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Civil Engineering structure and Bioengineering Technique for landslide reduction and there cost comparison; with reference to study in Kageshwori Manohara Municipality of Kathmandu, Nepal

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Abstract

Landslides pose a significant threat to communities in hilly and mountainous regions of Nepal where steep terrain and heavy monsoon rainfall contributes to their occurrence. This study focused on the study of four landslide sites for case analysis. Comprehensive data collection included Slope length, Slope width, Slope Angle, Material Drainage, Aspect, Site Moisture, Type of Soil, Type of Erosion/Mass Movement, past history of Landslide. Based on this data and suggestion from the expert, various bioengineering and civil engineering techniques were proposed for soil stabilization and erosion control. Bioengineering measures such as grass seeding, shrub and tree plantation, brush layering, jute netting, along with civil engineering methods like riprap, gabion work, soil nailing, shotcrete, chutes, and drains are suggested. The study also included a cost comparison between bioengineering and civil engineering measures. The cost analysis revealed that the expenditure for bioengineering measures amounted to NRs. 3,202,854.52, while civil engineering works incurred NRs. 6,199,496.55. Typically, the cost ratio between vi bioengineering and civil engineering is expected to be 1:3. However, due to the inclusion of water management components like stream chutes and riprap in bioengineering, the observed ratio is closer to 1:1.94.

In conclusion, this research highlights the significance of adopting bioengineering techniques as a sustainable, cost effective and community-centered approach to landslide risk reduction. The outcomes of this case study offers a holistic framework for mitigating landslide hazards in vulnerable areas like Adhikari Tole, ultimately contributing to the safety and well-being of its residents. The approach adopted in this

study can serve as a model for similar landslide-prone regions in Nepal and other countries facing similar challenges.

Keywords: Civil Structure, Hill Slope, Landslides, Bio engineering., cost effective, sustainable approach

1. Introduction

Bioengineering is the use of living plants or plant components to manage soil erosion and land movement for engineering reasons. Bioengineering, a non-traditional engineering method, uses vegetation as a key tool. Green infrastructure can help protect against natural disasters like landslides and soil erosion [5]. Civil engineering has been embracing the concept of bioengineering to minimize the overall cost of landslide mitigation techniques. Physical construction techniques provide instant protection in the form of a physical structure, whereas bioengineering vegetation techniques take time to demonstrate their effectiveness [10].

The practice of bioengineering stretches back to the Fifth Century AD in ancient China and was used in Europe during the Dark Ages and Medieval times. Although it has been widely practiced in different areas of the world for many years, it was only in the last 25 years that it was introduced and modified to local conditions in Nepal. Bioengineering is especially beneficial in impoverished countries like Nepal, where implementation is relatively inexpensive. The materials are easily available and entail little costs, with labor being the key input - a cost effective asset in Nepal [8]. The concept of bioengineering in hill road construction was introduced in Nepal 40 years ago with roadside plants on the Dhangadhi-Dadeldhura highway in western Nepal in a US-assisted project [7]. In the modern sense, bioengineering was first introduced in Nepal on a massive scale with the involvement of the UK-based Transport Research Laboratory on the eastern Dharan Dhankuta highway, supported by the British government. They then facilitated the transfer of the technology to Nepali institutions and professionals [11].

"Disasters bring serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community to cope using its own resources" [13]. In terms of natural disasters in general, the number of occurrences has increased dramatically over the last 1 30 years (1991-2020). This rising trend may be seen both globally and in the Asian region. The overall number of disaster incidents in 2021 was 436, which was higher than the annual average of 376 during the previous 30 years [1].

Nepal is vulnerable to several recurring threats. The country is ranked 20th among the world's most vulnerable to many hazards [2]. In terms of climate change, earthquake, and flood risk, the country ranks fourth, eleventh, and thirty-first, respectively. Landslides, fires, droughts, epidemics, storms, hailstorms, avalanches, and GLOF are some notable calamities in Nepal. Nepal is very vulnerable to a variety of hazards, owing principally to its diversified topography and climatic conditions, geological position, rough mountains, and steep geography. Nepal not only has young mountains and geology, but it also contains almost one-third of the world's total 2,400 kilometers of Himalayas. Natural disasters have become more often as altitudes range from 59 meters to 8,848 meters in less than 200 kilometers [9]. Landslides are quick mass-wasting processes in which gravity causes variety of slope-forming material, from soils to rock to artificial fill, moves down the slopes.

According to [16], the term “landslide” is used to denote the “downward and outward movements of slope forming materials along surfaces of separation,” but it is probably the most overused and loosely-defined term used in slope studies. Several types of landslide exist and different nomenclature is used to classify them. A growing body of scientific opinion is in favors of limiting the use of the term landslide to describe situations in which masses of material move down a slope by sliding and to reserve related terms like “mass movements”, “mass wasting”, “slope movements,” and “slope failure” for other phenomena. Landslides may be triggered by natural or anthropogenic factors. Nepal is highly vulnerable to landslide because of its steep mountainous train, weak geographical formation along with steep topography in hilly region, over grazing of protective slope cover high intensity rainfalls during monsoon. As Nepal is tectonically active many mass movements. Such as landslide avalanches glacial Lake Outburst flood is triggered by earthquake. Due to unique geological structure like many places in Himalayan region the Himalayan nation have frequently witnessed the increasing impact of climate change resulting into different type of water-induced hazards including landslides [15], The rapidly increasing construction of infrastructures, such as roads, irrigation canals, and dams without due consideration given to natural hazards, is contributing considerably to triggering of landslides.

Nepal is a mountainous country divided into three major regions: mountains, hills, and terai. Most Nepalese hill areas lack effective rural transportation, resulting in isolation, inadequate market access, high commodity prices, irregular public services, and limited economic possibilities [4]. The Nepalese government has prioritized the construction of hill roads as a primary infrastructure service to address the social inequities and physical, social, and economic hardships encountered by the local population due to lack of access. Road construction in these areas has become a big concern. This challenge introduced the concept of Green Roads and Bio-engineering solutions for addressing these issues [6].

Bioengineering technology, which blends flora such as grass, bushes, and trees with tiny buildings such as small dams, walls, and drains, has helped Nepal resist landslides. In central Nepal, these facelifts have mostly happened along the 110-kilometer Naubise-Mungling portion of the Prithvi highway and the 36-kilometer Mungling-Narayanghat route. The bioengineering technique depends on Nepali farmers' centuries-old tradition of employing trees on terraced slopes of their crops and forests. Scientists have succeeded in decreasing expenses while maximizing the benefits of slope protection and stabilization by merging this indigenous technology with modern engineering structures [7]. In the past, road development in Nepal was done haphazardly, ignoring critical factors such as environmental preservation, advantages to the rural poor, and asset management. Following that, the German government funded the development of the green road concept (GRECO), which has been effectively utilized by numerous rural infrastructure projects in Nepal's hill districts for many years [17].

The main causes of landslides in Nepal are steep slopes, loose material, and significant rainfall during the monsoon season. Human construction activities, such as excessive cutting into slopes, disrupting natural drainage systems, and unsuitable land use, all contribute to landslide risk [12]. 3 Bioengineering increases the life of roads while decreasing maintenance costs [14]. The study investigates the viability and environmental friendliness of bioengineering techniques for minimizing landslide hazards in this location. The study looks on the effectiveness, practicality, and applicability of various bioengineering measures in Kageshwari Manohara Municipality to decrease landslide hazards, giving significant insights for policymakers, engineers, and stakeholders in Nepal and other landslide-prone areas.

2. Materials and Methods

The study area lies in ward no 1, Gagalfedi of Kageshwori Manohara Municipality of Kathmandu District at Pipaldanda-Adhikari Tole. KageshworiManahara municipality is divided into 1 to 9 administrative wards, covering a total land area of 27.38 km2. It is bordered by Sankarapur municipality of Kathmandu and Changunarayan Municipality of Bhaktapur district to the East, Ward number 32 of Kathmandu metropolitan city and Gokarneshwor municipality to the West, while Sankarapur and Gokarneshwor municipalities lie to the North, and Madhyapur Thimi of Bhaktapur district is located to the South. Geographically the area is bounded by latitudes 27°45'21.57"N and longitudes85°27'9.88"E. The Site is situated in an elevation of 1610m above Sea Level.

Following steps was followed to reach the expected output:

a) Problem identification: Soil erosion and landslide
b) Selection of site: Kageshwari Manohara Municipality-1, Pipaldanda-Adhikari Tole;
c) Objective: To compare the cost of bio-engineering technique with civil structural work in controlling soil erosion;
d) Literature review: study of available related documents, reports etc;
e) Data collection: Both the primary data and secondary data in the format of Qualitative data and Quantities data has been collected as:
    i) Primary data:
        - Field Observation and Measurement;
        - Questionnaire Survey;
        - Focus Group Discussion;
        - Key Informant Interview.
    ii) Secondary Data
        - Municipality Reports/Database;
        - Other study/Reports;
        - Research Articles, Journals
f) Calculation and design: on the basis of data, best fit bio-engineering solution has been provided in association with necessary civil structures.
g) Data Analysis/Comparison and validation: Cost of bio-engineering works has been calculated in the basis of thumb rule (based on literature) and is compared with the

probable cost (estimation) of civil works for mitigation of the landslide. The calculations were carried out as:

- Cost of bio-engineering was calculated as per proposed design. The rate analysis was used from relevant literature
- Cost for civil structures was estimated on the basis of unit rate captured fromliterature and was validated with municipal estimation;
- Cost of bio-engineering and cost for civil structures has been compared alongwith the social and environmental benefits.

3. Result and discussion

For the selection of appropriate bio-engineering technique, average length and average slope of the landslide are primary factors. Beside these, width of the landslide along with depth of the landslide, moisture content (including information about drainage system) are required. Four landslide sites in ward no1 of Kageshwara Manohara Municipality were selected for the study.

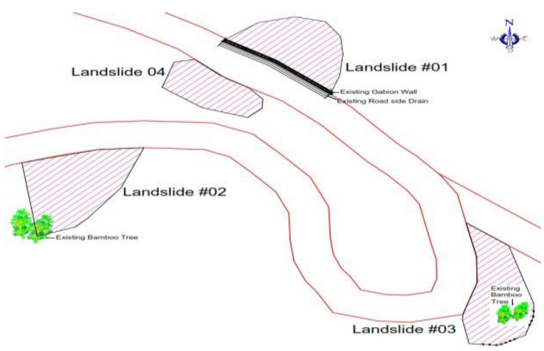


Fig1: Plan of Landslide (Field Survey, 2023) Fig2: Image of Landslide (Source: google map)

3.1 Description of Landslide of different zone

Landslide 1

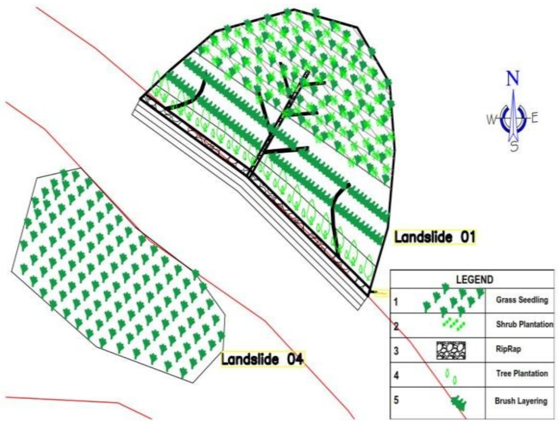
The landslide#1 measures 30m in both length and width, has a 45m slope angle, a depth less than 0.5m, and moderate material drainage. The aspect is south-facing, the site moisture is dry, and no gully erosion is noted. The measurement of the landslide 1 and other environmental factors are presented table 1

Table 1: Landslide Measurement

Description	Landslide #1
Average Length:	30m
Average Width:	30m
Average Slope Angle:	45m
Average Depth:	< 0.5
Material Drainage	Moderate
Aspect	South
Site Moisture	Dry
Gully erosion	no

Fig 3: Picture of Landslide 1

The potential solution for Landslide 1 is represented in Figure below:



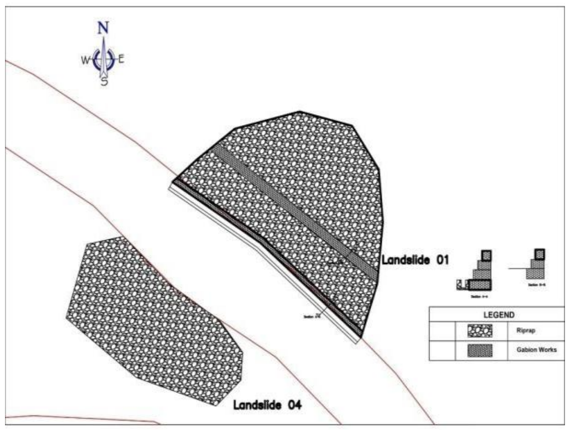


Figure 4: Proposed Bio-engineering solution for Landslide 1

Figure 5: Proposed Civil engineering solution for Landslide 1

In figure 4, bioengineering measures include planting trees at the base (Tree Plantation at Toe) to fortify the soil and prevent erosion, implementing a layer of brushwood on the slope (Brush Layering) for soil control and vegetation growth, introducing shrubs diagonally (Diagonal Shrub Plantation) to enhance soil structure and minimize runoff, establishing grass along contour lines (Contour Grass Plantation) to reduce water runoff and prevent erosion, and using stonesor hard materials (Rip-rap) as a protective layer to dissipate water energy and prevent further soil degradation. Together, these strategies aim to promote stability, control erosion, and restore the ecological balance of the affected area.

In figure 5, To prevent landslides, proposed civil engineering solutions include constructing gabion walls at the toe and middle of the slope. These structures, made of wire baskets filled with rocks, provide crucial support, contain soil, and minimize erosion. Rip-rap, involving the use of durable materials like stones, serves as a protective layer to dissipate water energy and prevent soil degradation. Additionally, implementing an effective drainage system is suggested to manage water flow and reduce the risk of landslides by alleviating excess water pressure in the soil. Collectively, these measures aim to enhance slope stability and prevent potential landslides.

Landslide 2

The landslide 2, measures 22m in length and 18m in width, has a 60 slope angle, a depth less than 0.5m, and moderate material drainage. The aspect is south facing, the site moisture is dry, and two number of gully erosion is noted. The measurement of the landslide 2 and other environmental factors are presented table below:

Table 2: Landslide Measurement

Description	Landslide #2
Average Length:	22m
Average Width:	18m
Average Slope Angle:	60
Average Depth:	<0.5
Material Drainage	Moderate
Aspect	South
Site Moisture	Dry
Gully erosion	Yes, 2 nos.

Figure 6: landslide at zone 2

The potential solution for Landslide 2 is represented in Figure below:

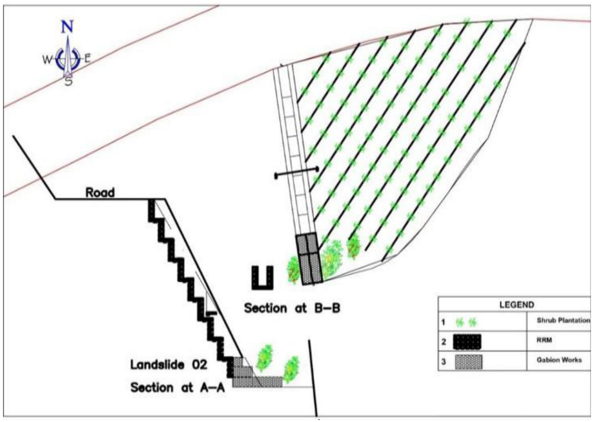


Figure 7: Proposed Bio-engineering solution for Landslide 2

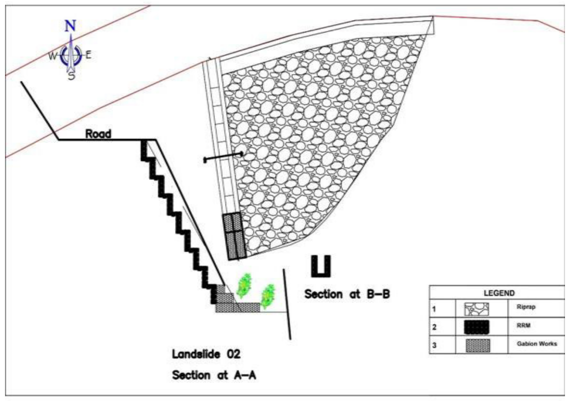


Figure 8: Proposed civil structure for Landslide2

In figure 7, A diagonal shrub plantation is employed to enhance soil stability and reduce surface water runoff.A chute is implemented to control the flow of debris and water, preventing excessive erosion. Additionally, a gabion wall with vegetation is constructed to provide structural support and ecological stability. Finally, a launching apron at the base of the slope absorbs the impact of falling debris, minimizing erosive forces and reinforcing overall slope resilience.

In figure 8, Solution including the implementation of a Chute (RRM) to control debris and water flow. A Gabion wall is constructed to provide structural support and contain soil movement. The introduction of a Launching Apron at the slope's base absorbs falling debris impact, reducing erosive forces. Additionally, Rip-rap is employed to create a protective layer, mitigating erosion and enhancing overall slope stability.

Landslide 3

The landslide 3, measures 15m in length and 25m in width, has a 50 slope angle, a depth less than 0.5m, and moderate material drainage. The aspect is South-East facing, the site moisture is dry, and three number of gully erosion is noted. The measurement of the landslide 3 and other environmental factors are presented table below

Table 3: Landslide measurement

Description	Landslide #3
Average Length:	15 m
Average Width:	25 m
Average Slope Angle:	50
Average Depth:	<0.5
Material Drainage	Moderate
Aspect	South-East
Site Moisture	Dry
Gully erosion	Yes, 3nos.

Figure 9: Landslide at zone 3

The potential solution for Landslide 3 is represented in Figure below:

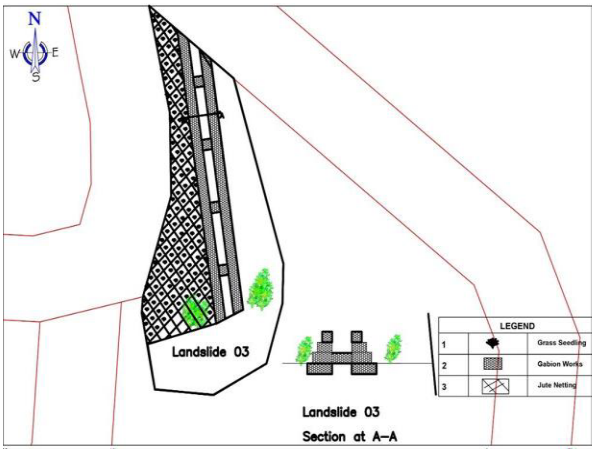


Figure 10: Proposed bioengineering solution

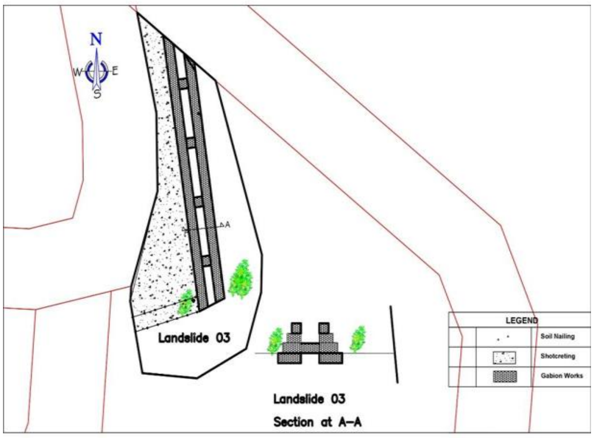


Figure 11: Proposed civil structure solution for landslide 3

Figure 10, shows the application of jute netting and grass seeding to promote vegetation growth, which aids in preventing soil erosion and enhancing the stability of the slope. Additionally, Gabion Retaining walls are being constructed on both side slopes, providing essential structural support to contain soil movement and prevent further destabilization. Another crucial measure involves the installation of a Check Dam using Gabion structures, acting as a barrier to slow down water flow, reduce erosion, and impede the transport of debris downslope.

Figure 11, shows the construction of gabion retaining walls on both side slopes to provide structural support and prevent further destabilization. A check dam, likely is recommended to slow water flow and minimize erosion. Additionally, shotcrete with soil nailing is suggested to reinforce and stabilize the slope.

Landslide 4

The landslide 4, measures 15m in length and 5m in width, has a 60 slope angle, a depth less than 0.5m, and moderate material drainage. The aspect is South-West facing, the site moisture is dry, no gully erosion is noted .environmental factors are presented table below:

Table 4: Landslide measurement

Description	Landslide #4
Average Length:	15 m
Average Width:	5 m
Average Slope Angle:	60
Average Depth:	<0.5
Material Drainage	Moderate
Aspect	South-West
Site Moisture	Dry
Gully erosion	No

Figure 12: Landslide Zone

The potential solution for Landslide 4 is represented in Figure below:

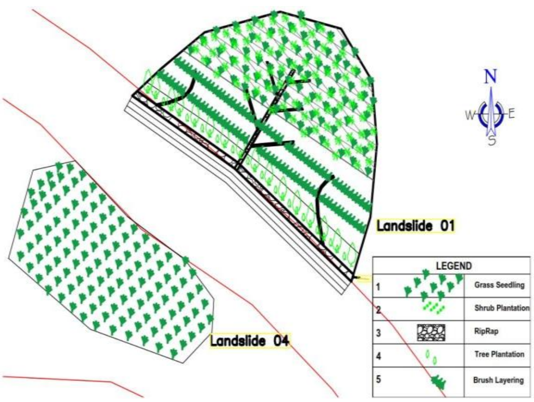


Figure 13: Proposed bioengineering solution for landslide 4

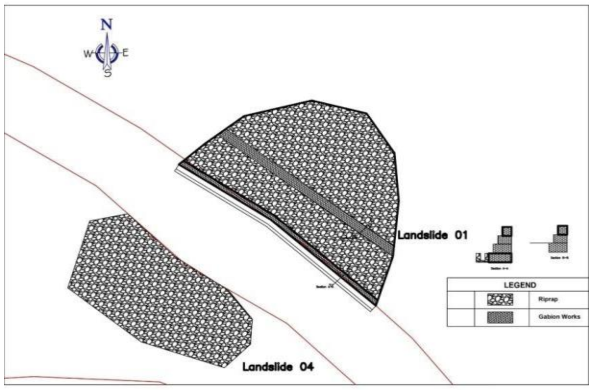


Figure 14: Proposed civil structure solution for landslide 4

Figure 13, shows implementation of diagonal/vertical plantation. This strategy entails planting vegetation in a diagonal or vertical pattern across the affected slope. The purpose of this plantation is to reinforce the soil structure and stabilize the landslide-prone area. Diagonal/Vertical Plantation serves multiple purposes. Firstly, the planted vegetation assists in reducing the velocity of surface water runoff, minimizing erosion and promoting soil retention. The roots of the plants play a crucial role in binding the soil particles, preventing them from being easily displaced.

Figure 14 shows specific Civil engineering solution, which involves the implementation of rip-rap. Rip-rap is a protective measure that utilizes durable materials such as stones to create a robust layer on the affected slope. This layer serves as a barrier against erosion,helping to dissipate the energy of flowing water and preventing further degradation of the soil. The use of rip-rap in Landslide #4 is intended to stabilize the slope, control erosion, andcontribute to the overall mitigation of the landslide risk in that particular area.

3.2 Abstract of Cost of Proposed Bioengineering and civil structure works

The quantity of various bioengineering works is determined by analyzing the drawings. This calculation involves employing established norms, specifically the Department of Roads (DOR) norms for bioengineering works, to facilitate a comprehensive Rate Analysis. The rates for labor,plants, and equipment are sourced from the District Rate of Kathmandu District.

Table 5: Estimated cost of bioengineering system

LANDSLIDE AT ADHIKARI TOLE, KAGESHWARI MANOHARA MUNICIPALITY-1,KATHMANDU, NEPAL					
Abstract of Cost					
Item No.	**Description**	**Unit**	**Quantity**	**Rate (NRs.)**	**Amount**
	Bio-engineering Work				
1	Tree Plantation	Nos.	10.00	250.00	2,500.00
2	Shrub Plantation	Nos.	533.00	250.00	133,250.00
3	Brush Layering	Rm	47.00	550.00	25,850.00
4	Grass Plantation	Sqm	446.00	200.00	89,200.00

5	Jute netting	Sqm	109.00	100.00	10,900.00
6	Earthwork excavation	Cum	174.95	350.00	61,232.50
7	Riprap	Cum	7.10	2,500.00	17,750.00
8	Dry stone soling	Cum	5.40	2,500.00	13,500.00
9	PCC (M20)	Cum	2.70	13,000.00	35,100.00
10	Rubble Random Masonry works	Cum	42.35	12,000.00	508,200.00
11	Gabion Works	Cum	368.00	5,000.00	1,840,000.00
	Total				**2,737,482.50**
				Total Cost of Part (1-11)	**2,737,482.50**
				VAT @13%	355,872.72
				Contingency @ 4%	109,499.30
				Grand Total	**3,202,854.52**

The estimated cost for the implementation of the proposed bioengineering system amounts to Rs. 32,02,854.52.

Table 6: Estimated cost of Civil Structure work

LANDSLIDE AT ADHIKARI TOLE, KAGESHWARI MANOHARA MUNICIPALITY-1,KATHMANDU, NEPAL

Abstract of Cost

Item No.	Description	Unit	Quantity	Rate (NRs.)	Amount
	Civil-engineering Work				
1	Earthwork excavation	Cum	712.90	350.00	249,515.00
2	Riprap	Cum	160.80	2,500.00	402,000.00
3	Dry stone soling	Cum	24.40	2,500.00	61,000.00
4	PCC (M20)	Cum	7.20	13,000.00	93,600.00
5	Rubble Random Masonry works	Cum	188.35	12,000.00	2,260,200.00
6	Gabion Works	Cum	368.00	5,000.00	1,840,000.00
7	Shortcrete	Cum	10.90	21,000.00	228,900.00
8	Soil Nailing	Rm	545.00	300.00	163,500.00
	Total				**5,298,715.00**
				Total Cost of Part (1-8)	**5,298,715.00**
				VAT @13%	688,832.95
				Contingency @ 4%	211,948.60
				Grand Total	**6,199,496.55**

The estimated cost for the implementation of the proposed Civil engineering system amounts to Rs. 61,99,496.55.

The cost analysis revealed that the expenditure for bioengineering measures amounted to NRs. 3,202,854.52, while civil engineering works incurred NRs. 6,199,496.55. Typically, the cost ratio between bioengineering and civil engineering is expected to be 1:3. However, due to the inclusion of water management components like stream chutes and riprap in bioengineering, the observed ratio is closer to 1:1.94.

Cost for Bio-engineering Works (NRs.)	**3,202,854.52**
Cost for Civil Engineering Works (NRs.)	**6,199,496.55**
Differential Amount (NRs.)	**2,99,6642.03**
Differential %	1.94
Ratio	**1:1.94**

4. Conclusion:

Appropriate bio-engineering technique, average length and average slope of the landslide are primary factors for selecting of appropriate bio-engineering technique. Beside these, width of the landslide along with depth of the landslide, moisture content (including information about drainage system) are required. Four landslide sites in ward no1 of Kageshwara Manohara Municipality were selected for the study.

Based on this data and suggestion from the expert, various bioengineering and civil engineering techniques were proposed for soil stabilization and erosion control. Bioengineering measures such as grass seeding, shrub and tree plantation, brush layering,jute netting, along with civil engineering methods like riprap, gabion work, soil nailing, shotcrete, chutes, and drains are suggested. Bio-engineering works holds significant advantages and importance when compares to traditional civil engineering solutions in the context of mitigating landslides. While civil engineering works have traditionally focused on rigid structures such as retaining walls and slope stabilization techniques, bio-engineering offers a more holistic and sustainable approach that leverages the natural processes of plant growth. The cost analysis revealed that the expenditure for bioengineering measures amounted to NRs. 3,202,854.52, while civil engineering works incurred NRs. 6,199,496.55. Typically,the cost ratio between bioengineering and civil engineering is expected to be 1:3. However, due to the inclusion of water management components like stream chutes and riprap in bioengineering, the observed ratio is closer to 1:1.94ecological systems to enhance the natural processes of plant growth and ecological systems to enhance slope stability and prevent landslides. -engineering works are less expenditure and environment friendly comparison to civil engineering works.

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Innovative thin shell structure in space

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Abstract

Thin-walled shell structure may achieve such innovative structure enhancing better aesthetic view which should lead better performance in aspect of structural response; conducting accurate optimistic analysis and design for geo-strata of Earth or space objects. Nowadays, in developing countries for design of Stupa, Gumbaz and several dome structure simple spherical, parabolic three-dimensional structures are being rapidly analyzed and designed without proper analysis in which continuity of elastic theory enhancing member and bending forces developed within such structure should be considered. In this paper it is explained how the peak stress in intersecting line of several complex shell structures are being normalized and the continuity of elastic theory is maintained even though the structures are to be used in space purpose and will be constructed on the geo-strata of Lunar and Planetary objects. Those shell structures are not only in simple type like conventional dome structures; but also, innovative shell structures like Mongue's surfaces, Barrel Vaults, folded plate structures may be selected for space to resist pressure difference of internal and external environment in space, moon or any planet creating complex and aesthetic performance by humankind.

