VOLUME 4

KEYSTONE

2019-20

MARADU FLAT DEMOLITION

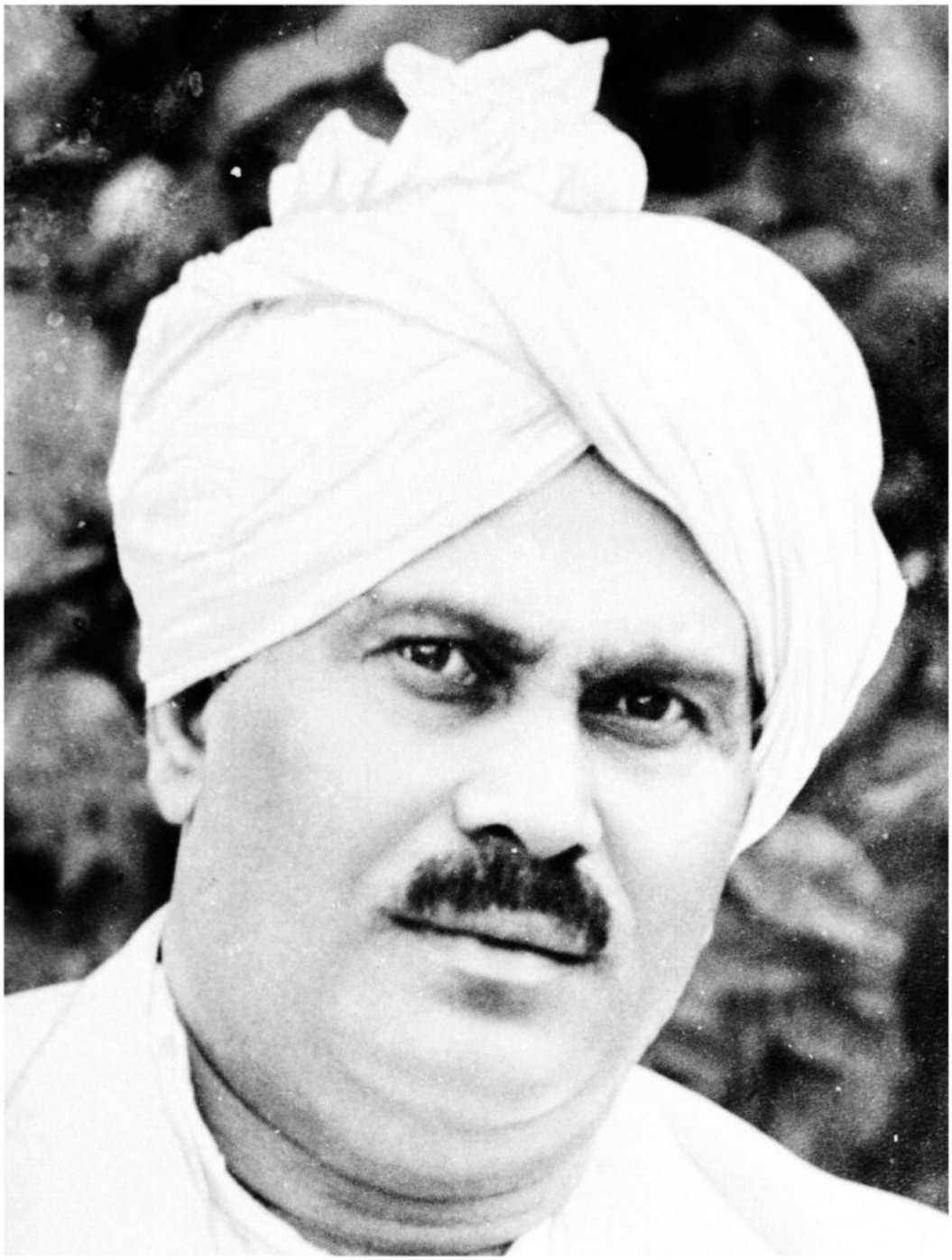
RECENT ADVANCES IN NDT TESTING OFCONCRETE

LACK OF UNIFORM TRENDS IN EXTREME TEMPERATURE INDICES OF INDIA

DEPARTMENT OF CIVIL ENGINEERING
TKM COLLEGE OF ENGINEERING

KEYSTONE

It is a wedge-shaped stone piece at the apex of a masonry arch or a vault. In both cases it is the final piece placed during construction and locks all the stones into position, allowing the arch or vault to bear weight



THANGAL KUNJU MUSALIAR
VISIONARY AND FOUNDER

ABOUT DEPARTMENT

Esteemed as the first Government Aided College in Kerala, the second most sought after destination for engineering aspirants across the state, TKM College of Engineering bears a transcendent acclaim with a plethora of academic excellence and ethos. Throughout its 60-year-old legacy, the college was successful in raising socially responsible engineers as our founder Janab Thangal Kunju Musaliar dreamt of with standing records of impeccable academic performances, brinking with exemious technical and innovative excellence.

The Department of Civil Engineering has proven to be one of the best in the state with its competent faculty, skilled staff force and the vibrant student community and continues to effectuate our founder's ideology of transforming the entire state's educational aspiration by equipping the students with the best engineering techniques and instilling in them a sense of responsibility since the inception of the institution in 1958. Our department has been successfully providing civil engineering aspirants, a high quality education covering the varied facets of civil engineering. The department aims at providing the best guidance, facilities and opportunities to develop the outlook, personality, research and technical skills of the students to cater the needs of the society and be the makers of the world. We have our alumni being forerunners in the professional diaspora in different parts of the world. Our department holds the title of only department in TKM College of Engineering with the B.Tech programme having been accredited by the National Board of Accreditation with the coveted status “Accreditation for 6 years” (2016-17, 17-18, 18-19, 19-20, 20-21, 21-22) and the

M. Tech programme for 2 years (2017-18, 18-19). The department is also a recognized QIP centre of the AICTE for PhD programme.

The department has a fully functioning research and consultancy wing. The list of clients associated with the department are: KMML, PWD, CPWD, Harbour Engineering Department, Kollam Corporation, ESIC, Indian Railways, KWA, Nirmithi Kendra, SILK, LSGD, IRE and many private agencies. The services offered by the department include structural design, detailing, testing, forensic investigations, field inspection and monitoring, surveying, site investigation report and expert opinion in various issues related to structural, geotechnical, transportation, environmental and water resources engineering.The research and developmental activities in the department are funded by the AICTE, TEQIP, the Institution of Engineers (India), the Kerala State Council for Science and Technology, and the Centre for Engineering Research and Development

The success of the department is the outcome of the teamwork of our well qualified and experienced faculty and an equally enthusiastic student community. Above all, it is the continuous effort towards improvement and keeping up to its vision and mission that sets apart the Department of Civil Engineering, TKMCE, from the rest.

MESSAGE FROM **PRINCIPAL**

I am extremely happy and proud to see the brimming students along with able stewardship of the teachers of the Civil Engineering branch has come up with a technical magazine for the year 2019-20.

I whole heartedly congratulate the students for nourishing such a great initiative, to ignite the spirits and talents for the students along with an insight to the professional knowledge. Such a venture will lead a long way to prosper professionally and academically. I am sure it will also bridge the gap of reality and help us all to invest in the social betterment of our society. Technology is developing at a very faster pace and platforms like this would definitely provide a space to discuss the new advancements and how it can be adapted and applied to solve problems of civil engineering relevance.

I appreciate and congratulate the team of staff and student editors for their tireless effort that have come to fruition in the form of this magazine. I expect all my students to be sincere, responsible and committed to their work and I wish my dear students success in all future endeavours.

Dr. T. A. Shahul Hameed
PRINCIPAL

MESSAGE FROM **H.O.D**

I am gratified to know that our department of civil engineering is bringing out the latest edition of KEYSTONE. I appreciate and applaud the editorial team for the hardwork and dedication they have invested in realizing this goal and wish my dear students success in all future endeavours.

Nurturing creativity and inspiring innovation are two of the key elements of a successful education and a magazine like this is a perfect amalgamation of both. Behind every developmental activity that takes place in our world, there is an inherent contribution of civil engineers. As a committed civil engineer, we should always be on the track of exploring new ideas, learning new skills and be ready to cope up with the changing and challenging framework. Every possibility of addressing the problem of our society should be dealt in an ingenious way and at the same time it should not pose any threats to our environment. Through KEYSTONE I firmly believe that the current research findings and innovative ideas in the field are being discussed and it would definitely be a guiding light to our student community.

Dr. M. Sirajuddin
H.O.D

MESSAGE FROM **STAFF EDITOR**

I consider it my proud privilege to be the staff editor of the technical magazine "Keystone" published by the Department of Civil Engineering. I appreciate and congratulate the sincere efforts of the students and the staff members in bringing out the magazine, especially during the trying times of the COVID-19 pandemic. I extend my hearty wishes for its success and hope that such efforts will be continued in the forthcoming years.

Dr. Anu V. Thomas
Professor

EDITOR'S NOTE

"Engineering is quite different from science. Scientists try to understand nature. Engineers try to make things that do not exist in nature. Engineers stress invention."
- Yuan-Cheng Fung

True, engineering stands on scientific principles, but there is quite a long way to go from principles to product. Here is where an engineer applies his creative potential and make the reality better every day. The things that are marked impossible are often unsolved engineering problems. As engineers, we have a lot to do, a lot to create and innovate, to contribute our part in serving the mankind.

Civil engineering as always, continue to dominate headlines across the world. It changes the face of the world every day. From the world's tallest building to the biggest manmade islands, people everywhere are dependent upon civil engineering innovations. All of this innovation and construction ties back to one main purpose, supporting human life, without forgetting the generations to come. And for that reason, sustainable engineering has overridden engineering.

KEYSTONE vol 4 will take you to the updated phase of the art and beauty of civil engineering. We hope this small piece of work would enrich your knowledge and ignite your young minds.

KEYSTONE TEAM

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Lack of Uniform Trends in Extreme Temperature Indices of India

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BACKGROUND

Global warming and resulting climate change are thrust areas of research for the meteorologist and hydrologists for the past fifty years, as significant increasing trend is noticed in temperature since 1970s at the global scale (Trenberth and Fasullo 2013).Many studies reported that there is an increase in the frequency of occurrence of extreme climatic events due to the climate change in India (Roxy et al. 2017). The occurrences of hydroclimatic extremes such as heavy rainfall, floods and droughts are posing serious impacts in Indian economy (Dash and Maity 2020). Apart from such direct signatures, the climatic extremes are also quantified by many other extremes, as they have significant implications on local hydrology. The joint venture of CCl/CLIVAR/JCOMM Expert Team (ET) on Climate Change Detection and Indices (ETCCDMI) has a mandate to address the characterization of climate variability and change. The group works in an international coordination contributed significantly for climate change detection (Folland et al., 1999; Jones et al., 1999).The climatic indices defined and devised by the Climate Variability and Predictability (CLIVAR) project of UNWMO's World Climate Research Programme jointly with the ETCCDMI is the most credible datasets which can be used for the studies on hydroclimatic extremes.According to ETCCDMI a total of 27 indices were considered to be core indices, which are based on daily temperature or daily precipitation values. It was reported that the global warming and resulting climate change have lead to significant changes in extreme precipitation indices even though the changes were more spatially heterogeneous than temperature extremes (Donat et al. 2013). Numerous studies addressed the analysis of prominent extreme indices of different meteorological variables of different parts of the globe (Roy and Balling 2004; Aguilar et al. 2010; Tong et al., 2019 and references therein).

Some studies reported lack of uniform trends in extreme precipitation in India based on raw data (Ghosh et al., 2014). Further, a large number of studies were performed on the spatio-temporal analysis of climatic indices of India in the past (Roy 2019; Kumar et al., 2020; Dash and Maity 2020 and references there in). From the review of literature it is noted that such studies differs in (i) data type (like station or gridded) and resolution (fine or coarse or point); (ii) the source of data; (iii) methods followed; (iv) spatial domain considered etc. This brings an inevitable heterogeneity in the outcome of the results. There is a scarcity of the studies on temperature indices in Indian context; none of them examined the pre and post-scenario of extremes with respect to the global climatic shift of 1976/77. In this context, we like to explore the signatures of spatial and temporal variability of trends of extreme temperature indices to bring new insights and scope for future works in this domain.

DATA and ANALYSIS

The 1° x 1° resolution rainfall and temperature data at daily time scale of the period 1951 to 2015 collected from India Meteorological Department (IMD) are used to determine all the 27 core indices using RClimDex package (https://www.climdex.org/). The 277 grid points were located all over Indian subcontinent, where the data of both variables are available in continuous. From the results, four annual extreme temperature indices are considered to analyze their spatio-temporal variability. The temperature indices include Number of summer days (SU), Number of tropical nights (TR), Warm spell duration index (WSDI) and Cold spell duration index (CSDI). The most popular non-parametric test Mann-Kendall (MK) test (Mann 1945; Kendall 1975) is used for the detection of magnitude of trends of extreme climatic indices assuming a 5% significance level.

RESULTS and DISCUSSION

Spatial variability of MK values exhibited by the four annual extreme temperature indices across India is provided in Figure 1. Figure 2 shows the percentage of grids exhibiting different trend characteristics on considering the four annual extreme temperature indices across India.

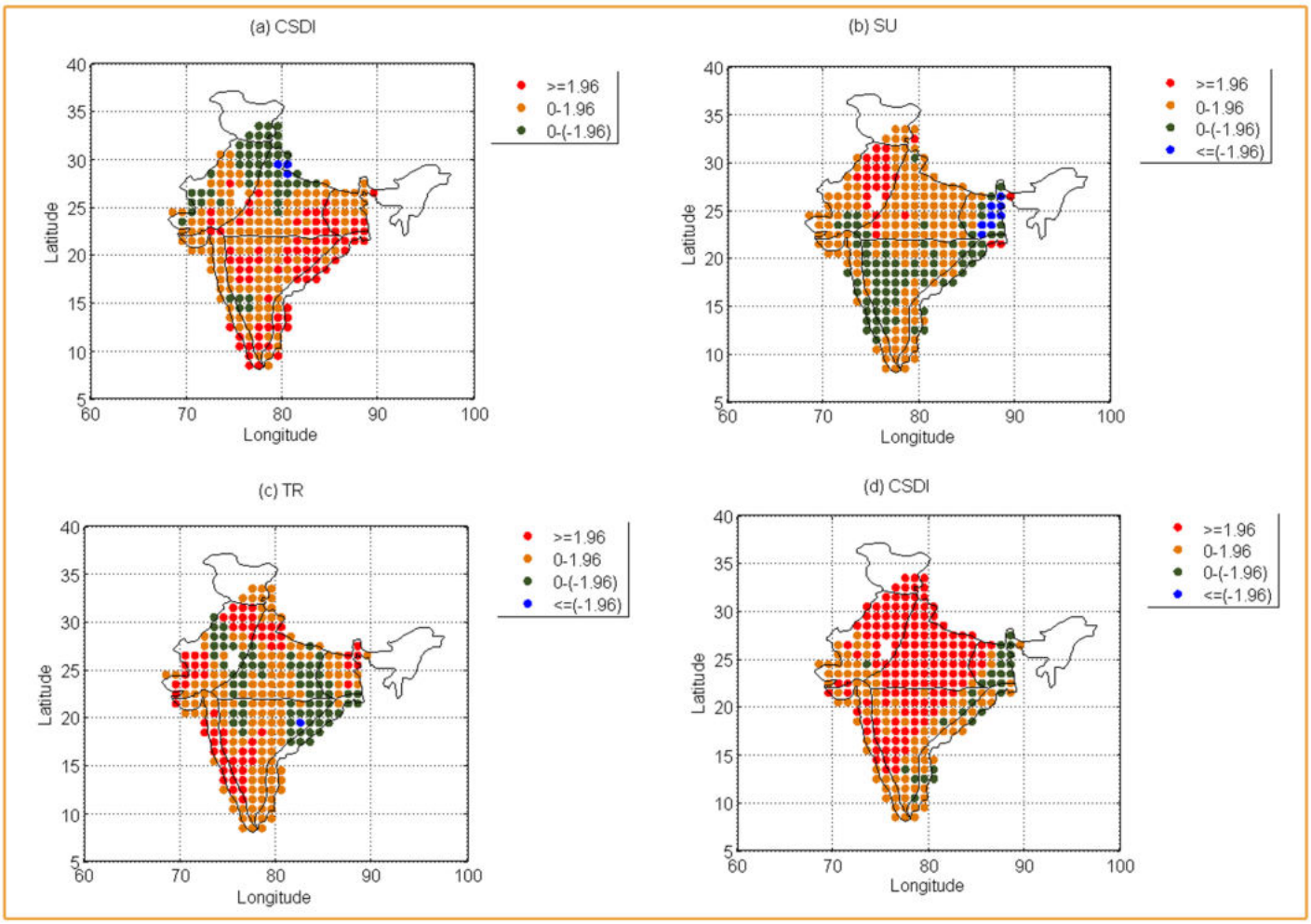

Figure 1 Spatial distribution of MK values of annual extreme temperature indices (a) CSDI, (b) SU (c) TR, (d) WSDI

From Figure 1, it can be noted that a large share of grids (152 grids) display statistically significant increasing trend in WSDI data, while 17 grid points showed a reduction, but none are significant. TR displays an increasing trend in 189 grid points, out of which the trend is statistically significant in 64 grid points. A similar behavior is noticed in the datasets of CSDI. The SU displays increasing trend in 189 grid points, while only 27 of which displayed a significantly increasing trend. In the spatial distribution plots of temperature trend we can see that, in WSDI plot, the MK value showing significantly increasing trend is more in the interior and northern part (North Central (NC) and North West (NW)) when compared to coastal belts like East Coast(EC) or West Coast (WC). The decreasing trend in CSDI is clustered in the upper Himalayan regions falling in NW and NC regions. The plots of SU show that MK values displaying significantly increasing trend is clustered in the NW regions.

