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Application of Automation Tool (BIM) for Seismic Retrofitting of SMM (Stone Masonry with Mud Mortar) Building

Darshana Dhaubanjar

Department of Civil Engineering, Pulchowk Campus, IOE, TU, Nepal
Corresponding Email: dhaubanjardarshana@gmail.com

Abstract

The primary motive of this paper is to understand the importance of accurate and quick result-oriented technology. Although Nepal is now into the recovery and reconstruction phase after Gorkha Earthquake 2015, maximum houses are still standing unsafe. Several factors hinder the workflow during the post disaster process. One of the reason for slow pace in terms of recovery is the absence of such effective technology. Because the reconstruction process needs to undergo as early as possible, applicability of new tools and technology needs to be understood. Initially, the paper identifies the rural typology of SMM (Stone Masonry with Mud Mortar) buildings. Based upon the study, retrofitting design for such buildings is incorporated. Furthermore, the ways in which the automation tool facilitates the process of retrofitting is studied. If there are possible ways that can facilitate to the effectiveness of retrofitting then such tools and technology should be put into consideration. So, to meet the objective of the study, partially damaged houses of Bhimphedi palika and Thaha palika of Makwanpur district are studied. An application of the tool is illustrated in one of the houses. In addition, the possibility, if most of the damaged houses of two palikas can be retrofitted or not will also be identified.

Keywords

Stone Masonry with Mud Mortar (SMM) Building, Retrofitting, Automation, BIM

1. Introduction

Stated by UNISDR, Disaster is defined as “A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts”[1]. Disasters cannot be absolutely avoided but we should be prepared enough for a natural disaster. Disasters have far-reaching effects on life, property and infrastructure. The society or community is more vulnerable to the damages caused by the disasters, in addition to continuous development. Societies are set back by the disaster’s adverse effects, which increase their physical, social, and economic vulnerability.

1.1 Background

The Mw 7.8 2015 Gorkha earthquake occurred at 11:56 NST on 25 April 2015 with a focal depth of approximately 15 km and an epicentre located near Barpak village in Gorkha district[2]. It has been five years after the April and May 2015 earthquakes hit Nepal. While the nation is now in the process of recovery and reconstruction, there is much to be achieved which is actually a slow rate of recovery. Stage of any disaster response and recovery is then followed by period of restoration and rehabilitation. Retrofitting, a part of reconstruction during the post-disaster process will serve as a catalyst.

Analyzing the current state of workflow, there are several factors hindering the process of post disaster recovery and one of them being the absence of accurate and quick result-oriented technology. During post-disaster situations it is necessary to act rapidly and the most feasible and efficient method should be adopted. Therefore, different methods should be implemented to assist architects, engineers, and others in making accurate and immediate decisions.

1.2 Need of Study

We all are aware of the fact that Nepal is subjected to various types of natural disasters. “Our country is comparatively ranked very high in terms of vulnerability to natural calamities. According to the disaster profile, Nepal comes under the world’s top 20 disaster-prone countries and has attained higher ranks in vulnerability to climate change, earthquake and floods. One potential hazard is the earthquake.”[3]

The Gorkha earthquake occurred on 25 April 2015, with a magnitude of 7.8. Among the 14 most affected districts and 17 affected districts, stone masonry with mud mortar (SMM) was the most common building typology in the severely affected rural areas. According to the survey conducted by Central Bureau of Statistics (CBS), maximum affected houses due to earthquake were SMM and a large number of buildings were partially damaged[4]. Therefore, it is not necessary that all the buildings need to be newly constructed. To all the houses that cannot be reconstructed, retrofitting can be an appropriate and affordable solution.

The new construction of buildings is comparatively expensive and nobody can ensure if all homeowners can afford the newly constructed buildings. In addition, the new designs do not fully ensure to satisfy the needs of the homeowners. Therefore, retrofitting helps the respective homeowners to return to their lifestyle immediately without compromising their previous needs. Thus, it would be beneficial if they incorporate retrofitting of SMM buildings as part of reconstruction.

During retrofitting, it is a tedious process to analyze every building individually. Keeping this in mind, if a single design can be implemented to numerous buildings using new tools, this can save a lot of time. This process can include many technologies and tools but such a method should be adopted whose applicability would not hinder the workflow.

