Shell Structures from Catalan to Mapungubwe

Lessons from Structural Efficiency for Sustainable Construction in Developing Countries

MR. KAVINDA ISURU UDAYANGA NANAYAKKARA

Postal Address	32, Keells Houses, Bomiriya, Kaduwela 10640, SRI LANKA
email	isuru_nanayakkara@live.com
IStructE Membership No	088381203
Date of Birth	23 August 1989

1. INTRODUCTION

In a world moving towards a sustainable earth, the developing world is faced with the dilemma of rapid expansion of housing and infrastructure needs on the one hand and the constraints of sustainability on the other. However, a closer look at local strengths and technology elsewhere can lead to creative solutions. Mapungubwe National Park Centre by Peter Rich Architects is one case study where the solution masterfully incorporates local socio-economic strengths and needs.

There is evidence of a rich architectural and construction tradition in Sri Lanka during the Middle Ages and early European Renaissance. Due to constant foreign invasions – by both South Indian Cholas and European colonists – local architectural developments stagnated. Once parts of the island fell to the European powers, their architecture and technology was introduced as "a better solution" without proper recognition for the local culture or climate. This is probably true of many other parts of the developing world.

In the hyper connected world of the 21st Century we need not wait for the trial and error development of a local solution. We can identify a potential solution from across the world and adapt it to the local conditions, making the development much faster.

Shells are a more efficient structural form than the widely used column-beam frames, which make use of bending strength and hence underutilize the structural capacity of members. Superior structural efficiency allows for shell structures to be lightweight and thus reduces the material demand. The wide range of possible material solutions – from compressed earth to concrete - allow for an appropriate local material to be used in the realization of the structural form.

Wattle and daub is the traditional housing construction methodology in Sri Lanka, and it has seen renewed interest from researchers as a low cost and sustainable housing solution. Catalan vaulting is a Mediterranean technology which could be incorporated with the local solutions currently being developed to come up with a fully earthen housing unit. However, a successful implementation of the technology would require a carefully developed strategy to make use of prevailing socio-economic conditions.

In this context I am proposing to study thin shell construction technologies with specific focus on Catalan vaulting. The study would also explore new frontiers in lightweight shell construction to scope out potential future growth. A socio-cultural assessment of Catalan vaults would give a better understanding as to how the technology can be appropriated to other local contexts. To make use of shell construction in Sri Lanka (for example) a local solution needs to be found, but the clues will lie within what the rest of the world is doing.

2. OBJECTIVES

There are three main objectives of the proposed travel;

1. Explore existing shell structures - including Catalan vaulting and its adaptations- to learn about construction, maintenance and socio-economic implications and interplays of these building technologies
2. Learn new theories, technologies and other developments related to the analysis and construction of thin shell structures
3. Gain practical experience in constructing thin shell structures. This would give a better understanding of both structural mechanics and construction aspects of the technology

3. OUTCOMES

The learnings form the proposed travel will be compiled as a technical report of 5000-10000 words, including photographs, sketches, etc. In addition I plan to document the travel as a series of video logs (vlogs) which can be published on social media (e.g. YouTube). Both these documentation types will be used to spur local research and general interest into thin shell structures for both niche architecture and common housing, in Sri Lanka and elsewhere.

4. TRAVEL PLAN

A travel plan is proposed with four primary stops; Barcelona in Spain, Zurich in Switzerland, Stuttgart in Germany and Auroville in India. Each stop is decided to meet specific requirements and objectives.

3.1. Barcelona, SPAIN

Barcelona - the capital of Catalonia - is the breeding place of Catalan vaults, and houses masterpieces of Catalan vaults by the likes of Antonio Gaudi, Lluís Domènech i Montaner and Rafael Guastavino. Catalan vaulting is not only used in iconic projects such as La Sagrada Familia, Casa Mila or Colonia Güell, but also as ceiling cum floor structures for domestic dwellings in Barcelona.

While in Barcelona, I plan to visit both public spaces and housing units which have incorporated Catalan vaulting technology. The aims of the visits are; (i) to identify/appreciate the structural system, the construction technology, and maintenance of the structure; and (ii) to appreciate how the existence of Catalan vaulting has influenced the society (employment, tourism, property values, heritage, etc.,) and vice versa (e.g. how socio-cultural and environmental forces have promoted such vaulting).

In addition to information, photographs, etc., collected during the visits, interviews with local architects are planned, to get more insights into both construction-maintenance aspects and socio-cultural aspects of Catalan vaulting.