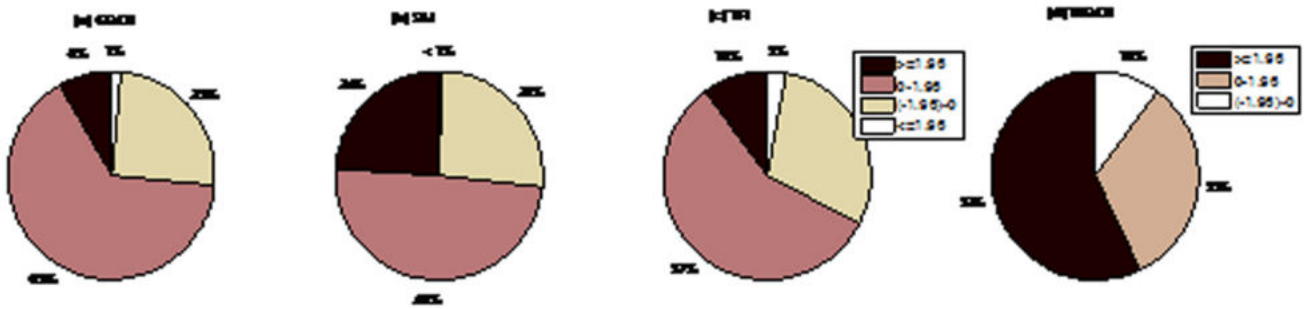

Figure 2 Percentage of grid points showing different trends of MK values of annual temperature indices (a) CSDI; (b) SU; (c) TR; (d) WSDI

From Figure 2 it is noticed that, for all the four indices majority of the grid points showed increasing trend, even though the percentage of grids showing statistically significant trend is noted to be high only for WSDI. For the case of all the four indices, only very less number of grid points displayed significant reduction.

Temporal change in trends of temperature indices

The temporal changes in the extreme climatic indices are of vital importance as it can give information on the changing characteristics of the time series. Such drastic changes in the properties may be the signatures of changing climate and in such a context it will be helpful in following appropriate design practices of hydraulic infrastructure. One possible reason for such changes could be urbanization, as the urbanization might be leading to more irregular profile influence on the local temperature characteristics (Karatasou and Santamouris 2018). It is further hypothesized that the change could also be linked with climate factors. Researchers identified a well debated Pacific climatic shift in 1976/77 period and the subsequent change in global temperature (Miller et al., 1994).In order to investigate the temporal changes accounting for the role of climatic shift, in the trend of different indices, the time series pertaining to different grid points are partitioned into two sub-series with respect to 1976/77. The MK values are determined for both sub-series of each grid and the results are interpreted based on spatial representation, non-parametric CDFs and transtion in behavior of MK values for the pre and post time series. The spatial representation of MK values of the four temperature indices of different grids, for the pre and post 1976/77 shift are presented in Figure 3.

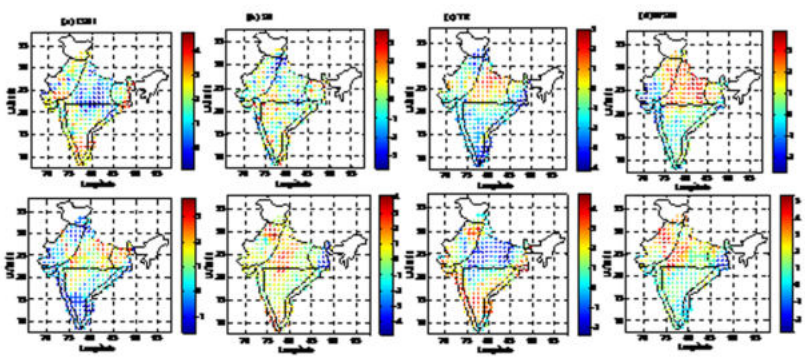

Figure 3 Spatial variability of trend of annual extreme temperature indices before and after the 1976/77 climate shift. (a) CSDI; (b) SU; (c) TR; (d) WSDI. Upper panels show the trend of extreme indices before the shift and lower panel show the the trend of extreme indices after the shift.

While plotting change of Mann Kendall values for pre and post 1976, it was observed that some indices showed significant variation from the existing trend, while some made no significant change. It is clear that the regions which showed significant increase before 1976/77 shift had significant decrease after 1976/77 and vice versa.Thus there is a transition in the nature of trend in the CSDI series. In most part of Interior Peninsular (IP) and coastal belts, there is a reduction in CSDI after 1976/77 period. There is a significant transition from decreasing to increasing nature in the SU series in parts of WC region like Kerala and an opposing nature in the West Bengal region. There is a clear dynamics in the nature and strength of trend values of TR series of pre and post climate shift. The WC, EC and part of IP there is a switch over to positive trend (from negative), whereas in the NC and NW region there is a clear switch over to negative trend (from positive) with respect to the climate shift of 1976/77 period. The transition in the nature of trend is practically absent in the WSDI time series. The non-parametric CDFs of the four temperature indices are presented in Figure 4.

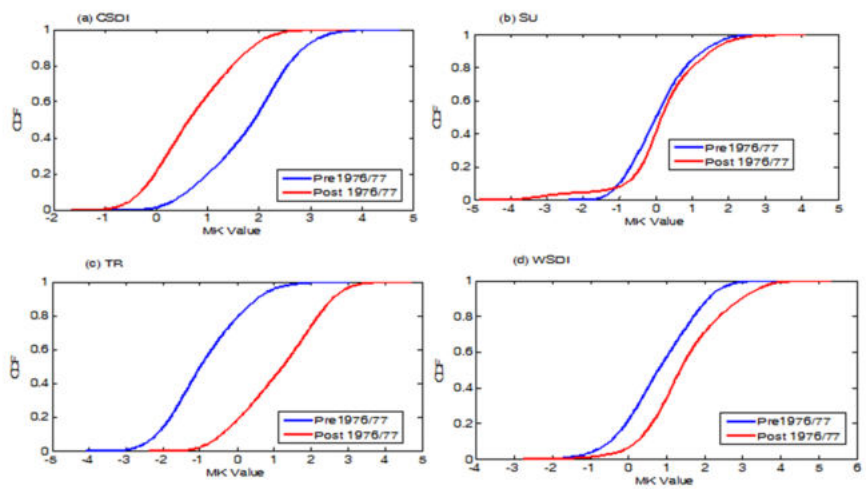

Figure 4 Non parametric CDFs of trend of temperature indices before and after 1976/77 climate shift (a) CSDI; (b) SU;(c) TR; (d) WSDI

Figure 4 clearly shows that there is a visible reduction in MK values of the post 1976/77 CSDI series, when compared with that of pre 1976/77 period. There is an apparent increase in the MK values of TR and WSDI series of post 1976/77 period, while the change in SU series was found to be marginal. The post 1976/77 scenario can also be considered to be an increased urbanization case. The amplified trend values under increased urbanization imply that the different temperature indices except CSDI exhibited more non-stationarity (NS). It is interesting to note that the wet conditions of temperature like CSDI are subjected to a reduced non-stationarity against the increased NS case for other indices. Figure 5 shows that for CSDI series, at 27 % of grids displayed a switchover from increasing trend to decreasing trend in all the cases, there is a substantial reduction in the number of grid points with a decreasing trend, after the climate shift. The increased urbanization and climate shift has more severe direct impact in inducing non-stationarity in temperature extremes in Indian context. The increased NS of the temperature is inextricably linked with the changing climate and its potential impact is leading to the behavior and frequency of extremes.

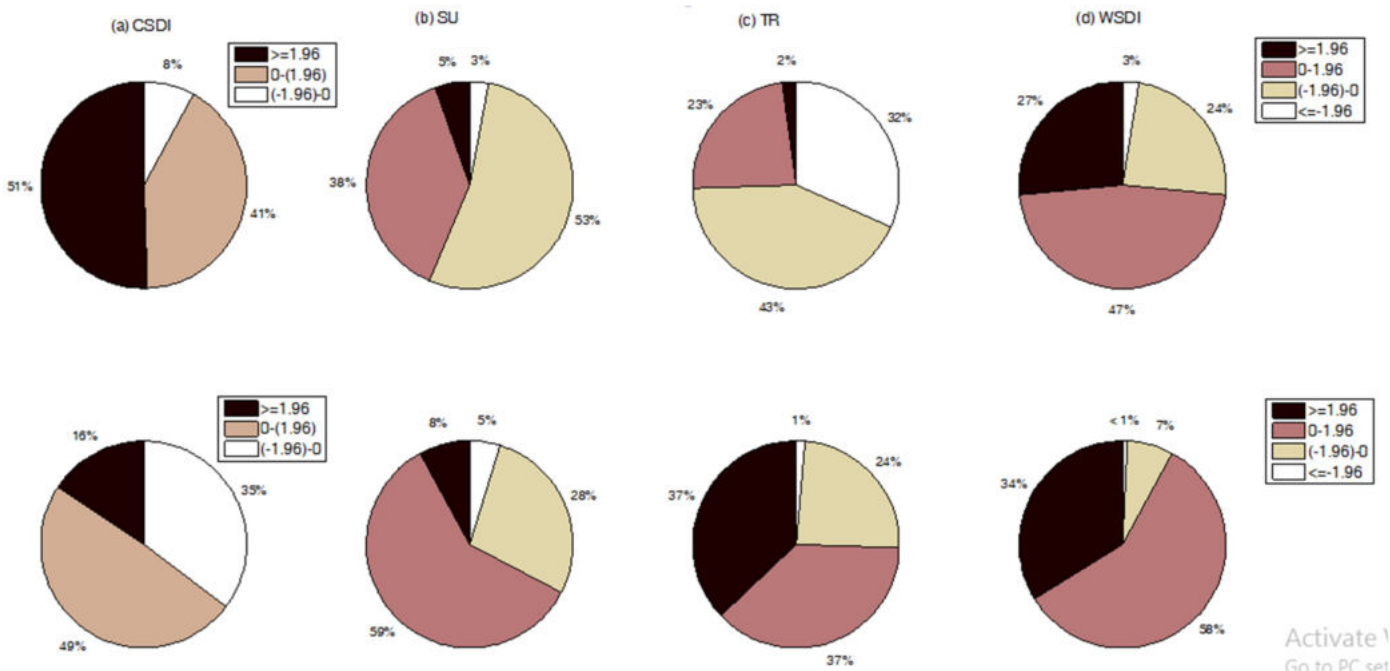

Figure 5 Percentage of grid points showing different trends of MK values of annual temperature indices before and after the 1976/77 climate shift. (a) CSDI; (b) SU; (c) TR; (d) WSDI. Upper panels show the trend of extreme indices before the shift and lower panel show the the trend of extreme indices after the shift.

This study examined the spatial and temporal variability of temperature extremes in India. In general, the different extreme temperature indices of India exhibited high degree of diversity in trend. It was well established that the large scale climatic oscillations from oceans play a major role on Indian monsoon system and the role of these circulations on the extremes of rainfall also cannot be ignored (Gupta and Jain 2020).Apart from the global parameters like terrestrial radiations and temperature the local factors like the latitude, topography and local processes along with oceanic and atmospheric circulations may influence the extremes of temperature. However, it will be hard to find a unique pattern in the changes in extreme indices with altitude, latitude or ocean proximity and urbanization. The climatic extremes over India may also be influenced by many local effects like terrain, moisture and vegetation conditions. Thus a concurrent impact of many such factors eventually may contribute to the occurrence of extremes and their frequencies. More studies need to be solicited using the seasonal climatic indices, station wise datasets need to be performed to corroborate this observation. Also, the studies on the physical reasoning of occurrence and frequency of temperature extremes of India are highly warranted.

CONCLUSION

This study examined the spatial and temporal variability of extreme temperature indices by performing the trend analysis of the indices at geographical grid level of 1° x1° spatial resolution. Four temperature indices at annual scale resolution are considered and the trend was analyzed for the pre and post 1976/77 climate shift. The major conclusions drawn from the study include:

• The trend analysis of extreme climate indices showed that there is a dominancy of increasing trend in all the four temperature extremes (CSDI, SU, TR and WSDI) with statistical significant trend in 57 % grids for WSDI

• There is a clear reduction in MK values of CSDI, after the climate shift of 1976/77, while there is an increase in MK values of rest of the indices

• Thus there is a lack of uniformity in the trend of temperature extremes in India both spatially and temporally, which could be attributed to the concurrent effect of local or regional urbanization and global climate shift.

ACKNOWLEDGEMENT

We thank India Meteorological Department (IMD) for providing the 1° x 1° resolution rainfall and temperature data at daily time scale of the period 1951 to 2016.

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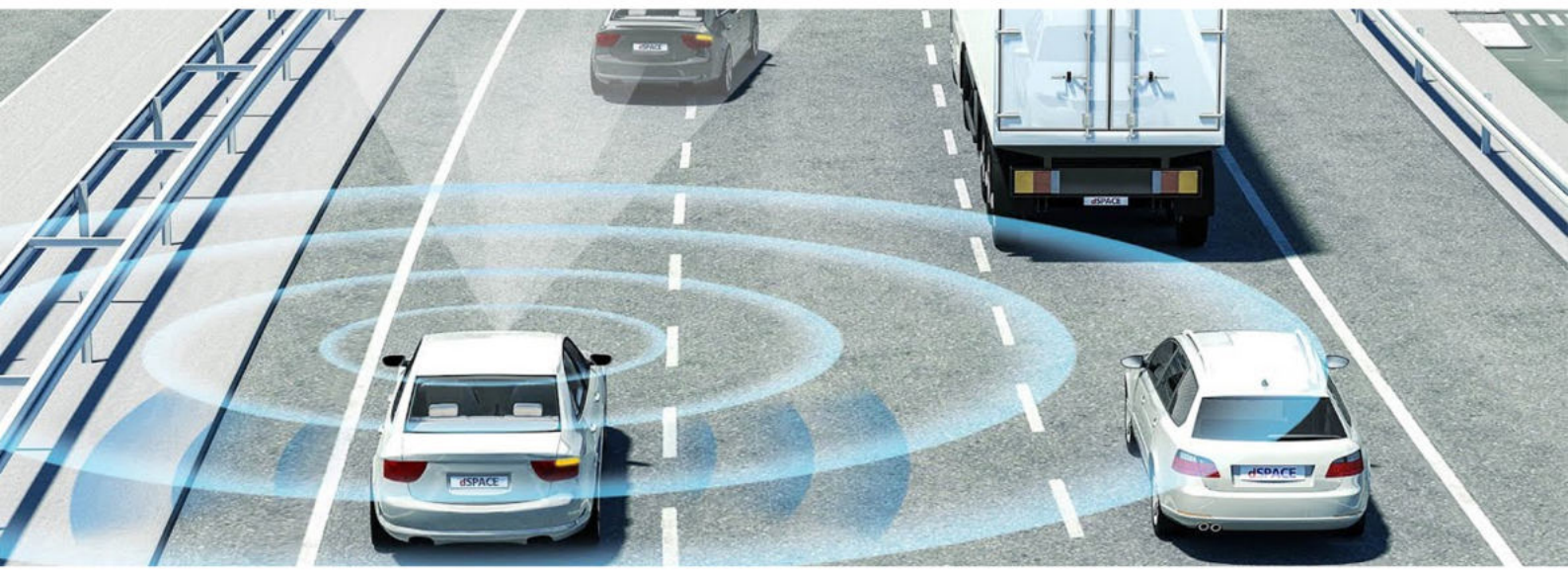
AUTOMATED HIGHWAY SYSTEM : A Tale for the Future

Akshay S, C4A



Introduction

Traffic congestion is a major problem in highways, and their effects include loss in productivity due to travel delays, increase in frequency and severity of accidents, and risk to public health due to increase in pollution. The traffic congestion can be relieved in a variety of ways such as by making a mass transit network, or a communication infrastructure which would reduce the need for travel. Since driver safety and vehicle efficiency are two major concerns for the future of transportation, the Automated Highway Systems (AHS) are considered to be one of the potential solutions to this problem among various Intelligent Transportation System (ITS) alternatives.

The Automated Highway System (AHS) concept defines a new relationship between vehicles and highway infrastructure. AHS refers to a set of designated lanes on a limited access roadway where specially equipped vehicles are completely operated under automatic control. As shown in figure 1, AHS uses vehicle and highway control technologies that shift driving functions from the driver/operator to the vehicle. Throttle, steering and braking are automatically controlled to provide a safe and convenient travel. AHS also uses communication, sensor and obstacle-detection technologies to recognize and react to external infrastructure conditions. Thereby AHS helps in improving safety and reducing traffic congestion..

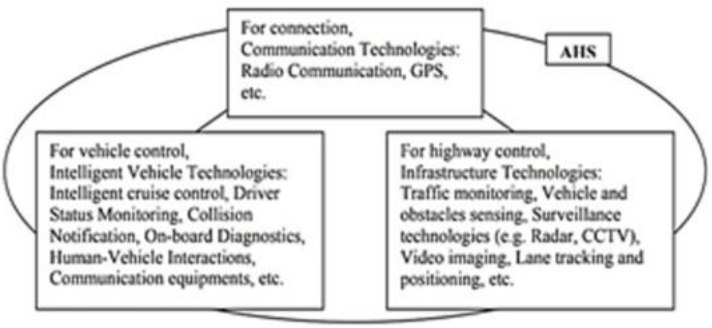


Figure 1 : Concept of AHS

Potential Benefits of Automated Highway System

Researchers have attempted to estimate the benefits that might accrue from the implementation of Automated Highway Systems, and a few have been listed below

1. Improvement in roadway capacity as more vehicles can be accommodated on the highway. The number of vehicles per hour per lane can be significantly increased as traffic speeds are standardized and increased, and headway distances are decreased.

