TOKYO CITY UNIVERSITY

Study on Thermal Environment and Adaptive Thermal Comfort of the Occupants in Temporary Shelters in Nepal after Massive Earthquake

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Abstract

Natural disasters and wars are the two main reasons that force populations to leave their homes; there emerges an urgent need to be provided the victims with temporary shelters. After massive earthquake in 2015, thousands of Nepalese who lost their home were doomed to live in temporary shelters, which can hardly provide sufficient thermal comfort. Temporary shelters are considered vital for personal safety, protection from thermal discomfort, security, and so on. Such types of temporary shelters are commonly used until a displaced people could be shifted new permanent accommodations. Natural disasters happened frequently around the globe and responsible not only for heavy loss of lives but also create a greater property loss, impacts on social life and also create the environmental problems. The people living in temporary shelters must not be aware of how the indoor environment can be improved in spite of the fact that they made their temporary shelters themselves. The indoor environments within these shelters are very much affected by local climate. The adverse effects on their health must be immense.

This study has following objectives; to evaluate the thermal characteristics of indoor thermal environment on the basis of materials used for the shelters, to know the seasonal changes of acceptable temperature range experienced by people living in various of temporary shelters mostly self-built after the massive earthquake, to examine the possible improvement of the shelters, and also to evaluate that earthquake impacts on social life. A series of survey on thermal comfort survey and questionnaires survey were conducted in five main earthquake affected districts; i.e. Lalitpur, Kathmandu, Gorkha, Sindhupalchowk and Dhading in three seasons; i.e. autumn, winter and summer in 2015/16. The thermal measurements of indoor environment in eighteen shelters were conducted. Through, thermal comfort survey, altogether 855 temporary shelters were randomly selected and data were collected from 1407 persons (547 males; 860 females). For social data collections, 424 respondents (177 male; 247 female) were interviewed.

The indoor air temperatures for all investigated shelters are highly dependent on outdoor air temperature. Especially, during the nighttime, the indoor air temperatures were much lower than those during daytime. The mean indoor globe temperature of four investigated districts varied between 12.1 and 18.5 °C in winter and between 26.9 and 33.2 °C in summer; thus, the seasonal difference is 20.1 °C. According to the respondents' preference, making it warmer in winter and cooler in summer was dominant. The lowest value of mean comfort temperature among the four districts was 15.0 °C and the highest was 28.6 °C; thus, the seasonal difference is 13.6 °C. The range of indoor globe temperature, within which 80 % of the respondents would accept, was found from 11 to 30 °C.

The mean indoor and outdoor air temperatures during the wintry nighttime were found to be 10.3 °C and 7.6 °C in five shelters in Lalitpur, respectively, and the nocturnal indoor air temperature remained below the lowest acceptable temperature of 11 °C. This result assured that these shelters are not good for winter and must create various problems. We therefore analyzed the thermal characteristics of those shelters based on the measured results in order to seek a possible improvement. In order to assess the possibility of improvement, we use simplified mathematical modeling for the calculation of indoor air temperature and we set up the energy balance equation. The total heat loss coefficient estimated per floor area in five shelters ranged from 11.3 to 15.2 $W/(m^2 \cdot K)$; that is thermal insulation was very low. We made a simple numerical analysis on the variation of indoor air temperature with the assumption of improved thermal characteristics and thereby found that it needs to be reduced about 2 to 7 $W/(m^2 \cdot K)$ to have the indoor air temperature higher than 11 °C for 70 % of the whole nocturnal hours. Such reduction of heat loss was found to be realized by adding affordable materials, e.g., cellular polyethylene foam sheets and clothes for respective walls and roof.

Most of the houses were fully collapsed and about 80 % of people doomed to live in temporary shelters built from zinc sheet after disaster. Nearly 70 % of people were outdoors and 30 % of indoors while the earthquake occurred. About 70 % of people did not satisfy in temporary shelters because of that poor indoor environment. There are no basic facilities in their temporary shelters related to privacy, drainage system, drinking water and so on.

The overall results showed that the indoor thermal environment of temporary shelters is considerably lower than the acceptable range, and felt extreme cold in winter and extreme hot in summer. Based on field survey, we have purposed the acceptable temperature for winter and summer and which can be used for guideline and standard of the temporary shelters. The indoor air temperature in winter can be improved by adding some local and affordable materials.

論文要旨

自然災害は人々が住居を利用できなくなる主な理由の一つであり，被災者には一時的な仮設住宅を提供する必要性が生じる。 2015 年にネパールで発生した大地震の後，家を失った多くのネパール人は一時的な仮設住宅に居住する必要があった。一時的な避難所は個人の安全だけでなく熱的不快感からの保護，セキュリティ対策などに不可欠であると考えられる。このようなタイプの一時的な仮設住宅は，被災者が新しい滞在施設に移れるまで一般的に使用される。自然災害は世界中で頻繁に発生しているが，人命の大きな損失だけでなく，財産の損失，社会生活への影響，環境問題も引き起こす。ネパール大地震直後、人々は自分たちで住むための仮設住宅を建設したが，どのように室内環境を改善できるかについてはあまり意識していない。これらの仮設住宅の室内環境は，地域の気候の影響を強く受けており，健康への悪影響は計り知れない。

この研究には次の目的がある。1）仮設住宅に使用される材料に基づいて室内の温熱環境特性を評価する。2）大地震後に仮設住宅に住んでいる人々の許容温度範囲を明らかにする。更に、これら仮設住宅の温熱環境の改善の可能性を検討する。3）大地震が被災者の生活に与えた影響を評価する。

これらを明らかにするために，温熱環境の測定と熱的快適性のアンケート申告を同時実施したフィールド調査を，大地震の影響を受けた主要な 5 地区の仮設住宅で実施した。フィールド調査は 2015～2016 年の秋，冬，夏の 3 季節において，ラリトプル，カトマンズ，ゴルカ，シンドゥパルコウク，ダーディンにある 18 戸の仮設住宅で行われた。熱的快適性調査を通じて，合計 855 の仮設住宅がランダムに選択し，そこに居住する 1407 人（547 人の男性と 860 人の女性）から申告データを収集した。社会的影響に関するデータは，424 人（男性 177 人，女性 247 人）から収集した。

調査対象のすべてのシェルターの室温は，室外気温変動に大きく依存していた。特に，夜間の室温は昼間と比較してはるかに低くなっていた。調査対象の 4 つの地区の平均室内グローブ温度は，冬は 12.1～18.5℃，夏は 26.9～33.2℃であり，季節差は約 20.1°C である。回答者の好みによると，冬に暖かく，夏に涼しくしたい申告が多い。 4 つの地区の平均快適温度は 15.0°～28.6°C であり，季節差は 13.6°C である。本調査における仮設住宅の居住者全体の 80%が受け入れられる室内グローブ温度は，11～30℃であることが分かった。

一方，冬の夜間の室内と外部の平均気温は，ラリトプルの 5 つの仮設住宅で 10.3° C と 7.6° C であり，夜間の室温は最低許容温度の 11° C 以下であった。この結果から，これらの仮設住宅は冬において寒い環境であり，快適性だけでなく健康上の様々な問題を引き起こす可能性が考えられる。このことから，実現可能性の高い改善案を検討するために，測定結果と建築材料に基づいてこれらの仮設住宅の熱的特性を分析した。改善の可能性を評価するため，室温の計算に簡略化された数理モデリングを使用し，エネルギー収支式をたてた。5 つの仮設住宅の床面積当たりの推定熱損失係数は，11.3～15.2 W /（m^2・K）であり，断熱性能が非常に低かった。仮設住宅の断熱性能の改善

を想定して室温変動の数値解析を行った結果，室温を 11°C より高くするためには，仮設住宅の断熱性能を約 2〜7 W /（m²・K）に低減する必要があることを明らかにした。これを実現するためには，例えば，それぞれの壁と屋根に発泡ポリエチレンフォームシートと厚い布といった手頃な材料を追加することで実現できることを明らかにした。

大地震時とその後の社会的状態についても調査を行ったところ，震災前に住んでいた住居のほとんどは完全に崩壊し，約 80％の人々が災害後にトタンで作られた仮設住宅に住んでいたことが明らかとなった。地震が発生している間，約 70％の人は屋外に，約 30％は室内に滞在していた。また，約 70％の人々はその劣悪な室内環境のために仮設住宅に満足していなかった。これらの仮設住宅には，プライバシー保護や排水システム，飲料水などの基本的な設備がないことも明らかとなった。

以上の結果から，仮設住宅における室内の温熱環境は，許容できる範囲より低く，冬は非常に寒く，夏は非常に暑く感じていることを明らかにした。また，エネルギー収支式を用いた分析を行ったところ，壁や屋根に発泡ポリエチレンフォームシートと厚い布を追加することで、仮設住宅の断熱性を向上させ，居住者の許容できる温熱環境に改善できることを明らかにした。現地調査に基づいた本研究で得られた知見は，仮設住宅を改善するガイドラインを作成するために有効的である。

CONTENTS

Chapter 1

Introduction

1.1. Background of research

Nepal, country of Asia, lying along the southern slopes of the Himalayan mountain ranges. It is a landlocked country located between India to the east, south, and west and China to the north. The capital is Kathmandu. Nepal occupies 147,181 sq. km of land and lies between coordinates approximately 28°N and 84°E. The entire distance from east to west is about 800 km while from north to south is only 150 to 250 km.

The country can be divided into three main geographical regions: Himalayan region, mid hill region and the Tarai region. The highest point in the country is Mt. Everest (8,848 m) while the lowest point is in the Tarai plains of Kechana Kalan in Jhapa (60 m). The Tarai region has a width ranging from 26 km to 32 km and varies in altitude from 60m to 305 m. It occupies about 17 percent of total land area of the country. Eight of the world's highest peaks (out of fourteen) that are above 8000 m lie in Nepal: Mount Everest (8,848 m), Kanchenjunga (8,586 m), Lhotse (8,516 m), Makalu (8,463 m), Cho Oyu (8,201m), Dhaulagiri (8,167 m), Manaslu (8,163 m) and Annapurna (8,091 m). The inner Himalayan valley (above 3,600 m) such as Mustang and Dolpo are cold deserts sharing topographical characteristics with the Tibetan plateau.

Nepal is a country of mixed settlements of various ethnic groups and castes. Nepal has 29.3 million populations, according to the census of 2010. There are 125 castes and 123 languages, varieties in costumes and rituals. Farming is a major profession in Nepal. Aryans (from south) and Mongolians (from north) are the inhabitants in Nepal. Nepali is the national language. However, many people speak their ethic mother tongue. About 23 million Nepalese are made of 69 different cultural and linguistic group also known as ethnic groups living in different, regions of the country. Mostly each ethnic group has their own unique costumes, speak their own languages or dialects, and follow their own religious practices. Nepal being a very broad diversified home land of several ethnical groups, it has common social family structure. In general living in joint family system at a home, respecting and following own socio-traditional conducts generation to generation.

Nepal has a monsoon climate and has four main seasons, which are June-September, October-December, January-March and April-June. From January till March, it is called the cold season with temperatures around 10°C. Nepalese climatic conditions vary from one place to another in accordance with its geographical features (Fig. 1.1).

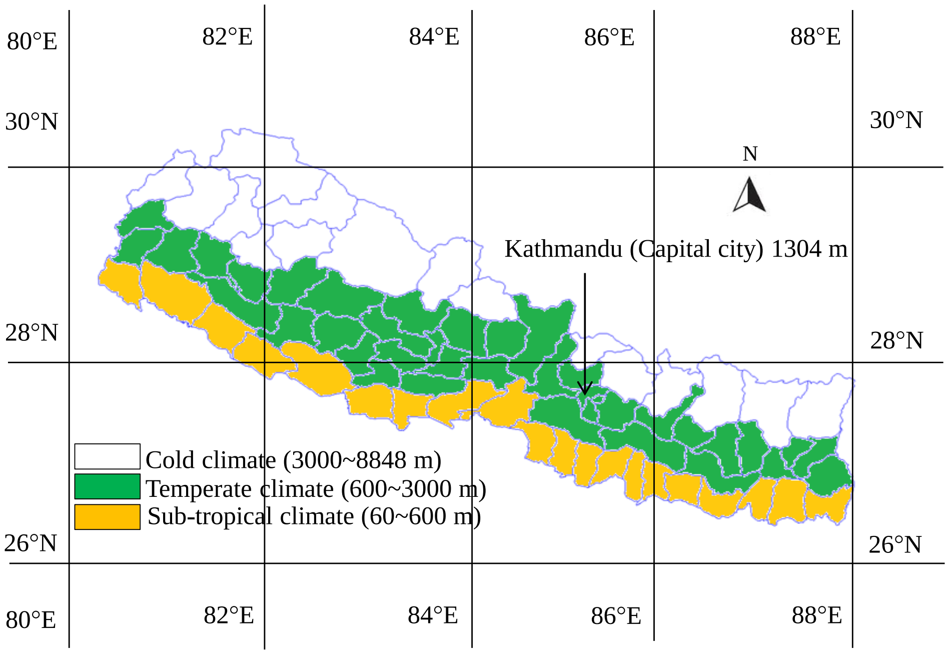


Fig.1.1 Map of Nepal with three geographical features.
(https://en.wikipedia.org/wiki/Geography_of_Nepal)

Nepal is highly vulnerable to a number of disasters for example: earthquakes, floods, landslides, fires, epidemics, windstorms, hailstorms, lightning, floods, droughts and dangerous weather events. Among these disasters name earthquake is the most- scary and damaging. The Gorkha earthquake of 25 April 2015 enormously affected human, socio-economic and other multiple sectors and left deep scars mainly in the economy, livelihood and infrastructure of the country. Nepal, is the 11th most earthquake prone countries in the world (Motra, 2015). Nepal has a history of being highly vulnerable to a range of natural hazards such as earthquakes, droughts, floods and landslides. On 25th April, 2015, an earthquake of 7.8 magnitudes struck Nepal and another of 7.3 magnitudes hit again on 12th May, sooner than three weeks from the 1st hit (Fig.1.2). The death toll reached nearly 9,000, more than 25,000 people were injured and destroyed 604,930 houses completely and 288,856 houses were partially damaged. It is estimated that the total value of the damages caused by the earthquakes is NPR 706 billion or equivalent to $US 7 billion (Government of Nepal, National Planning Commission, 2017). Around 800,000 people displaced by the earthquake in Nepal were struggled to survive in a context of persistent, a severe lack of safe and adequate housing (Amnesty International Nepal. Earthquake Recovery Must Safeguard Human Rights. London; 2015). Continued aftershocks occurred throughout Nepal at the intervals of 15-20 minutes. This was the largest earthquake in Nepal's history after Bihar-Nepal earthquake (8.1 magnitudes) occurred in 1934 (NSET, 2014). According to National Society for Earthquake Technology (NSET), Nepal had experienced many devastating large earthquake at the interval of 70 to 80 years. A series of aftershocks began immediately after the main shock, at intervals of 15–30 minutes, with one aftershock reaching 6.6 Mw within 34 minutes of the initial quake.

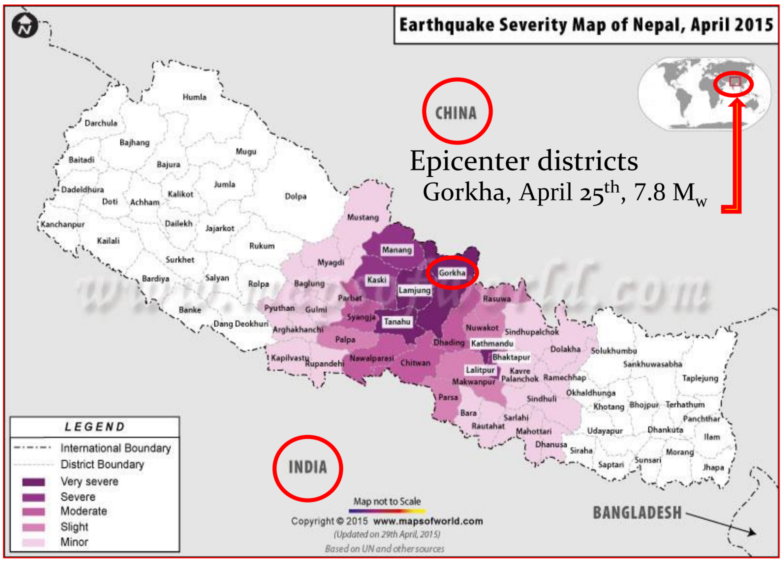


Fig. 1.2 Earthquake severity map of Nepal, 2015.

