ASNEngr

INAUGURAL ISSUE

INTERSECTION

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Editorial

Magazine Committee

It is our pleasure and honor to present the inaugral issue of the "Intersection" magazine of the American Society of Nepalese Engineers (ASNEngr) with a cornucopia of informative educative articles that will draw your interest. This magazine covers a wide variety of subjects ranging from the earthquake hazards in Nepal to the conservation of the Kathmandu Basantpur Durbar.

In his article, Dr. Rajendra Shrestha presents an example of the destruction caused by the 2015 Gorkha Earthquake in Nepal and its aftershocks and provides recommendations to mitigate risks of damages due to future earthquakes in Nepal. The 5G technology is a much talked about topic these days, and Dr. Jiwan Ninglekhu has provided some high-level objectives of the 5G network in offering high speed and mobility to the users. Sanjib Chaudary et al. discuss using Raspberry Pi computers to collect and maintain individual health records to improve health care in Nepal. Rabin Dhakal and his team at the Institute of Engineering, Pulchowk, Lalitpur, Nepal, were engaged in researching the Gravitational Water Vortex Power Plant (GWVPP) technology to address the energy needs in Nepal by constructing the low-cost power plants in the rivers across the country. UNESCO has recognized seven World Heritage Sites in the Kathmandu Valley, Nepal, among which the Kathmandu Durbar Square is one of them. Ananta Baidya, P.E., recommends preserving and conserving the historical and cultural heritage sites such as the Kathmandu Durbar Square. Srijan Rajbamshi et al. underline implementing the Science, Technology, Engineering, Arts, and Mathematics (STEAM) principles in the educational system in Nepal to enhance the critical thinking and problem-solving skills of the students. In the last article, Sujan Subedi emphasizes the need to use self-healing concrete to extend the life span of the infrastructures.

This Intersection magazine is the culmination of months of collective activities of article collecting, editing, laying out, and compiling at various stages to bring this initiative to fruition to the current form. True, the publication of this magazine took a bit longer than the anticipated time frame, nonetheless as the saying goes, "Better late than never." The Intersection magazine provides a common platform for sharing ideas, thoughts, and technical knowledge to fulfill one of the objectives of the American Society of Nepalese Engineers, "To collect, disseminate and exchange technical knowledge through publications, conferences, seminars, and workshops."

We take this opportunity to extend our appreciation to the authors for contributing their valuable thought-provoking articles and the ASNEngr leadership for providing continual encouragement to publish this magazine with great patience.

Finally, the "Intersection" magazine is in your hands, and we trust you will enjoy perusing it.

The Magazine Committee:


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Ph.D., Chair


Rajendra Shrestha,
Ph.D., Vice Chair


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The views and opinions, unless otherwise noted, contained in this publication are those of the authors and do not represent the official statements or views neither of the Intersection Magazine or the American Society of Nepalese Engineers.

President's Message

Thakur Dhakal, P.E.
President, ASNEngr

This is my great honor and pleasure to present you the very first issue of the Intersection Magazine of the American Society of Nepalese Engineers (ASNEngr). One of the objectives of ASNEngr is "To bring together people of Nepalese heritage and culture and other interested individuals pursuing profession in engineering, or closely related scientific and technical areas, for exchange and sharing of research, educational and practice related knowledge and experience, professional interaction, and collaborative activities" and I strongly believe that this magazine will a mouth peace of ASNEngr to share knowledge and experience.

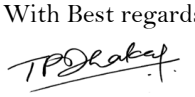
The initiative was started two years ago, and the magazine team was able to collect, edit and present various articles in the form of magazine even in the period of pandemic. As you go through this magazine, you will meet students, faculties, young and seasoned professionals and members of ASNEngr who give us the beauty of knowledge, experience, diversity of thoughts. This is indeed an intersection of various life experiences in the engineering and the professions closely related to engineering I truly believe that ASNEngr is fulfilling its vision and objectives by publishing such magazine in a periodic basis.

First of all, I would like to thank all the members of the Society for continuously supporting Society activities and initiatives. In addition, I would like to thank all the officers, members-at-large, Society Directors, Committees Members and Chapter officers and members for their continued hard work in helping the magazine team to get their job done.

I express my sincere thanks and deepest gratitude to all members of ASNEngr and Nepalese engineering and scientific community and friends for their help, support and continued involvement in the Society activities.

Finally, Jiwan Ninglekhu, Ph.D, Chair, Rajendra Shrestha, Ph.D., Vice Co-chair, Drishya Dahal, Vice Co-chair, and all the member of Magazine Committee, have been doing a tremendous job in putting together the Intersection Magazine. I truly appreciate their dedication and hard work for publication of first magazine of ASNEngr.

With Best regards,



Thakur Dhakal, P.E.
President,
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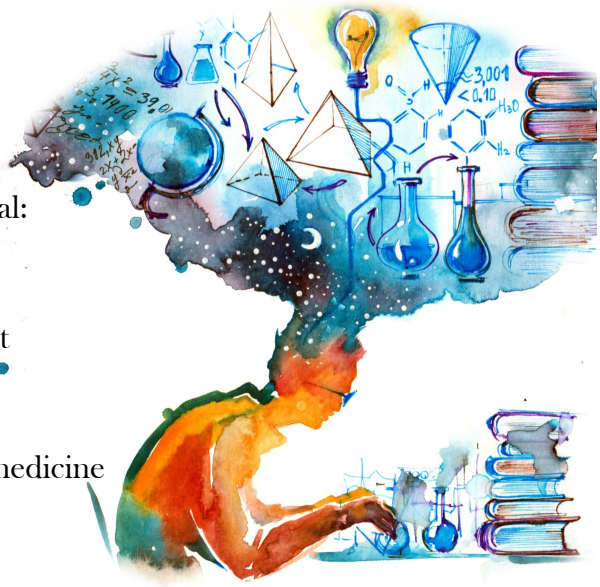
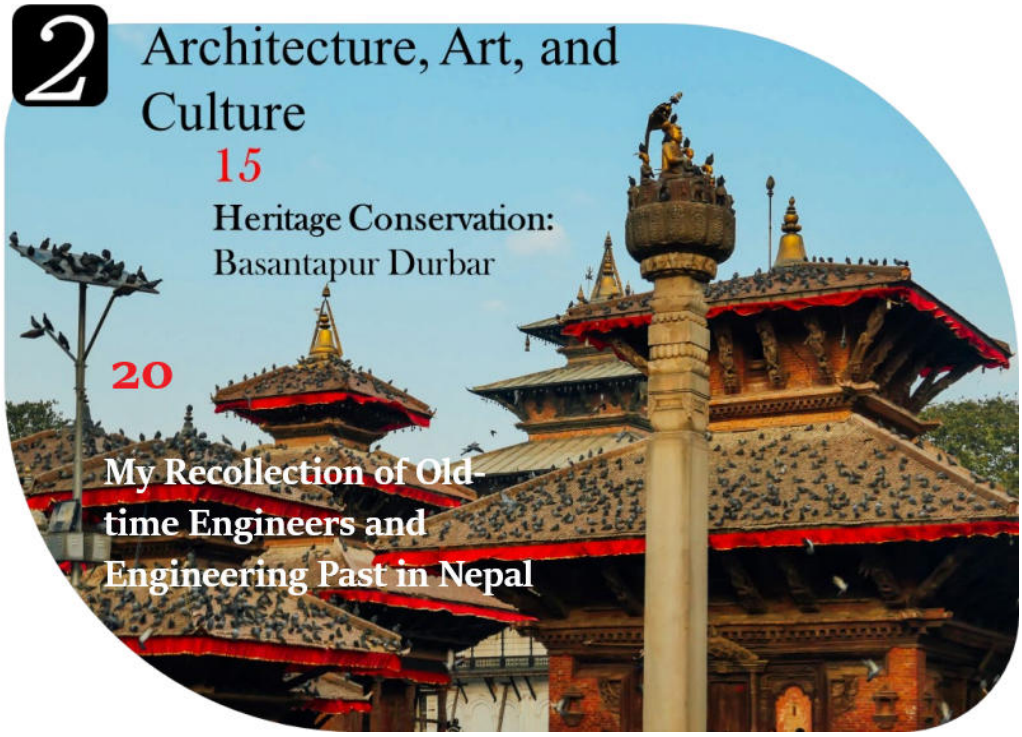


2 Architecture, Art, and Culture



3 Education, Careers, and Students

ASNEngr

The 2015 Gorkha Earthquake in Nepal: Analysis and Recommendations

Rajendra Shrestha, Ph. D.

Nepal is adorned with eight out of the ten highest mountains in the world. These mountains in Nepal Himalaya look magnificent. However, the tectonic forces that contributed to the creation of these majestic mountains also place the entire Himalayan Region in a seismically active belt posing threats of earthquake hazards.

The back-to-back earthquakes that struck Haiti on Jan. 12, 2010 (Mw 7.0) and Chile on Feb. 27, 2010 (Mw 8.8) served as a wake-up call to the Nepali diaspora in the U.S.A. Although the Chile earthquake was 500 times stronger than the one that hit Haiti, according to the United States Geological Survey (USGS), Haiti suffered a much larger proportion of devastation claiming the lives of 220,000, injuring more than 300,000, displacing 1.5 million, and affecting 3.5 million people. The Chilean earthquake killed 525 people, displaced 1.5 million, and affected 2 million. The stark difference in the level of destruction due to earthquakes in these two countries point to the fact that Chile had a much better preparation plan to manage the earthquake destructions. On the assumption that a large earthquake hits Nepal, a landlocked nation with only one international airport and a limited number of infrastructure for transportation, it is obvious that the devastation would be much severe without much preparedness to mitigate the damages. In consideration of these facts, the article titled Necessity of Earthquake Preparedness in Nepal was published in 2010 immediately after the Chilean earthquake online and, in newspapers and publications in Nepal and the U.S.A[5]. In March 2010, the American Society of Nepalese Engineers joined hands with the America Nepal Medical Foundation and Computer Association of Nepal U.S.A. to initiate the position paper titled Earthquake Preparedness and Disaster Relief in Nepal 9 that was published in May 2015.

Although minor earthquake tremors are part of life in the Himalaya, the 2015 Gorkha earthquake on April 25, 2015 of Mw 7.8 and the aftershocks have impacted central Nepal through enormous devastation to human lives and properties, infrastructures, and geomorphology. Nepal has experienced more than 548 aftershocks to-date including the one of Mw 7.3 on May 12, 2015, and Mw 5.3 on September 15, 2020. The earthquake and aftershocks ravaged settlements are still going through the process of restoration and rebuilding.

This article presents the underlying causes of earthquakes in the Himalayan Region and explores the aftermath of the 2015 Gorkha earthquake. In addition, based on the facts and analysis of the destruction due to 2015 Gorkha earthquake and its subsequent aftershocks, provides recommendations to mitigate the risks of damages for future earthquakes in Nepal.

Plate Tectonics and Himalayan Earthquakes

The Indian plate got detached from the Supercontinent Gondwana consisting of Africa, South America, Australia, Antarctica, Madagascar, and India about 120 million years ago and drifted towards the north at a rate of approximately 8 inches/year (20 cm/year). It later collided with the Eurasian plate circa 55 million years ago, followed by the closing of the Tethys Ocean existing between them.

Tectonic forces are constantly pushing the Indian Plate northwards thrusting under the Eurasian Plate and creating the Himalayan Range which is seismically active. Three prominent faults (thrusts) dipping north run along the Himalayan arc from south to north. They are known as the Main Frontal Thrust (MFT), the Main Boundary Thrust (MBT), and the Main Central Thrust (MCT). These thrust faults sole at depth into the Main Himalayan Thrust (MHT). The MHT dips about 10 degrees to the north and is approximately 1,243 miles (2,000 km) long and 62 miles (100 km) wide along the Himalayan arc1. The MHT, the plate boundary or decollement between the descending Indian Plate and the Eurasian Plate carrying the Himalayan geological sequence, assumes a crucial role in the Himalayan earthquakes. As the Indian Plate drives down the Eurasian Plate, an enormous amount of strain builds up due to the locking as a result of friction at the MHT boundary. The release of the energy caused by slip along the MHT, when the accumulated strain overcomes the friction, triggers earthquakes in the Himalayan Region. It is concluded that ten out of the fifteen segments of the entire Himalayan ranges (roughly 1,500 miles long), including Nepal, has the potential to earthquakes of magnitude 8 or higher, as a result of the analysis of slip potential of these segments based on the knowledge of the past 1000 years of earthquakes in the Himalaya using geodetic, historical and seismological data1.

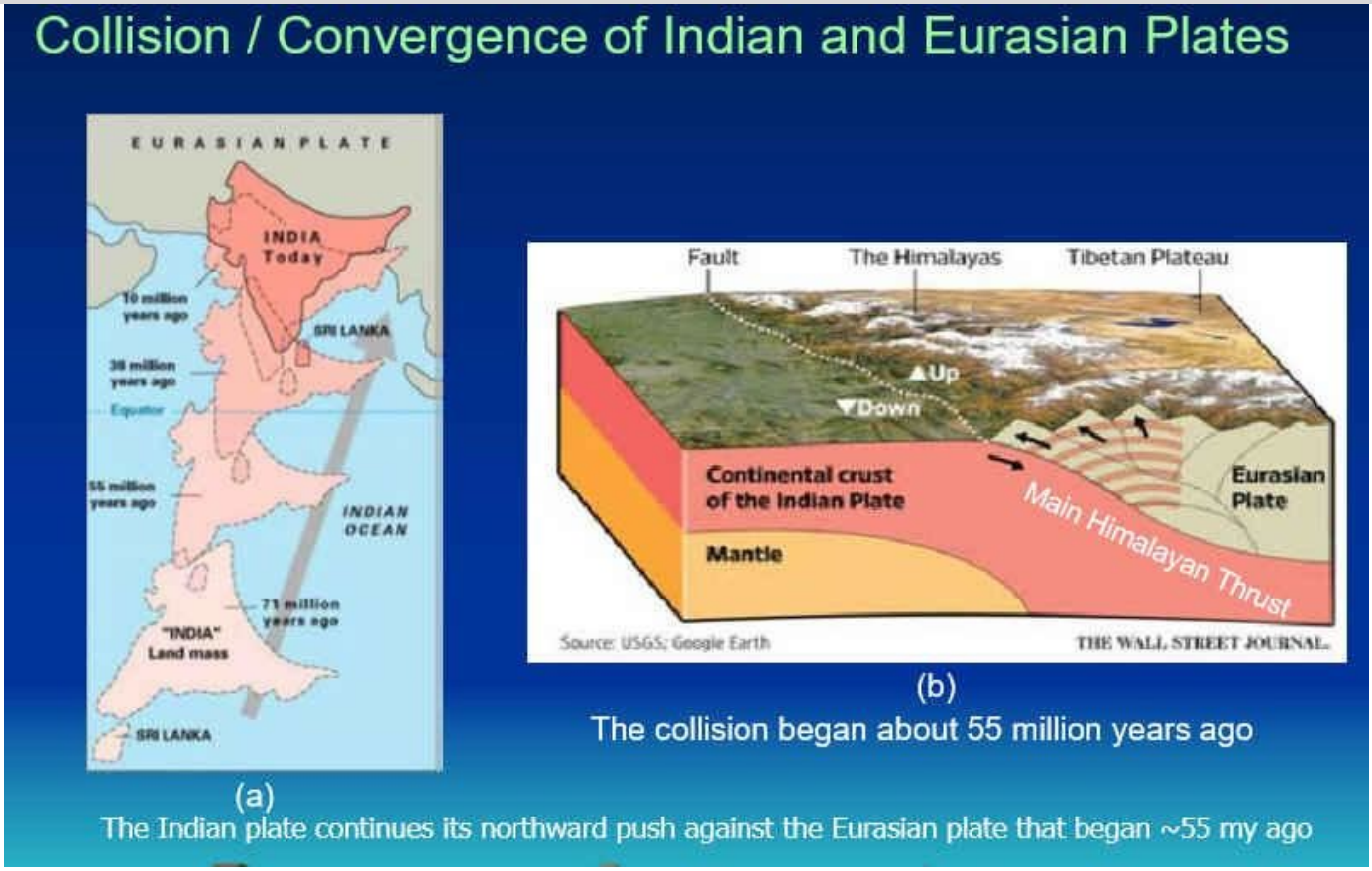


Figure 1. (a) Indian Plate got detached from Gondwana ~ 120 ma and collided with the Eurasian Plate ~55 ma ago; (b) Indian Plate pushing under the Eurasian Plate and the Main Himalayan Thrust (MHT) separating these two plates5, Source United States Geological Survey (USGS) and The Wall Street Journal.

