

## SUSTAINABLE ADVANCED CONSTRUCTION TECHNOLOGIES

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### Abstract

Advanced Construction Technologies (ACTs) are set to become the sustainable mainstay of the construction industry due to the demand for innovative housing solutions. Like most emerging economies, South Africa from a historical perspective and global trends in rural-to-urban migration, suffers an enormous service backlog and challenges in achieving millennium development goals of housing settlements. Current growth in ACTs is a result of advances in material science, building components production and assembly technologies. Ongoing commercialization of these technologies will improve building performance, reduce environmental impact and lead the growth of sustainable human habitats. The next-generation materials are mainly led by the polymeric-fiber based products, light-metals alloys, with high performance with qualities such high tensile and compressive strengths. Computerization of designs of building structures now allows the conceptualization on platforms that offer virtual modeling, simulation and optimization. Inadvertently this makes it easy to construct building structures faster than the traditional building methods relying on brick and mortar. New leaner, stronger, energy efficient buildings are constructed using ACTs that adopt line production techniques that are the backbone of industries such as the car manufacturing industry. Modular houses are designed and prefabricated away from site and assembled like Lego<sup>®</sup> prinzipts. Eco-Materials are also redefined and transformed with set standards and automated industrial production of building components using raw materials such as earth; prefabricated earth beams, columns and wall and floor panels fiber reinforced. Effective project management and logistics shall play an imperative role on speed and cost of modular construction housing in the future.

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## **1. Background**

About one billion people in the South or developing world who constitute about 40-50 percent of the urban population dwell in shacks or squatter camps that are generally defined as informal settlements or slums. In the SADC region alone, SA has an estimated informal settlement population of 4.5 million. The government's housing statistics backlog is about 3m, with Eastern Cape Province (one of the ten national) needing about 800 000 units. Zimbabwe in 2005 had a formal housing backlog of 2 million just before the Operation "Murambatsvina" (Discarding the Filth: see Figure 1) which then swelled by over 10%. Mozambique in 2007 had over 70% of its population of about 25 million in need of decent housing, both in rural and urban. In Cape Town (SA) informal settlements are growing by about 10% each year.<sup>[10]</sup>



**Figure 1:** Operation Murambatsvina, Harare, 2005 [IRIN, UN]

There are sustainability challenges existing in present day SA regarding housing delivery, which are driven by economic, social and environmental factors such as:

- **Housing Backlog about 2.2m**

Housing backlog can be said to be higher than official count of 2.2m due to increased inter-regional migration from for example neighbouring Zimbabwe and countries as far away as Somalia. Inadequate supply of low cost RDP (Reconstruction Development Programme) housing accompanied by poor service delivery is largely credited to the xenophobic attacks on foreign nationals experienced early 2008. This resulted to huge internal population displacement of foreigners and effects of that are still felt today.



**Figure 2:** Reiger Park Informal Settlement, Johannesburg, 2008 [UNESCO COURIER]

- **Electricity Supply and Demand**

Already SA and SADC regional countries have a huge energy supply side deficit i.e. electricity generation. In 2008 ESKOM the SA power utility supply company introduced electricity load-shedding. Statistics for SA show it needs 41 539 MW by 2013: renewable to provide 1 667 MW (4%) by 2013. About 44% of SA households do not use electricity for cooking but fossil fuels such as wood and about 20% of SA households do not use electricity for lighting.<sup>[10]</sup>

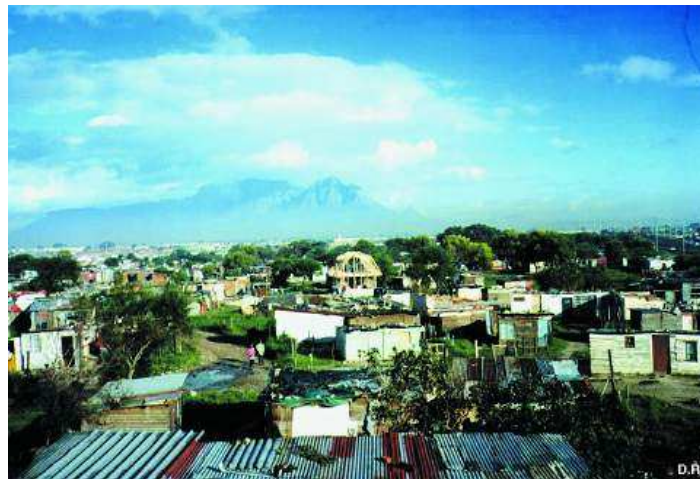
- **Water Supply and Demand in SA (water stress)**