About 459 aftershocks had occurred with different epicenters and magnitudes equal to or above 4 Mw (out of which 51 aftershocks are equal to or above 5 Mw and 5 aftershocks above 6 Mw) and more than 20,000 aftershocks less than 4 Mw National Seismological Centre, Nepal)] can be seen in Fig. 1.3.

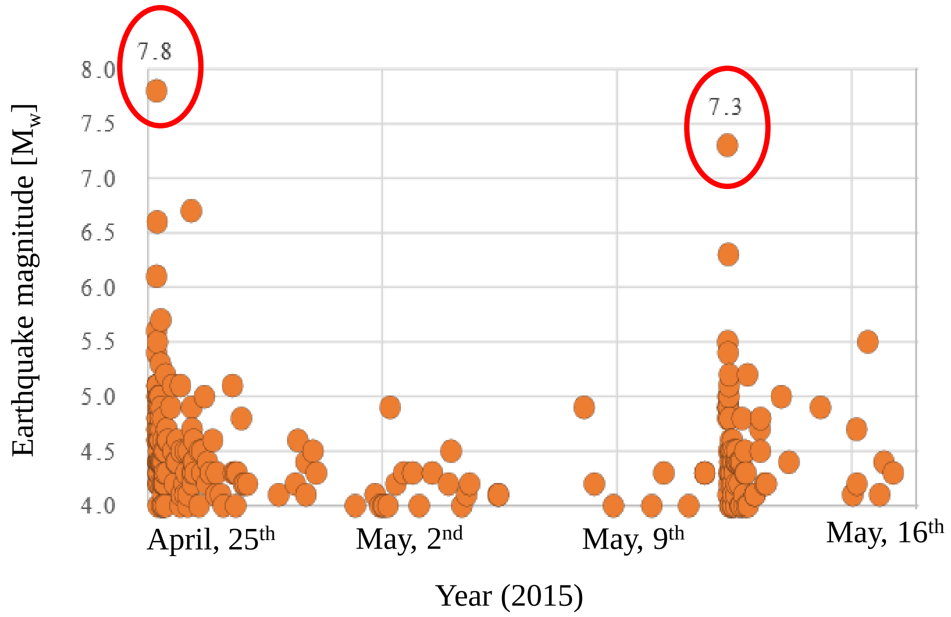


Fig. 1.3 Earthquake aftershocks.

(https://en.wikipedia.org/wiki/April_2015_Nepal_earthquake.media/File:2015_Nepal_earthquake.svg)

Sindhupalchok, Gorkha and Dhading are the priority districts for assistance. Although Rasuwa has a relatively small population, it is difficult to access and current information indicates over 80 % of the population are affected. UNDAC has established humanitarian hubs in Gorkha and Sindhupalchok. Total of 35 districts have been affected, 14 severely: Gorkha, Dhading, Rasuwa, Sindhupalchok, Kavre, Nuwakot, Dolakha, Kathmandu, Lalitpur, Bhaktapur, Ramechhap, Okhaldunga, Sindhuli and Makwanpur. Fig. 1.4 shows how the damage looks like in these four investigated districts.

After the earthquake, many families were sleeping in open areas without adequate cover, suffering cold night-time conditions and rain. The monsoon season (mid-June to early September) further exacerbated the existing shelter situation for thousands of families whose homes were damaged or destroyed. The monsoon arrived a few weeks after the second earthquake and people had to rely on emergency shelters, built with salvaged materials, plastics and tarpaulins, to withstand the heavy rains. Apart from shelter, people also needed a place to store their materials, crops, agricultural products and cattle.

(a) Lalitpur (b) Kathmandu

(c) Shindhupalchowk (d) Gorkha

Fig. 1.4 Damage looks in main earthquake affected districts: (Photos of ‘a, ‘b’ and ‘d’ was taken from internet_ https://www.google.co.jp/search?damage+looks+after+earthquake+2015 and photo of ‘c’ from author itself).

1.2. Literature review

The chapter presents a review of relevant academic research to this thesis. It reviews the thermal environment of temporary shelters, adaptive thermal comfort of occupants in temporary shelters. Natural and man-made disasters such as earthquakes, floods, wars, epidemics, etc. continue to affect the lives of millions annually. Furthermore, these disasters especially affect the environment, which can threaten the lives of people now and those in of future generations.

The last thirty years in this context, various regions of the world such events have been faced; as an examples: the Cabanatuan Earthquake in the Philippines in 1990, the Gilan Earthquake in Iran in 1990, the Kobe Earthquake in Japan in 1995, Sumatra Earthquake in Indonesia in 2004, followed by tsunami, Hurricane Katrina in America in 2005, the Nargis

Hurricane in Myanmar in 2008 and the refugee problem that emerged from the war in Syria, Great east Japan earthquake in Japan in 2011, Gorkha earthquake in Nepal in 2015 and so on.

1.2.1 Temporary shelters in Nepal

Temporary housing is defined as a place where families can re-establish household responsibilities and daily activities for an interim period until the permanent housing solution can be found (Quarantelli, 1995). Temporary shelters are the ones which present prompt solutions that emphasize the rapidity and the low cost. Therefore, they should be used only for a short period of time. Immediately after such a disaster, the major responsibility to be taken by the government is to provide temporary shelters. After a disaster, temporary shelters may have to be used for a longer period of time than to be used. Depending on the disasters' severity and the social conditions, they may need to be used for several months to several years.

In 2011 Japan earthquake, Japanese government provided temporary shelters where all the basic facilities were available (Nobuo, 2011). In 2008 Wenchuan earthquake in China, the Chinese government determined to adopt the program of interim settlements. One month after the earthquake, tens of millions of affected people were resettled in thousands of tents and then, two months later, the tents had been mostly replaced by portable housing (Jiuping et al. 2012). Permanent houses were designed and constructed and then most of people moved into those new houses by the end of 2008. But, in Nepal, four years after the devastating earthquake in 2015, the recovery is still very slow.

Those who lost their permanent houses by these hardest hits were forced to live in temporary shelters without basic facilities, and have been struggling to return in normal life. Many families are still living in temporary shelters due to various reasons such as: the lack of infrastructure, lands, manpower, economic condition, materials availability, and no formal rebuilding program has been commenced by the government. The Nepal government had announced for initial relief with NRs. 15,000 (about USD 150) in cash for respective victim families that allow them to buy corrugated zinc sheets and other materials to build temporary shelters on their own (Koirala, 2015). But due to the geographic circumstance of Nepal, the real victims were far from these kinds of relief. Most of the victims make their own makeshift shelters themselves by using their traditional method and available materials. But those makeshift shelters that they made can hardly provide with sufficient relief from hard rain, strong wind, scorching sun and biting cold because of their poor physical characteristics. What we should learn from these events is that a government has to be strong enough economically and to prioritize those who suffer most. Therefore, well before a next disaster may occur, the government is expected to establish national plans for temporary shelters, in which people can avoid a variety of discomfort as much as possible.

In this respect, temporary shelters need to be examined on their lightness, easiness of assembling and installation, thermally resistivity for providing minimal comfort. It is a well-known fact that basic designs of temporary housing have a direct impact on the residents' well-being and quality of life. Therefore, temporary housing designers must consider various properties of material and building structure to ensure occupants' overall well-being (FEMA, 2009). Temporary housing should provide protection from the outdoor environment to secure personal safety, health and well-being until the permanent houses become available (Silva, 2007).

More than four years after the devastating April 2015 earthquake that hit Nepal, we have now started to see the results of Post-Earthquake Housing Reconstruction in a few places. The National Reconstruction Authority (NRA) and NGOs/INGOs have supported people financially and technically to rebuild their houses. Several designs in several construction technologies have now been approved by the government as earthquake resistant construction technology, giving house owners various choices of materials and construction system. It is great to see families moving into permanent houses from temporary shelters. The government grant of 3 lakh rupees per house ensures that with some labor/material contribution from the house owner, they are able to build a decent 1-2 room house. This house is 150 – 250 sq. feet in area and has RCC/wooden ties, cement floor and light weight metal roof, mostly with an external toilet. It is built with earthquake resistant technology. This is definitely an upgrade from the temporary shelters/tents.

Hopefully that the economy of Nepal will grow, and with it, the aspirations of the people, they will aspire to have more than a basic house. They will want comfortable house-with running water, clean energy, in-house plumbing to begin with, or add rooms. Houses today are able to produce their own energy, and run for a lifetime on zero carbon footprints.

The house (Fig. 1.5) in itself should be the beginning of a process, not an end. The basic unit must allow addition of space and services in the future if needed. The building process should be designed factoring the financing capacity of an average grant beneficiary. To start with a two room house for a lower income group family but able to expand into a comfortable middle income group house, would mean providing the earthquake victims a chance at 'developing'.

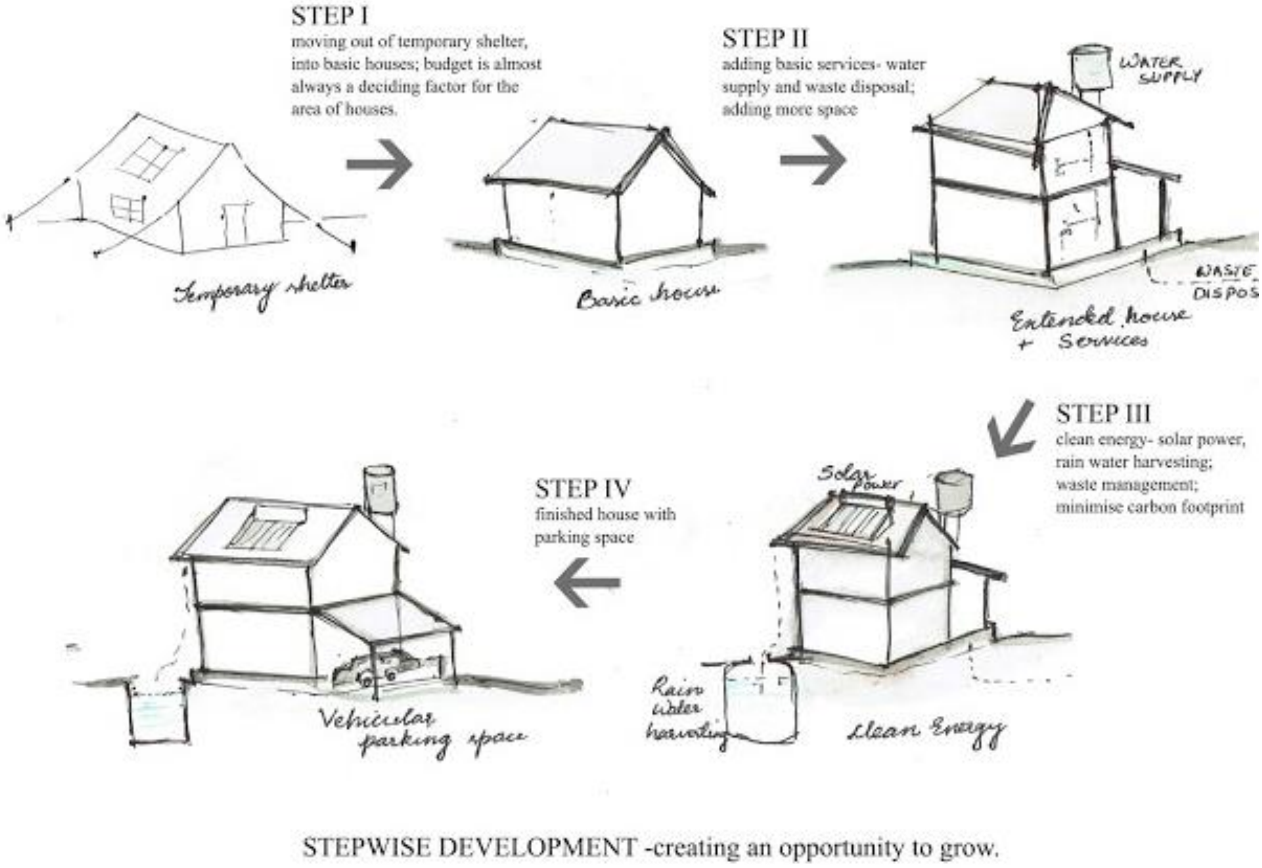


Fig. 1.5 The building process designed to expand into a comfortable. (housing[http://sonal7990.blogspot.com/2017/12/community-center-in-dhading.html#!/2017/07/re-construction-chance-at-developing.html).

Temporary shelters are the ones which present prompt solutions that emphasize the rapidity and the low cost. Therefore, they should be used only for a short period of time. Immediately after such a disaster, the major responsibility to be taken by the government is to provide temporary shelters. After a disaster, temporary shelters may have to be used for a longer period of time than to be used. Depending on the disasters' severity and the social conditions, they may need to be used for several months to several years.

Zinc or tarpaulin sheets are often handed out after a disaster, and people use them for the construction of makeshift shelters. Investigated shelters were found to be different in size and shape, mostly with small openings for ventilation and daylighting and irregular roofs. People residing in temporary shelters added some materials from damage houses and others available materials unknowingly to mitigate their discomfort, furthermore the materials used are not sturdy enough to protect from harsh climatic and to make good environment within these makeshift shelters. We have found square-shaped and dome-shaped shelters in investigated shelters i.e. Lalitpur, Shindhuplachowk and Gorkha as shown in Fig. 1.6 (a, c and d), and triangular-shaped shelters made of tarpaulin sheet in Kathmandu as shown in Fig. 1.6 (b). Most shelters have one single room for living and sleeping purposes combined with kitchen. We could not find good drainage system, heating and cooling system in those investigated shelters. There is also no electricity supply in most of the shelters.

(a) Lalitpur

(b) Kathmandu

(c) Shindhuplachowk

(d) Gorkha

Fig. 1.6 Temporary shelters in the investigated four districts: (a), (c) and (d) Shelters were built from zinc sheet (less than 1 mm) and (b) Shelters were built from tarpaulin sheet.

Due to the insufficient thermal properties of the materials used (Table 1.1), they have hardly been able to relieve from heavy rain, scorching sun or biting cold. Sick or injured people, pregnant women, children, and elderly people have been forced to be under very severe conditions in particular.

Table 1.1 the size of investigated shelters, the number of people living and materials used.

Shelter code	Depth [m]	Width [m]	Height [m]	No. of people	Density [Persons/m^2]	Wall [m]	Roof [m]		
							Internal	Middle	External
S1	5.0	3.5	2.1	4	0.23	Zinc sheet*	Thick clothes : 5×10^{-3} and CPF : 6×10^{-3}	Zinc sheet*	Straw : 6×10^{-2}
S3	3.7	2.5	2.0	4	0.43	Zinc sheet*	CPF : 6×10^{-3}	Zinc sheet*	Tarpaulin : 2×10^{-3}
S4	6.5	5.5	2.8	4	0.13	Zinc sheet*	Thick clothes : 5×10^{-3}	Zinc sheet*	None
S5	7.6	6.5	2.8	4	0.1	Zinc sheet*	Thick clothes : 5×10^{-3}	Zinc sheet*	None
S6	3.5	2.6	2.1	2	0.22	Bamboo : 8×10^{-3}, Mud plaster : 5×10^{-3}	CPF : 6×10^{-3}	Zinc sheet*	None

CPF : Cellular Polyethylene Foam, Zinc sheet* [m] : 0.26×10^{-3}.