2. Driving safety would be significantly greater than present as the human error factor would be removed.

3. Weather and environmental conditions may only have a little impact on high performance driving.

4. AHS offers enhanced mobility for people with disabilities, the elderly, and less experienced drivers.

5. Fuel consumption and emissions can be reduced.

6. AHS would help in using land efficiently.

7. Improve in efficiency of commercial and transit operations.

8. Travel time can be reduced as AHS can restore free flow travel conditions from congested speeds in urban highway travel.

AHS Control Architecture Model

One of the widely discussed AHS hierarchical control architecture is shown in Figure 2. This block diagram represents 5 layers. The top layer, known as the network layer, is responsible for the flow of traffic on the entire highway system. When a vehicle first enters the AHS, the network layer provides a route (sequence of highways) for the vehicle to follow in order to reach its destination as quickly as possible. In the event of traffic congestion, the vehicle may be rerouted by the network layer. The second layer, known as the link layer, coordinates the operation of whole sections (links) of the highway and it operates at the roadside. Its primary task is to maximize throughput while maintaining safe conditions of operation. It would calculate optimum platoon size and optimum velocity for each highway section, and would thereby assign a lane for each vehicle. The third layer is the coordination layer. Its task is to coordinate the operation of platoons with their neighbours. For example, it may ask two platoons to join to form a single platoon whose size is closer to the optimum or, may give a command like 30% of the vehicles going to the next exit have to immediately change their lane. The fourth layer is the regulation layer. Its task is to receive the commands from the coordination layer and to translate them into throttle, steering and braking inputs for the actuators on the vehicle. The bottom layer is not part of the control hierarchy. It is called the physical layer and it contains the actual plant (in this case the

vehicles with their sensors, actuators, communication equipment and highway topology).

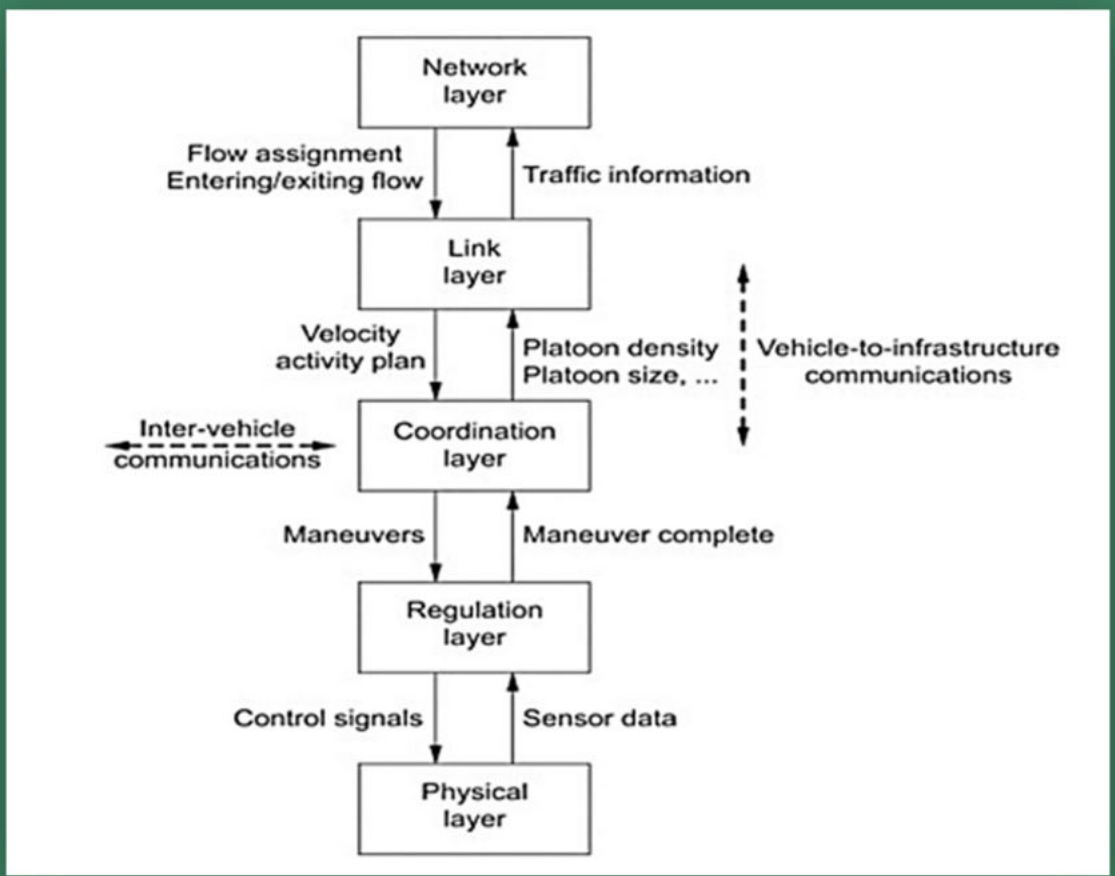


Figure 2. AHS Hierarchical Control Architecture Model

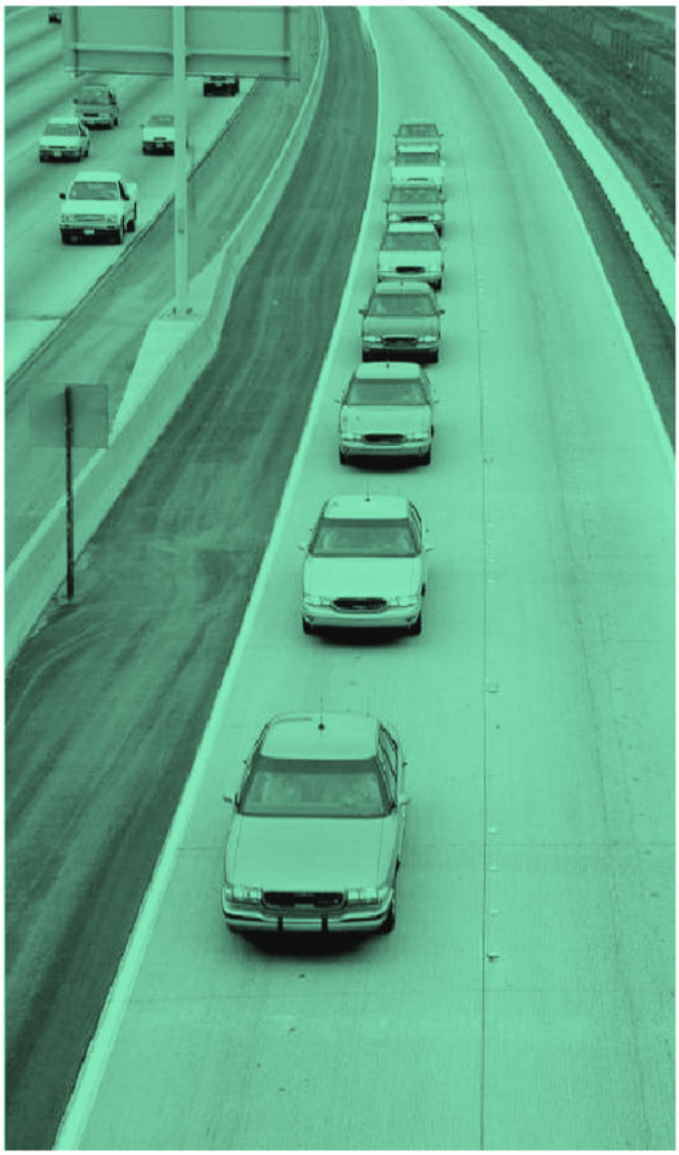
Design Issues of AHS

AHS in reality is a large scale complex dynamical system, and so it would be very difficult to synthesize and implement a centralized control scheme to ensure safety of the vehicles. Since each automated vehicle would be modelled as a hybrid dynamical system (i.e. a system whose behaviour is determined by a combination of both continuous and discrete event analysis), the interaction between such vehicles makes the overall system a dynamically changing network of hybrid systems. But presently, the design and verification issues for hybrid dynamical systems are in the stage of development and cannot be used for this problem.

During the last few years there have been many simulation tools to simulate the Automated Highway System before actually implementing it on the road, and one such good example is DYNAVIMTS. It stands for Dynamic Visual Micro/Macroscopic Traffic Simulation. It is a multi-purpose AHS simulation software developed using different software tools and platforms. It has a range of vehicle dynamics and control models that can be used for microscopic simulation studies. It is also designed to study the effects of highway automation on the overall traffic flow in the traffic network.

SmartPath is another example of AHS simulation tool. It has a simulation program and an animation program; the animation can

be used to show the simulation results as the simulation progresses (concurrent visualization) or can read the simulation results from a simulation-prepared data file. Two sets of constructs- primary and secondary are used to model AHS designs within this framework. The primary constructs in SmartPath provide basic structures for the simulation of an AHS scenario that complies with the AHS control architecture model, described earlier. The highway structure is the basis for the vehicle movement, detection schemes, and the interactions among network, link, and coordination layers of the vehicles. The secondary constructs provides a platform that would ease the implementation of this simulator. It includes providing communication facilities for vehicle to vehicle message transmission, and a set of controllers to accelerate, decelerate, and move the vehicle to an adjacent lane. SmartPath has been successfully used for AHS design and evaluations. It has helped in eliminating certain short comings in the design of vehicle controllers. Also it was shown that in certain situations, automated vehicles might collide with each other, if the sensor and actuator limitation of the vehicles are not taken into account while designing the controllers. The simulation results have also provided an insight into correcting the control laws.



Conclusion

Currently AHS has some institutional and societal challenges which is just as critical as the technical issues. Moreover, these institutional and societal issues cannot be settled in one day, because they are much to do with people's perception, behaviour, consensus and social changes based on those. Hence AHS development would be a long-term, multi-phase project. This slow and steady approach may help in achieving the AHS goals. In addition to that, a long-term implementation may ensure that the technologies needed in AHS design would be significantly more cost-effective and accessible when they are used in volume. Let us hope that AHS would usher in an era of rapid technological advancements that would improve the safety, efficiency, and convenience of highway transportation.

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CAPITAL GATE: World's furthest leaning SKYSCRAPER

Athira A, C2A

Capital Gate designed with a striking lean is a skyscraper in Abu Dhabi. It's one of the tallest buildings in the city and features an 18° inclination to the west (14° more leaning than Italy's Leaning Tower of Pisa). Owned by Abu Dhabi National Exhibitions Company (ADNEC), the iconic development is also known as the leaning tower of Abu Dhabi. The one of a kind edifice consist many structural innovations within the project's design. The dramatic 18° western ward has got a funnel shape. It widens as it spirals upwards and outwards. This gesture creates the dramatic sculptural form which is expressed architecturally in a variety of ways. This weaving pattern is further broken down with individual panes of glass on a complex mesh wrapping the entire building.

The 160m-tall, 35 storeyed Capital Gate was designed by Robert Matthew, Johnson-Marshall & Partners (RMJM) and is used for mixed commercial purposes, including offices and retail spaces, the Hyatt Capital Gate hotel and a tea house. It has 30 meeting rooms, conference facilities for 1,200 people, a Business Centre on the ground floor, a helipad and an eight-outlet food court. Construction work of the $231m project started in September 2007 and was completed in 2011. Commercial leasing of the tower began in April 2011.

Architecture and Design of Superstructure

Given the 18° lean of the building, the construction required two diagrid systems: an external diagrid defining the tower's shape and an internal diagrid linked to the central core by eight unique, pin-jointed structural members.

The external diagrid comprises 720 sections of varying shapes, as it is based on the direction in which the tower leans. The external grid carries the weight of the floor while the internal diagrid connects with the external and transfers the load to the core, thereby eliminating the need for columns in the floor. The building has diagrid specially designed to absorb and channel the forces created by wind and seismic loading, as well as the gradient of Capital Gate. Capital Gate is one of only a handful of diagrid buildings in the world.

Foundation

The structure rests on a foundation of 490 pilings that have been drilled 30 meters below ground. The deep pilings provide stability against strong winds, gravitational pull, and seismic pressures that arise due to the incline of the building. Of the 490 pilings, 287 are 1 meter in diameter and 20 to 30 meters deep and 203 are 60 centimeters in diameter and 20 meters deep. All 490 piles are capped together using a densely reinforced concrete mat footing nearly 2 meters deep. Some of the piles were only initially compressed during construction to support the lower floors of the building. Now they are in tension as additional stress caused by the overhang has been applied.

Project Timeline

- **September 2007**: Start
- **November 2007**: Started drilling foundations
- **April 2008**: Construction of core wall
- **February 2009**: Facade erected
- **May 2009**: Building reached a height of 100 meters
- **June 2009**: Incline started to take shape
- **October 2009**: Building reached final height of 160 meters
- **December 2009**: Exterior core structure completed
- **January 2010**: First phase of splash completed
- **February 2010**: Interior construction started
- **March 2010**: Started building the bridge to Abu Dhabi National Exhibition Centre
- **April 2010**: Started building the atrium roof
- **2011**: Construction completed
- **December 21, 2011**: Opening

Challenges faced during construction

As any other significant building the Capital Gate faced many engineering challenges during its construction. The tower is a two-layer design. The central core of the tower leans in the opposite direction to the inclination of the building and straightens with the height. Michael Johnson, who was appointed to oversee the final phase of construction of the building by ADNEC, said "Everything about the tower makes it wants to fall over, but it has been designed to stop".The top 17 floors hang over the edge putting thousand tonnes of pressure to the core of the building. Contractors and engineers devised a series of solutions, some of which have never been seen in the world of tower construction.

The piling of a normal tower goes straight down into the earth and holds the building steady. But for the Capital Gate engineers created two sections of piling, one deeper than the other. Together they create competing forces that keep the building upright. The core of the building was constructed with a slight lean away from the eventual slant of the building itself. As each consecutive floor was put in place, it too was pulled straight. To make it even more solid, the core was threaded with thick bundles of steel cables that were pulled tight. The amount of cable was 44 times that used on the Golden Gate Bridge in San Francisco.

Amidst all the challenges, in June 2010, Guinness World Records recognized Capital Gate tower as the world's "farthest manmade leaning building". The new record shows that the Capital Gate tower has been built to lean 18° west, which is more than four times that of the Leaning Tower of Suurhusen.

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MARADU FLAT DEMOLITION : AN OVERVIEW

Aswin A Nair, C2B

The Kerala State is the biggest violator of the Coastal Regulation Zone (CRZ) Notification, which regulates construction activities in the sensitive coasts of the sea and the backwaters in India. There are 1800 buildings, including star hotels, luxury apartment blocks, shopping malls and tourist resorts constructed in violation of the Notification.

The Maradu demolition saga began 13 years ago when the Maradu panchayat issued show cause notices to five builders including H2O Holy Faith, Alfa Serene, Golden Kayaloram and Jain Coral Cove for violating the Coastal Regulation Zone norms, Floor Area Ration and other building rules.The builders moved to Kerala High Court challenging the stay order. The Kerala Coastal Zone Management Authority approached the Division Bench with the review petition. The Division Bench rejected the review petition filed by the Authority.Later, the Authority moved a Special Leave Petition in the Supreme Court against the Kerala High Court order.

The history of building implosions began approximately 200 years ago. One of the earliest recorded demolition was the implosion of Holy Trinity Cathedral in Waterford, Ireland on 1773 using gunpowder.

The late 19th century saw the need of demolition of more complicated structures. This led to other considerations in this field such as worker and spectator safety and limiting collateral damage. Thus the technology of controlled implosions established. The Alfred P Murrah building in Oklahoma City, Seattle Kingdome in Washington, Martin Tower in Bethlehem etc. were demolished by controlled implosions.In the case of Maradu flats also, controlled implosion technology was used.

On 08 May 2019, the Honourable Supreme Court ordered the demolition of four illegal luxury apartments with a carpet area of 80,000 square meters in Maradu Municipality, near Kochi on the shore of the Vembanad Lake, which is a Ramsar Site. The Kerala State Coastal Zone Management Authority (KCZMA) was the appellant and the Government of Kerala (GoK) was the respondent. The demolition was done by the GoK and the Maradu Municipality. The review petitions filed by the residents were also rejected by the apex court.

LOCATION

Maradu Municipality is in Ernakulam district of Kerala. It has Lakshadweep Sea on its west. Vembanadu backwater and interconnecting canals crisscross the Municipality. The Kochi tidal inlet provides a permanent connection to the sea.The apartment blocks under demolition are located on the shores of Champakara Canal and Nettoor Stream of Vembanad Lake in Maradu Municipality near Kochi. The apartment Golden Kayaloram is located on the northern most branch of Champakara canal, while the Jain Coral is on its southern branch. Holy Faith and Alfa Serene are located on the eastern and western banks of the Nettoor stream.

CRZ CATEGORIES

The CRZ of Maradu consists of CRZ I (CRZ IA & CRZ IB), CRZ II, CRZ III and CRZ IV. The CRZ IA are those ecologically sensitive and the geomorphological features which play a major role in maintaining the integrity of the coast such as mangroves, corals, sand dunes, etc. The CRZ IB is area between Low Tide Line and High Tide Line. The CRZ II is those developed areas in legally designated urban areas. Maradu being a Municipal area, the CRZ in Maradu which have more than 50% built up area, is CRZ II. The CRZ III is undeveloped areas in the CRZ of Maradu Municipal area. The CRZ IV is the nearshore waters, the inland water bodies and the bed.