3.2. Swiss Federal Institute of Technology (ETH), Zurich, SWITZERLAND

The Block Research Group (BRG) at ETH Zurich, led by Professor Philippe Block, is a world leading research group in computational form-finding, digital fabrication and construction technologies of compression only structural forms.

During my proposed stay at the BRG at ETH Zurich I expect to make use of their expertise and cutting-edge facilities to expand my knowledge in analysis and construction of thin shelled structures. The activities planned at ETH, Zurich are aimed at achieving the following;

i. a thorough study of form finding and form exploration techniques developed at BRG
ii. study and experience cutting-edge construction and physical modelling methods
iii. explore how different material solutions have been integrated with compression-only forms
iv. visit (where possible), study and discuss various projects conducted by ETH Zurich, both at ETH and elsewhere

At the end of the stay at ETH Zurich I will be presenting my work to a weekly group meeting of the BRG.

3.3. The Institute for Lightweight Structures and Conceptual Design (ILEK), Stuttgart, GERMANY

Following the footsteps of Professors Frei Otto and Jörg Schlaich and currently chaired by Professor Werner Sobek, ILEK at the University of Stuttgart is a world leading research and design establishment in lightweight structures. With a highly interdisciplinary team ILEK develops building technologies and structural systems for lightweight structures using a wide range of materials.

The aim of my stay at ILEK-Stuttgart is to explore the new frontiers in lightweight structures and optimization for environmental sustainability. The main topics to be covered are;

i. Comparison of different material solutions (textile / glass / steel / pre-stressed concrete) in light-weight structures
ii. Optimization of forms for energy and resource consumption, durability and reliability, recycling potential and environmental sustainability
iii. New frontiers in smart shells, adaptive shells and rapidly deployable grid shell domes

3.4. Auroville Earth Institute (AVEI), Auroville, INDIA

Auroville, established in 1968, is a universal township situated in southern India. It is an internationally endorsed living experiment on human unity with concerns of and research into sustainable living, among various other topics.

The Auroville Earth Institute (AVEI) is the representative for Asia of the UNESCO Chair "Earthen Architecture, Constructive Cultures and Sustainable Development" and acts as a resource centre and research establishment for the development, promotion and transfer of earth-based building technologies.

I would be following their two week training program on arches, vaults and domes. The first week is a theory based study of arches, vaults and domes covering both structural and architectural aspects (symbolism and history). The second week is an intensive practical course on construction of arches, domes and vaults using Compressed Stabilised Earth Blocks (CSEB).

3.5. Supplementary Activities

Before embarking on the above travel, I will be traveling to the USA for the IASS symposium 2018. As part of the conference I will be visiting Rafael Guastavino's Catalan vaulted structures in Boston. This would be a precursor to the activities mentioned above.

Furthermore, I will be contacting Prof Peter Rich, the architect behind the vaulted structures constructed for the Mapungubwe National Park Visitor Center to get insights on their project and discuss the socio-economic aspects of the project. Although originally considered, it was decided not to visit the actual structure as the cost is too prohibitive for a short visit.

5. ITINERARY

#	Date	Day	Activity	Place
0	26 August	Monday	Travel from Colombo to Barcelona	
1	27 August	Tuesday		
2	28 August	Wednesday	Field visits [Casa Batlo/ Casa Mila/ Casa Fuster/ La Sagrada Familia/ Santa Pau]	Barcelona
3	29 August	Thursday	Field visits [Park Guell/ Colonia Guell/ residential units with tile vaulting]	
4	30 August	Friday	Field visits and discussions [the Institute for Advanced Architecture of Catalonia]	
5	31 August	Saturday	Field visits [Teatro La Massa/ Fábrica Batlló in Villasa de Dalt] Meeting with Pep Brazo i Ramírez (an expert in Catalan vaulting)	
6	01 September	Sunday	Travel from Barcelona to Zurich	
7	02 September	Monday	Simple introductory projects Training on software [RhinoVAULT and COMPAS]	ETH, Zurich
8	03 September	Tuesday	Training on software (ctd.)	
9	04 September	Wednesday	Scale model test	
10	06 September	Thursday	Digital fabrication	
11	07 September	Friday	Project visits and discussions Presentation of findings	
12	08 September	Saturday	Break	
13	09 September	Sunday	Travel from Zurich to Stuttgart	
14	10 September	Monday	Production Techniques [lab visits/meeting researchers/referring to documentation]	ILEK, Stuttgart
15	11 September	Tuesday	Field visits [The ILEK tent/ a prototype of the German Pavilion for the Montreal Expo 1967, Canada / The glass shell / The Stuttgart Smartshell / shells at Stadtmitte Campus and Natural Science Museum]	
16	12 September	Wednesday	Production Techniques (ctd.)	
17	13 September	Thursday	Software implementations	
18	14 September	Friday	Build a project	
19	15 September	Saturday	Discussions and meetings Presentation on findings	
20	16 September	Sunday	Travel from Stuttgart to Auroville	
21	17 September	Monday	An in-depth review of structural basics and various analysis methods for the stability of arches, vaults and domes with lectures, presentations, case studies and practical exercises	Auroville, India
22	18 September	Tuesday		
23	19 September	Wednesday		
24	20 September	Thursday		
25	21 September	Friday	Performing stability studies of vaults/ dome sections [case studies]	
26	22 September	Saturday		
27	23 September	Sunday	Break	
28	24 September	Monday	Study construction principles and techniques Build various types and scales of arches, vaults and domes using of Compressed Stabilised Earth Block (CSEB)	
29	25 September	Tuesday		
30	26 September	Wednesday		
31	27 September	Thursday		
32	28 September	Friday		
33	29 September	Saturday		
34	30 September	Sunday	Travel from Auroville to Colombo	