1.2.2 Temporary shelters in other countries

Natural disasters and wars are two main reasons that force populations to leave their home, which consequently pushes for an urgent need to provide temporary shelters or settlements as a disaster management plan (Dabaleh et al. 2015). Several studies have been carried out focusing on the indoor thermal environment in temporary settlements in international sector (Shinohara et al. 2014, Huang et al. 2015). Thermal performance analyses of emergency shelter using dynamic building simulation have been performed to clarify the basic requirements of a better emergency shelter with simple materials (Cornaro et al. 2015). Also in recent years, some international research laboratories have focused on studying shelters' indoor thermal conditions (Obyn et al. 2015), while various humanitarian organizations have made efforts to come up with effective solutions using low-tech and passive strategies, and still other researchers have investigated the use of high-tech materials (Cornaro et al. 2015). The case study on the life cycle performance of light-framed temporary housing with local technologies has been conducted in China (Song et al. 2016). Several researchers focused on thermal performance or energy efficiency of shelters (Crawford et al. 2005, Saleh, 2011). Others have focused on achieving thermal comfort while developing useful applications for prototypes considering cost, weight, volume and time for assembly (Manfield, 2000). Some other researchers have focused on the design and construction to improve the temporary shelters (Abulnou, 2014, Cassidy, 2007). Several robust papers have also tackled the problems of emergency shelters from a structural design and construction perspective, focusing on adaptability and compatibility (Manfield, 2000). Others focused on the socio-cultural aspects (Kumssa & Jones, 2014). Some researchers have focused on shelter design and construction in the post-disaster temporary housing during the emergency phase (Arslan et al. 2008 and Cassidy, 2007), and other applied Fangers PMV and PPD model to estimate indoor thermal environmental conditions in temporary shelters (Jeong et al. 2015 and Albadra et al. 2017). There were also found some researches related to simulation to establish the thermal model of temporary shelters (Ying et al. 2016, Salvalai et al. 2015 and Obyn et al. 2015).

To our knowledge, very few studies have touched on the connection between social aspects and technical aspects of refugee shelters (Manfield et al. 2004). We could not find robust published studies tackling both challenges; how to achieve a humanitarian shelter that respects the socio-cultural norms of the refugees while offering a comfortable and energy efficient shelter.

There are an estimated 68.5 million displaced people globally, of which 25.4 million are recognized as refugees, 40 million as internally displaced, and 3.1 million as asylum seekers (UNHCR 2018; UNOCHA 2018). The provision of adequate shelter for this population represents a significant challenge and the volumes of construction materials required present a further resource and environmental challenge (Branco and Feio 2013). The need to minimize the environmental impacts of temporary housing has been recognized for some time (Atmaca and Atmaca 2016; Hosseini et al. 2016; Song, Mithraratne, and Zhang 2016).

Despite being designed for a particular climate; similar temporary shelters are commonly deployed around the world. Annual case study reports on shelter designs (IFRC 2011 and IFRC 2013) deployed/supported by International Red cross shows multiple cases of replication of similar shelter design in various climate zones and locations. This trend has seen continuity with UN (United Nations) organizations partnering with the IKEA foundation to develop the Better Shelter (Better Shelter 2015) - a flat packed pre-fabricated shelter solution to be deployed globally. According to interviews with organizations involved in this sector, current temporary shelter responses are built under time and cost constraints without comfortable thermal conditions as a high priority. One interviewee witnessed expensive pre-fabricated shelters that were helicoptered into a remote, high-altitude site and later abandoned in the winter due to unbearable interior temperatures.

In this research, we used thermal simulation to test the thermal comfort and safety of fourteen of the most common temporary shelter designs in use today. We tested each one in its originally intended climate and in thirteen other global climate zones (ASHRAE 1-5) (ASHRAE, 2013). Currently there is no agreed-upon standard for upper limit in indoor temperature for thermal safety (Nicol 1995, Holmes et al. 2016). Author proposed 35 °C and 12 °C for the upper and lower "health risk" temperature threshold to evaluate thermal safety of the temporary shelters. The upper limit was based on ceiling fans being less effective at this temperature (World Health Organization Europe 2009) and statistical data on mortality rate during heat waves (World Health Organization Europe 2009). The lower limit is based on data suggesting that vulnerable population, i.e. the elderly, sick and small are susceptible to cardiovascular problems and strokes in sustained conditions below this temperature (Collins 1996).

The results showed not only that the interior temperatures exceeded the threshold for ASHRAE-55 adaptive thermal comfort (ASHRAE 2010) for more than half the year but also that they cross the above-mentioned health risk limits frequently. The internal temperatures exceeded the adaptive thermal comfort threshold by a huge margin indicating a real need for a new metric and threshold limits in order to compare performance and evaluate thermal safety. Authors synthesized the results data to produce a set of design guidelines to improve interior thermal conditions in existing temporary shelters as well as redesign the shelters.

In recent years, natural disasters happened frequently around the globe and responsible not only for heavy loss of lives but also create a greater property loss. The Sri Lanka flood (2003), Indian Ocean Tsunami (2004), earthquake in Bagh, Pakistan (2005), China (2008), Indonesia (2009), Haiti (2010) and Japan (2011) and recent typhoon in Philippines (2013), worth billions of reported damages. The average reported losses rose from around $US 50 billion a year in the 1980s to almost $US 200 billion a year in the past decade, totaling $US 3.8 trillion from 1980 to 2012 (World Bank 2013). During the Kosovo conflict, a third of the province’s housing stock was destroyed, while the destruction of an estimated 300,000 houses, leaving over a million people displaced (Barakat, 2003). This paragraph from (*A Review On Post-Disaster Reconstruction Project: Issues and Challenges Faced by International Non-Governmental Organisations (INGOs), Dzulkarnaen Ismail, 2014 Literature review*).

A temporary shelter is meant as an early recovery shelter until a more permanent shelter solution is found (Tuladhar 2019). This study reports that, three-phase process for resettlement commonly used (IFRC 2011).

1) The first phase is an emergency shelter (e.g. a tent), which is a life-preserving intervention meant to last 1-2 weeks,
2) Transitional shelters and,
3) Permanent re-construction temporary shelters.

Most of the literature on transformed, adapted, and improved houses focuses not on disasters but on low-cost, social, and informal housing, mainly in developing countries.

Table 1.2 Description of disaster and their solutions.

Disaster	Location Affected by disaster	Number of damaged buildings	Type of Solution		
			Emergency shelters	Temporary Housing	Permanent housing
Earthquake, (Johnson, 1999)	Marmara and Bolu (Turkey)	311693	12631	43454	43604
	Düzce (Turkey)	29000		2068	
Earthquake, 2011, Japan	The Great Eastern (Japan)	225000		115589	
Earthquake, (Authorized, 2008)	Java ve Yogyakarta (Indonesia)	532000		6923	7631
Earthquake AFAD, [Online, 2017]	Van ve Erciş (Turkey)	112758	76802	29486	
Earthquake, (2015, Earthquake report)	Nepal	900,000			
Earthquake, 1999	Turkey	380000			
15th August, (2007) 8.1 mw (Barakat, 2003)	Peru	52154			
27th February, 2010_8.8 mw (Barakat, 2003)	Chile	222000		70489	
Earthquake, (1999)	Colombia	1856			
Chamoli Earthquake, (1999)	India	2,595			
Hurricane, (Abulnour, 2014)	Misisipi (USA)			25000	
	Katrina and Rita (USA)			62000	
Refugee problem, (Filici et al. 2015)	Hatay (Turkey)		824	4013	
	Gaziantep (Turkey)		5091	908	
	Sanliurfa (Turkey)		22308	2000	
	Kilis (Turkey)			6756	
	Mardin (Turkey)			1335	
	Kahramanmaras (Turkey)			5006	
	Osmaniye			4102	
	Adiyaman (Turkey)		2302		
	Adana (Turkey)			6136	
	Malatya (Turkey)			1977	

1.2.3 Construction made after disaster

Specially, tents are the most common shelter structure used. However, studies show that the majority of current tent shelters do not satisfy comfort conditions for occupants (Obyn et al. 2015) and hardly satisfy privacy, hygiene and other social needs (UNHCR, 2006). (Giller, 2012) also shows how tents can adapt to a variety of environments, from the extreme heat to extreme cold. They can also accommodate different functions and cultures. In the summer, the tent living zone is placed facing pleasant prevailing cool winds. The sleeping zones face east to allow the morning sun to be stored in the tent envelop for cold summer nights. The solid part is positioned against the sandy seasonal storms. In summer, the tent offers an opportunity for natural ventilation with its open side for air exchange and top openings for air to escape. During cold winter nights, locals light a fire in the middle of the tent inducing the wool pores to get even smaller with exposure to smoke, which also aids in trapping heat inside the tent.

There is very little literature available that quantifies exactly how shelter provided to displaced populations impacts upon their quality of life and the risk they bear (Corsellis, 2001). Some different temporary shelters figures are shown in Fig. 1.7 whose built-in international sectors.

(a) Afganisthan (Plastic shelter)
(NRC Afghanistan Shelter Evaluation, 01.2019)

(b) Ethiopia better shelter (National Shelter Strategy, Refugee Operation Ethiopia 2017 – 2020)

(c) Indonesia (Timber frame shelter) (Indonesia , Sumatra, 2009)

(d) Haiti (Tarpaulin shelter) (Emergency response after Haiti earthquake, 2010)

Fig. 1.7 continue….

(e) Bangladesh (Zinc Shelter), 2007-2009

(f) Peru (Timber frame shelter)
(Elizabeth Wagemann, 2015)

(g) Pakistan (Mud timber shelter) (Improved Shelters for Responding to Floods in Pakistan, 2014)

(h) Srilanka (Zinc shelter, accessed, 2019/10/02)
(https://www.google.co.jp/search?q=shelters+photo+srilanka &sxsrf)

Fig. 1.7 As an example of temporary shelters built in international sectors.

In general speaking, "Shelter is a process, not a product" (Sheltering people after disasters: Lessons from the tsunami, 2008). Agencies should design shelter contributions to be part of a family's transition from emergency shelter to permanent housing. From "Living with hope: People wait for homes even three years after tsunami" (Oxford, UK: Oxfam International, 2008), Oxfam briefing paper. Fig. 1.8 shows an example of process for making shelters.

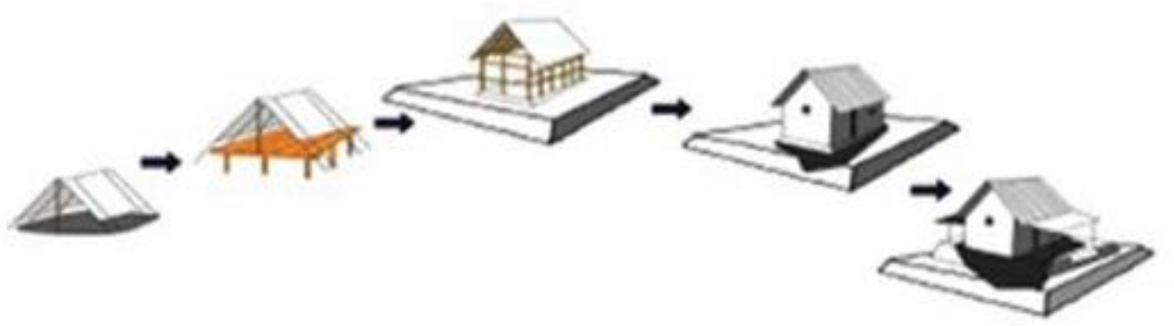


Fig. 1.8 An example of process for making shelters (Oxford, UK: Oxfam International 2008).

In Nepal, the government grants of 0.3 million per house ensures that with some labor/material contribution from the house owner, they are able to build a decent 1-2 room house as can be seen in Fig. 1.9. This house is 150 – 250 sq. feet in area and has RCC/wooden ties, cement floor and light weight metal roof, mostly with an external toilet. It is built with earthquake resistant technology. However, people built houses on their capacity (Fig. 1.10).

Fig. 1.9 As an example of newly constructed buildings (within government support)_Source: (https://www.google.com/search?q=Newly+constructed+buildings+in+Nepal).

Fig. 1.10 As an example of newly constructed buildings in Lalitpur (Government support and added additional expenses by respondents themselves. Source: Photo taken by author itself).

1.3 Importance of research

Research has its special significance in solving various problems along with motivational. Our research is based on field survey where we took data from indoor thermal environment and thermal comfort of the occupants' residing in temporary shelters. Before presenting the results of the empirical research, it is important to address some of the limitations of this thesis. Thus, the perspective of homeless people is represented in my study as voter. I conducted interviews with them, as well as measure the indoor and outdoor thermal environment parameters.

In general, it is important to ensure that shelters provided protect people against adverse seasonal environmental conditions and help reduce social problems in the disaster areas. Over time, the technology of temporary housing has changed and any experience from past performance, aspects such as design, construction, transportation, erection, use, performance, end of use/life, demolition or dismantlement, and perhaps recycle and reuse will be useful for designers and developers of future temporary housing systems (Sagiroglu et al. 2018).

In order to develop a thorough understanding of outdoor sociality and miscellaneous environmental factors, it could be conduct the social research in another context. In the case of developing countries like Nepal, the shelters built for temporary living tend to be used for a longer period of time. They have been forced to live in temporary shelters due to various reasons such as the lack of social infrastructure, poor materials, availability of lands, manpower and so on. Another reason may be, at that time, an unofficial blockade announced by the neighboring country, India that has badly affected the supplies of essential commodities including construction materials and raw materials needed to build shelters. Due to these reasons the construction process went late. Eighty-three years have passed, since the last big earthquake, and there were no such historical records of victims and their living conditions. Therefore, this study focuses on the present conditions of temporary shelters built after the earthquake in 2015, and tries to identify the problems and possible solution.

Indoor environment and living condition under makeshift shelters are to be concerned and need an urgent attention in the context of future disasters to come. It is important to ensure that these shelters can protect the occupants from seasonal environmental conditions and help to reduce social problems in the disaster areas (Sagiroglu, 2018). They are facing extreme hotness in summer and coldness in winter in temporary shelters. The adverse effects on their health must be immense. The people living in temporary shelters must not be aware of how the indoor environment can be improved in spite of the fact that they made their temporary shelters themselves. The indoor temperature should not be too high or too cold, since it is related very much to human health (Ponni, 2015). It should be useful to make some required improvements in the indoor thermal environment of temporary shelters. Since the last big earthquake, 83 years have passed but there were no such historical records of victims and their living conditions.

There is a need for good planning before any kinds of disasters to come in the future. For this reason, this study focused on the present conditions of temporary shelters built after earthquake 2015 and tried to identify the problems and the possibility of improvement. What has been found in this study should be hopefully applied to actual improvement of indoor thermal environment in existing shelters and also to the development of the possible preparation for the future disaster. The disaster may occur in the future and as a consequence the demands of temporary shelter shall continue to exist. With the knowledge of acceptable range of indoor globe temperature, we discussed here in this paper, we should be able to develop thermally acceptable shelters. Our study is a first step towards the search of acceptable range of indoor temperature in temporary shelters. This type of research is considered to be necessary for finding effective solutions in the preparation to be made before a disaster to occur in the future. Thus this research is important.

1.4 Research questions

1. How is the seasonal indoor thermal characteristic of temporary shelters?
2. What kind of living environment should be arranged for temporary living condition as well as consider their thermal comfort?
3. How could make this harsh disaster to be learnt for lesson and keep records for the future generation?
4. What kind of numerical analysis does helps to concern their structure and improve for future disasters?
5. How Gorkha earthquake impacts on social life and other miscellaneous environmental factors?

1.5 Objectives

The objectives of this research paper are:

1. To find out the actual conditions of thermal environment of temporary shelters.
2. To investigate the respondents’ perception in thermal responses.
3. To explore seasonal and regional differences of comfort temperature.
4. To estimate the acceptable range of indoor temperature of the people living in the temporary shelters.
5. To evaluate the thermal characteristics of indoor thermal environment on the basis of materials used for the shelters.

6. To examine the possible improvement of the shelters that can provide the occupants with a better indoor thermal environment.
7. To evaluate, how Gorkha earthquake impacts on social life and other miscellaneous environmental factors in earthquake affected areas.

1.6 Thesis contents

Here, the thesis contents are summarized:

Chapter 1 : Introduction

- General information related on Nepal, Gorkha earthquake, temporary shelters and their indoor thermal environment are discussed.
- Literature review done and the importance of this research and objectives are presented.

Chapter 2 : Thermal environment of temporary shelters

- Survey on 2015 and 2016
- Analyze indoor thermal conditions of respected temporary shelters (During voting time and continuous measurement)
- Discuses here autumnal, wintry and summer thermal environment and also to find the seasonal indoor thermal performance of temporary shelters built after massive earthquake 2015.

Chapter 3 : Thermal comfort in temporary shelters

- Estimate the seasonal differences of comfort temperature of people residing in temporary shelters.
- Comparison comfort temperature of this study with other studies.
- Try to find the seasonal acceptable temperature range of people and also would like to know how people adjust their seasonal indoor thermal environment by adjusting clothing insulations.

Chapter 4 : Wintry thermal improvement of temporary shelters

- Asses the possibility of improvement of temporary shelters by using simplified mathematical modeling for the calculation of indoor air temperature.
- Here we set up the energy balance equation to be expressed as [Thermal energy input] = [Thermal energy stored] + [Thermal energy output].