COMPANIES APPROACHED

13 companies including one from the United States responded to the expression of interest floated by the Municipality. The technical committee appointed by the state government selected two contractors for demolition of four apartmentment blocks on 12 October 2019. Finally, it was decided that the Mumbai based Edifice Engineering would demolish Golden Kayaloram, Holy Faith, and Jain Coral Cove while the Chennai based Vijaya Steels and

Explosives would raze two towers of Alfa Serene.

PHASES OF DEMOLITION

The first phase involved the inspection of the building plan of the apartment to be demolished. This helped in understanding how the building was constructed and where the main pillars are located. In the second phase, the team of demolition experts inspected the building. The structure of each floor of the building was scrutinised and notes were documented.

In the third phase, the plan for demolition was formulated. This plan was prepared by considering the building plan, inspection of the building and take-aways from earlier demolitions. In some cases, a 3-D model was developed using the computer. This helps in virtually checking what would happen during the time of demolition.

EVACUATION & INSURANCE COVERAGE

During the implosions, the neighbourhoods were evacuated to a safer distance. There must be provision for third party insurance coverage, in case of injuries or damages to the properties. Insurance policy was also the responsibility of the contractors. As the contractor did not do this, the GoK has paid the premium, two months after the award of contracts. Details of seismic monitoring and finalization of insurance policy must have been completed before signing of the demolition contracts. According to the latest announcement, the radius of evacuation zone was 200 m and the insurance coverage was 50 m.According to finalized agreement, the two towers of Alfa Serene and H2O Holy Faith were insured for Rs 25 crore each. Jain coral cove and Golden Kayaloram were insured for Rs. 10 crore each.

TECHNOLOGY USED FOR DEMOLITION

Implosion method was used here to demolish the building without affecting the nearby buildings. This is based on the principle that if the main pillars of a building are removed, it would collapse on its own. If the upper floors are heavier, when they come crashing down, the lower floors would be destroyed. Explosion would be carried out on several floors to weaken the main pillars. Once the pillars are destroyed, the building would collapse due to the gravitational force.Determining the time of the detonation is a crucial part of the building implosion method. The impact caused on the earth when the building comes crashing down and the subsequent tremors would depend on this timing. A building implosion carried out with extreme caution would trigger less than 25 millimetres of tremors per second on earth.

Several small explosions would be carried out to demolish one building. The first explosions would be on the main pillar of the ground floor. This is to give maximum power in the fall. The pillars for the first demolition are decided based on where the building rubble should fall.

When one pillar is demolished, the other building structures on top of it would start falling down. The speed of the falling rubble would increase by 10 metre per second. Other pillars or beams can turn out to be obstacles in the path of the falling structures. To avoid such obstacles, the explosion would be timed for different floors. Like this, the building would fall on to its base on its own. It is also possible to change the timings of the detonators and make the building fall towards a particular side in the desired angle. Prior to demolition, walls, windows, doors and iron frames of the flats would be removed. Only the pillars and beams would remain.It will be ensured that there are no hazardous objects.

EXPLOSIVES USED

The four explosives used for the demolition include emulsion, shock tube detonator, detonating fuse, and electric detonators. When the explosive kept at the blast shed 100 metres away, was operated, pow was conducted through the detonators and the explosion took place.

Emulsion 'Superpower 90' emulsion of the Nagpur-based Solar Explosives was used to demolish the Maradu flats. Ammonium nitrate is the main constituent of this explosive.

Totally 943kg of explosives were used which include 372.8kg for Jain coral cove, 343kg for Alfa Serene, 212.4kg for H20 Holy Faith and 14.8kg for Golden Kayaloram

● Shock tube detonator

Non-electric detonators or shock tube detonators were the main explosive used for the demolition. Instead of electric wires, hollow plastic tubes were used for combustion.

● Detonating fuse

Detonating fuse is a thin and flexible plastic tube, which was filled with pentaerythritoltetranitrate (pentrite).

● Electric detonators

These are delay electric detonators that can determine the time for the explosion. The explosions of various floors can be timed with a time gap of milliseconds.

● Exploder

The blasting exploder is the switch used to conduct electricity through detonators. This was set up in a shed, 100metres away from the flats.

CHALLENGES & SOLUTIONS

40-odd houses were there around the Alfa Serene. It is a densely populated area. Another multi-storeyed building was next to the flat. Explosion had to be carried out without affecting the houses nearby. But cracks already developed on 18-odd houses in the area. The plan was to make the apartment collapse into the space between the two towers.A house was at a distance of 1.5 metres away from the Holy faith H20. Right next to that stood the petrohouse of the Bharat Petroleum. The Thevara-Kundannoor bridge was at a distance of 10-metre from the front of the flat. Petrol, diesel pipelines of the IOC also passing through the underground in front of the flat. Fuel would be completely removed and the pipeline would be filled with water for a distance of 16km from Boat Jetty to Irumpanam. The plan was to make the flat collapse at an angle of 36 degree towards the side of the bridge.

An anganwadi was located near to the Golden Kayaloram. Another multi-storeyed building and several houses were in this area. It was feared debris would fall into the backwaters and the area would be engulfed by dust after demolition. The smaller part of the building would be made to collapse towards the Thaikkudam bridge, and the larger portion towards the opposite side.Jain coral cove was surrounded by backwaters. The flat had to be demolished even while ensuring that the rubble does not fall into the backwaters. A KSEB electric tower stood next to the flat. Another small building was also in the area but fewer houses. The plan was to make flat collapse towards the eastern side.

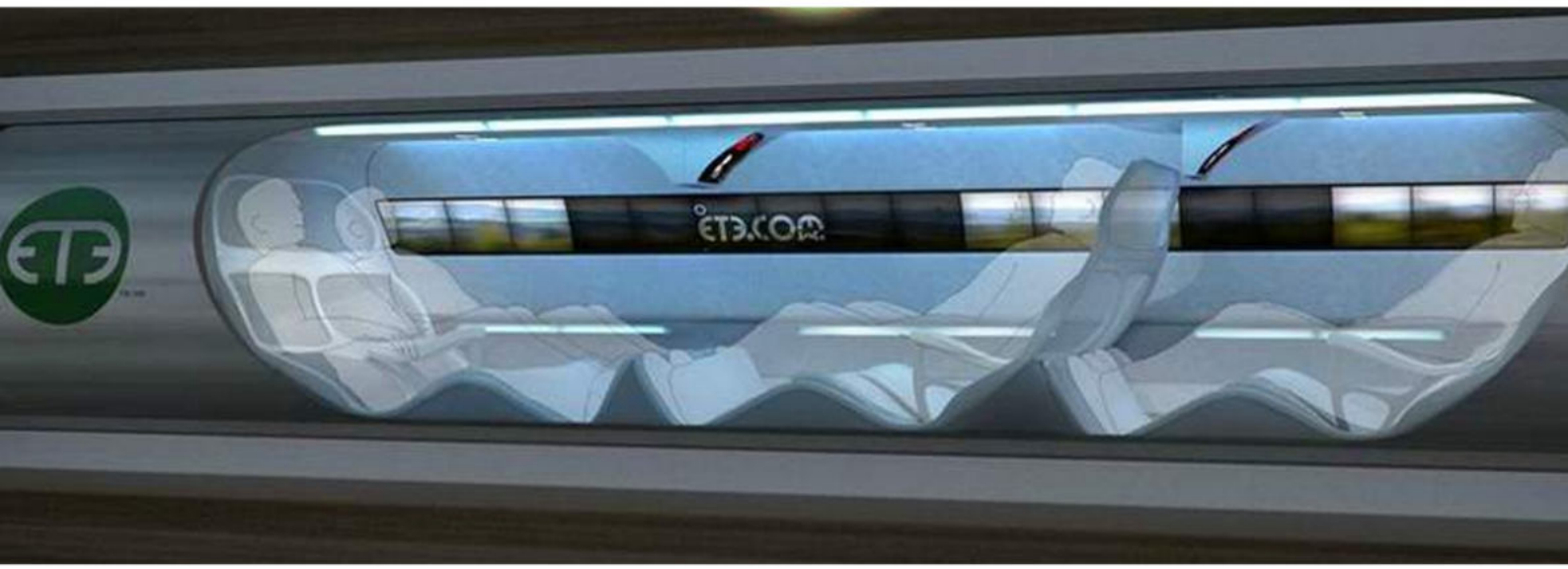
AFTER THE EXPLOSION

Extreme caution should be exercised while removing the rubble. The remains have to be reused as much as possible. Concrete and iron rods would form bulk of the debris. Iron rods can be processed and used again. Concrete parts too can be used in the construction of roads and buildings.

The demolition of highrises at Maradu will serve as an eye-opener in future for the government, the LSG institutions, builders and also for the prospective buyers. Though the Maradu affair will act as a deterrent to erring builders, legal action should be taken against the officials concerned and others involved in such illegal activities. Such buildings not only destroy vulnerable local ecosystem but also cause huge casualties during natural calamities like flood and cyclones. The recently established Real Estate Regulatory Authority must ensure that in the future, construction of highrises is done complying with all existing building laws.The Maradu episode points to the fact that in the end, the law of the land will prevail.

FUTURE OF TRANSPORTATION-EVACUATED TUBE TRANSPORT SYSTEM

Rincy Raju , C8B



Think of how well-travelled and eco-responsible you would be if you could economically zip between countries at speeds with relatively little power- upto 6,400-8000 km/hr (4000-5000 mph) in a comfortable, carbon neutral way. That's the promise of evacuated tube trains..

The scientific principals of Evacuated Tube Transport Technologies (ET3) are highly proven. ET3 is literally "Space Travel on Earth" where car sized passenger capsules travel in 1.5 m (5') diameter tubes on frictionless maglev (magnetic levitated vehicle). Air is permanently removed from the two-way tubes that are built along a travel route. Airlocks at portals allow transfer of capsules without admitting air. Linear electric motors accelerate the capsules, which then coast through the vacuum for the remainder of the trip using no additional power. Most of the energy is regenerated as the capsules slow down where kinetic energy is converted to electric power through electromagnetic induction. ET3 can provide 50 times more transportation per kWh of electricity than the most efficient electric cars or trains.

ET3 is networked like freeways, except the capsules are automatically routed from origin to destination. Speed in initial ET3 systems is 600 km/h (370 mph) for local trips. This will be developed to 6 500 km/h (4 000 mph) for international travel that will allow passenger or cargo travel from New York to Beijing in 2 hour. Velocity may even extend to that of a rocket in future.ET3 capsules weigh only 183 kg (400 lbs), yet like an automobile, can carry up to six people or 367 kg (800 lbs) of cargo. Compared to high-speed-rail (HSR) trains, ET3 needs less

Fresh ice and water transportation

Natural resources are not evenly distributed. The scorching hot desert nations have oil to burn, but there is little fresh water to sustain life. Fresh water supply is the critical factor limiting city growth.

Enormous quantities of fresh water (mostly in the form of ice) are in the most remote and inhospitable places like Greenland, the north pole or south pole. ET3 can carry them in a flash of time. Fresh ice can be served to Beijing or Arabic countries on demand. Japan has a lot of fresh high quality water all over the country. ET3 can provide high quality fresh water on demand to parched cities.

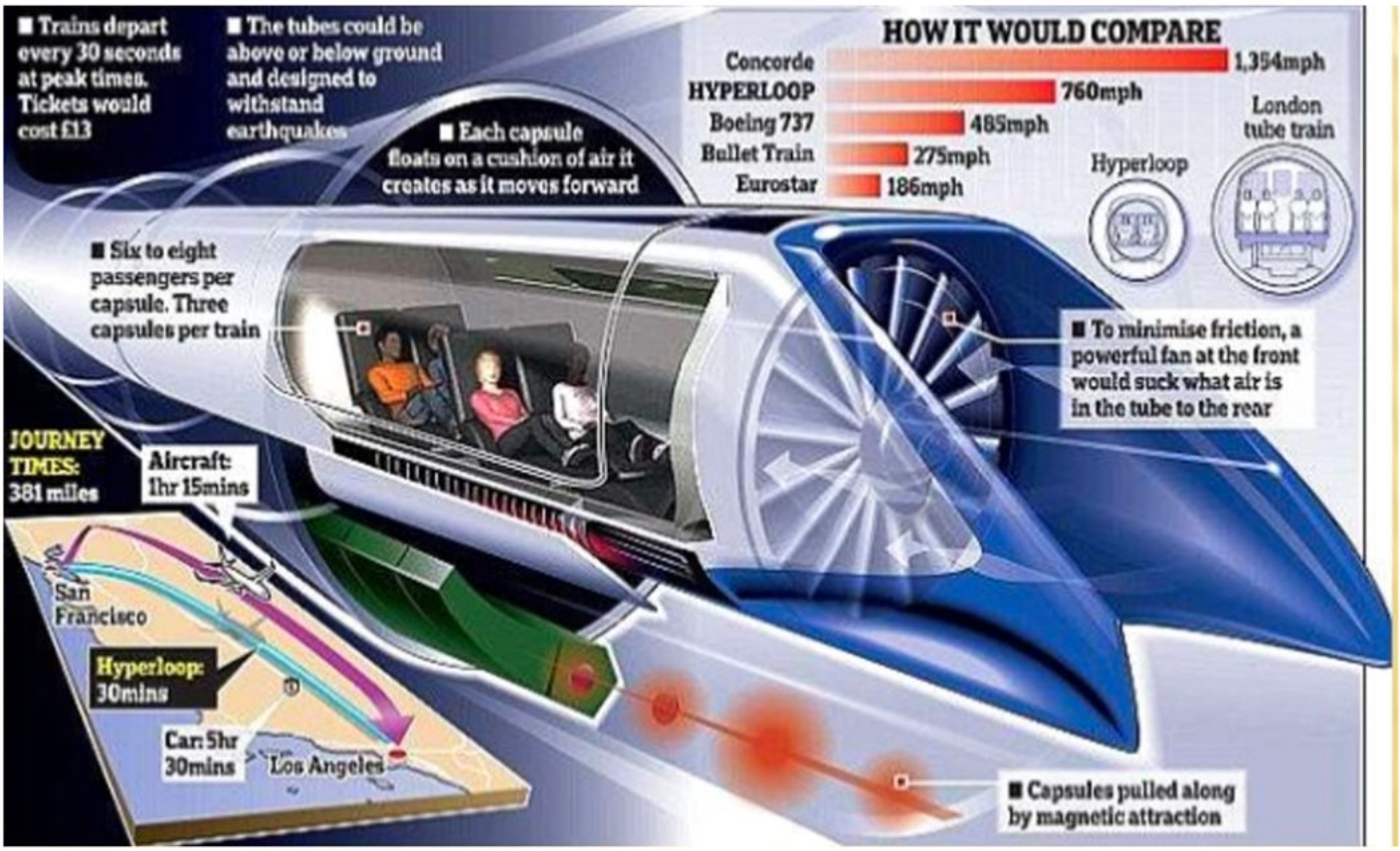
Conclusions

ET3 will create expanding potentials for several generations. The first nations to implement ET3 will invigorate their economies, then the focus will shift to the enormous opportunity of accelerating the sustainable development of nations now in poverty. ET3 will allow sustainable prosperity to take root in developing nations at a much faster rate. This will improve peace, green the earth, arrest population explosion, and create an age of global prosperity.

ET3 will be virtually silent (sound cannot be transmitted in a vacuum). ET3 will not cause ground vibration like trains (an advantage of the light weight). The path of ET3 capsules is fully isolated within the tube guideway, and therefore it is impossible for birds, animals, or people to be in conflict with the path of the capsules. Much of the electrical energy used to accelerate the capsules can be recovered when the capsules slow down (Energy Recovery System), the energy may be used to accelerate outbound capsules, stored in a flywheel, or used in the power distribution grid. Because ET3 uses electrical energy and the consumption per passenger/mile is less than 1% of an electric train at the same speed, ET3 will not have a negative impact on air quality if renewable sources are used. There will be a positive effect from reducing automobile and aircraft pollution and Green House Gas (GHG). In fact, ET3 can play a key role to meet Kyoto Protocol by eliminating over 90% of fossil energy use for transportation. ET3 operates in controlled conditions at all times, and has much less opportunity of failure. ET3 is also built to 3 times higher margin of safety than aircraft. In the rare event of cabin pressure loss, aircraft must descend thousands of feet before enough air is available for survival. In the rare event of catastrophic emergency with ET3 the affected branch can be isolated with gate valves and, air can be admitted along the entire section. This can occur in a fraction of the time it takes an aircraft to reach safe conditions. This air is metered to quickly slow the capsules and cushions any collisions, as well as provide a breath of fresh air. And many more advantages are there.

The need for transportation crosses all borders. To facilitate ultra efficient and effective transportation for the entire world, we must employ open standards that may be continuously improved, and not encumbered by old ways that are no longer sustainable. We should never restrict ET3 based on: sex, age, race, religion, nationality. We believe that ET3

will greatly increase the present peace that more than 99% of the world's population enjoys more than 99% of the time.



TACOMA NARROWS BRIDGE

Athira A, C2A

Tacoma narrow bridge is a pair of twin suspension bridges. The cable suspension bridge, the first of its kind was constructed in the state of Washington was opened for traffic on July 1, 1940. The bridge had a unique slender design and it spanned over a mile connecting the city of Tacoma with the Kitsap Peninsula. Because of its extremely long length, it was considered a 'narrow bridge'. The bridge collapsed little more than four months later from its opening due to aero elastic flutter. Since then the bridge has become popular, with several case studies discussing the failure phenomenon of suspension cable bridges. It was the very first bridge to incorporate a series of plate girders as roadbed support, and also the third largest suspension bridge of its time. The big budget construction which lasted over only for few months remains as a great engineering feature for civil engineers to ponder over.