1.3 Objective of Study

- To understand how the automation tool can facilitate the process of retrofitting of SMM (stone masonry with mud mortar) buildings during pre-construction phase.
- To explore the applicability of tool in providing appropriate solutions.
- To study the importance of technology in increasing the pace of reconstruction.

1.4 Study Area

The study area will cover municipalities of Makwanpur. Because large number of SMM houses that could be retrofitted are in two municipalities, that is Thaha and Bhimphedi, the houses of these two palikas are studied. The houses of those areas and the application of the tool will be studied at designing and analysis level.

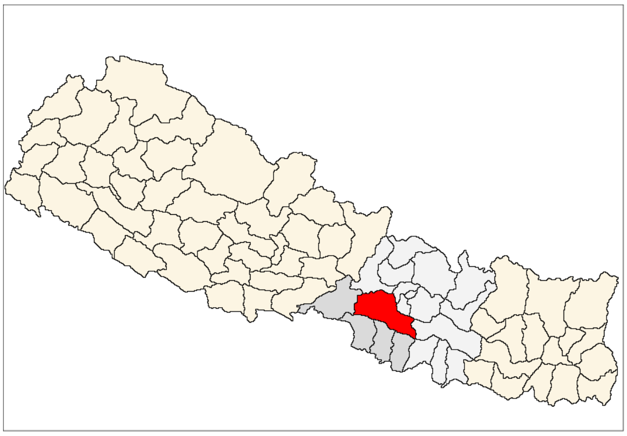
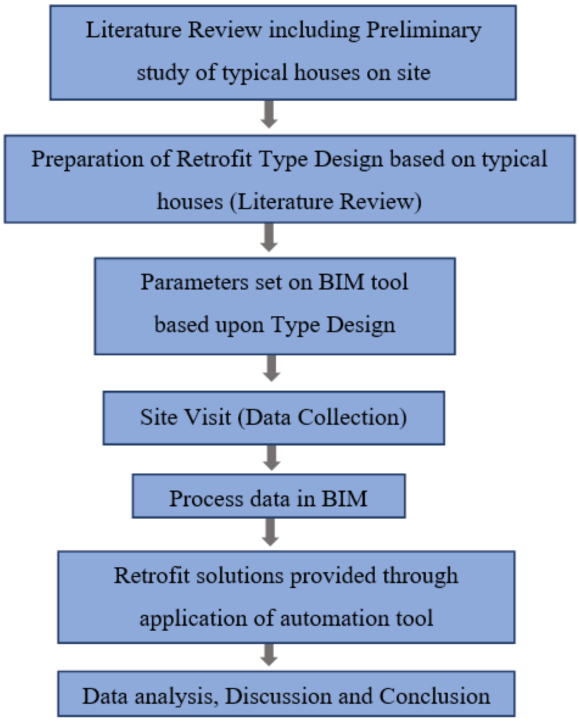


Figure 1: Figure showing Makwanpur district

1.5 Methodology



The basic Research method involves Descriptive and Explorative approach. The study of the tool on how it facilitates the retrofitting process will be descriptive research. In addition, the research done to verify if the project can be up scaled or not with help of the tool will be conducted in an exploratory manner. Overall the process is a qualitative research.

2. Literature Review

2.1 Rural SMM Building Typology

"The most common building type outside the Kathmandu valley and its periphery include rubble masonry stone buildings. Most of these houses were designed without concern to seismic activity. The field survey after the 2015 Gorkha earthquake indicated the wall thicknesses to be between 390 and 530 mm. The SMM buildings are mostly one to three story structures, which had shallow foundations. Some of the buildings have no plaster, and if they did, they are plastered both internally and externally with mud. The buildings are constructed as such that the floor are supported by timber joists which rests upon structural walls. Roofing material might vary. The middle mountains used corrugated galvanized iron (CGI) sheets or thatched roofing. The high mountains had heavy stone roofing (sliced stones) or mud blocks. Rural SMM buildings are usually rectangular constructions with a roof sloping in two directions. Masonry partition or cross walls are rarely provided. These buildings used irregularly shaped and sized stones, with timber and bamboo materials and had elements restricted to joists, purlins, and rafters."[5]

