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KAP of Retrofitting of Typical Stone in Mud Mortar Residential Structures of Siddhalekh Rural Municipality, Dhading

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Abstract
Nepal lies in active seismic region. It has experienced many destructive earthquakes in the past. Majority of building type almost half of Nepal includes low strength masonry structure such as mud bonded brick or stone structure followed by wooden pillar structure, which constitute one fourth of the total houses. To protect lives and property from earthquake it is very important to seismic retrofit of the existing non earthquake resistant structures. The study aims to examine gap for lack of expansion of retrofitting technique through the determination of knowledge attitude and practice of house owners of seismic retrofitting whose house is feasible for retrofitting and knowledge, attitude, and practice about seismic retrofitting of local authorities whose area of governance possess structures feasible for retrofitting along with the relationship between the knowledge attitude and practice. Knowledge and attitude of masons and attitude of technical personnel towards retrofitting was determined to determine perception of retrofitting in community. Moreover, the research aims to determine the motivating factors and barriers for stake holders namely house owner, local authority, engineer, and masons to focus on those primary barriers for future expansion of the retrofit project. On top of that, the research determines the major technical construction difficulties faced by masons during the retrofitting of residential buildings and provides valuable solutions to those problems through consultation with the experienced masons and engineers working in the field of retrofitting.

Keywords
Retrofitting, Earthquake, Stone masonry mud mortar, KAP survey

1. Introduction

Upgrading the structural strength and improvement of inelastic deformation capacity or ductility of the structure is the basic concept of seismic retrofitting. Assembly of old and new material is one of the key points of seismic retrofitting technique[1]. Retrofitting refers to application of new technologies in the existing system, which in the process add new earthquake resistant element in the system, and hence make the structure earthquake resistant or seismic resistance.

Retrofitting improves the response of prevailing un-reinforced structure to seismic load as gravity by eliminating the seismic deficiencies, it rises the flexural strength of un-reinforced piers and walls as well as improves the "box type" performance. Configuration improvement, connections, ductility, capacity, and load path are incorporated under retrofitting. On the contrary, structural strength is not improved through repair, which is very deceptive for achieving the required strength for the future seismic events[2]

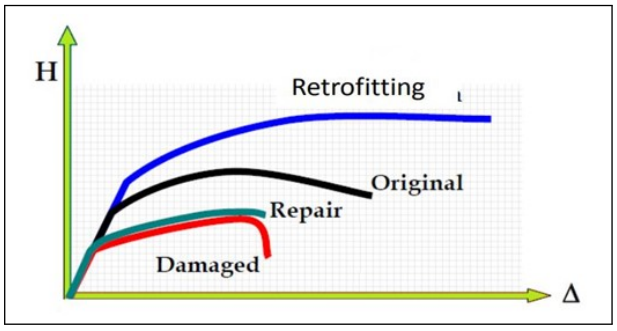

Figure 1: Comparison of repair and retrofit

1.1 Progress of Retrofitting

Table 1: Retrofitting progress

Location	Enrolled	Completed	Remaining
Rural	30267	158	30109
Urban	16966	106	16860

From Table 1 we can clearly see the progress of retrofitting as not up to the mark as less than 1 percentage of total household has only been able to retrofit their house in the span of more than 5 years. Retrofitting was undertaken in a relatively small-scale intervention compared to new construction post 2015 earthquake[3].Although reconstruction of the completely damaged structures due to Gorkha earthquake 2015 is about to accomplish, retrofitting of partially damaged buildings, on the other hand, has not gained momentum.Although National Reconstruction Authority possesses the manual that support in the construction and design of retrofitting, it lags the key challenges faced by masons and supervisor during the construction phase of retrofitting[4]

1.2 Study area

The study area taken for research is Siddhalekh Rural Municipality, which is located to around 86 km North West from capital city, Kathmandu. It lies within the Dhading district in the Bagmati province .Siddhalekh is surrounded by Neelkantha Municipality and Jwalamukhi Rural Municipality at its north,Galchi Rural Municipality at East, Gajuri and Benighat Rorang Rural Municipality at its south and Gandaki Rural Municipality at its South. Total area of Siddhaleh R.M is 106.1 sq. km with population of 23,729 as per census 2011. However, only ward no 1 and 2 of Siddhalekh are taken for the study purpose. The area consists of both the urban as well as rural settlements. Due to Gorkha earthquake Siddhalekh rural municipality was highly affected with its shaking. Total no of full beneficiaries in within Siddhlekh 1 and 2 no ward is 1607 whereas retrofitting beneficiaries are 110 among which 18 households has retrofitted their house.