Figure 2. Map of Nepal showing the epicenters of the April 25 earthquake (Mw 7.8) and the May 12 aftershock (Mw 7.3) of the 2015 Gorkha earthquake.

The 2015 Gorkha Earthquake and its Aftermath

The Mw 7.8 Gorkha earthquake that struck Nepal on April 25, 2015, had its epicenter located in Barpak, Gorkha, about 48 miles northwest of Kathmandu (Fig. 2). The focus of this earthquake is shallow at a depth of approximately 9 miles. This main shock was followed by the aftershock of magnitude Mw 7.3 on May 17, 2015, with the epicenter in Dolakha District (Fig. 2).

The generalized cross-section schematic through the central Nepal Himalaya (Fig. 3) shows the modeled slip of the 2015 Gorkha earthquake on April 25 (Mw = 7.8) and the aftershock on May 12 (Mw = 7.3)[8]. Also displayed are the major faults and the Main Himalayan Thrust (MHT), where the slip occurred in that earthquake.

The 2015 Gorkha earthquake did not produce any rupture in the Main Himalayan Thrust1, however, it uplifted the Kathmandu valley by 3 ft. (1 m), and mountainous regions north of Kathmandu subsided by 5 ft. (1.5 m)[1,3]. There was no evidence of surface rupture or ground deformation during the earthquake[2,4]. The earthquake elevated groundwater levels and increased the streamflow volumes in the watersheds along the Main Boundary Thrust (MBT)[4].

The 2015 Gorkha earthquake impacted central Nepal through enormous devastation to human, livestock, properties, and geomorphology, since the powerful magnitude 8.4 Nepal-Bihar earthquake in 1934. According to the Government of Nepal report, the earthquake and the aftershocks caused nearly 9,000 fatalities, 22,304 injured, 505,577 homes fully damaged, and 279,000 homes partially damaged, displacing 2.8 million people and affecting 8 million people[2]. Also, seven UNESCO World Heritage Sites of historical, archaeological, and cultural significance in the Kathmandu Valley suffered partial or complete destruction. The affected people, traumatized by the quake and aftershocks, were forced to take shelter in the open air for an extended period for safety reasons.

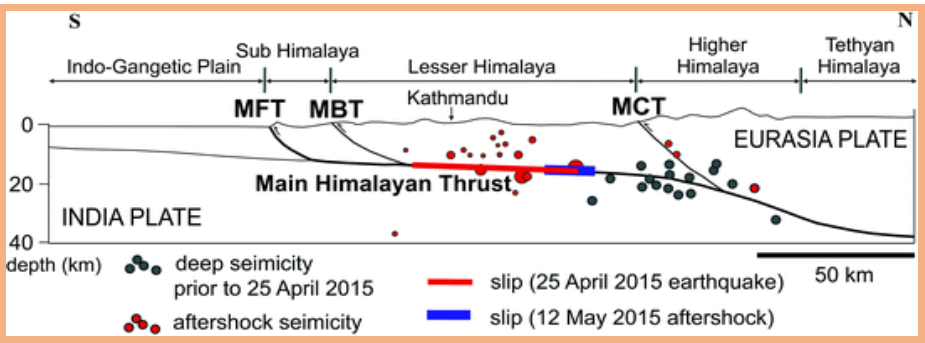


Figure 3. Generalized cross-section through the central Nepal Himalaya and the modeled slip of the 2015 Gorkha earthquake on April 25 and the aftershock on May 12 compiled by Geotechnical Extreme Events Reconnaissance (GEER) from source United States Geological Survey (USGS)[8].

The scene in Nepal after this earthquake was that of chaos and confusion because of the lack of a disaster management command center for effective communication for relief supplies distribution and the rescue and relief operations in the affected areas.

When the earth shakes during the earthquake, the saturated soil behaves like a fluid and loose strength and stiffness in a phenomenon called "liquefaction." Liquefaction affects the foundations by making them weak and potentially damages buildings and engineering infrastructures. Liquefaction is also the reason for lateral spreading that creates cracks in the roads, bends the railway tracks, and triggers landslides. Since liquefaction is mainly dependent on the soil condition, an examination of the soil profile before the earthquake-resistant building construction is recommended[6].

Earthquakes don't kill, but poorly constructed buildings do. That is exactly what happened during this earthquake. People who fled from their homes survived, those who opted to stay inside lost their lives or got injured.

The known trend in Nepal is to initially build two to three story homes, and subsequently add multiple floors, and rent out the lower floors. Since the foundation is built for only two to three floors, it cannot support the weight of additional floors and becomes unstable. During an earthquake, such houses tend to develop structural failure and collapse. Most of the high-rise apartment buildings in the Kathmandu Valley developed cracks and some became uninhabitable due to the earthquake. There was also a constant fear among citizens that the buildings with structural failures belonging to their neighbors were unsafe and could collapse any time over their homes.

The boundary walls surrounding a building are the weakest part of the structures as they lack reinforcement. The wall collapses were also liable to numerous human casualties.

The aftershocks following the earthquake put people in Nepal in a state of intense fear. Some people wouldn't even shut their bathroom doors as they feared that the doors could jam if the ground rumbled. The main gates of some of the homes were stuck because they were distorted due to the tremors.

The earthquake also triggered avalanches in the higher Himalayas and landslides, debris flows, and rockfalls in the mountainous regions. Almost all houses in the Langtang valley were turned into rubble. Even the Kali Gandaki River changed its course, and the glacial lakes were in the brink of bursting and flooding the nearby villages.

Most of the buildings damaged due to the earthquake were poorly constructed with brick and mud mortar with no reinforcement. Although the Nepal National Building Code (Seismic Design of Buildings in Nepal) has been in effect since 1994, it was hardly observed during the building construction phase. The penalty for violation of the building code is currently set at Nepalese Rupee 50,000, which is trivial, and it is understood that penalties are rarely issued on the defaulters of the building code.

"According to the Government of Nepal report, the earthquake and the aftershocks caused nearly 9,000 fatalities, 22,304 injured, 505,577 homes fully damaged, and 279,000 homes partially damaged, displacing 2.8 million people and affecting 8 million people"

Some schools in the Kathmandu valley that were retrofitted, survived the earthquake very well, indicating how important it is to retrofit the public buildings such as schools, colleges, universities, and hospitals, to make them withstand the earthquake tremors without destruction.

The 2015 Gorkha earthquake brought tremendous hardship to women, children, elderly and disabled people in the affected areas. It also wreaked havoc to the livestock, which killed countless buffaloes, goats, cows, and sheeps.

Fortunately, the 2015 Gorkha earthquake also had some positive aspects as noted below[7].

- The only international airport in Kathmandu was operational, and the highways across the country weren't damaged much, except the Araniko Highway linking Nepal and China, which suffered some landslide related destruction.
- The banking sector was also open for service during the quake.
- The international media, including BBC and CNN, gave continuous coverage of the disaster, spreading the news across the globe, giving people the idea of the scale of the catastrophe Nepal was facing, and sensitizing the general mass about the urgent need for humanitarian aid in Nepal.
- There was no long interruption in the communication systems, so the Nepali diaspora worldwide could keep in touch with their loved ones in Nepal.
- The April 25 earthquake occurred during daylight hours on Saturday around noon. Because Saturday is a holiday in Nepal, the schools, colleges, universities, and private and government offices were closed, leading to a minimized human casualties.

If the earthquake had occurred at night and exceeded an 8.0 magnitude, human casualties and property damage could have attained a much larger proportion.

Social Response

The crisis due to the Gorkha earthquake also brought illustrious cohesiveness and solidarity among people in Nepal, which was evident in people helping people, be it relatives, neighbors, social workers, or a volunteer from another country. It also gave rise to a sense of volunteerism in the country, specifically in the youth groups, who wholeheartedly participated in the rescue and relief operations as well as in the recovery and reconstruction efforts. This indicated the dawning of a new era of volunteerism in Nepal, which the government should help foster and continue.

However, a lack of elected representatives was deeply felt in the local areas in the 2015 earthquake. They could have been a great resource, who could have mobilized rescue and relief operations or the recovery and reconstruction efforts in the aftermath of the earthquake.

Analysis and Recommendations

Since large earthquakes and heavy rainfalls are observed to cause landslides, mudslides, and rockfalls, the Government of Nepal needs to prohibit the development of new settlements in the foothill and in proximity to the steep unstable hills-slopes. Thapa[8] observed that poorly constructed buildings with inadequate or no reinforcements suffered large damages. Furthermore, settlements situated close to the unstable hill-slopes and steep-slope hills were highly vulnerable to landslides, rockfalls, and debris flows8.

Houses in Nepal are usually constructed in multi-stages over many years. In other words, the first floor is built first. Additional floors are added to the building as funds become available. Some houses add two to six floors on top of the first floor with little adherence to the earthquake-resistance practice. Such houses developed cracks and were damaged during the earthquake.

Retrofitting should be considered a possibility. However, in some houses that sustain minimal damage to their frames, replacing the wall panels may be a better alternative as well.

The design of the buildings and structures should, therefore, include a detailed geological study, identification of seismogenic faults and dynamic soil properties in the area input into the probabilistic seismic hazard analysis to determine seismic design parameters for buildings and structures such as amplification factor, peak ground acceleration (PGA) and foundation factor, and liquefaction assessment and remediation[6].

The building code on "Guidelines for Earthquake Resistant Building Construction" in Nepal dates back to 1994. Unfortunately, more than five million buildings in Nepal do not comply with the earthquake-resistant design prescribed in the Nepal Building Code. Stringent enforcement of the Nepal Building Code should be the priority of the Government of Nepal, as part of the earthquake preparedness.

The Kathmandu Valley lacks open space and ground for the preparation for natural disasters such as earthquakes or floods. The uncontrolled urbanization of the Kathmandu Valley due to the construction of houses, commercial and apartment buildings led to the rapid disappearance of open spaces. The local municipalities need to take control of the few remaining open spaces and designate them as emergency shelters in disaster situations.

Most houses in the rural areas of Nepal are built without due consideration to the earthquake-resistant technologies. Therefore, the vulnerability of such buildings to the earthquakes can be greatly reduced by imparting the knowledge of technologies to make the structural framework of the new constructions earthquake-safe.

The basic knowledge about earthquakes and their destructive power should be disseminated to everybody. The government of Nepal needs to involve communities at the local level and educate them in the rescue and recovery operations and the first aid, so that individuals can act as the first responders at the time of the catastrophe.

Lack of command-and-control centers to communicate accurate and timely information to all involved in the rescue and relief operations at the local and national levels were sorely felt during the 2015 Gorkha earthquake. Therefore, the Government of Nepal needs to establish disaster command and control centers in all regions at all levels of the nation.

The Disaster Risk and Management Act has been promulgated by the Government of Nepal in 2017, after the 2015 Gorkha earthquake. Nepal's National Policy for Disaster Risk Reduction was also prepared and enacted in 2018. The main objective of this policy is to reduce loss in lives and properties, and infrastructures and cultural assets due to natural disasters. However, the success of this policy is solely dependent on its effective implementation by getting the actors in all levels informed and involved in disaster management and timely information dissemination.

The earthquake seismology can only identify the earthquake-prone seismically active regions but is not able to predict the timing and exact location of the earthquakes[5]. Since earthquakes cannot be predicted, it becomes a paramount necessity to be always prepared for one. Therefore, the development and implementation of a solid disaster mitigation plan can greatly reduce the damage and save lives ensuing from it. Needless to say, the role of earthquake hazard assessment and remediation process based on geological investigation and geotechnical earthquake engineering study is of crucial importance.

Conclusion

It is the question of when and not if the next large earthquake will occur in Nepal, because the Indian and Eurasian plates are constantly in action, building up the strain in the locked segments in the Main Himalayan Thrust (MHT) at the contact between these two plates. The technology of predicting the timing of earthquakes is still in infancy and under development. Therefore, the only approach to mitigate the destructive impacts of the earthquake is to adequately prepare for it with a sense of urgency. The nation has already learned from the 2015 Gorkha earthquake and its aftershocks continuing to-date. Understanding the value of the lessons learned and realizing them in devising solid plans for preparations for any future earthquake occurrences will help mitigate their impact in saving lives, properties, infrastructures, and more.

The Haiti and Chile earthquakes in 2010 also offer us the example that the nation will be much better off by implementing and exercising disaster management practices for risk reduction than being complacent, doing nothing, and waiting for it to occur.

Although the Disaster Risk and Management Act has been promulgated by the Government of Nepal in 2017 and the National Policy for Disaster Risk Reduction enacted in 2018, the success of such policies is solely dependent on their implementation and enforcement for disaster reduction.

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5G is Less About Mobility More About Availability

Jiwan Ninglekhu, Ph.D.

5G has become a buzzword recently. Grand View Research estimates the 5G services market size to reach USD 41.48 billion by 2020 and may get up to 200B by 2027. 4G LTE market size, on the other hand, is estimated to be 322B by 2023[1]. This gives us a perspective of where we are and where we are heading with respect to wireless communication technology. For now, 2020 may be regarded as a transition period from 4G LTE to 5G.

In addition to a picture of the coolest smartphone that displays a '5G' ideogram, one attribute we are quick to associate with 5G is its download speed. But very rarely we think of what we can do with that speed, except accrediting speed with the price and luxury of downloading a 4GB of UHD movie in seconds. However, if you are like me, you don't think you even need to download 4GB of UHD movie, as one cannot watch the whole movie in seconds, and may find it relatively unnecessary. But it appears that with 5G, we can do things that are only imaginable to date. So what is it that makes 5G so ambitious yet debatable, necessary but politicized? What is 5G technology which is able to make and break diplomatic relationships between countries?