2.2 Damage Pattern of Gorkha Earthquake 2015

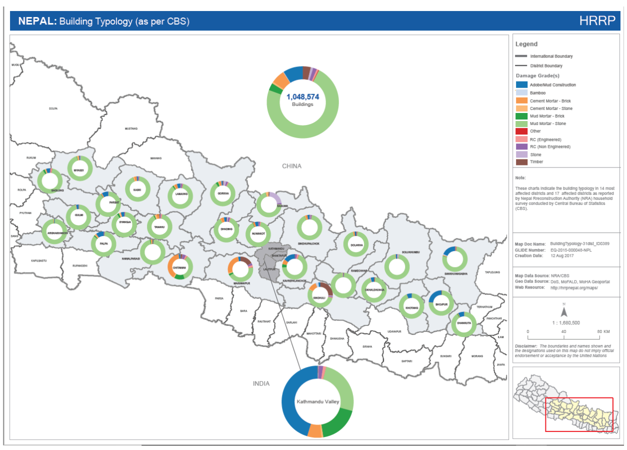


Figure 2: Building typology of 31 districts affected by the earthquake until August 2017

The chart attached illustrates the building typology in 14 most affected districts and 17 affected districts as reported by Nepal Reconstruction Authority (NRA) household survey conducted by Central Bureau of Statistics (CBS). The chart indicates that stone mud masonry (SMM) is the most common building typology in the severely affected rural areas[4].

"According to National Planning Commission (2015), 498,852 houses were completely damaged and 256,697 were partially damaged. Out of the 474,025 collapsed rural buildings recorded in central Nepal, approximately 90 percent were constructed of rubble stone, while nearly 70 percent of the 173,867 damaged buildings were rural stone masonry constructions."[5]

So, the Damage Mechanisms in Stone Masonry Buildings can be summarized as[6]:

- Wall delamination
- Out-of-plane failure mechanisms
- In-plane failure mechanisms

2.3 Retrofitting

The intervention works for seismic damaged or capacity deficient structures would be repair and retrofitting[7]:

Repair: When a building is repaired, it does not improve the structural strength of the building and it does not fulfill the strength requirements of the next earthquake.

Retrofitting: When the building is retrofitted, it removes the seismic deficiencies of a structure.

2.4 BIM (Building Information Modelling)

Autodesk defines BIM as "Building Information Modeling (BIM) is a process that begins with the creation of an intelligent 3D model and enables document management, coordination and simulation during the entire lifecycle of a project (plan, design, build, operation and maintenance)"[8]. BIM is used not just to design but also to document the building as a whole. Every detail of a building is modeled in BIM. The BIM model helps to look at different design options and facilitates in visualizing the building.

2.5 SMM Retrofit Type Design

Based upon the study of rural SMM (Stone masonry with mud mortar) buildings that are abundantly found in site, a retrofit type design has been prepared by Build Change organization. The National Reconstruction Authority (NRA) approved the retrofitting type design submitted by Build Change for stone masonry buildings in mud mortar on June 4th, 2017, after review by Technical Committee including representatives from the Ministry of Urban Development (MoUD) and leading Nepali structural experts[9]. The design has been made with study of guidelines of "Repair And Retrofitting Manual For Masonry Structure" published by the government. This design by the organization is being taken as reference for this study in order to study the application of BIM tool during retrofit.

The type design is a set of pre-engineered design that makes a structure safe against the seismic deficiencies[10]. This one type design can be applied to numerous houses that falls under the category that type design has targeted on. To be clearer, we apply this one design to all the buildings that fulfil a predefined criteria. The criteria's include shape, proportion, story height, number of stories, opening percentage, opening size, wall thickness, vertical discontinuities and other geological criteria's.

2.5.1 Elements of Type Design

The major elements of type design includes[10]:

1. Ring Beam: To connect the independent longitudinal and transverse wall and to increase the capacity of building for out of plane loads.

2. Strongback: To resist the seismic out of plane loads.

3. Slabstrip: To increase the rigidity of the floor and strengthen the walls at the floor level.

4. Through concrete: It is casted of specific size and length equals to wall width so as to bind both the wyths of a wall.