Chapter 5 : Gorkha earthquake 2015: Its impact on social life and other miscellaneous environmental factors

- Here, we would like to discuss about how Gorkha earthquake impacts on social life and others miscellaneous environmental factors.
- We interviewed 424 respondents in three seasons i.e. autumn, winter and summer for four districts, i.e. Gorkha, Shindhupalchowk, Dhading and Lalitpur.
- The questionnaires are related on their social life and other miscellaneous environmental factors that impacts by Gorkha earthquake 2015.

Chapter 6 : Conclusions and recommendations

- Here the results of the above chapters will summarize and discuss.

Chapter 2

Thermal environment of temporary shelters

2.1 Introduction

The indoor environment is of key importance for human health and well-being, not only due to the time spent indoors during our lifespan (approximately 90 %), but also due to the combination of health and safety threats encountered on a daily basis (Charles 2009). Thus, indoor environment and living condition under makeshift shelters are to be concerned and need an urgent attention in the context of future disasters to come. It is important to ensure that these shelters can protect the occupants from seasonal environmental conditions and help to reduce social problems in the disaster areas (Sagiroglu 2018). The people living in temporary shelters must not be aware of how the indoor environment can be improved in spite of the fact that they made their temporary shelters themselves. They are facing extreme hotness in summer and coldness in winter in temporary shelters. The adverse effects on their health must be immense. The indoor temperature should not be too high or too cold, since it is related very much to human health (Ponny 2015).

2.2 Research areas and climate

Nepal has a variety of altitudes from 60 to 8,848 m. It has three climate regions: i.e. subtropical; temperate; and cold. Summer is from April to August and winter is from November to February. Climate change, on the other hand, has become ‘extreme.’ Nepal is ranked as the fourth most climate vulnerable country in the world in the climate change vulnerability index (Government of Nepal, Ministry of Home Affairs 2018). Five districts: Lalitpur; Kathmandu; Sindhupalchowk (the most devastated and the epicenter of the second large tremor and small aftershocks); and Gorkha (the epicenter of the first tremor), and Dhading have been chosen for the survey. Fig. 2.1 shows the map of Nepal with these five investigated districts and the numbers in brackets denote the height above the sea level.

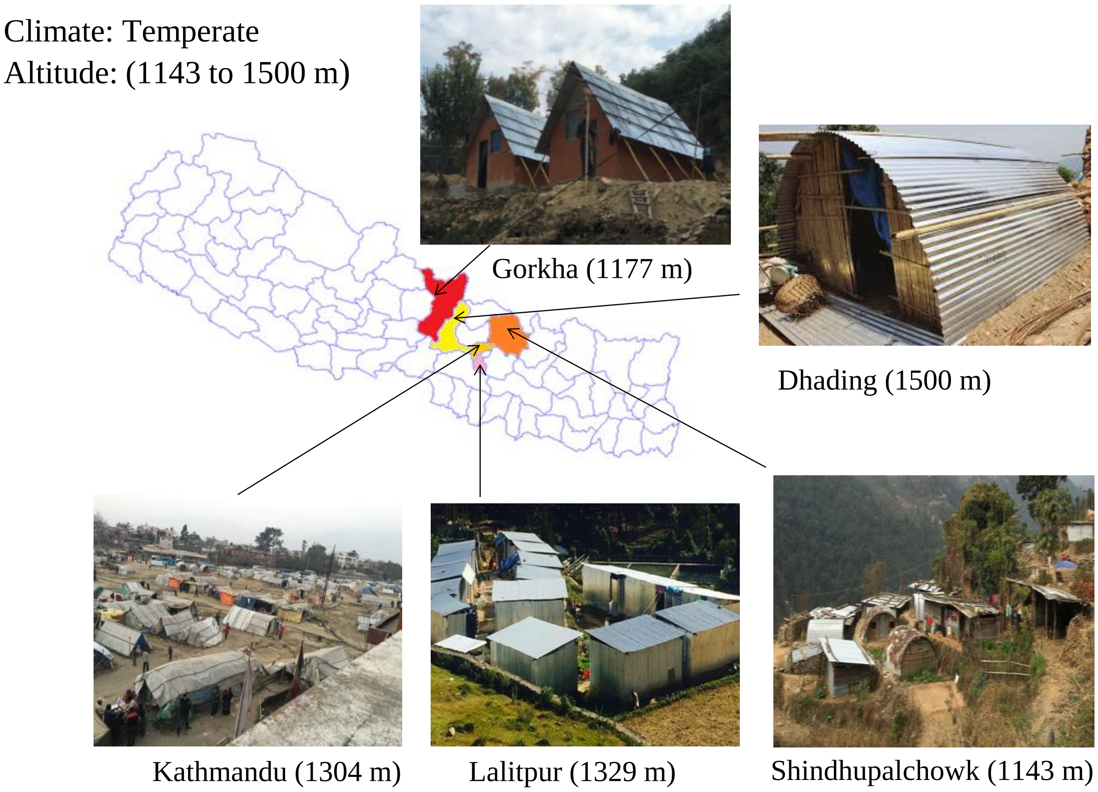


Fig. 2.1 Research areas with an example of temporary shelters were built.

Fig. 2.2 (a) shows the monthly mean outdoor air temperature obtained from the nearest meteorological stations of those investigated districts (Meteorological observatory 2016). Throughout the year (2016), the outdoor air temperature is the highest in Gorkha, the 2nd highest in Kathmandu, then followed by Lalitpur and then the lowest in Shindhupalchowk. In all five districts, the differences in outdoor air temperature between the highest (maximum) and the lowest (minimum) are identical by 12 to 13 °C.

Fig. 2.2 (b) shows that throughout the year (2016) from nearest meteorological stations of those investigated districts (Meteorological observatory 2016). Relative Humidity (*RH*) is the most commonly used measure of the moisture content in the air. The Relative Humidity is defined as the ratio of the partial vapor pressure to the saturation vapor pressure at a given temperature. By measuring the relative humidity, the actual quantity of water vapor to the maximum quantity of water vapor present in the ambient temperature and pressure is known. Outdoor relative humidity fluctuates from one season to another season. During the January, the relative humidity becomes high, although the water holding capacity in the cold air is less. So the air during the cold days gets saturated even with less moisture content in the air, and the relative humidity gets high, whereas during the rainy and warm monsoon season (June, July and August), the water holding capacity of the air is high and the moisture content in the air is also high. So during the monsoon season both the absolute and relative humidity remains very high. During the rainy season between June to August, it rains to an average of 200-375 millimeters in Kathmandu. There is always a chance of occasional rainfall during other seasons too. Specially, in Kathmandu, an average, 1300 millimeters of rain fall in every year.

Nepal is the country of extremes climate due to its high Himalayas range. The lowland plains of the Terai can have tropical temperatures calls mosquitoes near to you. The Himalayas can get to sub-zero temperatures, but the sun blaze can bring some warmth during the day, even in the mountains. While the temperature of major cities like Kathmandu and Gorkha might go below 1 °C in winter, while rises to an average of 33 °C in summer.

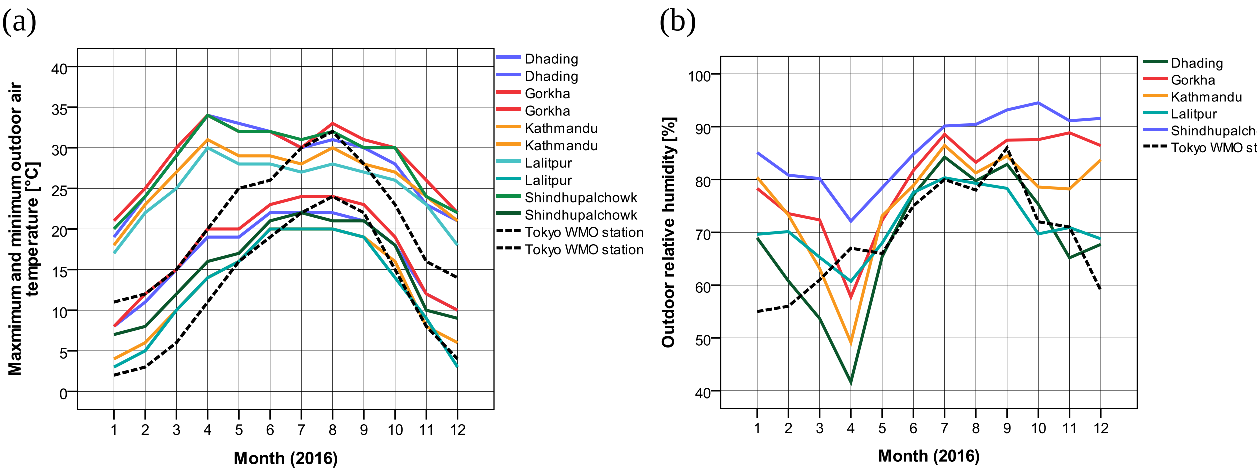


Fig. 2.2 General climatic condition of research areas including with Japan: (a) Monthly maximum and minimum outdoor air temperatures, and (b) Monthly mean outdoor relative humidity.

Here we briefly introduce the investigated districts:

(a) Kathmandu (https://en.wikipedia.org/wiki/April_2015_Nepal_earthquake)

Hundreds of thousands of Nepalese were made homeless with entire villages flattened, across many districts of the country. Kathmandu is the capital city of the Federal Democratic Republic of Nepal, the largest Himalayan state in Asia. In Kathmandu, centuries-old buildings were destroyed at UNESCO World Heritage Sites in the Kathmandu valley, including some at the Kathmandu durbar square, the Patan durbar square, the Bhaktapur durbar square, the Changu- narayan temple, the Boudhanath stupa and the Swayambhunath stupa. Dharahara, also called Bhimsen Tower, which was a nine-stores and 61.88 meter tall tower, was destroyed. It was a part of the architecture of Kathmandu recognized by UNESCO. The Kathmandu at 1,400 meters (4,600 feet) above sea level, and the climate is mild, generally warm and temperate. The city was the royal capital of the Kingdom of Nepal and features palaces, mansions, and gardens of the Nepalese aristocracy. Kathmandu is named after the Kasthamandap temple, which could be found in Durbar Square. Kathmandu has been the center of Nepal's history, art, culture, and economy. It has a multi-ethnic population with the majority being Hindu and Buddhist. Religious and cultural festivities form a major part of the lives of people residing in Kathmandu.

The Kathmandu valley belongs to the warm temperate zone, where the climate is fairly temperate. The valley's average summer temperature varies from 28-30 ºC and average winter temperatures are around 10 ºC. However, cool nights and mornings and unpredictable weather can be expected given that winter temperatures can drop to 1 ºC or less. The average annual temperature is 18.1 °C. During the monsoon season (June to August) heavy rainfalls about 1505 mm of precipitation falls annually reach the city with average humidity of about 75 %.

(b) Lalitpur (https://wiki.openstreetmap.org/wiki/Lalitpur_District)

Lalitpur district is a district in Bagmati Zone, Central development region, Nepal at latitude 27°32′53.88″ north, longitude 85°20′15.00″ east. The climate here is mild, and generally warm and temperate. The average annual temperature is 25.7 °C and precipitation here averages 1128 mm. Lalitpur metropolitan city known as historically city which is the third largest city of Nepal after Kathmandu and Pokhara and it is located in the south-central part of Kathmandu valley which is a new metropolitan city of Nepal. The city has an area of 15.43 square kilometers and is divided into 29 municipal wards. It is best known for its rich cultural heritage, particularly its tradition of arts and crafts. It is called city of festival and feast, fine ancient art, making of metallic and stone carving statue. At the time of the 2011 Nepal census it had a population of 226,728 in 54,748 individual households. Climate is characterized by relatively high temperatures and evenly distributed precipitation throughout the year. The city was extensive damage from an earthquake on 25th April 2015.

(c) Sindhupalchowk

(https://reliefweb.int/map/nepal/nepal-earthquake-affected-areas-sindhupalchok-district-26-nov-2015)

Shindhupalchowk is one of the worst-affected districts as a result of the earthquake that took place on the 25th April. According to district authorities 63,885 houses are severely and 2,751 houses are moderately damaged. Based on government reporting on damaged houses as of 6th May an estimated 109,000 people (Ministry of Home Affairs 7th May) are affected (40 % of district population as per the 2011 Census). Sindhulpalchok can be roughly divided into two areas; mountains (with elevations of above 3,500 meters) and the more density populated hilly areas. Shindhupalchowk, with an area of 2,542 km^2. The district's headquarters is in Chautara.

(d) Gorkha (https://en.wikipedia.org/wiki/Gorkha_District)

Gorkha District is a district in Gandaki Zone, Western Development Region, Nepal at latitude 28°10′36.12″ North, longitude 84°48′27.36″ East. Gorkha is the main epicenter of Earthquake 2015. A part of Gandaki Pradesh, is one of the seventy-Seven districts of Nepal and connected historically with the creation of the modern Nepal and the name of the legendary Gurkha soldiers. The Gorkha Municipality covers an area of 3,610 km2 (1,390 sq mi) and has a population (2001) of 288,134 (National Population and Housing Census 2011). It is the location of the Manakamana Temple. Also, the temples of great sage Gorakh Nath and goddess Gorakh Kali temple is located in district, after which the district got its name.

(e) Dhading (http://ddcdhading.gov.np/en)

Dhading is the only district of Nepal which ranges from the mountain Ganesh Himal to the Churevawar pradesh of Terai (Chitwan). Geographically the district spreads from 27'40" E to 28'17"E and 80'17" N to 84'35" N. Dhading is the only district of Nepal which ranges from the mountain Ganesh himal to the churevawar pradesh of Terai. The mountain range Ganesh Himal is the predominated mountain range located winthin Dhading and the highest peak is the Pabil that measures 7110 m. The prithvi highway connecting Kathmandu, Pokhara and Bharatpur runs through the southern portion of the district is one of the major link to the boarder of India. It has a population of 336,067 in 2011. Most of the ethnics in dhading are Brahmin and chettri in southern part followed by the number of Tamang and Gurung in Northern. Dhading is 80% farmland and 20% forest.

Table 2.1 Damage conditions in five investigated districts (http://drrportal.gov.np/publication).

Description	Gorkha	Shindhupalchowk	Kathmandu	Lalitpur	Dhading
No. of deaths	996	4389	1840	435	1239
No. of injured	1866	2735	9329	3329	1941
House fully destroyed	70143	92364	29310	30256	83221
House partially destroyed	13675	3558	11237	8718	4034
Affected family	44997	100665	10505	3996	50349

2.3 Investigated temporary shelters

We investigate 18 randomly selected shelters denoted from S1 to S18, for which six are rectangular-shaped shelters (S1, S2, S4, S5, S6, S7, S8, S9, S10, S13, S14, S17 and S18) and one dome-shaped shelter (S3, S11, S12, S15 and S16) can be seen in Fig. 2.3. The eighteen investigate shelters, selected randomly denoted from S1 to S18, for which six are rectangular-shaped shelters (S1, S2, S4, S5, S6 and S7) and one dome-shaped shelter (S3). Regrettably, the sensors used in two shelters, S2 and S7, were found to have malfunctioned (Thapa et al. 2019). Therefore, these two shelters were excluded in the present study and we analyzed the thermal environment of five shelters.

(a) S1

(b) S2

(c) S3

(d) S4

(e) S5

(f) S6

Fig. 2.3 continue….

(g) S7

(h) S8

(i) S9

(j) S10

(k) S11

(l) S12

(m) S13

(n) S14

Fig. 2.3 continue….

(o) S15

(p) S16

(q) S17

(r) S18

Fig. 2.3 Investigated shelters (continuous measurement).

2.3.1 Materials used

Fig. 2.4 shows the materials used in temporary shelters with adding insulating materials. In the immediate aftermath of the earthquake 2015, emergency shelter assistance was provided to more than 1.2 million houses in the 14 most affected districts (Shelter report, Housing Recovery and Reconstruction, 2018). With a mission of completing the reconstruction of earthquake affected infrastructures, National Reconstruction Authority (NRA) was established (Berlaer et al. 2017). NRA will also provide grants on the basis of some terms and conditions for reconstruction.

However, most of the people built temporary shelters themselves according to their family size and available and affordable materials. Most of the shelters were made through salvaged local materials from their previous homes too. The stones, bricks, wood, bamboo along with the doors and windows were reused. The walls of these shelters were made from zinc sheet. The foundations of these shelters have completed between concrete or mud/stone.

