Infrastructure in the promised Land of the Future

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It is the year 2103; we are in the beautiful kingdom of Khushali – a remote island in an Asian archipelago which survived the last holocaust. World population has dwindled to a mere 2 billion. The air is fresh, the lakes and rivers sparkling with crystal clear waters full of fish and other marine creatures. It's almost like we are in paradise. There's a new life around.

About 40 years ago civilization had reached the brink of extinction. After the 3rd world war in 2047 which lasted a decade – fought mainly over water, life became miserable. Water became a rare commodity. People would get mugged in the streets for half a bottle of water. Gastro-intestinal infections from drinking too less water became the main cause of death. The average life expectancy fell down to 40. Most of the landscape became a desert – no precipitation, no trees, no fruits and no birds. And then a miracle happened.

The accumulated Green house gases escaped through the hole in the ozone layer – sucked away by an unknown pulsating star. Mother earth's fever began to ebb. Climate changed again – stabilized. Nature's fury died down, restoring old habitats and here we are in the 22nd century.

In the following paragraphs we will get a chance to sit in the time machine to visit Khushali as well as come back to the present, several times, to realise our follies and learn the tricks of a long lasting sustainable infrastructure. As a result of these travels, let's see how we can engineer the immediate future in our hands with the tools that are available to us from modern technology as well as traditional wisdom. If only we could learn and pick the appropriate tools – each one of us – the holocaust may well be averted.

> Infrastructure in its usual sense means the physical networks - basic services and facilities required by a society to function. Typically these include roads, bridges, water distribution systems, sanitary and waste water management systems, power production and distribution systems, telecommunication systems as well as other basic facilities like hospitals, schools etc.

The adjective – "Green" pertains to environment-friendliness and long term sustainability.

As mankind realizes its ugly footprint on the environment - the growing imbalance being created from its so called "progress", there is a luke warm effort to mitigate the negative impacts so generated. The adjective "Green" therefore finds easy use in almost everything we do. Hence the term Green Infrastructure seeks to design and build the society's support systems in such a way so as to be least disturbing to the environment, tight-fisted on resources as well as being sustainable in the long run.

Sustainable Concrete

The most widely used material for construction is concrete. It is also used more than any other man-made material in the world, popular because of its versatility, weather resistance and economy. The world's vast infrastructure, tall reinforced concrete buildings, road and highway pavements, bridges, airport runways, dams, power houses, railway line sleepers, train station buildings, underground pipes for water supply & sewerage and support structures for all these use concrete. Unfortunately, Portland cement - the critical component of modern-day concrete is not so environment friendly. Every ton of cement produced also releases approximately a ton of CO_2 in the atmosphere – the main greenhouse gas. With infrastructure expansion plans estimated in billions of dollars in the developing world it would seem a terrible oversight if we do not look at greening our concrete. Fortunately the high performance, sustainable concrete for the 21st century HVFAC is already available but unfortunately it is largely unknown to many. High Volume Fly Ash Concrete – as the name suggests is a specially designed concrete containing high volumes of fly ash, lower water/cement ratio, chemical admixtures and much reduced portland cement. The four major advantages of this concrete include:

- Uses nearly half the cement thereby reducing emissions from cement production to half, hence is more environment friendly;
- Uses up large quantities of fly ash which is a byproduct of coal combustion, otherwise a major industrial waste;
- Performs as a far superior, more durable concrete compared to conventional concrete, saves precious resources;
- Is usually cheaper or at the most – at par with conventional concrete of same strength.

It has other advantages too, such as lower heat of hydration, lower permeability and nearly non-existent micro-cracking. HVFAC, developed at CANMET, Canada in 1985, has been used in several large projects all over the world including the Platanovryssi dam in Greece, the highest in Europe. In India it has been successfully demonstrated on heavily trafficked highway pavements in Punjab, Faridabad, Gujarat, the metro station at Rajiv Chowk in Delhi, the Rajasthan atomic power plant and most of all the Bandra-Worli sea link bridge in the Arabian Sea. HVFAC therefore offers a unique opportunity to meet the developing needs of the future- cost effectively and ecologically. The world especially the developing countries should adopt this technology without delay.

Water supply, sanitation & waste water management

Water requirements of our present society have shot up tremendously. Comfort demands and the lifetstyle habits concerning water and body hygiene have strongly changed compared to the past times.