5. Light Weight Gable Wall: To forbid force induced due to heavy gable.

3. Data Collection and Findings

3.1 Houses Surveyed

The houses of earthquake affected districts were surveyed by NRA (National Reconstruction Authority). The building damage assessment list was then prepared accordingly. Depending upon the damage level, the buildings were given grades in the list. Mostly Grade 2 and Grade 3 category includes houses that needs major or minor repair which means they can be retrofitted. With reference to this assessment list, houses are filtered and study of the automation tool is carried out.

For this research, this damage assessment list is taken into consideration. The two municipalities of Makwanpur district, Thaha palika and Bhimphedi palika are selected.

3.2 Data Collection

The houses are surveyed from site. The information of the houses are collected digitally in forms. There are various apps like FieldSight and KoBoCollect that allows the personnel on site to collect data and submit it. These apps may or may not have free access. There are a list of questionnaires set in the form. Through observations and measurements, the questions are answered and data is collected. The data can be accessed as an excel file which will then be processed in the software automation tool (Dynamo).

3.3 Application of Automation Tool

After the data of the house has been collected from site, it is stored as an excel file. This data is then processed into the tool. The tool reads the excel file and helps to provide solutions to the building based upon the type design. Not every building requires individual analysis. The tool checks the compliance and helps to know what interventions are required during retrofit. The tool checks:

- Maximum Opening Percentage
- Strongback
- Spacing of Concrete Strongbacks
- Location of Strongback
- Pier Size: Piers are the wall widths between openings (window or door).

So, the overall sequence of automation can be described as follows:

1. The data is measured from site and filled into app forms through mobile, tablets, or other possible methods.

2. The form includes all information of the particular building in format of questionnaires.

3. The data is then extracted as an excel file and then processed into the tool.

4. Parameters are set into the tool such that it reads the excel file and then prepares the existing building in the revit format.

5. The tool is run and the existing building is prepared automatically.

6. After the existing set is prepared, the tool is used to check the structural stability and where it provides the possible interventions as well.

7. Followed by rule check is the preparation of retrofit package. Based upon the solutions provided by the tool, retrofit package is prepared manually.

8. Finally, the tool is used to prepare the bill of quantities.

The house of Uddhav Bista of Thaha palika is illustrated below as example. Initially, the existing set is prepared:

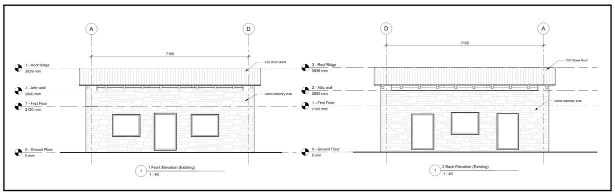


Figure 3: Figure showing front elevation (left) and back elevation (right)

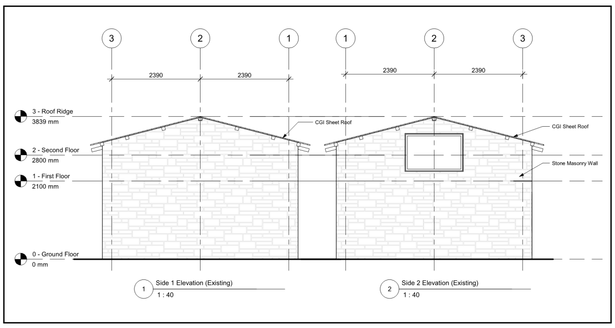


Figure 4: Figure showing two side elevations

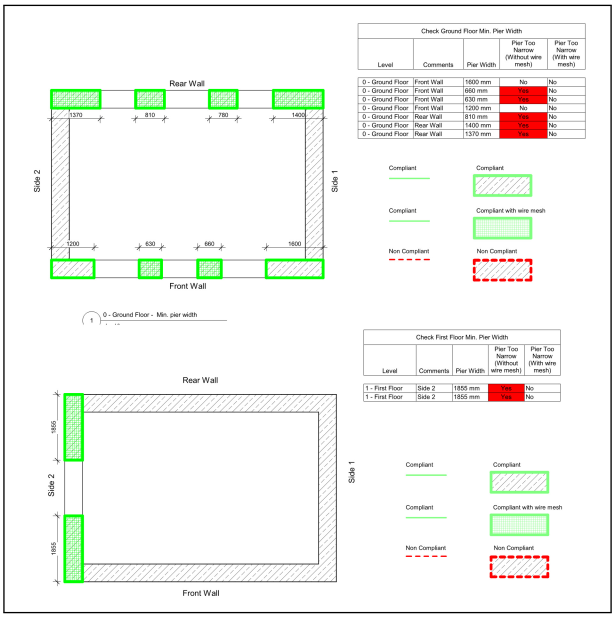


Figure 5: Figure showing pier check to verify if the piers are within the safe limit or not