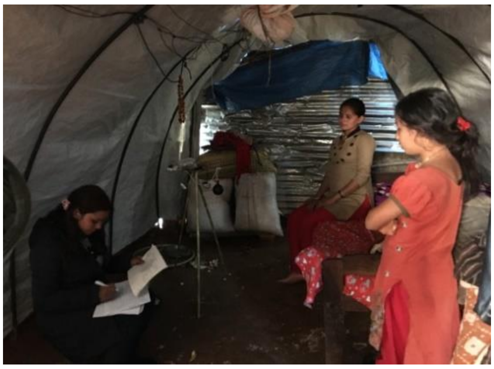
Straw on roof

Jute in internal roof

Dry grasses on roof

Tarpaulin sheet on roof

Mud plaster on wall



Tarpaulin sheet in internal roof

Fig. 2.4 Insulation materials used in temporary shelters.

Here in Fig. 2.5 shows the thermal adjustment of people as season change; (a) summer adjustment and (b) winter adjustment. General speaking, humans have an ability to adapt biologically to our environment. An adaptation is any variation that can increase one’s biological fitness in a specific environment; more simply it is the successful interaction of a population with its environment. What type of adaptation is activated often depends on the environment? Cultural adaptations could occur based on religion and ethnic group.

(a) Summer adjustment

(b) Winter adjustment

Clothing for summer

Clothing for winter

Staying in shading place

Taking sun bath

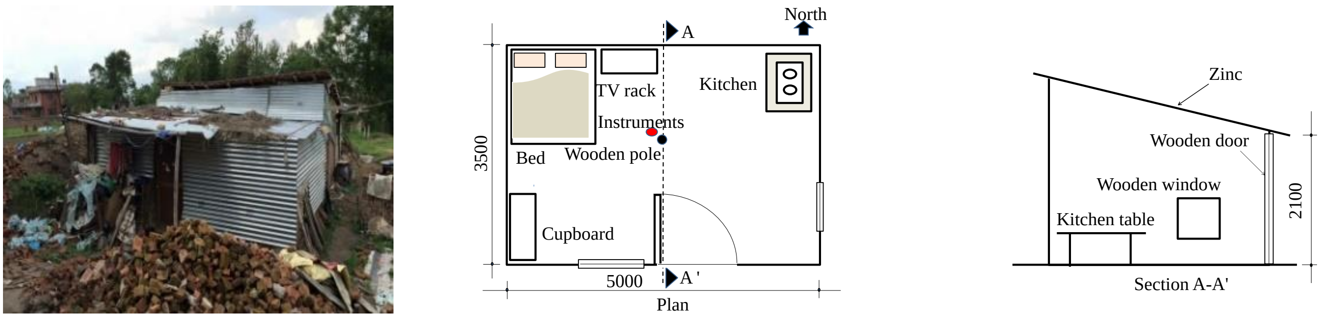
Posture change

Fire wood

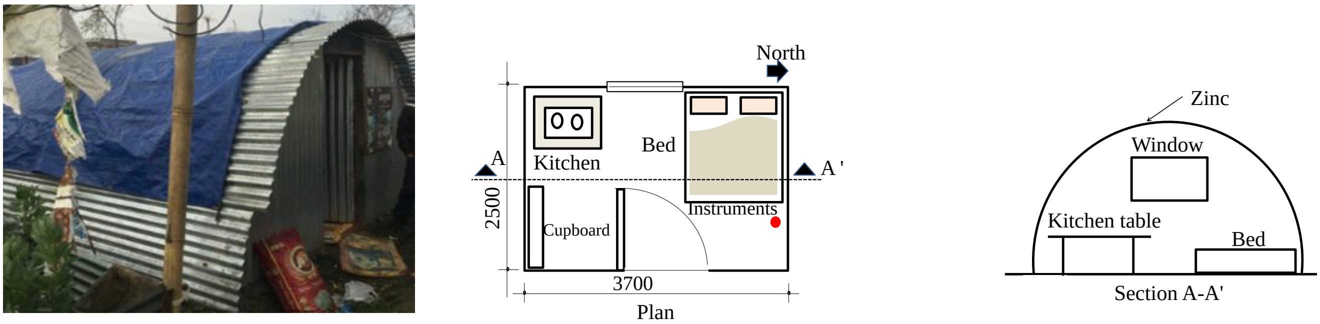
Fig. 2.5 Thermal adjustments for thermal comfort as season change.

2.3.2 Plan and sectional view

Fig. 2.6 shows an examples of photos, plan and sectional views of investigated shelters. Fig. 2.7 shows the composition of floor materials of five investigated shelters. Table 2.3 shoes the description of the instrument used. Each of these shelters has single room for living, sleeping and kitchen. The structure, size and materials used for insulation of the shelters are different from each other. People used local and affordable materials such as straw, tarpaulin sheets, cellular polyethylene foam, clothes and others on the interior and exterior sides of zinc sheets. No heating systems were used in all of the investigated shelters. Table 2.4 shows the details of field measurement.

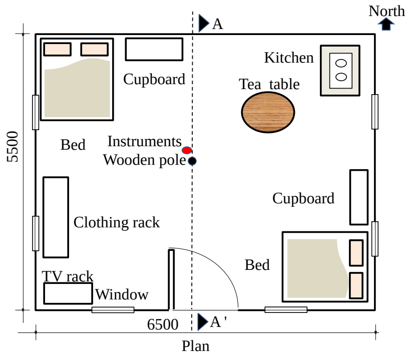


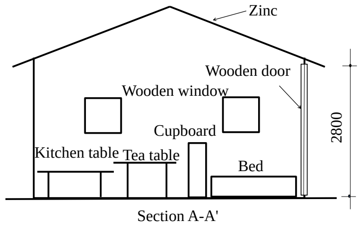
S1



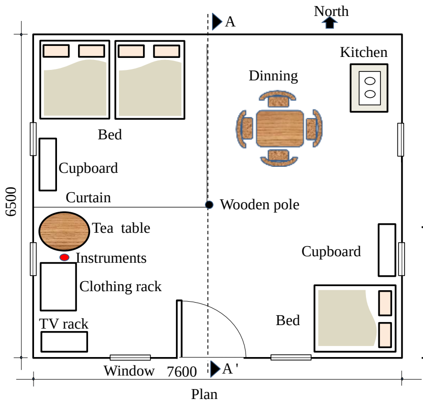
S3

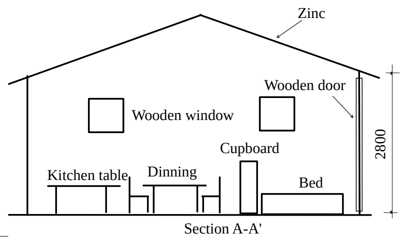
Fig. 2.6 continue….



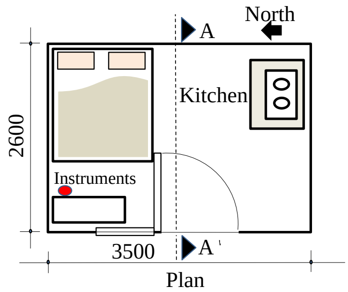


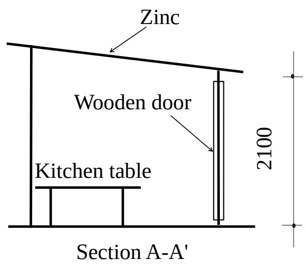
S4





S5





S6

Fig. 2.6 Photos, plan and sectional views of the five temporary shelters: S1, S3, S4, S5 and S6. The unit of length is mm. In sectional view, zinc sheets alone are shown.

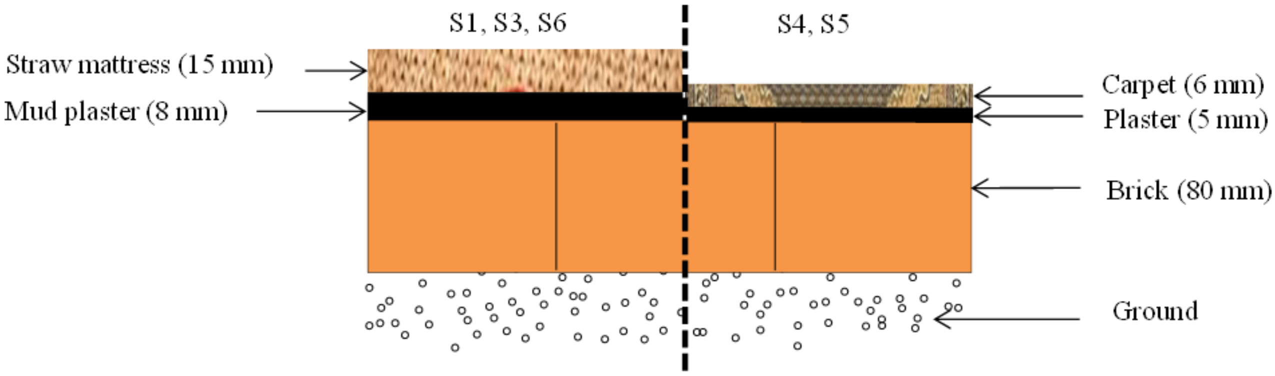


Fig. 2.7 Composition of floor materials of the investigated shelters.

2.3.3 Description of instrument used

Continuous measurement for indoor air temperature, outdoor air temperature, indoor globe temperature, indoor relative humidity and outdoor relative humidity were measured by respective sensors with data loggers as can be seen in Fig. 2.8 and Fig. 2.9. These instruments have set in the middle of shelters and the digital instruments were attached in middle of each wall (four directions; east, west, north and south directions), middle of ceiling and middle of floor areas for measuring surface temperatures.

Thermal comfort survey, we set the sensors with data loggers and move to each shelter as can be seen in Fig. 2.10 and respondents were asked questionnaires related on their thermal perception and also note the indoor thermal parameters.

Table 2.3 Description of the instrument used.

Parameter measured	Sensors	Range	Accuracy	Name of instruments
Air temperature, relative humidity	Thermistor and polymer membrane	0.55 °C, 10-95%	± 0.5 °C, ± 5% RH	TR-74 Ui
Globe temperature	Black painted, 75 mm-diameter globe	-60 to 155 °C	± 0.3 °C	Tr-52i, SIBATA, 080340-75

Fig. 2.8 Installed instruments in middle of shelter.

Fig. 2.9 Installed instruments in shelters (surface areas; four walls, ceiling and floor) for continuous measurement.

Fig. 2.10 Installed instruments in middle of shelter at 1.1m and also nearly 1 m far from respondents.

2.4 Method of thermal measurement survey

The continuous thermal-environment measurement was performed for 16 days from 30th January to 14th February, 2016 in Lalitpur district. Indoor air temperature, outdoor air temperature, indoor globe temperature, indoor relative humidity and outdoor relative humidity were measured by respective sensors with data loggers at the interval of 10 minutes. Table 2.4 shows the instruments used in this field measurement. The data loggers were placed in the middle or the corner of respective investigated shelters; they were set 1m above the floor level as shown in Fig. 2.8. The outdoor air temperature was measured just outside the shelter S1. We assumed the same outdoor air temperature for other investigated shelters because all of the investigated shelters are located only 50 m to 5 km away from shelter S1.

Table 2.4 Details of the thermal measurement survey at interval of 10 minute.

Season	District	Shelter code	Survey period		
			Start date	End date	Total days
Autumn	Lalitpur	S1	10/4/2015	10/20/2015	16
Winter	Lalitpur	S1 to S3	1/20/2016	2/14/2016	26
		S4 to S7	1/30/2016	2/14/2016	16
	Shindhupalchowk	S11 to S13	1/19/2016	1/22/2016	4
	Gorkha	S14 to S16	1/26/2016	2/26/2016	1
Summer	Lalitpur	S1 to S3	3/29/2016	4/20/2016	23
		S7	3/29/2016	4/6/2016	8
		S8	3/29/2016	4/2/2016	5
		S9	3/29/2016	4/5/2016	8
		S10	4/4/2016	4/20/2016	17
	Shindhupalchowk	S11 to S13	4/6/2016	4/8/2016	2
	Gorkha	S17 to S18	4/16/2016	4/16/2016	1

2.5 Autumnal thermal environment

2.5.1 Variation of monthly indoor, globe and outdoor air temperature

Fig. 2.11 shows the profile of indoor air temperature, indoor globe temperature and outdoor air temperature of overall days (16 days) of selected shelter and Fig. 2.12 shows 24-hour temperature profile of a typical day (8th November). We selected November 8th (one day) because on that day no drastic deviation in weather conditions is observed. From the figure we can see that the indoor air temperature and indoor globe temperature are tracing each other and are is significantly higher than outdoor air temperature in early morning, after noon and at night time.

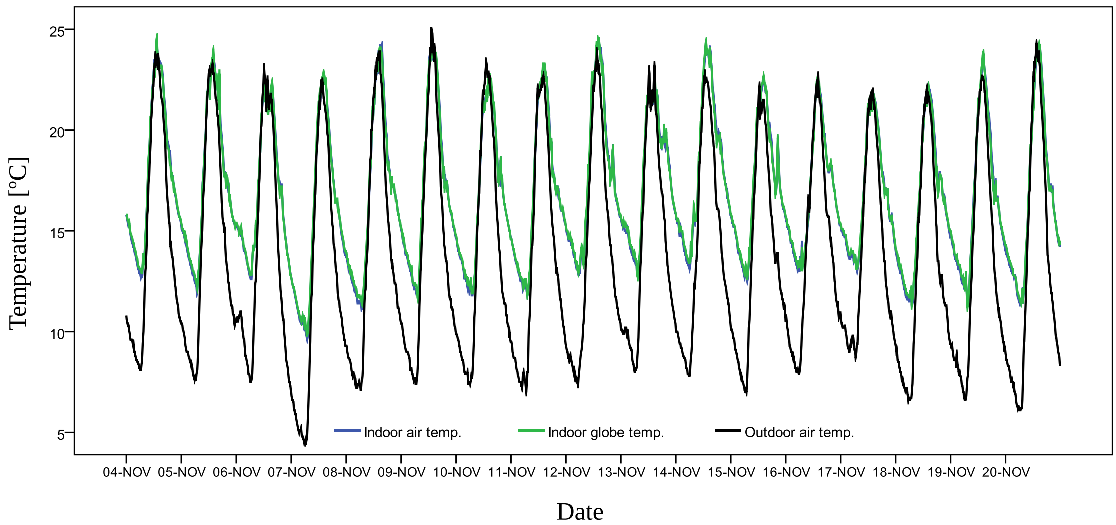


Fig. 2.11 Variation of indoor air temperature, outdoor air temperature and globe temperature.

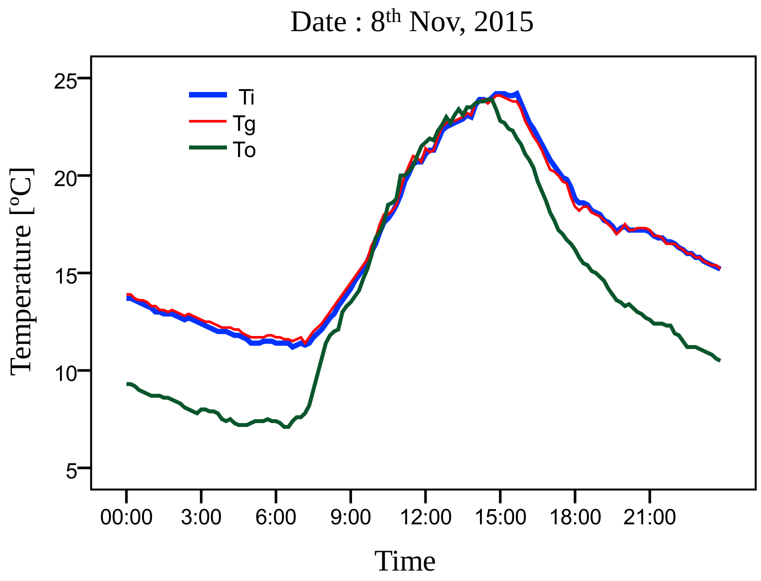


Fig. 2.12 Variation of indoor air temperature, outdoor air temperature and globe temperature in a day (8th November).