The bridge which was constructed in 1940 is considered as the original bridge and it received a nickname "Galloping Gertie" because of the vertical movement of the deck during windy conditions. The bridge collapsed on November 7, 1940 morning, without any human mortality. The only fatality was the death of Cocker Spaniel breed that was abandoned in a car by his owner. However, this collapse was deemed "the Pearl Harbor of engineering."

THE HISTORIC COLLAPSE

On November 14 1940, the bridge collapsed due to aero elastic flutter that was caused by high-speed winds that matched with the natural frequency of the structure. Even with the normal winds, the bridge was undulating noticeably, and this had the engineers worried

as to the conditions in the presence of high winds. Alarmed by this, many engineers started conducting experiments in a wind tunnel on the structural behavior of the bridge when subjected to wind loads. On the day of the Tacoma Narrows Bridge collapse, it experienced winds of about 70kmph. The center stay was torsionally vibrating at a frequency of 36 cycles/min, in nine different segments. Over the next hour, the torsional vibration amplitude built up and the motion had changed from rhythmically rising and falling to a two-wave twisting. Despite all these motions, the center part of the bridge (along the length) remained motionless, while its other two halves twisted in opposite directions. The bridge was twisted noticeably into two parts, experiencing 14 vibrations/min. This drastic torsional motion was started by a failure of a cable (located along the north side) band connecting to the center of the diagonal ties. Due to alternative sagging and hogging of span members, the towers holding them were pulled towards them. Further, visible and predominant cracks developed before the entire bridge crashed down into the river.

CONCLUSIONS MADE ON THE COLLAPSE

A three-dimensional scaled model of 1:200 scale was built for wind tunnel experiments and to explicitly understand the reason for failure. The experiments brought about a new theory: wind-induced oscillations. The shape of the bridge was aerodynamically unstable along the transverse direction. The vertical girders of the H-shape allowed flow separation, thus leading to vortex generation that matched the phase of oscillation. These vortices generated enough energy to push the girders out of their position. The problem that caused the Tacoma Narrows Bridge collapse was not a new problem, but one which had been unspecified. Due to wind action, increased stiffness can be seen through various design methods such as adding a greater dead load, adopting dampers, stiffening trusses or by guy cables. However, these factors were not originally considered and only became part of the later forensics.

RECONSTRUCTION

After the Tacoma Narrows Bridge collapse, the new bridge was redesigned and rebuilt in 1950. Engineering issues, as well as the United States' involvement in World War II, postponed plans to replace the bridge for about 10 years. The newly built bridge incorporated open trusses, stiffening struts and allowed the wind to flow freely through openings in the roadbeds. Compared to the previous design, the twisting that developed in the new bridge was considerably less severe. Because of the disaster of the Tacoma Narrows Bridge, the Whitestone Bridge in the US was strengthened by adding trusses and openings below road decks to decrease oscillations, and these are found to be working even today.The idea of using dynamic and modal analysis for the design of bridges received much greater impetus after this disaster. The deflection

theory serves as a model for complex analytical methods used by many structural engineers to obtain stresses, deflections, etc. This eventually led to the development of finite element analysis (FEA) as a generic tool for designing civil engineering structures.

Nowadays, in bridge design, engineering simulation plays a crucial part in the testing process. Using CFD to simulate wind loads and FEA to investigate stresses and the structural behavior of bridges, engineers can prevent failures like the Tacoma Narrows Bridge collapse and build better and stronger bridges and buildings.

collapse. The film later revolves around how he solemnly reviews the damage.

"A Kaleidoscope of Campus Life", the footage itself is framed at the start and finish with scenes of Farquharson. The film's topic includes the Tacoma Narrows Bridge and newspaper headlines of its dramatic collapse, including one about a talk by Frederick K. Kirsten, then a professor of aeronautics. We see Farquharson inspecting the broken bridge, followed by what appear to be scenes of tests on structural models of a similar bridge design.

THE FILM COLLECTIONS

"Governor's Day 2," a silent, six-minute montage of colorful campus scenes dating back to 1940. The film boasts some great footage of the Tacoma Narrows Bridge collapse. It shows F. B. Farquharson, a UW professor of engineering and an eyewitness to the bridge's dramatic

The striking photos and motion pictures of the failure of the 1940 Tacoma Narrows Bridge seem destined to fascinate viewers indefinitely. For over six decades the images have been shown around the world and have appeared in thousands of publications and Internet web sites.

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REDISCOVERING THE FALL OF ST.FRANCIS DAM

Haritha R, C4A

The St. Francis Dam disaster has been called “the worst civil engineering failure " of 20th Century America.The forensic work on St. Francis Dam failure, located in the city of Los Angeles, California illustrates the complex and interdisciplinary nature of working with earth, water, and structural systems, and conveys the frailties engineers and geologists possess, based on the limitations of their training and professional experience. Its untimely and high-visibility failure had an enormous impact on dam engineering, raising consciousness about the need for engineering geologic input and appreciation of uplift forces in siting, design, and construction of dams.

Construction

The process of surveying the area and determining the location for the St. Francis Dam began in December 1922. A distinctive aspect of the St. Francis Dam was its stepped downstream face. While the height of each step was a constant 1.5 m,the width of each step was unique to its respective elevation above sea level.

When completed on May 4, 1926, the stairstep faced dam rose to a height of 56.3 m above the canyon floor, both faces leading up to the crest were vertical for the final 7.0 m. On the downstream face, this vertical section was fashioned into 7.3 m wide sections. A portion of these made up the spillway, which consisted of 11 panels in total, divided into two groups. Each spillway section had an open area that

was 46 cm high and 6.1 m wide for the overflow to pass. The dam also had five 76 cm diameter outlet pipes through the center section which were controlled by slide gates attached to the upstream face.

Instability beforemath

Water rose steadily and rather uneven fully, although several temperature and contraction cracks did appear in the dam and a minor amount of seepage began to flow from under the abutments. The most notable incidents were two vertical cracks that ran down through the dam from the top.Workers were ordered to seal off the leak, but they were not entirely successful and water continued to permeate through the face of the dam.

Leaks had appeared in the same area as in the past and also the muddy color of the runoff indicated that the water was eroding the foundation of the dam.Chief Engineer, William Mulhollan along with his Assistant Chief Engineer and General Manager Harvey Van Norman, inspected the dam, various leaks and seepages, finding nothing out of the ordinary or of concern for a large dam.

Failure of the Dam

Two and a half minutes before midnight on March 12, 1928, the St. Francis Dam catastrophically failed.Given the known height of the flood wave, and that within seventy minutes or less after the collapse the reservoir was virtually empty, the failure must have been sudden and complete. Seconds after it began, little of what had been the dam remained standing, other than the center section and wing wall.

Five minutes after the collapse, then a 37 m high flood wave had traveled one and one-half miles (2.4 km) at an average speed of 29 km/h, destroying the heavy concrete Powerhouse No. 2 there and taking the lives of 64 of the 67 workmen and their families who lived nearby.

Causes of failure

An investigation into the disaster concludes several reasons.Some of them are :

- The unsuitability of the San Francisquito rock for supporting a dam and a reservoir.

- Lack of hydraulic uplift theory being incorporated into the dam's design, especially on the sloping abutments.

- Failure to provide the dam with grouted contraction joints.

- Failure to analyze the arch stresses of the main dam, which were overstressed in the upper 11 feet of the structure.

- Lack of any meaningful seepage cutoff, preferably situated near the upstream heel.

Aftermath Benefits

Some of the more positive aspects that came about as a direct result of the St. Francis Dam failure are briefly profiled below :

- **Review of federal dams :** All the dams must be promptly examined by a competent engineer and reported on as to their safety.
- **Dam safety legislation :** All plans for dams and reservoirs should be submitted to the State Engineer for approval, but the act provided no penalty for failure to comply.
- **Professional engineering registration :** Any person who practices or offers to practice civil engineering in any of its branches must be registered, and created The Board of Registration for Civil Engineers.

Lessons to learn

"For every complex problem, there is a solution that is simple, neat, and wrong" – H. L. Menken. St. Francis Dam Collapse provides us with engineering lessons for future.

- A calculated Factor of Safety less than 1.0 does not, in of itself, mean that a structure failed via the precise mechanism analyzed. All manner of failure mechanisms should be evaluated without prejudice.
- We will not identify those geologic features or structures for which we are not specifically looking for. We have to have in mind what we are seeking, realizing that we will seldom be able to recognize those features with which we've had little prior experience.
- Structures that place the public at risk, must be treated with greater care, ensuring redundant systems that cannot trigger catastrophic failure if one or more of their components fail to perform as assumed.

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An Outlook on Recent Advances in Non-Destructive Testing of Concrete

Nishanth Chakravarthy, C6A

The last few decades have seen considerable amount of work being done regarding infrastructure monitoring, repair and design code specifications. Maintaining safe and reliable civil infrastructures for daily use is important for the wellbeing of mankind. Concrete degradation, steel corrosion, change in boundary conditions and weakening of connections in structures over time are major concerns in most civil engineering structures. The integration of Non Destructive Testing (NDT) techniques and risk assessment tools is seen as an efficient method of managing safety and ensuring performance effectiveness of these structures.

Common Defects in Concrete/Structural Systems

Defects in concrete systems result from the deterioration of concrete over time. Proper understanding of these defect mechanisms will augment the development of strategies aimed at mitigating the effect of these defects.

● Disintegration or Scaling

It is the physical deterioration or loss of the surface portion of concrete into smaller particles or fragments as a result of freezing

and thawing. It happens when pressure from water freezing with concrete exceeds tensile strength of the concrete.

● Delamination

It is the detachment of a thin surface layer from the rest of the system and usually manifested by a sound. It is often caused by trapped air or water content which combines to make larger bubbles during concrete finishing operations.

● Spalling

It is also referred to as extended lamination. It describes areas of concrete which have cracked and delaminated from the surface of substrate. It occurs due to freeze thaw cycling, exposure to fire or corrosion of embedded steel reinforcement bars or steel sections.

● Cracking of Concrete

It can occur as a result of volume changes and repeated loading of 2 members. The reason, type of crack and their effect on structural integrity need to be studied so as to develop appropriate repair method.

● Honeycomb

The defect looks like a honeybee nest and has a rough pitted surface or voids on concrete formed due to improper compaction or incomplete filling. It is a serious problem of concrete which should be treated in order to avoid failure of the structure with long term economic and environmental consequences.

NDT Methods Used in Industry

The steps for choosing an effective NDT method are (Shull, 2002):

1. Understanding the physical nature of the material property or discontinuity to be inspected.

2. Understanding the underlying physical processes that governs the NDT methods.

3. Understanding the physical nature of the interaction of the probing field with the test material.

4. Understanding the potential limitations of available NDT technology.

5. Considering economic, environmental, regulatory and other factors.

Conventional NDT techniques include Acoustic Emission Testing, Leak Testing, Electromagnetic Testing, Thermal/Infrared Testing, Neutron Radiographic Testing, Liquid Penetrant Testing, Magnetic Particle Testing, Radiographic Testing, Ultrasonic Testing, Vibration Analysis.

Advanced NDT methods (validated) include Phased Array Ultrasonic Testing, Alternating Current Field Measurement, Long Range Ultrasonic Testing, Pulse Eddy Current Testing, Digital Radiography Testing, Time of Flight Diffraction Testing.

During application, the personnel make an interpretation of the signal response to show if the flaw is relevant.

● Resonant Frequency Test Method

It is a non-invasive NDT method used to determine material properties by assessing their natural frequency of vibration. The most commonly used methods are resonant frequency by vibration and resonant frequency by impact.

Rebound (Schmidt) Hammer Method

It can be used to evaluate the quality of concrete near the surface. These methods highlight empirical correlations between strength properties of concrete and surface hardness. A site-specific calibration on concrete cores can be used to predict the strength of concrete on site.

Penetration Resistance Method

It is an invasive procedure that explores the strength properties of concrete using previously established correlations. The method involves driving probes into concrete samples using a uniform force. The depth of penetration provides an indication of concrete compressive strength by referring to correlations. Windsor probe system is the most commonly used method.

Pull Out Resistance Method

It measures the force required to extract standard embedded inserts from the concrete surface. Using established correlations, the force required to remove the inserts provide an estimate of concrete strength properties. The two type of inserts, cast-in and fixed-in-place define the two types of pull out methods.

Pull Off Resistance Method

It was developed with the aim of determining the strength of concrete in situ due to problems associated with high alumina cement. The test has the ability to evaluate the resistance of concrete and to verify the adhesion strength of repairing materials.

Maturity Test Method

It is a technique on the measured temperature history during curing. The maturity function is presented to quantify the effects of time and temperature. The resulting maturity factor is then used to determine the strength of concrete based on established correlations.

Permeability Test Method Test Method

Permeation tests are NDT methods that measure the near surface transport properties of concrete. Permeable concrete can cause corrosion due to the presence of oxygen, moisture, CO^{2-}, SO^{3-} and Cl-. This formation of rust due to corrosion becomes nearly 6 times the volume of oxide layer, leading to cracking and spalling in reinforced concrete. Permeability represents the governing property for estimating durability of concrete structures

Ultrasonic Pulse-Echo Method

It is a method used to assess homogeneity and integrity of concrete. This is achieved by propagating ultrasonic waves through solids from a transmitter and then received by a receiver and then studying the output displayed. It can be used to assess strength, thickness, degradation in different locations, discontinuity, etc.

Ground Penetrating Radars

It is used to scan concrete using pulsed EM radiation to evaluate structural integrity of concrete. It consists of a transmitter, receiver antenna and two signal processing unit. Due to its suitability, GPR method scans large areas of concrete in a limited period of time and scan steel reinforcement concrete over existing

coatings where potential delamination and other discontinuities are identified.

Impact Echo Method

It is ideal for measuring the thickness of concrete slabs and for identifying delamination. On a broader level, it is also used for detecting mechanical impedance contracts.

Half Cell Corrosion Mapping

It is a widely used test procedure to identify areas with active corrosion activity. It can reveal locations with high likelihood of corrosion and can also be used to evaluate quality of repair.

The advent of smart concrete means an addition of IOT technologies which allows challenging NDT inspections to be carried out with ease. This technology makes internal structures to be accurately monitored and maintained while maximizing their lifespan with repairs made at the most cost effective point of intervention. It is envisaging that the use of specialized and modern NDT tools and risk assessment methodologies will help in broadening the scope and usage of NDT technology for evaluating material integrity and management.

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BAMBOO
The Building Material For The Future

Megha P, C6B

Introduction

"Yes , humans have the incredible capacity to destroy , also an equal ability to create " Orin Hard , the co-founder of kul-kul farm and bamboo U ,truely meant what he said as he is rewriting the history of construction industry by re-introducing the most sustainable structural building material - "The Bamboo".

Bamboo is the oldest and also long forgotten building materials known to humans.The main drawback was the lack of durability of the structure.Anyhow due to innovative treatments methods the bamboo can regain its glory as material which is un paralleled in its strength , durability and beauty.
ome of the many advantages of bamboo over other materials include is it's short growth cycle . it has a growth period of 3-4 years whereas softwood will require about 10-20 years to reach its maturation and later harvesting .It is the fastest growing plant with growth rate as much as 2 inches an hour , some species even grow one and half meters a day .Bamboo strands release 35% more oxygen than the equivalent amount of tree strands . Bamboo also have the carbon sequestration capacity of 12 tonnes per hectre .With bamboo being the fastest growing plant the rate of carbon sequestration is unmatched by any other tree species.

In addition to its incredible sustainability it is one of the structuraly sound construction material available .The tensile strength of bamboo per weight is 3-4 times more than that of steel .The tensile strength of bamboo is 432 kN per sq mm compared to steel which is 355kN per sq mm. The compressive strength of bamboo is twice that of concrete. In fact the

hollow tube gives a strength actor of 1.9 over equivalent solid . With concrete jungles dotting the global landscape,the carbondioxide emissions are exorbitantly increasing in the construction industry whereas bamboo offers both strength and beauty. If given the chance, it can transform our spaces into extensions of nature rather than isolating boxes of concrete.

The most recent technique of bamboo treatment that researchers have discovered is the modified boucherie technique in which pressurised preservative solution is applied on basal end, which pushes the sap contained in the vascular bundles out and then replaces it with a preservative solution. Eventhough the good old water logging works fine for temporary structures but more dependable techinques like above have to be used to build permanent structures.

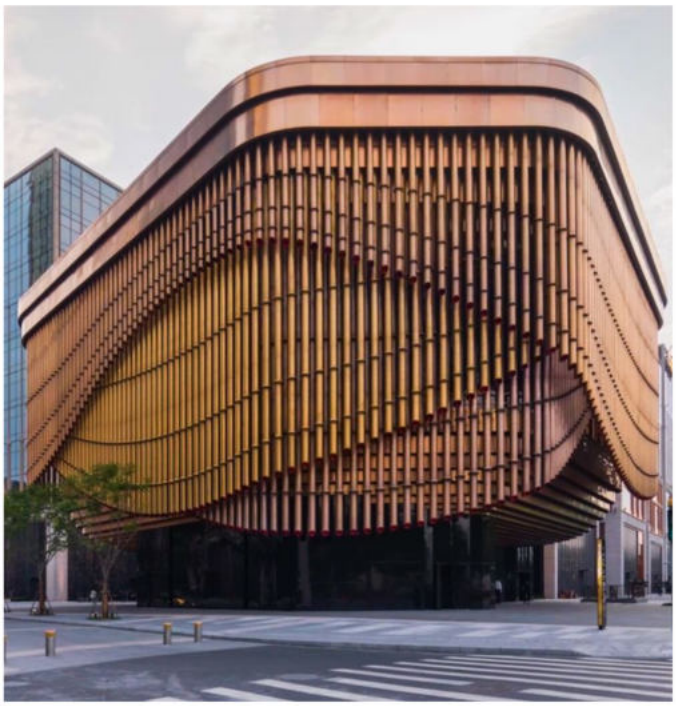
Modified Boucherie Treatment

Bamboo culms are divided into nodes and internodes and are composed of two types of tissue; parenchyma cells and vascular bundles. The latter consist of vessels, thick walled fibers and sieve tubes and it is through these that water movement takes place in the living plant. In Modified Boucherie Technique, (aka. sap displacement technique), pressurized preservative solution is applied on the basal end, which pushes the sap contained in the vascular bundle out and then replaces it with a preservative solution. This technique is only possible on a freshly cut bamboo because vascular bundle is still wet.