Thin-walled spatial structures used in various fields of technology are often combinations of sectors of thin shells and plates which may be connected at edge zones or may be intersected to each other along common intersecting line which will form its own continuity function. During analyze of various responses of connected structures, it is necessary to take into account the joint work of the sections of the structure, especially in the zone of intersection of the sections. At the same time, both two sectors or more than two sectors of thin shell may intersect in the intersection zone for covering large space consisting only peripheral stiff columns within shell structures. Intersecting sectors may be either of the same geometric shape or different depends upon designer in aesthetic sense, environment of space vacuum and geo-strata of space objects. The article provides study of innovative thin shell structure used in space which is found rarely

explained worldwide. An approach for analyzing connected or intersected thin shell structures based on the variation-difference method and the super element method is considered either using force or stiffness method to obtain optimization of structural parameters. The main aim of this paper is to focus on to conduct analysis of shell structure for Lunar surfaces or surfaces of other planetary objects which may resist extreme temperature, cosmic radiation and pressure difference. The boundary conditions for such shell structure are introduced as zero gravity, spring elements and assigned restrained in periphery of the shell must be matching with real features. This paper also motivates the structural engineers to develop innovative design of buildings, bridges and other monuments for future generations conducting construction of such shell structure in Earth and space as well.
Keywords: thin-walled spatial structures, connected thin shells, innovative, variation-difference method, shell structure in space

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Introduction

Thin-walled spatial structures used in mechanical engineering, construction [1; 2], shipbuilding [3], rocketscience [4;5], aircraft industry [6] and other fields of technology, most often represent combinations of structures from sectors of shells and plates of the same [7-9] or various geometric shapes [10-12]. Many literatures on the analysis of shells are explained with analysis of shells of specific simple conventional shapes. In the literature on the analysis of combined structures, most works consider methods for calculating tanks and conjugate shells of revolution [13-18]. When designing combined shells of revolution, there is a problem of conjugated transition of the shell sectors, which provides a more correct shape and less concentration stresses in the contact zone or intersecting zone depending upon how the sector of shells are combined to each other [19]. Analytical error and issues arise in particular, when connecting cylindrical shells with different diameters. Super Element method, which appeared in the twentieth century allow to carry out analysis of the stress-strain state of complex spatial structures. However, FEM based software packages do not take into account geometric characteristics of the curved shells which may defined as Monge surfaces, which can lead to peak stress strain during analysis of shells of complex geometric shapes to create innovative thin shell structure, including in the interface zones of the shell sectors of the spatial structure. Therefore, the development of alternative methods and programs for analysis of thin shell structure with complex geometry is main objective of this paper. Below is a method for calculating combined spatial structures based on the variation-difference method for analysis of thin shell sector following rules of elastic theory related function of continuity along with geometric shape of innovative thin shell structure. The method of super elements for the analysis of connected shell structures was explained but still to optimize analysis is necessary to follow rule of elastic theory. [20]

on the Lagrange principle - the minimum of the total strain energy. In FEM software systems, usually onlythe equation of the middle surface of the shell is used to break down the structure into final elements without taking into account the geometric characteristics of the surface.

The VRM Shell software package includes a library of curves, on the basis of which the shell sectors are formed and the coefficients and derivatives of the quadratic forms of the surface at the nodal points are calculated difference grid. The software package includes: analysis s of bending of plate shell and a planestress problem of elasticity theory in rectangular and polar coordinate systems, plate bending on curvilinear-trapezoidal plans (pseudo-polar coordinate system), analysis of cylindrical shells, shells of revolution, shells in the form of Joachimsthal surfaces, carved surfaces of Monge. Various line support conditions, edge zones are used, including elastic footings and elastic supports and considering with holesor without holes in shell surfaces Any types of loads over the shell structure directed to normal and tangentialsurfaces of shell structure, like nodal loads, distributed loads including moment, and self-weight of shell structure.

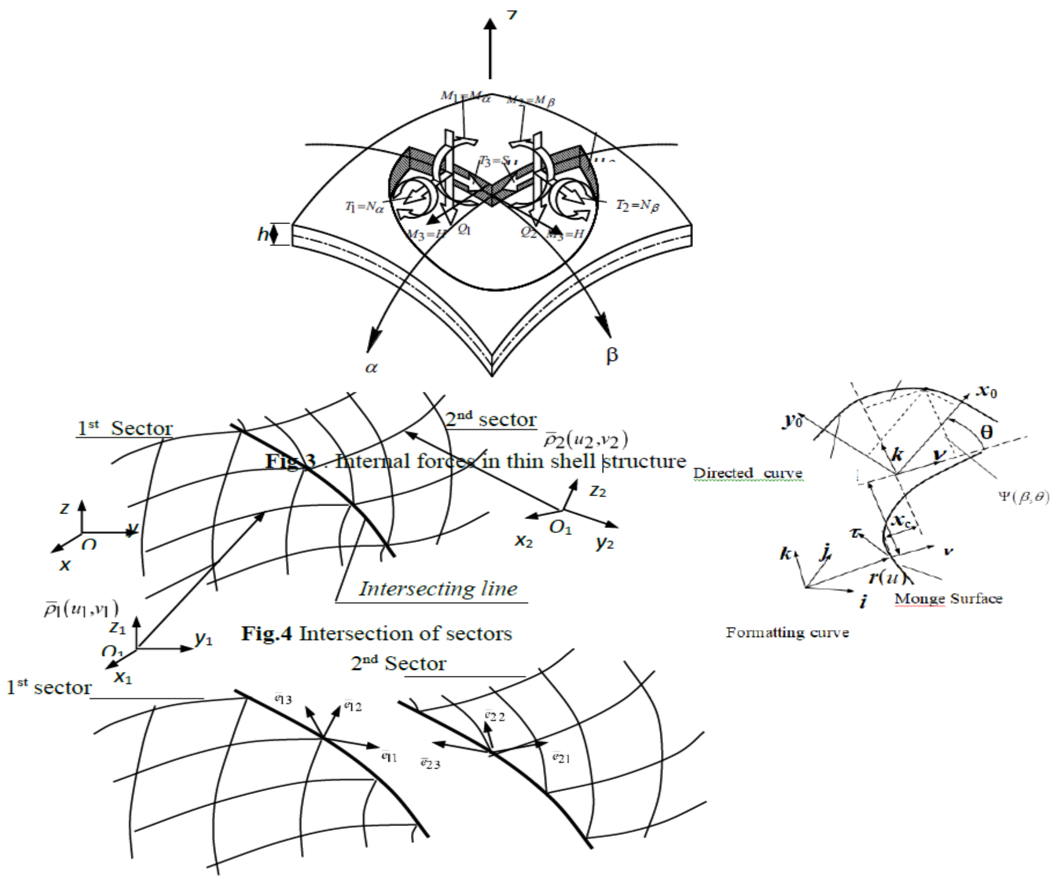


Fig.1: Orthos of sectors of shell

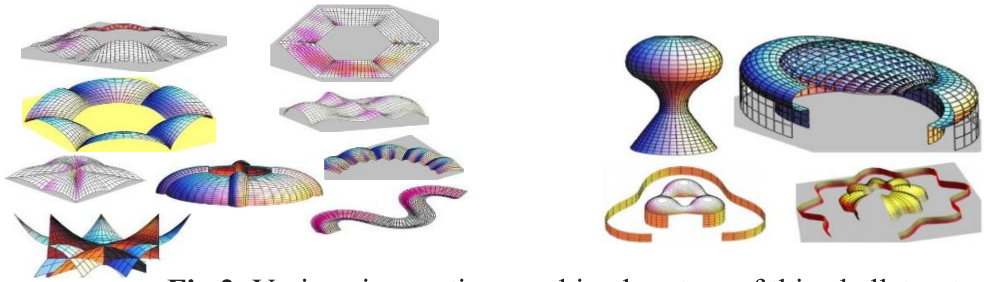


Fig.2: Various innovative combined sectors of thin shellstructure

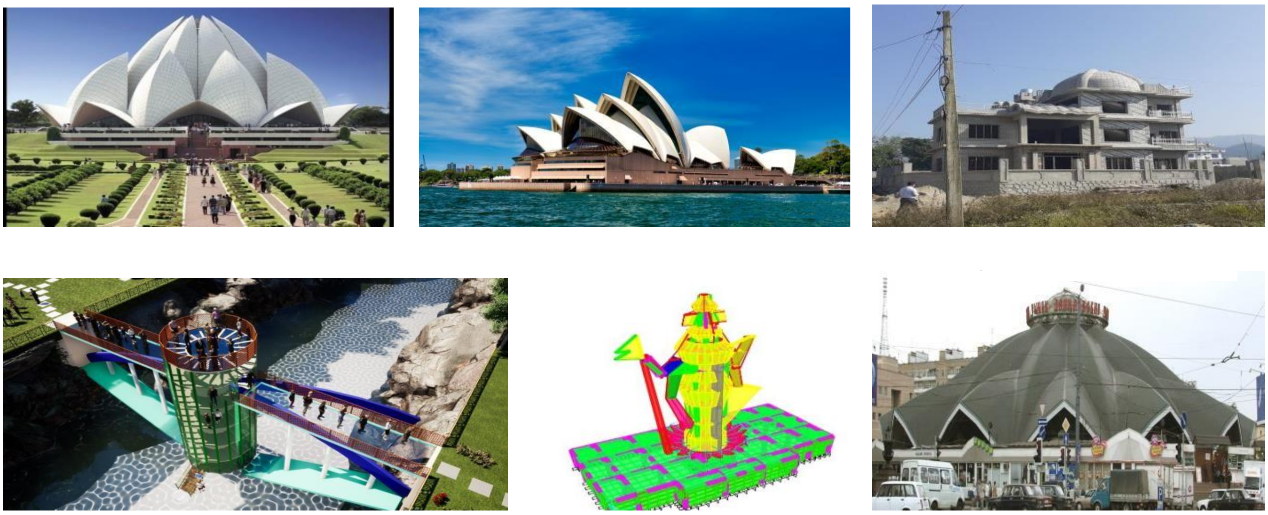


Fig.3: Various innovative combined sectors of real thin shell structures

Methods

The super element method is based on the method of forces [20]. Each sector of the combined spatial structure is calculated on the basis of the VRM Shell program for the load acting on the sector and unit forces at the grid nodes considering specially 4^{th} degree of redundancies at the intersection lines of the sectors. From conditions for equality of nodal displacements of sectors of thin shell structures at grid nodeson lines intersections in the global coordinate system [22], nodal efforts. Next, the stresses and strains in the shell sectors are summarized from the action of the load and nodal forces in the zone of suppression of the sectors. At dividing the structure into sectors, some sectors may not have supports in all or some directions. To stabilize such sectors conditional elastic foundations are introduced. For conditional spring stiffness coefficients of the elastic foundation, small values are set so that the elastic foundation had no significant effect on the stress-strain sector status pretending zero stiffness as in the case of cantilever thin shell structure.

For analysis of thin shell structure two variants of interface of sectors are possible:

1. Sectors of thin shell structure with various geometrical structure are interfaced on a line, a being commoncoordinate line of both shells. Such analysis is possible, in particular, at formation of sectors of thin shellsin the form of cyclic, irregular or carved surfaces of Monge, revolution of shell and also interface of sometypes of cylindrical of various diameters. Analysis of designs from replicated sectors of shell of innovative structure is also possible.

2. Solving system of the algebraic equations (10), we define unknown forces in units on a line of interface ofsectors. Further each sectors pays off independently on action of the loading, acting on a sectors and systemof efforts in units on a line of interface of sectors.

3. On offered algorithm of analysis of thin shells using method of super elements the program in language FORTRAN has been realized and test analysis s of various analysis and designs are adopted. The analysis results show good convergence at comparison with known decisions in the literature those used FEM.

The Matrix for Mongue surface to change in global to local coordinates as follow;

$$\{\gamma_0\} = \begin{Bmatrix} (i\cdot e_1) & (j\cdot e_1) & (k\cdot e_1) \\ (i\cdot e_2) & (j\cdot e_2) & (k\cdot e_2) \\ (i\cdot e_3) & (j\cdot e_3) & (k\cdot e_3) \end{Bmatrix} = \begin{Bmatrix} \dfrac{x'_H}{s'_H} & \dfrac{y'_H}{s'_H} & 0 \\ -\dfrac{\dot{\varphi}\cdot y'_H}{s'_H\cdot \dot{s}_0} & \dfrac{\dot{\varphi}\cdot x'_H}{s'_H\cdot \dot{s}_0} & \dfrac{\dot{\psi}}{\dot{s}_0} \\ \dfrac{\dot{\psi}\cdot y'_H}{s'_H\cdot \dot{s}_0} & -\dfrac{\dot{\psi}\cdot x'_H}{s'_H\cdot \dot{s}_0} & \dfrac{\dot{\varphi}}{\dot{s}_0} \end{Bmatrix}$$

$$P_\alpha=\{\gamma\}_0\left(\{\gamma\}_H P\right)=\{\gamma\}_H\{\gamma\}_H P=\{\gamma km\}P$$

$$\{\gamma km\}=\{\gamma\}_H\{\gamma\}_H$$

$$\{\gamma\}_H=\begin{Bmatrix} \cos\omega & \sin\omega & 0 \\ -\sin\omega & \cos\omega & 0 \\ 0 & 0 & 1 \end{Bmatrix}$$

The matrix of transformation of one local systems of coordinates in global is defined by system directing cosines or scalar products ortho of two systems which will lead easy to transform the local coordinates into any form of three-dimensional coordinates for space structure in static as well as in dynamic sense.

$$[Cs]=\begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{bmatrix}, \qquad (1)$$

If projections of a vector in the first system of coordinates $-P_{1i}$ multiplying a matrix of transformation on a vector it is received its decomposition in global system of coordinates –

$$\overline{P} = P_{11} \cdot \overline{e}_{11} + P_{12} \cdot \overline{e}_{12} + P_{13} \cdot \overline{e}_{13} = P_{21} \cdot \overline{e}_{21} + P_{22} \cdot \overline{e}_{22} + P_{23} \cdot \overline{e}_{23};$$

$$\left\{P_{ei}\right\} = \begin{Bmatrix} P_{e1} \\ P_{e2} \\ P_{e3} \end{Bmatrix} = \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{bmatrix} \cdot \begin{Bmatrix} P_{11} \\ P_{12} \\ P_{13} \end{Bmatrix} = \left[Cs\right] \cdot \left\{P_{1i}\right\}; \qquad (2)$$

$$\left\{P_{ei}\right\} = \begin{Bmatrix} P_{e1} \\ P_{e2} \\ P_{e3} \end{Bmatrix} = \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{bmatrix} \cdot \begin{Bmatrix} P_{21} \\ P_{22} \\ P_{23} \end{Bmatrix} = \left[Cs\right] \cdot \left\{P_{2i}\right\}. \qquad (3)$$

For analysis of crossed sectors of thin shells, we shall apply a method of forces. Dismembering sectors on a line of interface, equal and opposite nature of unit vectors will be introduced in each grid- nodes of shell surface. A condition mutual works on a line of crossing and a perpendicular in a plane normal moment will be introduced into a line of crossing sectors, in case of their rigid interface. At hinged connection on a line of crossing only unit forces will be considered.

Also to adopt force methods for unknown redundancies per node of grid shell we introduce units vectors on a line of the crossing of sectors shells in a direction of the local system of coordinates of the first sectors and the moment

$$Z_m = X_{1,k}; \quad Z_{m+1} = X_{2,k}; \quad Z_{m+2} = X_{3,k}; \quad Z_{m+4} = M_{n,k}, \qquad (4)$$

Where k – number of unit on a line of crossing, k = 0, 1, … Kyз; m = 4□(k - 1); (k - 1); Kuz – quantity of units on a line of crossing; - effort in k-th unit in a direction of i-th orthos - the moment in a plane normal to a line of crossing. in k-th unit.

The first and second sectors pays off on individual forces in a direction on a combination of projections of individual forces in global system of coordinates in units and the individual moment in normal to a line of crossing of a plane.

$$\overline{Z}_{k+i} = 1 \quad \rightarrow \quad \alpha_{i1(k)} \cdot \overline{e}_{21(k)} + \alpha_{i2(k)} \cdot \overline{e}_{22(k)} + \alpha_{i1(k)} \cdot \overline{e}_{21(k)} \qquad (5)$$

Here k – number of unit on a line of crossing.

As a result of analysis s receive systems of Rotation and corners of turn in units in a plane, normal to a line of crossing from all individual efforts

$$\delta_{(t)mn} = \delta^{(k)}_{(t)\,in}, \qquad (6)$$

Where t = 1, 2 - number of a sectors; k - number of unit on a line of crossing of sectors; i = 1,2,3 – number of orthos in local system of coordinates in which direction moving is calculated; i = 4 - a corner of turn in a plane normal to a line of crossing; ; $m = 4x(k - 1)$ - a serial number of moving on a line of crossing of sectors; n – number of individual effort from which action moving is calculated.

Besides Rotation and in units of sectors on a line of crossing from the loading operating within the limits of a sectors are to be calculated.

$$\delta'_{(t)\,mn} = \sum_{l=1}^{3} \alpha_{i\,l(k)} \cdot \delta^{(k)}_{(t)\,l\,n}, \quad m = 4\times(k-1)+i, \;\; \mathrm{i} = 1{,}2{,}3. \qquad (7)$$

Similarly, from loading in the second sectors.

$$\Delta'_{(t)\,mP} = \sum_{l=1}^{3} \alpha_{i\,l(k)} \cdot \Delta^{(k)}_{(t)\,l\,P}. \qquad (8)$$

For a corner of turn around of a normal to a line of crossing (i =4)

$$\delta'_{(t)\,mn} = \delta^{(k)}_{(t)\,4,n}, \quad m = 4\times(k-1)+4. \qquad (9)$$

Then, conditions of mutual work of rotation on a line of interface of sectors will enter the name in the form of:

$$\sum_{n=1}^{4\times K} \left\{ \delta'_{(1)mn} - \delta'_{(2)mn} \right\} \cdot Z_n + \Delta'_{(1)\,mP} + \Delta'_{(2)\,mP} = 0,. \; m = ,2, \ldots 4 \cdot K_{y3} \qquad (10)$$

Solving system of the algebraic equations (10), we define unknown forces in units on a line of interface of sectors. Further each sectors pays off independently on action of the loading, acting on a sectors and system of efforts in units on a line of interface of sectors.

On offered algorithm of analysis of thin shells using method of super elements the program in language FORTRAN has been realized and test analysis s of various analysis and designs are adopted. The analysis results show good convergence at comparison with known decisions in the literature those used FEM. Analysis of structure in Space shall be focused mainly into pressure difference between normal internal pressure and zero pressure on outer layer of thin shell structure (23). As per situation and environments of objects in space thin shell structures shall be designed and constructed into form of intersected and connected thin shell plates with curved shell structures. In fig 4 to 7 the various complex shapes of shell structure are illustrated to construct on surface of planetary objects and in space as well.

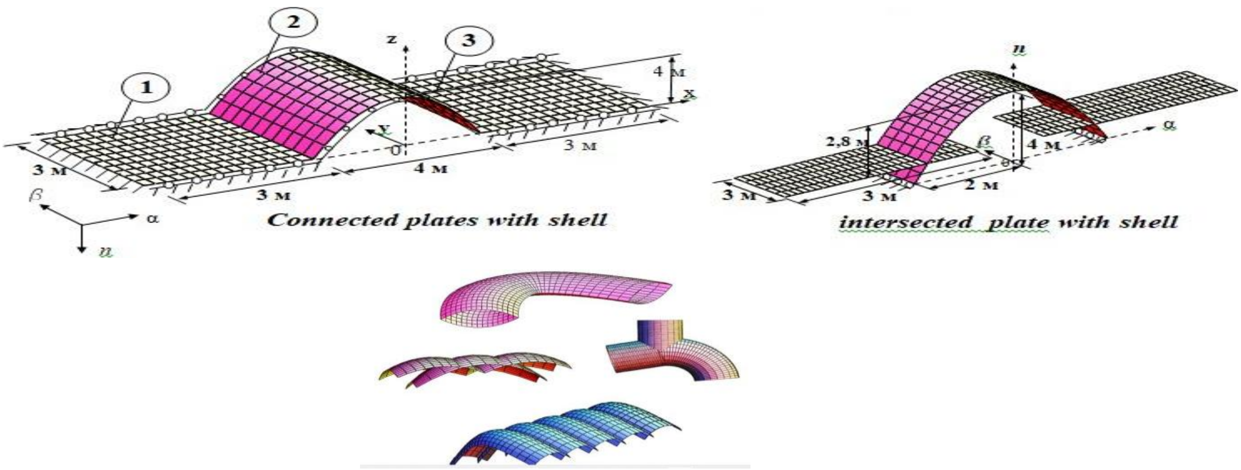


Fig.4: various types of formation of innovative shell structure

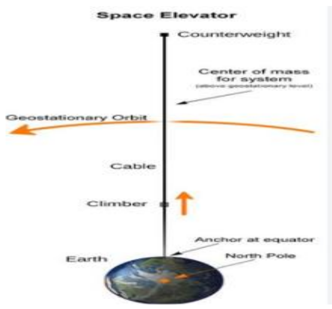


Fig.5: Space Elevator

Fig.6: Lunar structure as thin shell

Fig.7 a: Space elevator source: Projects/ NCSS

Fig.7 b: Mars colonies as thin shell structure as

At the stage of end of analysis, the developed module of the program in FORTRAN complex realizing calculation of crossed sectors of thin shell structures by a method of Super elements and test calculationsare adopted. In particular, calculation of the Parabolic-sinusoidal wave carved innovative thin shell structure is divided into two sectors. Results were compared to calculation of the whole sectors. Results ofcalculations have completely coincided.

On fig. 8 and 9 the design of the thin shell structures, consisting of 4 consistently connected sectors with a mediancarved parabolic-sine wave surface variable Gausses curvature with positive and negative radii is formed. The design may not be presented by performing uniform continuous surface, and will be analysed as a setof crossed sectors of thin shell structures.

Results and discussion

Sectors of an thin shell structures with a symmetric directed parabola – of size -15m to 15m and a sinusoidalcurve forming within the limits of two half waves - 0 to 16 m. as shown in fig 6.

The all properties are kept as concrete shell structure with thickness of 10 cm. For Planetary objects the thickness will vary from 1.5 cm to 10 cm as per environments leading minimization of materials during cast in-situ of the surface of the objects. The foundation for such thin structure will be chosen as deep and stiff foundation for stability of thin shell structure.

Results of calculations: rotations (slope); tangential efforts, S; bending and twisting the moments M, T are presented.

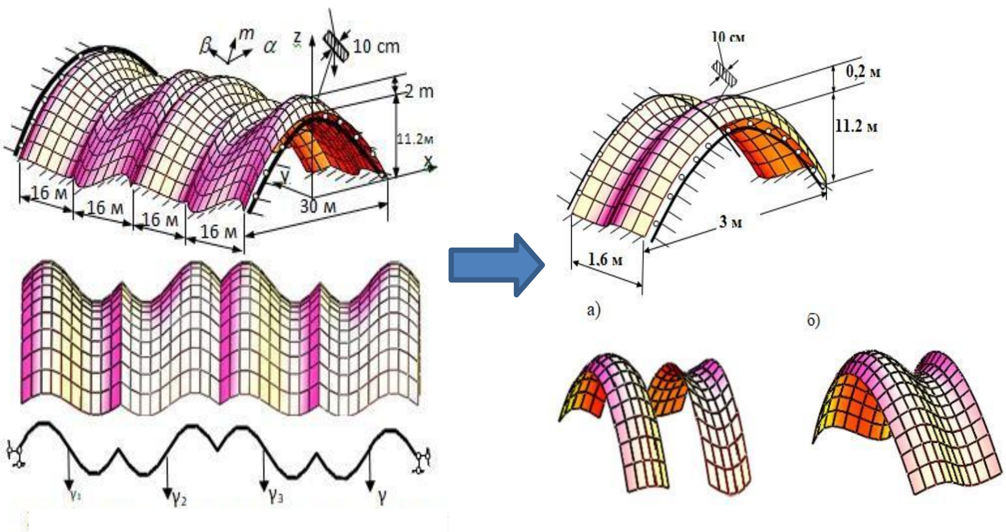


Fig.8 a: Parabolic sinusoidal thin shell structure in Planetary surface resisting self-weight

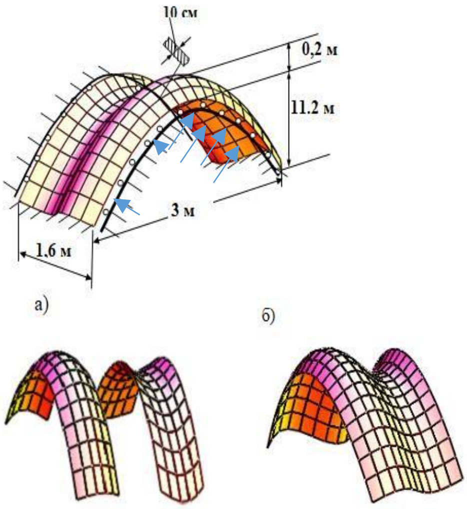
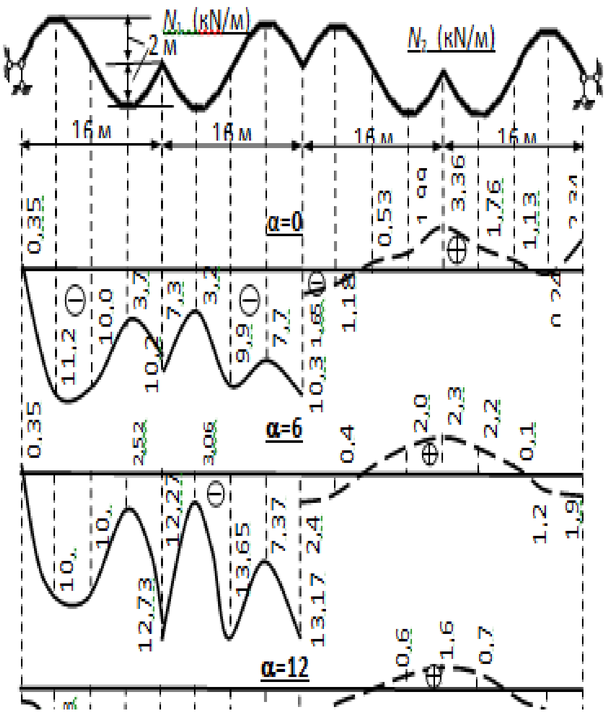


Fig.8 b: Parabolic sinusoidal thin shell structure in Planetary surface resisting Intense internal pressure



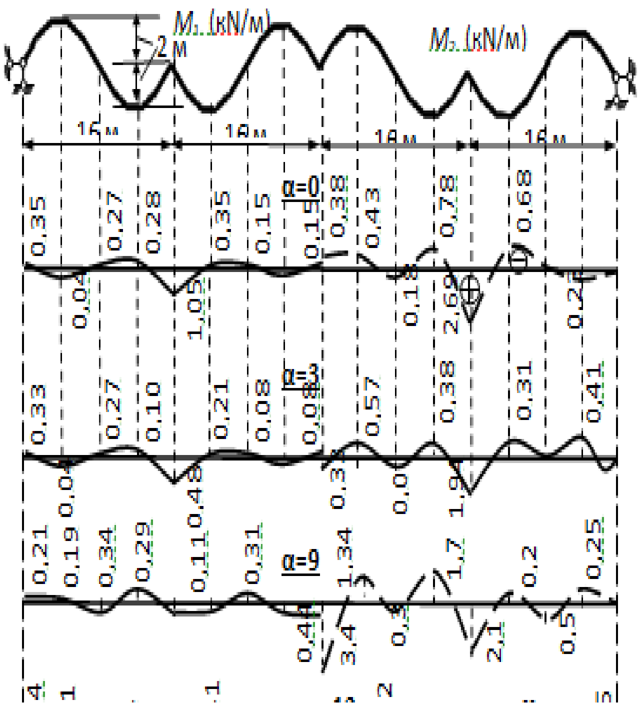


Fig.8 c: Axial force (N) **Fig.8 d**: Bending Moment (M)

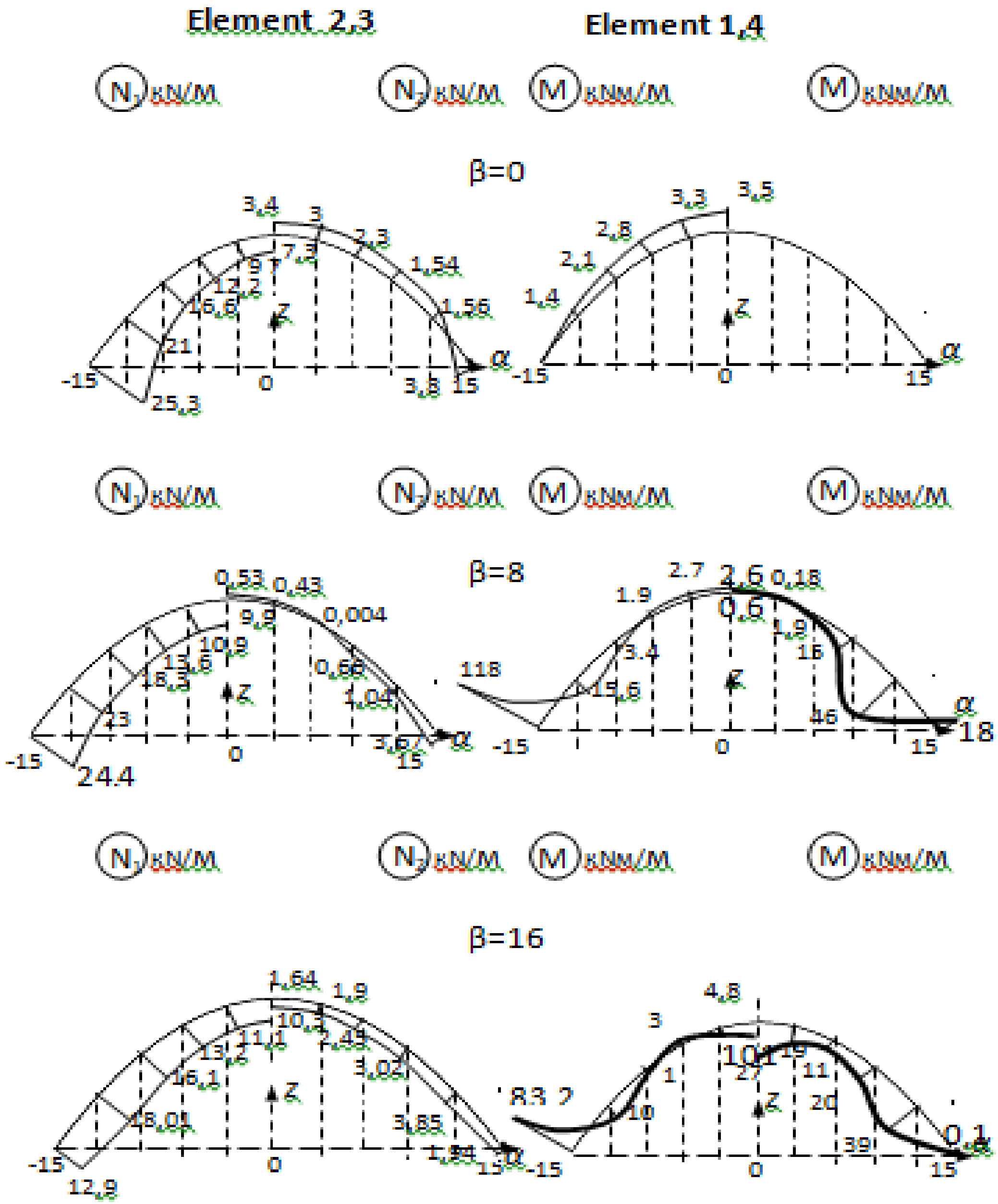


Fig.9: N and M along X direction of Module

Table 1. Analysis of Global Element 1, 4

Section	α	N_α [кN/м]	N_β [кN/м]	M_α [кN·м/м]	M_β [кN·м/м]
$\beta = 0$	-15	0	0	0	0
	-12	-0,854E+00	-0,569E+01	-0,137E-02	-0,648E-07
	-9	-0,656E+00	-0,437E+01	-0,211E-02	-0,157E-06
	-6	-0,285E+00	-0,190E+00	-0,279E-02	-0,318E-06
	-3	0,150E+00	0,100E+00	-0,331E-02	-0,525E-06
	0	0,351E+00	0,234E+00	-0,351E-02	-0,634E-06
$\beta = 4$	-15	-0,689E+01	-0,103E+01	0,286E-02	0,430E-03
	-12	-0,377E+01	-0,173E+01	-0,309E-02	-0,152E-01
	-9	-0,622E+01	-0,165E+01	-0,194E-02	-0,151E-01
	-6	-0,879E+01	-0,122E+01	-0,825E-03	-0,898E-02
	-3	-0,106E+02	-0,581E+00	-0,352E-03	-0,410E-02
	0	-0,112E+02	-0,248E+00	-0,284E-03	-0.954EE-03
$\beta = 8$	-15	-0,237E+02	-0,355E+01	-0,118E+00	-0,178E-01
	-12	-0,227E+02	-0,112E+01	0,156E-01	0,461E-01
	-9	-0,182E+02	-0,692E+00	0,342E-02	0,147E-01
	-6	-0,136E+02	0,153E+00	-0,191E-02	0,193E-02
	-3	-0,109E+02	0,897E+00	-0,272E-02	-0,185E-03
	0	-0,100E+02	0,113E+01	-0,268E-02	-0,597E-03
$\beta = 12$	-15	-0,232E+02	-0,348E+01	-0,142E-01	-0,213E-02
	-12	-0,141E+02	0,771E+00	-0,447E-02	-0,187E-01
	-9	-0,547E+01	0,166E+01	-0,294E-02	-0,194E-01
	-6	-0,252E+01	0,222E+01	0,149E-02	-0,532E-02
	-3	-0,316E+01	0,202E+01	-0,381E-05	-0,315E-02
	0	-0,375E+01	0,176E+01	-0,332E-02	-0,680E-02
$\beta = 16$	-15	-0,253E+02	-0,380E+01	-0,832E-01	0,113E-03
	-12	-0,209E+02	0,156E+01	0,101E-01	0,395E-01
	-9	-0,166E+02	0,154E+01	0,106E-01	0,201E-01
	-6	-0,122E+02	0,231E+01	-0,294E-02	0,110E-01
	-3	-0,901E+01	0,304E+01	0,483E-02	0,194E-01
	0	-0,733E+01	0,336E+01	0,104E-01	0,269E-01