2. Methodology

To achieve these objectives, firstly, systematic literature review method has been adopted. A systematic literature review provides a proper understanding of the background of the study and research that have been carried out till date within the limit of the objectives of the study. With the aim of covering all the materials regarding the topic of this study, technical reports, governmental and non-governmental reports, thesis works, and newspaper articles are also taken into consideration as existing literature. A combined approach method is used for the study which is quantitative as well as qualitative approach. Quantitative analysis involve analysis of numerical data using specific statistical techniques to get the required solution[5].However, quantitative analysis refers to the analysis of in depth data collected through observation, discussion video-graph. Quantitative analysis generally provides more qualitative data as it is obtained through open ended questions which does not has any limit or boundary.

3. Data Analysis

The data collected from each survey through use of google form were compiled separately and analyzed using SPSS16.0 to determine the relationship between different variables. MS Excel was used to plot charts and graphs, which were used to demonstrate the visual representation of the findings.The data collected from each survey through use of google form were compiled separately and analyzed using SPSS16.0 to determine the relationship between different variables. MS Excel was used to plot charts and graphs, which were used to demonstrate the visual representation of the findings.

3.1 Cronbach's alpha test

Cronbach's alpha is a measure of internal consistency, that is, how closely related a set of items are as a group. It is considered to be a measure of scale reliability[6]. The value of Cronbach's alpha was calculated by using equation (2):

$$\alpha = \frac{N\bar{c}}{\bar{v} + (N-1)\bar{c}} \tag{1}$$

where,
N = number of items
$\bar{c}$ = average inter-item covariance among the items
$\bar{v}$ = average variance

3.2 Relative Importance Index (RII)

Relative Importance Index (RII) is used to determine the Barriers and motivating factors for implementing retrofitting for various stakeholders. The points of Likert scale used is equal to the value of W, weightage given to each factor by the respondent[7].The Relative Importance Index (RII) was calculated by using equations (3) and Applied Technology Council 40:

$$\mathrm{RII} = \frac{\sum W}{A * N} \tag{2}$$

where,
$\sum W = 5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1$
W = weightage given to each factor by the respondent
n_5 =frequency of very high priority
n_4 = frequency of high priority
n_3 = frequency of neutral priority
n_2 = frequency of low priority
n_1 = frequency of very low priority
A = the highest weight that can be given
N = total number of respondents

3.3 Pearson's Correlation test (r)

Pearson's correlation coefficient determines the level of strength and associated direction between two scale variable. The Pearson's correlation coefficient represents the distance between the points from the best fit line[8]. Relationship between knowledge, attitude and practice is determined using the principle of Pearson's correlation using SPSS 16.0.

$$r = \frac{N\sum xy - (\sum x)(\sum y)}{\sqrt{\{N\sum x^2 - (\sum x)^2\}\{N\sum y^2 - (\sum y)^2\}}} \tag{3}$$

Where,
r=Pearson's Product Moment Correlation Coefficient
N=Number of pairs of value or scores
$\sum xy$ = Sum of the product of x and y
$\sum x$ = Sum of x values
$\sum y$ = Sum of y values
$\sum x^2$ = Sum of x square values
$\sum y^2$ = Sum of y square values
$(\sum x)^2$ = Square of sum of x values
$(\sum y)^2$ = Square of sum of y values

4. Result and Discussion

4.1 Knowledge, attitude and practice

Level of Knowledge, attitude and Practice of house owner and local authorities were determined along with the co-relation between knowledge attitude and practice within each stakeholders.

4.1.1 House Owner

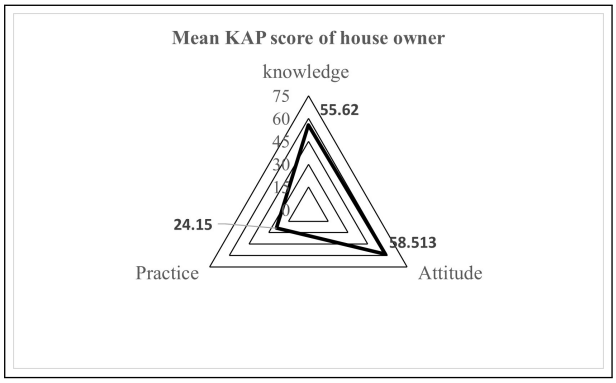

Figure 2: Knowledge attitude and practice of house owner

The value of sig.(p-value) is less than 0.05 between knowledge and attitude(0.000) and knowledge and practice(0.000) as well as attitude and practice(0.000) There is significant relationship between knowledge, attitude and practice.