• The cylinder is ¾ filled with preservative. We are now using boron compound, and we are testing neem and cow urine.
• The cylinder is pressurized (up to 20-25 psi) using a simple manual pump.
• Valve in the nozzle is open for a split second to let the air out
• Nozzle is connected to the bamboo, which is made airtight using rubber tube.
• Sap starts dripping from the branch in almost 5 minutes. It takes about half hour for the preservative to come out from the opposite end)
• Treatment is done for atleast an hour so that the preservative can reach all parts of the bamboo.
• Bamboo is then stored horizontally in a rain-protected area till it dries.

Modified Boucherie Treatment Process

Bamboo construction is gaining acceptance all around the world. Green school by John and Elora hardy was a milestone in making bamboo construction more viable and astheticaly pleasing. They have opened up new avenues of bamboo construction and undertakes several courses and programs to make architects , designers , engineers other curious heads to understand and build with this magical piece of bamboo. Organisations like IBUKU , a daughter organisation of the green school takes up bamboo construction all over the world . ABARI , is a specialised bamboo research and design firm of Nepal which is finding the roots of ancient Nepali bamboo construction to cope with the modern needs is also spreading the word of greener tomorrow . Hopefully few years from now we can see a bamboo skyscraper fading into the skyline.



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SHOTCRETE

Sona PS , C8B

We all are familiar with the term concrete. But what is shotcrete?

Is that any building material like concrete? No! Shotcrete is not considered as a unique material, but rather as a special process to place concrete. Shotcrete is widely used in different fields, such as tunnel support, rapid repair, slope support, gas and oil wells, and other underground structures. Because of its very rapid setting property, it is also used when uncontrollable water penetration occurs.

Shotcrete is a special type of concrete which is conveyed under pressure through a pneumatic hose or pipe and projected into place at high velocity, with simultaneous compaction, condensation and hardening. It is also called as 'sprayed concrete'. Compared with ordinary concrete without accelerator, accelerated shotcrete has short final setting time and high early-age mechanical properties, which are achieved by means of a setting accelerator, together with the spraying procedure. So it allows concrete to be placed without extra support, sticking to the surface and hardening within minutes.

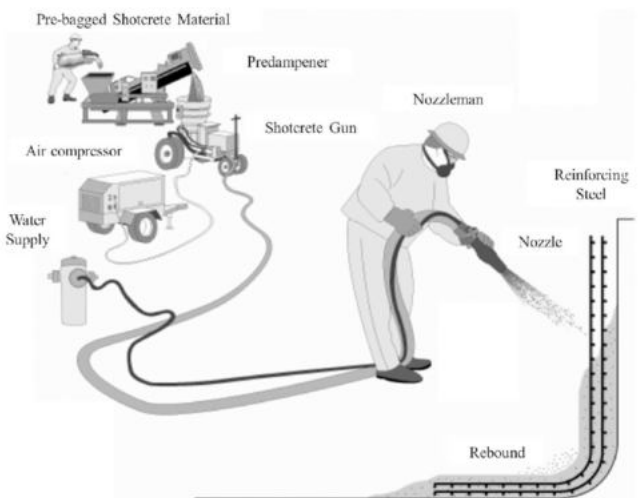
Generally, shotcrete is used where access is difficult and standard concrete casting and application is not possible. Shotcreting is also preferred where very rapid setting is required. The support of rock in mining and tunneling is probably the most important application of shotcrete, but it is also used for structural

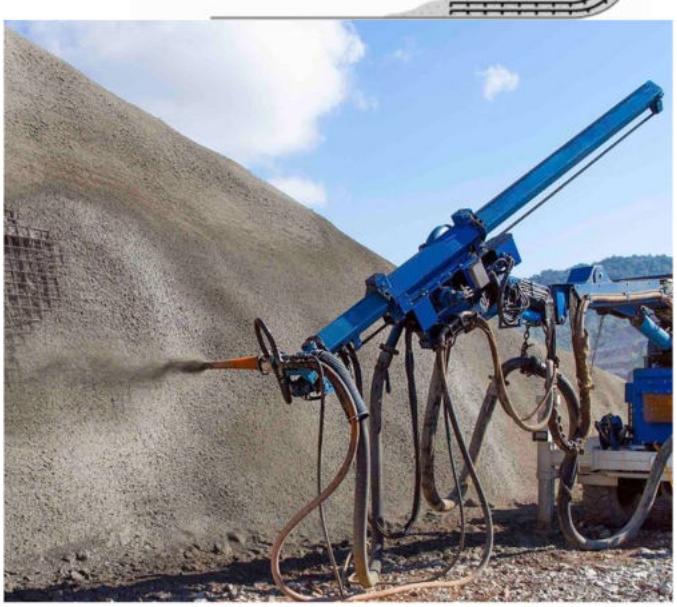
repairs, refractory linings, soil stabilization and installation of shell structures, swimming pools, river walls, domes and even houses. In the case of tunnels, drilled in unconsolidated sediments, soft rock or soils, shotcrete has been mainly used as a temporary ground support whereas in hard rock tunneling shotcrete is often conceived as a permanent shell.

Shotcreting process can be divided in to two, wet-mix process and dry-mix process. In the wet-mix process the aggregates, water and binder are mixed and then conveyed and pumped to the nozzle, where the wet-mix, together with an accelerator and pressured air, is sprayed towards the substrate (like soil, rock, tunnel walls, and linings of water pipes). In the dry-mix process the water is added at the nozzle of the delivering hose to the flow of a humid or oven-dried pre-mixed dry mix. Nowadays, the wet-mix process is used more frequently in tunneling because of the much higher throughout and the lower dust production, as compared with the dry-mix process. Furthermore, the amount of rebound material, comprising mainly of coarser aggregates that do not stick to the substrate and bounce off, is significantly reduced by the wet mix process, contributing to economic benefits and minor changes in the composition of shotcrete. On the other hand, the dry-mix process requires smaller machines, and thus lower power, and its use is needed in confined construction or inner city sites.

The durability of shotcrete has been identified as an important performance aspect in best practices and quality assurance. The durability of shotcrete is affected by the same variables as that of concrete, that is, mix composition, microstructure, permeability, compaction, curing, environment, etc. In addition to this, there are some other relevant parameters to shotcrete, which affect the durability are, composition and amount of accelerator, rock and water in contact with the shotcrete and application (shooting).

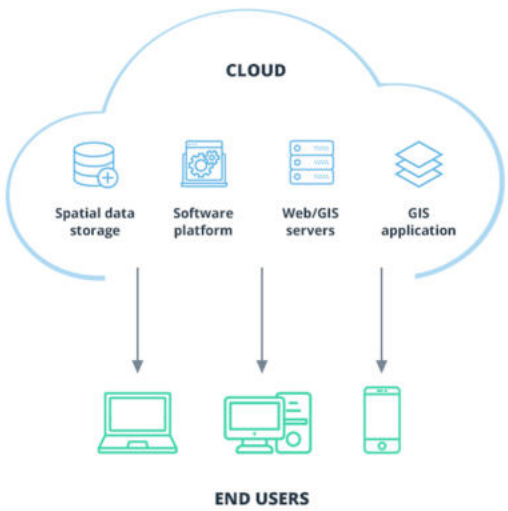
Even though it has different durability issues such as leaching, sintering, sulfate attack, freeze-thaw electrochemical corrosion etc, it has become a vital material today because of it being versatile in shape, high strength, durability and good bonding ability. And in areas of difficult access it can be easily sprayed onto a surface at high velocity, making it handy for operation. The selection of shotcrete for a particular application should be based on knowledge, experience, and a careful study of required and achievable material performance. The success of the shotcrete for that application is contingent upon proper planning and supervision, plus the skill and continuous attention provided by the shotcrete applicator.





A TECHNOLOGY FOR THE FUTURE - Cloud Computing in GIS

Rithwik , C6B



The field of Geographic Information System (GIS) has advanced rapidly over the past few decades. GIS has evolved from a theoretical concept of digitally creating maps into an array of methods and software with wide-ranging applications. Geospatial technology now offers much more than a system for capturing and organising positional data. Since its inception in mid-1960s, GIS has paired up with advancing technologies of each time period - Processor intensive task management in the beginning of 90s, moving to geodatabases in mid 90s and most recently, Cloud computing in the 21st century.

Cloud computing is emerging as an important technology trend in almost every industry, including the GIS community, and rapidly moving into the mainstream. Cloud computing delivers technological capabilities on demand as a service via the Internet. Rather than the classic computing model of operating system plus software applications with files and database storage, 'the cloud' model consists of services, clients, hosted content, and virtual machines. In other words, we do not load and run software and store data on our computer; we log in and use the system in the cloud. One major difference between traditional and cloud computing is the scalable and elastic nature cloud computing provides. Instead of a static system architecture, cloud computing supports the ability to dynamically scale up and quickly scale down, offering cloud consumers high reliability, quick response times, and the flexibility to handle unpredictable traffic fluctuations and sporadic demand. Cloud computing also supports multi tenancy, providing systems configured in such a way that they can be pooled and shared by many

organizations or individuals.

The greatest impact of making GIS softwares cloud-ready is that people will be able to rent and deploy GIS servers in the cloud, quickly and easily scaling their system up to solve large problems. For many users, this will provide a more efficient solution for maintaining infrastructure. Also, for many government agencies, it provides a solution for them to serve their data without the cost of administering hardware. Also, a physical software can now pave path for SaaS (Software-as-a-Service), which is the future of software computing, through the advanced cloud infrastructures.

From a British physician's idea of comparing data for pinpointing an epidemic outbreak, to being used by every governments and enterprises, irrespective of their sizes, GIS has come a long way. The introduction of cloud computing to it is only one of many technical changes that it has undergone in decades. However, this is the most ambitious of them all. The day that it comes in handy for even the most inexperienced user, is not far. After all, with Data Science shaping how people view and handle data these days, it's only a matter of time before the whole world shrinks into one mouse-click.

GIS Software-as-a-Service provides focused, cloud-based clients and applications that easily solve complex business problems using GIS tools and data but don't require GIS expertise to use. The latest version of ArcGIS (a widely used professional GIS software), ArcGIS 10 is the best example known for its flexibility to run as a SaaS, which employs wide customisation features like on-the-go editable enterprise geodatabases accessible via ArcGIS server on Amazon.

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INTERNET OF THINGS (IoT) in Construction Industry

Sarath VR, C8B

"The best way to create value in 21st century is to connect creativity with technology". These are the words of Steve Jobs about how technology would impact modern world. Our world is changing rapidly and advent of new technologies is altering the traditional dimensions of world. IoT is such an advancement that is creating miracles from Nano level to cosmic level. IoT finds applications in almost all the fields from manufacturing industry to military service.

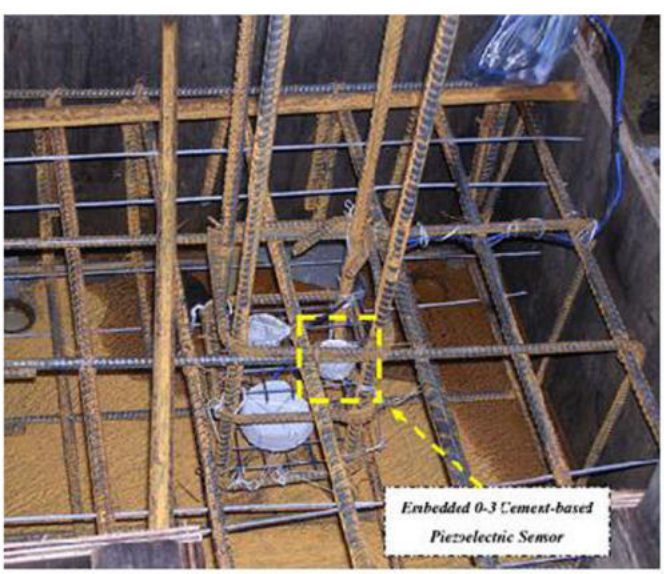
The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. In construction and building industry IoT is mainly dealing with development of smart buildings or green buildings. But the potential of IoT is very vast in building industry from location studies to deconstruction of buildings. The main advantage of employing IoT like technologies in construction field is the reduction of human force and enhancement in quality of construction. Better and efficient energy management and optimum utilization of resources can also be achieved. The scope of IoT in construction industry can be analysed in three levels- constructions of buildings, operation and management, demolition and deconstruction.

Seeing further restrictions arise in India's construction sector, a diverse approach to the problem is pertinent. A large number of buildings are being erected with renovations being done to existing ones. A significant reason for the creation of the dead zones are in fact the interference of such structures. With concrete and steel being used extensively for majority of these constructions the problem is only being worsened. Brick, concrete and steel are notorious for cell signal obstruction. Another obstacle is the relative heights of transmitting and receiving stations. A large portion of the transmitted signals are intercepted by these structures meaning the effective range is greatly reduced. As a result, there has been an increase in unsanctioned cellular towers being erected in sub-urban communities to battle this. A 2015 ruling sentencing the removal of 5000 such towers lead telecom companies to recruit specialists for the strategic placement of new towers.

IOT IN CONSTRUCTION OF BUILDINGS

One of the major applications of IoT in construction industry is in 'concrete curing'. In concrete curing, sensors are embedded during casting, and they follow curing of concrete in real time allowing the construction manager to monitor and plan their schedules with certainty. An accurate in-situ estimation of the compressive strength of concrete provides the opportunity to optimize critical construction operations, such as formwork removal time, opening a bridge/road to traffic, pre-stressed cable tensioning time and optimization of the concrete mix design. "Sensohivematurix" and "Doka concremote" are some of the implementations of IoT in concrete curing. Ready Mix suppliers, cement manufacturers, consulting engineers and concrete testing labs can also rely on this IoT technology to enhance service delivery.

Scarcity of efficient workers is one of the main problems that construction industry faces now. IoT can play a crucial role in that sector. Japan is one of the countries where IoT and Robotics are used to solve the scarcity of construction workers. It finds applications in real time observation and in ensuring the safety and security of workers. From website observation to surveys, information from sensors enhances critical stages of a construction project, to avoid project delays, and delivers the catalyst for better ways of operation. IoT allows for the creation of a digital real-time job site map together with the updated risks associated with the works and notifies every worker when getting closer to any risk or entering a dangerous environment. For example, monitoring the air quality in an enclosed space is critical for workplace safety. IoT technologies will not only prevent staff from being exposed to dangerous conditions but can also detect those conditions before or as they happen. Cement based piezoelectric sensor is a good example for how IoT can be inculcated in construction materials.



CEMENT BASED PIEZOELECTRIC SENSOR

IOT IN OPERATION AND MANAGEMENT OF BUILDINGS

A smart building is any structure that uses automated processes to automatically control the building's operations including heating, ventilation, air conditioning, lighting, security and other systems. Smart buildings encompass a wide variety of sensors, actuators, devices, and control systems that are interconnected and jointly function to improve the service for its occupants. A part of the concept of smart buildings involves integrating a communication network within the buildings' elements so that they can be manipulated or monitored remotely.

IoT finds applications in "Energy Management, Localization for occupants and resource tracking, Building health control etc.". Buildings account for 40% of the total energy consumption in the world. Some commercial Building Energy Management Systems (BEMS) are already available that help control, monitor, and optimize building energy use currently. These systems normally installed non-intrusive meters at electric circuits to collect energy use data for users and managers. HVAC system needs to be set in accordance with the number of people in the room and the lighting system should monitor the lighting intensity outside of the building and set the lighting inside in accordance to that. With the support of IoT, this mechanism can be achieved.

IoT provides other services in buildings like occupant safety (gives burglar alerts and ensures fire safety) and health security, facility management, efficient resource management for convenience and indoor comfort enhancement. IoT is able to increase convenience and efficiency in a building via resource management. Incorporating IoT into parking structures is applied in the industry, for the purpose of reducing unnecessary search of parking.

IOT IN DECONSTRUCTION AND DEMOLITION OF BUILDINGS

In demolition, the goal of the project is to simply tear down a structure, building, or property. The objective of deconstruction is not only to tear down the structure, but has an added goal of salvaging whatever parts, components, or materials that can be reused and recycled. Demolition is simply crashing down the building; whereas, deconstruction is reusing and preserving the demolished fragments. It enables you to make use and recycle old materials.

Internet of things finds applications in the demolition of buildings, especially in controlled building implosion. In the controlled demolition industry, building implosion is the strategic placing of explosive material and timing of its detonation so that a structure collapses on itself in a matter of seconds, minimizing the physical damage to its immediate surroundings. Sensors are installed at various parts of the structure going to be demolished and changes in temperature, heat etc. are studied. By analysing this data, exact position where explosives can be placed is determined. IoT also helps in the real time monitoring of implosion process.

Another application of IoT in controlled implosion is the study of seismic variations during implosion. Sensors capable of detecting seismic vibrations and waves are installed in buildings. The data collected by this method is analysed using software and possibility of cracks and damages to surrounding structures can be evaluated.