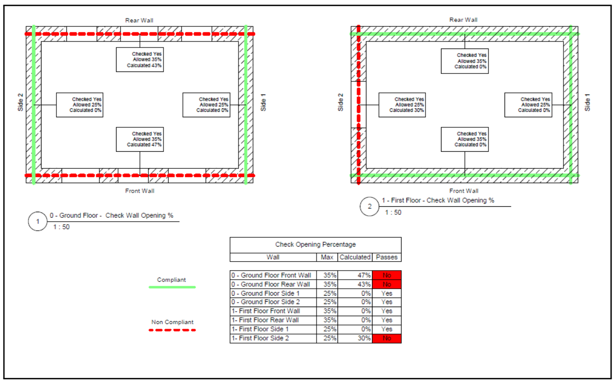


Figure 6: Figure showing opening percentage check

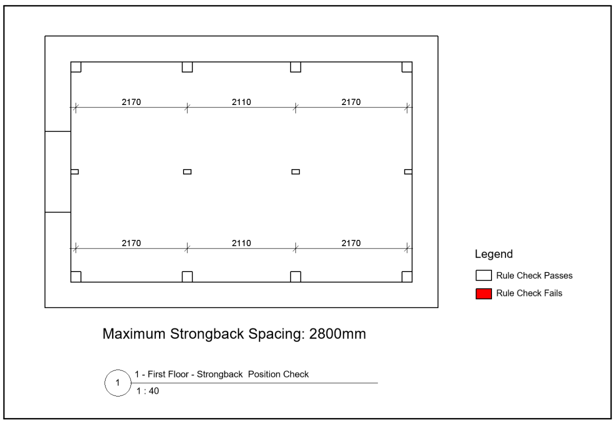


Figure 7: Figure showing strongback position check

The tool then checks the pier size, opening percentage and other checks and thus guides engineers/ architects to provide interventions which can be explained as:

After all the checks have been made, interventions are done as per the tool suggests. Thus, the retrofit solutions are prepared. The opening percentage is not within safe limit. Therefore, the solution is to close or reduce the size of the opening. Also, most of the pier size seems to be too small. Therefore, the solution is to either provide a wire mesh both internally and externally, or close the openings. The retrofit package is prepared accordingly.

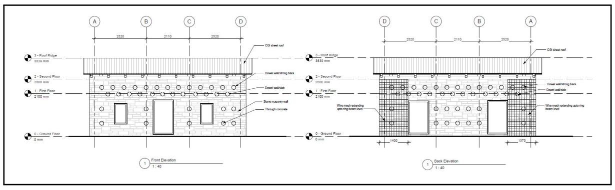


Figure 8: Figure showing retrofitted front elevation(front) and back elevation(right)

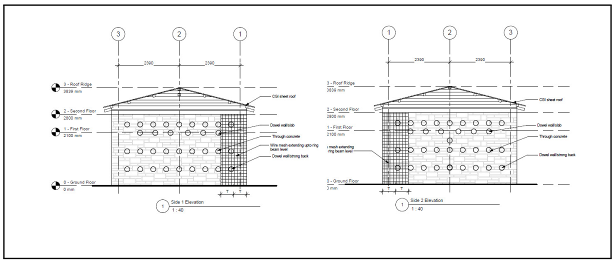


Figure 9: Figure showing retrofitted side elevations

Along with the solutions, bill of quantities can also be estimated which reduces the time during the pre-construction phase. Similar to Uddhav Bista of Thaha palika, majority of the SMM houses of these two palikas can be analyzed and the solutions can be provided accordingly with the help of this tool.