Table 2. Analysis of Global Element 2, 3

Section	α	N_α [кN/м]	N_β [кN/м]	M_α [кN·м/м]	M_β [кN·м/м]
$\beta = 0$	-15	-0,253E+02	-0,380E+01	-0,832E-01	0,113E-03
	-12	-0,209E+02	0,156E+01	0,101E-01	0,395E-01
	-9	-0,166E+02	0,154E+01	0,106E-01	0,201E-01
	-6	-0,127E+02	0,230E+01	-0,294E-02	0,110E-01
	-3	-0,983E+01	0,302E+01	0,465E-02	0,194E-01
	0	-0,831E+01	0,334E+01	0,102E-01	0,269E-01
$\beta = 4$	-15	-0,242E+02	-0,363E+01	-0,145E-01	-0,218E-02
	-12	-0,153E+02	0,671E+00	-0,411E-02	-0,169E-01
	-9	-0,664E+01	0,149E+01	-0,264E-02	-0,175E-01
	-6	-0,306E+01	0,209E+01	0,150E-03	-0,490E-02
	-3	-0,292E+02	0,211E+01	-0,769E-04	-0,379E-02
	0	-0,317E+02	0,199E+01	-0,339E-02	-0.781E-02
$\beta = 8$	-15	-0,244E+02	-0,367E+01	-0,106E+00	-0,159E-01
	-12	-0,229E+02	-0,104E+01	0,138E-01	0,408E-01
	-9	-0,182E+02	-0,658E+00	0,299E-02	0,132E-01
	-6	-0,136E+02	0,365E+00	-0,175E-02	0,218E-02
	-3	-0,109E+02	0,435E+00	-0,218E-02	-0,479E-03
	0	-0,990E+02	0,526E+00	-0,188E-02	-0,201E-03
$\beta = 12$	-15	-0,106E+01	-0,160E+01	0,511E-02	0,767E-03
	-12	-0,607E+01	-0,155E+00	-0,258E-02	-0,117E-01
	-9	-0,673E+01	-0,159E+01	-0,179E-02	-0,139E-01
	-6	-0,737E+01	-0,148E+01	0,950E-02	-0,952E-02
	-3	-0,767E+01	-0,128E+01	-0,583E-05	-0,568E-02
	0	-0,770E+01	-0,118E+01	-0,523E-02	-0,430E-02
$\beta = 16$	-15	-0,129E+02	-0,194E+01	-0,144E-00	0,188E-03
	-12	-0,180E+02	-0,385E+01	0,129E-01	0,649E-01
	-9	-0,161E+02	0,301E+01	0,441E-02	0,314E-01
	-6	-0,131E+02	0,245E+01	0,702E-03	0,102E-01
	-3	-0,110E+02	0,190E+01	0,827E-03	-0,333E-03
	0	-0,103E+02	0,165E+01	0,147E-02	-0,381E-03

Conclusion

The Paper describes a method for Analysis shells of complex shape based on vibrational-difference method to create innovative thin shell structure- in the base the software package "VRM Shell" and leading continuity fully following theory of elasticity which will be sever used in space elevator suspending structure and as well as on Geo- surface of moon or mars. The analysis of combined spatial structures – software Global Comb Shell complex in FORTRAN using Geometric Characteristics middle surfaces of complex shell s allows to obtain more reliable results of the analysis of the stress-strain state of spatial structures specially in intersection of two sectors of shell structures. The operation of software systems was checked by comparison with the analysis of available analytical solutions and with analysis that carried out by FEM software packages. The analysis showed reliable accuracy when compared with analytical solutions and close results with used FEM tools. The structural performance of thin shell structure for any type of loadings seen realistic and accurate as enhanced following theory of elasticity unlike framed structures which need resist sever bending stress mainly for surface of planetary objects. Thin shell structures in planetary objects shall be chosen observing their light weight having small thickness

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Effect of Post-Earthquake Rural Housing Reconstruction on Housing Types and Family Debt

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Abstract

This research investigates the impact of post-earthquake rural housing reconstruction in Nepal, focusing on changes in housing sizes, typologies, and financial debt among affected families. It highlights a significant reduction (i.e. 61% of respondents have two-room houses after earthquake) in average house size from pre- to post-earthquake periods, driven by constraints related to time, resources, and financial capacities. The study reveals that reconstructed homes are notably smaller and often do not meet the spatial needs of households compared to their pre-disaster counterparts. The quantitative analysis, which involved random sampling of household data complemented by secondary data from literature reviews and project reports, uncovers several key findings: The average reconstruction cost per house is NRs 6,14,600 significantly exceeds the government grants provided, leading to increased household debt and financial strain. Changes in construction materials and housing typologies, 75% of respondents with SMM typology decreased to 9% after the earthquake and the BMC had increased to 61% from 2% which reflect that beneficiaries are more likely to have BCM typology. The study finds that the lack of consideration for settlement-level dynamics in reconstruction efforts has resulted in incomplete recovery, indicating the need for a more integrated approach.

The research also assesses the applicability of Central Place Theory in the housing reconstruction process, suggesting that incorporating this theory could improve planning and contribute to more

sustainable outcomes. Overall, the research provides valuable evidence for refining policies and strategies related to rural housing reconstruction. It advocates for a revised approach that considers settlement dynamics and aligns with the spatial needs of affected communities, aiming to enhance the effectiveness and sustainability of future reconstruction efforts both within Nepal and in similar contexts worldwide.

Keywords: housing reconstruction, housing trends, recovery, housing finance, lessons learned, settlement approach.

1. Introduction

Nepal faces a complex and recurring challenges of multi-hazard disasters due to its diverse geography and climatic conditions from sea level to Himalayan terrain. Earthquake is one of the major hazards causing huge impact in terms of casualties, fatalities and economic loss as it is located between two tectonic plates: Indian plate and Tibetan plate. As per observed earthquake history of Nepal, there is possibility of earthquake with magnitude of 7 and above in every forty years and magnitude of 8 plus in every eighty years.

Following the devastating earthquakes that struck Nepal in April 2015, the nation faced unprecedented challenges in addressing the extensive damages to private and public house, infrastructure in 31 districts. Major impact of the earthquake is detected in rural area of affected districts. Two consecutive earthquakes with magnitudes of 7.8 and aftershock 7.3, resulted in intensive destruction, causing loss of lives, dislocation of societies, and sizable damage to homes, infrastructure, and livelihoods. In the aftermath, the Nepalese government, along with various international organizations and NGOs, initiated the emergency response followed by extensive reconstruction efforts to address the housing crisis and support affected families. The reconstruction efforts were focused not only on restoring homes but also on promoting resilient and culturally appropriate housing designs. The initiatives considered the socio-economic conditions of the affected families, ensuring that the new structures were both sustainable and reflective of local traditions. By prioritizing resilience and cultural relevance, the reconstruction aimed to provide long-lasting, suitable housing solutions that would support the communities' recovery and strengthen their ability to withstand future challenges. The reconstruction process involved various strategies, including technical support, financial aid, and housing design guidelines, to facilitate the rebuilding of homes in affected areas. Government had deployed the numbers of engineers for the technical support in reconstructing the house of affected families along with the various earthquake resilience design in the affected district. Financial aid came in the form of grants from government and loans provided to affected families to support their reconstruction efforts.

The financial burden on affected families increased significantly during the reconstruction period. Government subsidy is not enough for reconstruction and many households were compelled to take loans or incur debts to supplement the government grants, raising concerns about the long-term financial sustainability of these households. Despite the assistance provided, the post-earthquake reconstruction process encountered several challenges. Delays in disbursing financial assistance, bureaucratic obstacles, geographical challenges in accessing remote areas, and complexities related to land ownership and documentation significantly impeded the speed and effectiveness of the reconstruction efforts. The reconstruction efforts resulted in changes to housing typologies, where traditional architectural designs were adapted to incorporate earthquake-resistant features and to meet the evolving cultural and social needs of the communities. Consequently, the new housing structures and layouts differed from those of the pre-earthquake homes.

Following guiding principles should form the basis of strategy and planning of recovery and reconstruction as per PDNA (Commission, 2015).

- Facilitate community engagement by empowering residents to take charge of their home reconstruction projects.
- A comprehensive view of housing reconstruction should include holistic habitat development, with basic services and community infrastructure. The principle of build back better (BBB) should translate into a concept of safer settlements.
- Reconstruction should be viewed as an opportunity to enhance long-term community resilience by addressing vulnerabilities and bolstering community capacities. This involves adopting improved construction practices to strengthen the majority of the building stock and better prepare for future disasters.
- Enhance the local economy through reconstruction initiatives that specifically support the poor and marginalized, especially those in the informal sector. This approach should

provide these communities with opportunities to upgrade their living conditions and achieve greater economic advancement.

- Ensure that the reconstruction process is sustainable and environmentally friendly by considering climate change, managing natural resources responsibly, and incorporating scientific risk assessments.
- Ensure that rehabilitation is equitable and inclusive.

2. Materials and Methods

Tanahun district is in the Gandaki Province with the area of 1,546 km². Tanahun District share boarders with Grokha in east, Kaski in west, Lamjung and Kaski in North and Chitwan and

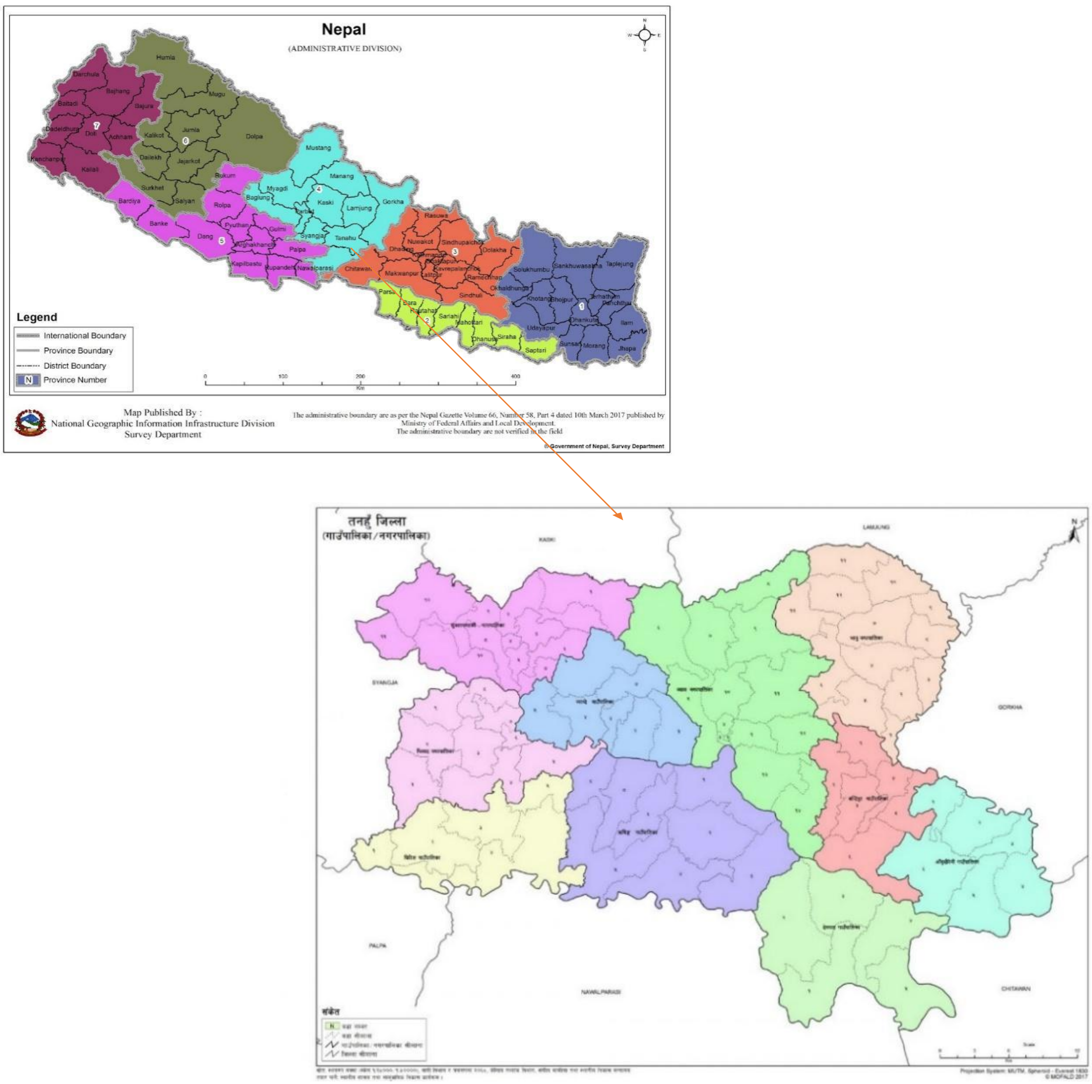


Fig. 1: Topographic map of Tanahun District Source: Nepal Census 2068

Nawalparasi in south. It consists of total 10 local level where 4 are urban municipalities and 6 are rural municipalities where Bhanu, Bhimd, Shuklagandaki and Vyas are municipalities and remaining Aabukhaireni, Bandipur, Devghat, Ghiring, Myagde and Rhishing, Ghiring are rural municipalities. Tanhun district has been taken as study area of the research as this district was least affected district among the major affected fourteen districts. According to the national census 2078 BS, total population of the Palika is 321,153.

2.1 Data Collection

2.1.1 Nature of data

To assess the effectiveness of shelters reconstructed by the National Reconstruction Authority (NRA) across various Palikas within Tanahun District, a comprehensive methodology will be adopted. This study will involve the utilization of both primary and secondary data sources. Primary data will be gathered through field visits, while secondary data will be acquired from reputable sources including Palika Offices, district Offices, the National Reconstruction Authority (NRA), the Department of Urban Development and Building Construction (DUDBC), Non-Governmental Organizations (NGOs), and relevant publications and periodicals to ensure a thorough analysis.

2.1.2 Data collection technique

The main purpose of the study is to determine the "Impact of Rural Housing Reconstruction Post Earthquake on Housing Typologies and Financial Debt Status of Affected Families." Thus, both quantitative and qualitative method will be applied. Key informant interview (IDI), questionnaire survey and field observation were the major tools for this study.

I. **Field observation**

   In this method observations will be made in field where reconstructed house is located. Visualization of house site is carried out and measurement of plinth area of house along with typology of house is recorded. Number of rooms in house and storey of house is recorded. Status of earthquake affected house is observed along with other facilities in house. Availability of latrine throughout the kitchen is also observed during the field visit.

II. Key informant interview

KII is carried out with those who have specific knowledge or expertise relevant to the reconstruction in different municipalities of Tanahun District. It helps to provide insights, perspectives, and context that can enhance understanding or validate finding of assessment. Also, the key person who have been engaged with the specific activities and have experience on the scenario.

III. **Questionnaire survey**

Questionnaire survey will be held in each household of selected sample size according to the structured questions.

2.2 Sample size

According to the profile of Tanahun district, there are 88,583 houses (National Population and Housing Census 2021). As per latest list of Nepal Reconstruction Authority (NRA), there is 16,168 households listed under NRA beneficiaries where 15,129 household had received first tranche, and 14,880 household had received third government tranche. So, 14,880 beneficiaries had been considered for the study. A total sampling frame was prepared. Simple random sampling technique was used for identifying the sample. Hence, a total of 201 respondents were interviewed who were residing in Tanhaun district. Married, unmarried, male and female, rich and poor who live within a study area were considered eligible for a study population. The sample size was calculated by using Slovin's formula (n=N/ (1+Ne2). Where n is the sample size, N is the population size and error are margin of error which is taken as 7%. (Here N=14880).

Calculation:

Total populations (N)	=	14880
Margin of (e)	=	7% (Provision range: 5-10%)
Sample Size (n)	=	?
Using Slovin's formula	n =	N/ (1+N e2)
	n =	14880/ (1+14880 x 0.07 x 0.07)
	n =	201.3 nos.

Hence, taking sample size as 201 numbers of the study from NRA listed beneficiaries.

3. Result and discussion

The reconstruction efforts following the earthquake in moderately affected districts are influenced by a multitude of factors, affecting both housing trends. This complex situation emerges from a variety of contributing factors. A thorough analysis of measurable parameter is analyzed based on the information received. Understanding the financial aspects of households, including income and expenditure, was crucial for a comprehensive debt analysis among respondents.

Furthermore, we consulted secondary data sources to explore additional factors that shape individuals' decision-making regarding housing trends and debt management. Our study conclusively shows a significant shift in housing patterns, evident in changes in house size, typologies, living areas, and patterns observed before and after the earthquake. Notably, the data reveals that many individuals continue to struggle with underlying debt, posing potential challenges to both economic development and the overall well-being of families and the nation.

3.1 Tranche received from NRA

Out total number of households surveyed, 96% of respondents surveyed received the third tranche whereas 0.5% and 3.5% received first and second tranche only respectively as shown in figure 2. Despite constructing new house, 3.5% and 0.5% of households were unable to receive all the government tranche due to non-compliance issue.

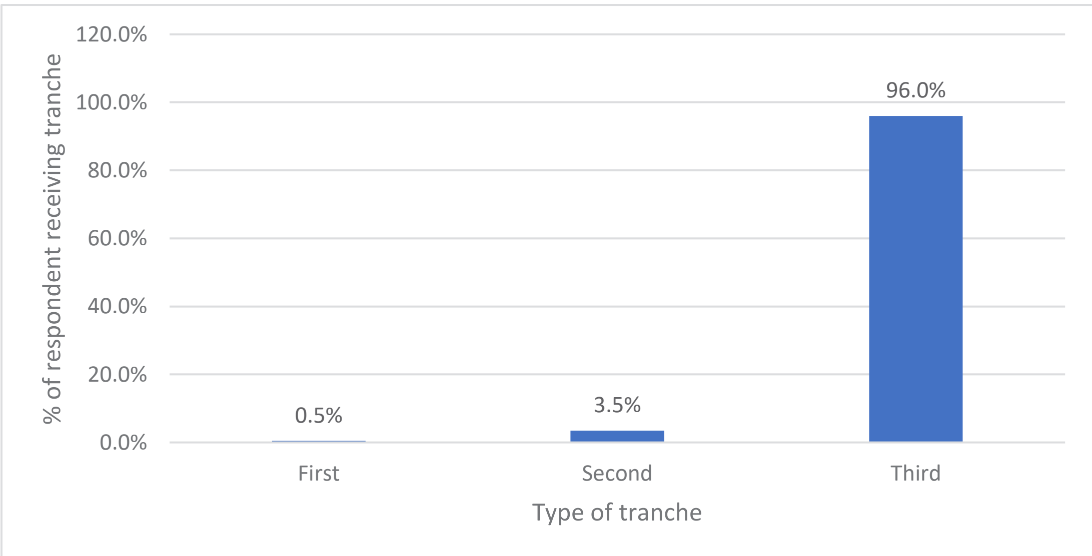


Fig. 2 % of sample surveyed participants with tranche status

3.2 Comparison of housing area

There is not much difference in the plinth area after the earthquake. The plinth area range between 147 to 270 is 68% which is increased from 43% as shown in figure 3. Though NRA didn't promote the single room house for reconstruction, vulnerable single headed family use to reconstruct the one room house and 16% respondents belongs to it. It is observed that higher plinth area more the 541 square feet is usually made up of RCC typology and also of two storey house.

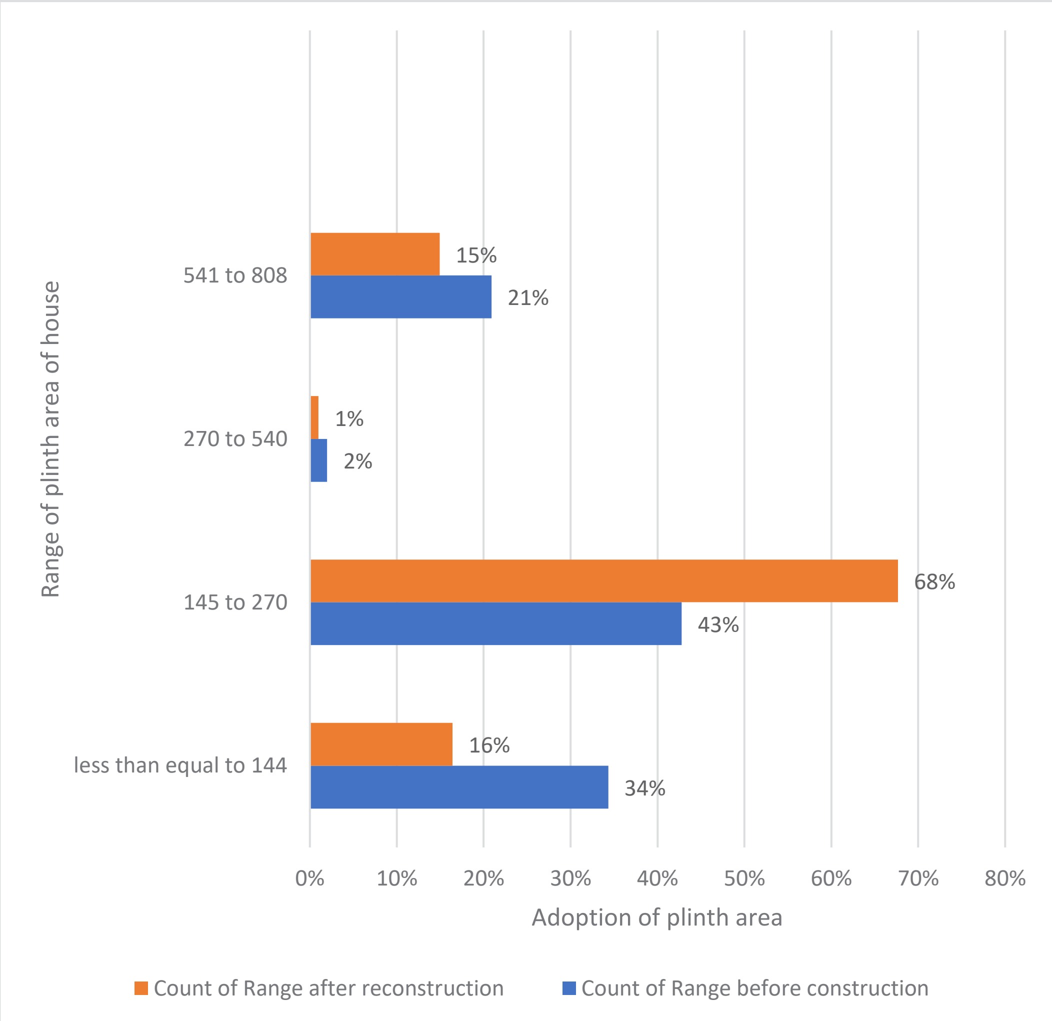


Fig. 3 Comparison of plinth area of house before and after earthquake

The comparison between Central Bureau of Statistics (CBS) damage grade assessment survey and house size data was collected from HRRP analyzed on 15 April 2019 clearly indicates that house sizes have significantly reduced after reconstruction. The analysis of the change in house size showed decreased in housing area from 51-75 m2 to 26-50 m2 from pre- to post-earthquake (HRRP, 2019, p.27).

3.3 Comparison of House storey

There is significant difference in storey of house before and after earthquake as shown in figure 4. 38% of respondents surveyed used to live in two storey houses before earthquake which is decreased to 3% and 21% of surveyed respondents used to live in one storey house which increased to 84%. Only 2% and 3% have their house story two or more. It indicates that majority of people choose to build small and limited to one story houses which may be because of the misunderstanding as NRA norms to receive the tranche is only one storey building. And even NRA deployed engineers used to prioritize for one storey house.

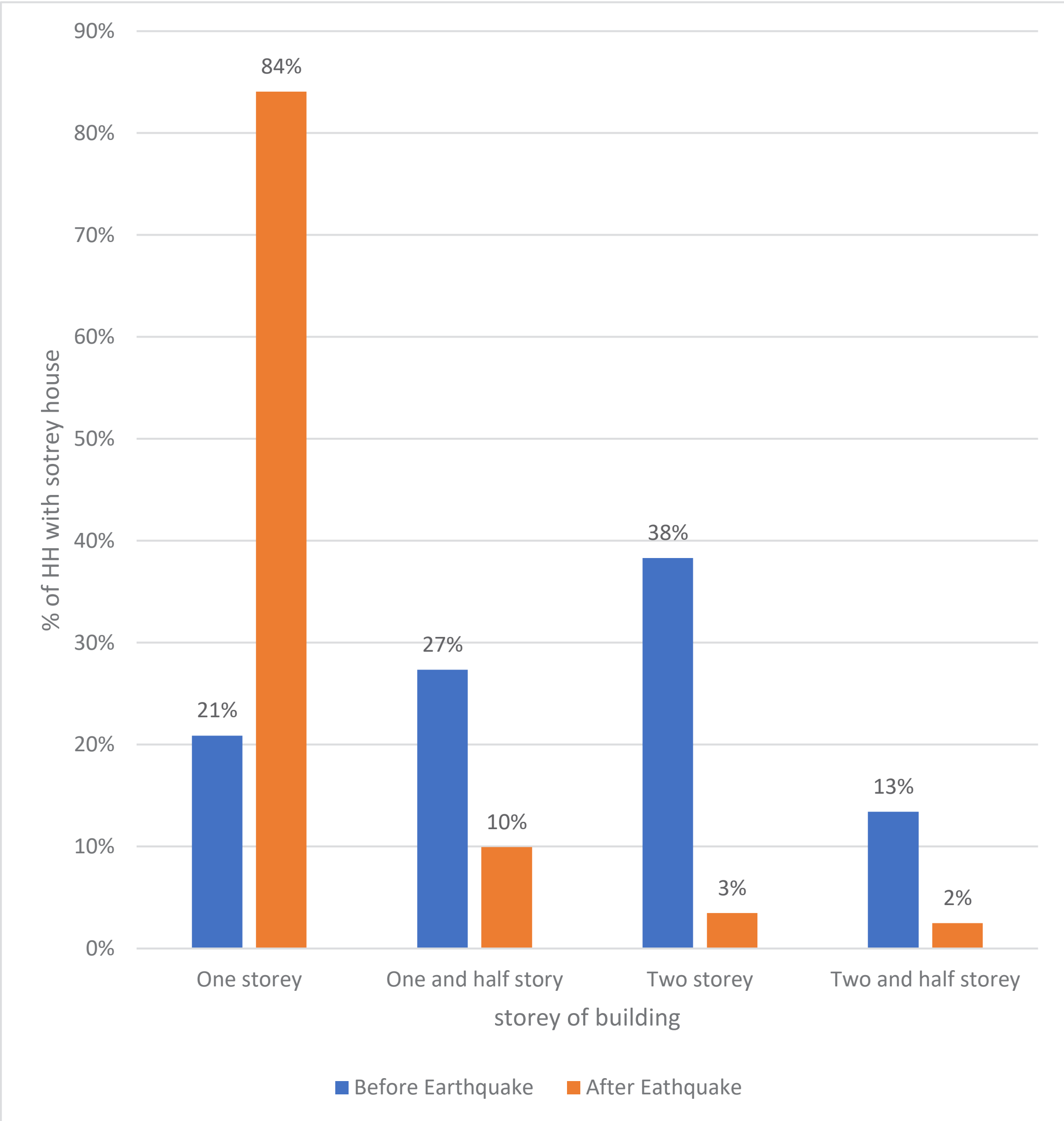


Fig. 4 Comparison of Storey of house before and after earthquake

Table 1 Comparison of storey of house before and after house

Storey of House	Before Earthquake	After Earthquake
One storey	42	169
One and half story	55	20
Two storey	77	7
Two and half storey	27	5

3.4 Earthquake resilient element in house

Only limited houses had horizontal bands before earthquake. Those houses which are built earlier had not earthquake resilient element. The survey reflects that after the earthquake; beneficiaries

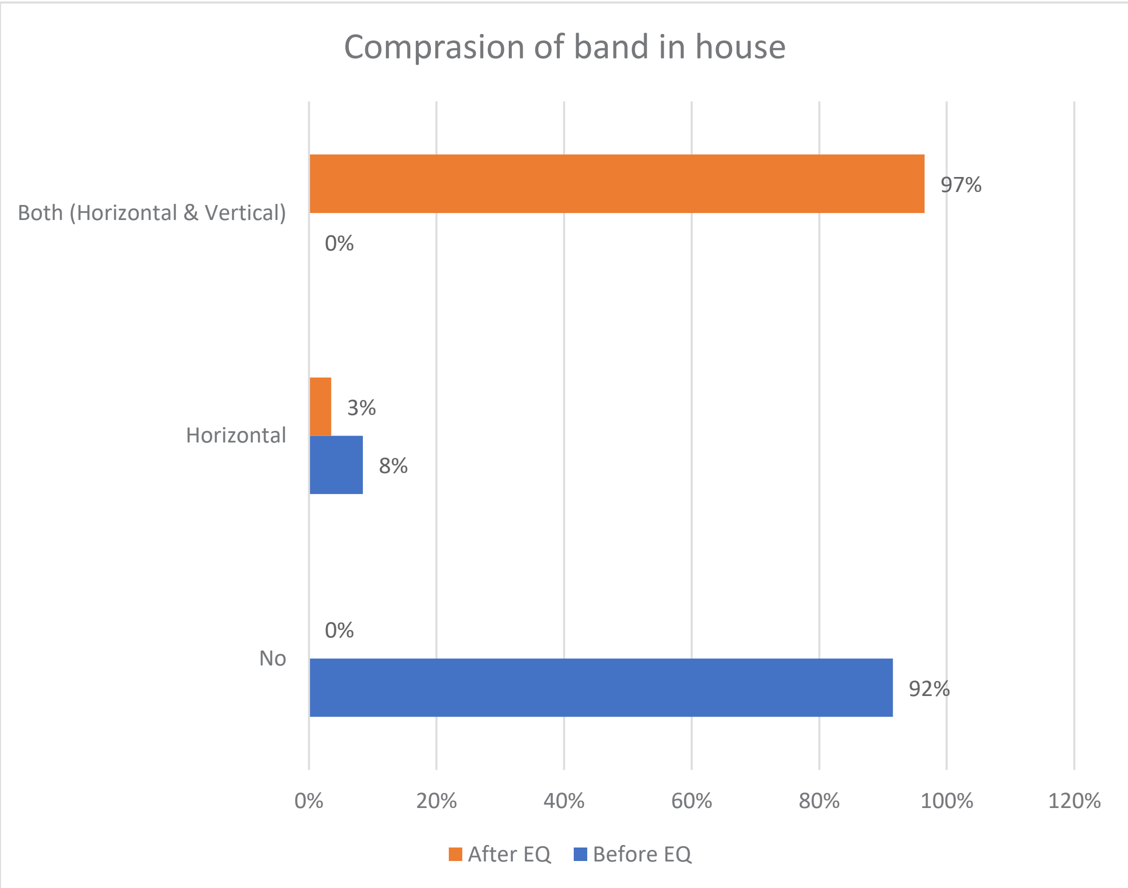


Fig. 5 Comparison of EQ resilient element per and post-earthquake in house

are more concerned to reconstruct the safer/stronger house. Also, the government requirement for the tranche is earthquake resilient element which is horizontal band (plinth level, sill level, lintel level and roof level) and vertical band at corner and opening is mandatory. According to the data surveyed, most families didn't have bands in their house before earthquake. Only 8% of respondents reported to have horizontal band before earthquake. Only 3% of respondents reported to have horizontal bands whereas 92% of respondents shared to have both horizontal and vertical band in their house after earthquake as shown in figure 5.