IOT IN BUILDING INDUSTRY: INDIAN SCENARIO

Application of IoT in building industry is at a nascent stage in India when compared to other countries like Japan, Singapore, western European countries, USA etc. But a large number of buildings, (mainly hotels and airports) in India make use of IoT services. Infosys' software building in Pune which won the smartest single occupant private office award, is a good example of IoT enabled smart building in India (from construction stage itself).

Bangalore and Mumbai are the two cities in India where IoT has significant role in construction industry. It is estimated that around 3000 buildings in India partially or completely make use of services of IoT.

Infosys building, Pune

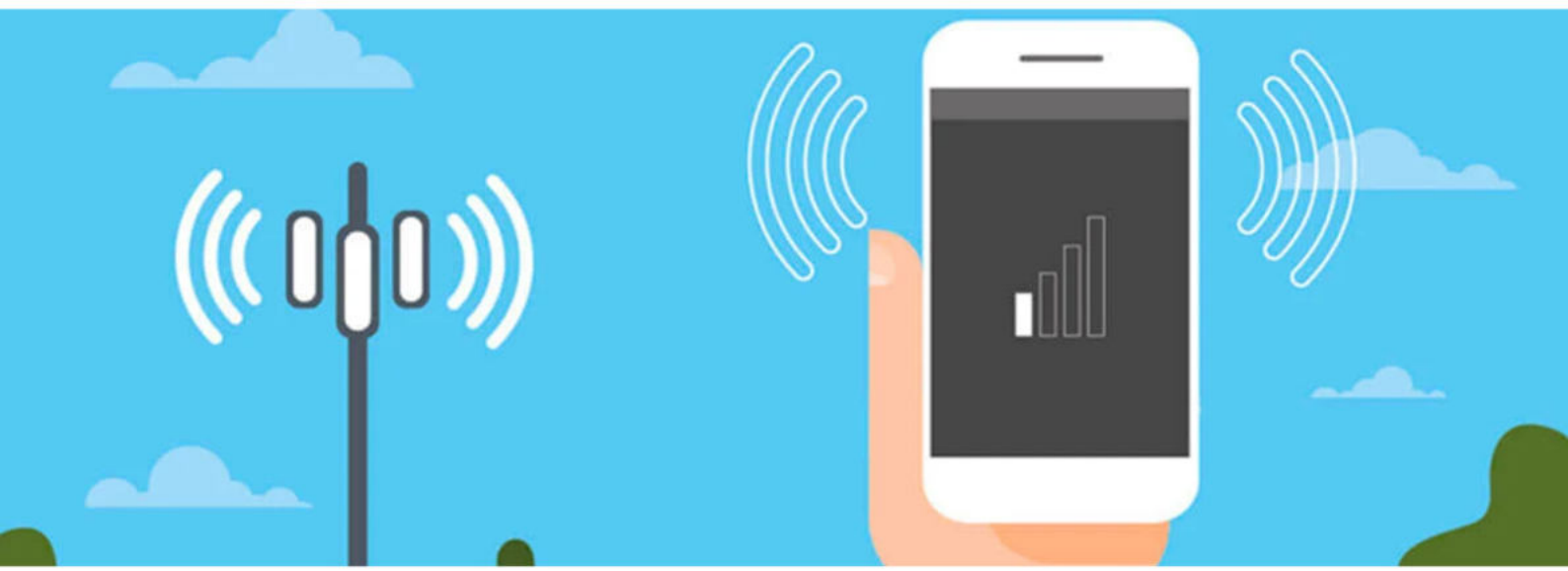
WAY FORWARD

It's been argued that the construction industry has been a bit slow in adopting new technologies like IoT, and according to McKinsey, the construction industry is under-digitized, with companies failing to realize the potential of AI, IoT and other digital tools as drivers of growth and efficiency. But in a recent survey conducted by KPMG, 95% of construction companies said they believe emerging technologies including IoT will fundamentally change their industry, while a further 72% say new tech adoption, including IoT implementations, is part of their strategic plan or vision.

Since the world is aiming to move to more sustainable pathways , IOT has a great a role to play in construction industry which is one of the major contributors of pollution and resource depletion. what we need is a holistic approach by taking into consideration of the existing conditions, limitations, possibilities and opportunities.

CELLULAR DEAD-ZONES : a result of poor town planning?

Ameen S, C6A



As of 2015, 18.21% of India's total population owned a smartphone, a figure that was set to rise over 25 percent by 2017. Owing to aggressive sales and the intervention of Chinese smartphone manufacturers, this number has overtaken the 500 million mark in December 2019. This brings the total population of broadband dependents to 77 percent. It has been stated as an indicator of economic development which is apparent in the case of USA and South Korea.

With smartphone penetration crossing such huge figures, telecom companies have already set target on 5G technology but the numbers don't reflect the exact state of events. Even in heavily populated areas there are still cases of poor reception and dropped calls. Not to mention that existing 4G service users are complaining of unreliable network speeds on reliable networks. Backed up by the surge in internet usage as a result of recent events, it has aided in collecting data for rescue operations and their analysis. A large part of contact tracing in countries like Taiwan and South Korea were made possible due to the extremely high smartphone penetration (85%) and location sharing.

In spite of all this, towns in India are plagued by cellular dead zones - where you lose connectivity all of a sudden and entire blocks of buildings experience little to no reception. While in the past this could be attributed to the developing state of infrastructure and the low number of towers, today the problem is much more complex. In 2015, a petition submitted by Maradu Municipality, Kerala HC said that even if municipal building rules allow construction of mobile towers in residential areas, such use cannot be allowed if the town planning scheme prohibits it [1].

Seeing further restrictions arising in India's construction sector, a diverse approach to the problem is pertinent. A large number of buildings are being erected with renovations being done to existing ones. A significant reason for the creation of the dead zones are in fact the interference of such structures. With concrete and steel being used extensively for majority of these constructions the problem is only being worsened. Brick, concrete and steel are notorious for cell signal obstruction. Another obstacle is the relative heights of transmitting and receiving stations. A large portion of the transmitted signals are intercepted by these structures meaning the effective range is greatly reduced. As a result, there has been an increase in unsanctioned cellular towers being erected in sub-urban communities to battle this. A rule in 2015 sentencing the removal of 5000 such towers led telecom companies to recruit specialists for the strategic placement of new towers.

The introduction of dynamic town planning is essential for further progress. The use of anonymized Call Detail Records can efficiently capture city dynamics. This in turn could give insight into the nature of the population and the dynamic nature of the city with detailed heat maps of activity during times of the day – evident from A tale of one city by Richard et al. [2]. So, town planning is to be dependent also on the increasing electronic interaction of people. Inefficient town planning can deviate us from efficient transfer of information.

India has local governing bodies that has specific guidelines to be followed for the erection of subsequent towers while countries like USA and Germany have regulations for outsourcing the right to install towers in any town where a market exists, given that their erection brings about manageable impacts. Cell phone companies thereby are free to use viewshed analysis to map out terrain and existing manmade features to simulate line of sight and interference related problems.

One such analysis conducted by the Town of Paxton, Massachusetts employed a combination of tools in TerrSet to determine view sights in regions classified into relevant land use categories. [3] The elevation models generated would help to identify sites.

A need for novel approach to regulations regarding the further construction processes is evident. In densely built-up areas with reflective exteriors, the placement of base stations need to accommodate the unpredictable nature of scattering and reflection. A rising concern is the misinformation regarding cellphone signals and their role in aggravating cases of induced cancer. While they haven't been directly linked to the cases, there hasn't been conclusive evidence excluding the possibility. In rural areas with little interference, it is safer and more economic to place fewer towers with possibly modular mechanisms that allow upgrades as and when they are introduced. To make this possible and to optimally utilize resources, there needs to be
an integration of technology into the further planning of cities.

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LIMESTONE CALCINED CLAY CEMENT (LC^3)

Sneha S, C8B

Cement is an indispensable civil engineering material to meet modern society's needs for infrastructure, industry and housing. The annual consumption of cement is on an increasing scale as concrete is relatively green when compared to other available building materials such as steel having a higher rate of CO_2 emission than concrete. But extremely high demand of concrete results in higher CO_2 concentration. It has been estimated that the manufacturing of cement is amongst the largest CO_2 emitters within the mineral processing industry, contributing about 5% to the global CO_2 emissions annually. Due to the decomposition of limestone, the main raw material for cement production and the fuel used for burning the clinker, the global average gross CO_2 emissions is on it's hike.

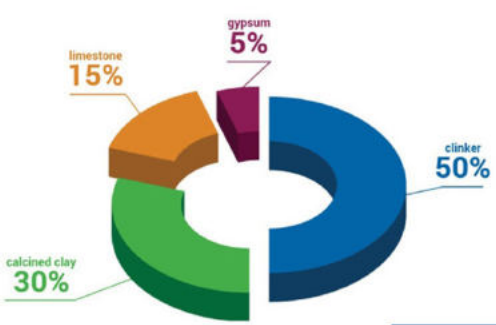
Generally, Portland cement is manufactured by grinding clinker along with gypsum. It is during the decomposition of limestone in rotary kiln that the carbon dioxide emission turns out to be around 50-55% and the rest are contributed by the burning of fuel.

$$CaCO_3 \text{ --------> } CaO + CO_2$$

This implies that an immediate action towards reducing the clinker content without compromising it's performance is the need of the hour. The World Business Council for Sustainable Development provides ideas and approaches to reduce this level of CO_2 emissions up to 50 % by 2050.

The four main points are improvement of energy efficiency, replacing high-carbon fuels with low-carbon fuels, CO_2 capture technologies and the use of blended cements.

Partial replacement of clinker by supplementary cementitious materials (SCMs) in blended cement or concrete is by far the most promising strategy for reducing the environmental impact. The most popular cement replacing materials are Fly Ash and Ground Granulated Blast Furnace Slag (GGBFS), which are already taken up in standard cements in many countries. But their availability is locally imbalanced and the amounts produced are much less than the world-wide production of cement. This led to an increasing interest for alternative sources of SCM's such as calcined clays.The widespread availability of clay as well as limestone makes Limestone Calcined Clay Cement(LC^3) a practical solution for the cement industry worldwide, particularly in developing nations.



Raw Materials For LC³ Production

Various raw materials required in the production process are Limestone, Clinker and Calcined clay

Limestone

Limestone is used in LC³ systems in order to provide carbonate ions that combine with reactive alumina to form carboaluminate phases and to act as a filler that enhances the hydration reactions of clinker phases. It is the main component used for the production of clinker, which should be of relatively higher quality with high calcium oxide content. Magnesium oxide content in the limestone must be as low as possible as it can make the cement unsound. X-Ray diffraction (XRD) analysis can be used for the characterization of limestones. Dolomite and marble dust are considered to be the sources of limestone.

Calcined Clay

Most suitable calcined clay for LC³ system is kaolinitic clay which possess higher pozzolanic activity than other clay minerals. Calcination of kaolinite is also practically more feasible. Clay is calcined by heating to around 700-850^{0}C. Since the calcination temperature is low, compared to clinker production, no sophisticated equipment is necessary to produce the calcined clays.

Clay may be calcined in conventional rotary kilns, flash calcination units, fluidized bed, roller hearth kilns or even by static calcination in tunnel or shuttle kilns normally used in the ceramic or refractory industry. Clays with 50–60% kaolinitic content have been found to be suitable for use in LC³.

Clinker

Cements in India typically have a low-to-medium alite content when compared with European cements. This is primarily due to the difference in the composition of the raw materials used for the production of clinker. The relatively lower C_3A content in the clinkers in India can be observed which implies that majority of alumina in the LC³ systems is contributed by calcined clay. The sulfate addition must, therefore, be higher than the usual addition to OPC.

Manufacturing Process

Manufacturing of Limestone calcined clay cement is no different from the manufacturing process of Ordinary Portland Cement. Only the replacement of clinker material with a sufficient quantity of calcined clay and limestone differs it from the former. These are to be separately ground and blended to produce LC³.

Unique features of LC³

Cost of production

Comparing to the cost of production of OPC and PPC,LC³ is more economically sustainable. The reduction is primarily due to two factors:

(i) low clinker factor and

(ii) less fuel and electricity requirement for calcination of clay compared to that for production of clinker.

Lower production costs are one of the main drivers for technology uptake.

Low carbon emission

Due to reduced amount of clinker in cement, the amount of CO_2 in the atmosphere is reduced. Now, the amount of clinker is reduced by half in LC³. LC³ allows growth without abstinence due to resources and CO_2 efficiency. With current clinker production facilities, production capacity for cement can be increased twofold without increasing total CO_2 emissions. Quarry life can then be considerably extended and costly Carbon capture and storage technologies for emission abatement can be avoided. Emissions of LC³ are estimated to be 20-30% lower than Portland cement because reduction in clinker content leads to less process emissions from the decarbonation of limestone in clinker and less emissions from heating limestone to form clinker. Grinding of limestone requires less energy than heating it.

Use of existing equipment

LC³ can be produced with existing manufacturing equipment, leading to only marginally increased investments for calcining equipment. But the net capital investment required in the production line is comparatively low.

Resource efficiency

Using low-grade clay and limestone does not require opening new quarries nor deplete agricultural soils. Also limestone and clay that are not fit for other industries use can be easily utilized thus improving the net efficiency and comparatively reduced cost.

Scope Of LC³ : Indian Scenario

The construction sector is one of the fastest growing sector with an average growth rate of 7%, contributing to 22% of the total CO_2 emissions in India. Within the construction industry, cement sector ranks second only to the steel in terms of revenue and forms the backbone of any shelter and infrastructure initiatives catering to all classes of life. Though India has it's majority population below poverty line, the new developmental policies implemented by government aims to provide affordable housing for the urban poor by the year 2022. Increasing development as a result of increasing construction activity further results in higher use of cement and resultant concrete. Increase in the cement demand makes low carbon dioxide technologies vital for Indian Cement industry. .

Currently, the environmental emissions and amount of natural resources, especially in the form of limestone and coal, depleted by the cement industry is at its peak. The cement industry also uses a substantial amount of thermal power plant waste in the form of fly ash to produce Portland pozzolana cement. The resources of making the cement are finite. With increasing depletion of natural resources raw materials are becoming increasingly scarce, which will affect the production of cement in the future. To optimize the use of natural resources, supplementary cementitious materials (SCMs) are a viable alternative.

At present, India uses a substantial amount of fly ash as SCM's. But this material tends to exhibit significant variation in properties that are available in India and their substitution is limited to 30% since these materials reduces the early age mechanical properties. Another challenge is the transport of flya ash. Presently, grinding units have been set up near the thermal power plants where clinker is transported to produce PPC. This might not be economical for many regions for example, the north-eastern part of India. Around 10Mt of GGBS is produced in India annually by the iron and steel industry, most of which is used to produce Portland slag cement. While higher replacement levels (around 70%) are possible by replacing clinker with slag, the low annual availability creates a bottleneck for widespread utilisation. It is apparent that any potential candidate for mass adoption needs to be easily available, with uniform and predictable characteristics, while also satisfying economic considerations.

Kaolinite (white china clay) reserves in India are estimated to be on the order of 2•4 billion tonnes and most portion of this high purity clay is utilized by ceramic industry to produce high value products. Kerala, Gujarat, Rajasthan and West Bengal are having significant reserves of clay resources in India. Clays required for the production of LC^3 need not be of higher grade. Ie, it can contain impurities.Hence those deposits that are unfit for it's use in ceramic industry which would be present as an overburden in existing clay mines or would not be commercially exploited due to aesthetic reasons such as coloue can be made use in LC^3 production (Shah et al., 2019).

Limestone is yet another crucial resource required in the production of clinker. It should be of high grade and should not contain impurities such as dolomite. But such low grade limestone can be used for LC^3 production. Alternate carbonate sources such as marble dust powder and dolomite can also be utilized for the same. Hence it is clear that raw materials required for the production of LC^3 is well distributed throughout India.

Applications

LC^3 can be utilized in the large scale production of different types of building materials. These were micro concrete roofing tiles, solid concrete bricks, hollow concrete blocks, RCC door and window frames and low duty paving blocks of various water-cement ratios. It is identified that the building materials met the requirements of the relevant standard without any changes to the usual mixture designs and production processes. No need of replacement of the equipment or retraining of the workers is required when OPC is substituted by LC^3. A two-storey building with plain- and reinforced-concrete elements was built in central India, completely using LC^3 as shown in figure.

LC^3 house constructed at Orchha, India

No major changes to mixture designs were also required to produce concretes similar to those usually used in such construction. These observations are perfect demonstrations of the applicability of LC^3 in general-use applications, as a replacement of OPC or PPC. Additionally, to test the suitability of the cement in automated production processes, concrete paver blocks and AAC blocks were produced in fully automated plants.

The AAC blocks were used for the construction of the walls of a building in the complex of Swiss Embassy in New Delhi, without any change needed in the construction process.

A building in the complex of the Swiss Embassy in New Delhi, which was made using LC³ AAC blocks

Conclusion

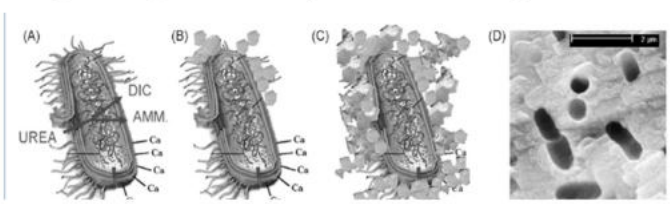
The development of alternative cement in developing countries is facing a triple challenge: a very fast increase in demand due to population as well as economic rise, low capital investment possibilities in an economic market with risky perspectives and a need to mitigate greenhouse gas emissions. In this constrained context, this study has shown that LC³ represent a grounded alternative. It is viable to use supplementary cementitious materials, calcined clay and limestone as an alternative source for cement production, especially in a developing country like India. Limestone calcined clay cement is such an innovative type of cement with an interesting series of applications such as micro concrete roofing tiles, ACC pavement blocks, etc. Widespread availability of clay as well as limestone makes LC³ a practical solution to meet increasing demand for cement. It is highly advantageous to use this particular type of cement in the rapidly growing Indian economy as it suggests a reduction in the net cost or without increasing the cost of production and decreased CO_2 emissions.