*“Up to 1000 people from informal settlements could be using the contaminated water. Greenbelts, dams, wetlands and a canal that hundreds of people in an informal settlement use for washing, have been identified as radioactive or toxic — within 100km of South Africa’s biggest city. Fifteen sites close to Johannesburg have been named in a 210-page report as being toxic. Some register radiation levels 200 times the legal limit. Long-term exposure to toxic chemicals and radioactivity has serious health side effects and may cause cancer. However, the pollution could be far worse than the report suggests, according to one of the authors, Professor Frank Winde. He said the document should be used as a basis for further studies.”* The Sunday Times, SA.19 July,2009. About 12 – 14 m people in SA alone have no access to clean, safe water and over 20m have no adequate sanitation.

- **Global Warming Impacts on South Africa**

Climate change causes less precipitation generally in some parts of SA but also increased rainfall with flash flood in some. Informal settlements especially along the coast e.g. in Cape Town suffer perennial flooding and destructions of their shacks.

Other factors such as land distribution, Legislation, standards and norms and political and economical instability in form war, famine and flooding affect sustainability.



**Figure 3:** Cape Town informal Settlements [UNESCO COURIER]

Back in the late 1980s, Dr J. Nyerere, then Tanzanian President commented in frustration:- *“The widespread addiction to cement and tin roofs is a kind of mental paralysis.”* Again David Ismail, Zambia in his 1990 paper titled "Retention of the traditional values of Africa Earth Architecture" wrote: *“The critical shortage of housing countries in Africa today. Severe economic restraints,*

*coupled with unimaginative and ill-directed policies by developers have created hectares of sterile concrete block units unaffordable to the average worker.”<sup>[10]</sup>*

Advanced construction technologies (ACTs) as fast prefabricated construction system can resolve the housing and infrastructure shortages due to their rapid pace of erection. **Are ACTs the solution to allow for sustainable construction in future for SADC region and SA in particular?**



**Figure 4:** Xenophobia Attack Victims, Germiston, Johannesburg, RSA, 06.2008 (AP/Temba Hadebe)

## 2. Introduction

ACTs are an adaptation of modular construction techniques from the process industry which is tailored to large production plants. The system combines the advantages of factory offsite construction with the benefits of modular construction. ACTs mimic the ordinary procedures of process plant construction yet provide the advantages of traditional skid units. Modules are assembled from subcomponents built in specialty shops. The components are then moved to the assembly floor where the module is constructed at floor level. This technique produces plants that have appropriate access for operations and maintenance. Two systems from German and Austria are used as examples in this paper. These technologies were used in Germany for the World Cup in 2006 to build Macdonald Restaurants etc. These firms include MMM (Muenchener Medizin, Mechanik) GMBH, Germany for steel frame polystyrene insulated building technology for housing, schools and fully equipped hospitals, Geiger, Compaktbau Raumsysteme and MSL Modular System.

## 3. Current Construction Operation Systems

There are basically three different ways to classify building of houses:

- Conventional
- Elemental or panel prefabrication
- Modular also known as volumetric units prefabrication

Table 1 summarizes existing technologies in the SADC region, which have to date, for a plethora of reasons failed to adequately achieve desired housing delivery. These are mostly a mixture of

the conventional/traditional and elemental prefabricated technologies. Industrial product driven technologies are less applied relative to distances from the cities or reliable trunk road networks.

**Table 1: Matrice of Low Cost Technologies in Zimbabwe and SADC Region<sup>[10]</sup>**

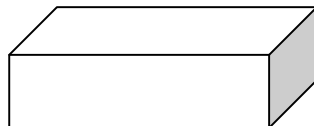
SYSTEM	COMPOSITION	DIS/ADVANTAGES
1. Frametech	Gypsum panel boards	Standards / Easy, fast construction
2. Frametech	Concrete / Wire Mesh (durawall)	Standards / Easy, fast construction
3. Frametech	Wood panels	Standards / Easy, fast construction
4. Wood Cabins	Wood planks / boards	Standards / Easy, fast construction
5. SSB / CB	Earth cement / Earth	Quality of product
6. SFB	Earth, Agric waste, (Saw Dust, Bagasse, cement, Pozzolana)	Quality / Easy, fast construction
7. Rammed Earth	Earth / Cement	Quality / Easy fast construction
8. MCR Tiles	Cement, Sand, BFS	Quality, Cheap
9. Earth Domes / Vaults	Earth Bricks	Quality, Climate Stability
10. Reinforced Earth	Grass, Bamboo, Wood, Earth	Standards, Easy, fast construction
11. Concrete Blocks	Cement, Sand, PFA	Quality / Easy, fast construction

