Use of Pine-Needle Reinforced Composites in Kashmir, Pakistan – A Critical Review

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Abstract

Previously, pine-needles were used for many decades in mud-house construction in Kashmir, Pakistan which is an earthquake prone region. But with the passage of time, its utilization is reduced. There are still many houses in different conditions e.g. well-reserved (livable for residence and storage), above-average (for storage only and useable for residence after repair), below-average (useable after repair only) and poor (to be demolished). The overall aim of the study program is to evaluate the reasons for reduced use of pine-needle reinforced composites and to check the possibility of revival of its utilization in house construction. For this, it is important to collect the information about the type/location of houses, age of houses, detail of composite composition used in plaster and mortar of external and internal walls, and different cracking patterns (if any). Street survey is conducted for taking the information from owner. The gathered data is recorded in a systematic way to analyze the reasons for its reduced use. The retrofitting/repair of existing structures is also discussed. For future studies, the lab testing is recommended for exploring its potential as a construction material. Accordingly, the revival of its use is possible in construction of new houses.

Keywords: Pine needle, reinforced composites, plaster, mortar, street survey, construction material.

1. Introduction:

The Kashmir earthquake 2005 was ranked amongst the worst natural disasters in the history of Pakistan and the Indian subcontinent (Durrani et al. 2005). It had widespread destructive effects i.e. 86,000 people killed and over 80,000 severely injured (Mulvey et al. 2008). Rossetto and Peiris (2009) reported that the violent ground shaking caused damage to more than 450,000 buildings, leaving about 2.8 million people without shelter. According to early estimates (WB-ADB, 2005), the total cost of reconstruction of the damaged infrastructure and rehabilitation was in excess of five billion dollars.

Fiber reinforced composites with steel, polymeric, glass, carbon and natural fibers had been evaluated for structural applications (Parra-Montesinos 2005). Mortar-free construction using coconut fiber reinforced concrete and coconut-fiber ropes had been evaluated for seismic-resistant houses (Ali 2016). Coconut fibers were preferred because of its toughness property. It was concluded that coconut fibers had the potential to be used in composites for house construction. Wang and Chouw (2017) investigated the effect of coconut fibers on impact resistance of concrete. Coconut fiber reinforced concrete (CFRC) cylinders were tested under impact load and reduced spalling of concrete was observed as compared to that of plain concrete. Failure pattern of CFRC under the impact load was different than that under static load.

Rapid street screening for potential seismic hazards was a simple and effective seismic risk assessment method. The procedure was applied to detect and rank the most vulnerable buildings that might damage during a forthcoming earthquake. This was based on the observations and giving score for the selected buildings, considering some selected parameters from the street (Albayrak 2015). Similarly, the condition of different houses can be assessed by visual inspection. Some parameters to be assessed can be: age of houses, detail of composite composition used in plaster and mortar of external and internal walls, and different cracking patterns. Majority of people lived in traditionally constructed mud houses in developing countries. The performance of traditional adobe construction during numerous Iranian earthquakes had generally been poor. Low material strength, poor workmanship, lack of proper connections between building elements, and the excessive weight of the building contributed in weakness of these buildings under earthquake loads (Maheri et al., 2005).

In Egyptian times, the straws or horsehair were added to mud bricks. Straw mats serving as reinforcements were also found in early Chinese and Japanese housing construction (Li et al. 2002). Farraj and Varney (2009) used straw bales for constructing the load bearing walls. Coconut fibers were used in house construction in exterior and interior walls (Luisito et al., 2005). On the other hand, pine needle reinforced composite is also traditionally used in mud in Kashmir, Pakistan. But now, its usage is reduced. The overall aim of the study program is to evaluate the reasons for reduced use of pine-needle reinforced composite and to check the possibility whether it can be utilized as a construction material in future or not.

2. Adopted Procedure:

2.1. Street Survey

Out of eight districts of Azad Kashmir, the survey was conducted in only two districts. Figure 1 shows the map of Kashmir, Pakistan in which the targeted area is enlarged and the studied regions are encircled**.** The mud houses of village "Dara Sher Khan" in District "Poonch" and village "KiniSyedin, Haji Abad" in District "Kotli" of Kashmir, Pakistan are assessed. 100 houses are taken as a sample for this study.