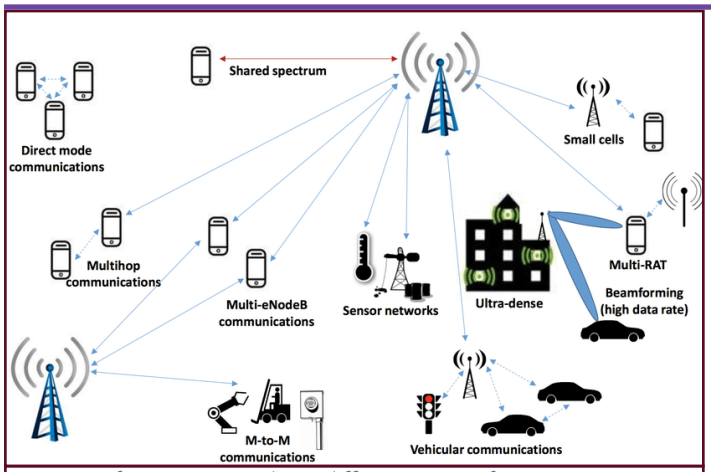
When we think about 5G, we also attribute it to mobility. If we look at the recent past, what mobility has brought to us is connectedness-- contributing to mobility. With 4G/LTE we already have great video and voice quality even when we are moving at a very high speed. Most recently, multiple mobile network operators (MNOs) have talked about 5G technology services, mostly with marketing motives, that would hopefully lead towards their sales of 5G related services to individual users, starting with mobile phone services. Apparently, that is where MNOs can begin generating revenue from their existing user base and established infrastructure thanks to the interworking between 4G/LTE and 5G architecture, essentially as a first step towards their transition to 5G technology. However, this is just the beginning.

Here we will look at some high-level objectives and use cases that may be able to give readers a sense of how 5G technology is able to make mobility a subset of a much bigger picture.

Short Overview of 5G Architecture

The development of 5G technology is led by 3GPP. The 3rd Generation Partnership Project (3GPP) is an umbrella term for a number of standards organizations that develop protocols for mobile telecommunications[2]. A high-level overview of 5G Network is depicted in the following picture.

At a very high level, 5G architecture may be interpreted as four different pieces. The User Equipment (UE), the Access Network (AN), the Core Network, and the Data Network.



5G Infastructure involving different types of user equipment

> *"This means that a vehicle can talk to any other vehicle in the 5G network. But isn't this possible today via LTE or On Star? Yes, but what 5G has is much more at its disposal. 5G will enable a vehicle to talk to another vehicle directly, vehicle to a mobile phone or a flying drone, or even to a lamppost. "*

The UE may be a mobile phone but in 5G, it can take all different forms such as a vehicle, a drone, a ship, a moving container in a ship, an IoT device, etc. The access network may be a traditional Radio Access Node but may also be a Non-3GPP access point such as a Wi-Fi router or an ethernet connected network.

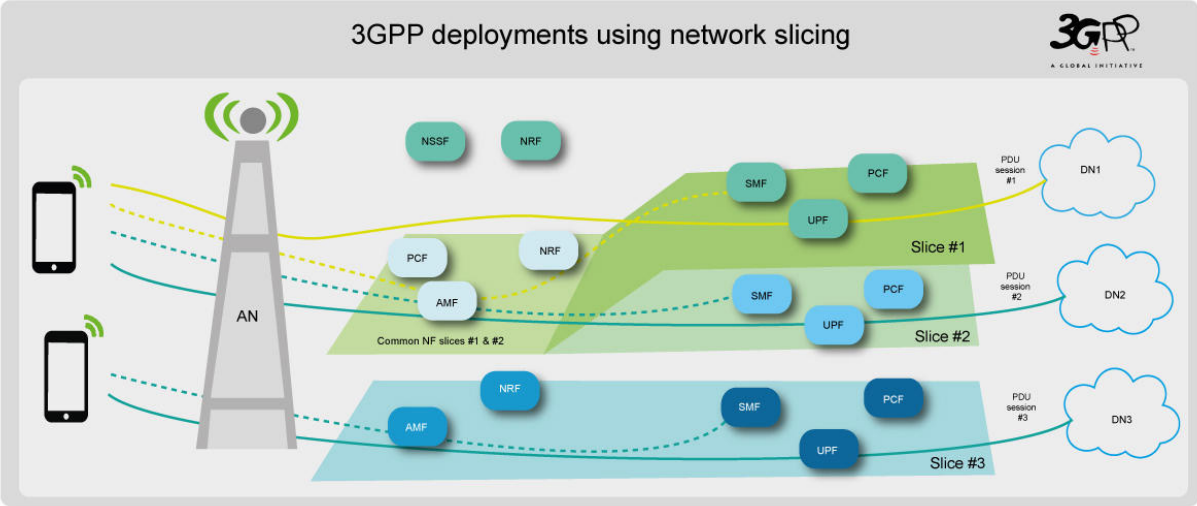
The core network is where requests from a UE are processed primarily to serve versatile forms of UEs, primarily to deliver service quality based on service level agreement (SLA). Data Network is not a part of the 3GPP standard but complements 5G technology. A data network may be the internet or any other network.

There are many new technologies that have contributed to the development of 5G core network technology. Virtualization, Cloud-native architecture, Containers, Micro Services, and Automations are the main ones. 5G core consists of different multiple network functions, which are animated using virtual machines (VMs), Containers, and network function virtualization (NFV). This allows the 5G core network to be elastic so as to meet the changing demands from the UEs and Data Networks. Additionally, the 5G core adopts service-based architecture passing requests and responses within the core network using microservices. One great feature that is driving 5G is its use of automation. The 5G core network will also use Machine Learning (ML) and Artificial intelligence (AI) for prediction and recommendation, which further the 5G network towards its capability of self organization, selfconfiguration, self-optimization, auto-anomaly detection and much more.

5G system (5GS) has two planes: the user plane and the control plane. The Control plane handles all the control functions like registration requests, UE policy delivery, timers, etc. The user plane is used when UE sends and receives actual data from the Data Network. Some primary network functions in 5GC's control plane are Access and Mobility Function (AMF), Session Management Function (SMF), Network Data Analytics Function (NWDAF), User Data Management (UDM), Authentication Function (AMF), Network Slice Selection function (NSSF), etc. In the User Plane, there may be User Plane Function (UPF). Some of these functions are shown in the 5G System Architecture diagram.

5G is More Than Cellular

When 1G was developed it was about transforming from wired to the wireless connection, when only a limited number of cellular devices were able to connect. 2G wireless brought mobile voice service to general people. At this point, cellular services became publicly



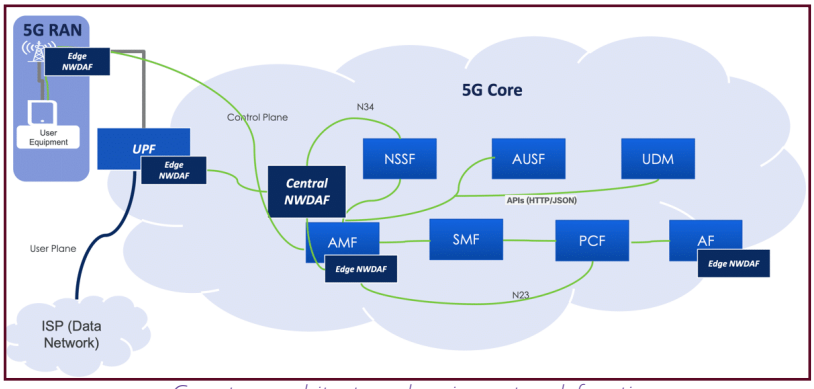
Network Slicing in 5G

available and widely commercial. As cellular technology was advancing, a parallel advancement in internet technology was happening. The Internet was transforming from dial-up connection via landline telephone to DSL/cable internet. Ethernet and Wi-Fi connections amazed us. By then, it became obvious that the next innovation was internet access on the phone. 3G cellular technology made this one possible. But to leverage the internet and the power of mobility, there needed to be a revolutionary phone design. That's when Google and Apple were able to develop smart phones that could deliver high-quality photos and videos in addition to voice and text messages and change our lives forever. I still remember how Google had first failed to bring the chat technology into the web. In 2010, live text editing on the web was a big experiment that had failed. But when the G1 phone was released and Apple iPhone shortly after, with 3G technology that had a speed of up to 42Mbps, the difference between text messaging and chat had disappeared. In addition, these smartphones paved a path where multiple wireless technologies such as LTE, Wi-Fi and Bluetooth would become not an option but a necessity. 4G/ LTE on the other hand has allowed us to stream HD videos, do live video conferences, broadcast high-quality live webcasts, and also allowed us to get a taste of Augmented Reality and Virtual Reality. So what is 5G offering us that is more than high-speed internet?

5G Equals Availability

5G is cellular and more. 5G is cellular technology native but It is now able to incorporate non-3GPP radio access (e.g. Wi-Fi) and wired access (e.g. Ethernet) with later releases. 3GPP Standard has already published Release 16 specification[2] for 5G networks which can allow any UE to send and receive its data from a Wi-Fi or Near Field Communication (NFC) interface for example, via the 5G network. 5G is also introducing its 5G wireless gateways that could complement or replace existing Wi-Fi routers and possibly internet cable services. These gateways act as UEs by themselves that can deliver lightning-fast data speeds enabling ordinary people to have interactive AR/VR experience at home. With 5G, not only can we have a virtual watch party, but we may be able to play ping pong or racquetball with a friend while being 100s of miles apart.

Another feature that is being enhanced from 4G/LTE is direct communication between UEs. 5G will faster UE-to-UE direct communication. This allows UE to contact another UE directly without any technical support from the network. The most common UE-to-UE connection is a Bluetooth enabled voice and data transfer experience. But imagine having an ability to connect directly with a 5G device anywhere regardless of whether you know the person using the device.



5G system architecture showing network functions

V2X

V2X stands for Vehicle-to-everything. Well, 3GPP has defined what X is. Currently, there are four different entities that may fall into the category of X. They are Vehicle-to-Vehicle, Vehicle-to-Infrastructure, and Vehicle-to-Pedestrian. This clearly shows 5G has stepped beyond just cellular and wireless. This means that a vehicle can talk to any other vehicle in

the 5G network. But isn't this possible today via LTE or On Star? Yes, but what 5G has is much more at its disposal. 5G will enable a vehicle to talk to another vehicle directly, vehicle to a mobile phone or a flying drone, or even to a lamppost. This requirement of a UE (e.g. mobile phone, car, etc.) being able to talk to another UE directly initiated the study of Proximity Services (ProSe). On the one hand 3GPP, working groups are studying ways by which we can leverage this feature on the other hand trying to overcome the problems that are on its way. It is because of the ultra-high-speed that 5G has brought, it is now possible to upload, download control signals data as well as user data with absolute reliability. This means ACE vehicles are coming to life. ACE stands for Autonomous, Connected, and Electric, and the term was coined by Dr. Evangelos Simoudis vehicles in his book titled The Big Data Opportunity in Our Driverless Future. In his book, he explores several stages by which Autonomous Vehicles will come to life which can be made possible by connectedness where 5G technology along with cloud and AI shall play a significant role.

With connected vehicles powered by 5G technology, we may be able to register our vehicle's capabilities to the 5G core network, which shall allow us to exchange support with another vehicle on the road or even socialize. While fixed-track transportation like trains and hyperloop shall enjoy a seamless autonomous control with full-fledged virtual entertainment or work, modular and mobile emergency vehicles health professionals may be able to perform surgeries without transporting patients to the hospital.

The ability to connect with many other infrastructures and other vehicles with ultra-reliable low-latency communication brings opportunities for reliable emergency services. Among many use cases, 5G capable emergency rescue and support enables any 5G capable devices to participate in monitoring rescue missions. For example, drones, cars, mobile phones, cameras, etc. can participate in emergency data collection and rescue, that can draw a picture of the situation, and, further with the help of AI, may be able to predict the degree of emergency and possible occurrence of a similar emergencies.

Network Slicing

Unlike previous generations of wireless telecommunications networks, the 5th generation has features that make it stand out in a unique way. 5G network has a core network that is cloud-native, supports virtualization, and follows service-based architecture. This has allowed for the 5G core network to "slice" the network. Network slicing simply means having network resources in the core network dedicated to particular service or ownership. This provides the ability for a network operator to offer private slices to businesses or separate slices based on the type of service. The type of service may be driven by the quality of service, guaranteed uplink/downlink data, sensitivity (security), etc.

Network slicing plays a significant role in delivering the required service to the users. 3GPP has standardized 4 different types of slices: Ultra-Reliable Low-Latency (URLLC), Enhanced Mobile Broadband (eMBB), Massive Internet of Things (MIoT), and V2X. The majority of 4G/LTE devices were mobile phones. However, we have already discussed that there shall be a variety of user equipment in the 5G network. The aforementioned slices are designed to serve specific categories of UEs. For instance, IoT devices in an industry or home will have certain

types of data. For example, the data reporting may be periodic and the UEs fixed (immobile). They may be small data and mostly may not need low latency service. However, URLLC is designed to provide very low latency services such as remote UAVs control or autonomous driving control, which uses ML/AI massively. eMBB is dedicated to offering ultra-high-speed internet service.

In addition to standard slices, a mobile network operator may offer custom network slices based on customer's needs such as privacy, security, and reliability. Network slicing adds to the 5G network its flexibility, availability, and efficiency.

There are many more cutting-edge features that 5G technology incorporates such as AI/ML for automatic UE and network optimization, mission-critical services, and edge-computing for reliable services. With such massive capabilities, the 5G network is just waiting for creative minds and innovators for them to exploit its extraordinary potential.