2.5.2 Mean indoor air temperature in different time zone

Mean indoor, globe and outdoor air temperatures observed during the 16 days of research are shown in Table 2.5. Here, 24 hour of a day is divided into two sections i.e. Day time (6:00 to 17:50) and night time (18:00 to 5:50). We can see the mean indoor air temperature in day time is 18.7 °C which is similar to indoor globe temperature. The mean indoor air temperature in night time is 15.2 °C which is similar to indoor globe temperature (Fig. 2.9). Sleeping hour mean indoor air temperature is 14.3 °C which is also similar to globe temperature. The result showed that the indoor air temperature is 5 °C higher than outdoor air temperature.

Table 2.5 Mean and standard deviation of temperatures during autumn.

Variables	Day time			Night time			Sleeping hour		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
Indoor air temp. [°C]	1224	18.7	3.9	1225	15.2	2.1	919	14.3	1.5
Indoor globe temp. [°C]	1224	18.7	3.9	1224	15.2	1.9	918	14.4	1.5
Outdoor air temp. [°C]	1224	17.1	5.1	1225	10.4	2.5	919	9.3	1.6

N: Number of sample, S.D.: Standard Deviation

2.5.3 Relationship between the indoor air temperature, globe temperature and outdoor air temperature

Fig. 2.13 shows the relationship between indoor air temperature [T_i] and indoor globe temperature [T_g] of the studied shelter. They are highly co-related. The higher numbers of data at 12-16 °C, are seems higher than above 18 °C. This result suggested that indoor environment was slightly cold. Here, we obtained the following equation to predict the temperature.

$T_g = 0.981T_i+0.379$ (2.1)

(N = 2448, R^2 = 0.997, S.E. = 0.001, $P < 0.001$)

N: Number of sample, R^2: Coefficient of determination, S.E.: Standard Error of the regression coefficient, P: Significant level of regression coefficient.

If we know the indoor air temperature, we can predict the indoor globe temperature by using this equation. For example, if indoor air temperature is 18 °C, then the indoor globe temperature would be 18.1 °C.

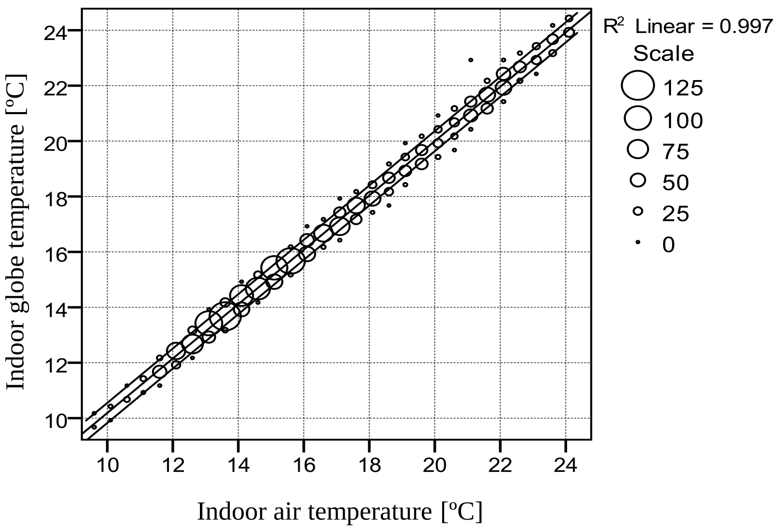


Fig. 2.13 Relation between the indoor globe temperature and indoor air temperature.

2.5.4 Prediction of indoor air temperature by outdoor air temperature

Fig. 2.14 shows relation between indoor air temperature (T_i) and outdoor air temperature (T_o) with 95 % of data point. We have obtained the following regression equation from the regression analysis.

$T_i = 0.658T_o+7.869$ (N = 2449, R^2 = 0.93, S.E. = 0.004, P<0.001) (2.2)

If we know outdoor air temperature, then we can predict the indoor air temperature by using this equation. For example, if outdoor air temperature is 15 °C, then indoor air temperature would be 17.1 °C.

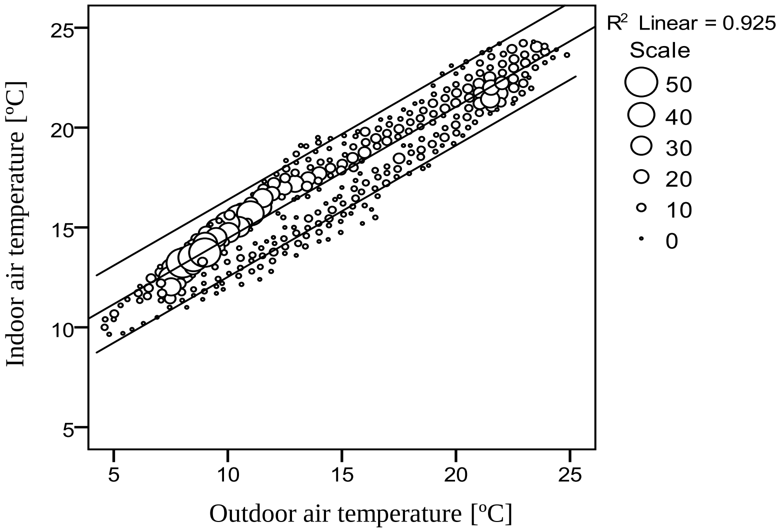


Fig. 2.14 Relationship between indoor air temperature and outdoor air temperature.

2.6 Wintry thermal environment

2.6.1 Variation of monthly indoor and outdoor air temperature

Fig. 2.15 shows the profile of indoor air temperature and outdoor air temperature of overall days (26 days) of selected shelter S1, S2 and S3. Fig. 2.16 shows the 24 hours indoor and outdoor temperature profile for a typical one day (1st February, 2016) of seven shelters in Lalitpur. We have selected that day because there was no drastic deviation in weather condition. The indoor air temperatures are close to outdoor air temperatures for all shelters. The indoor air temperature of shelter S7 is sharply increasing (maximum 23 °C) and decreasing (minimum 3 °C) during the day and night time.

Fig. 2.17 shows the profile of indoor air temperature and outdoor air temperature of selected shelter S4, S5 and S6 (N = 2304, 16 days) for Lalitpur, S11, S12 and S13 (N = 576, 4 days) for shindhupalchowk and S14, S15 and S16 (N = 144, 1 day) for Gorkha district.

The indoor air temperatures are close to outdoor air temperatures for all shelters. So, it can be said that same as shelters in Lalitpur, the thermal insulation is very poor, thus, need to improve the indoor air temperature for consider peoples' health. So, it can be said that the thermal insulation is one of the most effective measures to improve the indoor air temperature. According to Ponni & Baskar (2014), roof and walls are important element which directly receives the solar radiation in different angle than other elements of the building and it receives the heat or cold and also responsible to the outside thermal variations. As for other shelters, the indoor and outdoor air temperatures are gradually increase and decrease. But case of shelter S3 indoor air temperature is sharply increasing about 27 °C and decreasing about 7 °C during the day time. The result might be the poorest insulations among other six shelters and also least heat storing capacity.

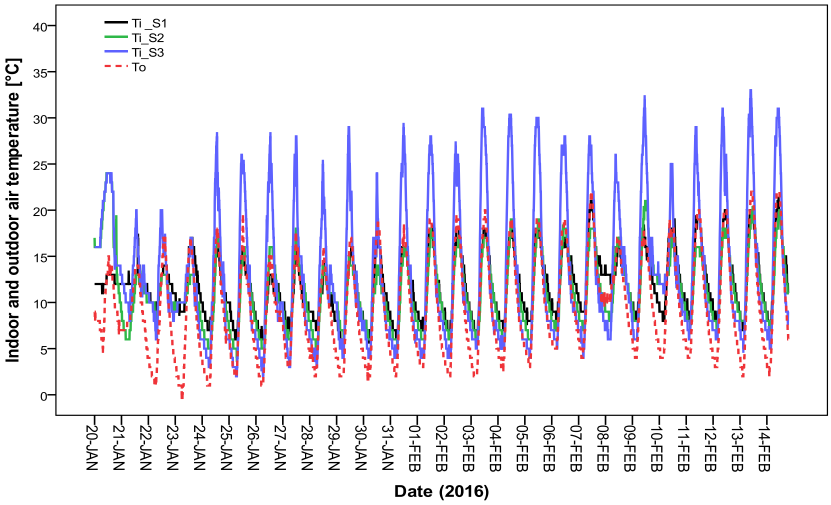


Fig. 2.15 Variation of indoor and outdoor air temperature for 26 days for winter.

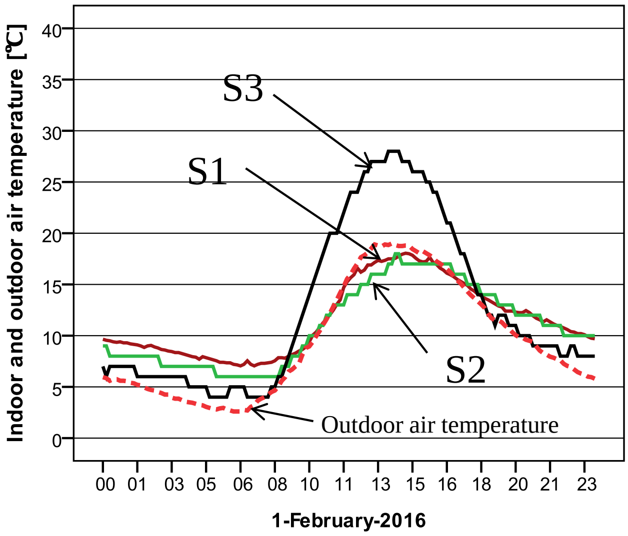
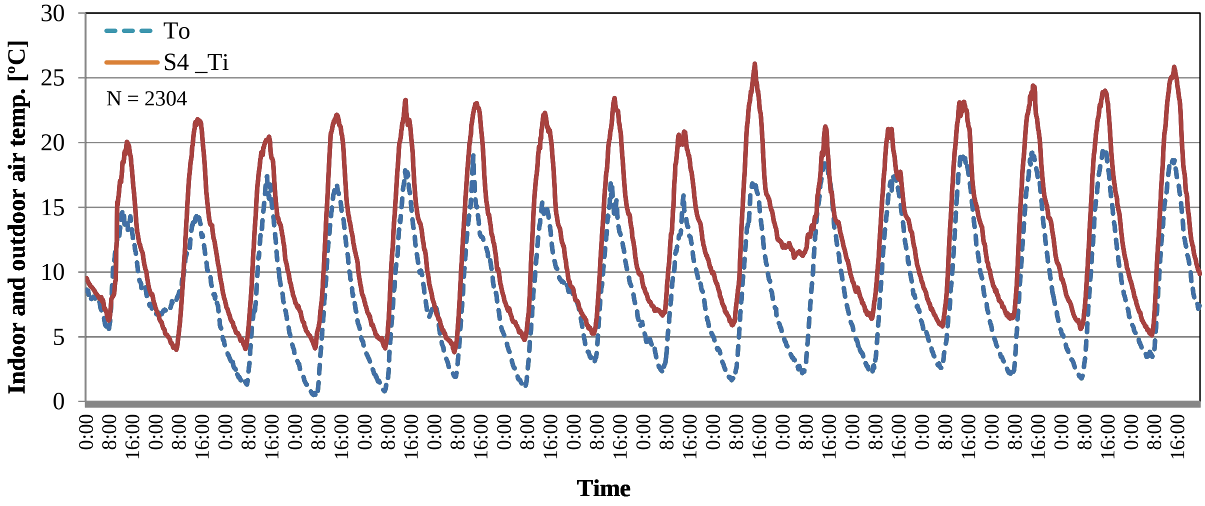
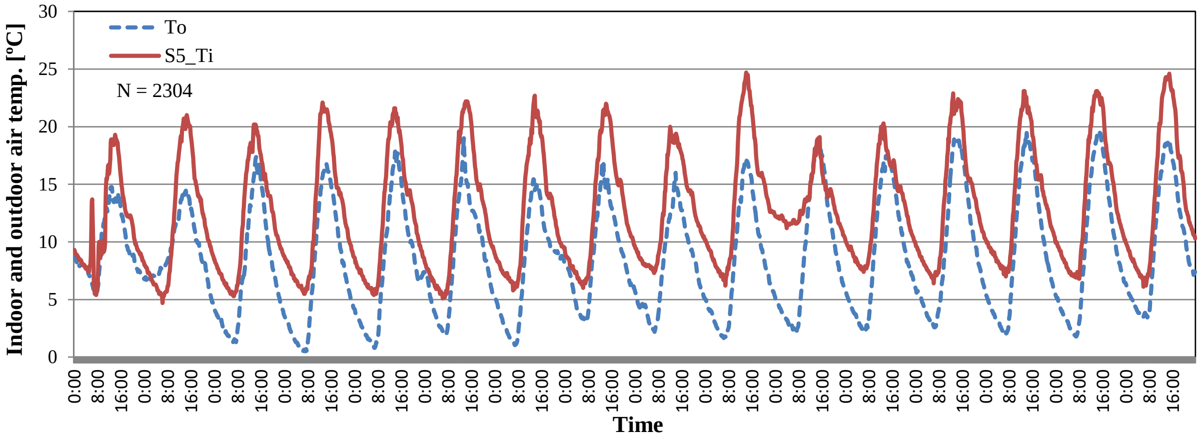


Fig. 2.16 Variation of indoor and outdoor air temperature in a day in winter.

(a) S4



(b) S5



(c) S6

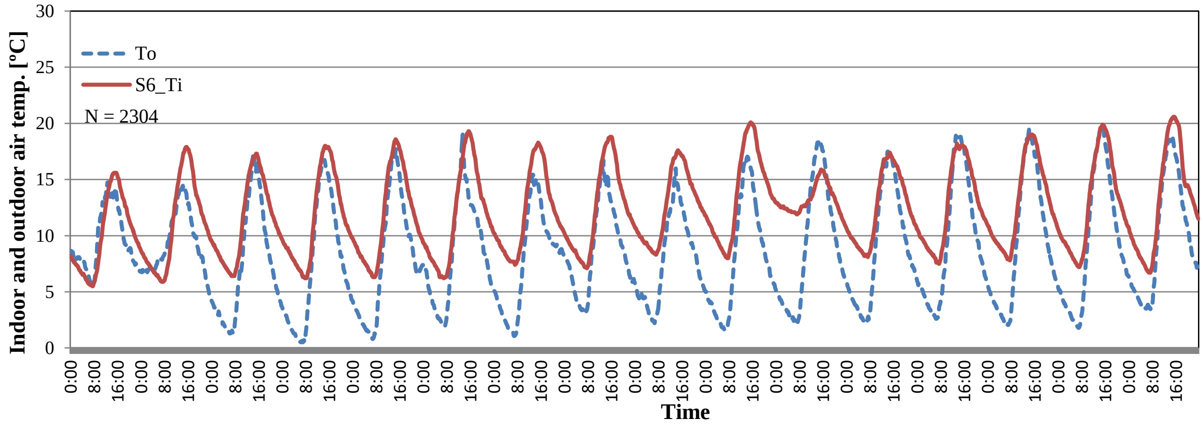
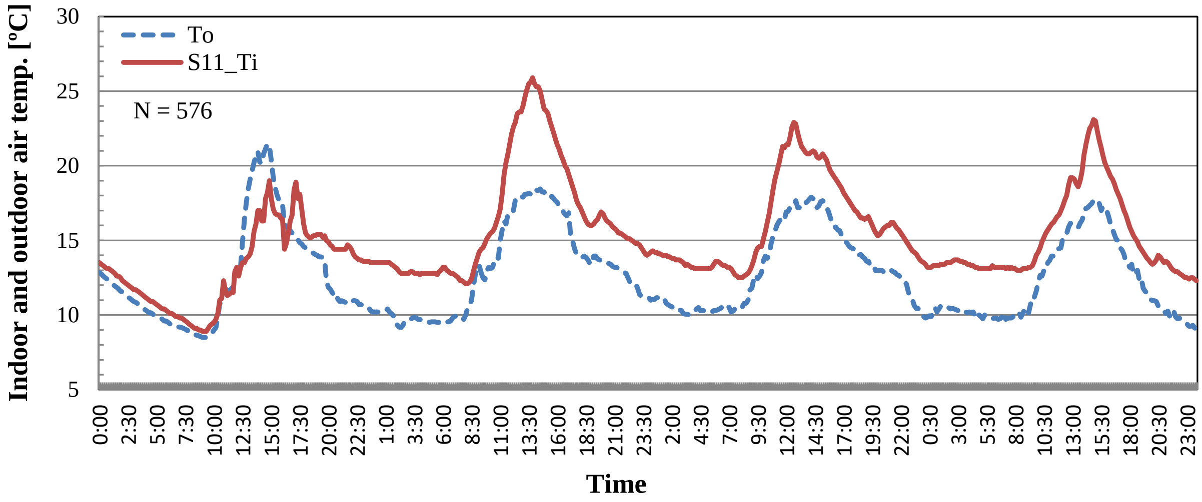
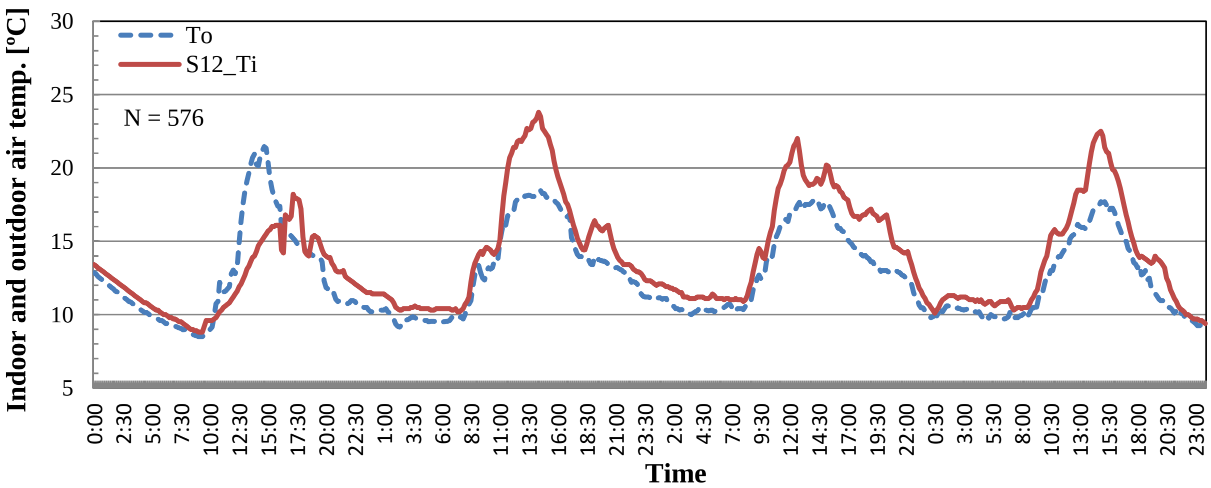