BOQ - Material Breakdown								
Items	Quantity	Multiplier	Total	Cement (m3)	Cement (bags)	Sand (m3)	Aggregate (m3)	Bundles
Total Concrete (m3)	6.19	1.1	6.81	1.94	57	2.93	5.85	
Total Plaster (m2)	144.72	1.1	159.19	0.99	29	4.97		
Total 7mm Rebar (kg)	150.65	1.3	195.84					3.26
Total 10mm Rebar (kg)	32.29	1.6	51.67					0.52
Total 12mm Rebar (kg)	361.74	1.25	452.18					4.52
Total 16mm Rebar (kg)		1.2						

BOQ - Material Summary			
N°	Material	Unit	Quantity
1	Cement	Bags	86.0
2	Sand	m3	7.9
3	Aggregate	m3	5.85
4	7mm Rebar	kg	195.84
5	10mm Rebar	kg	51.67
6	12mm Rebar	kg	452.18
7	Binding Wire	kg	20
8	Rope	Nos	100
9	Bamboo	Nos	40
10	Plywood	Nos	6
11	CGI sheet(12')	Nos	5
12	Nails	kg	14
13	Threaded Rod 12mm (Optional)	kg	12
14	GI wire	kg	15

BOQ for paint			
S.n	Material	Unit	Quantity
1	Wood Primer	ltr	1
2	Metal Primer	ltr	1
3	Solvent (Turpentine)	ltr	1
4	Black Japan Paint	ltr	1

Note: Black Japan Paint can be used both in exposed rebar and wood.

Total 16mm Rebar (kg) = 191.88

Figure 10: Figure showing final bill of quantities

FInally, the retrofit package becomes ready and sent to the site for its construction.

4. Result and Discussion

4.1 Data Analysis and Discussion

From the damage assessment list by NRA, the houses of Bhimphedi municipality are filtered with reference to their damage level (Grade 2 and 3). The houses are filtered on basis of criterias like building typology, building shape, number of story's, building height and land surface type. Among the total houses of 2547 that can be retrofitted, the number of houses of Bhimphedi palika that can be retrofitted with Type Design using BIM automation tool are 1897. This shows that BIM automation tool can be applied to more than half the population of selected houses.

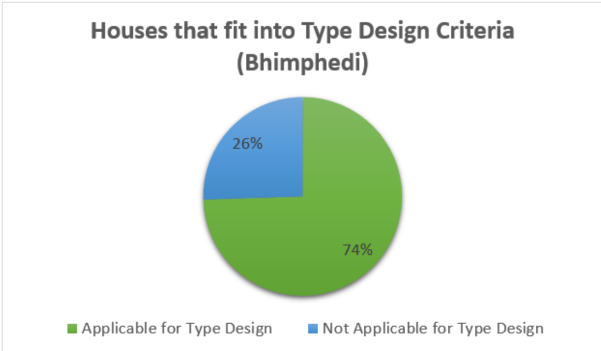


Figure 11: Pie chart showing number of houses applicable for Type Design in Bhimphedi

Similarly, the houses of Thaha municipality are filtered with reference to their damage level (Grade 2 and 3). The total houses that can be retrofitted are 4778. The number of houses that can be retrofitted with Type Design using BIM automation tool are 3314. This shows that BIM automation tool can be applied to more than half the population of selected houses.

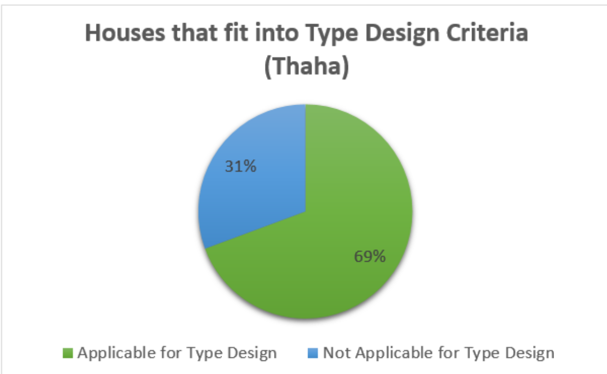


Figure 12: Pie chart showing number of houses applicable for Type Design in Thaha

In both the municipalities, the number of houses in which type design could be applied exceeded 50 percent. This means the automation tool would work for more than half the population. This proves the significance of tool during retrofit. For the remaining houses where type design cannot be applied, it is possible to go with any other retrofit approach, for instance, Splint and Bandage.

