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Improving comfort levels in a traditional high altitude Nepali house

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ABSTRACT

Humla Province is a remote mountainous region of northwest Nepal. The climate is harsh and the local people are extremely poor. Most people endure a subsistence culture, living in traditional housing. Energy for cooking and heating comes from fuelwood, supplies of which are diminishing. In order to improve the indoor environment and reduce fuelwood use, smokeless stoves are being introduced to replace the open fire in Humli homes. There is some concern, however, that comfort levels may not be as acceptable with these stoves. The aim of this research was therefore to investigate ways in which the comfort levels in traditional Humli housing might be improved using simple and low cost strategies. Temperature data was recorded in four rooms of a traditional Humli home over a 12-day period and used with fuelwood data to validate a TRNSYS simulation model of the house. This model was then used to evaluate the impact on comfort levels in the house of various energy conservation strategies using PMV and PPD indicators. As a single strategy, it was found that reducing infiltration of outside air was likely to be more effective than increasing the insulation level in the ceilings. The most successful strategy, however, was the creation of sunspaces at the entrances to the living rooms. This strategy increased average internal temperatures by 1.7 and 2.3 °C. In combination with increased insulation levels, the sunspaces reduced comfort dissatisfaction levels by over 50%.

1. Introduction

Nepal is a developing country and is ranked 142nd out of 177 countries in terms of the Human Development Index [1]. In terms of income, it is ranked 68th out of 102 developing countries with an annual GDP per capita of US$ 252 [2]. In 2004, the country had a population of 26.6 million, of which 40% were aged 15 or less; and approximately 85% of the population lived in rural areas [2]. Traditional fuel consumption represents 93% of the country's total energy usage and the average annual per capita electricity consumption is only 91 kWh. Fuelwood, the traditional source of domestic energy, is burned on an open fire inside most traditional Nepali houses, and this practice results in a poor indoor environment. Indoor pollution impacts adversely on the health of occupants, particularly women and children, e.g. [3,4]. In addition, fuelwood is now in short supply in many areas and this means that increasing time is spent travelling to and carrying heavy loads from remaining fuelwood sources.

On the basis of anecdotal evidence and unpublished survey data [5], it has been found that for approximately 10 months of the year, the open fire simultaneously provides a source of heat and light, both of which are vital for domestic life. Heat is particularly important in the mountainous areas of Nepal, where low ambient temperatures are common. In an attempt to reduce fuelwood consumption and improve the indoor environment, smokeless cooking stoves have been introduced into rural Nepal, as in many other developing countries. This is the case in Humla, a remote mountainous region in the northwest of the country, where approximately 2000 smokeless metal stoves have been installed by a local NGO (RIDS-Nepal) since 2002. Quantitative evidence indicates that when properly used a smokeless stove can reduce the indoor PM_{10} level generated by an open fire by over 90%. Unpublished data measured using a portable air monitor (SKC Inc., Model EPAM-5000) shows that over a typical 24-h period the average indoor PM_{10} in a kitchen with a smokeless stove was 0.056 mg m^{-3}, compared to 1.28 mg m^{-3} in a similar kitchen using an open fire place. However, there is some concern that comfort levels may not be as acceptable as before because of a reduction in radiant heat. Since there is a need to continue to introduce improved cooking stoves because of the health benefits, there is also a need to address comfort levels. If comfort levels are not improved, the continued acceptability of the stoves may be compromised.

One approach to improving the comfort level of occupants is to redesign the stoves that are introduced. Another approach, taken in this research, is to analyse the thermal performance of the

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Table 1
Summary of climatic data collected at HARS between May 2004 and March 2007

Month	Average monthly horizontal solar radiation (MJ/m^2/d)	Average monthly ambient temperature (°C)	Average monthly maximum ambient temperature (°C)	Average monthly minimum ambient temperature (°C)
January (82)	12.6	6.6	13.2	−1.4
February (55)	14.0	6.6	14.5	1.2
March (79)	17.4	8.1	15.4	2.5
April (44)	20.1	11.5	17.8	6.0
May (93)	19.0	14.5	20.0	9.4
June (90)	17.2	17.1	22.6	12.3
July (93)	14.9	17.9	22.5	14.9
August (77)	14.7	17.2	22.2	14.0
September (57)	17.7	16.8	22.6	12.4
October (39)	16.7	12.4	19.5	6.4
November (42)	14.2	8.5	17.4	1.1
December (93)	12.1	7.4	16.0	1.1

Figures in parentheses indicate number of days of complete data.

traditional house and investigate simple ways of improving the building envelope to improve comfort levels. In this research, a validated dynamic model of a traditional house was developed and current comfort levels were predicted. The model was then used to investigate the effects on those comfort levels from changes to the building envelope. The paper initially describes the location of the research and the climate in the region. Previous similar research is then reviewed and the model used in this research and its validation are described. The impact on comfort levels achieved by implementing various energy conservation measures is then predicted using the validated model.