Amount of money preferred to spend by house owner on retrofitting Almost 74 percentage of house owner are ok to invest 1 months to 6 months of their monthly income to protect their house and themselves from earthquake by retrofitting their house whereas around 13 percentage population can invest maximum of 6 moths to 1 year of their monthly income and remaining around 13 percentage are capable to invest 1-2 years of their monthly income to retrofit their house.

Expected support from house owner 54.55 percentage of the population wants subsidies as support, around 31 percentage expect the mason support, almost 13percentage expect loan at low interest rates and remaining 1.82 percentage expect free technical support.

4.1.2 Local Authority

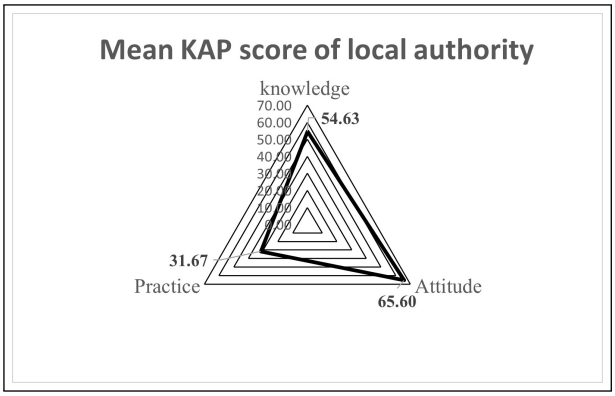

Figure 3: Knowledge attitude and practice of local authority

The value of sig.(p-value) is less than 0.05 between knowledge and attitude (0.000), knowledge and practice(0.023) and attitude and practice(0.011) which shows a significant relationship between knowledge attitude and practice.

4.1.3 Engineers

Engineers attitude to wards retrofitting was found to be 63.335 percentage.

4.1.4 Masons

Knowledge of mason was found to be 60.15percentage with standard deviation of 14.98 and attitude towards retrofitting was 73.027percentage with standard deviation of 10.125. The value of sig.(p-value) is less than 0.05 between knowledge and attitude(0.0014).Hence, there is significant relationship between knowledge and attitude.

Difficulty of construction process of retrofitting Almost 50 percentage of the masons participated in retrofitting process find the difficulty level of retrofitting process as moderate , 46 percentage of the population find it easy and remaining 1.45 percentage found it difficult.

Perception of mason to retrofit residential structure Among 74 masons surveyed almost 23percentage of them believe that they can retrofit residential structure without support from engineer whereas remaining 77percentage requires minimal support from engineer to retrofit the private residential buildings.

Expected support from masons Most of the masons expect support for location and width of splint and bandage which is 80percentage whereas remaining 20percentage knows the locations of splint and bandage but require support from engineer to specify the width of splint and bandage.

4.2 Motivating factors and Barriers for retrofitting

Earthquake resiliency, time relevancy and lower cost are the three major motivating factors followed by dynamic use able space and preservation of culture for the engineers. Local authority are more fascinated for preservation of culture due to retrofitting followed by the resiliency they possess. Masons seems to be motivated by the strength of building, lower cost, and culture preservation and for their new skill development. House owner are motivated as it preserves their cultural house, house become earthquake resistant, lower cost of retrofitting and incentives by government and Ngo's.Initial high cost and house owner demand has been the major barrier of retrofitting as per the engineer, local authority and masons whereas high initial cost, lack of government support and opportunity to covert to full beneficiaries are the major barriers.

4.3 Technical challenges during retrofitting and its solution

Full anchorage Major difficulty was faced by mason in the earlier stage of retrofitting to perform full anchorage whose major task is to tie-up outside and inside splint and bandage through GI wire .Use of drill machine to penetrate the through hole in a stone masonry wall was a tall order. As a solution 12 mm diameter rebar was cut into length of 25 inch and pointed at one end and hence through hole was drilled through use of pointed rebar and hammer.

Installation of metal plate The typical SMM structures with flexible floor have wooden horizontal members named Nidal (primary beam) and Dalin (secondary beam or joist) which are normally rested on the horizontal wooden platform but most of the structures missed those horizontal platform which made installation of metal plate difficult at required locations. To iron out the problem metal plates (designed for lateral strain) were replaced with the traditional wooden nail, where the nails were installed adjacent to the wall by penetrating through the

wooden member.