#### 4. Principles of Modular Building

According to Michel Shwarz of Arch – Nova modular building can be divided into four basic steps which are as follows:

##### a. Modular Basic Cell

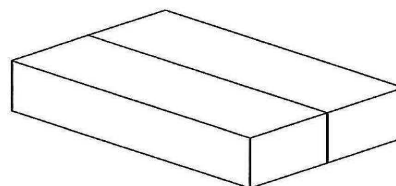
A modular basic cell describes the smallest (factory fabricated) volumetric unit of a building. It is a rectangular with structural skeletal wall system covered in wall cladding to a specific size.



**Figure 5:** Basic Cell[,Michael Shwarz,04.2008]

##### b. Horizontal Addition

The basic cells can be added to make buildings. A room does not have to be equal to a module or cell. Several modules can build one room as well.



**Figure 6:** Horizontal addition [Michael Shwarz, 04.2008]

##### c. 3 Design and Dimensional Addition

Architectural design focuses on addition and 3 dimensional alignment. This allows creation of more complex buildings such as hospitals, hotels, office buildings or student apartments, even

barracks. The different floors can be reached by internal stairs made up of modules or prefabricated steel or concrete construction panels that are then added on site.

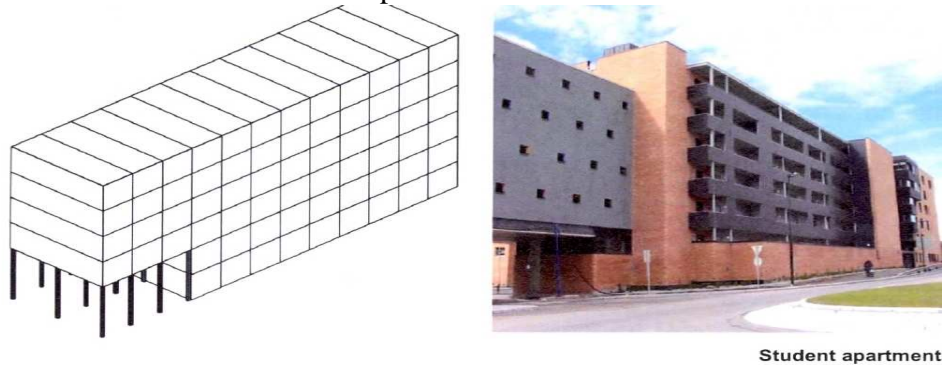


Figure 7: Student Apartment, Norway, [Michael Shwarz,04.2008]

Accommodation of the troops is a challenge for any army. The uniformity and amount of repetition is very suitable for the modular design construction. The great speed of erection is very suitable for mobility of the army and structures can be added or subtracted in rapid response to logistical demands.



Figure 8: Barracks, [,Michael Shwarz,04.2008]

#### d. Individual Housing

Individual needs / solutions for housing can also be achieved through modular construction. Various Structures can be developed through increase in amounts in different module size.