With the growing population and the increased migration to cities, the water supply systems as well as waste water management systems are being stressed beyond their limits. Instead of unreasonable demands for water, we need to rein in our requirements. In others words – change our paradigm – Instead of water supply management to concentrate on water demand management.

Presently, an average urban citizen consumes 135 litres of water per day, out of which nearly 40 ltrs. is consumed by flushing, and 25 ltrs for the gardening and car washing etc.

The kingdom of Khushali has reduced this requirement to nearly half by using the ECOSAN system, (Ecological Sanitation) the 40 ltr. flushing requirement has been obviated. Further the grey water from bathing and laundry is used for gardening etc. after an elementary treatment thus saving another 25 ltrs.

The ECOSAN system, essentially a dry system works thus:

The human urine and excreta, rich in nitrogen &, phosphorus are treated as resources rather than a waste, to be disposed of. The nutrients are brought back into the native soil restoring the natural cycle of life-building materials that had been disrupted by the sanitation practices a century ago. The toilet receptacles are designed so as to collect the urine and the solid waste in separate containers below the receptacles.

ECOSAN receptacles – European, Asian. – keeping the faeces and urine seperate

No water is allowed to come in contact with faeces or urine. After defecation, the user covers the faeces by throwing in a trowel-ful of a dry mixture of ash, sawdust and lime readily available in stores. This helps

A trowelful of a mixture of ash, sawdust and sand is put in after every use, to enhance drying and help early destruction of pathogens

in de-hydrating the waste as well as raising its PH, both favourable for destroying pathogens. With the dry system, the harmful bacteria are more effectively destroyed than the flush & discharge system of the previous centuries which actually offered a ground for the bacteria to multiply. Another interesting invention has been the high temperature composting in which a parabolic solar concentrator of scheffler type design raises the temperature of the faecal waste bin higher than 60 °C, killing the bacteria in minutes as compared to weeks in olden times. The correct use is known to everyone, children are trained right from childhood. The toilets have 3 separate collection chambers beneath the floors – one for faeces, another for urine and the third for the wash water. Many people service these themselves while there are others who hire outside labour for the same. Being mandatory by law, the building plans invariably incorporate this system in all establishments, residential as well as commercial. Engineers have gradually devised ingenious tracked systems to handle excreta in multistoried flatted construction.

The sanitized solid and liquid wastes are collected weekly by the municipality, stored and then sold to farmers as natural fertilizers at a handsome price. The system was proven long ago in Sweden and India during the beginning of the 21st century. The compost used as a natural fertilizer gives a richer and healthier produce that is pretty much in tune with nature. Artificial fertilizers are considered inferior and are largely unpopular – resorted to only where completely unavoidable.

Compared to this ecologically friendly system of today, the flush and discharge system of the previous era (considered ideal in those days) seems primitive. In order to dispose off a relatively small amount of faeces or urine, more than10 litres of pure water was flushed down every time. Then nearly double this amount of water coming from the bath, laundry and the kitchen called grey water would join the black water. Further down the pipe the storm water from the roads as well as the waste water from industries was allowed to join this. In short, a small amount of disease causing matter was allowed to contaminate a large amount of harmless water which would then go untreated into the rivers causing a reckless pollution of the sources of the elixir of life. The water wars of the mid 21st century were only inevitable, as urban population increased and water shortages became more and more stark. The deprived sections of the society kept getting marginalized further while the rich continued to waste water irresponsibly in washing their SUVs and long shower baths. As anticipated, clashes between the haves vs. the have-nots became the order of the day. Society started crumbling and it was the rule of the jungle again.

In Khushali, every house harvests water because rain constitutes the world's best renewable freshwater supply. Harvesting systems have been perfectly completed with:

- Programmable valves which can separate the first rain from contaminating the rest of the water collected;

Programmable valve to divert a rain's first flow away from the cistern.

- Graded filters & UV sterilizers to maintain a drinkable quality and

Purifying Rain water - Two particulate filters in series, rated at 20 and 5 micron particle size & an ultraviolet light sterilizer.

- Pressure pumps to elevate the water in overhead tanks or sending it directly into the piping system.

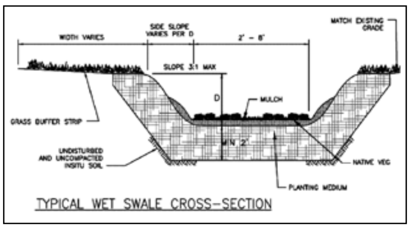
These are installed and inspected every year by the designated government personnel. Innovative architectural details include grey water collection tanks at every floor which may be used for miscellaneous purposes. Waste water now in manageable quantity and quality, flows to an effluent treatment plants (ETP) at a central location, is treated easily to drinkable quality and then discharged in the river. All industrial units must also treat their effluents to drinkable quality. Violators are fined heavily.

