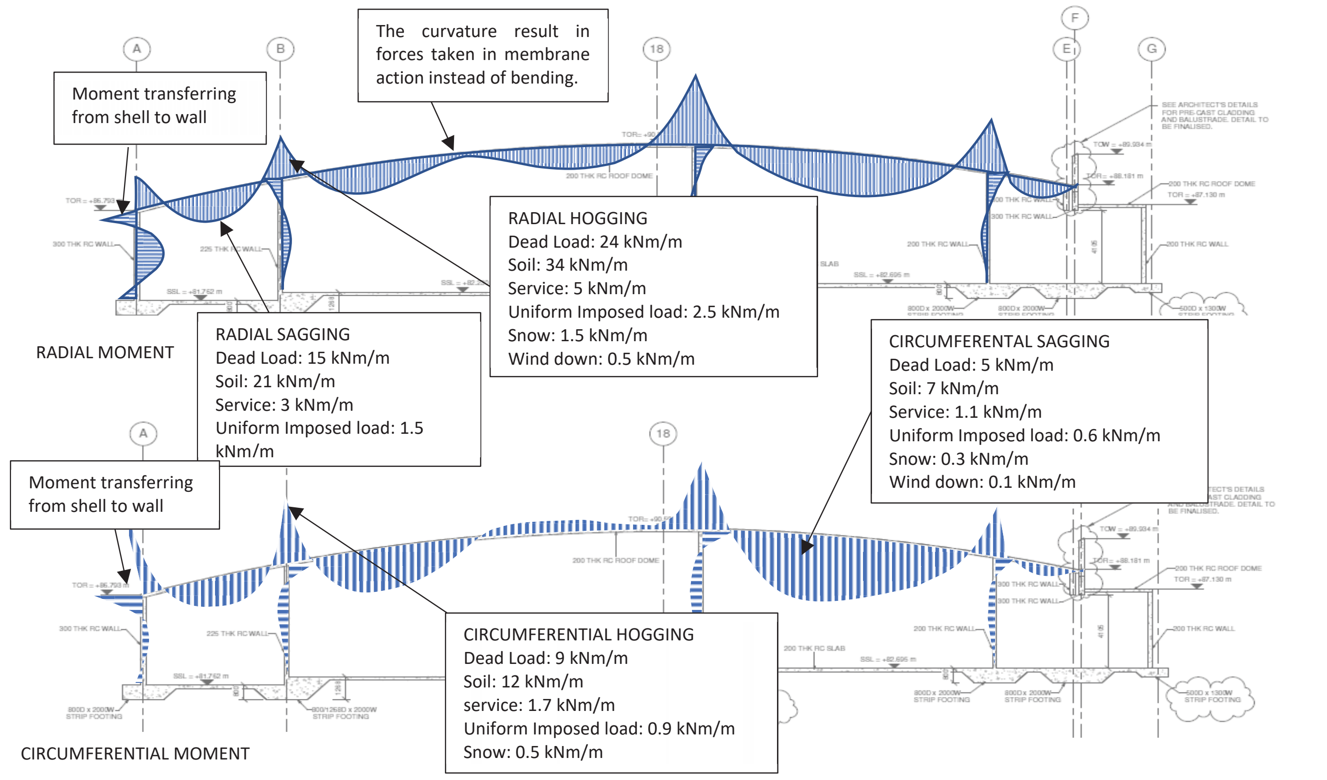


Figure 8. Magnitude of Bending Moments

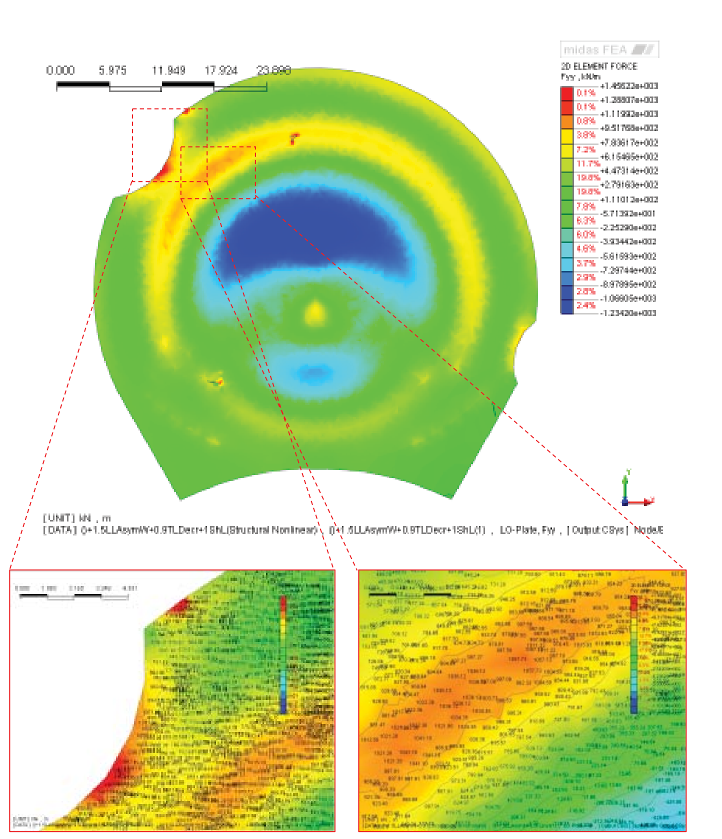


Figure 9. Circumferential Membrane Forces in Midas FEA

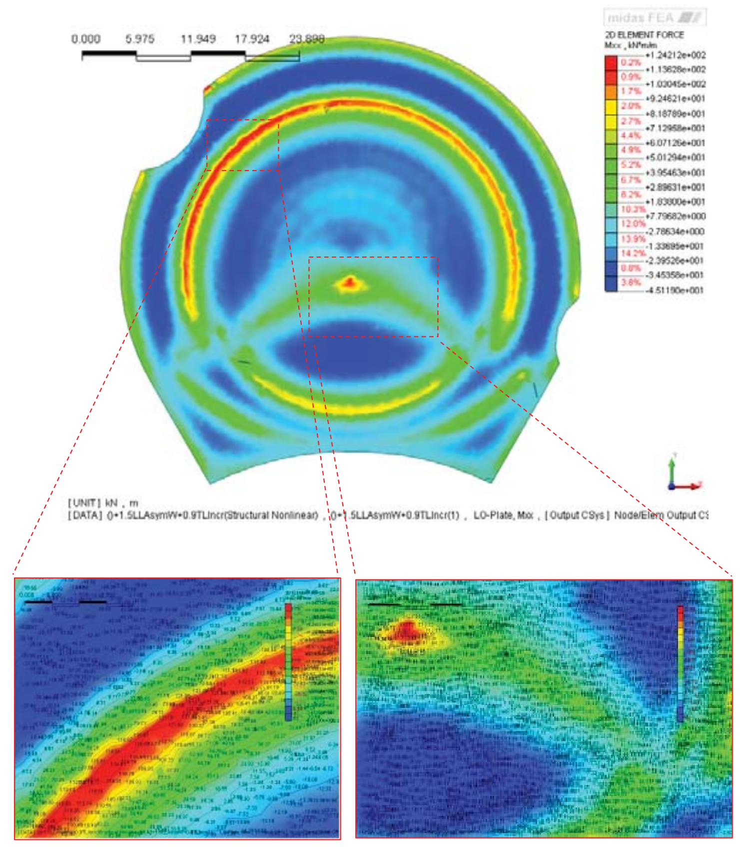
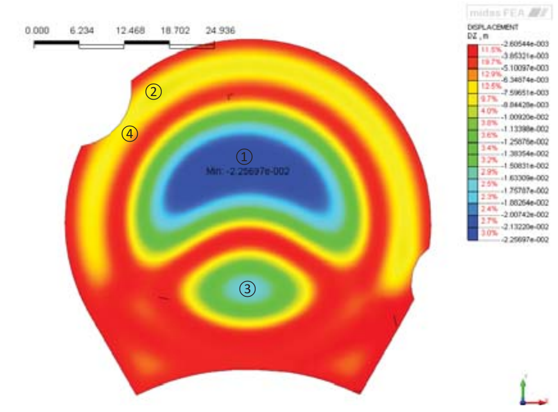


Figure 10. Radial Moment in Midas FEA

The shell was analysed in two separate Software analysis packages, Autodesk Robot and Midas FEA, to verify the behaviour. Midas FEA has the possibility to consider non-linear material properties by automatically taking cracking into account but is normally used to verify smaller extracts of a structure since it is a heavy software not fully suitable for large scale models. Robot does not have the ability to consider non-linear material behaviour but works well with large models and produces fast results. A procedure for modelling the full structure in a simplified way to verify the cracking behaviour in the two software programs was created.



		LOCATION 1	LOCATION 2	LOCATION 3	LOCATION 4