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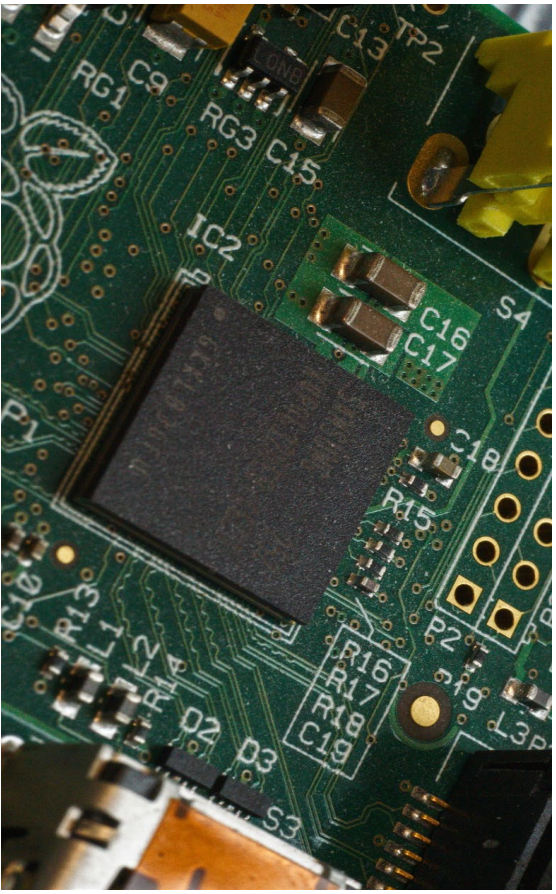


Sustainable Raspberry Pi enabled telemedicine and innovation hub in NEPAL

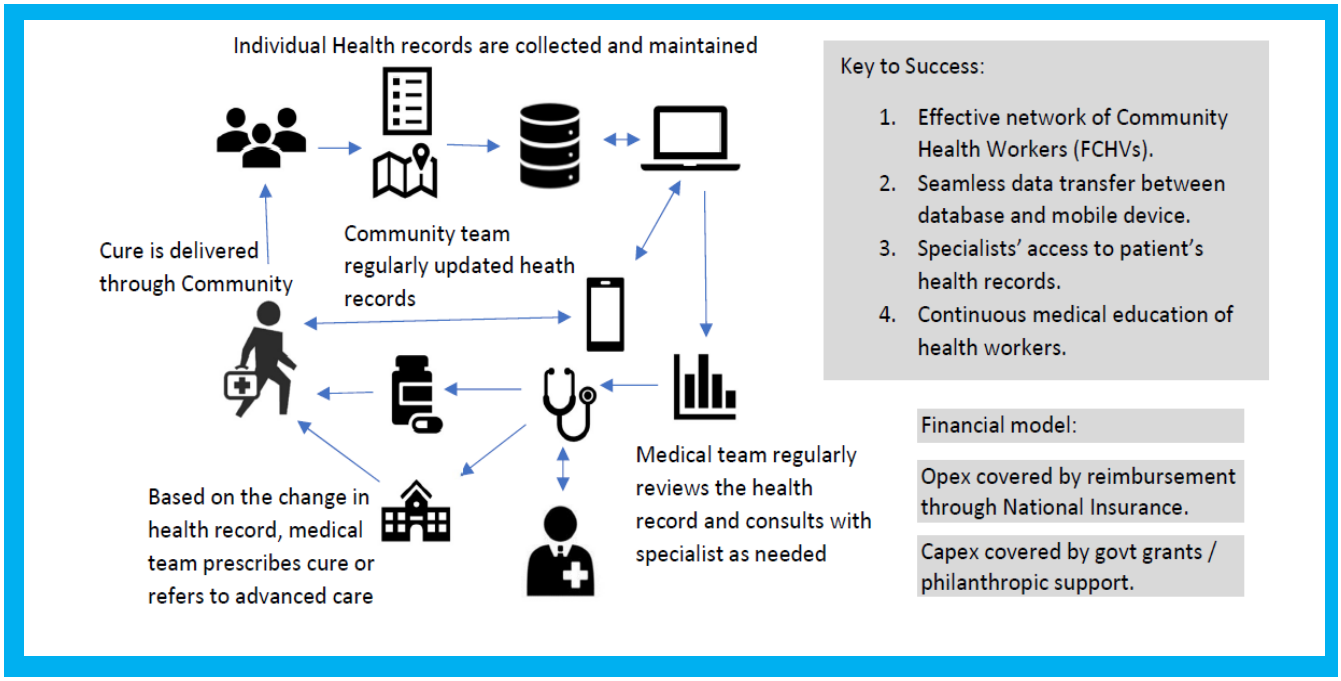
Sanjib Chaudary;
Saurav Dhakal;
Uddip Gajurel;
Sanjaya Gajurel

Raspberry Pi is a single board computer, easy to install, cheap and effective IoT (Internet of Things) device. By adding a screen and keyboard, it turns it into a full-time computer. The latest version of Raspberry Pi costs around NRs 5000 and it can be used for various applications.

The goal of the project initiated by StoryCycle (https://storycycle.com/about) in coordination with Nepali American Organization of Ohio (NAOO) and American Society of Nepalese Engineers (ASNEngr) is to improve the health status of the community through durable healthcare. This innovative healthcare solution was expected to improve quality and delivery of healthcare supplies by lowering the costs with the following initiatives:

- Develop and maintain a digital health records database of all members of the community (vitals, medical history, medication history, test results, etc.). The system will have a mobile interface.
- Develop a GIS Mapping of covered area with house ID and personal ID.
- Develop a system of Longitudinal Health Monitoring System.
    - A medical team of mid-level health professionals (Health Assistant, Staff Nurse) under the supervision of Medical officers will review medical records in a regular frequency determined by a person's age and medical condition. A team is responsible for X number of people.
    - A community team of community health workers (FCHVs) will transfer information (update health records as required) between the health workers and the people. A FCHV is responsible for a certain area or ward.
    - A mobile data transfer system will facilitate the communication between the teams.
- Develop an algorithm for diagnosis and specialist consultation.
    - A flow chart type of algorithm for disease identification based on symptoms.
    - A network of specialists to consult if the case is not definitive in the algorithm. Key consultants will have access to the patient's medical history in the database.
    - A network of Hospitals and health posts to facilitate advanced care and laboratory services.
- Maintain pharmacy and deliver medications to home through the community team.
- Develop an innovative and adaptive preventive care program and educate the community through FCHVs and home visits by medical professionals.
- Develop a continuous Health Education program for Health workers.

Internet service is available in almost all 77 districts of Nepal. Internet users have grown significantly in the recent years. The project aims at complementing the services at health centers in local level by establishing



Raspberry Pi-enabled telemedicine kits with sensors that can collect readings for body temperature, blood pressure, blood sugar level, heart rate. The collected data is transmitted to the doctors who may be located at city hospitals via the Internet of Things (IoT). These services can help people in rural areas record their health information and send it so that they can receive needed help remotely.

To make the telemedicine centers self-sustainable, the project will have dedicated Raspberry Pi terminals connected to the internet which will be rented out to people wanting to connect with their relatives, friends and family members who work as migrant workers in the Gulf and other countries. The income from these terminals may also help run a self-sustained center so as to cover the cost of utilities like internet fee, electricity bill, salary of the center coordinator, rent of the center, etc. The public buildings like government schools or buildings of trusts or charities will be targeted as the hosting center which will reduce the running costs and help focus on serving poor people.

The first telemedicine and innovation hub will be established in Birendra Bazaar of Saptari district and the second one will be established in Sindhuli district. Once established and sustained, more hubs will also be opened in economically disadvantaged remote areas of Nepal like Upper Dolpa after the investigation on solar powered Raspberry Pi.

As the first phase of the project, a community mapping and storytelling camp was organised in

Lahan, Siraha with an objective of assessing the situation and orienting the communities about

the project through community mapping and storytelling. The camp also aimed at supporting

the local partner Shripurraj Community Development Centre on identifying the strengths and

weaknesses of the four thematic areas namely agriculture, tourism, heritage, and arts and crafts. The camp objectives were:

- To assess the situation of health centers and communities in Saptari's Surunga Municipality
- To capacity build the community members on community mapping and storytelling
- To identify strengths and weaknesses of agriculture, tourism, heritage, and arts and crafts thematic areas
- To link the probable entrepreneurs and businesses with online portals and businesses in Kathmandu
- To promote the local products and places to a wider audience

The project also aims at empowering the community. Students in nearby public schools and the poor (who can't afford) can use the internet service once a week for free as an incentive to carry out volunteer community services in the village. That way they feel that they are getting something with their volunteer work which in turn induces self-reliance.

This technology can be tailored for various purposes besides social media and tele-medicine. For an example, the textbooks that are being transported to school at Upper Dolpa could be e-transported, eliminating the hassle of carrying them for several days. It can also be used as a water pump controller that can provide drinking water and irrigation services in places where the lands are dry despite having a huge source of water (Koshi) flowing below them.

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Sanjib Chaudary, Saurav Dhakal, and Uddip Gajurel worked in Raspberry PI project in Nepal and Sanjaya Gajurel is the current Vice President of ASNEngr

ULTRA LOW HEAD MICRO HYDROPOWER PLANT IN NEPAL

RABIN DHAKAL

Photo: Pilot installation of 1.6 Kw at Bagmati, Gokarna in background

It is often claimed that scientists and researchers are the citizens of the world; they have no boundaries. But as a researcher of a developing country like Nepal, the real challenge lies in making the research work recognized in the whole world. Almost all of the researchers have a dream to discover new ideas that induce a high impact on society and also want the ideas to be implemented in the real world. To represent one's nation in the international arena, and hold its flag high amidst other nations, is a matter of great pride. The Research and Practice on Gravitational water Vortex Power Plant was the perfect opportunity for me and my fellow researchers at Institute of Engineering, Central Campus, Pulchowk.

After rigorous research of 3 years, we - the researchers of the Institute of Engineering, Pulchowk Campus have been successful in optimizing a design of new and innovative technology addressing the current energy need in Nepal. The Gravitational Water Vortex power plant (GWVPP) is a new type of technology in which the energy of flowing water is extracted by a turbine placed at the center of a vortex that develops in a rotation tank (basin). Since such vortex can be formed at heads as low as 0.7 m, the gravitational water vortex power plant does not need a large head like other hydroelectric power plants. The construction cost is also relatively low.

This makes them suitable for the rivers across Nepal, in thousands of locations. GWVPP is designed to be installed across remote areas of the Terai region that might have never seen grid expansion in the past. It is designed to electrify a small community of up to 200 homes per plant under Nepali consumption patterns. As most of the cottage industries are located in these regions, they can benefit from GWVPP. It has the potential of removing the need for mega hydropower stations. The installation of the GWVPP could be an exemplary project that can have huge environmental benefits with minimum environmental impact. Thus, for a developing country like Nepal, this technology of power production can be a boon to eradicate the energy crisis.

A low head turbine is the most suitable option for rural electrification. GWVPP is a new and emerging technology in the context of low head hydropower. The research on the gravitational water vortex power plant originated in Austria in 2007. After the introduction of GWVPP in Nepal as a master's degree research project in the year 2012, it became an eye-catching and appealing topic to engineering researchers around Nepal. Two other batches of 2013 and 2014 of mechanical engineering students continued the research focusing to optimize the efficiency of power plants. Conventionally, the Austrians are using cylindrical basin structure to form a water vortex which is the main source of power in GWVPP. Our main interest to design the parameters of the vessel to increase the strength of water vortex. With the rigorous research on the design parameters for about 3 years, we have developed a new mathematical model for the design of the basic structure and came to a conclusion that the conical basin structure is more efficient than cylindrical basin structure to create water vortex. After finding a suitable basin structure to form water vortex, we move forward to optimize the design of the turbine of the power plant. With many experimental testing and mathematical analysis, we have concluded that the position of a turbine inside the basin affects the efficiency to a large extent. It was found that positioning about 60%-70% height of basin from the bottom is optimum for maximum power generation. These two findings are breakthroughs in research and development of GWVPP. We have published research articles in many national and international conferences including world hydro conference at the USA and Renewable Energy Conference at Korea, and have won multiple awards for innovation, best practices, and along with other recognitions. The most prominent one is the publication in the world's top Journal in Renewable Energy Field i.e. Renewable and Sustainable Energy Reviews.

We are striving to commercialize the research findings. Some generous people from inside and outside of the country helped us to initiate a commercial size project which was noteworthy and made it conducive enough to test the patent-pending design successfully in Bagmati River at Gokarna, Kathmandu for a 1.6kW capacity. We are planning to supply the electricity to an orphanage house and Martyr's Park near the installation site.

Photo: Experimental Setup during research(top two photos);Pilot installation at Bagmati, Gokarna (bottom two photos)

We have also taken the initiative to commercialize this project in various regions of Nepal by doing feasibility studies at many locations with goals to lessen the imbalance between energy supply and energy demand prevailing in the country by the effective utilization of this technology and bringing about the economic benefit for all. We have taken a goal that by the fifth year of the project, minimum of 50 GWVPP of the capacity ranging from 5kW to 20 kW will be installed with the continuation of the research in collaboration with Institute of Engineering (TU), Turbine Testing Lab of Kathmandu University School of Engineering, and University of Bristol, United Kingdom.

In conclusion, our vision of empowering Nepalese society by utilizing our immense water and natural resource through promising technology is appreciated by all. The experiences acquired during the research and development of the gravitational water vortex power plant made us realize one important fact - we can lead in research and development in the globe if only we focus on the research-based on technology that we have within Nepal.

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HERITAGE Conservation:

Basantapur Durbar

Ananta R. Baidya, P.E.

Imagine experiencing the Indra Jatra festivities at one of the World Heritage Sites in Nepal, Hanuman Dhoka Durbar Square, during 1800 AD. A sketch dated 1857 AD by surgeon at the British Residency in Nepal, Dr. Henry Ambrose Oldfield, allows for that imagination.

Comparing the landscape shown in Dr. Oldfield's sketch, done around 16 to 17 years after the 1833-34 AD earthquake with photographs of "Gaddhi Baithak" and the surroundings taken before the devastating 2015 Gorkha-Nepal earthquake (during the 2014 Indra Jatra festivities) raises the concerns and provides interesting conclusions (Photo 1).

Limited records indicate that earthquakes have impacted Nepal since 1255 AD (Photo 2). These natural hazards in disaster prone Nepal cannot be minimized. Emphasis on safety from natural and man-made hazards in the current construction practices of heritage and modern infrastructures in Nepal is critical. The destruction from the recent 2015 Gorkha-Nepal earthquake bears the testimony.

The discussions in this article may persuade those interested in and involved with the conservation, preservation, and reconstruction of heritage, culture, and tradition and recreation of heritage structures to change reconstruction approaches and practices currently prevailing in Nepal.

Temples and buildings sketched some 170 years ago can still be identified in today's photographs. Tragically, other fascinating structures maybe "no more" because of demolition or change or replacement. Other paintings of Kathmandu in the 1800 AD attest to the reconfiguration and reconstruction of Hanuman Dhoka Durbar Square. Some of the structures shown in Oldfield's sketch may well be based on imaginative recreation of the original structures damaged by the earthquake.