3.5 Number of rooms in house

The change in number of rooms was not significantly different before and after the earthquake as more than 50% of people used to have two room houses and still maintain similar ratio in new

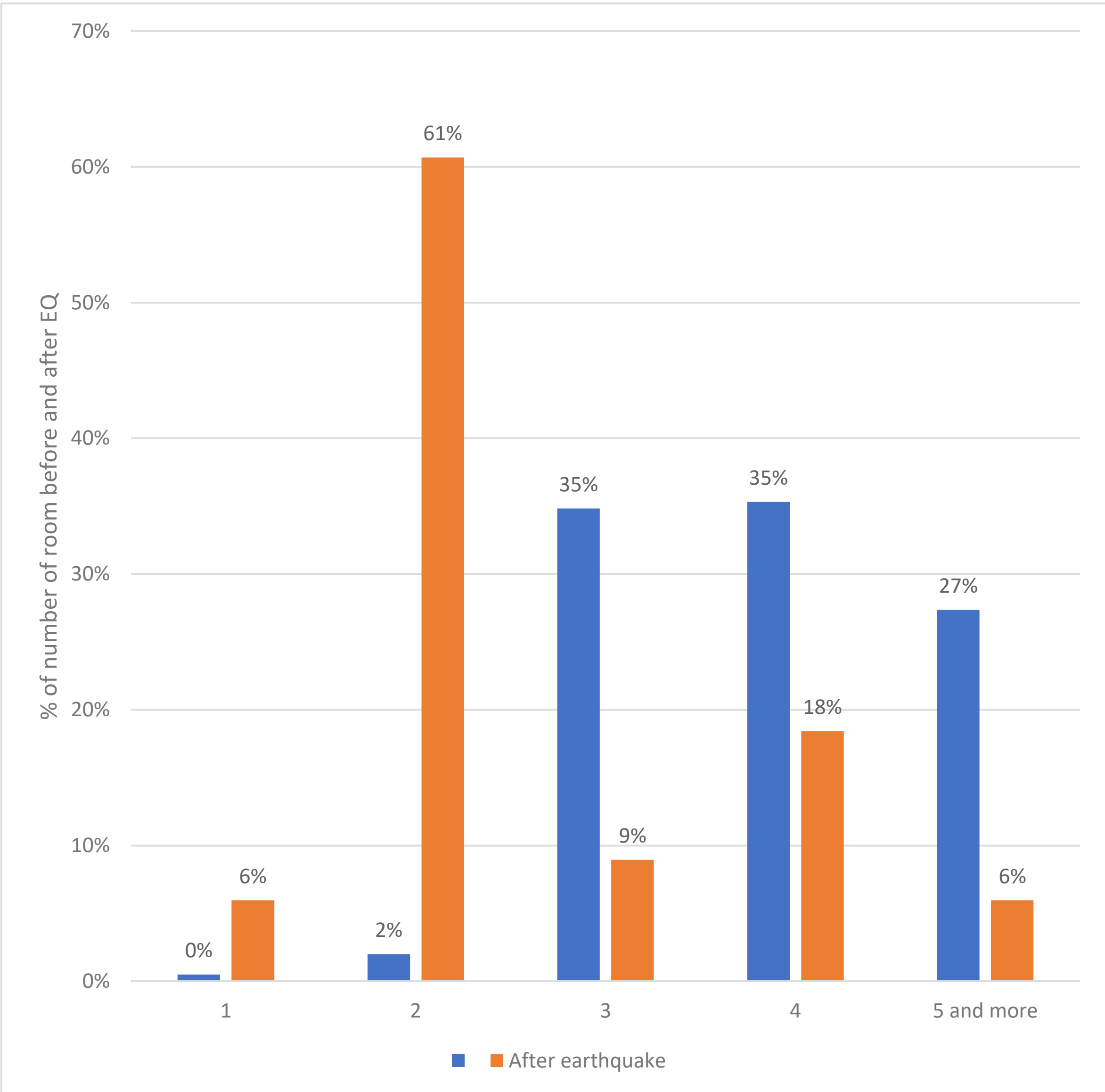


Fig. 6 Comparison of rooms in house before and after EQ

construction. 61% of survey respondents have two room house which increased from 2% after earthquake as shown in figure 6. Reconstruction of house with more than two room is decreasing in percentage after the earthquake. According to surveyed data, numbers of room after earthquake has been limited to two room.

3.6 Housing Typology

Following significant changes, the architectural landscape often undergoes transformations. In Tanahun district, prior to the earthquake, the prevalent construction method was stone and mud mortar masonry, constituting over 75% of the buildings as illustrated in figure 7. Conversely, alternative typologies only accounted for a quarter of the structures, with Reinforced Cement

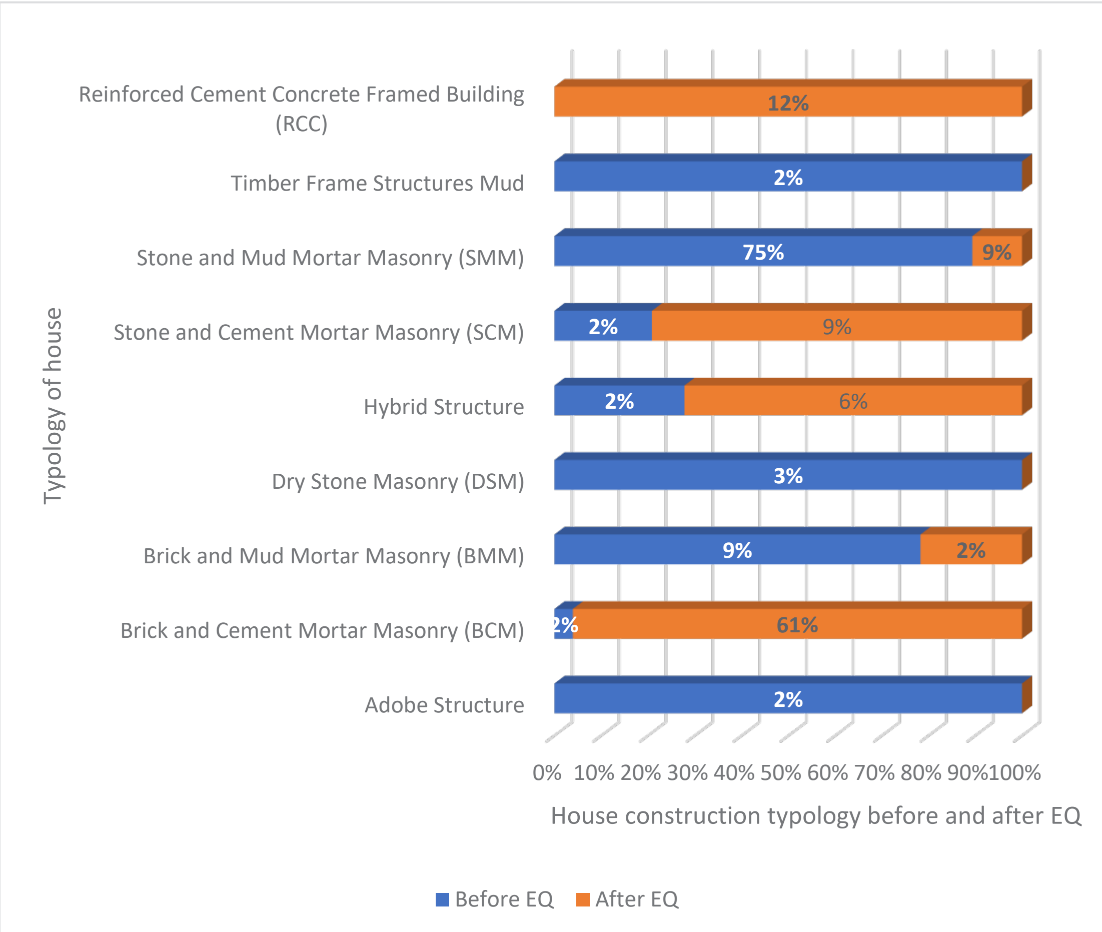


Fig. 7 Comparison of typologies of houses built before and after the earthquake

Concrete Framed Buildings (RCC) being the least popular. However, in the aftermath of the earthquake, there has been a notable shift in preferences towards Brick Cement Mortar Masonry

(BMC) and RCC structures. Despite this shift, a substantial portion of the populace still favors traditional methods, perhaps influenced by perceptions of strength, communication channels, government regulations, material scarcities, economic factors like inflation, or aspirations for modernization.

75% of surveyed respondents with SMM typology decreased to 9% after the earthquake. 12% of surveyed respondents built RCC after earthquake which is null before EQ. The Brick and cement mortar Masonry had increased to 61% from 2% which reflects that beneficiaries are more likely to have BCM typology. Earthquake affected beneficiaries from Tanahun district are most likely to reconstruct the two room BCM model 1.1 typology of house shown in figure 3.7 as it is easier to construct and consume less time and NRA deployed engineer also recommend and is approving for the further tranche.

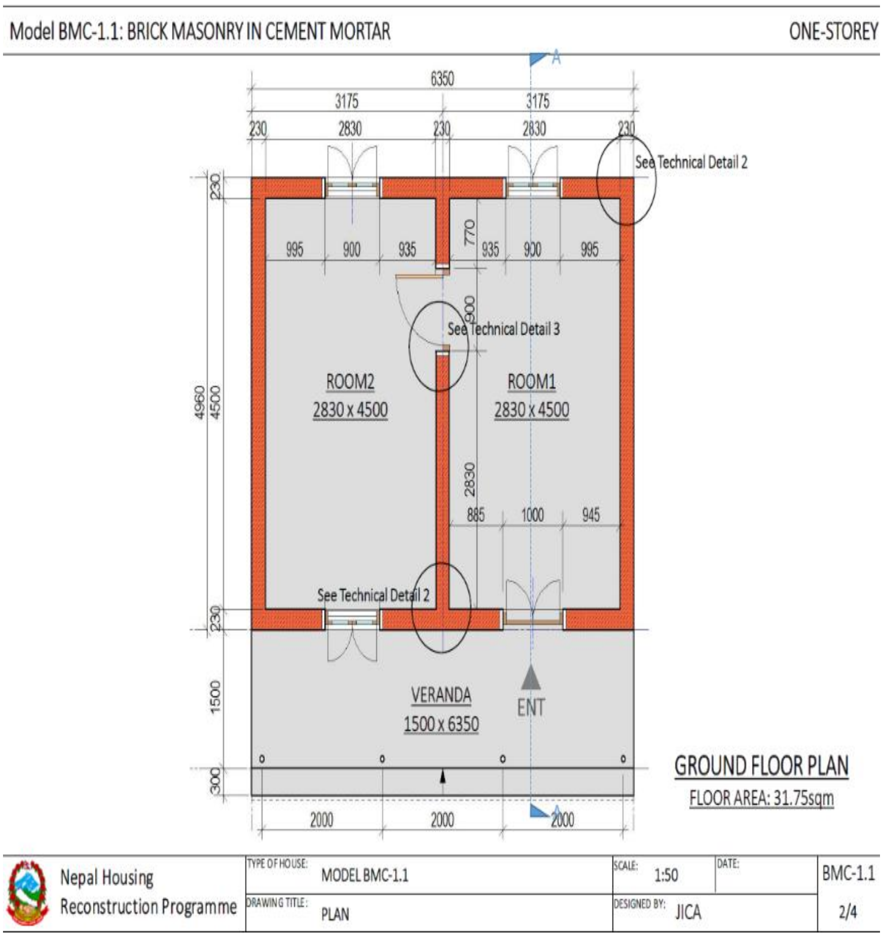


Fig. 8 NRA approved BCM building from Volume I catalogue. Source: NRA

3.7 Family additional need

When we investigate the housing needs, it is not just living or sleeping area, but it consists of at minimum toilet and cooking area. Except 10.2%, all 89.8% families have functional toilets available inside or outside of their house shown in figure 8. But when we ask about the availability

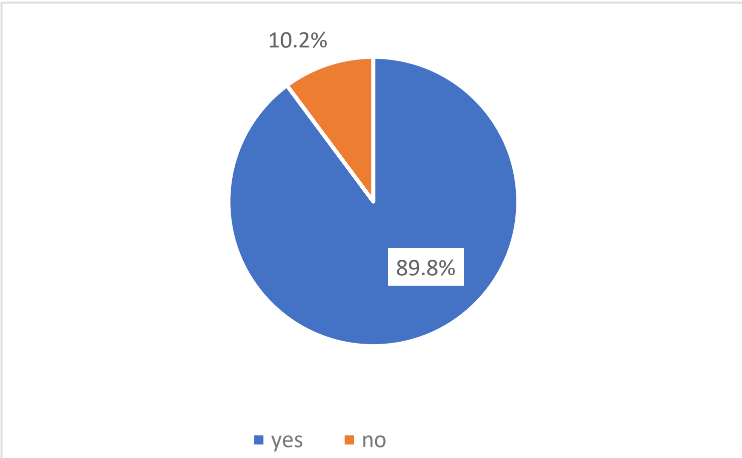


Fig. 8 % of status of latrine in reconstructed house

of separate kitchen, 42% of families didn't have kitchen in their newly reconstructed houses as illustrated in figure 9. This indicates either the families must cook outside the room or construct additional space. The family will gradually plan for extension to existing structures either vertically or horizontally in various ways.

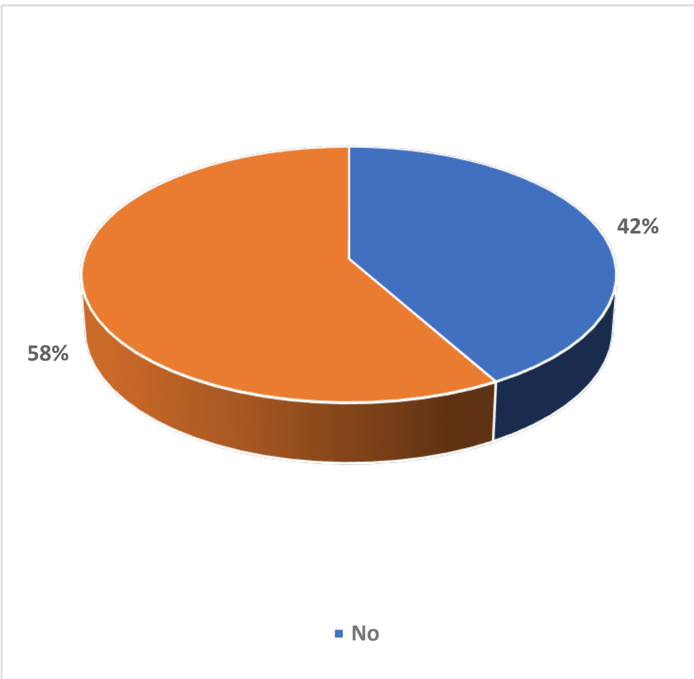


Fig. 9 Availability of separated kitchen in newly reconstructed houses

As Nepal is 'Open Defecation Free (ODF)', it is observed that 18.7% population still have no toilet where 9.8% in urban and 25.0% in rural area. Also, poorest family is the one who don't have toilet It indicates that there is strong association of prosperity with available toilet facility. However, the proportion of no toilet household has declined from 2014/15 when it was 22.0% (CBS & UNDP, 2015/16). There are limited families who didn't have toilet in their house and used to share with other. Most of the families are waiting for other to extend their house so that they too can extend their house for the kitchen and other purpose.

3.8 Building design adopted during reconstruction

After the earthquake, most families are concerned with the design of building as it directly affects the government tranche. It is observed that 81% of surveyed families had rebuilt their house following the NRA building catalogue so that there won't be any difficulty in receiving the government all tranche and only 5% have rebuilt following own traditional design incorporating the earthquake resilient element in consultation with NRA engineers as illustrated in the figure 10. 13% of surveyed families rebuild their house as per municipal engineer design as most of them

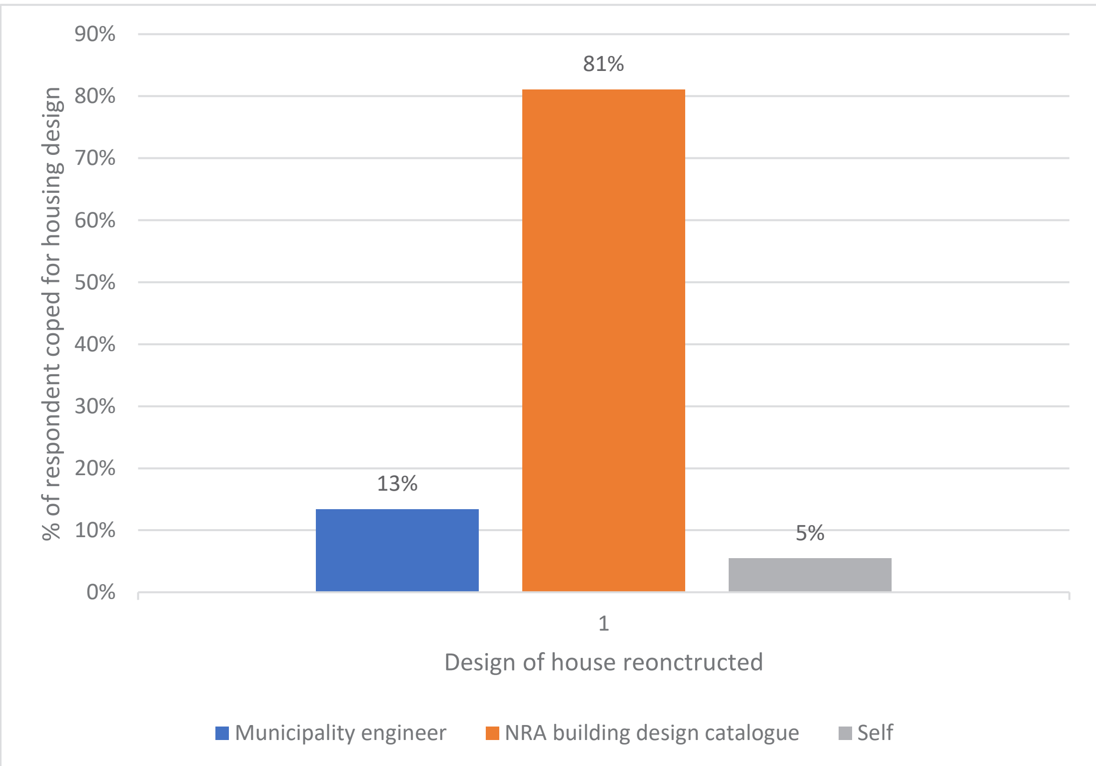
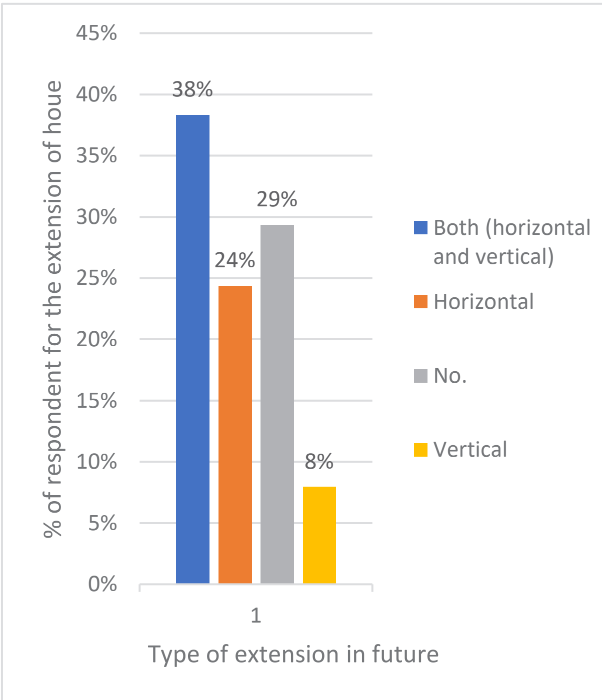


Fig. 10 Design adaptation for reconstruction

had already reconstructed house just after the earthquake where are remaining want more space and follow the traditional design for the reconstruction.

5.9 Extension of house

As most of the houses are one storey with 2 room houses, the need of extension of house is



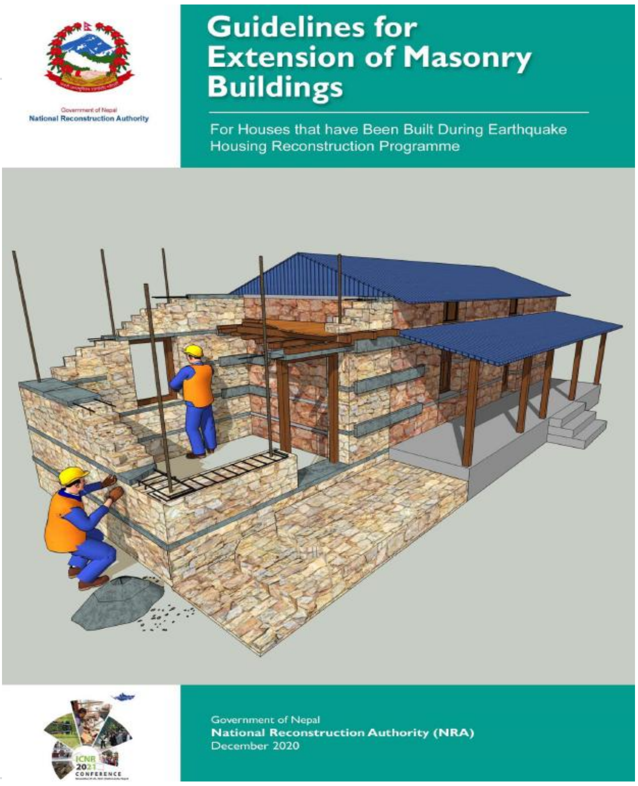


Fig. 11 % of respondent for future f extension of house

Fig. 12 NRA house extension guideline Source NRA

explored. According to surveyed families' 38% respondent want to extend both horizontal and vertical, 29% respondent want to extend horizontal and 8% vertically as shown in fig. 11. Also, 29% respondent don't want to extend their house as they feel safe during disaster.

Nepal Reconstruction Authority had published the Guidelines for Extension of Masonry Buildings for houses that have been built under Housing Reconstruction Program on December 2020 as shown in figure 12. The guideline consists of extension procedure in both horizontal and vertical way for single and double room house. It provides the minimum requirement for the element at the junction of the new and the existing walls, connection of roof members along will construction steps. The guideline also focusses on the addition of floor in the case of cement mortar and mud mortar and replacement of light roof with reinforced concrete roofing for the vertical expansion.

4. Conclusion:

- Significant Changes in Housing Size and Conditions:

  The earthquake-induced rural housing reconstruction process has led to significant changes in housing size and living conditions, deviating notably form pre-earthquake norms. This shift has impacted not only the physical dimensions of homes but also raised concerns about the potential loss of traditional architectural styles and vernacular building practices. The departure from these established methods poses a threat to cultural heritage, which once characterized the rural environment.

- Number of house reconstructed verse quality of house

  The reduction in living space has presented practical challenges for families, who often try to address their spatial needs by expanding their homes. However, such expansions can potentially undermine the structural integrity of the buildings, raising concerns about long-term safety and stability. Despite the success in the number of houses rebuilt, there are significant concerns regarding the quality of these structures. The emphasis on quantity rather than quality has led to mixed outcomes, particularly in terms of spatial adequacy, socio-economic effects, and settlement integration.

- Increase the financial debt of families

  The financial burden on households has greatly increased due to the reconstruction efforts. Many families have had to cover over half of the reconstruction costs themselves, exacerbating their debt and financial stress. This issue is further compounded by inadequate subsidized loans and limited access to formal financial support, forcing households to manage substantial costs without sufficient financial assistance. Consequently, national debt projections have become alarmingly high, reflecting the extensive economic impact of the reconstruction process.

- Need for the further research

Addressing these challenges requires further research. It is crucial to investigate the decision-making processes of individuals affected by the earthquake, beyond financial, technical, and governance factors. Future research should focus on how families are adapting their homes post-reconstruction and the strategies employed by households, communities, and local governments. Additionally, employing a detailed settlement approach, such as Central Place Theory, in housing reconstruction models could provide valuable insights into the socio-economic impacts of the reconstruction process. This approach would improve our understanding of the broader effects and inform future housing and settlement strategies.

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Flood Hazard and Risk Assessment of Settlement at the Bank of Bagmati River of Kathmandu Valley, Nepal

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Abstract

Bagmati River originates from Northern hills of Kathmandu valley and flows through the middle of the valley. Kathmandu valley is vulnerable to flood hazard due to rapid encroachment of settlement in flood plains of the Bagmati River. This objective of this study is analyzing the flood hazard and risk of settlement at the bank of Bagmati River from Shankhamul to Balkhu of Kathmandu valley and the expected number of people affected. The flooded areas along the catchment area have been mapped based on the flow rates for different return periods using the HEC-RAS model and GIS for spatial data processing and Analysing the result from HEC-RAS 6.3.1. The areas along the Bagmati River from Shankhamul to Balkhu in the study area were simulated to be inundated for 50 and 100 years return periods. An inundation map displays the spatial extent of probable flooding for different scenarios and can be present either in quantitative or qualitative ways. The flood inundation maps for 50 and 100 years return periods were prepared using HEC RAS and Risk on the basis of depth map generated from Arc Map GIS. Population under risk is analyze on the basis of population density and Inundated area. The major findings in the study is 31391 & 32141 Population and 1.835575 & 1.879375 km2 area are in the inundated in 50 and 100 years return Period respectively. Therefore, proper flood management can be adopted to reduce the adverse effects of flooding of Settlement living at the bank of Bagmati River.

Key words: Bagmati river, Flood Management, Hydrograph, Vulnerability

Introduction

Flood is one of the striking water induced disaster that hits most of the part of the world. In Nepal also it is one of the serious disaster which affect the human lives and huge amount of property. The increase of population and squatter settlements of landless people living at the bank of the river has tremendous pressure in encroachment of floodplain making them vulnerable to flood damage [4].

In South Asia, there is an increasing trend in the number of people affected by floods. India has the highest number of people affected by floods followed by Bangladesh. In the period from 1976 to 2005, 332 flood events killed about seven million and affected billion people 1 in South Asia [2]. Developing countries are particularly vulnerable to extreme weather events especially given the current climatic instability which can cause substantial economic damage [11].

Concerns for flooding and the associated human impacts are clearly of global significance, especially when allied with the fears of climatic change and associated changes in rainfall events and sea level rise [9]. The rapidly growing urban environments in many areas correspond with a lack of urban planning strategies, the deterioration and lack of capacity of urban drainage infrastructure and an increased rate of development on floodplains. Floods that cause substantial devastation in Nepal are triggered by five different mechanisms: continuous rainfall and cloudbursts, glacial lake outbursts, landslide dam outbursts, failure of infrastructure, and sheet flooding or inundation as a result of excessive rain, bank overflow, or obstruction to the flow from infrastructural development. According to [6] Nepal falls in 11th position on disaster venerability in the world and half of its population is under the threat of four types of disaster at a time including flood. Nearly 77% of the total losses caused by water-induced disasters – floods, landslides, and avalanches occur where in the Terai region the main water-induced disasters are floods.