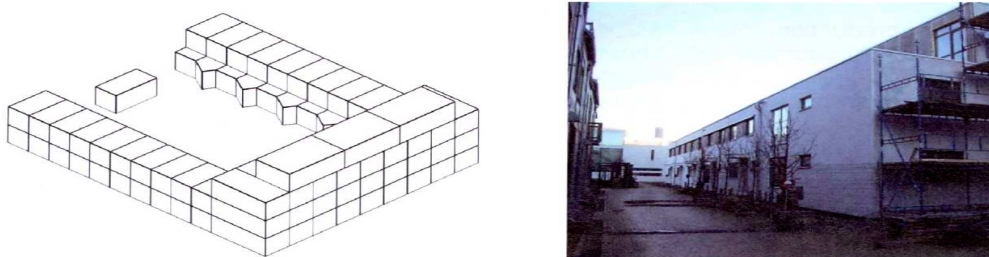
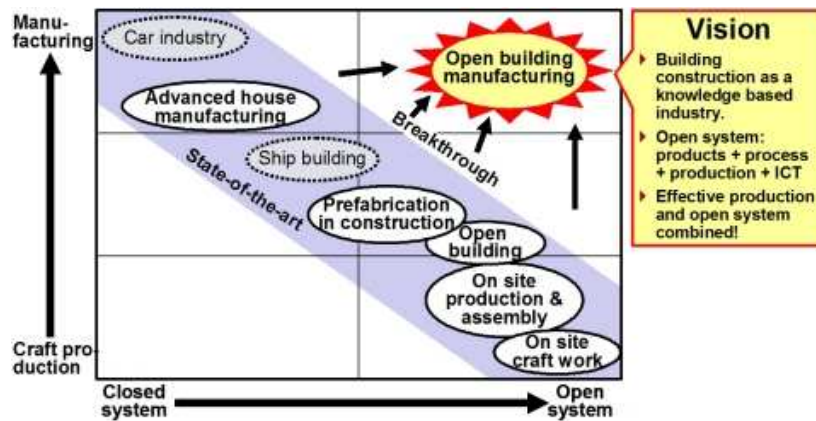


Figure 9: Apartment block [,Michael Shwarz,04.2008]

#### 5. ACT Strategy for Sa – ACTP

The ACTs Strategy for SA leans on the ECT (European Construction Technology) and is carried under the ACTP (European Construction Technology Platform) a national project under CSIR

since 2007. Various technologies are conceptualized, adopted and tests within the ACTP laboratory. The whole process is shown in Figure 10



**Figure 10:** Open Building Manufacturing, ACT for SA<sup>[10][11]</sup>

- **Vision:** “A future where customers will be able to purchase high quality manufactured buildings having a high degree of design flexibility and at low cost compared to today”  
Current Material Research Areas being carried out focus on advanced light metals, thin concrete and fibre composites using advanced production technologies, logistics, LCA and ICT.

## 6. Technology Acceptance Assessment – Challenges

The following is a summary of challenges to face any new technology in SA: -

- **Materials, Methods and Construction Industry Development**

The cement industry plays a leading role in SA construction by driving areas of research, standards and product development. Naturally the largest construction firms Murray and Robert, Group Five, Basil Read, WHBO and Grinaker LTA are mainly concrete builders or contractors. The construction method ranges from in-situ and precast concrete technology. SA construction industry employed about 543 686 people and had an income of R174 471 m in 2007. Due to 2010 World Cup there has been a huge increase in both employment and income figures.

- **Low R&D investment and level of technology use by sector**

Due to SA’s history and accompanying legislation there is /was low level of technology uptake. The self protection tendency and creation of entry barriers within the industry has led also to low R & D investment. The process of registering new housing technology in SA is an innovation entry barrier i.e. it is very complicated bureaucratic process managed through the NBRC (National Home Builders Registration Council) and a technology assessor Agrément SA.

- **Low skills levels**

As mentioned above the historical perspective in SA and ‘laager’ siege apartheid mentality inherited in statues and regulatory framework passively and actively still play a role in the slow uptake of technology in the country. The framework views external innovation and expertise as patently inferior until assessed internally (this assumes the expertise to do so is always ahead) or prior multi-lateral mutual technical exchange agreements exist between SA

and source country. In general, it can be said attitudes towards collaboration, skills and building systems technology transfer in most cases is about 10 years behind. ECSA (national engineering body for professional registration) has proved a stumbling block to transformation and diversity for expatriate engineers and researchers trained elsewhere even from the first world (EU, USA, Japan, Russia etc.). The historically disadvantaged majority of the black population lack basic education and cannot read or communicate in any other language apart from their mother language.

The New ANC government after 1994 took away the system of apprenticeship or artisanship there robbing the industry of a cornerstone in technology acceptance and implementation.

- **Informal Settlements Policy/Legislation (Protection from Eviction)**

Informal settlements are built mostly in corrugated iron sheets, plastic sheets and cardboard boxes supported by tied up timber or iron poles structure, which at times is covered with wire-mesh. Most these shacks used to house migrant workers from within South African and those from neighboring countries. Since 1996 there is a legislation which does not allow eviction or forceful removal of such settlements without offer of alternative habitat/dwelling. It must be noted that access to housing is a basic right enshrined in the South African Constitution. Most shack dwellers build using waste or recycled material which is very cheap and are averse to spending, new technology therefore has to be very, very cheap or for free.