ENZYME INDUCED CALCIUM CARBONATE PRECIPITATION

Soorya Gayathri , C8B

Nowadays, the availability of land suitable for construction is decreasing even though the population and the demand for land keeps increasing tremendously. In order to enhance properties of weak soil formations (for example: deep loose sand deposits), a wide range of ground improvement techniques have been introduced over the past decades. Majority of these ground improvement techniques utilize mechanical energy and/or man-made binders like Ordinary Portland Cement (OPC), both of which require substantial energy for material production and/or installation. Moreover, injection and grouting techniques have been used to improve soils by injecting chemical materials into the pore space to bind soil particles together. Nowadays, there is a high demand for new sustainable methods to improve soils. Over the last decade, extensive research has been undertaken to find alternative soil binders to replace OPC for soil improvement. Among other alternatives, calcite precipitation has been intensively investigated as a sustainable alternative for soil improvement and soil grouting. There are several techniques used to induce calcite precipitation, including urea hydrolysis, microbial denitrification, and sulfate reduction. The hydrolysis of urea is the most advanced mechanism to induce calcite precipitation in terms of development, and most often used due to its simplicity.

Enzyme Induced Calcium Carbonate Precipitation(EICP) is a biogeotechnical technique for improving the engineering properties of granular soil in which calcium carbonate is precipitated from an aqueous solution within the soil pores. That is, in EICP, free urease enzyme catalyzes the hydrolysis of urea in an aqueous solution, which results in carbonate ion production. In the presence of calcium ions, the carbonate ions precipitate as calcium carbonate when the concentration of carbonate ions exceeds the level of supersaturation. The calcium carbonate precipitation improves the strength, stiffness, and dilatancy of the soil by pore filling, particle roughening, and interparticle binding.



The products used to produce the grout which is used to combine the soil particles together are the urease enzyme, urea [$CO(NH_2)_2$] and calcium chloride [$CaCl_2$] with purity level of 99.5 percentage and 95 percentage respectively. The process of precipitation of calcium carbonate in a porous medium using the enzymes to biocatalyze the urea hydrolysis is described using the given occasion equation:

$CO(NH_2)_2(s) + H_2O\ (l) \rightarrow 2\ NH_3\ (aq) + CO_2(g)$ [pH↑]

$2\ NH_3\ (aq) + CO_2(g) + H_2O\ (l) \rightarrow 2NH_4^+\ (aq) + CO_3^{2-}\ (aq)$

At a pH of 7.0 and 38 degree Celsius the urease promotes the hydrolysis of the urea 10^{14} times faster than spontaneous hydrolysis. In an environment with high pH value and rich in calcium ions (Ca^{2+}) supplied by calcium chloride resulting from the below given reaction:

$CaCl_2 \rightarrow Ca^{2+}(aq) + 2Cl^-(aq)$

The carbonate ion reacts spontaneously with $Ca2^+$ and thus calcium carbonate ($CaCO_3$) is produced resulting from the reaction given below:

$Ca^{2+}(aq) + CO_3^{2-}\ (aq) \leftrightarrow CaCO_3\ (s)$

The remaining ion (chloride and ammonium ion) produce ammonium chloride (*) by the reaction given below which induces the decreases in the pH value.

$2NH_4^+\ (aq) + 2Cl^-(aq) \rightarrow NH_4CL\ (aq)$ [pH↓]

EICP is distinguished from microbially induced carbonate precipitation (MICP) by the use of free urease enzyme to catalyze the hydrolysis reaction rather than microbial intercellular urease as used in MICP. The free enzyme may be derived from agricultural, microbial, or fungal sources.

MICP has received the most attention by researchers studying biogeotechnical soil improvement. In MICP, either exogenous ureolytic bacteria are introduced to the soil as part of the treatment solution or appropriate nutrients for bacterial growth are provided in the treatment solution to stimulate indigenous ureolytic bacteria. Both EICP and MICP treatment solutions include a calcium salt, usually in the form of calcium chloride ($CaCl_2$), and urea. In MICP, bacterial cells may also act as nucleation sites through adsorption of calcium ions to their negatively charged surface and by creating localized supersaturation.

However, relying upon bacteria as the source of urease for MICP creates many unknowns and uncertainties (e.g., physical nonhomogeneity, oxygen availability, complex pore fluid chemistry, and the presence of other microorganisms) that can raise difficulties. These difficulties can include controlling bacterial growth and their enzymatic activity, bacterial cell attachment to soil particles, and interaction between target species and other microorganisms in soil. In addition, MICP via bioaugmentation (i.e., by introducing exogenous bacteria to the soil) generally cannot be applied in soil with pore throats smaller than the ureolytic bacteria, limiting its applicability in finer-grained and denser cohesion less soil. Biostimulation, in which indigenous ureolytic bacterial cells are activated in situ, has been developed to overcome some of these difficulties. However, issues associated with pore fluid chemistry, oxygen availability, and competition with other microorganisms still remains.

EICP has been suggested as a means to eliminate some of the challenges in improving the geotechnical properties of soil caused by using bacterial cells as the source of urease in MICP. The free urease enzyme used in EICP has a size on the order of 12 nm per subunit and is soluble in water, facilitating its transport within the pores of soil. Thus the worry about pore size is eliminated. Using EICP, there are no concerns about providing nutrients for bacterial activity, the competing effect of other microorganisms, oxygen availability for deep soil treatment, or cell attachment to soil particles. Right now, the commercially available urease enzyme is expensive, because it is produced in small quantities at high levels of purity for use in sensitive applications (e.g., food and medical applications). However, it is reasonably anticipated that industrial use of urease of lower purity would result in a significant decrease in the cost of the enzyme without any loss of precipitation efficiency or effectiveness.

Both EICP and MICP produce an ammonium by-product via the hydrolysis reaction. When calcium chloride is used as the calcium source, this by-product is in the form of ammonium chloride. Ammonium chloride can reduce the pH value of the soil and exposure to it is moderately hazardous, causing irritation, shortness of breath, cough, nausea, and headache. The environmental impact of this by-product and the potential for acidification leading to reversal of carbonate precipitation must be addressed if these techniques are to be used in field applications. Later it was seen that use of zeolite resulted in removal of ammonium chloride with an efficiency of about 75%. Since EICP has more advantages over MICP and at the same time EICP is efficient and eco friendly it has been a major breakthrough and is the most preferred ground improvement technique.

Reference

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ASSOCIATION INAUGRATION

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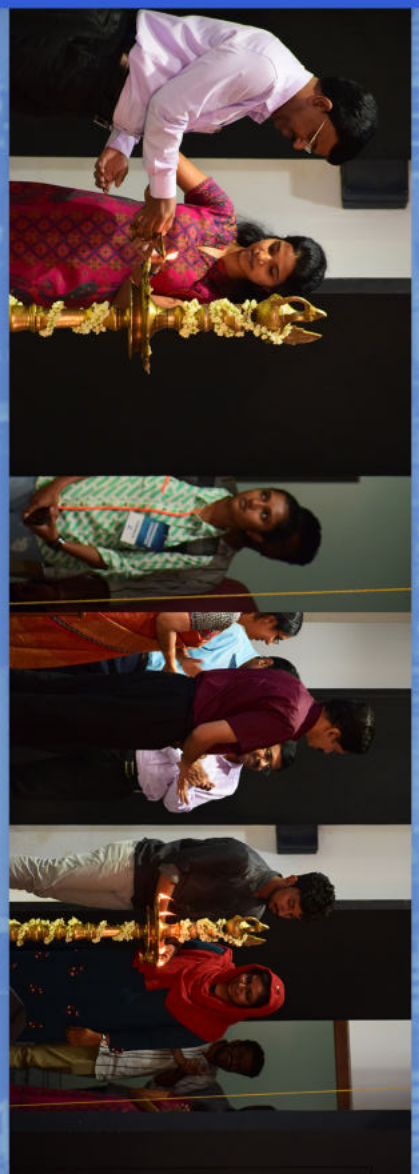

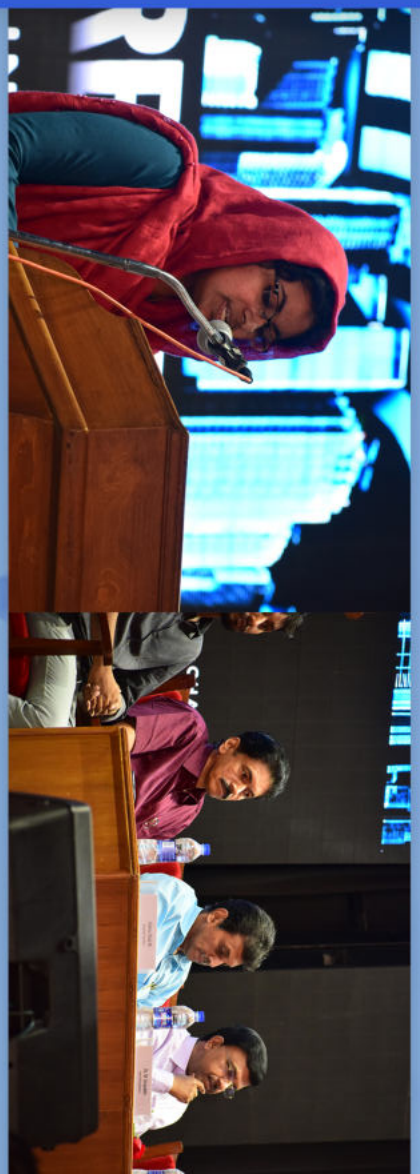


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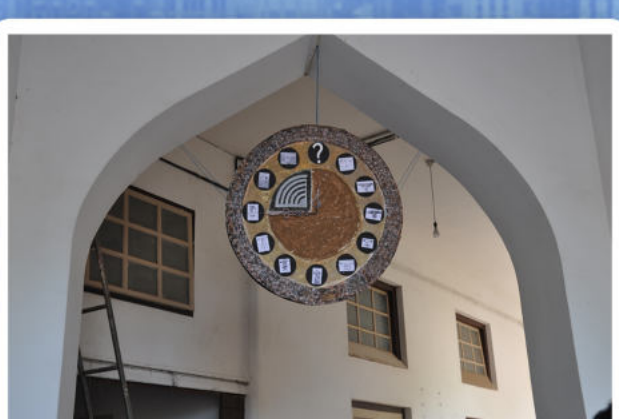

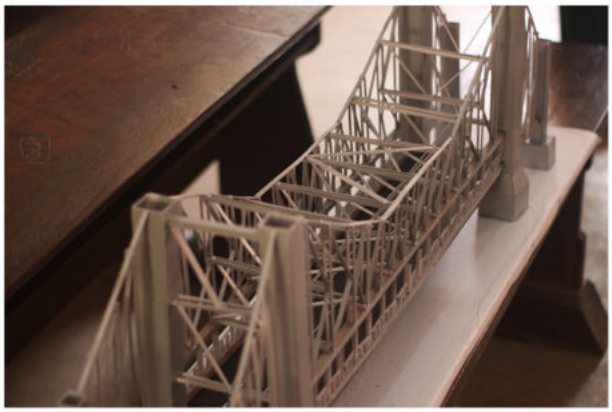

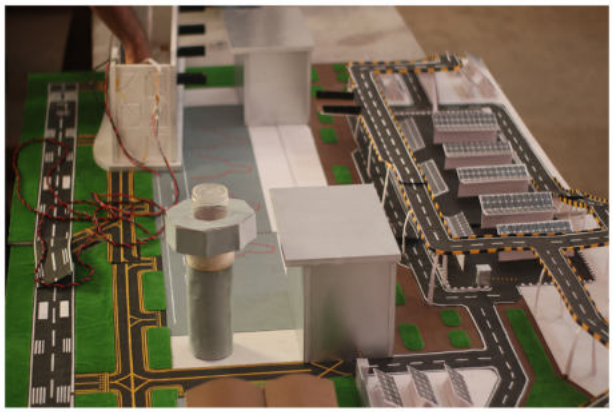

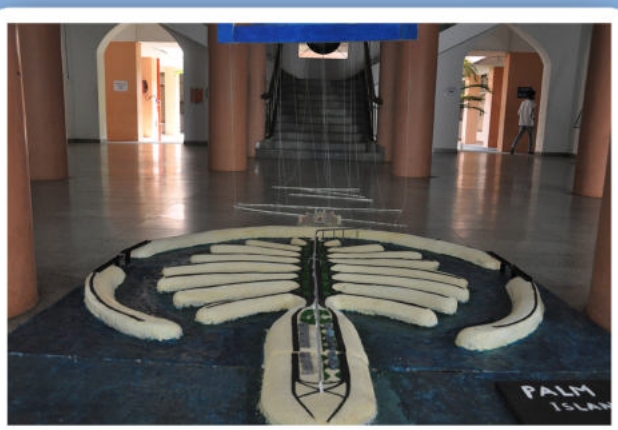

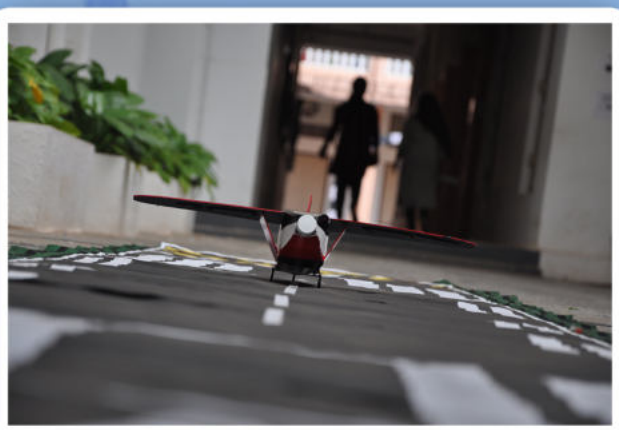

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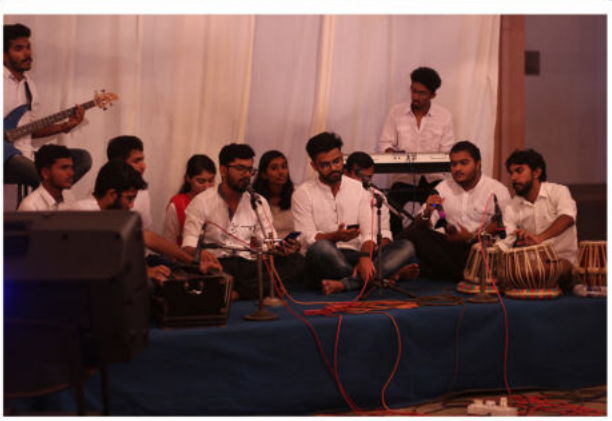

MIX DESIGN WORKSHOP

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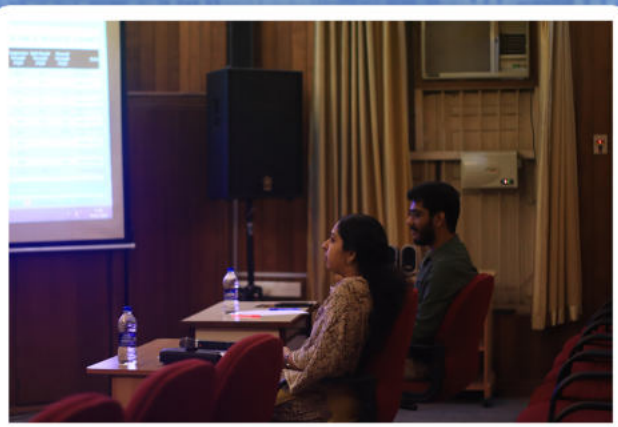

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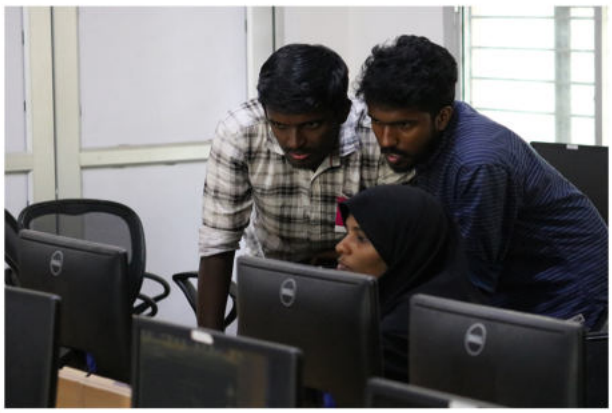

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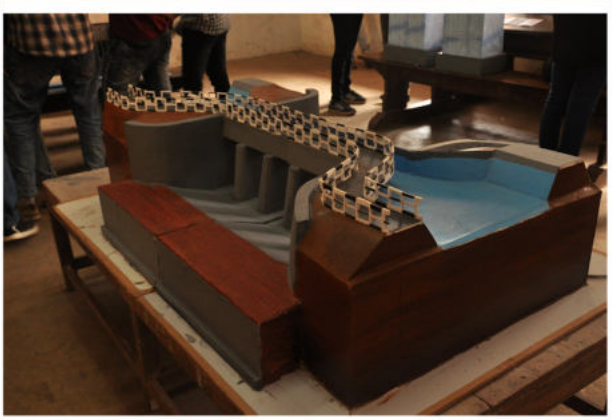

HANDS ON TRAINING WORKSHOP

KEYSTONE Vol.4

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