Fig. 2.17 continue….

(d) S11



(e) S12



(f) S13

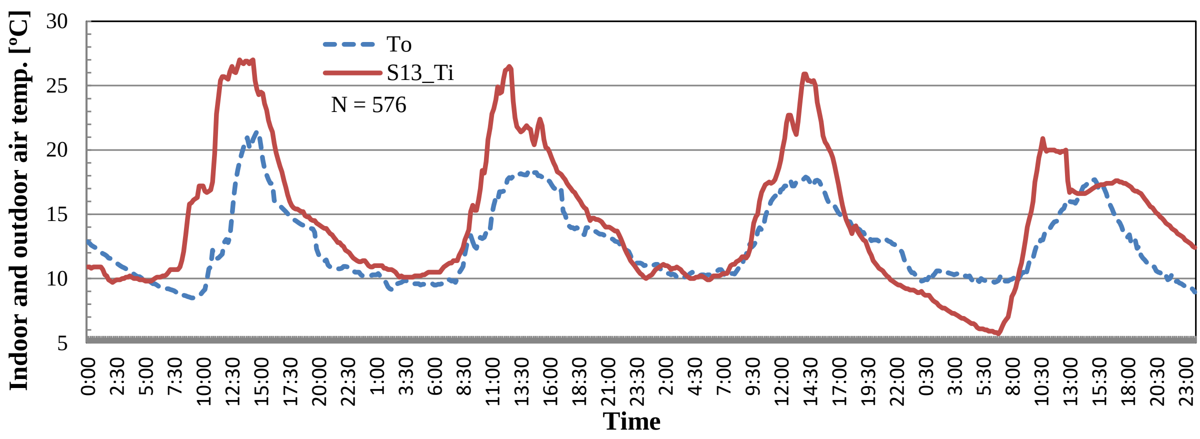
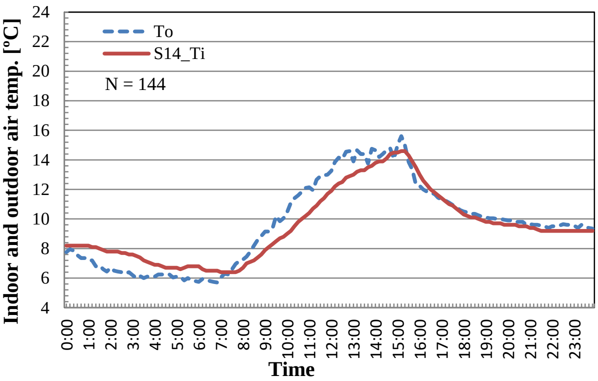
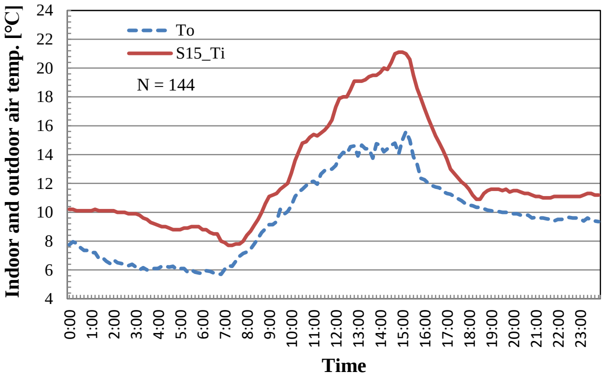


Fig. 2.17 continue….

(g) S14



(h) S15



(i) S16

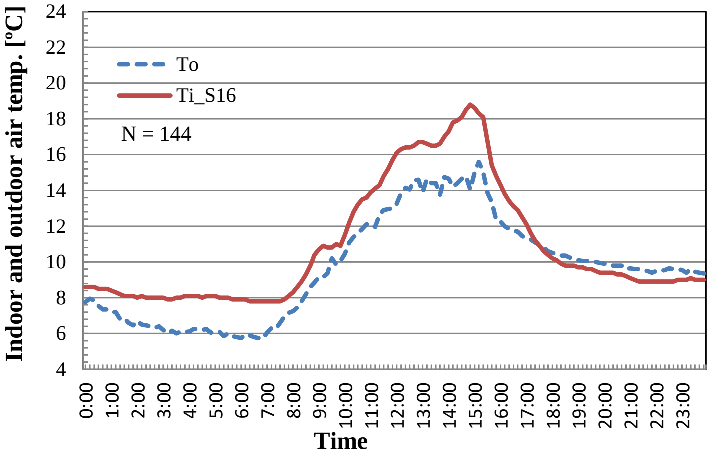


Fig. 2.17 Variation of indoor and outdoor air temperatures of S4, S5 and S6 in Lalitpur, S11, S12 and S13 in Shindhupalchowk and S14, S15 and S16 in Gorkha district for winter.

2.6.2 Relationship between indoor and outdoor air temperature

Fig. 2.18 shows the relationship between indoor air temperature and outdoor air temperature of three investigated shelters for all 26 days in winter. The indoor air temperatures for all shelters are highly dependent on outdoor air temperature. The reasons for this, these investigated shelters were made of zinc sheet which directly receives the solar radiation, and also responsible to the outside thermal mass of walls and roof.

The most of the data tend to be slightly above from the diagonal line in both seasons. It seems that local and available materials are marginally useful as insulations for mitigating discomfort. Furthermore, living conditions under the temporary shelters are literally pitiful due to these poor qualities of materials used as mention in 2.6. It can be said that, these materials used are not sturdy enough to protect from harsh climatic conditions in both seasons for temporary shelters. Here, we have obtained the following regression equation of three shelters to predict the indoor air temperature by outdoor air temperature in winter and summer.

Winter (S1) $T_i = 0.597T_o+6.2$ (N = 3744, $R^2 = 0.888$, S.E. = 0.003, $p<0.001$) (2.3)

Winter (S2) $T_i = 0.616T_o+5.6$ (N = 3744, $R^2 = 0.692$, S.E. = 0.007, $p<0.001$) (2.4)

Winter (S3) $T_i = 1.211T_o+1.5$ (N = 3744, $R^2 = 0.783$, S.E. = 0.010, $p<0.001$) (2.5)

N: number of sample, R^2: coefficient of determination, S.E.: standard error of the regression coefficient, p: significance level of the regression coefficient.

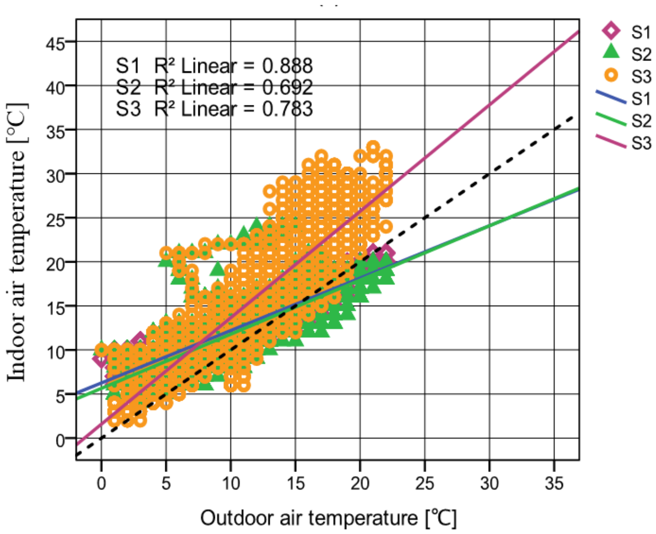


Fig. 2.18 Relationship between indoor and outdoor air temperature (Winter).

2.6.3 Mean temperature of day, night and sleeping time

Table 2.6 shows the result of mean indoor and outdoor temperature of day time, night time and sleeping time in winter. Here, in this section we focused to analyses the mean indoor air temperature for sleeping time. The mean indoor air temperature during the sleeping time has found large difference (4.7 °C) between S1 (10.1 °C) and S3 (5.4 °C) in winter. The mean maximum indoor air temperature of ordinary building is 12 to 15°C (Bajracharya, 2013), which is higher than temporary shelters. It seems that the overall mean indoor air temperature is very low and respondents are compromising the indoor environment by adapting their clothing insulations. The mean clothing value was found 1.29 clo in winter (Thapa et al. 2018).

Table 2.6 Mean indoor air temperature and standard deviation in winter.

S.C.	Variables	Monthly mean [ºC]			Day time (6:00~17:50)			Night time (18:00~5:50)			Sleeping time (21:00~5:50)		
		N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
S1			11.9	3.3		13.0	3.9		12.6	2.0		10.1	1.7
S2	T_i [ºC]	3744	11.5	3.9	1800	12.4	4.2	557	11.9	2.6	1297	9.5	2.1
S3			13.1	7.1		16.7	8.0		11.8	2.7		8.2	2.5
All Shelters	T_o [ºC]	3744	9.5	5.2	1800	12.0	5.7	557	10.0	2.9	1297	5.7	2.3

S.C.: Shelter code, N: Number, S.D.: Standard Deviation [ºC], T_i: Indoor air temperature [ºC] , T_o: Outdoor air temperature [ºC]

2.6.4 Water vapor concentration

Fig 2.19 show the relationship between indoor water vapor concentration and outdoor water vapor concentrations for six investigated shelters in winter for 16 days (N=2304).
It is difficult to understand the level of thermal environment by observing the relative humidity only (Ogawa 1999). So, here in this study, we tried to observe the amount of water vapor concentration of the temporary shelters. The water vapor concentration was estimated using the equation (2.6) given in (Nicol and Roaf 1996).

$$C_{wv} = 2.167 \times Pwv/T \qquad (2.6)$$

where C_{wv} is water vapor concentration (g/m^3), P_{wv} is water vapor pressure (Pa) and T is temperature in Kelvin scale (K).

The variation of indoor water vapor concentrations looks quite similar to outdoor water vapor concentrations in all investigated shelters. The water vapor concentration as can be found around 3 to 10g/m^3 in S1, S4, S5 and S6 but S3 water vapor concentrations is found 2 to 20 g/m^3. This result suggest that S3 has moister or humid than others shelters due to less ventilation and cause of shelters height.

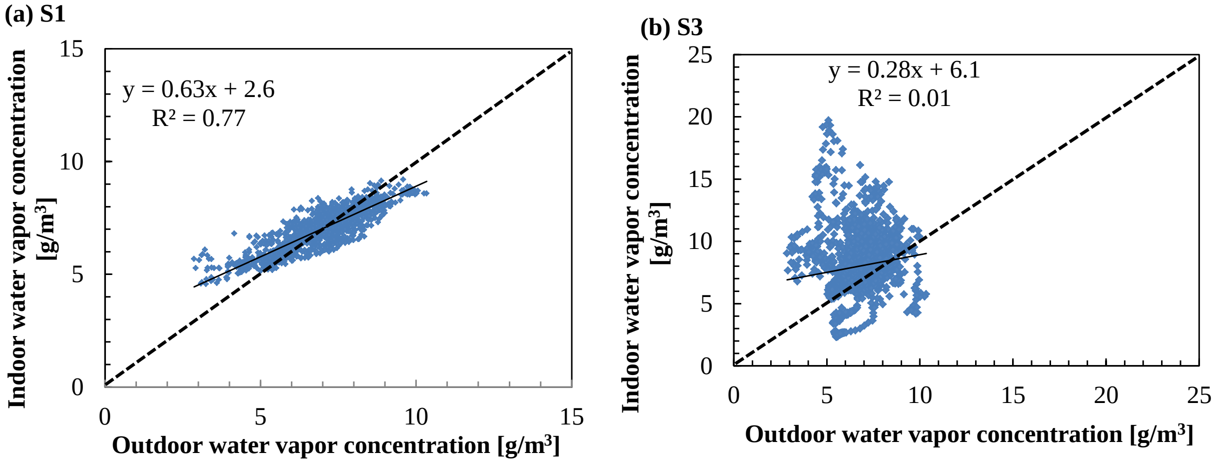


Fig. 2.19 continue….

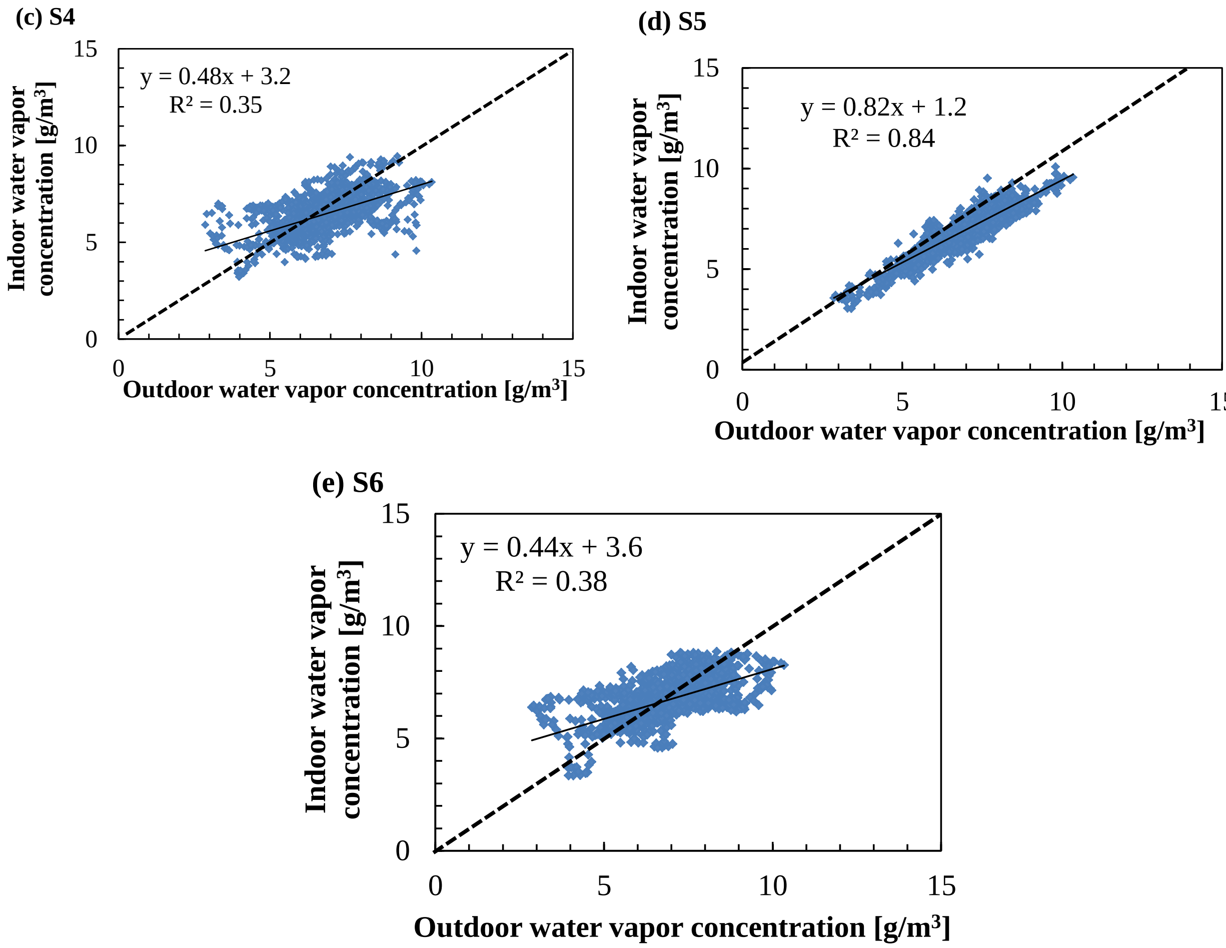


Fig. 2.19 Relationship between indoor and outdoor water vapor concentration for Lalitpur.