Floods have always been natural disasters, which are associated with human and financial losses and have influenced human's life [1]. While the number of deaths has not been increasing, there have been observed increases in the total number of people affected and monetary damages [13]. Floods are natural events and not only replenish alluvial soils, substantially increase the yield of the land, and sustain rich habitat for natural systems, but also inflict substantial damages on human activities in the floodplain [12].

The Bagmati River emerge into the Kathmandu from steep and narrow mountain gorges, they spread out with an abrupt gradient decrease causes deposition of the bed load, changes in river course, and frequent floods. Each year, floods of varying magnitudes occur due to intense, localized storms during the monsoon months (June to September). The settlement at the bank of Bagmati river of Kathmandu valley increases rapidly and population density is high. People residing in settlements having problems like improper sanitation, unhygienic environmental conditions, social, economic, health, educational and cultural. The informal buildings made of GI sheets and some of houses are solid, due to their generally poor or non-existent structural detailing and the material used for their construction, are particularly vulnerable to water infiltration and seepage during extreme rainfall and/or flooding. The lack of formal engineering criteria in the construction of informal settlements together with their generally poor construction quality renders them particularly vulnerable to extreme natural phenomena [5].

Bagmati River Basin and settlement of Kathmandu

The Bagmati River is the main cradle of the Kathmandu valley having very rich in cultural as well as aesthetic value. The Bagmati River originates in Baghdwar of Shivapuri hills in the north of the Kathmandu Valley. The river is fed by numerous tributaries originating from the Mahabharata and Siwaliks range before it reaches the Terai at Karmaiya and to the Gangetic plain. The total catchment area of the Bagmati River is about 157 sq. km with the length of 44 km from its origin at an elevation of 2732m to Katuwal daha, which lies at an elevation of 1140m. The Bagmati is the principal river of the Bagmati basin in Nepal. The Bagmati basin is characterized as medium or dry basin fed by springs and monsoon rainfall [3].

The Bagmati river system includes seven tributaries - Bagmati, Bishnumati, Dhobikhola (Rudramati), Manahara, Nakkhu, Balkhu and Tukucha (Ichhumati) rivers and the five sub-tributaries Godavari, Hanumate, Sangla, Mahadev and Kodku Khola. The water flowing in the Bagmati River is considered holy and is used for cultural and ritual ceremonies practiced at the many significant temples located along its banks. In 1985 it was estimated that there were only 17 settlement communities in Kathmandu, but now the number has grown to 40. There are a total of 12,726 people (6,612 males and 6,114 females) living in 2,735 households in the

40 settlements of the valley [9]. Similarly, about 2.9% of the total population of Kathmandu lives in informal settlements (KMC/ WB, 2001).

Table 1: Name of River and Settlements close to bank of river of Kathmandu valley

S.N	River of Kathmandu valley	Name of Settlements
1	Bagmati River	Shanti Nagar, Bijay Nagar, Jagrit Nagar, Gairigaun, Chandani Tole, Pragati Tole, Kalimati Dole, Kimal Phant, Bansighat, Kuriyagaun and Sankhamul
2	Bishnumati River	Dhikure Chouki, Kumaristhan Buddhajyoti Marga, Balaju Jagriti Tole, Sangam Tole, and Ranibari
3	Hanumante River	Manohara Bhaktapur
4	Dhobikhola	santi Binayak, Devi Nagar, Bishal Nagar, Kupondole and Pathivara
5	Tukucha Khola	Narayantole, Maharajgung and Khadipakha Maharajgung
6	Others location	Palpakot, Anamnagar, Maijubahal, Kumarigal, Radhakrishna Chowk, Mulpani, Kapan Dhungen, Subigaun, Ramhiti, Mahankal, Dhumbarahi Sukedhara, Mandhikhatar, Galfutar, Ramghat, Dhaukhel and Bhimmukteshwor

Above table shows number of settlement and household population of settlement, it shows maximum number of household and population along the Bagmati River. It is a question that the existing morphology of a river system can accommodate these frequent and prolonged high floods. The other question is the increasing settlement at the bank of Bagmati River modifying the floodplains of river systems. All these factors contribute to the increasing damages and risks caused by floods. Due to fast growing and opportunities in Kathmandu valley, increasing Settlement encroachments which make the population more vulnerable to frequently occurring floods.

Those factors emphasize the importance of mitigating flood related disasters of settlement. At present structural measures are not suitable in that task due to the question of sustainability of such measures. Most of the time non-structural measures like flood forecasting, proper early warnings and conducting awareness programs among the flood affected community etc, can be very effective. Modelling of watersheds with modern technology makes this easy. Application of GIS and remote sensing technology to map flood areas will make it easy to plan non-structural measures which reduce the flood damages and risks involved. HEC RAS is one-dimensional hydrodynamic model capable of performing water surface profile calculation for steady and unsteady flow in natural or constructed channels [7]. It will be a great benefit to the people to implement a flood management program that consists of the digital data were overlaid on the image and flood hazard mapping was done.

Developing reliable watershed simulation models and calibrating as well as validating them for watersheds with measured and simulated data is a challenging issue [3]. The study presented here consists of hydraulic modelling and flood damage assessment focusing on the settlement near to Bagmati river of from Balkhu to shankhamul. The hydraulic model of the Bagmati stream bed was developed using the Hydrologic Engineering Center’s River Analysis System (Hec-RAS).The flooded Area of settlement was identified with Arc GIS Software. The study presents Practical action and solution to increase safety of settlement by flood protection in the study area of Kathmandu. The study focused on impact of flood and assessment of the proposed flood mitigation measures and the selection of the best alternative of the flood protection for settlement settlement1 at the bank of river.

2. Materials and Methodology:

The case-study focuses on flood risk assessment for the settlements located from shankhamul (27°40’43.16‖ N, 85°20’1.26‖ E) to balkhu (27°41’5.2‖ N, 85°17’59.3‖E) near to bagmati river of Kathmandu valley. The settlements of study area are Shankhamul,UN park, Balkhu are lies in flood-prone area of Bagmati River. The flood hazard mapping is created between Shankhamul to Balkhu. The River originates in the Kathmandu Valley,which comprises about 15% of the area of the Bagmati basin in Nepal.

The data used in this study are Settlement Data and Hydrologic data which includes DEM of Bagmati River Catchment of Spatial resolution 5x5 m collected from Department of Water Resource and Irrigation analysis daily maximum river discharge data from gauge stations 550.05 for a period 1992 to 2010 years collected from Department of Hydrology and Meteorology. Land use data from USGS, GIS data from department of survey, and others various data from Cross sections along the river channel created by the HEC-RAS, different

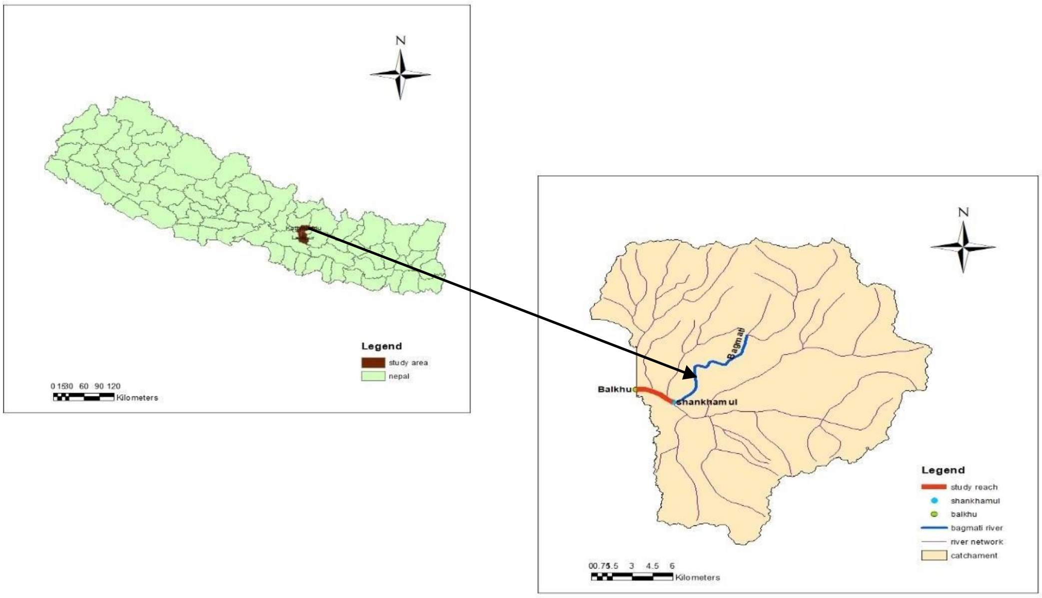

Figure 1: Study Area of Bagmati River Basin (Produce From GIS)

sources, like college library, ICIMOD library, Central Bureau of Statistics, and Department of Survey.

From the data various analysis was carried out like hydrograph analysis, Catchment area ratio Analysis, flood frequency ratio analysis, vulnerability analysis of settlement, Flood risk analysis of settlement and Flood plain mapping. The general method for creating floodplain maps for a river has following major stages:

Step 1. Setting up the HEC-RAS model

Step 2. Creating RAS

Step 3. Adding river attributes

Step 4. Creating RAS mapper

Step 5. Run HEC-RAS model.

Step 6. Export HEC-RAS Output

Step 7. Mapping inundated areas in HEC-RAS and Analysis of Output Result in GIS

2.1 Mapping inundated areas in HEC-RAS and Analysis of Output Result in GIS

Inundation area with depth can be seen in RAS mapper and output exported is analysed in GIS. Classify different depth area and Hazard and Vulnerability and risk map are generated and data find out.

Floods are prevalent and recurring natural hazards that disrupt social and economicactivities. This hazard leads to many fatalities and extensive damage to livelihood systems, property, infrastructure, and utility services (Amarasinghe et al. 2020). This can be attributed to various factors, including rising urbanization, increased developmental and economic activities in flood plains, and global warming. Recent research has also shown that large-scale human interference in nature's order (deforestation, increased sedimentation rate in river channels, intrusion of human settlement in riverbank areas, etc.). The floodplain mapping for this study was done with ArcGIS (Arc Map 10.4) and HEC-RAS(6.3.1version). The processing stage was done completely within HEC-RAS using the river geometry prepared in the previous stage. The final stage consists of analysing the results from the HEC-RAS model within ArcMap.

No of settlement household were used for assessment of vulnerability of flood prone areas. Vulnerability was assessed for using data of no. of household. The household Polygon was overlaid with flood extent maps corresponding to 50 and 100 year return period flood events. Household vulnerability maps were produced corresponding to 50 and 100 year return period floods. Considering risk as a function of Hazard & Vulnerability, map multiplication was done in ArcGIS environment to generate the Risk Maps corresponding to 50 and 100 year flood event with respect to household. Then risk of settlement is obtained by multiplying risk map with population.

Flow chart of the whole process is shown below:

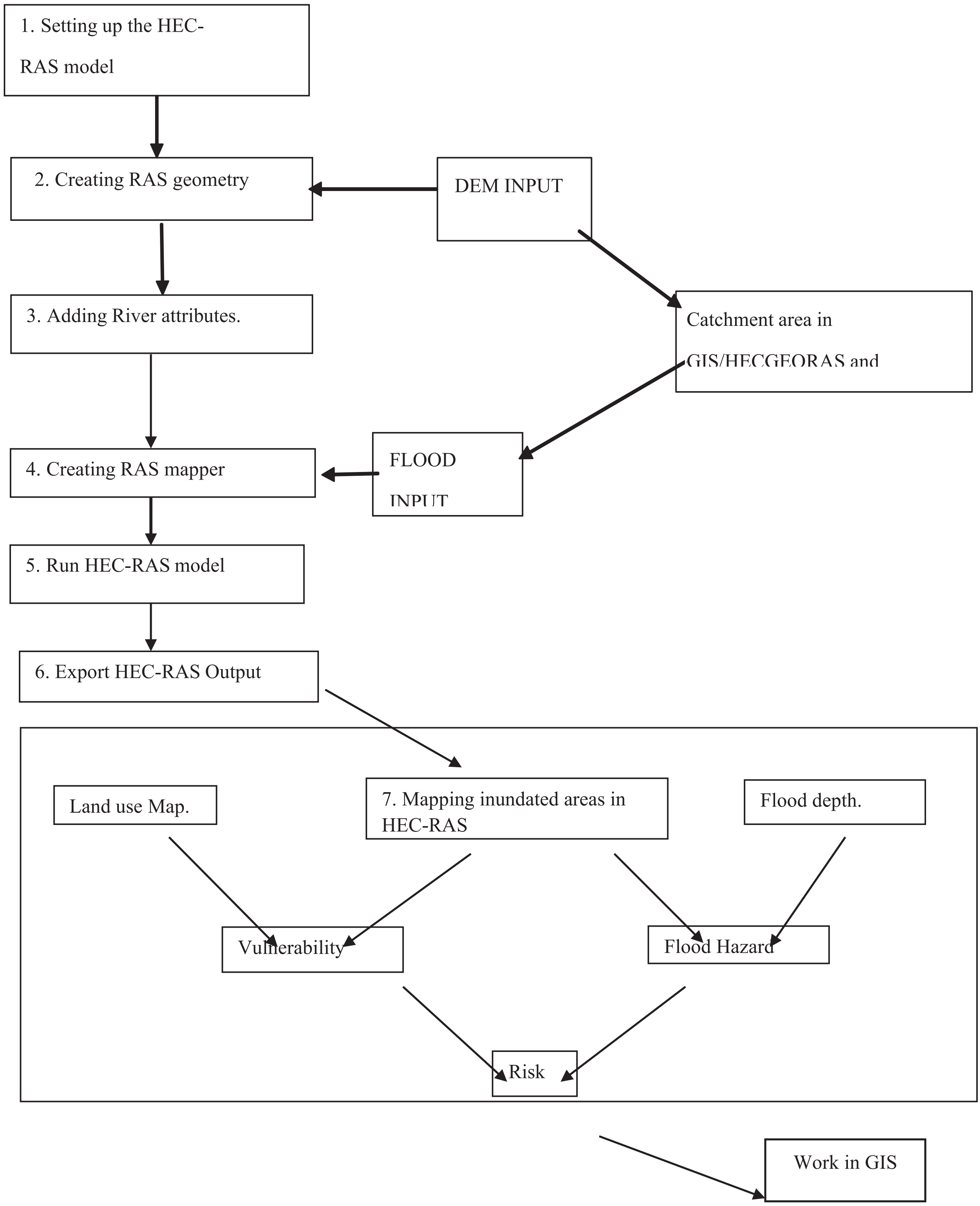

Figure 2: Flood Hazard Modelling Flow Chart

3. Result and Discussion:

The average size of household of settlement of Bagmati River is 4.5 (10). Kathmandu District is a district located in Kathmandu Valley, Bagmati Province of Nepal. It is one of the 77 districts of Nepal, covers an area of 413.69 km2 (159.73 sq mi), and is the most densely populated district of Nepal with 1,081,845 inhabitants in 2001, 1,744,240 in 2011 and 2,017,532 in 2021. The administrative headquarters of Kathmandu district is located in Kathmandu and population density of Kathmandu metropolitan city is 17,103 per square kilometre (Kathmandu District - Wikipedia), With the help of formula Population =population density in per square kilometer * area in square kilometer population was calculated and shown in table.

3.2 Hydrograph Analysis

Hydrograph is plotting of mean maximum monthly discharge of gauge station 550.05 at Khokana of Bagmati River can be seen in figure below. Maximum discharge of each month of the year1992 to 2010 taken. Mean monthly maximum discharge of each month is obtained by average of maximum discharge of each month of each year.

Table 2: Mean Monthly discharge of Bagmati River

Month	Bagmati River discharge(m^3/s)
Jan	9.11
Feb	7.27
Mar	5.90
Apr	7.38
May	20.24
Jun	72.03
Jul	220.20
Aug	205.09
Sep	108.71
Oct	29.75

Nov	11.35
Dec	8.85

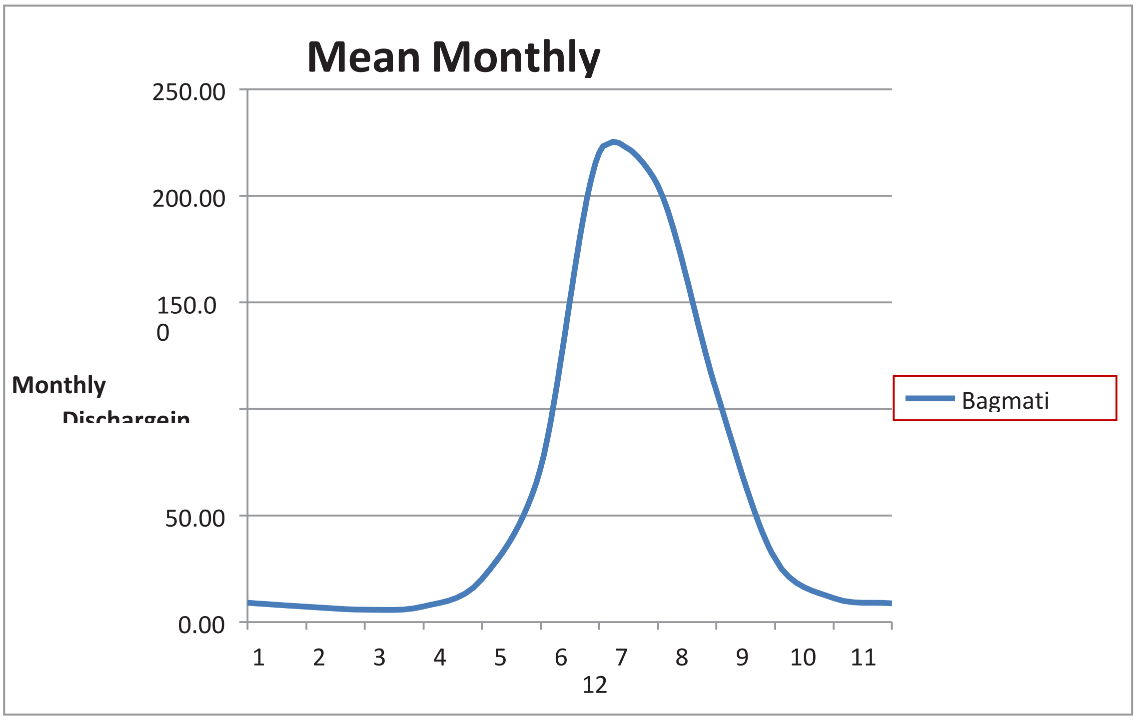

Figure 3: Mean monthly Hydrograph of Bagmati River

3.3 Catchment Area Ratio Analysis

The Catchment area of Gauge station (550.05) and study area at Balkhu of Bagmati Riverare 606 & 445.40 km2 respectively as shown in table 6 below.

Table 3: Catchment area of Bagmati Rivers

S.N.	Location	Catchment Area (km2)	Area Ratio
1	Gauge station(550.05)	606	

2	Balkhu (27º41’5"N, 85º17'58‖E)	445.4	0.7349

Cathment area of Bagmati River At Balkhu

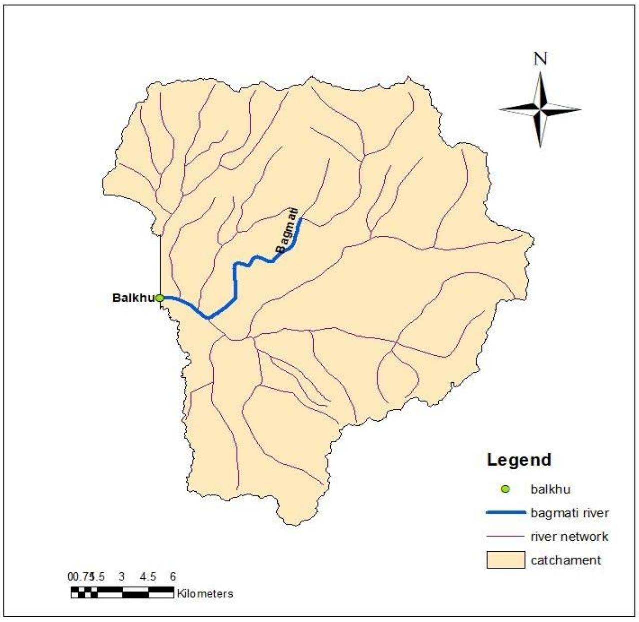

Figure 4 : Catchment of Bagmati River for study Area at Balkhu

Cathment area of gauge station(550.05) 0f Bagmati River

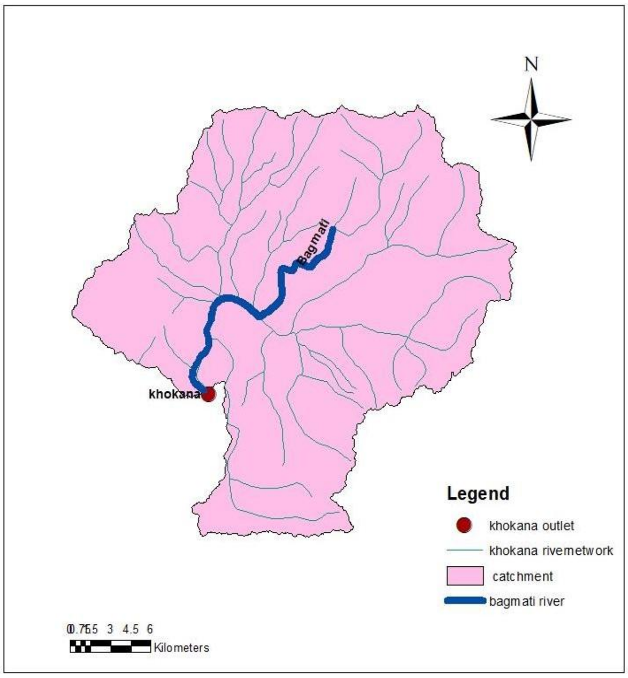

Figure 5: Catchment of Bagmati River of gauge station (550.05) at Khokana

Table 4: Maximum Discharge of gauge station and study area at Balkhu of Bagmati River

S. N.	Year	Q_550.05(Khokana)m3/s	Area Ratio (A_Balkhu/ A _550.05)	Q_Balkhu m3/s
1	1992	103	0.73 5	75.705
2	1993	447		328.545
3	1994	318		233.73
4	1995	230		169.05
5	1996	266		195.51
6	1997	367		269.745
7	1998	501		368.235
8	1999	349		256.515
9	2000	331		243.285
10	2001	211		155.085
11	2002	814		598.29
12	2003	265		194.775
13	2004	195		143.325
14	2005	197		144.795
15	2006	122		89.67
16	2007	340		249.9
17	2008	103		75.705
18	2009	348		255.78
19	2010	221		162.435

The above table shows the discharge of study area at Balkhu Outlet using CAR Method from year 1992 to 2010.discharge at Balkhu calculated by multiplying discharge of gauge station with area ratio of catchment.

3.4 Flood Frequency Analysis

Flood frequency analysis is a used calculates flow values corresponding to specific return periods or probabilities along a river. Using annual peak flow data that is available for a number of years At Balkhu of Bagmati River, flood frequency analysis is used to calculate using Gumbel's, Log Pearson Type III (LP III) and the Log Normal (LN) Method are summarized below in Table 2.

The Table 5 shows that flood frequency analysis calculate by Gumbel showed discharges of 610 and 690 m3/sec for 50-years and 100-years return periods respectively, which were slightly higher as compared to the results obtained by Log-pearson type III Distribution and, Log Normal method, Maximum discharge obtained from Gumbel method of different return Period is used for modelling.

Table 5: Flood frequency analysis using Gumbel's, Log Pearson Type III (LP III) and theLog Normal (LN)

Return period	Gumbel (m3/s)	Log-Pearson type 111 Distribution (m3/s)	Log Normal Distribution (m3/s)
2	203.7	195	195
5	333.9	303	304.5
10	420.1	382	384.4
20	502.8	463	466
50	610	576	579
100	690	668	669
200	769.9	765	763
500	875	903	895.5

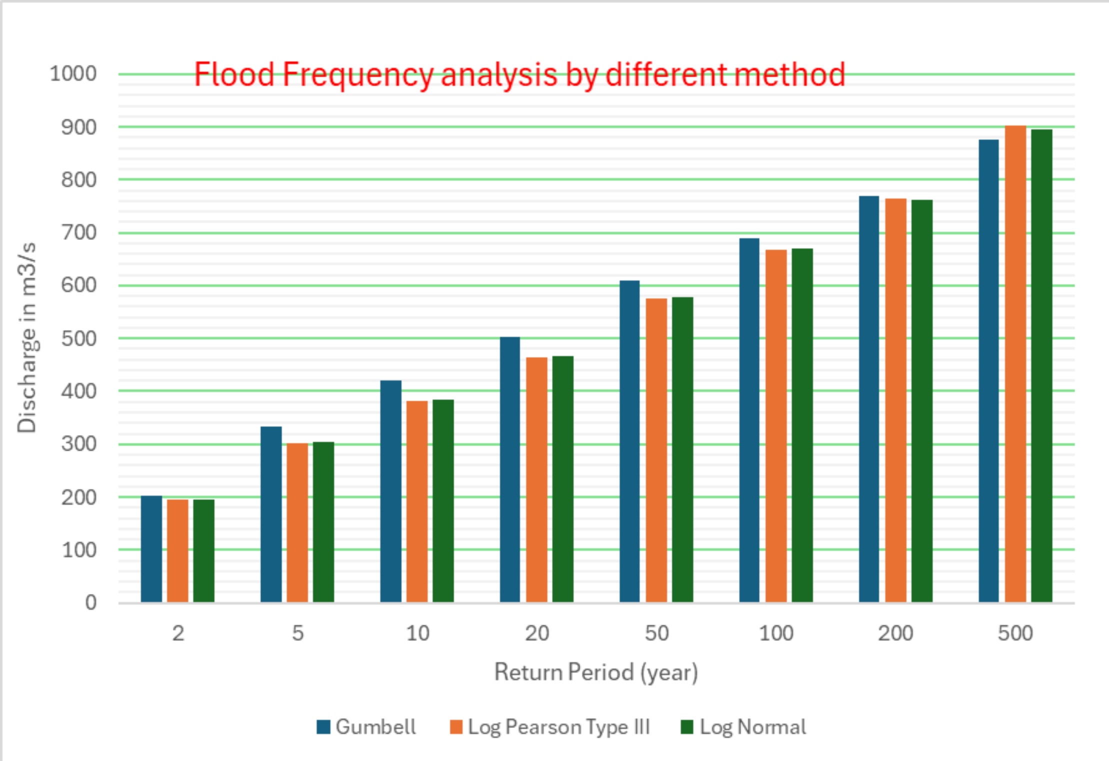

Figure 6: Flood frequency Analysis results in different Method

3.4 Flood Hazard Mapping Analysis

The floodplain mapping for this study was done with ArcGIS, HECGeoRAS, and HEC- RAS. The Preprocessing stage consisted mostly of model input data preparation and was done in ArcGIS using the HECGeoRAS extension. The processing stage was done completely within HEC-RAS using the river geometry prepared in the previous stage. Thefinal stage consists of analyzing the results from the HEC-RAS model. Within ArcMap. HEC-GeoRAS helps in creation of the data needed for the HEC-RAS model and the transfer of data between ArcGIS and HEC-RAS.

The preprocessing stage consisted mostly of collecting and preparing data for the hydraulic model. To begin, a section of the major Bagmati River was defined in the study area. Once the study area was defined, the features that might be affected in the event of flooding can be deduced. In order to create the necessary Bagmati river geometry for HEC-RAS, elevation data were needed. Digital elevation model data of 5m resolution is use as shown in figure. The elevation data were converted to a triangulated irregular network (TIN) elevation model, then the next step was to create the river geometry in ArcGIS (Figure).

The HEC-GeoRAS extension was used to set up the necessary features that would be needed for the HEC-RAS model (i.e., stream centerline, bank lines, cross sections, etc.). HECRAS uses these features to obtain an accurate layout of the river and to establish the cross-sectional elevations of the potential floodplains. The cross sections must extend far enough to ensure that all water from the flood is contained within the cross-sectional area. Methods for setting up the model using HEC-GeoRAS were taken from the HEC-GeoRAS user manual. The river geometry was digitized using the ArcGIS editing features. Figure (shows the digitized river features on top of the TIN. HEC- GeoRAS uses the line features in conjunction with the TIN to extract elevations for the cross sections and flow profile. The Manning's roughness values

DEM

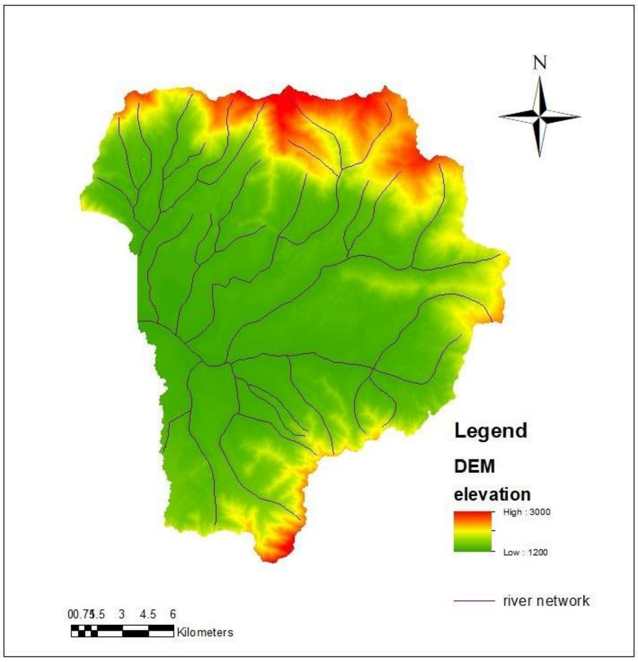

Figure 7: DEM of Bagmati river Basin

TIN MAP

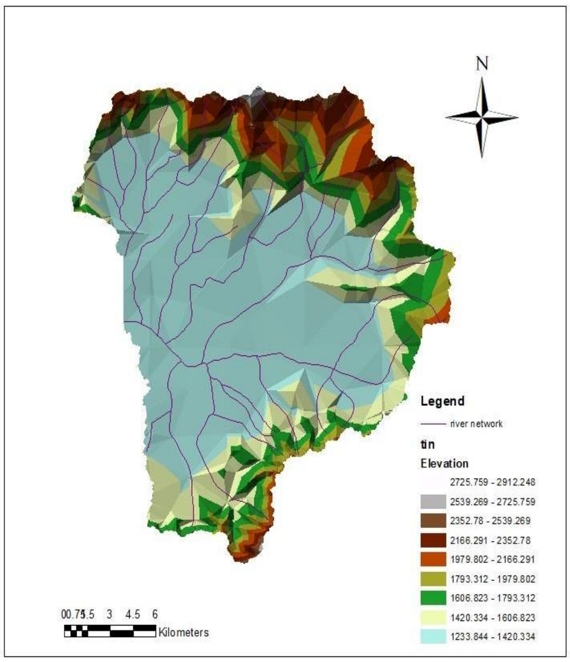

Figure 8: TIN of Bagmati Basin

represent the roughness of the channel surface, which can influence the overall flow rates and velocities in the channel. The land cover data for the study area were downloaded and converted from a raster to a polygon shape file. A value of Manning's roughness was assigned to each land cover category.