- **Migration, mining development patterns**

The patterns of migration (mostly economic) in the SADC region is such that the sense of permanent house or abode was never a priority, one had a roots; a home to go back to somewhere. Not surprisingly in large mining towns migrant labour were put up either in dormitories, hostels or in shacks. For mine owners and employees a mine is was a temporary place to stay. Any investment in much more durable structures and sustainable settlements was considered a waste of resources. History is littered with examples in SADC region where mining towns and infrastructure were literally bombed out after the end of the mine life.

- **Land Redistribution**

SADC countries Zimbabwe, SA, Namibia are involved in one form of land distribution or another whereby peasant farmers are being resettled in more arable lands. In most cases these farmers are very poor and have no money. Left to build own houses, they build with local materials their first abode, mostly pole and dagga and grass or reeds.

- **Costs – logistics, Transport Infrastructure, Maintenance**

Transport infrastructure in many SADC countries ranges from modest to poor in particular after the liberation wars most states have failed to invest adequately in roads and rail. In SA infrastructure is much modern in particular networks for city to city but there is poor accessibility for the rural destinations. Severe transport trauma exists for workers to travel to and from work. Most informal settlements in SA are not networked by road, electricity and even water. In Zimbabwe mostly resettled farmers have no reliable access roads to the markets or basic service centres.

## **7. Conclusion – Way Forward**

People in SADC countries e.g. SA have tended to use building materials within their locality unless otherwise forced to or given viable options. Figure 11 illustrates this for Boane near Maputo, Mozambique. This is particularly true for the rural areas and for the urban poor recycling or reuse of materials such as earth material as mud or brick, corrugated sheets, plastic etc. is the norm. The late Mrs Indira Gandhi, Prime Minister of India once said: *"All the new houses are built for energy consumption. They are hot in summer and cold in winter, whereas*



our old houses are not. So we have not only to have new technology, but to look to the old technology. There is much sense in what people have evolved over the years to suit their climate, their environment, their way of living. You can not keep all of it, because our way of living has changed, but I think a lot of it can be adopted and made different."<sup>[5]</sup>



**Figure 11:** Typical Pau-a-Pic Stone, Pole Dagga hut, Boane, 2006 <sup>[7][8]</sup>

Hassan Fathy "The father of contemporary Islamic Architecture" remarked on the cost of affordable housing: *"The cost of building present ugly town developments will drive us to build more beautiful homes in mud as this is all we can afford."* The onus is on all of us to define or redefine, implement and improve on low-cost building/construction/housing appropriate technology to suit our needs e.g. the reconstruction and development programme and national housing backlog challenge while at the same time being in harmony with the local climate.

#### Military use

Portable modular buildings offer a wide variety in the military use. Optimized sizes together with a high-tech interior offer the best and fastest possibility to support military operations. Soldier barracks, clinics, water treatment units or control rooms – the different fields of application are hardly limited.



**Figure 12; Modular Building Usage** [Michael Shwarz, 04.2008]

Modular systems offer an alternative for deliberate temporary settlement, as in war and disaster management, as depicted in figure 12. They in effect have higher carbon emission due to their production method and transport system. The high skills requirements and maintenance problems associated with the materials of this technology in an area already beset by shortages makes it difficult for it to dominate. Customized construction of quality rammed-earth, stabilised soil bricks, cast earth and eco-material structures for homes, business, and hospitality and landscaping projects will still be only viable construction for most rural population. Modular systems will service mainly cities.

Individual modular 40m<sup>2</sup> house in SA will cost at least US\$10 000 compared to conventional concrete block at US\$7 000, clay brick at US\$6 000 and SSB at US\$4000. However they attain low-cost leadership for compact dense settlements, apartment blocks three storey and higher. Modular systems open up ways or challenges to the traditional materials in the way the cement

industry technology assisted improvements for the earth building technology. The modular building system has one big negative impact however in that it pushes back the DIY (Do It Yourself) quite dramatically. The use of traditional, conventional building materials and technologies will continue to dominate the building sector sustained by mine and industrial waste. Modular building systems however will offer a life-cycle delivery advantage for authorities as institutional solutions for rapid settlement delivery, war and natural catastrophes such as reconstruction after flooding.

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