Anchorage of installed wire mesh at the side of doors and windows Problems in anchorage of wire mesh at the side of openings such as door and windows were encountered during the retrofitting as pebble stones placed in the middle of wall and in the side of the openings with thick mud mortar and mud plaster which makes half anchorage inappropriate as the slurry inserted in the half anchorage will get mixed with mud making it fragile. As a solution of problem, the wire mesh in at the side of openings were anchored with the help of 10 Gauge GI wire by connecting inner and outer splint through the path of mesh placed at the side of opening.

Plaster above the welded wire mesh Plastering above the wire mesh was found to be challenging by the masons during retrofitting as the striking cement sand mortar in one location would cause vibration and make the finalized plaster fall in adjacent location. As a solution rough plastering was done throughout the surface at once to make plaster intact in the surface and finishing was done in the following day. As shown in figure below area inside the read lining was plastered roughly yesterday as smoothing was done the next day to solve the problem of uprooting of newly plastered surface.

5. Conclusion

Knowledge, attitude, and practice of house owner was found to be 55.62 percentage, 58.51 percentage and 24.15 percentage respective which displays clear gap between knowledge and attitude with practice. However, Significant relationship was found between knowledge, attitude and practice when measured in house owner which proves that if we want to more houses to be retrofitted proper knowledge should be imparted among the people which will change the attitude and hence increase in practice. For local authorities Knowledge, attitude and practice was found to be 54.63 percentage, 65.6 percentage and 31.67 percentage and there was significant relationship between knowledge attitude and practice. The practice score of both house owner and local authority seems to low which is 24.15 percentage and 31.67 percentage as compared their score of knowledge and attitude which explains that people are knowledgeable and positive towards retrofitting but it's not into the practice. To determine these above relationship correlation tests was performed within knowledge, attitude and practice. Average attitude of technical personnel towards retrofitting was 63.33 percentage which shows that they are positive towards retrofitting. Average knowledge and attitude of masons in Siddhalekh RM were found to be 63.15 percentage and 73.03 percentage which proves they are capable as well as positive towards the expansion of retrofitting in their locality.

Majority of the house owner around 75 percentage prefer to invest half to one year's income to retrofit their house to make it earthquake resistant where almost 72 percentage of them have income of less than 15,000 and remaining 23 percentage have their income from 15,000 to 30,000 and remaining 5 percentage have more than 30,000 incomes. Majority of the house owner expect subsidies support (54.55 percentage) followed by mason support (30.91 percentage) and around 13 percentage expect loan at low interest rates. These above data suggests that if we can support people with subsidies and masons support there will be a lot of house owners willing to retrofit their house it's just the initial ignition that is needed to be given by the local government as the survey proves they are knowledgeable as well as have the positive attitude towards the technology.

Engineers seems to gain knowledge of retrofitting form their work experience and training's, masons through training's and demonstration houses, house owners got their knowledge through Demonstration houses awareness program and relatives and local authorities got knowledge from demonstration houses workshops and awareness programs. Awareness program and demonstration houses seems to be the major source of knowledge for retrofitting as all stake holders.

Motivation factors of various stake holders were determined through Relative Importance Index (RII) Engineers and masons seems to be motivated by its ability to make the structure earthquake resistant and its importance as it is time relevant and new skill to possess whereas house owner and local authority are more fascinated with the preservation of their culture and property, Earthquake resiliency and Incentives. As per the engineers' local authorities and masons the major barrier of expansion of retrofitting seems to be the house owner's demand to retrofit their house and high initial cost and when further asked about the barrier of house owner its seems that the High initial cost and opportunity to convert to full beneficiary are the major barriers in expansion of retrofitting.

All stake holders engineer, mason, house owner and local authority itself believes Government role is of paramount importance in expansion of residential retrofitting in Nepal. Majority of the masons were comfortable with the construction process of retrofitting. Almost one fourth of the masons were confident of performing retrofitting on their own where remaining three fourth required support of engineer to locate the splint and bandage.

The four major technical construction difficulties encountered by masons during retrofitting of residential households were determined which were creating through hole, installation of metal plate where horizontal wooden member were absent, anchorage of mesh at the side of openings and plastering over the wire mesh and solutions to those problems were also found using the ancient construction technique through the discussion with the masons and engineers.

6. Recommendation for further Research

This study has its limitations regarding the field of survey, depth of study, study area and study variables. The future researchers are welcome to work on the shortcomings of this literature. The following are the recommendations to the future researchers:

•Study area can be expanded with an aim to represent whole Nepal

•Perception change about retrofitting among the stake holder's masons, house owner and local authorities can be analyzed.

•In depth research can conducted focusing more on the the cost of retrofitting of residential structures.

•Further research can be performed on factors affecting for expansion of residential retrofitting

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