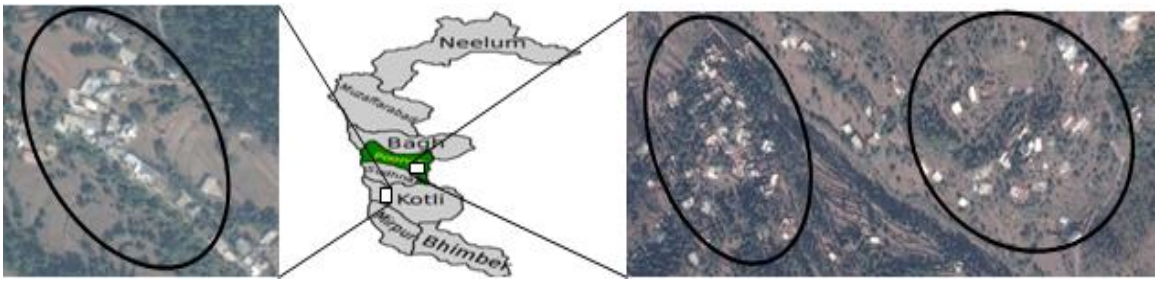

Fig.1 Focused area in Kashmir Pakistan

2.2. Information to be collected

The information is collected about the type of houses, age of houses, detail of composite composition used in plaster and mortar of external and internal walls, different cracking patterns and condition of houses. The conditions of houses are checked by visual inspection and the cracking pattern is observed. Interviews are taken from the local people about their houses which are made of pine-needle reinforced composite.

3. Observation and Analysis:

3.1. Characteristics of Houses

In Kashmir Pakistan, mud houses are reinforced with pine needle for its durability. Local people prefer mud houses because of the wide availability of raw materials and local knowledge for traditional construction. Houses are made of stone/bricks and the pine-needle reinforced mud. Pine-needle reinforced mud is used as mortar and plaster in external and internal walls as well as roofing material. The information collected about house constructed with pine needle reinforced composites (i.e. mud + pine-needle) is summarized in Table 1. Different conditions of houses are observed during survey such as: well reserved; above average; below average and poor. Well Reserved houses are very safe for residence and storage. One reason for these safe houses may be the quality of construction and labor expertise. These houses are in excellent condition and do not need any repair. Thus, these can be used for long duration. Houses, which are usable after little repair for residence and storage, are considered as above average. Above average houses are those which are not constructed by expert labors. Houses, which are usable after major repair for storage only (i.e. not suitable for residence), are considered as below average. Houses (that are categorized as poor) are usually made for intention of storage only. That is why, these are not properly maintained. These houses are in critical condition (i.e. can not be repaired) and need to be demolished. The condition of houses

does not depend only on the age of the house but also on its regular maintenance. There are many houses having same age but some are below average and others are poor. Out of 100 houses, 28 percent are well reserved (07-47 years old), 18 percent are above average (12-52 years), 34 percent are below average (10-57) and 20 percent are poor (19-73 years old). In well reserved houses, only hairline cracks are observed; while in poor houses, severe diagonal and horizontal cracks and major spalling are observed.

Table 1: Summary of houses constructed with pine-needle reinforced composite (mud + pine-needle)

Sr. No.	Condition of Houses	No. of houses	Age of Houses (Years)	Observed cracking pattern
1	Well reserved	28	07-47	• Hairline cracks in external and internal plaster
2	Above average	18	12-52	• Minor spalling in external and internal plaster and mortar • Zig zag cracks in external and internal plaster and mortar
3	Below average	34	10-57	• Diagonal cracks in plaster near openings • Zig zag cracks in external walls
4	Poor	20	19-73	• Diagonal cracks in external walls • Horizontal cracks near openings in plaster • Major spalling in external and internal plaster and mortar

Note: Pine- Needle reinforced composites (mud + pine-needle) are used in mortar and plaster of internal and external walls, the composite is also used as roofing material.

Fig. 2 Selected houses of different conditions in Kashmir Pakistan

3.2. Condition of Houses

Selected houses of different conditions (i.e. well reserved, above average, below average and poor) are shown in Figure 2. Wooden stiffeners (i.e. columns) are used in almost every house. The conditions of these houses are also dependent on these wooden stiffeners. Because, with the passage of time, these wooden stiffeners are liable to vermin attack. In addition to this, shrinkage due to weather, regular maintenance and labor expertise are also important factors. In rainy season, the mud starts eroding with water and ultimately cracks appear. It is also observed that, due to capillary action, walls get wet in areas of high water table. That is why, regular maintenance is very necessary. Stone masonry is not properly adjusted in the walls of below average and poor houses by inexperienced labors. Well reserved houses have good quality of construction and are maintained regularly.