Photo 1: *Comparing Landscapes - 1857 AD Oldfield Sketch; 2014 Indra Jatra in front of Gaddhi Baithak; 2015 Gorkha Nepal Earthquake*

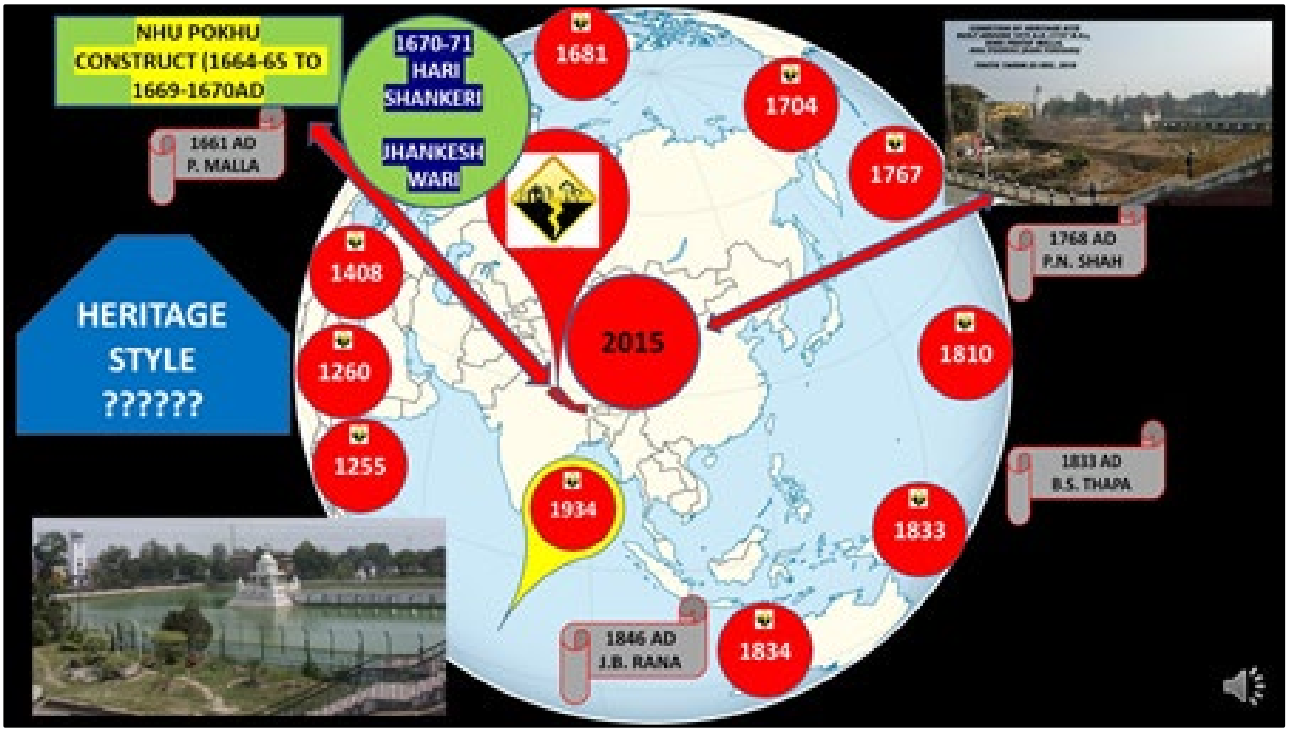

Photo 2: *Historical Earthquakes of Nepal*

The two tiered pagoda of Bhagavati temple (or Mahipatrindra Narayana temple, originally built in 1766 AD) foreshadows the tree in front of the Degutale temple (built between 1559 and 1620 AD by Shivasinha Malla) and the Taleju temple (built in 1501 AD) are in the sketch. How they were impacted, reconstructed or recreated after past earthquakes remains unstudied. The tree behind the Bhagavati pagoda, by comparison, could be over 170 years old.

In Oldfield's sketch, Newari style buildings surround the building in white. Rectangular window latticed with vertical and horizontal strips still prevails in the photograph from 2014 Indra Jatra. Some observations on the photograph are listed below:

- The rectangular European style windows replaced the Newari "tiki jhya".
- A fourth story has been added.
- The new balcony projecting from original third story roof replaced the original traditional clay tile roofing.
- Damage to the fourth story in the 2015 Gorkha-Nepal Earthquake shows metal roofing.

The taller building next to the three-storied white building, with "Tiki Jhya" and the "chhane shaili" roof is a mixture of Newari and European styles (Photo 3). The taller structure with the extended balcony supported by tall white columns, "chhaney shaili" roof and European styled arched windows predates World War I and the 1857 AD sketch. A similar structure is also shown in paintings of the area done by an unknown Nepali artist in 1865 AD. They are possibly remnants of the addition that was made to Hanuman Dhoka palace complex after its capture and occupation by Prithvi Narayan Shah, King of Gorkha, in 1769 AD. Perhaps, they even predate 1769 AD and reflect the influence of British India during the Malla period in Kathmandu valley. Portions of these structures may have been damaged during the of 1834 AD earthquake.

This building seems to have been used for ceremonial state functions. Could this be the probable prelude to the Gaddhi Baithak constructed by Prime Minister Chandra Shumsher Rana in 1908 AD?

The Malla era Trilokya Mohan temple (built in 1679 AD) was completely demolished by the 2015 Gorkha-Nepal earthquake and all that remained was the braced dome style temple next to the status of Garudha. Trilokya Mohan temple may also have been rebuilt following the 1833-1834 AD and 1934 Bihar-Nepal earthquakes. Immense interest to traditionists and passionate heritage protectors would be to research the style, construction and configurations and relative layouts of these lost items of Newari heritage.

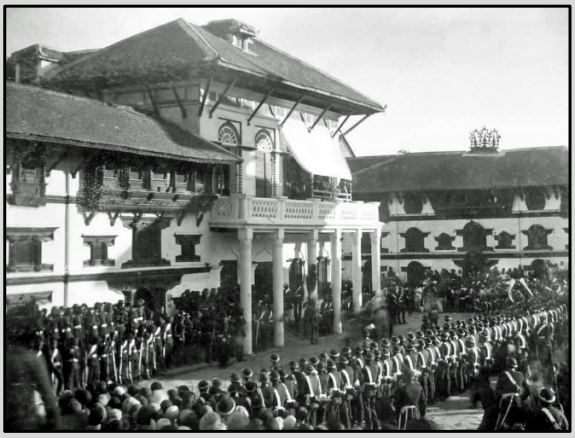

Photo 3: *Building with Newari and European Style Roofs*

The embedded plaque confirms the initial erection date of Gaddhi Baithak was 1908 AD during the "Administration of HH the Maharajah Major General Sri Chandra Shamsher Jung Bahadur Rana". The traditional celebration of Indra Jatra continued in front of Gaddhi Baithak after its construction in 1908 AD (Photo 4).

The main entrance to this Gaddhi Baithak (Photo 5) seems to have been from the open space in front of the Kumari House situated to the right with a building adjoining the Kumari House and going towards New Road per current configuration. There is no wall or balcony in front of the entrance but there are steps with a person of distinction mingling with the public at the Indra Jatra festivities. This was the configuration before the 1911 AD changes and prior to repairs done to the building after the devastating 1934 Bihar-Nepal earthquake.

Photo 4: *Erection Date Plaque - 1908 AD – Gaddhi Baithak*

Photo 5: *Main Entrance Ghaddi Baithak Prior to 1911 AD*

The photo captioned "Basantapur Durbar Square before earthquake" (Photo 6) presents Gaddhi Baithak with a balcony and guardrails over the entry stairway at the location of the entry shown. A structure adjacent to the Kumari house is also shown and the installation of an electrical light pole with streetlights is clearly visible in the photograph. Electricity was introduced in public venues after 1911 AD, upon the commissioning of Panauti Power House during the reign of Chandra Shumsher Rana. It was not available during Indra Jatra festivities. Apparently, modifications and an alternative access to the Gaddhi Baithak was completed between 1908 AD and 1911 AD.

The face of Kathmandu's heritage again changed after the catastrophic 1934 AD Great Bihar-Nepal earthquake (Photo 7). During the reconstruction effort by Prime Minister Juddha Shumsher Rana, New Road or Juddha Sadak was created. Some heritage structures were rebuilt. Others were left to languish and were demolished years later. One victim of this building adjoining the Kumari Ghar was a victim of this approach. In the post 1934 AD photograph, this building is not present. Indra Jatra celebrations of 2014 shows the same configuration (Photo 8). It was demolished around 1950 AD to create the Basantapur Durbar Square. Kumari House, however, has received a facelift - the white painted exterior now perhaps shows the original brick finishes. The traditional style remains as a contrast to the white colored European style Gaddhi Baithak and its adjoining structures.

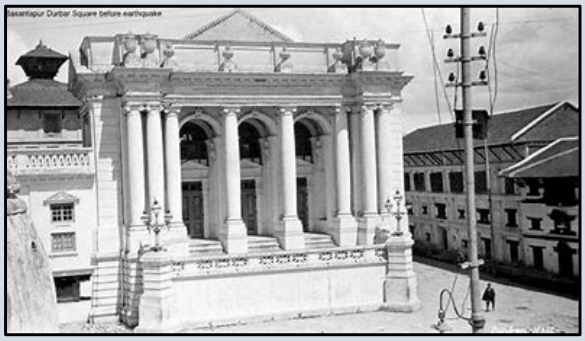

Photo 6: *Modified Gaddhi Baithak Pre 1911 AD*

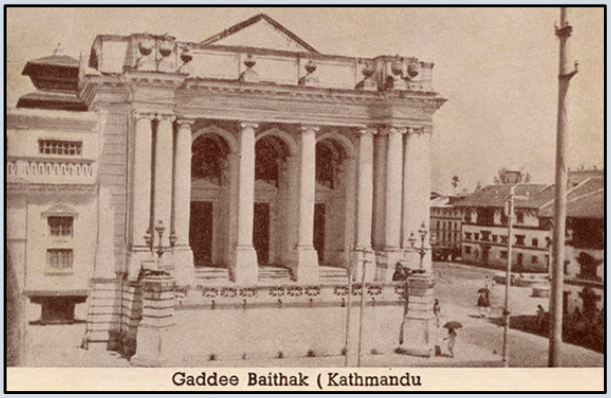

Photo 7: *Gaddhi Baithak Landscape Around 1950 AD*

Photo 8: *Kumari Chey (House) in 2014*

Changes to the shape of the Nau Talley Tower, built in 1770 AD by Prithvi Narayan Shah, and located behind Gaddhi Baithak facade is noticeable. It has a broader frontage. How much of heritage was lost from these activities remains unknown.

Much was damaged by the 2015 Gorkha-Nepal earthquake of April 15, 2015, others remain in ruins and on braces and life support (Photo 9). Much of heritage has been demolished and restoration has been unmanaged and chaotic.

Gaddhi Baithak and the surrounding including the Kumari House received their share of damage from the 7.8 Richter magnitude jolt. Some damages around the area can be seen in the photograph (Photo 9). It had been refurbished with a grant from the US Ambassador's Culture Fund (Photo 10) and stands regal today.

Photo 9: *Damage from 2015 Gorkha-Nepal Earthquake*

During the 2019 visit, the all-important and annual festivities of Indra Jatra Festival was in full swing around Gaddhi Baithak and Kumari House which is still in braces and in life support. To this day, buildings and structures are still on life support and on braces in every nooks and corners of Kathmandu valley. These are the conclusion on heritage conservation, reconstruction and pride in Kathmandu Valley based on comparisons of photos collected over time for this article (Photo 11).

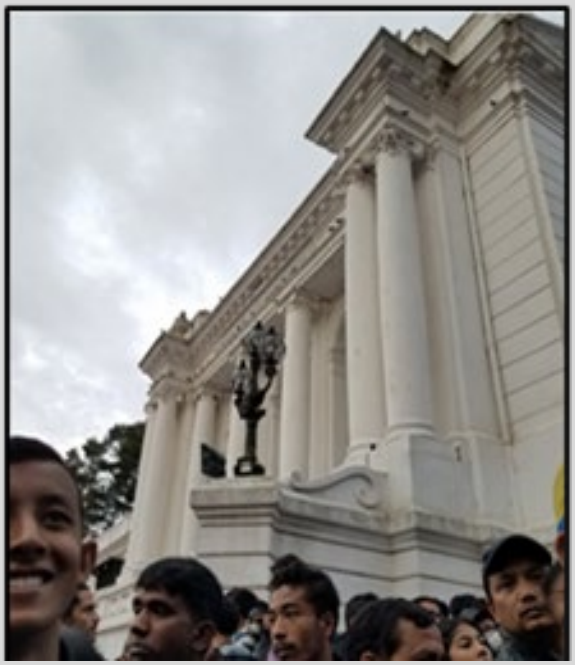

Photo 10: *Gaddhi Baithak Refurbished*

Photo 11: *Kumari House – on Life Support and Braces*

Should the collective knowledge and experiences of the members of the American Society of Nepalese Engineers, USA, be channeled and shared, the current gaps in Nepal's practices can be bridged. Conservation, preservation, reconstruction, recreation and repair of heritage structures and monuments and modern structures from natural disasters such as earthquakes, floods and landslides and other man-made disasters such as fires can be achieved using Modern Earthquake Engineering Knowledge [MEEK] and other state of the science approaches. "Public Safety for All including for People with Disabilities and the Elderly" can be ensured and precious lives can be saved.

ABOUT THE AUTHOR

Ananta R. Baidya, P.E is a licensed civil engineer in the state of California. He is the owner of AB&H Engineering Code and Consulting Services and the Chairperson of the Nepal Liaison Committee at ASNEngr.

Nyatapola Temple in Bhaktapur, Nepal

My Recollection of Old-time Engineers and Engineering-past in Nepal

Kanhaiya Lal Kayastha, M.S., P.E., S.E., AIA, SECB, F.ASCE, F. ASNEngr

Engineering and Architectural Background

The archeological records of Nepal indicate that there are more than 10,000 man-made caves on the high mountains, along Kali Gandaki River of the Kali Gandaki valley in Mustang. These multi-storied caves were built in the mountains, around 1000 B.C. and many of them are more than 1000 years old. They were initially used as burial chambers but were later used for living quarters and for meditation. The villages were developed along the banks of Kali Gandaki River in the Kali-Gandaki valley in the Mustang area. (http://uppermustangtour.com;MustangCaves–Wikipedia)

It is observed that the ancient Hindu temples, Buddhist shrines and stupas in the Kathmandu valley and outside the valley were mostly built during the Lichchhabi period in Nepal, around the 5th century, however, some of them are said to be much older. During the Malla dynasty (12th to 18th century), a ruling Newar dynasty of Kathmandu Valley, the UNESCO World Heritage Sites like Bhaktapur Durbar Square (the palace of 55 windows), Hanuman-Dhoka Durbar in Kathmandu Durbar Square were built in Newari style of Architecture. Similarly, "Nyatapola" (1701-1702 AD), the five-story temple with five-tier pagoda roofs in Bhaktapur (https:llen.wikipedia.org/wiki/Nyatapola_Temple) is considered one of the tallest pagoda-roofed temples in the world (Fig. 1). Another prominent example of the ancient temples from the Lichchhabi period built of wood is "Changunarayan" in Bhaktapur (325AD). It is interesting to note that the "Gorkha Durbar" (A Palace, fort, and a temple) in Gorkha, Nepal, built by Shah King in the 16th century, was also constructed in a Newari style of Architecture.

Nepal used to be a transit for traders between India, Nepal, Tibet and China in its early history. Also, Nepal has a record of exporting its rich architectural beauty and values to the neighboring countries. The most famous among Nepal's travelers at that time was probably "Araniko". In 13th century, a group of Nepalese artists under the leadership of Araniko went to China and constructed numerous monuments including the famous "White Pagoda" (Article Oped eKantipur.com, by Shaphalya Amatya, former Director General of the Department of Archaeology, Tribhuwan University: Oct 16, 2011).

Hillside home in Nepal with stone wall and straw roof

Construction Methods and Techniques used in old Temples and Houses

Looking at the constructions built in the Lichchhabi and Malla periods, it appears that they were constructed by the local workers and craftsmen. They were built mostly using the locally available materials by manual laborers. The designs must have been crafted by the local artists with the help of the local craftsmen, sculptors and metal workers. In addition, they must have been constructed under the religious faith and guidance from the Hindu priests and directives from the prevalent dynasties at that time. Normally, the series of prayers and offerings made, starting from laying the foundation-stone to finishing the roof of the house, are conducted under the supervision of the priest and the owner during construction. This tradition continues, to some extent, in Kathmandu valley and outside the valley by local communities.