4.2 Tool Limitations

It is true that some extra time and effort is required during the initial stage where all the parameters need to be set within the tool. However, once the tool is ready, it can cut off all the extra input and time before the construction phase. Although the application of BIM tool can extend throughout the project cycle, this research covers its use during pre-construction phase only. Despite of all the advantages of the tool, it has some limitations as well:

- During measurement or data collection process, some manual errors might be recorded. It would be hard to identify them since we have less control over errors in data entry.
- Cost of BIM tools can be expensive if the project scale is small.
- Since the users might not be familiar with the tool, a certain amount of time must be invested in training them.

5. Conclusion and Recommendation

The study done in two municipalities of Makwanpur shows how maximum number of houses can be retrofitted using the tool. If the same tool is used for other more districts and municipalities, the same project can be up scaled. Large number of affected districts can be considered during short span. To break down some of its application, we can sum up as:

- The lengthy manual process of extracting data from site is minimized.
- No individual calculation required with use of tool.
- Tool analyses the structural condition based upon the type design and helps us to provide solutions.
- The tool is feasible as it provides options for homeowners as well.

The illustration verifies the effectiveness of this tool only. However, other new tools and technology should be put into consideration as well. The research illustrates how new technologies can be beneficial and have positive impacts in the industry. It not just saves time and money but improves project performance and enhances project delivery.