As a result 95% of the lakes and open water bodies in the country are of drinkable water quality. The government rewards conservation, penalizes waste, and stimulates innovation.

Storm water Drainage

In the early 21st century the monsoon was a difficult time. Every down pour resulted in inundating roads and streets, disrupting life tremendously. Further, this ponding would often damage pavements beyond repair and the maintenance department could never catch up with this problems. Besides poor maintenance, one of the reasons for flooding was that storm water drainage designs always fell short of the volume of water to be handled. The prevalent paradigm was to transport all this water through a long heirarchy of drains to a central location and then discharging into the river. Much of the paving was impervious, in hind-sight, not a very wise system since it was not able to control storm water runoff effectively.

The new paradigm which did not get very popular then but is seen fully assimilated in Khushali is to "catch it where it falls" or "control it where it originates". Low Impact Development (LID), innovative engineering and landscape techniques have resulted in neighbourhoods where homes are nestled among oaks, magnolias and



Swales are roadside depressions – designed to reduce storm water runoff and encourage local water table recharge

palmettos with a series of swales to capture storm water before it leaves the site. Swales are basically shallow depressions running parallel along the road sides neatly constructed, landscaped with native vegetation and well maintained. These are constructed with porous material underneath so as to encourage soaking and recharging of the ground water table. Often there are small check dams in these depressions in order to hold the water from running off too fast. During a storm the excess water just sits in the swales slowly infiltrating into the underground aquifers. Drains, open as well as covered, wherever provided are also designed with porous bottoms to allow water to percolate into the ground. So are the roads made of pervious concrete. They invented it 100 years ago, by using a no-fines concrete and found that in addition to the benefits due to its perviousness, it could resist freeze thaw far better than conventional concrete. Rain water directly seeps into the ground beneath the road pavements reducing runoff, at the same time keeping the water table comfortably high. There is community cohesiveness since all the residents are engaged in the planning, planting and maintenance of such neighborhoods.

Overall, LID system works in tune with nature by encouraging native vegetation, by reducing the amount of hard surfaces, by keeping the soil not compacted too hard, by treating storm water runoff close to the source, and slowing the flow of runoff so that it's closer to pre-development rates.

In general, there is a strong recognition of the "life support" functions provided by a network of natural ecosystems, as well as a conscious effort not to disturb them. Landscapes, homes and neighborhoods are designed such that they complement rather than compete with nature.

Energy

The hydrocarbon fuel economy started fading with the 3rd world war. As the climate change effects pushed mankind closer to the wall, Clean Coal Technology took over and continued for several decades. In this technology, Gasification techniques strip the pollutants and sequester (stored) them deep in old oil wells, effectively putting the emissions back where they came from rather than releasing them into the atmosphere.

One of the main benefits of sequestration, other than saving the planet, was that when pumped into depleted oil wells, it acted as a natural detergent, breaking the remaining oil from the porous rock resulting in old oil wells producing again. The oil supply was thus extended by a few years.

Slowly however as water and energy became scarce in the post-war period the energy scenario started shifting towards nuclear, hydrogen, solar-thermal, wind, and tidal. Production plants that synergized a cluster of technologies like solar power, combined cycle gas turbines and reverse osmosis desalination became common. Brine from desalination was harvested on land and refined into commercial grade salt, leaving the marine environment least disturbed.

The result was more electricity and water, lower costs and a protected natural environment. With years and more research, economies of scale helped make solar power comparable to nuclear energy. Endless rows of huge parabolic mirrors could be seen lined up in areas with abundant sunshine. The concentrated heat turned water into superheated steam which would then run power turbines. At a smaller scale, generating one's own electricity with solar-wind hybrid generators became popular with consumers feeding their surplus back to the grid. The trend continues in the 22nd century. In many places now, the regulations allow excess electricity produced by the turbine to spin the existing home or business electricity meter backwards, effectively banking the electricity until it is needed by the customer.