Aesthetically, the temple structure resembles a pyramid, with a wide platform at the bottom and narrows down as it goes up in stories. It finally ends up to an apex in the roof where a "Gajur" is placed as a sacred temple symbol. In principle, this kind of structural form that is symmetrical and proportionate, without much structural irregularities, normally provides a better structural stability. Similarly, the typical Newar community dwellings are constructed in cluster blocks around the central open courtyards to provide light and ventilation (Fig. 3). In addition, these blocks of houses around the courtyard are tied to each other which help increase the overall structural stability. The materials used for construction are primarily the burnt and/or sun-dried clay bricks, wood, stone, and the roofing clay tiles. The locked joints in woodworks and the plenty of wooden brackets (chukul in Nepali) driven into walls throughout the construction, may have created better response to various past earthquakes in Nepal. The Nepal earthquake historical records, however, indicate that there had been damages to these structures in the past needing repairs. In fact, the history of Nepal-earthquakes goes back to 1255 AD to the ancient days of the Malla dynasty, when the king had died in the earthquake.

Nepal now has a National Building Code since 1994 in order to provide the basic design norms and standards for the earthquake-resilient building construction. In addition, the American Society of Nepalese Engineers, jointly with the America-Nepal Medical Foundation and the Computer Association of Nepal-U.S.A. has published a position paper in April 2015, entitled, "Earthquake Preparedness and Disaster Relief in Nepal", in order to provide general awareness to public regarding earthquake safety.

Hillside home in Nepal with stone walls and slate roofs

(Courtesy: robertharding.com)

Engineering and Constructions during the Shah Dynasty and Rana Regime

A drastic change is found in the architectural and the overall aesthetic looks of the buildings and palaces built under the Rana regime (1846 AD to 1951AD) and the Shah dynasty in the 18th century in Nepal. They were built under the direct ruling of Rana Prime ministers holding power at various periods. These constructions had begun after the Rana Prime minister Jung Bahadur had visited Europe in 1850 AD (1906 Bikram Sambat). It is apparent that the European style of architecture practiced in the western world during that time, was imported to Kathmandu by the Rana rulers. However, it is interesting to note that the cluster of building blocks, built around the central courtyards, were maintained in the construction of Rana palaces, echoing the art of Newari culture and architecture.

Some of the examples of the Rana built palaces in Kathmandu are Singha Durbar (1908 AD) (Fig. 2), Keshar Mahal, Babar Mahal, and Shital Niwas (1923 AD) built by Chandra Shamsher JBR, Narayanhiti Durbar, Lal Durbar (1890 AD), and Seto Durbar (1893 AD) built by Bir Shamsher JBR, Man Bhawan, Narayan Bhawan, and Kalimati Durbar built by Juddha Shamsher JBR; and Thapathali Durbar (1860s AD), Singha Mahal (1855AD), and Gol Baithak (1852 AD) built at the time of Jung Bahadur Rana himself. (https://en.wikipedia.org/wiki/Rana_palaces_of_Nepal). These building complexes and palaces built by the Malla Kings and Rana rulers were upgraded later by Shah Kings in according to their needs.

Furthermore, these European designs were duplicated by the descendants of the Rana rulers, the top Army officers and higher Administrative officials of the Rana Administration, to construct their own residential complexes, including the public buildings, e.g., Durbar High School (1854AD), Tri-Chandra College (1919 AD; 1975 Bikram Sambat), and Bir Hospital (1891AD; 1947 Bikram Sambat). Recall that the buildings on both sides of the New Road (from New Road gate to the Indrachowk area), damaged by the major 1990 Bikram Sambat (1934 AD) Bihar-Nepal earthquake, were rebuilt to resemble the European style of architecture. This appears to be in contrast with the traditional neighboring houses.

Figure 2. Singha Durbar Building Facade

(Courtesy: https://en.wikipedia.org/wiki/Singha_Durbar)

In retrospect, Nepal went through some of the most important infrastructure development works, the life-line utilities and service facilities, during the Rana regime of approximately 104 years. They are listed as under: (Ref: Google search and Wikipedia on Nepal)

- Cargo Ropeway transport from Dhorsing to Kathmandu (1022 AD);
- Pharping Hydroelectric Project (1911 AD) (named earlier as "Chandrajyoti Hydro-electric Power Station);
- Sundarijal Hydro-Powerhouse (1934 AD);
- Kathmandu Grass Airport (1949 AD);
- National Mint (Taksar) Building (during the Malla and Shah period);
- The National Museum of Nepal, Chhauni, Kathmandu (1928 AD) (1985 Bikram Sambat);
- Nepal Government Railway (NGR) (1927 AD) - Raxaul to Amlekhganj (24 miles) and Jayanagar to Janakpur.
- The Nepalese Army barracks and facilities (Formerly Gorkhali Army).

During the 1950s, Nepal began receiving help from the International donors. The Indian Aid Mission in 1954 AD - changed to Indian-Nepal Cooperation Mission in 1966 AD - was involved in assisting Nepal in many sectors of development works. Since the early 1950s AD, Nepal had received assistance from the United States Agency for International Development (USAID), Britain, then "the Soviet Union", China, Switzerland, Japan and many other International donors, to support Nepal in various development projects and programs.

The Old-time Pioneer-Engineers in Nepal

It is a great pleasure and respect to list the names of the old-time pioneer engineers in Nepal.

They were involved in the overall development of Nepal during the Rana Prime ministers and Shah Kings' administration. Also, an attempt is made to list the senior-most engineers in Nepal who were active during 1950s, 1960s and in the early 1970s AD, in the development of the modern-day Nepal. The names were collected as best as possible - from reliable sources and from inquiries to the related professionals in Nepal. Additional information was gathered from Google search and Wikipedia Internet search. It is possible that the names of other senior-most engineers of the time are missing in the list. The missed names can be added later in the updated list, as they become available. Since the names of the above pioneer and old-time engineers were not found well documented, the author has made an attempt to document them in this article for reference.

The engineers' names are listed below:

- Kishor Narshing Rana and Kumar Narsingh Rana – who supervised the construction of Singha Durbar Building and most of the Rana Palaces in Nepal, including the Clock Tower (Ghantaghar) and Tri-Chandra College. They were also Nepal's first engineers to visit Japan for training.
- Dilli Jung Thapa - Chief Engineer, who was the first engineer to introduce Reinforced Concrete (RCC) Buildings in Nepal, including Bed Prashad Lohani among the senior-most engineers at the time.

Figure 3: A small Newari House with a Courtyard

(Courtesy: buddhaair.com)

- Padma Sundar Malla – He was Nepal's first qualified Electrical Engineer, also the first engineer to visit the U.S.A.

- Kula Ratna Tuladhar – the first chief engineer of Nepal's Public Works Department and the first Principal and Dean of "Nepal Engineering Institute", Pulchowk, Kathmandu.

- Jyan Bahadur Pradhan – the first chief engineer of Nepal's Civil Aviation Department. He was the first engineer to receive training in the U.S.A. in Airport planning and design. He was also the first President of "Nepal Engineers' Association (NEA)", in 1969AD (2025-26 Bikram Sambat); NEA was established in 1962 AD; the subsequent chief engineers were: Tirtha Bahadur Pradhan, Laxman Das Hada; and senior engineers: Keshab Prashad Ghimire, Bhim Raj Thapa, Prakash Tuladhar, and others

- Mukunda Bahadur Thapa – the first chief engineer of Nepal's Electricity Department; the subsequent chief engineers were: Ram Prashad Nepal, Pashupati Pratap Shah, Shanker Krishna Malla, Harsha Man Shrestha; and the Senior-most Engineers: Hari Man Shrestha (the first Ph.D. in Electrical Engineering), Tara Bahadur Pradhananga, Devi Prashad Chapagain (Electrical/Computer), Harishankhar Man Pradhan, and Senior Civil Engineers: Gokul Lal Amatya, Jaya Prakash Pradhan, Rabindra Bahadur Shrestha (one of the first Civil Engineer studied in China), and others.

- Bishnu Bahadur Karki – the first chief engineer of Nepal's Roads Department; the subsequent chief engineers were: Gyan Prashad Sharma, Birendra Keshari Upadhyay, Dipti Jung Thapa, Shiva Bahadur Pradhanang, Narayan Dutta Sharma, Ram Babu Shrestha; and the Senior-most engineers: Harihar Man Amatya, Pralhad Dhoj Pant, Hari Bahadur Basnyat, Chandra Bahadur Piwa, Laxman Krishna Malla, Suresh Raj Dali and others.

- Medini Prashad Bhattarai – the first chief engineer of Nepal's Irrigation Department; the subsequent chief engineers were: Karna Dhoj Adhikary, Bhubaneswar Kumar Pradhan, Chita Dev Bhatta, Mohan Dhoj Karki, and Senior-most engineers: Shiva Raj Sharma, Prabinja Man Singh Pradhan, Ratneswor Lal Kayastha, Rameshor Man Singh Amatya, Mohamad Ansari, Upendra Karna, and others.

- Krishna Raj Pandey – the first chief engineer of Nepal's Building Department; the subsequent chief engineers were: Gauri Nath Rimal, Bhubaneswar Lal Shrestha, Gyan Prashad Sharma, Hajmonia Lal Rajbhandari, Satya Narayan Rathi, Shanker Man Pradhan (Architect/Planner), Padam Bahadur Chhetri, Jig bar Joshi, Anand Raj Pant, Umesh Bahadur Malla (Engineer/Planner); the first plan check engineer of Building Department (Check Phaant in Nepali) was Shambhu Lal Kayastha; Senior Engineers:

  Manohar Rajbhandari (Structural), Rama Kant Adhikary, Durga Bahadur Gurung, Shanta Bhakta Mathema, Hari Krishna Upadhyay, and others

- Heramba Prashad Upadhyay – the first chief engineer of Nepal's Telecommunication Department; the subsequent chief engineers were: Naval Raj Vaidya, Ram Prashad Nepal, Udaya Bahadur Nakarmi, Bhup Raj Pandey, Suresh Kumar Pudasaini, Gajendra Singh Vohra, and others.

- Khadga Narsingh Rana – the first chief of Nepal's Geology and Mining Department; the subsequent chiefs were: Pushpa Bhakta Malla, Durga Nath Rimal, Mahendra Narsing Rana, Arhat Hussein Khan, Shambhu Man Singh, Padma Lal Shrestha, Narendra Bahadur Kayastha, and others.

- Rajendra K. Shrestha, Ph.D., the first Project-in-Charge of the Petroleum Exploration Promotion Project in Nepal.

- Bharat Bahadur Pradhan – He was the first Electrical/Mechanical Engineer of Nepal; He was also the first engineer in Nepal's National Mint (Taksar in Nepali) Department; the subsequent engineers were: Iswari Man Pradhan, Raghu Raj Dali, and others.

- Huta Ram Baidya – the first chief engineer of Nepal's Agriculture Department; the subsequent chief engineers were: Purushottam Gorkhali, Top Bahadur Basnyat, and others.

- Hiranya Jit Malla – the first chief Engineer of Nepal's Water Supply Department; the subsequent senior-most engineers: Ratna Man Pradhan, and others.

- Janak Raj Shrestha – the first chief engineer of Nepal Army, the senior-most mechanical/electrical engineer Raghu Raj Dali, Pioneer Army engineers: Rishi Kumar Pandey, Pratap Singh Malla, and others.

- Bhuban Bahadur Piwa – the first Engineer of Nepal Government Railways.

- Tirtha Bahadur Pradhan – the first Mechanical Engineer of Nepal Government Ropeway.

Typical Village Homes in Terai, Nepal

- Ek Raj Shrestha – the first Aeronautical Engineer, (or, one of the first) in Nepal, worked in Nepal Government Airlines (RNAC).
- Gyan Prashad Sharma, Birendra Pratap Shah, Ram Prashad Sharma, and others – the initial General Managers/Chief Engineers of the original "National Construction Company of Nepal (NCCN)" (Estb. 1961AD), (closed in 2010 AD)
- Gangadhar Halwaimukkadam – the first Architect of Nepal (designed City Hall, Kathmandu); subsequent Architects: Dhurba Bahadur Pradhananga (designed the first Shopping Mall in New Road), Shanker Man Pradhan, Sudarshan Tiwari, Rashmi Bahadur Shrestha, Kirit Tuladhar, Matseyendra Kayastha, Chandralekha Kayastha, Surya Bhakta Sangachhen, Ambika Adhikary, Jib Raj Pokherel, Ranjan Shah, Uttam Shrestha, Raja Ram Bhandari, and others.
- Shanker Man Pradhan, Umesh Bahadur Malla, and Madhab Bhakta Mathema were the pioneer Planners in Nepal during the earlier time (as I remember); later planners: Bal Krishna .Shrestha, and others.

"Kishor Narshing Rana and Kumar Narsingh Rana – who supervised the construction of Singha Durbar Building and most of the Rana Palaces in Nepal, including the Clock Tower (Ghantaghar) and Tri-Chandra College."

- Shanker Nath Rimal – He is one of the senior-most pioneer engineers in Nepal (designed many prominent buildings in Nepal, including the "Sahid Gate" statue in Kathmandu).
- Shanti Malla – the first women engineer of Nepal; the subsequent women engineers - Tara Lakshmi Saakha, Subhadra Sharma Manandhar, and others.
- Kanhaiya Lal Kayastha, Rama Kant Adhikary – the first engineers to represent "Nepal Engineers' Association (NEA)" to attend a conference in the U.S.A, in 1974 AD.
- The Old-time Senior-most Engineers and Architects contributed to Teaching: The names are only those who were in teaching in "Institute of Engineering, Pulchowk Campus, Kathmandu (as per my memory): Kula Rana Tuladhar, Ram Krishna Sharma, Pushpa Man Shrestha, Ananta Baidya, Seeri Ram Mathema, Rajan Pradhan, Pramod Bahadur Shrestha, Ambika Adhikary, Jib Raj Pokherel, Matseyendra Kayastha, Chandralekha Kayastha, Babu Ram Bhattarai, Hisila Yami, Ramesh Maskey, and others.