2. The Humla valley

According to Ref. [6], Nepal can be divided into seven natural topographical "units", which can be clearly distinguished from each other. One of these regions is known as the Inner Himalayas. It is the name given to the valleys, which lie to the north of Nepal's principal and well-known chain of mountains, the Himalayas. These inner valleys are described by Ref. [6] as "the real high mountain valleys of Nepal, surrounded on all sides as they are by ice clad giants". One of these valleys, located on the western end of the country, is the Humla valley, which is over 400 km west of Kathmandu.

Of the 75 districts in Nepal, Humla has been judged to be one of the most deprived. Humla ranks second to last in terms of poverty, socio-economic and infrastructural development, and female empowerment [7]. The population of the Humla District is approximately 47,000, which is very low for its district size, resulting in less than 10 persons per km^2 [8]. Since the district does not have any road infrastructure, people and goods are transported on foot or by animal along mountain tracks. The climate in Humla is also challenging. Table 1 shows some climatic data collected at the High Altitude Research Station (HARS) of RIDS-Nepal in Simikot between May 2004 and March 2007, inclusively.

3. Previous research

Although limited, there is some previous research into the thermal performance and associated comfort levels in traditional Nepali houses. A very useful report was prepared by Ref. [9] as part of a project to "develop and apply effective affordable (low-cost) thermal insulation solutions for traditional stone dwellings … in the Northern Areas of Pakistan". Revised for Nepal, the document contains a list of priorities and suggested improvements to the building envelope. These include: closing the open hole in the roof used to vent smoke, applying internal wall insulation, keeping the roof and walls dry, installing a suspended ceiling, installing double glazing and curtains, filling cavity walls with insulation, and keeping foundations dry and insulating the floor.

The performance of a two-storey traditional dwelling in an unspecified mountainous area of Nepal was predicted by Ref. [10]. The dwelling had a total area of 54.5 m^2, each floor being a single room. A modified Japanese heating and cooling load calculation programme was used to perform the simulations. Modifications to the programme were reported to be the addition of "the calculation of natural ventilation rates for a building with multiple compartments" and "the calculation of heating and cooling loads, considering simultaneous heat and moisture flow in the building and existing materials in components". It was found that reducing infiltration by closing of doors and windows, and the addition of roof insulation improved the thermal conditions by between 4.4 and 12.7 K. After reducing fuelwood consumption by 60%, night-time temperatures were still 1.0–4.0 K higher than the unmodified house. The applicability of research of Ref. [10] to Humla Province is, however, limited by several factors. Although often multi-storey, the Humli houses are typically much smaller, and unfortunately the climatic data values used by Ref. [10] are not stated and the hourly variation in measured indoor temperatures is not shown.

A 4-day thermal comfort study of 36 residents in the town of Lomantang in the Mustang District of Nepal was also conducted by Ref. [11]. This area is mountainous, but located at 3705 m, this town is nearly 700 m higher than Simikot, the location of this research. Although both locations experience severe winters, there are some important differences. While the mean monthly outside ambient temperature for the two locations in May is very similar, Simikot is significantly warmer in January. Relative humidity levels for the two locations are also quite different. In Mustang, mean monthly relative humidity levels are reported to be 97% and 71% in January and May respectively, while in Simikot 2006 data indicate average values of 29% and 62%, respectively. The authors in Ref. [11] found that the residents of three houses investigated were "highly satisfied with the thermal conditions of their houses". The researchers also established that the mean neutral temperature for the surveyed residents was only 10.7 °C, although there was considerable variation in the neutral temperature established in the three houses measured. The detailed analysis used a nine-point scale, in preference to the seven-point scale used by ASHRAE. Because there was no electricity in the houses investigated and residents went to bed at 8 p.m., the study was only conducted in the daytime. The researchers in Ref. [11] established high levels of personal insulation, measured in clo, by