Requirements have also gone down by incorporating innovations like 'passive solar design" and "Green roofs". Undulating roofs covered in flowers and grasses mirror the local terrain, re-establishing several acres of the native ecosystem that is destroyed by the building's footprint. The living roof also absorbs storm water and provides thermal insulation, making the landscape an integral part of the building's energy systems. And instead of using thick hose water for irrigation, subtle, drip water irrigation systems operated automatically at night provide the necessary moisture to the green roof.

Biomimicry

One of the major paradigm shifts that have taken place in this new age is in the design philosophy, from the old 'Cradle-to-grave' principle to the new 'Cradle-to cradle' approach. Earlier, a typical product would be manufactured (born in the factory), serve its useful life and then head for the landfill (grave). A small fraction of the products would be 're-cycled'(downcycled) into lower grade products – which also would ultimately join the one-way bus to the landfill.

Prior approaches to sustainability often made the efficient use of energy and materials their ultimate goal. Sustainability meant mitigating the effects of human intervention by using less fuel to heat energy-efficient highrises and sending less to the landfill. But this did not address the deep flaws of the basic design philosophy; it simply limited the negative impact of poor design.

Cradle-to-cradle design is based on the closed-loop nutrient cycles of nature, in which there is no waste. By modeling human designs on these regenerative cycles, cradle-to-cradle design seeks, from the start, to create infrastructure that generates wholly positive effects on human and environmental health. Instead of being kind to nature, the new designs imitate nature. Not less waste and fewer negative effects, but more positive effects. For instance, buildings that make oxygen, sequester carbon, fix nitrogen, distill water, provide habitat for thousands of species, accrue solar energy as fuel, build soil, create microclimate, change with the seasons, and are beautiful. By clearly understanding the chemistry of natural processes and

Parabolic mirrors concentrate heat to produce steam to run power turbines

their interactions with human purpose, engineers and architects have created buildings that are delightful, productive and regenerative by design. From inanimate, one-size-fits-all metal and glass boxes, to buildings as life-support systems in-tune with the material and energy flows of particular places. A beginning with this trend was made in the early 21st century and it was discovered that designing for human and environmental health increased worker satisfaction as well as economic productivity by upto 25 - 30%.

One of the first few such buildings, a 40 storey skyscraper was designed and behaved like a tree. It generated its own power, 40% from solar panels and balance 60% from natural gas

"The tower of tomorrow" is full of biomimetic functions including: self-cleaning interior spaces(plants filtering the air), the aerodynamic shape diffusing wind load on the facades, and a water reclamation system redistributing greywater for toilets and other non-potable systems.

powered generators. A series of "atrium gardens" on the western side cleaned the air inside the building. There was clear glass on the northern side in front of which, mosses absorbed particulates in the air. The building recycled waste water for use in the building's gardens which, after cleansed by the plants was fed back into the grey water system once more.

The new paradigm now – a hundred years later is well embedded in all material research and design education. The presence of such buildings all around the world suggests that human activity can indeed create footprints to delight in rather than lament.

Needless to say that the inspiration for the new philosophy came from the quiet, hidden intelligence of the splendid laboratory that is nature. In the natural world, which is a grand, evolving system based on hundreds of millions of years of research and development - the processes of each organism contribute to the health of the whole. One organism's waste is food for another and nutrients and energy flow perpetually in closed-loop cycles of growth, decay and rebirth i.e. waste equals food. This Biomimicry, learning from natural systems, allows architects and designers to recognize that all materials can be seen as nutrients that flow in natural or designed metabolisms.

Infrastructure and building design now is ecologically intelligent. It honors not just human ingenuity but harmony with the exquisite intelligence of nature. Sensitivity to ecology is integrated into the curricula of many disciplines. Chemists aware of the concerns of sustainability have mastered the skills necessary to assess the environmental health and safety of industrial and architectural materials. "Green" engineers, who are employed throughout the sustainable design process, have garnered the technical know-how to develop an array of sustainable systems, from solar collection technology to chemical recycling processes that allow the re-use of valuable materials.

It is with this vision of the prosperous Khushali, beginnings of which have already been made in the form of ecologically sensitive architecture in various parts of our present world, that we need to move forward – aligning our design philosophy with the "cradle-to-cradle" approach. Then only we can hope to slowly cure Mother Nature's rising fever.

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His achievements include: Construction of the first HVFAC building in India in 2002 and development of an RCPT apparatus to assess the durability of Pozzolanic High performance concretes.

He was invited by the ITSA to Oregon in 2005 and by the American Concrete Institute to Poland in 2007 for making presentations on HVFAC. He can be contacted at sing.tp@gmail.com