Acknowledgments

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Annex

district_id	vdcmun_id	ward_id	count_floors_post_eq	height_ft_post_eq	land_surface_condition	plan_configuration	has_superstructure_adobe_mud	has_superstructure_mud_mortar_stone	has_superstructure_stone_flag	has_superstructure_cement_mortar_stone	has_superstructure_mud_mortar_brick	has_superstructure_cement_mortar_brick	has_superstructure_timber	has_superstructure_bamboo	has_superstructure_rc_non_engineered	has_superstructure_rc_engineered	has_superstructure_other	condition_post_eq	damage_grade	technical_solution_proposed
31	3103	310301	2	12	Moderate slope	Rectangular	0	1	0	0	0	0	1	0	0	0	0	Damaged-Repaired and used	Grade 2	Major repair
31	3103	310302	2	20	Flat	Rectangular	1	1	0	0	0	0	0	0	0	0	0	Damaged-Repaired and used	Grade 2	Minor repair
31	3103	310302	2	20	Flat	Rectangular	0	1	0	0	0	0	1	1	0	0	0	Damaged-Used in risk	Grade 3	Major repair
31	3103	310302	2	20	Flat	Rectangular	0	1	0	1	0	0	0	1	0	0	0	Damaged-Used in risk	Grade 3	Major repair
31	3103	310302	2	18	Flat	Rectangular	0	1	0	0	0	0	1	0	0	0	0	Damaged-Used in risk	Grade 3	Major repair
31	3103	310302	2	20	Flat	Rectangular	0	1	0	1	0	0	0	0	0	0	0	Damaged-Used in risk	Grade 3	Major repair
31	3103	310302	1	10	Flat	Rectangular	0	1	0	0	0	0	1	0	0	0	0	Damaged-Used in risk	Grade 2	Minor repair
31	3103	310302	2	15	Flat	Rectangular	0	1	0	0	0	0	0	0	0	0	0	Damaged-Used in risk	Grade 3	Major repair
31	3103	310302	2	12	Flat	Rectangular	0	1	0	0	0	0	0	0	0	0	0	Damaged-Repaired and used	Grade 2	Minor repair
31	3103	310302	1	10	Flat	Rectangular	0	1	0	0	0	0	0	0	0	0	0	Damaged-Used in risk	Grade 3	Major repair
31	3103	310302	2	22	Moderate slope	Rectangular	0	1	0	0	0	0	1	0	0	0	0	Damaged-Used in risk	Grade 2	Minor repair
31	3103	310302	2	7	Flat	Rectangular	0	1	0	0	0	0	0	0	0	0	0	Damaged-Repaired and used	Grade 2	Minor repair
31	3103	310302	2	16	Moderate slope	Rectangular	0	1	0	0	0	0	0	0	0	0	0	Damaged-Repaired and used	Grade 2	Major repair
31	3103	310302	2	14	Flat	Rectangular	0	1	0	0	0	0	0	0	0	0	0	Damaged-Used in risk	Grade 3	Major repair
31	3103	310302	2	12	Moderate slope	Rectangular	0	1	0	0	0	0	0	0	0	0	0	Damaged-Used in risk	Grade 3	Major repair
31	3103	310302	1	10	Moderate slope	Rectangular	0	1	0	1	0	0	0	0	0	0	0	Damaged-Used in risk	Grade 3	Major repair
31	3103	310302	1	10	Flat	Rectangular	0	1	0	0	0	0	0	0	0	0	0	Damaged-Used in risk	Grade 2	Major repair
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31	3103	310302	2	15	Flat	Rectangular	0	1	0	1	0	0	0	0	0	0	0	Damaged-Repaired and used	Grade 3	Major repair
31	3103	310302	2	15	Flat	Rectangular	0	1	0	1	0	0	0	0	0	0	0	Damaged-Used in risk	Grade 3	Major repair
31	3103	310302	2	15	Flat	Rectangular	0	1	0	0	0	0	0	0	0	0	0	Damaged-Used in risk	Grade 3	Major repair
31	3103	310302	2	15	Flat	Rectangular	0	1	0	0	0	0	0	0	0	0	0	Damaged-Repaired and used	Grade 2	Minor repair
31	3103	310302	2	13	Flat	Rectangular	0	1	0	0	0	0	1	0	0	0	0	Damaged-Used in risk	Grade 2	Minor repair
31	3103	310302	2	13	Flat	Rectangular	0	1	0	0	0	0	1	0	0	0	0	Damaged-Not used	Grade 2	Minor repair
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31	3103	310302	2	13	Flat	Rectangular	0	1	0	0	0	0	1	0	0	0	0	Damaged-Used in risk	Grade 2	Major repair
31	3103	310302	2	13	Flat	Rectangular	0	1	0	0	0	0	0	0	0	0	0	Damaged-Used in risk	Grade 2	Major repair
31	3103	310302	2	13	Flat	Rectangular	0	1	0	0	0	0	0	0	0	0	0	Damaged-Repaired and used	Grade 2	Minor repair
31	3103	310302	2	13	Flat	Rectangular	0	1	0	0	0	0	0	0	0	0	0	Damaged-Used in risk	Grade 2	Minor repair
31	3103	310302	1	7	Flat	Rectangular	0	1	0	0	0	0	0	0	0	0	0	Damaged-Used in risk	Grade 2	Major repair

Figure 13: Sample of damage assessment list of Bhimphedi palika prepared by NRA that is taken as reference to check the validity of tool

district_id	vdcmun_id	ward_id	count_floors_post_eq	height_ft_post_eq	land_surface_condition	plan_configuration	has_superstructure_adobe_mud	has_superstructure_mud_mortar_stone	has_superstructure_stone_flag	has_superstructure_cement_mortar_stone	has_superstructure_mud_mortar_brick	has_superstructure_cement_mortar_brick	has_superstructure_timber	has_superstructure_bamboo	has_superstructure_rc_non_engineered	has_superstructure_rc_engineered	has_superstructure_other	condition_post_eq	damage_grade	technical_solution_propose
31	3111	311108	2	18	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	22	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	22	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 2	Major repair
31	3111	311108	2	22	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	22	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	20	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	18	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	22	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	22	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	1	12	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	22	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	22	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	22	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	22	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	22	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	22	Flat	Rectangular	0	1	0	0	0	0	0	0	0	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	16	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	22	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	22	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	16	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	22	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	1	16	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 2	Major repair
31	3111	311108	2	22	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	1	18	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	2	22	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	1	21	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair
31	3111	311108	1	17	Flat	Rectangular	0	1	0	0	0	0	0	0	1	0	0	Damaged-Not used	Grade 3	Major repair

Figure 14: Sample of damage assessment list of Thaha palika prepared by NRA that is taken as reference to check the validity of tool