Pre-Processing

The geometry data created in ArcMap were exported into HECRAS. Once in HEC-RAS, it was necessary to modify and correct the designated left and right banks of the river. Theleft and right banks defined in ArcMap using the HEC-GeoRAS extension didn't match the actual left and right banks. The solution to this problem was to use the cross section editor in HECRAS and manually select the left and right banks based off of the cross section geometry. After correcting the geometry, a steady flow analysis was used to route two flows of 609.79 and 689.99m3/s through the river. The steady flow analysis producedwater surface profiles and the extents of each floodplain. HEC-RAS uses a number of input parameters for hydraulic analysis of the stream channel geometry and water flow.

These parameters are used to establish a series of cross-sections along the stream as shown in Figure 6. In each cross-section, the locations of the stream banks are identified and used to divide into segments of left floodway, main channel, and right floodway. HEC-RAS subdivides the cross sections in this manner, because of differences in hydraulic parameters. For example, the wetted perimeter in the floodway is much higher than in the main channel. Thus, friction forces between the water and channel bed have a greater influence in flow resistance in the floodway, leading to lower values of the Manning coefficient. As a result, the flow velocity and conveyance are substantially higher in the main channel than in the floodway.

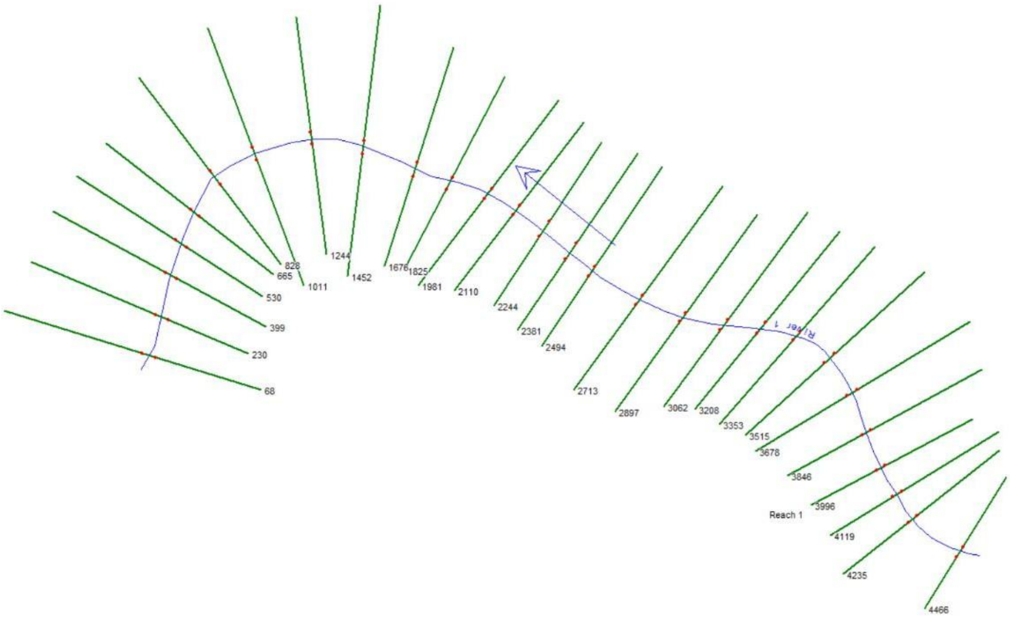

Figure 9: Location of the selected cross sections along the main reach of Bagmati River

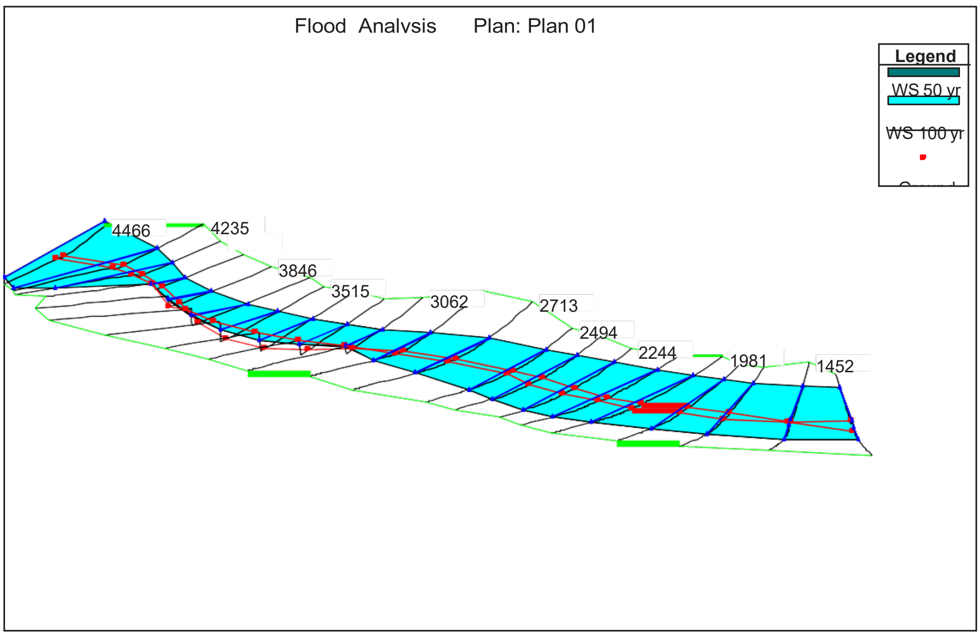

Fig10: view of water surface profile for a flood of 100 years return period.

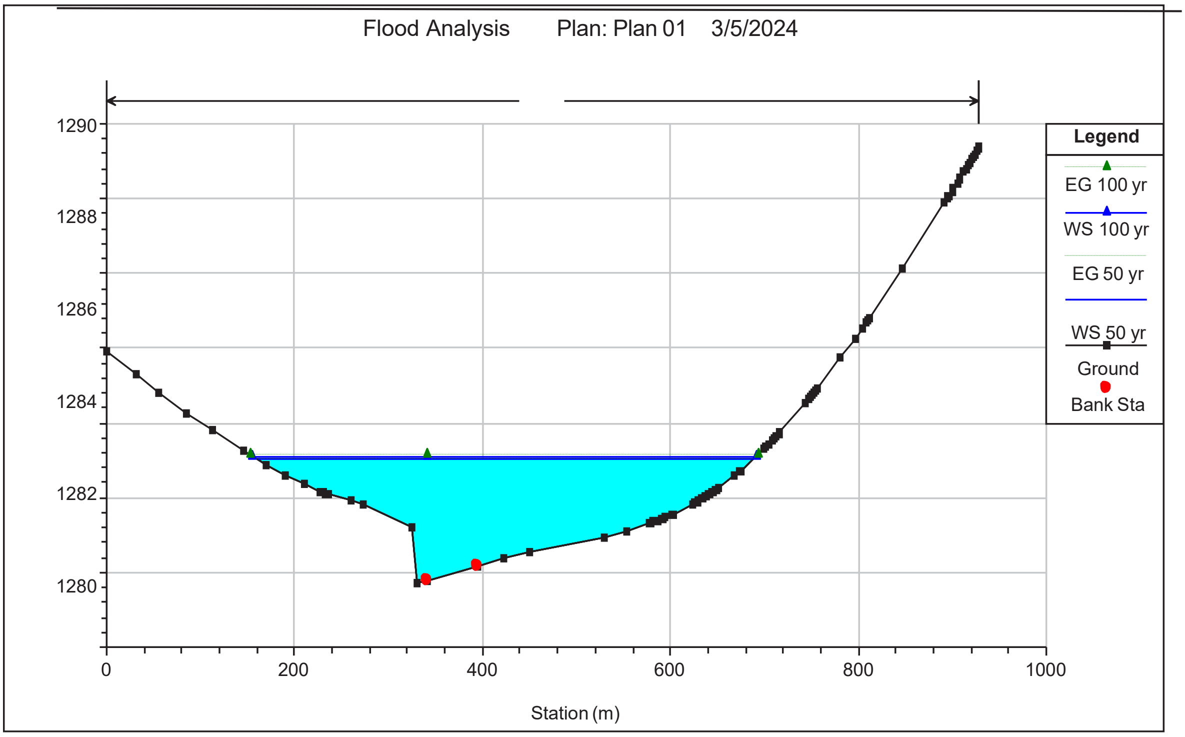

Figure 11: Cross-section for a flood of 100 years return period

Post processing

The results from the HEC-RAS model were then imported back into ArcMap using the HEC-GeoRAS tool. After importing the results into ArcMap it was clear it was necessary to correct errors in the extents of the flood plains. The error seen in the HEC-RAS model results was flooding being shown in ineffective flow areas. Ineffective flow areas are areas of low elevation that do not connect with the main floodplain area. If not defined, HEC-RAS will route water through these areas in the simulation. The solution to this problem was to use the cut tool in ArcMap, and remove the erroneous results.

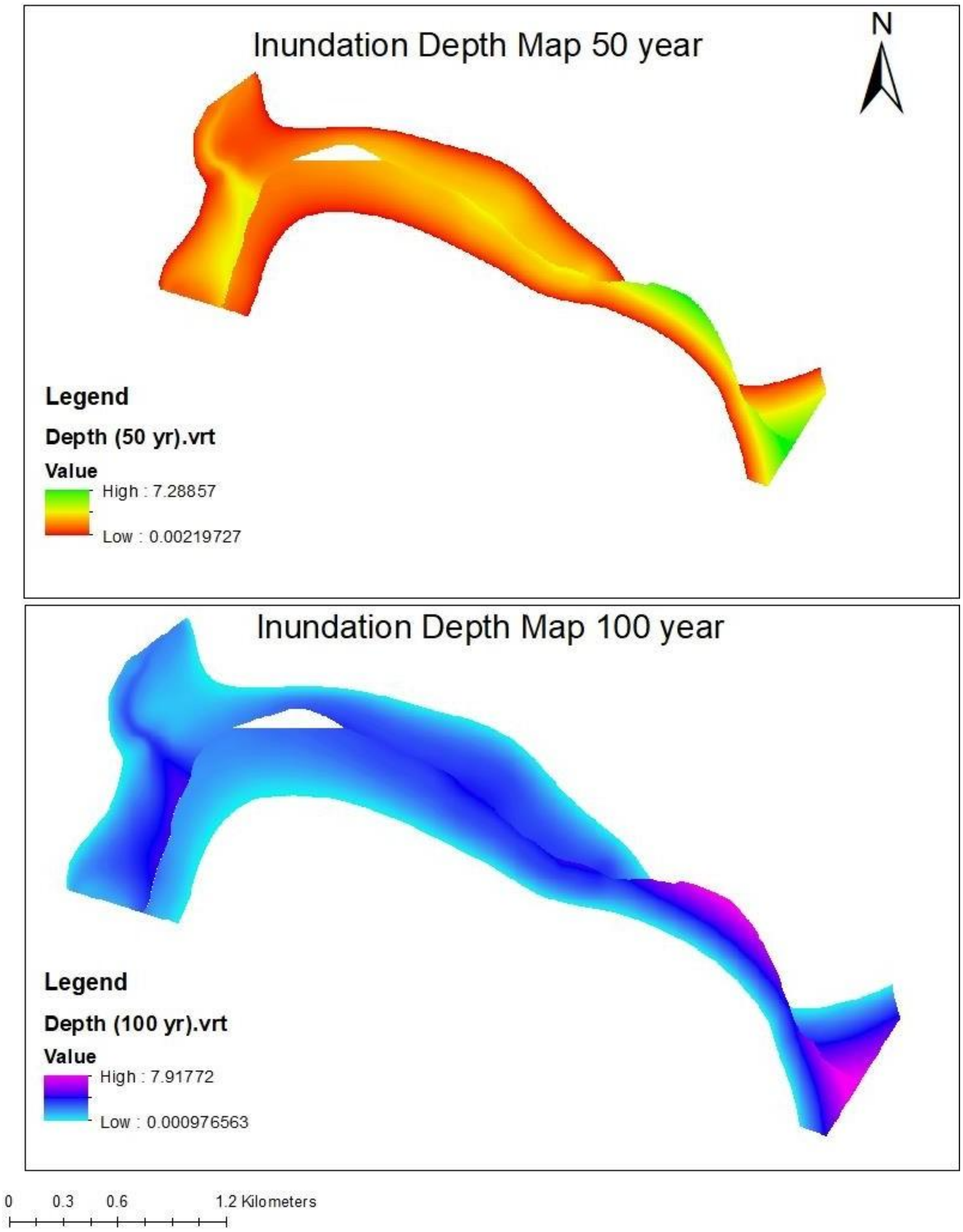

Fig12: Inundation Map of river for 100 Year Return Period

Flood hazard is categorized based on the level of difficulties in daily life and/or damage to properties. Flood hazard assessment is the estimation of overall adverse effects of flooding. It depends on many parameters such as depth of flooding, duration of flooding, flood wave velocity and rate of rise of water level. One or more parameters can be considered in the hazard assessment. In the present study, depth of flooding was considered for hazard assessment.

3.5 Vulnerability Analysis

No of household were used for assessment of vulnerability of flood prone areas. Vulnerability was assessed for using data of no. of household. The household Polygon was overlaid with flood extent maps corresponding to 50 and 100 years return period flood events. Household vulnerability maps were produced corresponding to 50 and 100 years return period floods. Can be shown in figure

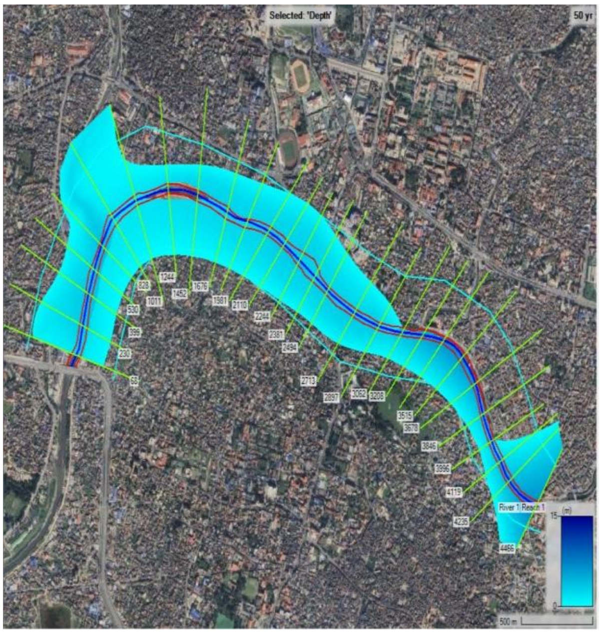

Figure 13: Vulnerability Map of Settlement Household of Bagmati River of 50 Year Return Period

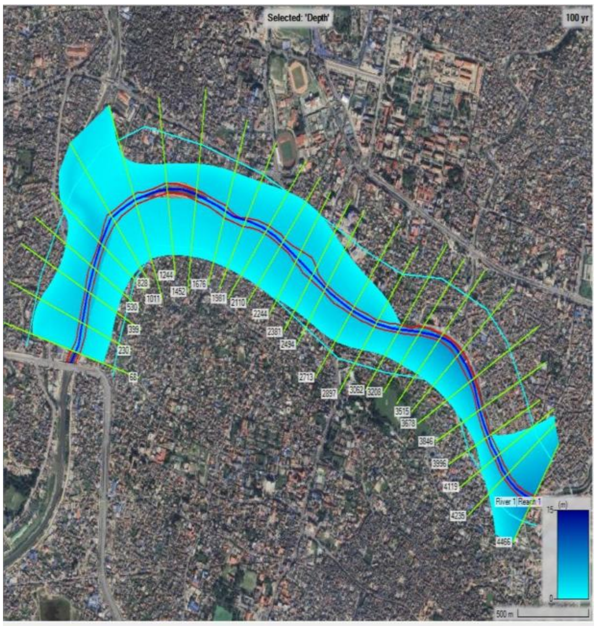

Figure 14: Vulnerability Map of Settlement Household of Bagmati River of 100-year return period

3.6 Flood Risk Analysis of settlement

Considering risk as a function of Hazard & Vulnerability, map multiplication was done in ArcGIS environment to generate the Risk Maps corresponding to 50 and 100-year flood event with respect to household. Then risk of settlement is obtained risk map multiply by population.

The assessment of flood indicates that number houses of located under more than 1m depth of flood is high. It seen from map that 31391and 32141 population of settlement are under the risk of flood of 50yr and 100 year return period respectively. Flood risk of settlement increased with increase in depth of flood. For 50-year flood and 100 flood are high risk population are 11278 and 12134 respectively. From result it shows that All people in this zone are not safe in their homes but at the most they may be safe on their roofs. All building types vulnerable to structural damage. Flood risk analysis showed that settlement at the bank of Bagmati River live under high flood risk. This indicated potential damages to settlement.

Table 6: Flood Risk of Number of Household and Population of Settlement

SN	Hazard	Depth(m)	Area of Inundation for 100 yearReturn period(Sqkm)	Vulnerable Population for 100 yearReturn period as per population density 17,103per sqkm	Area of Inundation for 50 year Return period(sqkm)	Vulnerable Population for 50 year Returnperiod as per population density 17,103per sqkm
1	Very Low	<0.5	0.200375	3427	0.208125	3559
2	Low	0.5-1	0.2863	4896	0.305625	5227
3	Medium	1.0-2.0	0.62505	10690	0.612275	10471
4	High	2.0-5.0	0.7095	12134	0.65945	11278
5	Extreme	>5	0.05815	994	0.0501	856
	Total		**1.879375**	**32141**	**1.835575**	**31391**

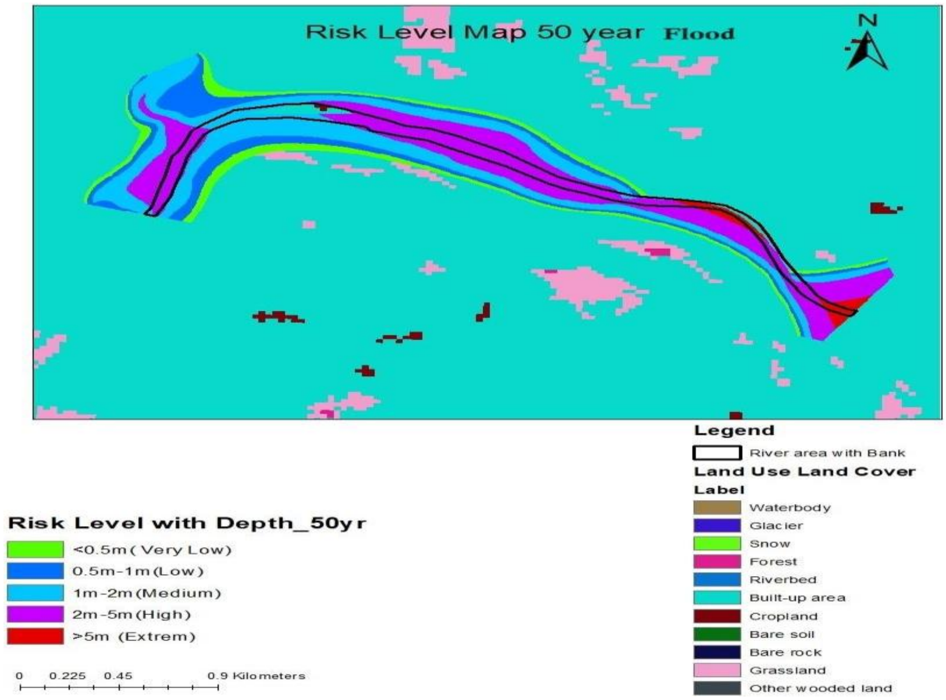

Figure 15: Risk Map of Settlement of Bagmati River 0f 50 Year Return Period

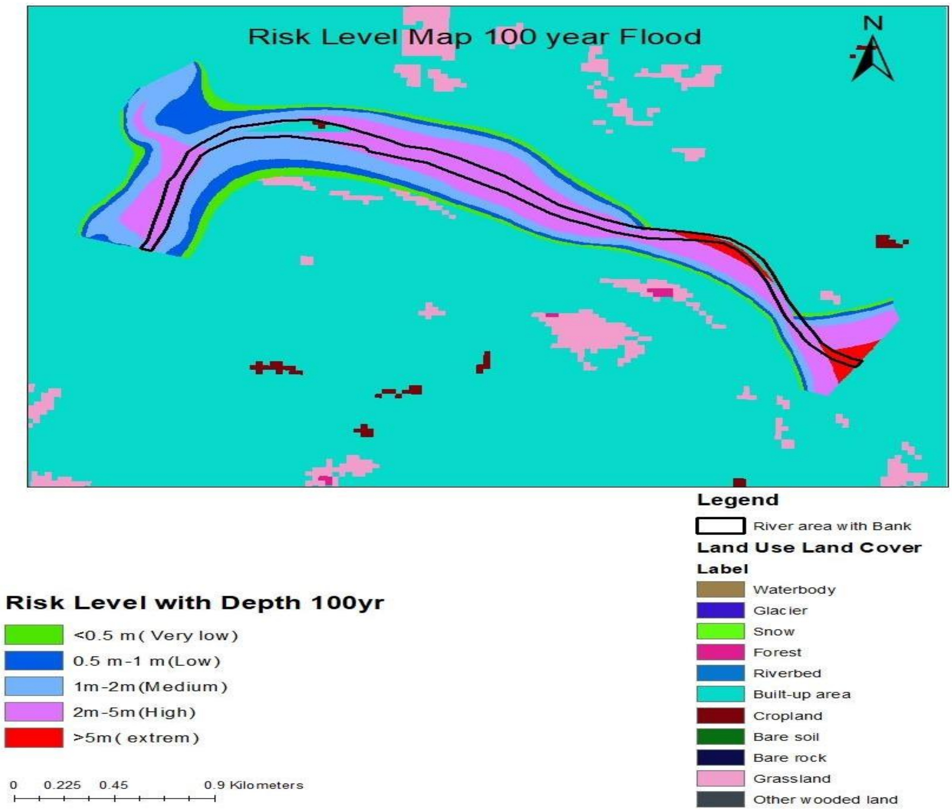

Figure 16: Risk Map of Settlement of Bagmati River 0f 100 Year Return Period

4. Conclusion

Settlement of Kathmandu valley had their impoverished living conditions, highly congested spaces and an absence of public facilities such as education, health, safe drinking water, sanitation and waste management. Residents of these settlements are also highly vulnerable to flood disaster. The study shows the systematic process of preparation of hazard maps of Bagmati River and flood vulnerability settlement living at the bank of river with the application of one-dimensional model HEC RAS and Arc Map GIS. The application of this models and procedure provide effective results within less time consumption and little resources. The result obtained as graphical output (maps) from the model for different return period of flood can help in decision making of flood risk analysis of settlement for disaster preparedness and mitigation activities.

Flood hazard assessment was also done according to different return periods. The relation between flood discharge and flooded area shows that there is increment of flooded area with increase in discharge. Total flooded Area is 1.835575 and 1.879375 km2 of 50 years and 100-year flood respectively. One of the biggest challenges remain here is the generation of the precise DEM. In this study DEM of 5m resolution has been used whichis not sufficient for hydrological modelling in a small catchment. Thus, availability of high resolution DEM is necessary to get higher accurate results. This kind of models is very useful and important for preplanning of disaster and also planning for proper land use, land development and settlement planning.

The flood vulnerability was assessed with regard to number of household in the flood plain of the study area. It showed that 31391 and 32141 Population of settlement are vulnerable to flood of 50yr and 100yr of flood respectively from Shankhamul to Balkhu. For 50-year flood and 100 flood are high risk population are 11278 and 12134 respectively. All building types vulnerable to structural damage. The result of this reportis very important as a preliminary information guide for settlement planning, decision making in preparedness and mitigation of flood disaster to settlement.

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Study of Seismic Performance of Vertical Irregular Structure with Glass Fiber Reinforced Shear wall.

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Abstract
At present days building a structure with all the regular configurations is not feasible in most of the cases due to the irregular plot dimensions, aesthetic visual and functional requirements in the urban cities. The structures with more irregular configuration either horizontally or vertically are more vulnerable to earthquake. Such vertical irregularity stabilized by providing Shear wall. GFRP bars are light weight, ductile and noncorrosive in nature so GFRP bars were used in shear wall. So, this study aims to find out seismic response of vertical irregular building with GFRP shear wall under seismic load. The setback at both sides building with GFRP shear wall at corner analyzed using Response spectrum analysis method using NBC 105:2020 and ACI 440 1R 2006 code on ETABS software. It found that percentage of decrease of displacement with GFRP shear wall 39.52% and 37.98% in X and Y-direction respectively, percentage of decrease of drift with GFRP shear wall 44.79% and 43.43% in X and Y-direction respectively and Base shear increased by 2.42%.

Keywords: Base shear, response spectrum, storey displacement, storey drift, storey stiffness

1. Introduction

The increasing in demand for high raised building, shortage of regular plot and some architectural purposed vertical irregular building are frequently used. These vertical irregularities are such as setback, mass irregularity, soft storey etc. This vertical irregularity can significantly influence the seismic behavior of structure often making them vulnerable to earthquake forces compare to the regular structure[1]. Therefore such vertical irregularity is critical area of research in structural engineering.

Such critical are is stabilized by using the shear wall. Shear walls are parts of a structure that resist two principal forces: a) in-plane shear forces and b) in-plane bending caused by moments developed as a result of such shear forces. Also, along with these, the shear wall, as a structural functional unit, also tends to resist plane shear in the vertical direction (as a direct consequence of shear in the horizontal direction) and the buckling effect of dead loads coming from the top[2]

Glass is a nonmetallic fibre, widely used as an industrial material these days. Glass fibres refer to the fibres that are derived from naturally occurring minerals consisting of (SiO_2) monomers. Such glass fibre impregnated with an alkaline design, glass fibre reinforced polymer (GFRP) bars are made[3] At recent year Glass fiber reinforced polymer (GFRP) emerged as a promising material in engineering field of construction due to it's high strength to weight ratio, ductility, corrosive resistance . When GFRP is use in shear wall, offers effective load resistance contributing to the overall flexibility and durability of structure[4].

This study is aim to study the seismic performance of vertical irregular building with Glass fiber reinforced shear wall. The goal is to evaluate how composite material influences the seismic behavior of the vertical irregular (setback) building using ETABS software, Response Spectrum Method and NBC 105:2020[5] code. In this study such GFRP Bars are used instead of steel reinforcement in shear wall according to ACI 440.1R-06.The research parameters are such as storey displacement, storey drift, storey stiffness and base shear. The finding aim to provide the viability of GFRP reinforced shear wall as to seismic design solution in setback building.

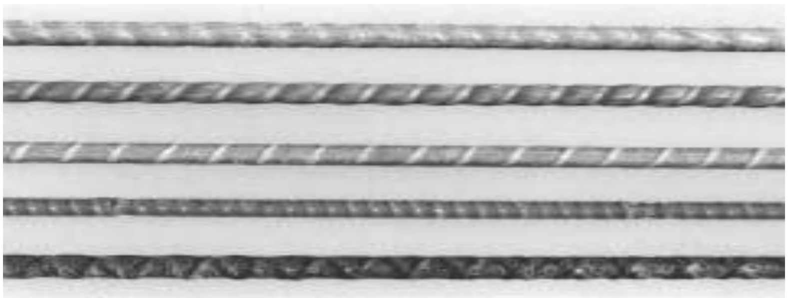


Figure 1 Different Dia of GFRP bars

2. Literature Review

Chavhan, 2015 conducted a study on "Vertical Irregularities in RC Building Controlled By Finding Exact Position of Shear Wall," using Response Spectrum Analysis method on 11th storey building with four concentric shear walls (2 shear walls in the x- direction and 2 shear walls in the y- direction), with thickness of 150 mm and 250 mm, respectively using ETABS software. It was concluded that shear wall should be placed at points by coinciding centroid of building and the center of gravity.

Student, 2018 conducted a study on "Seismic Analysis of Shear Wall at Different Location on Multi-story RCC Building," using Response Spectrum Analysis method on G+9storey building with different locations of shear wall. Four models of buildings with different locations of shear wall were modeled using STAAD PRO software. It was found that maximum lateral displacement increased as the story height increased and also time period increased as the model frequency increased. Due to the presence of a shear wall at the center of model 4, the minimum lateral displacement of building was reduced compare to all models. The maximum base shear was observed in model 4 in both X and Y-directions and minimum moment was observed for model 4 compared to other models. The maximum axial force was found to be in model 2 and the maximum shear force and moment were found in model 1 compared to all models. In types 2, 3 and 4 the maximum displacements were reduced to 40 to 50%, the maximum base shear was reduced to 10 to 20% and the maximum shear force was reduced by 30 to 50% as that of bare frame type. Hence the building with type 3 shear wall was more efficient than 6 all other type of shear walls.

Shahrooz & Moehle, 1990 conducted an experimental and Analytical study on "Seismic Response and Design of Setback Buildings," taking 6th storey building with a setback. The study combined of experimental test (simulate earthquake motion by shaking table) and analytical modeling (analysis using uniform Building code (UBC) static method and model analysis). It was found that both the conventional static and conventional dynamic design methods were found inadequate to prevent concentration of damage in members near the setback for certain configurations. Some building code defined effectively irregular setback buildings as those having either 33% reduction in floor mass at the setback or 25% reduction in plan dimension at the setback, the analysis of fame having various setbacks and designed by both static and dynamic method showed that simple definition was not appropriate. For setback structures, design should impose increased strength on tower and relative to the base. The static analysis method proposed that amplifies design forces and improves behavior of the tower.