3.3. Condition of Structural Walls

Observed cracking pattern in plaster and mortar of exterior and interior walls of load bearing walls with pine needle reinforced mud are shown in Figure 3. It may be noted that the plaster was intentionally removed to check mortar in walls of well reserved and above average houses. Cracks usually develop due to shrinkage because of loss of moisture. Only hairline cracks are found in plaster of well reserved houses. Minor spalling and zig zag cracks are found in above average houses which are not severe and need little repair. In below average houses, diagonal and zig zag cracks are developed which are thin and deep. These are the severe cracks and need major repair. Poor houses are more severe because of diagonal and horizontal crack and major spalling. So, poor houses need reconstruction.

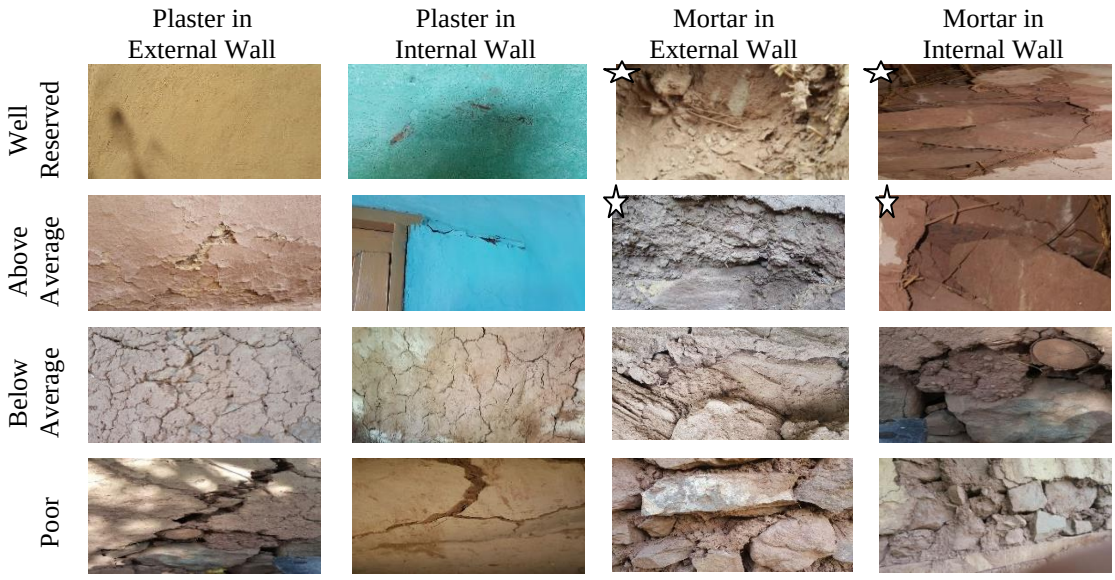

Fig. 3 Observed cracking pattern in plaster and mortar of exterior and interior walls

(Note: ☆ means plaster was intentionally removed to check mortar)

4. Discussion:

The presence of some narrow cracks is usually tolerated and even expected if the house is old. But it is not always obvious that what level of cracking is acceptable? And when building repairs are necessary? Cracks in mud brick walls can be caused by a number of factors. One of the most important is the shrinkage of soil. Just after the construction, when the water evaporates, the soil shrinks, ultimately resulting in cracking. Well reserved houses are well maintained and have no cracks or acceptable hairline cracks. The reason for well reserved houses is that these houses are usually made for residence and are regularly maintained. Above average houses can be considered as well reserved after little repair. Below average are more severe and need retrofitting as soon as possible. Poor houses should be demolished.

Well reserved houses are made of good mud/soil type. The bond between soil, pine needle and stone is proper. This is so because soil is retained by pine needle. Above average houses are not well maintained and soil type is not as good as that of well reserved. By little repairs, these houses can be made useable for residence also. Below average houses are in sever condition and soil type is very poor. But the pine needle holds the mud together. These houses can be useable only after repair for storage purposes. Poor houses cannot be repaired so it is better to demolish and reconstruct.