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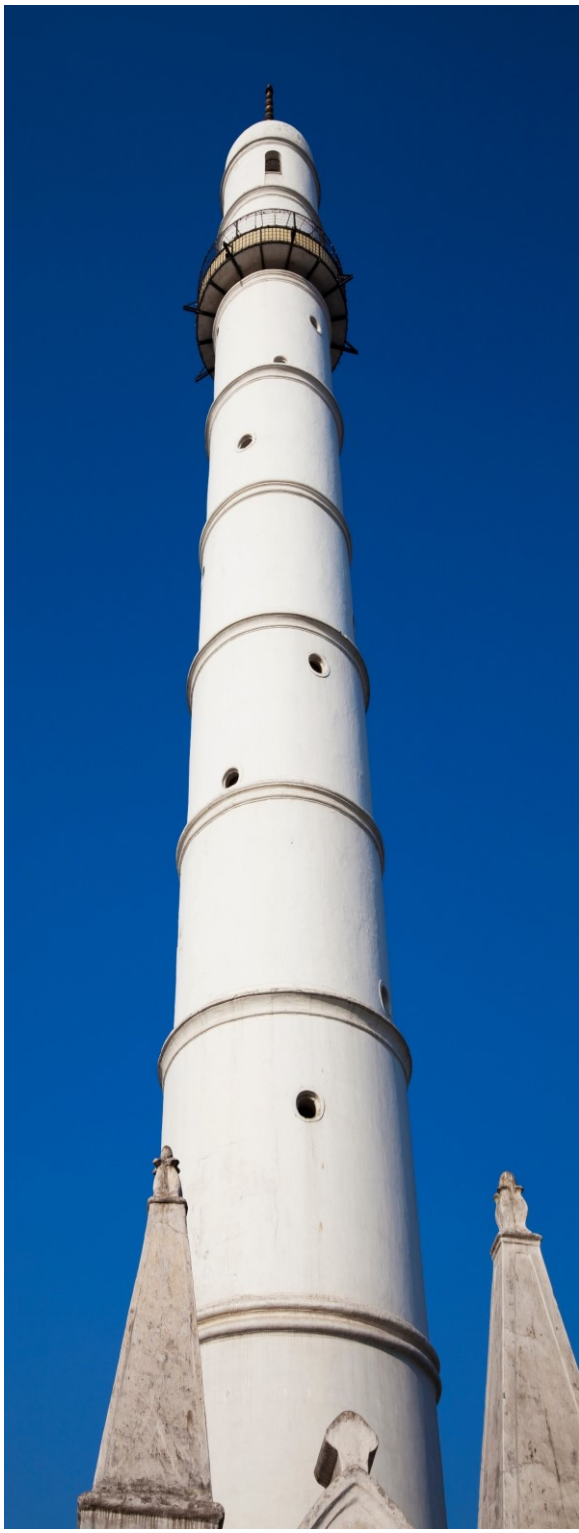
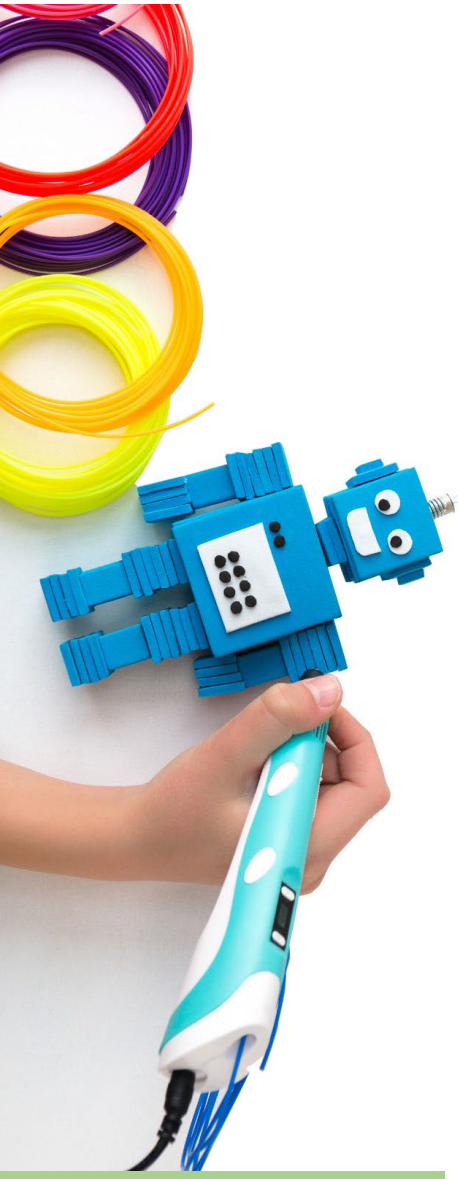


Dharahara (Prior to 2015 Earthquake), Kathmandu, Nepal



STEAM Education in NEPAL

Srijan Rajbamshi;
Manish Man Shrestha;
Rupak Aryal;
Vivek Raj Shrestha;
Bikash Nakarmi

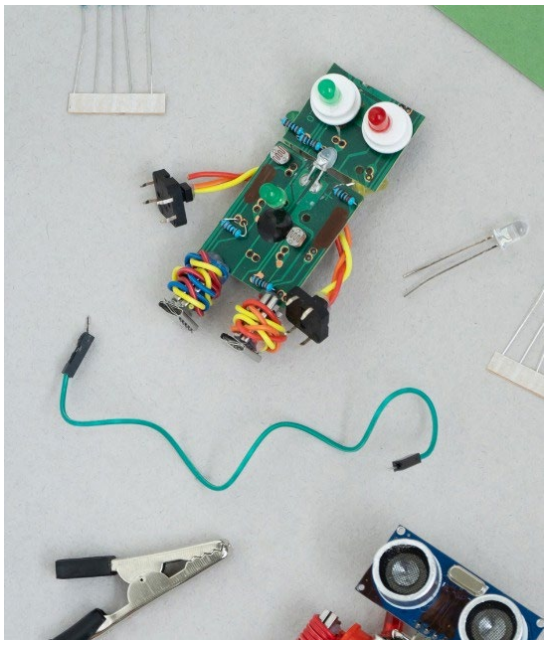
With the strategy to equip students with the skills and knowledge required to become successful innovators of the 21st century, STEM education is emphasized in the educational systems around the world. STEM education incorporates and engages students to integrate and apply knowledge across multiple disciplines, i.e., Science, Technology, Engineering and Mathematics. In recent years, the concept of STEM education has expanded and incorporated other disciplines as well e.g., Arts. The term STEM, was coined in 2001 by a scientific administrator at the United States National Science Foundation (NSF). The traditional STEM education transitioned to STEAM, adding to the acronym an "A" to represent the arts. While traditional STEM education has always incorporated arts into the curriculum, the push to change the acronym highlights the importance the arts education has on a child's personal and academic development.

STEAM aims to strengthen the foundation of education by helping students enhance their critical thinking and problem-solving skills. It assists students to explore innovative and creative ways of problem solving, projecting data and interlinking multiple fields. Therefore, implementing STEAM principles into education allows for more creative and cohesive education and helps to develop an innovative learning approach for students.

STEM Education: Scenario across the world

The United States has boosted its STEM education in every possible way. The US Bureau of Labor Statistic (BLS) 2015 report stated that STEM jobs paid well above the national average. The BLS data showed that 93 of the top 100 STEM occupations pay above average wages, and the average STEM job salary is $87,570, which is almost double the non-STEM national average[1].

Currently, the world is witnessing the 4th technological revolution in which rapid flow of information coupled with high-tech innovations and inventions are transforming all aspects of our lives. To prepare the next generation workforce who can contribute towards the ongoing technological revolution, all countries are relying on STEM education. For instance, in the European Union countries, the share of employed professionals in this area has increased by 12% from 2000 to 2013. Moreover, in the European countries, it is predicted that the demand for STEM professionals will grow to 8% by 2025, whereas the demand for other professions will grow only by 3%[2].



Our neighboring country, China also issued the "Guidelines on comprehensive and in-depth promotion of STEAM education" in September 2015, via the Ministry of Education. Similarly, in 2015 the prime minister of India initiated the "Skill India" campaign that aimed at training 400 million young people in different STEAM skills by 2022. In September 2017 the US President Mr. Donald Trump signed a presidential memorandum to expand the access to high quality STEM education for young people. On 20th July 2019, Bangladesh established a STEM body called the Bangladesh STEM (bdSTEM) society, which is running successfully with active participation of university teachers all over Bangladesh[3]. Pakistan also invested Rs. 3Billion on STEM school projects in 2019 to promote digital education[4].

The World Economic Forum reported that China had 4.7 million STEM graduates in 2016. India, another academic powerhouse, had 2.6 million new STEM graduates and 568,000 students graduated from US universities with STEM degrees in 2019.

STEAM Education in Nepal: Baby steps

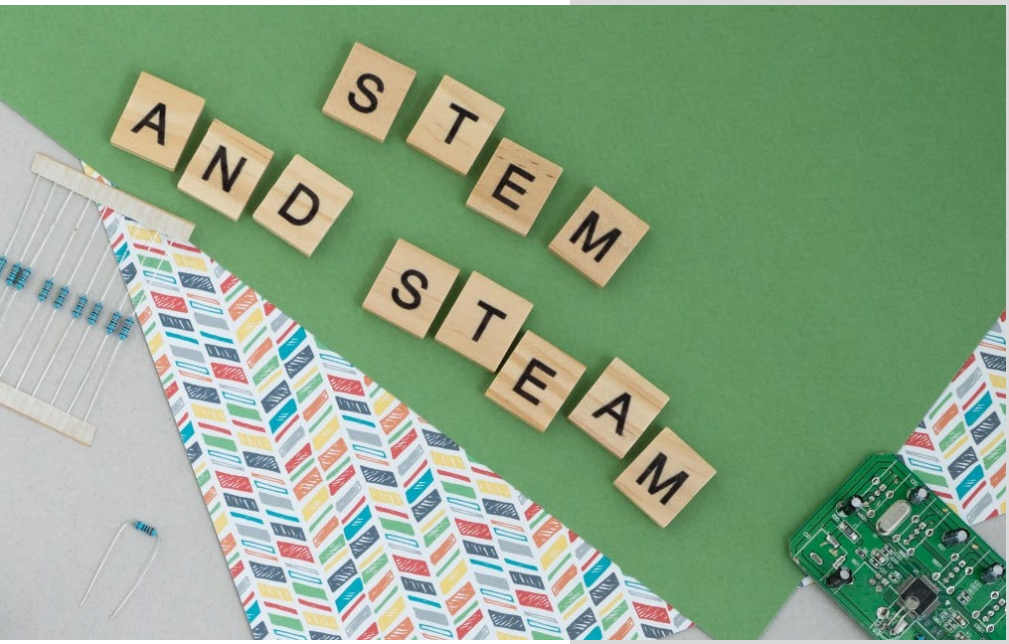
While the concept of STEAM education has flourished widely in developed countries, Nepal is still in its infancy. A handful of schools and other educational institutions have introduced STEAM education.

STEM Foundation Nepal is one such company that was established in 2017 with a group of Nepalese STEM professionals with the purpose of providing STEM exposure to Nepalese students. Similarly, Karkhana is an organization that has worked effectively in the fields of science and technology in collaboration with many schools in the country. In 2010, a non-profit organization named Robotics Association of Nepal (RAN) was established. Under RAN, over 4000 students have already received preliminary training on robotics and automation.

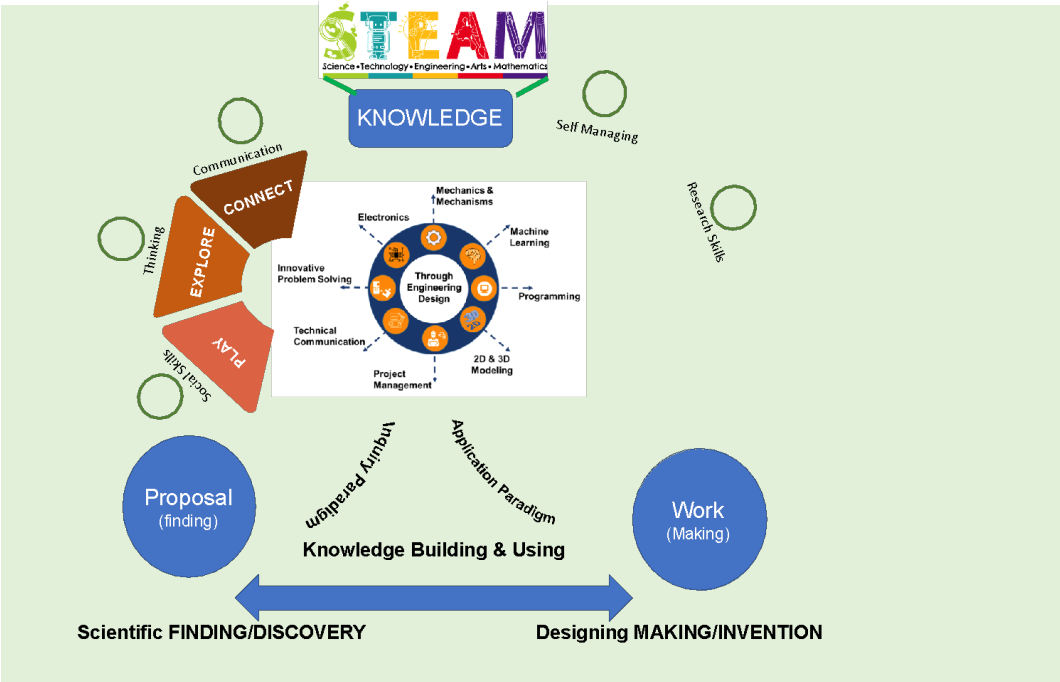
"Bhawisya 2074 - First Inter-School Science Competition" was held at the Army Physical Training and Sports Center at Lagankhel in Lalitpur in February 2018. This competition is regarded as the Nepal's very first school-level STEAM projects competition. The event was conducted by the Ministry of Science and Technology in collaboration with Karkhana, RAN and Nepal Innovative Lab (NIL), where 180 students from over 110 schools participated[5]. Kathmandu University, which is renowned for its science and engineering education, has taken an additional step in STEAM education by instituting a new Master of Philosophy (MPhil) degree in STEAM education.

With increasing popularity, STEAM education has faced different challenges due to the complexity of integration and, silo mentality of teachers, educators and parents. STEAM takes a trans-disciplinary approach to teaching and learning of mathematics, science, arts, technology and engineering. Each of these subjects is guided by its own uniqueness. Therefore, the differences in nature and process of learning must be conveyed in the curriculum integration plans, policies and actions. Matching the student's interest and their capacity with a well-trained teacher may also be a challenging task, which must be addressed.

Barriers like a lack of investment in teacher's professional development, a lack of collaboration with STEAM experts, a lack of adequate support from the National Curriculum Development Centre, etc. needs to be urgently addressed to expand the scope of STEAM education in Nepal. When the mono-disciplinary approaches are no longer able to provide solutions to the complex social problems like economic disparity, increasing digital divide, trade deficits, etc., the incorporation of STEAM education nationwide could be an answer.



"STEAM aims to strengthen the foundation of education by helping students enhance their critical thinking and problem-solving skills.



Model of Knowledge based STEAM Education of Samadhan Engineering

Knowledge-based STEAM education: a paradigm changer?

While general education facilitators in Nepal have limited the STEM learning as mere project works, a new approach is being undertaken by Samadhan Engineering, a company that provides Knowledge Based STEAM Education (KBSE) to the students from all levels-- from Kindergarten to the professional levels. Samadhan Engineering has developed a modern co-curriculum, adapting state of the art global STEAM teaching techniques to the conventional national curriculum of Nepal. Samadhan Engineering has a background of working in mechatronics research in addition to many years of experience in the education field, both nationally and globally. In a resource strapped country like Nepal, Samadhan Engineering has come up with resource pooling solutions thereby minimizing tools and manpower development costs. In addition to optimum allocation, resource pooling has made experience sharing between schools seamless.

Only after a few months of commencement, KBSE has been successfully implemented in 3 schools and 3 colleges directly engaging over 1000 students from grade 1 to college seniors. In its short span of operation, Samadhan Engineering has been able to facilitate STEAM showcase in its partner institution, and form collaboration with various organizations. Mostly revved up by positive feedback, Samadhan Engineering has been able to collect valuable suggestions for incremental improvement from its partner institutions and the participants.