Deflection	DL	23 mm	8 mm	17 mm	7 mm
	TOT	29 mm	12 mm	22 mm	10 mm
Deflection limit l/500		40 mm	15 mm	35 mm	15 mm

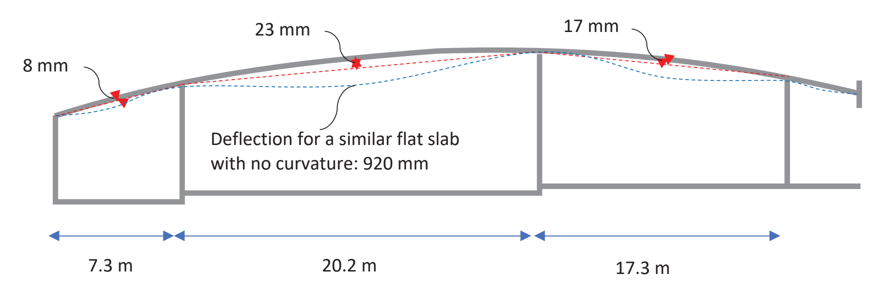


Figure 11. Deflection under Dead Load and Soil Load

Making use of shell action enables the structural concrete shell to be very thin since a load path in pure tension and compression is much more efficient than a structure working in bending. The span to depth ratio is as high as 250 which means an incredibly slender structure. Additionally the deflections of the First Light Pavilion shell are only 2.5% compared to a similarly spanning flat slab without curvature. The variable properties of reinforced concrete also make it possible to adapt capacity exactly where it is needed by adapting the reinforcement layout. The reinforcement for the First Light Pavilion is divided into zones based on the moment and membrane force plots. All of this together makes the structure exceptionally material efficient and is thereby contributing to reduced consumption of natural resources.