Well reserved houses are built 7 to 47 years ago. There are houses which have 10 years of age but are below average. Some houses are 19 years old but they are poor. It may be noted that 47 years old houses are well reserved. It clearly shows that houses need maintenance for long term utilization. The damage in houses is not only due to its age but also it depends on expertise in construction techniques and its proper maintenance. Cracks appear in every house with the passage of time. Well reserved houses are constructed by expert labors that can be seen from the quality of construction along with its well maintenance. On the other hand, it is noted that poor houses are not well constructed. This is clear from the bonding and interlocking of stones/bricks. These houses are also not maintained.

Samples should be extracted from all existing houses for testing so that the properties of pine-needle reinforced composite can be explored. These tests include compressive and shear strength tests. The results can be used to predict the feasibility of pine-needle reinforced composite as a construction material. Also, the information can be used for the retrofitting recommendation of the existing houses.

The use of pine-needle reinforced composite is reduced because of the fact that 80% of houses have cracks in their walls even in well reserved and above average houses but these cracks are in acceptable limits. However, these cracks disable aesthetics of the walls. The reason for these cracks could be the improper composition of pine needle reinforced mud (i.e content and length of pine-needle in mud). Another reason of its reduced use is the introduction of new construction material (e.g concrete) in the region.

The cracks in the external and internal walls of below average and poor houses can be repaired by replacing the existing plaster with new one. For the cracks across the wall thickness, remove plaster, anchor pine-needle mesh and replaster both sides of wall.

5. Conclusion and Recommendation:

A total of 100 houses made of pine needle reinforced composites are assessed. Following are the conclusions:

- 28 percent houses are well reserved (07-47 years old), 18 percent are above average (12-52 years), 34 percent are below average (10-57) and 20 percent are poor (19-73 years old).
- The severity of damage in houses does not only depend on the age of the houses but also the quality of construction and regular maintenance.

The good percentages of well reserved and above average houses are promising for sustainability of pine needle reinforced composite. The testing of mortar and masonry sample are necessary to identify the future directions.

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References:

ADB-WB (2005). Preliminary Damage and Needs Assessment. *Asian Development Bank and World Bank Report.*

Albayrak, U., Canbaz, M., & Albayrak, G. (2015). A rapid seismic risk assessment method for existing building stock in urban areas. *Procedia Engineering*, 118, 1242-1249.

Ali, M. (2016). Use of coconut fibre reinforced concrete and coconut-fibre ropes for seismic-resistant construction. *Materiales de Construcción*, *66*(321), 073

Durrani, A. J., Elnashai, A. S., Hashash, Y., Kim, S. J., &Masud, A. (2005). The Kashmir earthquake of October 8, 2005: A quick look report. *MAE Center CD Release* 05-04.

Farraj, A., & Varney, E. (2009). Straw Bale Construction. https://courses.cit.cornell.edu/crp384/2009reports/Farraj&Varney_Straw%20Bale%20Construction.pdf

Li, V. C. (2002). Large volume, high-performance applications of fibers in civil engineering. *Journal of Applied Polymer Science*, 83(3), 660-686.

Luisito JP, Neil JM, Rolendio N (2005). Coconut fibre boards. http://www.ecocoboard.net/dwnloads/Presentations%20workshop/Penamora_Coconut%20fibre%20cement%20boards.pdf

Maheri, M. R., Naeim, F., & Mehrain, M. (2005). Performance of adobe residential buildings in the 2003 Bam, Iran, earthquake. *Earthquake Spectra*, 21(S1), 337-344.

Mulvey, J. M., Awan, S. U., Qadri, A. A., & Maqsood, M. A. (2008). Profile of injuries arising from the 2005 Kashmir Earthquake. *Injury* 39(5), 554-560.S

Parra-Montesinos, G. J. (2005). High-performance fiber-reinforced cement composites: an alternative for seismic design of structures. *ACI Structural Journal*, 102(5), 668.

Rossetto, T., & Peiris, N. (2009). Observations of damage due to the Kashmir earthquake of October 8, 2005 and study of current seismic provisions for buildings in Pakistan. *Bulletin of Earthquake Engineering*, *7*(3), 681-699.

Wang, W., & Chouw, N. (2017). The behaviour of coconut fibre reinforced concrete (CFRC) under impact loading. *Construction and Building Materials*, *134*, 452-461.