Mohamed et al., 2014 conducted a study on "Experimental Investigation of Concrete Shear Walls Reinforced with Glass Fiber–Reinforced Bars under Lateral Cyclic Loading,". Four models of shear walls (1 steel reinforced shear wall and 3 GFRP shear walls) were used in this experimental study. GFRP bars with specific properties and compressive strength of 40 Map concrete were used. It was found that Glass fiber reinforced shear wall showed stable hysteretic behavior with no strength degradation, acceptable performance, drift capacity of over 3% for GFRP reinforced wall and 2.6% for steel reinforced wall. At high drift level moderate damage (cover splitting) occurred in GFRP reinforced walls compared to steel reinforced wall. GFRP reinforced shear wall showed elastic behavior with recoverable deformation up to lateral drift of 2%. GFRP reinforced shear wall dissipated energy as effectively as steel reinforced wall. Steel reinforced shear wall showed higher energy dissipation through inelastic deformation, whereas GFRP reinforced shear wall showed no permanent deformation up to 80% of ultimate capacity. Hence, GFRP reinforced shear walls demonstrated good strength, energy dissipation and deformation capacity, GFRP-reinforced walls showed recoverable and self-centering behavior up to allowable drift limits.

Mohamed et al., 2014a conducted an experimental study on "Drift Capacity Design of Shear Walls Reinforced with Glass Fiber-Reinforced Polymer Bars". Four samples (1 steel reinforced shear wall and 3 GFRP reinforced shear walls) were used in this experimental study. This study focused on getting the characteristics and behavior of GFRP reinforcement in shear wall. It was found that elastic deformation dominated in GFRP shear wall, whereas inelastic deformation dominated in the steel reinforced shear wall. In the GFRP reinforced shear walls the virtual plastic- hinge length lp was found to be equal to 0.5 lw and lw for the lower and upper limits respectively. The rotational capacity must be within 1.5% to 2.5% and for GFRP shear walls the minimum value of 0.4% for rotational demand must be provided to ensure a minimum level of deformability.

Sree & Priya, 2021 conducted a study on "Analysis of Vertical Irregular Building with Shear Wall Using ETABS". Two models of 10th story were modeled in ETABS with varying thickness of shear walls with a thickness of 150 mm and 200 mm respectively. Response spectrum analysis method was used to analyze the building to obtained shear force, torsion, bending moments, and displacements. The results of 150 mm and 200 mm thickness of shear walls were compared. It was found that 200 mm thickness shear wall performed better than the shear wall 150 mm thickness and the model 1 was less economical than the model 2.

3. Methodology

This study adopted the computational analytical approach to investigate the seismic response of vertical irregular (setback) with GFRP reinforced shear wall. This analysis is based on structural modeling using the simulation software. A regular building was model as (G+10) storey using ETABS software and response spectrum analysis conducted to check the design was safe or not and fixed the section dimension which satisfy the critical shape of building then the regular building was cut to make setback shape. Four setback buildings were made which were setback at half, setback at 2 positions, setback at both sides and setback at four sides. Among the 4 setback buildings setback at both sides found weakest shape using response spectrum analysis. Setback at both sides building was modeled with different location RC shear wall (at Corner, along X-axis, along Y-axis and Periphery). It's found that optimum location of shear wall of setback at both sides building was at corner, setback at both side building was modeled with GFRP reinforced shear wall at corner and Response spectrum analysis conducted.

3.1 Data collection

Story = G+10

Grade of concrete = M25

Grade of steel = HYSD- 500

Story height = 3 M

Column size = 800mm X 800mm

Beam size = 650mm X 750mm

Slab thickness = 125mm

Shear wall thickness = 230mm

Wall thickness = 230mm

Partition and Parapet wall thickness =115mm

Soil type- D and Zone factor (Z) = 0.35

Material = Glass fiber

Properties of the GFRP material as per[10].

Density = 2100 kg/m3

Modulus of Elasticity = 50000 MPa

Coefficient of the thermal expansion = 6 x 10-6 1/C

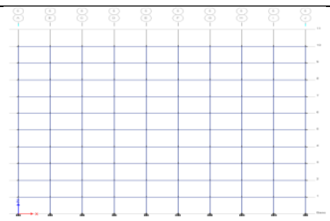
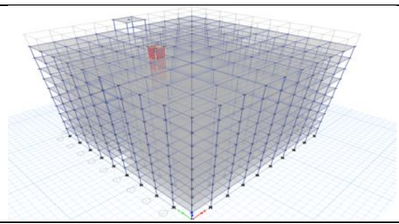
Tensile Strength = 483 to 1600 Mpa

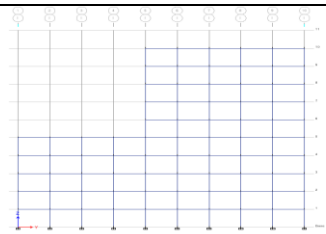
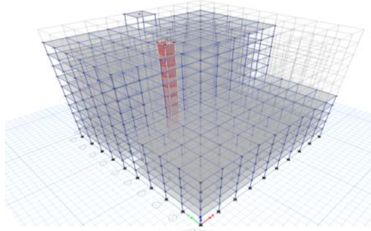
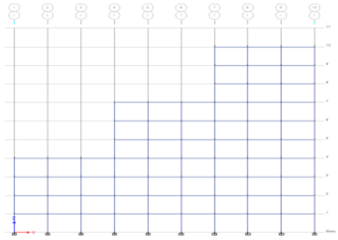
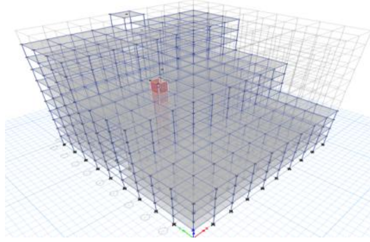
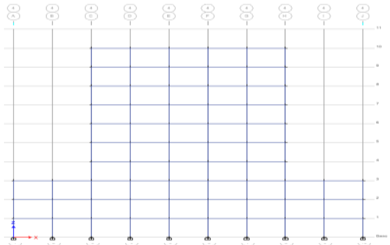
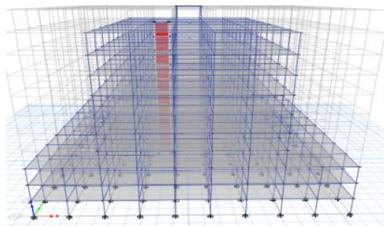
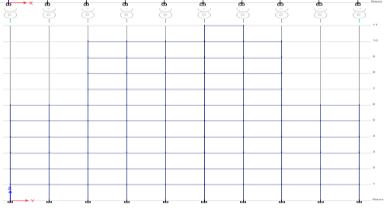
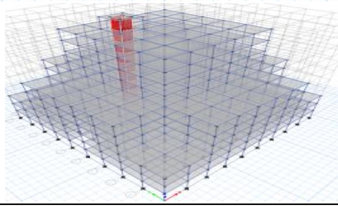
It has high electrical insulating properties.

Good heat resistant material.

It has Less stiff and light weight.

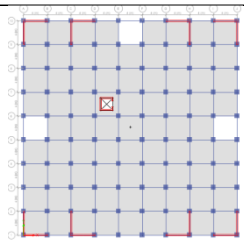
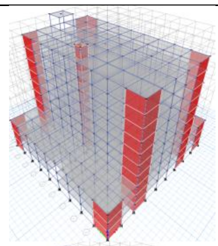
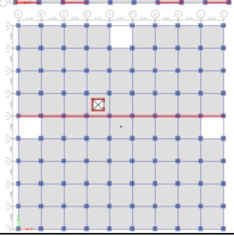
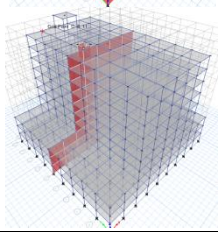
Table 1 Different types of building.

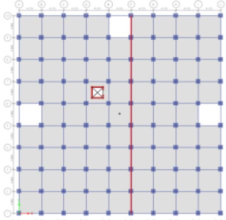
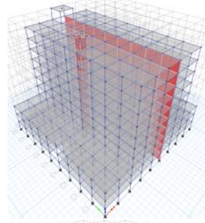
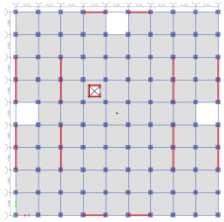
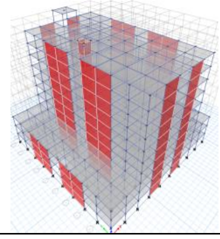
Type of building	Elevation	3D model
Regular building		

Setback at half with shear		
Setback at 2 positions		
Setback at both sides		
Setback at four sides		

Setback at both sides building found weakest setback shape among four setback shapes. Setback at both sides building modeled with the shear wall at different position of building which are at corner, along X-axis, along Y-axis and at periphery are tabulated below.

Table 2 Setback at both sides buildings with different position of shear wall

Position of shear wall	Plan	3D model
Shear wall at Corner		
Shear wall along X-axis		

Shear wall along Y-axis		
Shear wall at Periphery		

4. Result and Discussion

From the Response Spectrum analysis of setback at both sides building with GFRP shear wall at corner in ETABS software using NBC 105:2020, the results obtained are as follows.

4.1 Maximum Storey displacement in X-direction due to RSA, ULS

The maximum storey displacement of setback at both sides building with and with GFRP shear wall due to RSA, ULS in X-direction, without shear wall (66.932mm) > with GFRP shear wall (40.445mm). The maximum storey displacement is decreased by 39.563% with GFRP reinforced shear wall.. The values of storey displacement in X- direction are tabulated below.

Table 3 Maximum storey displacement in X-direction Due to RSA, ULS.

Storey	Elevation	Without shear wall	GFRP shear wall
	m	mm	mm
Storey 10	30	66.932	40.445
Storey 9	27	63.602	36.514
Storey 8	24	58.573	31.999
Storey 7	21	51.839	27.026
Storey 6	18	43.628	21.722
Storey 5	15	34.321	16.288
Storey 4	12	24.495	10.988
Storey 3	9	15.44	6.325
Storey 2	6	9.107	3.508
Storey 1	3	3.371	1.272
Base	0	0	0

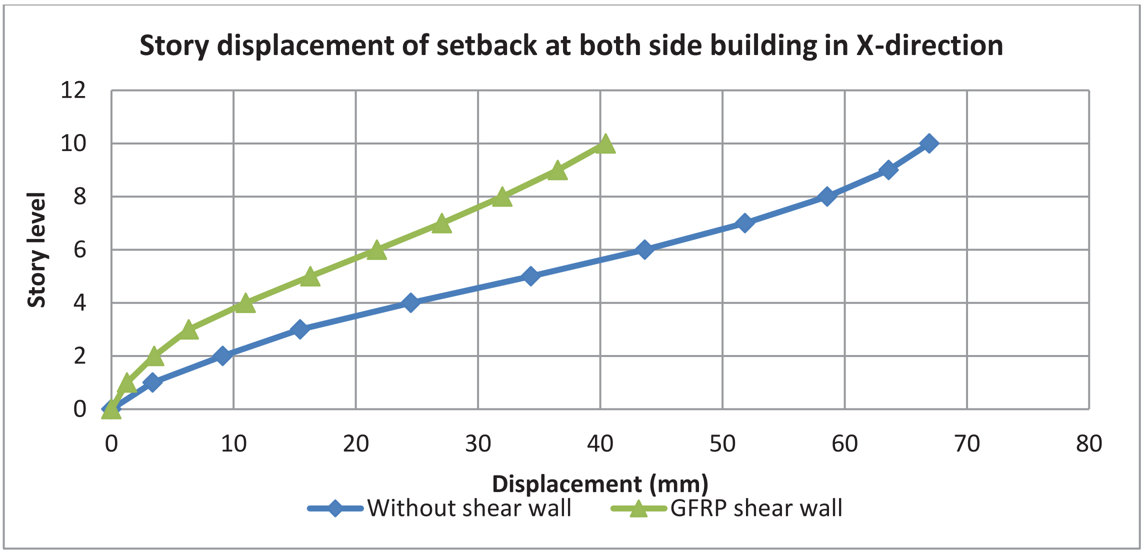


Figure 2 Storey dispacement in X-direction due to RSA, ULS

4.2 Maximum Storey displacement in Y-direction due to RSA, ULS

The maximum storey displacement of setback at both sides building with GFRP shear wall due to RSA, ULS in Y-direction, without shear wall (55.909mm) > with GFRP shear wall (34.671mm). The storey displacement has been decreased by 37.986% with GFRP shear wall. The values of storey displacement in Y-direction are tabulated below.

Table 4 Storey displacement in Y-direction due to RSA, ULS.

Storey	Elevation	Without shear wall	GFRP shear wall
	m	mm	mm
Storey 10	30	55.909	34.671
Storey 9	27	53.559	31.505
Storey 8	24	49.697	27.793
Storey 7	21	44.343	23.648
Storey 6	18	37.711	19.175
Storey 5	15	30.091	14.539
Storey 4	12	21.897	9.964
Storey 3	9	14.779	6.036
Storey 2	6	8.789	3.365
Storey 1	3	3.273	1.227
Base	0	0	0

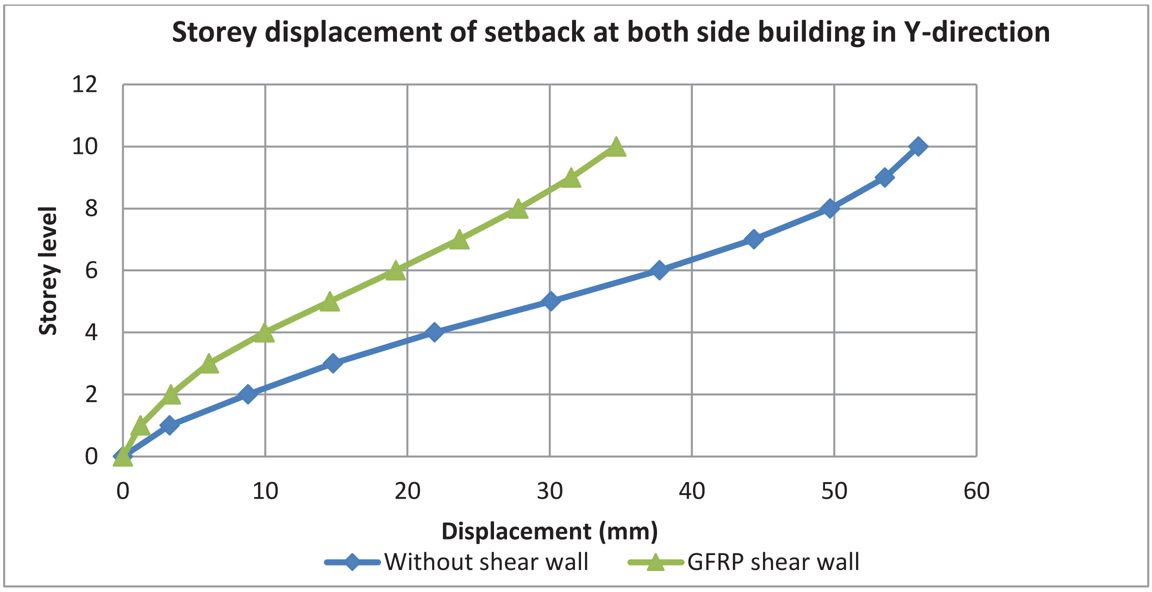


Figure 3 Storey diaplacemnt in Y-direction due to RSA, ULS

4.3 Maximum storey drift in X-direction due to RSA, ULS

The maximum storey drift of setback on both sides of the building in the X-direction is due to RSA, without shear wall (0.003282) > with GFRP shear wall (0.001812). The storey drift is decreased by 44.789% with GFRP reinforced shear wall. The values of storey drift in X-direction are tabulated below.

Table 5 Storey drift in X-direction due to RSA, ULS.

Storey	Elevation	Without shear wall	GFRP shear wall
Storey 10	30	0.00111	0.00131
Storey 9	27	0.001677	0.001505
Storey 8	24	0.002244	0.001658
Storey 7	21	0.002737	0.001768
Storey 6	18	0.003103	0.001812
Storey 5	15	0.003282	0.001767
Storey 4	12	0.003023	0.001554
Storey 3	9	0.002133	0.000939
Storey 2	6	0.001912	0.000745
Storey 1	3	0.001124	0.000424
Base	0	0	0

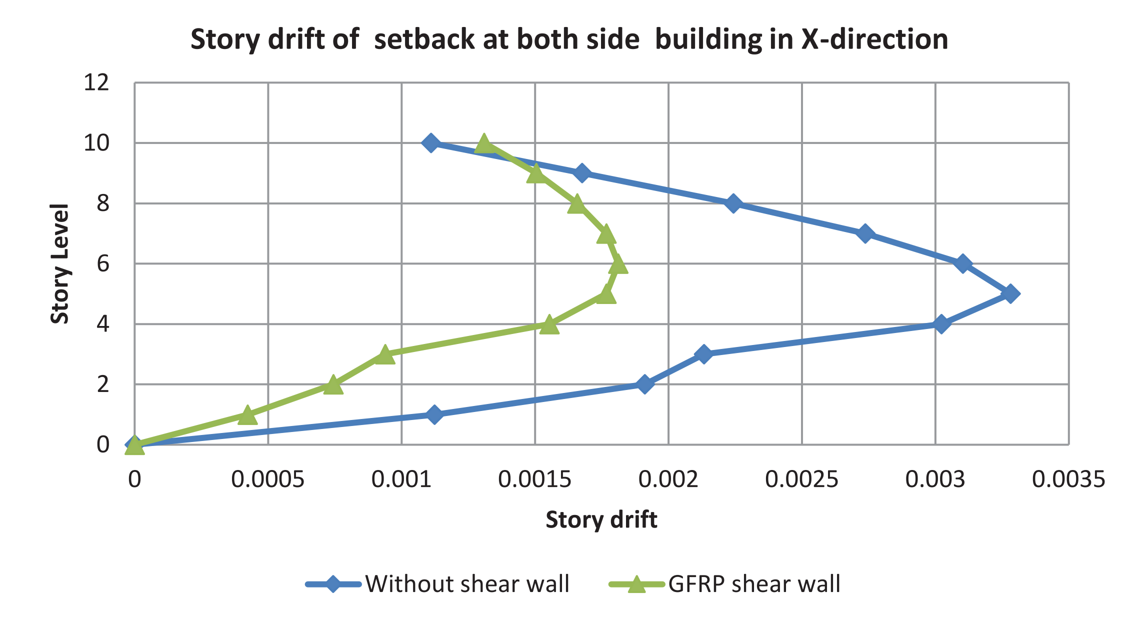


Figure 4 Storey drift in X-direction due to RSA, ULS.

4.4 Maximum storey drift in Y-direction due to RSA, ULS

The maximum storey drift of setback on both sides of the building in the Y-direction is due to RSA, without shear wall (0.002731) > with GFRP shear wall (0.001545). The storey drift is decreased by 43.427% with GFRP reinforced shear wall .The values of storey drift in the Y-direction are tabulated below.

Table 6 Storey drift in Y-direction due to RSA, ULS.

Storey	Elevation	Without shear wall	GFRP shear wall
Storey 10	30	0.000821	0.001055
Storey 9	27	0.001295	0.001238
Storey 8	24	0.001785	0.001382
Storey 7	21	0.00221	0.001491
Storey 6	18	0.00254	0.001545
Storey 5	15	0.002731	0.001525
Storey 4	12	0.002609	0.001373
Storey 3	9	0.001997	0.00089
Storey 2	6	0.001839	0.000713
Storey 1	3	0.001091	0.000409
Base	0	0	0

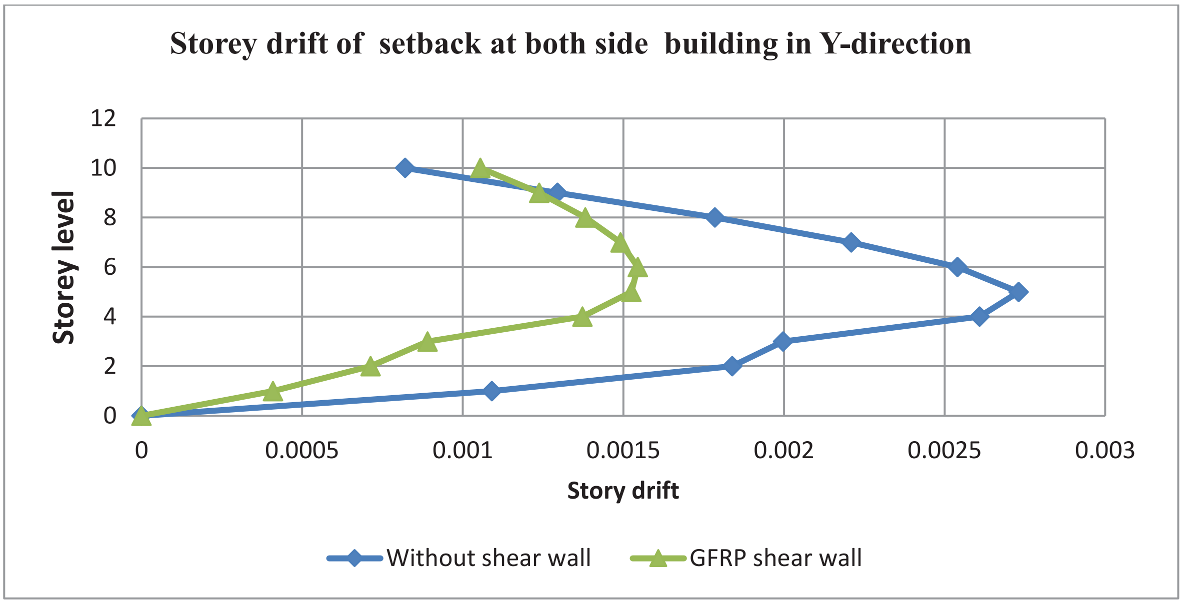


Figure 5 Storey drift in Y- direction due to RSA, ULS.

4.5 Maximum storey Stiffness in X-direction due to RSA, ULS

The maximum storey stiffness of setback on both sides of the building in X- direction due to RSA, with GFRP shear wall (24118522.84KN/M) > without shear wall(9349082.6KN/M). The building with the GFRP reinforced shear wall is stiffer than without shear wall. The values of storey stiffness in X- direction are tabulated below.

Table 7 Storey stiffness in X- direction due to RSA, ULS.

Storey	Elevation	Location	Without shear wall	GFRP shear wall
	M		KN/M	KN/M
Storey 10	30	Top	1629515.9	1397277.755
Storey 9	27	Top	2299518	2555786.629
Storey 8	24	Top	2484528.1	3333149.806
Storey 7	21	Top	2559739.4	3898527.242
Storey 6	18	Top	2627459.6	4402934.539
Storey 5	15	Top	2755709	4981663.647
Storey 4	12	Top	3182385.6	6046753.232
Storey 3	9	Top	4610999.5	10298483.9
Storey 2	6	Top	5337556.1	13474408.25
Storey 1	3	Top	9349082.6	24118522.84
Base	0	Top	0	0

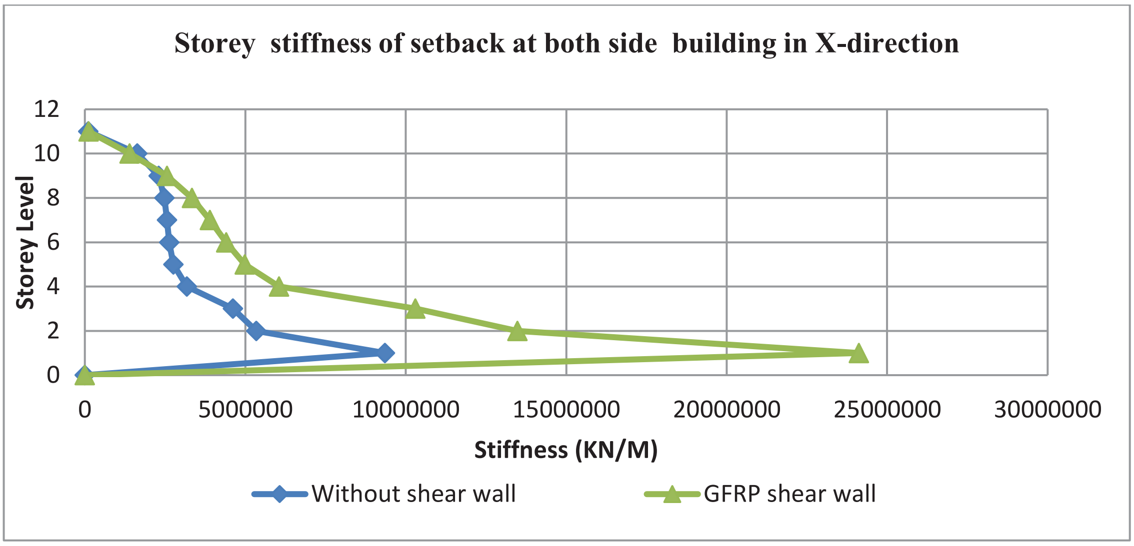


Figure 6 Storey stiffnessin X-direction due to RSA, ULS.

4.6 Maximum storey Stiffness in Y-direction due to RSA, ULS

The maximum story stiffness of setback on both sides of the building in Y- direction due to RSA, with GFRP shear wall (23803451.59KN/M) > without shear wall(9107427.3KN/M). The building is stiffer with the GFRP shear wall than without shear wall. The values of story stiffness in Y- direction are tabulated below.

Table 8 Sotrey stiffness in Y- direction due to RSA, ULS.

Storey	elevation	Location	Without shear wall	GFRP shear wall
	M		KN/M	KN/M
Storey 10	30	Top	1890439.1	1510681.793
Storey 9	27	Top	2542972.3	2727861.259
Storey 8	24	Top	2703987.1	3530443.116
Storey 7	21	Top	2766523	4101137.375
Storey 6	18	Top	2817517.2	4599591.107
Storey 5	15	Top	2914231.9	5161618.184
Storey 4	12	Top	3251738.3	6133975.728
Storey 3	9	Top	4634147	10276924.42
Storey 2	6	Top	5285899.7	13382704.69
Storey 1	3	Top	9107427.3	23803451.59
Base	0	Top	0	0

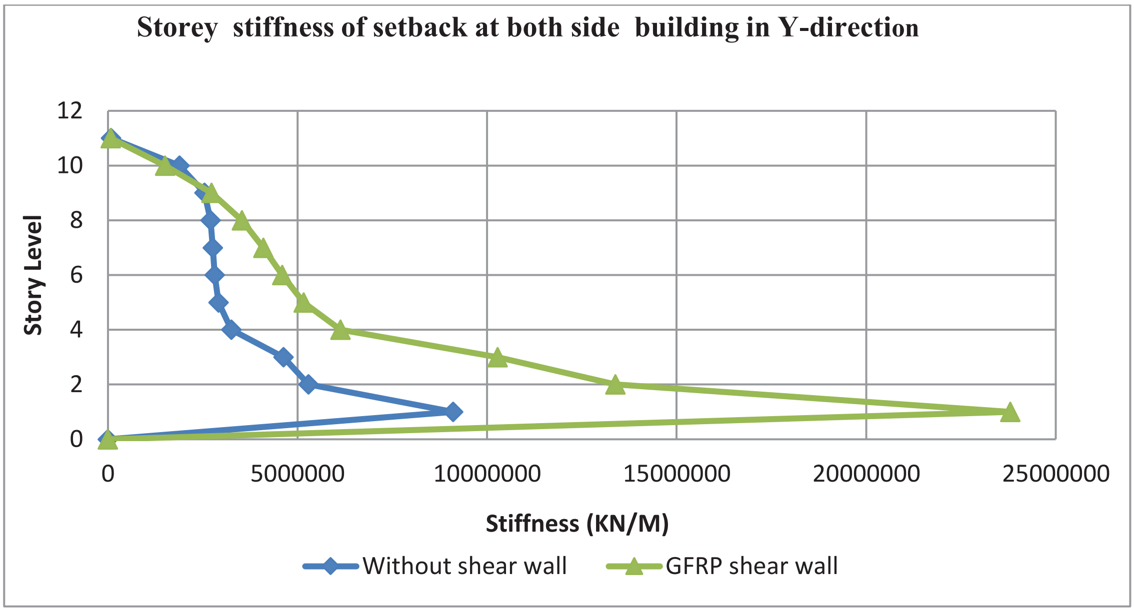


Figure 7 Storey stiffness in Y-direction due to RSA, ULS.

4.7 Maximum base shear due RSA, ULS

The maximum base shear was shown by setbacks on both sides building with with GFRP shear wall (26973.97KN) >, without shear wall (26335.29KN). The base shear is increased by 2.42% with GFRP reinforced shear wall. The base shear diagram is shown below.

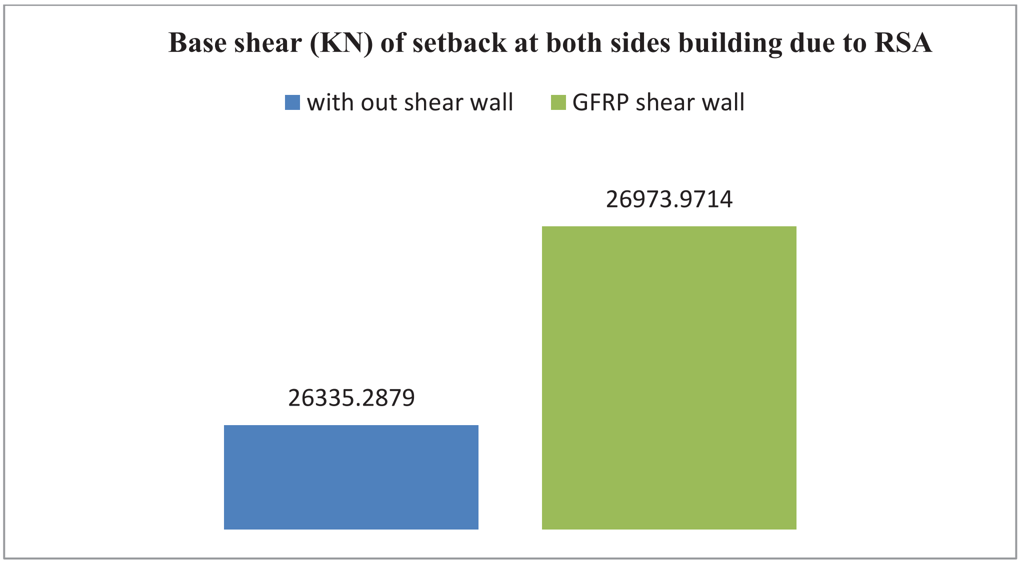


Figure 8 Base shear due to RSA, ULS.