With comprehensive implementation of KBSE, Samadhan Engineering expects to better prepare kids in developing nations to go hand in hand with kids from developed nations. However, finding financially sustainable solutions for students outside urban areas is a major challenge. Providing service to the rural areas faces a double whammy-- limited accessibility of transport and technology and impoverished families. Arranging subsidies from national and international sources to support students in rural areas is also a call of the hour.

To tackle the aforementioned challenges, substantial and strategic investment is required from the public, private and the combined sectors. Significant attention will be required on developing the process of delivering knowledge to the students of today's generation. New generations of digital natives need to be taught in an intelligible manner such that they value the knowledge they receive. Thus, there is no other alternative than to integrate our current education system in Nepal with STEAM education.

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Self-Healing Concrete

Sujan Subedi

Introduction

Concrete is the most abundant construction material used in the construction of structures. It is also evident that cracks are inevitable in the structures. They don't only decrease structural performance but also increase the life-cycle cost of structures as the repair is labor-intensive and time-consuming. As per the ARTBA (American Road And Transportation Builders Association) 2019 Report, 47,052 of America's 616,087 bridges are rated as 'structurally deficient' and need urgent repairs. Studies have shown that just within Ohio, 1,518 (5.6%) of 27,277 bridges are structurally deficient. At the present rate of repairs, it would nearly take 80 years to make significant repairs as per ARTBA. The basics of the weakening of the bridges and structures may be attributed to the formation of cracks either due to the internal or external stresses, and then subsequent weakening of the rebar and concrete strength due to percolation of water, and so on. Therefore, serious measures are to be taken in order to cope with the situation.

As concrete has a high compressive strength in comparison to tensile strength, steel is combined with the concrete to withstand the tensile stress. Even though the addition of steel does improve the tensile capacity of the concrete, it does not guarantee the complete prevention of the cracks. Since crack prevention and repair are very costly, the concept of self-healing concrete has been evolving as a new field of research.

Need of Self Healing Concrete

It is certain that concrete will be an important construction material in the near future. Tiny cracks present in the concrete structures will make it vulnerable to water seeping into the cracks. In order for the steel reinforcement to not corrode due to the water ingress in the cracks, there should be some mechanism that could help to get the cracks sealed. This problem is mostly faced in the structures built in the high-water environment, such as the underground basements and marine structures. Similarly, the motorway bridges are also vulnerable to crack ingress water because salt is used to de-ice the roads. Repairs of the cracks involve the application of the mortar which is bonded to the cracked surface. Repairs can be time-consuming. So the self-healing concrete compliments a need for sustainable and durable concrete which does not compromise the strength of the structure.

Approaches of Self Healing

As described by Blaiszik[1], there are three 'self-healing' approaches namely Intrinsic Healing, Capsule Based Healing, and Vascular Healing.

1. Intrinsic Healing

Intrinsic Healing is the healing of the concrete due to the composition of the cementitious matrix. It can be autogenous healing or improved autogenous healing depending on the application of the different admixtures in the concrete.

As per Ramm et al.[2], autogenous crack healing is attributed to two primary mechanisms: hydration of the unhydrated cement particles, and the carbonation of the Ca(OH)2. Apart from these, the swelling of the matrix and blocking of the crack due to the debris resulting from the cracking may also help in autogenous healing. As per Neville, A.[3] in the young concrete, hydration is the main mechanism for self-healing; while precipitation of the Calcium Carbonate (CaCo3) is the major mechanism for self-healing of the concrete at a later age.

However, Ter Heide et al.[4] found from their study that improved healing was obtained when the compressive force was used on the crack faces to contact each other. So, the concept of improved autogenous self-healing came into play. In order to restrict the crack width and subsequently help in self-healing, several researchers used several methodologies. At first, Li et al.[5] used Polyethylene as the Engineered Cementitious Composites (ECC) to restrict the crack width to help in self-healing. As per the study, the ECC helps in restricting the crack width because instead of one single large crack, several cracks form in the matrix which are smaller in size than that of the single crack. Similarly, Homma et al.[6] researched on the steel cord (SC), Polypropylene (PP), Polyethylene (PE) and Poly-Vinyl Alcohol (PVA) to examine

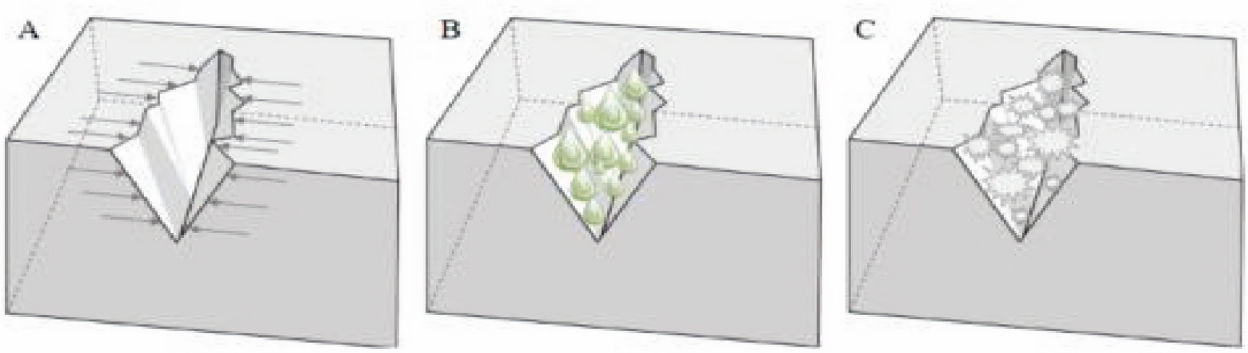

Figure 1: Intrinsic Self-Healing Approaches. (A) by restriction of the crack. (B) by water supply and improved hydration. (C) by crystallization.

the crack closing efficiency among them. It was found that the PVA showed the most effective healing, probably because the PVA induced the deposition of the hydroxyl group which attracted the calcium ions that helped in the closure of the cracks.

Similarly, the autogenous self-healing behavior of the concrete could also be improved by the use of additional water in the cement matrix. Several researchers have tried to put additional water in different forms into cementitious materials. Lee et al.[7] tried to mix Super Absorbent Polymers (SAP) to provide additional water to the mixture. SAP is the polymers that can absorb water to form hydrogels, which can swell to form a soft and insoluble gel. During the dry season, SAP releases water that is stored within it as a result of swelling, to help in the autogenous self-healing.

Autogenous healing can be stimulated by the addition of the agents that helps to deposit the crystals inside the crack. However, the main disadvantage of the addition of the particles which may crystalize is that their functionality is stopped as the healing agent itself is consumed in the process. So, researcher Jonker[8] stated that it will be necessary to use CaCO3 emitting bacterial spores (Bacillus Cohnii) as they don't die and help in the healing process. The CaCO3, thus emitted, was deposited in the crack surface, and the Ca(OH)2 which leaked from the concrete matrix also reacted with the CO2 that was emitted due to the bacterial reaction to form additional CaCO3. However, the research suggested that the bacteria will die when the cells are embedded by CaCO3 crystals and the bacterial activity will cease when all the nutrients are finished. So, in another experiment, Jonkers encapsulated the bacteria so as to protect them from killing. So encapsulating bacteria can be a possible way to go into the research to see the self-healing behavior in the concrete.

2. Capsule Based Self Healing

Self-Healing is attained when the healing agent is placed in a capsule and then added to the concrete matrix. The microcapsule based self-healing is a promising way to restore the strength and durability of the concrete as well. These capsules can be triggered in the region of damage by different agents like heating, or contact with the matrix itself, or by contact with the second component or additional capsules that are present in the matrix. The leakage of the healing agent is passed through the cracks due to the gravitational and capillary forces, which finally helps in filling the cracks. The capsules can be spherical or cylindrical.

• Reaction due to external agents like moisture or heat: Several types of research required the capsules to get triggered with external agents like moisture, air, or heat. Cailleux and Pollet[9] encapsulated Ca(OH)2 in the spherical microcapsules with a gelatin shell. They were mixed in the mortar, some of which got burst during the mixing process; while some of them only ruptured when the crack appeared. This reaction caused the formation of the CaCO3 that hardened within the cracks. Similarly, in another research by Dry[10], she embedded the porous and cylindrical polypropylene capsules that were coated with wax and filled with Methyl Methacrylate (MMA). However, heat needed to be provided to the beams that had cracks, which ultimately helped in curing the cracks in the concrete.

• Reaction with the Cementitious Matrix: Jonkerset. al.[11] found that the bacteria died when the cells were embedded by CaCO3 crystals, and the bacterial activity would cease when all the nutrients were finished as in their previous experiment. So, they decided to put in the clay particles with both the bacterial spores and the calcium lactate (CaC6 H10 O6) which served as nutrients for the spores. Although clay particles prevented the crushing of the spores, this approach was not advantageous as the clay particles substantially decreased the com-

pressive strength of the concrete.

• Reaction with Second Component present in the matrix: In this approach, the healing agent does not directly react with the cementitious matrix, but reacts with the agent that is added to the matrix. An example of this approach is described by Cailleux and Pollet [9] in which an epoxy resin was encapsulated within the spherical capsules. The hardener was present in the matrix, which when came in contact with the resin after being released from the capsule, the polymerization reaction was triggered which helped in the filling of the cracks.

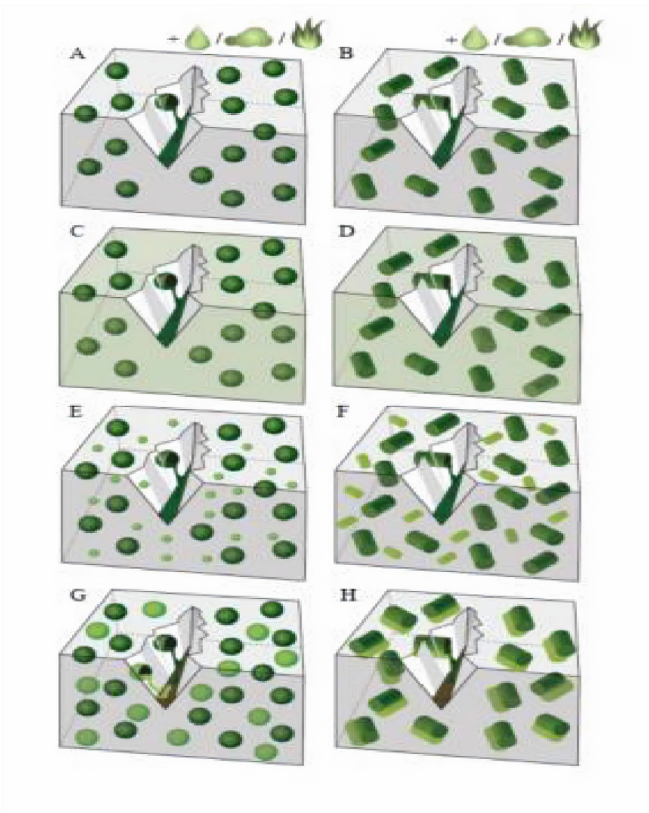

Figure 2: Capsule Based Self-Healing Approaches: Leakage of healing agent from the capsules into the crack due to gravitational and capillary forces. Reaction of spherical/cylindrical encapsulated agent upon contact with (A, B) moisture or air or due to heating; (C, D) the cementitious matrix; (E, F) a second component present in the matrix (small, light colored inclusions), and (G, H) a second component provided by additional capsules (big, light colored inclusions).

• Reaction with the second component provided by the additional capsules: In this approach, the multi-capsule system is engaged; and the capsules have different components of the whole healing mechanism. The healing process only occurs when all the capsules rupture and the healing agents come out and react within the matrix. Various types of research have been undertaken under this approach. Mihashi et al.[6] had used the spherical capsules with urea formaldehyde formalin (UFF) shell containing the two-component epoxy. However, it was found that the two-component epoxy barely hardened due to insufficient mixing. Several researches have been undertaken after Mihashi in order to adjust the viscosity so as to help in the mixing of the two-component epoxy.

However, this research is still in progress.

3. Vascular Healing

In this approach, the healing agent leaks from the external tank through the vascular tubes into the cracks due to the gravitational and the capillary forces. According to the number of the healing agents, there may be one channel or multiple channel vascular system.

However, even though the larger cracks can be healed and the method can heal the crack for many times due to continuous self-healing; the healing agent may leak out when the cracks become too wide, which has the harmful effect on the mechanical properties of the concrete.

An example of this approach was performed by Joseph et al[12] . In his experiment, he used air curing cyanoacrylate (CA) provided by the glass tube; one end of which was open to the atmosphere and was available to supply the healing agent from outside. When the larger cracks occurred, the additional agent could be added through the open end of the glass tube.

From the various approaches as described above, it can be clear that autogenous healing will always be restricted to the smaller cracks and then the re-

searches also show that the reliability of autogenous healing is also less as it always depends on the composition of the matrix.

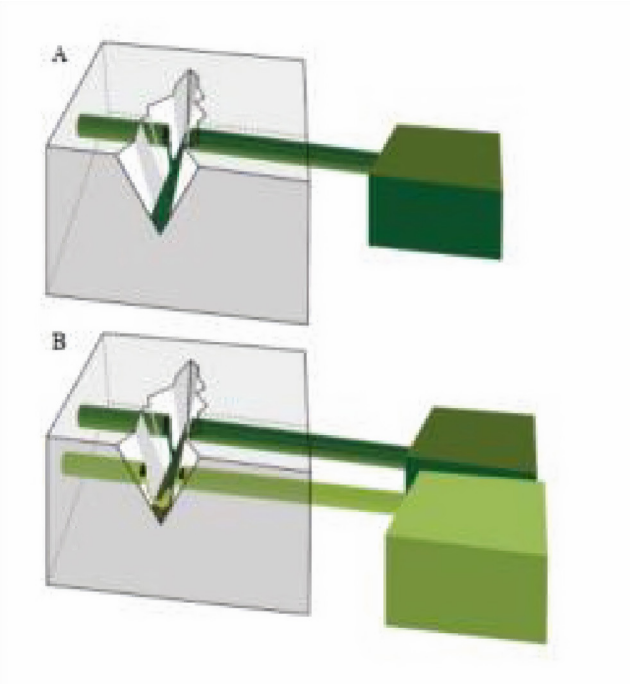

Figure 3: Vascular Based Self- Healing Approaches. Leakage of healing agent from the tank via the vascular into the crack due to gravitational and capillary forces and hydrostatic pressure. One-Channel (A), and multiple channel vascular system (B).

Conclusion

Concrete is very sensitive to crack formation, because it is very weak in tensile strength, and also because of the presence of the inter-facial transition zone in between the components of the concrete. Due to the crack propagation, the durability and strength of the concrete is compromised. With the use of self-healing concrete, not only the cost and time of repairing the cracks will be substantially reduced, but the problem of repairing the smaller cracks will also be properly addressed. However, since this field is still in the research phase, a lot of the aspects like compatibility of the self-healing agents with the concrete, durability, amount and, the effective response time are to be studied. Similarly, there is the difficulty in casting the concrete with self-healing agents. These may also alter the mechanical properties of the concrete as a whole. Although there are a lot of difficulties associated with the preparation and research in this sector of sustainability of the concrete, but with the grave concern of handling the cracks in the concrete, this field of research could bring promising results in the near future.

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