6. ESTIMATED EXPENSES

		Per day (GBP)	(GBP)	sub-total (GBP)	Notes
Lodging:					
	Barcelona	75.00	375.00		2 star hotel
	Zurich		335.00		Student hostel
	Stuttgart		250.00		International student hotel
	Auroville	-	-	960.00	Included in registration
Food:					
	Barcelona				
	Breakfast	5.00	25.00		
	Lunch	10.00	50.00		
	Dinner	15.00	75.00		
	Zurich				
	Breakfast		5.00		Provided Mon-Fri
	Lunch	20.00	140.00		University catering
	Dinner	10.00	70.00		Self-prepared
	Stuttgart				
	Breakfast	-	-		Included in lodging
	Lunch	06.00	42.00		University catering
	Dinner	15.00	105.00		
	Auroville	-	-	512.00	Included in registration
Travel (local):					
	Barcelona				
	Barcelona Card		10.00		T-10 card
	Zurich				
	Airport to city and return		12.00		
	Daily commute				Free Shuttle
	Site visit to Dübendorf		10.00		
	Stuttgart				
	Airport to city and return		7.00		
	Public transportation		35.00		
	Auroville				
	Airport to city and return		80.00	154.00	
Travel (international):					
	Colombo to Barcelona		465.00		SriLankan Airlines
	Barcelona to Zurich		73.00		Swiss International Airlines
	Zurich to Stuttgart		82.00		Austrian Airlines
	Stuttgart to Chennai		490.00		KLM/ Jet Airways
	Chennai to Colombo		55.00	1165.00	Air India
Activity related expenses:					
	Barcelona				
	Entrance fees		115.00		
	Zurich				
	Consumables for 3D prototype		265.00		
	Auroville				
	Registration for training course		310.00	690.00	
Stationary and other consumables:					
	Note books, pens, etc.		20.00		
	Communication		20.00	40.00	WorldSIM
VISA fees:					
	Schengen VISA		54.00		
	India VISA		50.00		
	Travel insurance		28.00	132.00	
Contingencies				347.00	Approx. 10% of total
	TOTAL			4000.00	

7. CONTACT POINTS

7.1. Barcelona, Spain

Pep Brazo i Ramírez

Technical Architect at URCOTEX, Barcelona

+34 646 471 628

David López López

MAP13 Architects and Block Research Group at ETH, Zurich

lopez@arch.ethz.ch

+41 44 633 08 44

7.2. ETH, Zurich*

Dr. Noelle Paulson

Block Research Group at Eidgenössische Technische Hochschule (ETH), Zurich

paulson@arch.ethz.ch

+41 44 633 38 35

7.3. ILEK, Stuttgart*

Dr.-Ing. Traian-Nicu Toader

Institute of Lightweight Structures and Conceptual Design (ILEK) at University of Stuttgart

traian-nicu.toader@ilek.uni-stuttgart.de

+49 711 685 63765

7.4. Auroville, India

Saravanan

Training courses coordinator at Auroville Earth Institute

training@earth-auroville.com

+91 413 262 3330

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* Letters are received from these institutions agreeing to host me as a visiting student, and are provided as annexures to this document