5. Conclusion

After completion of analysis of setbacks on both sides, the building with GFRP reinforced shear wall at Corner results were presented above. From the observation of the results presented above, it can be concluded that setbacks on both sides' buildings with the GFRP shear wall performed better than without shear wall.

1. Setback at both sides building with GFRP shear wall at optimum position which is at corner, the maximum percentage of decrease of displacement showed by setback at

both sides with GFRP shear wall 39.52% in X- direction and 37.98% in Y-direction. The maximum percentage of decrease of drift with GFRP shear wall 44.79% in X-direction and with 43.43% in Y-direction. The maximum stiffness with GFRP shear wall is 24118522.844 KN/M in both X and Y-direction. The percentage of increase of base shear values with GFRP shear wall 2.42%.

2. GFRP shear wall showed better performance in terms of controlling displacement, drift and providing higher stiffness, making them more suited for seismic resistance in setback building.

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Comparative study of Coarse Aggregate Properties along the Longitudinal Sections of Kaligandaki River in Mustang

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Abstract

The most significant component of concrete is aggregate. The demand for aggregates is quite high in Nepal's construction sector for road construction and concrete works. River-borne aggregate material still meets a large portion of the need. The Kaligandaki river is one of most prominent among others for extraction of riverbed material in Gandaki Provine and it is the most economic supplier for aggregates in Mustang district. The quantity of sediments attracts construction stakeholders for use of locally available materials. This study's goal was to analyse the properties of aggregates and variation in aggregate strength at a particular stretch of the Kaligandaki river basin in Mustang district. On the basis of accessibility and deposition, representative samples were taken for study purposes from five carefully chosen riverbank locations. Lab tests for physical properties (FM, specific gravity, water absorption, combined FI and EI) and mechanical properties (LAA, AIV and ACV) were conducted on the samples to evaluate their quality and strength for the construction works. Suitability of aggregates based on strength assessment samples was assured by compliance test to limits specified in DOR specification.

FM, specific gravity, water absorption, combined FI and EI were found in range of (6.57-7.05), (2.62-2.71), (0.485-0.723)% and (33.14-42.29)% respectively. It was concluded that aggregates from all the sources are suitable in their hardness, toughness and compressive strength. A linear relationship between the combined flakiness and elongation index, LAA, AIV and ACV values with longitudinal variation of Kaligandaki river was established.

Keywords: Concrete materials, aggregate sources, properties of aggregates, quality assessment, aggregate strength, longitudinal variation.

Introduction

Concrete is a widely used construction material known for its durability, versatility, and strength. It is composed of a mixture of several key ingredients, each playing a crucial role in the overall performance and properties of the finished product. The main ingredients of concrete include cement, aggregates, water, and sometimes admixtures. The amount of binder required is determined on the size distribution of the aggregate. The largest gaps are found in aggregate with a relatively equal size distribution, but adding aggregate with smaller particles tends to fill these gaps. The binder, which must fill the spaces between the aggregate as well as paste the aggregate surfaces together, is usually the most expensive component. As a result, the size and quality of the aggregate have a direct impact on its economy and strength. The most significant component of concrete is aggregate. They provide the concrete body, minimize shrinkage, and have an economic impact. Natural aggregates are inert granular components such as sand, gravel stone or crushed stone that

are mixed with the binding mediums such as water, bitumen, portland cement, lime or other materials to produce compound materials such as asphalt concrete and cement concrete.
Huge amounts of construction materials are required to fulfil demand of construction works, which are being done by private and Government sectors and searching for good quality construction materials is a tough job **(Nayaju & Tamrakar, 2019)**. Water resources not only generate many forms of energy but also transport massive sediments from the lower and Sub-Himalayan Himalayas to the Terai region. The river sediments are mostly gravel, with a little sand and muck. During each flood season, gravel can be easily recovered from the river area following deposition. As a result, the river is a consistent supplier of coarse sediments. Because of the strong need for construction materials, coarse aggregate extracted from rivers has been widely used as a construction material.
The Kaligandaki River, originating from the Tibetan plateau and winding its way through the arid landscapes of Mustang, carries with it a diverse array of sediments. Among these, aggregates, comprised of various-sized particles such as gravel and pebbles, form a crucial component. These aggregates are transported by the river's currents, sculpting the riverbed and contributing to the dynamic nature of the watercourse. The geological diversity of the region influences the types and sizes of aggregates, giving rise to a distinctive mix that shapes the river's morphology.
The construction industry in the Mustang region relies on local materials for infrastructure development. Large amount of construction materials is required for Mustang district in the form of fine and coarse aggregates for development of infrastructure which can be extracted from the deposition of Kaligandaki River. The major infrastructure such as irrigation, roads, urban development, water supply scheme, hydroelectric projects that can be developed within the Kaligandaki basin also demands huge amount of construction materials whose quality is of great concern.

Research objectives

The main objective of the research is to analyze the properties of coarse aggregate along the different selected sections of Kaligandaki River. The specific objectives of the study are:

1. To determine the physical properties (FM, Specific gravity and water absorption) and mechanical properties (LAA, AIV and ACV) of coarse aggregate at the different selected sections along the longitudinal profile of Kaligandaki River.
2. To assure the suitability of aggregates based on strength assessment of specimens prepared from selected sections of Kaligandaki River.
3. To Compare the physical and mechanical properties of coarse aggregate along the selected sections of Kaligandaki River.

Literature Review

Concrete is one of the well-known as well as pioneer and most common construction materials used globally, mainly because of its availability, convenience, low cost, long durability, versatility and ability to sustain extreme weather environments. Although aggregate is considered as an inert filler material, it is a necessary component of concrete that occupies most volume and it defines thermal and elastic properties and dimensional stability of concrete **(Kalra & Mehmood, 2018)**. Aggregates have different physical, mechanical, chemical and thermal properties which directly affect the strength and durability of concrete product **(Zega, et al., 2010)**. The compressive strength of aggregate is an important factor in the selection of aggregate from any source. The compressive strength of concrete depends on the water to cement ratio, ratio of cement to aggregate, degree of compaction, bond between mortar and aggregate as well as size, grading, shape and strength of the aggregate **(Abdullahi, 2012)**. Despite researches have shown reluctance to utilize gravel in the production of concrete, the use of locally sourced coarse aggregate materials cannot be prohibited once all their engineering properties are known **(Nduka, et**

al., 2018). Physical and mechanical properties of aggregate must be known before the production to make a desirable mix and desired strength of concrete. These properties include shape, size, texture, gradation, moisture content, specific gravity, water absorption, soundness and bulk unit weight etc. These properties aggregates determine the strength, workability, and durability of concrete. Aggregates strongly influence freshly mixed and hardened properties, mixture proportions, and economy of concrete. Aggregates from different sections of the same river basin vary along longitudinal profile. The variation affects the quality and strength of road and concrete structures So, selection of good quality aggregates is an important process in accessing local material for construction.
Study conducted by **(Maharjan & Tamrakar, 2007)** in Rapti River, Central Nepal Sub-Himalaya to evaluate the quality of gravel for concrete and road aggregates to discover their suitability for construction purposes, different properties such as petrographic, physical, mechanical and chemical properties were analysed and it was found that sample were mostly subrounded, oblate triaxial ellipsoid with high sphericity, rough to smooth surface texture, the water absorption value from 0.69 to 1.12% which is <3%, dry density ranged from 2460 to 2680 kg/m3 which means normal density aggregates, aggregates impact values of samples ranged from 14.10 to 16.10%, Los Angeles Abrasion value 29.83% which is<30% and sodium sulphate soundness values ranged from 4.46 to 7.19% which is <10%. All the tested results are complied with the exiting Nepal Standard, British Standard and American Standard and it showed that the samples are suitable for road aggregates and concrete works.
Study done by **(Madai, et al., 2019)** to find the suitability of aggregates of Kavre and Sindhuli district quarries for different layers of Flexible Pavement using the standard material test procedures, they discovered that the aggregates from the three quarries included in the study, Challal Ganesh- Kavre, Aapghari- Ghampyakhola, and Bhyakurkhola, met the specifications needed to be used for various layers of flexible pavement.
Similarly, a study done by **(Adhikari, et al., 2022)** to analysis of aggregate strength variation at selected section of Biring river basin concluded after conducting the lab test of physical properties of aggregate, Fineness Modulus, Water Absorption and Specific Gravity were found in the range of (7.16-7.49), (0.72-1.15) % and (2.616-2.712). The linear equations for the longitudinal variation of LAA, AIV and ACV value along the river profile were established. For a longitudinal variation equation for LAA value $y=-0.352x+37.41$, AIV value an equation $y=-0.0189x+27.15$ and ACV value an equation $y=-0.212x+29.88$ where y = Value of LAA, AIV and ACV value and x = distance in km from upstream origin point. They found the average compressive strength M20 grade concrete cubes for 7 and 28 days to be within standard required and that of 28 days above 20Mpa.

Research Methodology

Study Area

The study area is geographically located in Mustang district. Kaligandaki River flows in south-west direction through enchanting landscape of Varagung Muktichhetra RM, Gharapjhong RM and Thasang RM including major cities closer to river bank. There are some major flood plains from which riverbed materials can be extracted. Different five sites are identified for sample collections on the basis of deposition of materials, residential area for the consumption and accessibility to site.

Data Collection

Primary data which were collected through the lab test by the means of observation, recording, testing and measuring. Lab experiment reports of aggregates form different sources made adequate primary data for the study purpose. Secondary source of information was collected from the different source such as documents, data from government office, various standard codes, international journals, newspapers, books, national and international research articles, different web sites.

Results and Discussion

Gradation analysis for gravel (Granular Sub base)

The particle size distribution curve of gravel of all the different sources are as follows:

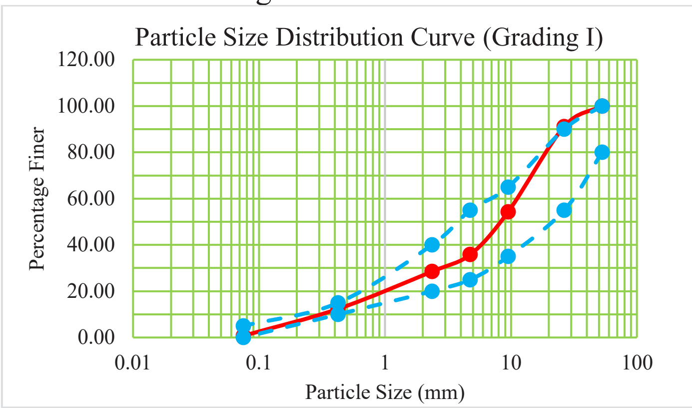

Fig. 4.1. Particle size distribution of gravel from Kagbeni Source

From above Fig. 4.1, it was found that Gravel from Kagbeni Source did confirm grading envelop as per DOR standard specification.

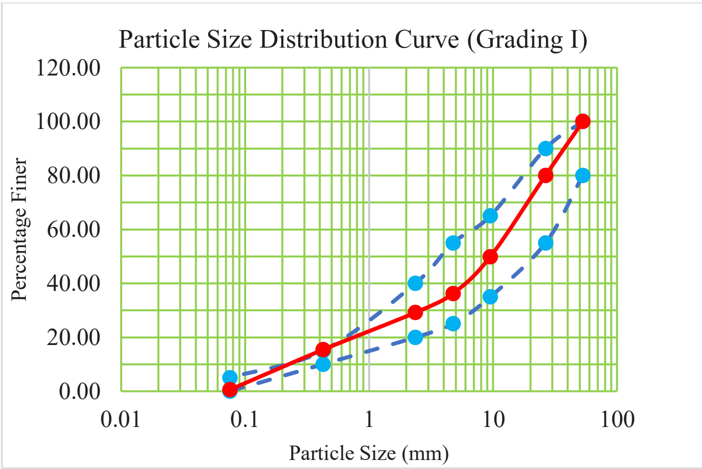

Fig. 4.2. Particle size distribution of gravel from Jomsom Source

From above Fig. 4.2, it was found that Gravel from Jomsom Source did confirm grading envelop as per DOR standard specification.

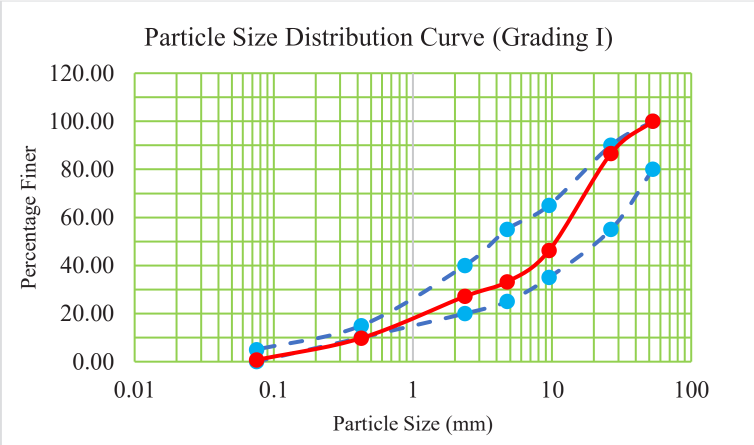

Fig. 4.3. Particle size distribution of gravel from Marpha Source

From above Fig. 4.3, it was found that Gravel from Marpha Source did confirm grading envelop as per DOR standard specification.

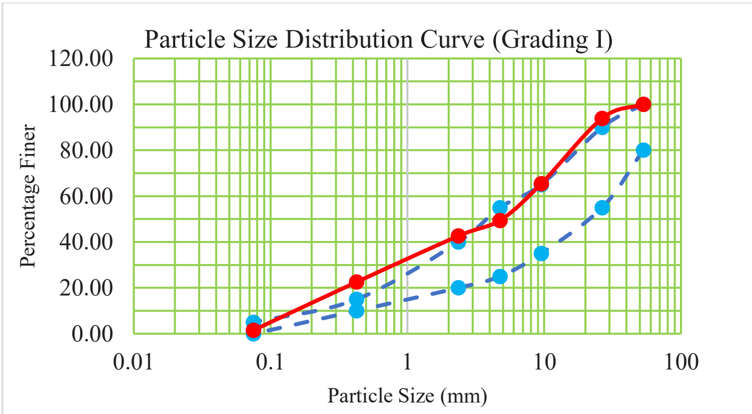

Fig.4.4. Particle size distribution of gravel from Tukuche Source

From above Fig. 4.4, it was found that Gravel from Tukuche Source did not confirm grading envelop as per DOR standard specification having slightly fine particles.

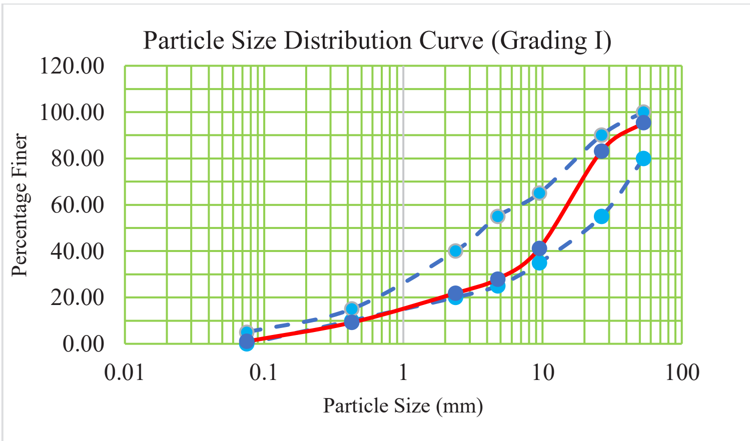

Fig. 4.5. Particle size distribution of gravel from Dhampu Source

From above Fig.4.5, it was found that Gravel from Dhampu Source did confirm grading envelop as per DOR standard specification.

Physical Properties of coarse aggregates

Lab tests of the aggregates from the different sources were carried out using standard test procedures and after calculation following values of physical properties were obtained. These values of fineness modulus, specific gravity, water absorption, flakiness and elongation indices were presented in the table as follows.

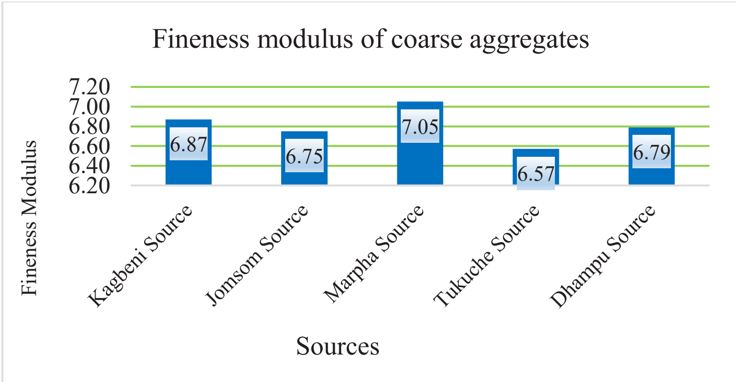

Fig. 4.6. Fineness Modulus of aggregates from different sources

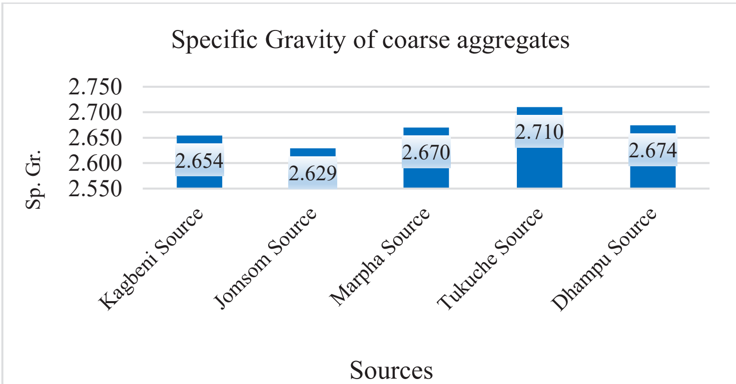

Fig. 4.7. Specific Gravity of aggregates from different sources

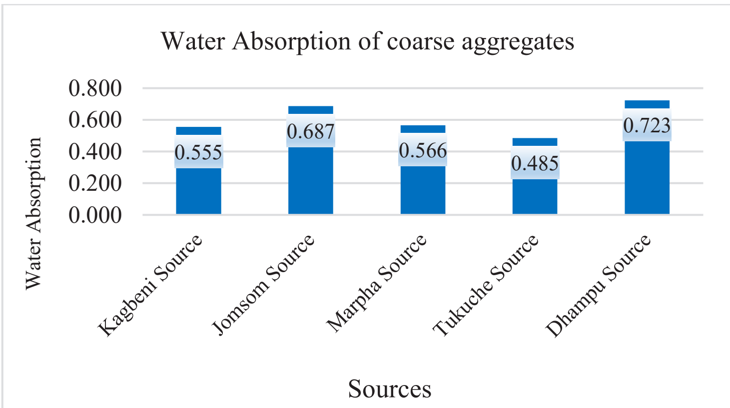

Fig. 4.8. Water Absorption of aggregates from different sources

The highest value of fineness modulus was found on Marpha source as 7.05 which represents average particle size is coarser than 10mm sieve size (index number 7) and the lowest value of fineness modulus was found in Tukuche source as 6.57 which represents average particle size is finer than other sources. The highest value for the specific gravity was found to be 2.710 that of Tukuche source and lowest value of specific gravity was 2.629 that of Jomsom source aggregates. The lowest value of water absorption was found on Tukuche source aggregates as 0.485% and the highest value of water absorption was found on Dhampu Source aggregates as 0.723%. High value of specific gravity and low value of water absorption represents higher quality aggregates. The combined flakiness and elongation index seemed in gradually decreasing order along downstream sections ranging from 42.29% at the first source to 33.14% at the last source of material.

Comparative analysis of Physical Properties of aggregates

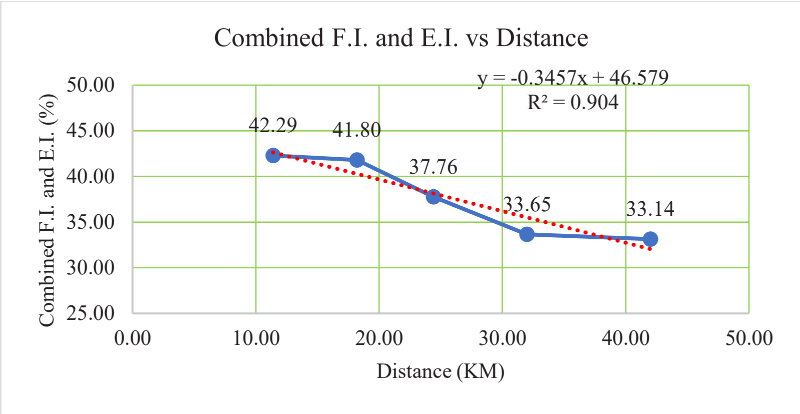

Fig. 4.9. Variation of Combined F.I. and E.I. along longitudinal profile of river

It was clearly observed that aggregates from lower sections had lesser values of combined flakiness and elongation index which means better quality aggregates found in lower portion of Kaligandaki river in Mustang. Aggregates from Kagbeni source had highest combined flakiness and elongation index as 42.29% and Dhampu source had the same lowest as 33.14%. Combined flakiness and elongation index followed down trendline as the distance from the origin source was increased. The linear equation developed for combined flakiness and elongation index was:

$y = -0.3457x + 46.579$ …………………Eq. (1)

where x = distance from the origin source.

Comparative analysis of Mechanical Properties of aggregates

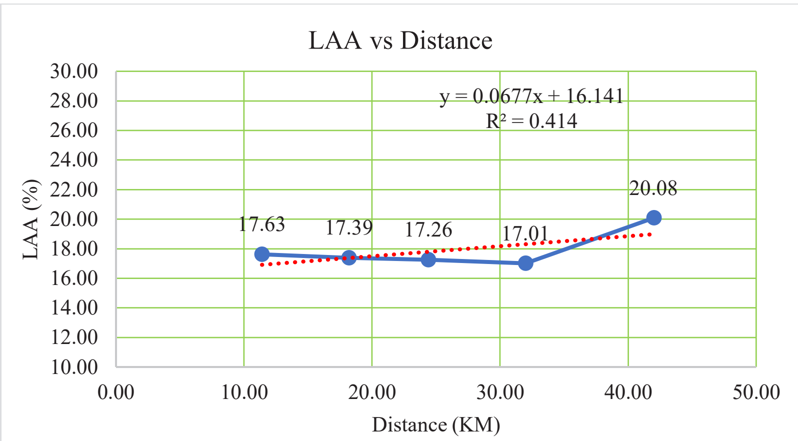

Fig. 4.10. Variation of LAA along longitudinal profile of river

It was observed that Los Angeles Abrasion Values of aggregates of lower sections had lesser values from Kagbeni source to Tukuche source representing aggregates with more resistance against wear and tear as distance was increased but the LAA value of aggregates from Dhampu source was found to be highest among all other sources representing aggregates with less resistance against wear and tear. LAA followed up trendline as the distance from the origin source was increased. The linear equation developed for Los Angeles abrasion value was:

$y = 0.0677x + 16.141$ …………………Eq. (2)

where x = distance from the origin source.

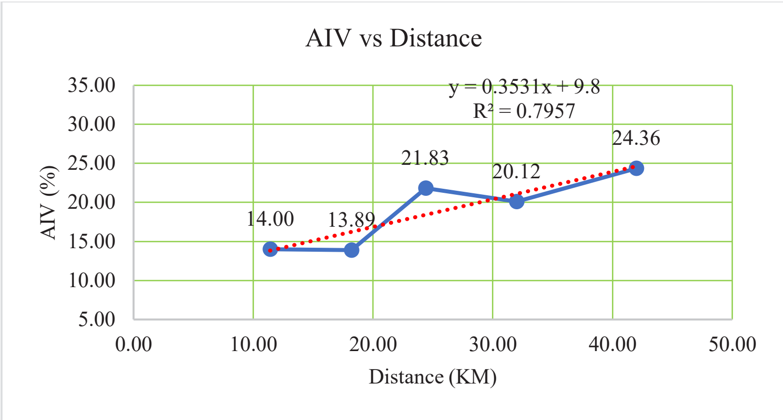

Fig. 4.11. Variation of AIV along longitudinal profile of river

It was observed that Aggregate Impact values of aggregates from Kagbeni and Jomsom source had lesser values representing aggregates with more resistance against impact load. AIV value of aggregates from Dhampu source was found to be highest as 24.36% among all other sources representing aggregates with less resistance against impact. AIV followed up trendline as the distance from the origin source was increased. The linear equation developed for aggregate impact value was:

$y = 0.3531x + 9.8$ …………………Eq. (3)

where x = distance from the origin source.

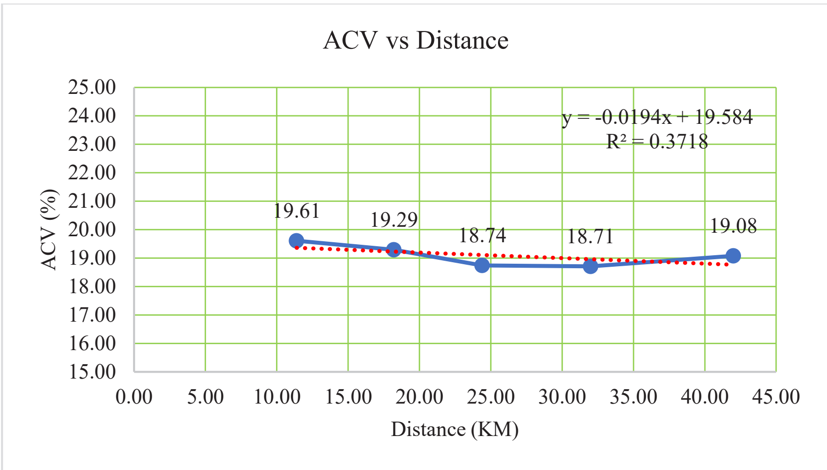

Fig. 4.12. Variation of ACV along longitudinal profile of river

It was observed that Aggregate Crushing values of aggregates of lower sections had lesser values from Kagbeni source to Tukuche source representing aggregates with more resistance against gradually applied compressive load as distance was increased but the LAA value of aggregates from Dhampu source was found to be higher than that of Marpha and Tukuche sources representing aggregates with slightly less resistance against gradually applied compressive load than that of Marpha and Tukuche sources. ACV followed down trendline as the distance from the origin source was increased. The linear equation developed for aggregate crushing value was:

$y = -0.0194x + 19.584$…………………Eq. (4)

where x = distance from the origin source.

Relationship between Physical and Mechanical Properties of aggregates

Among the physical properties under this study, water absorption values showed significant relation with the mechanical properties. As the coarse aggregate material with higher water absorption are considered to be more porous and sustain higher amount of water within it, the strength of such aggregate would be less. Here the water absorption of aggregate from Tukuche source was found to be the least as 0.485% and LAA value of the same source was found to be the least as 17.01% indicating good quality aggregates. Similarly, Dhampu source aggregates had highest value of water absorption as well as LAA as 0.723% and 20.08%. The Pearson's Correlation coefficient is 0.728 (>0.5), which indicated that water absorption has direct correlation with LAA value.

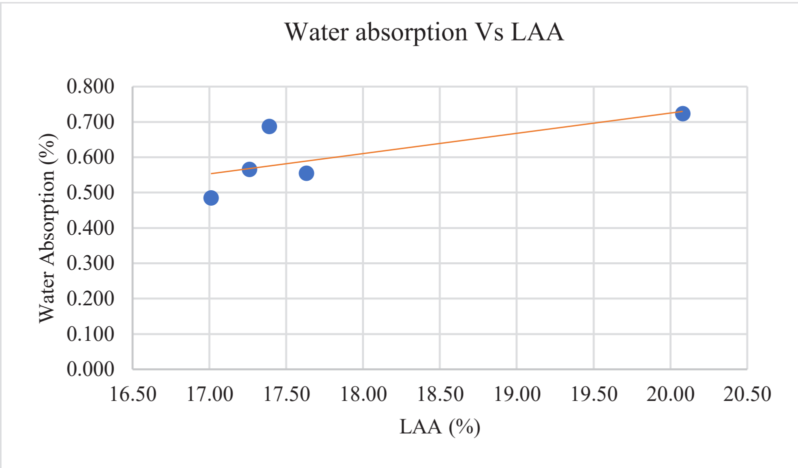

Fig. 4.13. Relationship between Water absorption and LAA

Conclusion And Recommendation

Conclusions

The conclusions of the study regarding the qualitative assessment of aggregates of the Kaligandaki River in Mustang are as follows:

1. Specific gravities of the aggregates sample from all five selected sections have no significant differences along the river length. Water absorption of aggregates from Dhampu source is relatively higher.
2. Except combined flakiness and elongation indices aggregates sample of Kagbeni, Jomsom and Marpha sources, the physical and mechanical properties of riverbed aggregates from all five selected sections of Kaligandaki river basin are satisfactory. Riverbed aggregates of Kaligandaki river in Mustang are flaky and elongated. Combined flakiness and elongation index goes on decreasing at downstream sources of Kaligandaki river.
3. Regarding the mechanical properties of aggregates, LAA and ACV goes on decreasing along lower portion of Kaligandaki river from origin source to Tukuche source, it means lower portion of river have relatively better quality of aggregates. But aggregates from Dhampu source have relatively higher values of LAA, AIV and ACV

than upstream sources, it means aggregates from this source are of low strength. The tributary river sources also effect on strength quality of aggregates.

4. Water absorption has direct correlation with LAA value.

Recommendations

As aggregates from sources of upper portion along Kaligandaki river in Mustang are flaky and elongated, flakiness and elongation may be the major issue in the case of riverbed aggregates from Kaligandaki river. Hence, proper attention should be taken in the collection of riverbed aggregates so that good quality can be achieved in road construction and concrete works.

It was found that the aggregates from every source satisfied the minimal strength requirements for the construction projects covered by this study. Therefore, it is recommended that aggregates from the distinct sources of Kaligandaki river can be used road construction and other concrete works. Among the five sources, aggregates from Tukuche source have highest specific gravity, lowest water absorption, highest mechanical strength, so it is recommended to use aggregates from Tukuche source for pavement works, high strength concrete and wearing course works.

There are enormous amount aggregates present in Kaligandaki river bank in Mustang. From the study conducted, it is found that the aggregates are of very good quality and strength. Therefore, it is recommended to utilize these resources with sustainable management that locally available construction materials contribute for local infrastructure development as Well As Local Source of Income.

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