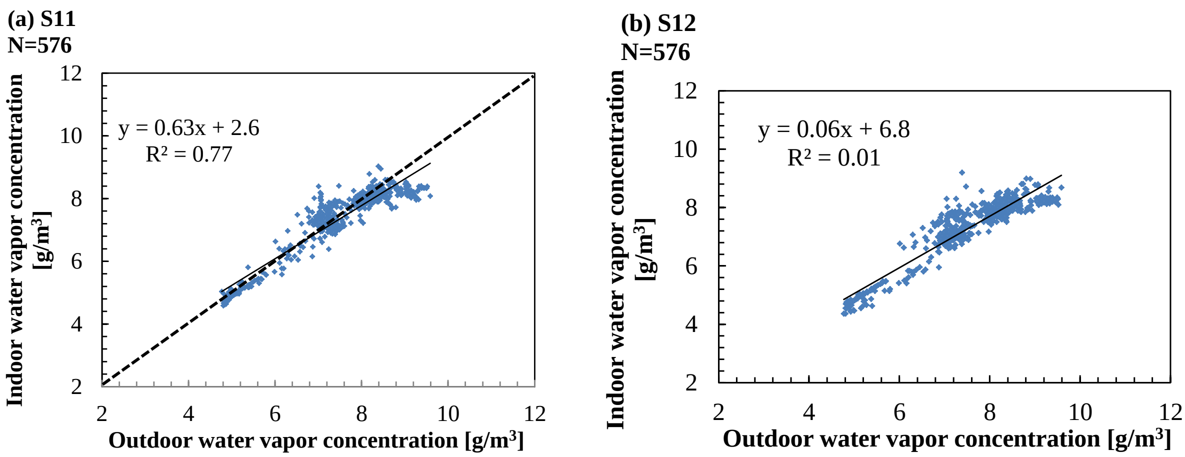


Fig. 2.20 continue….

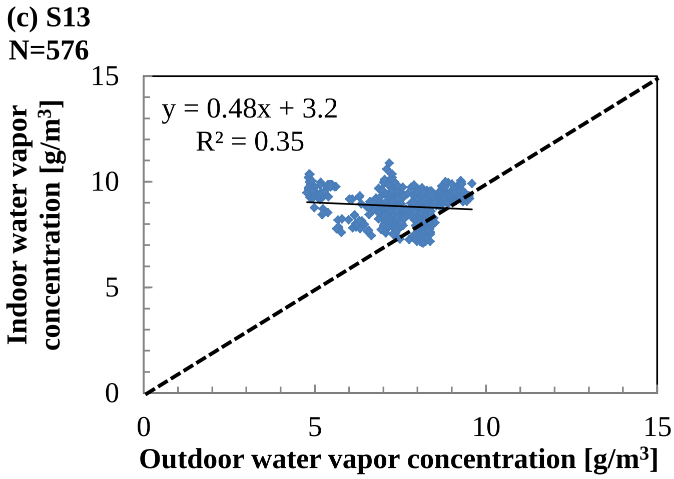


Fig. 2.20 Relationship between indoor and outdoor water vapor concentration for Shindhupalchowk.

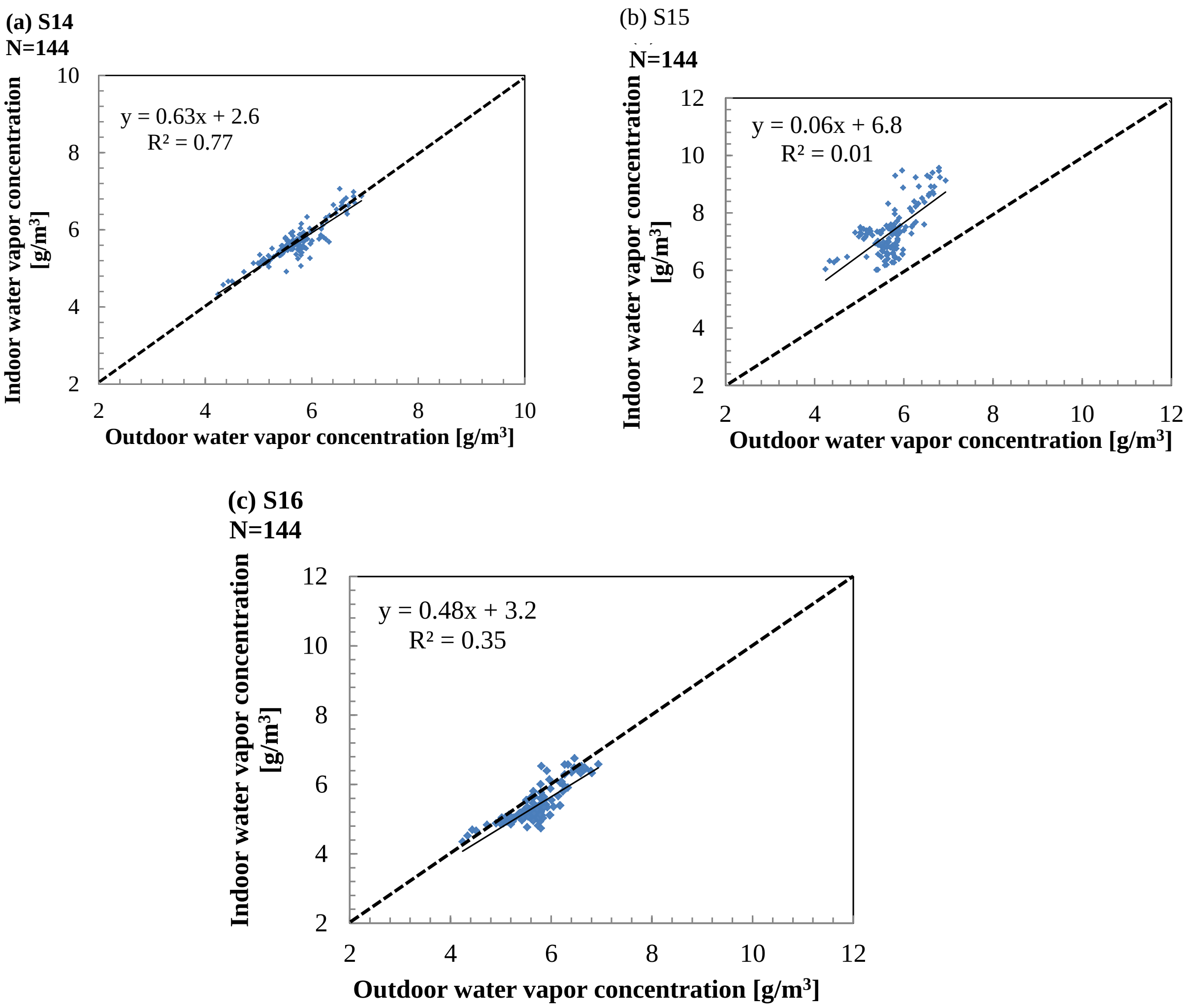


Fig. 2.21 Relationship between indoor and outdoor water vapor concentration for Gorkha.

2.7 Summer thermal environment

2.7.1 Variations of monthly indoor and outdoor air temperatures in Lalitpur

Fig. 2.22 shows the profile of indoor air temperature and outdoor air temperature of overall days (24 days) of selected shelter S1, S2 and S3. Fig. 2.23 shows the variations of indoor and outdoor temperature for a typical one day (10th April, 2016) of three shelters. We have selected that day because there was clear weather condition. The indoor air temperature difference of S1 and S2 are smaller (2 to 3°C). But, the indoor air temperature in S3 fluctuates most; the maximum reaches about 38°C in day time and minimum reaches 13 °C in night. The highest indoor air temperature at 38 °C in S3 is approximately 6 °C higher than outdoor air temperature.

Fig. 2.24 shows the variation of indoor and outdoor air temperature of S7, S8, S9 and S10 in Lalitpur, S11, S12 and S13 in Shindhupalchowk and S17 and S18 in Gorkha for summer. The outdoor air temperatures are highly influences the indoor air temperatures. It means Outdoor and indoor air temperature looks very similar.

This result might be due to no ventilation and thermally poorest materials used as insulations. As mention in Table 1 and Fig. 3, these thermally conductive materials used as insulation are not sturdy enough to protect from harsh climatic conditions during summer. The people compromise such a high temperature by adapting clothing behaviors where we found the mean clothing value of 0.52 clo in summer (Thapa et al. 2018).

Hence, these investigated shelters were made of zinc sheet which directly receives the solar radiation in different angle, and also responsible to the outside thermal variations. If the thermal mass of walls and roof is less than the transmission of heat is more during the day time.

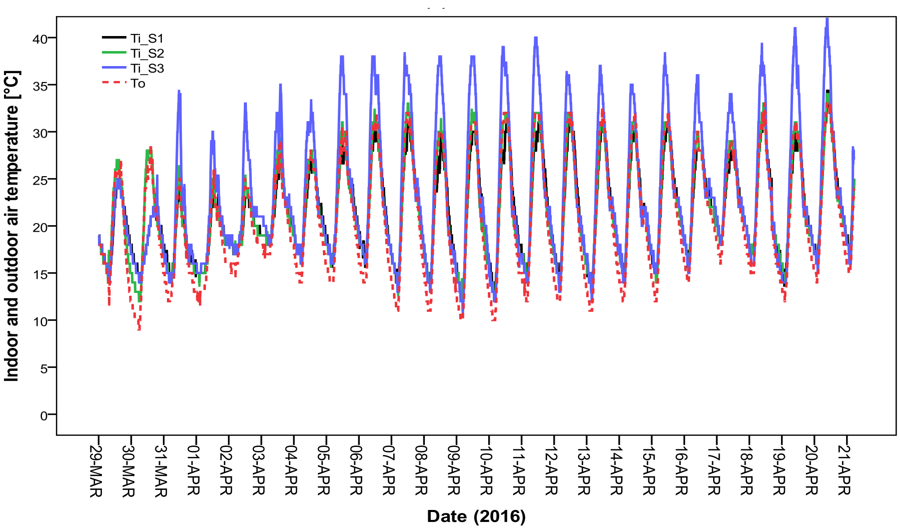


Fig. 2.22 Variation of indoor and outdoor air temperature for 24 days for summer.

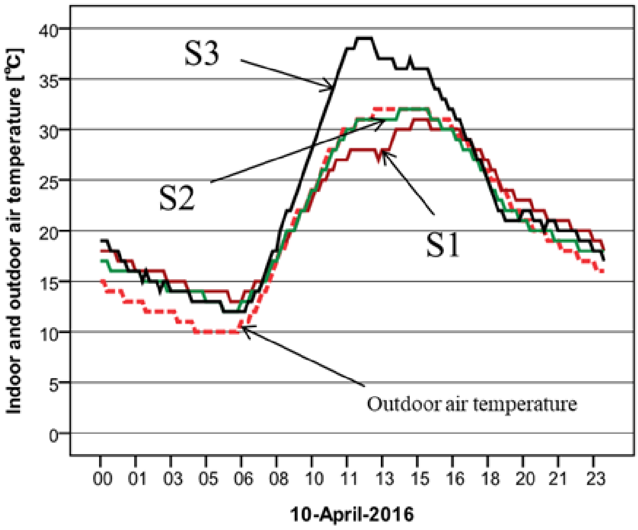
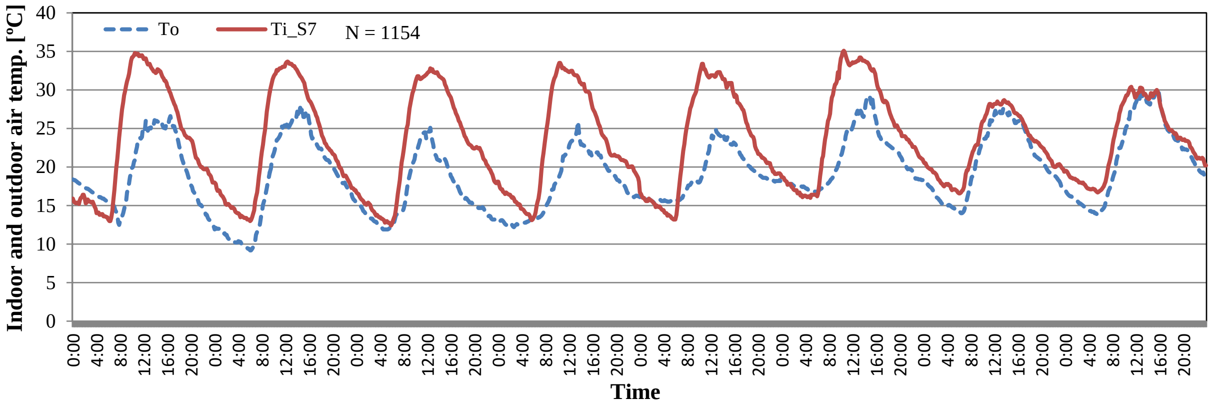


Fig. 2.23 Variation of indoor and outdoor air temperature in a day in summer.

(a) S7



(b) S8

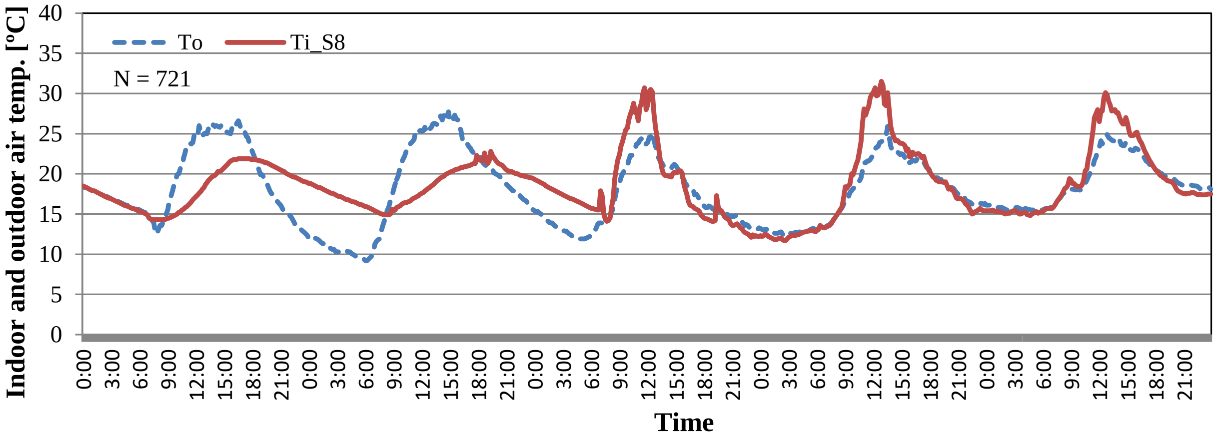
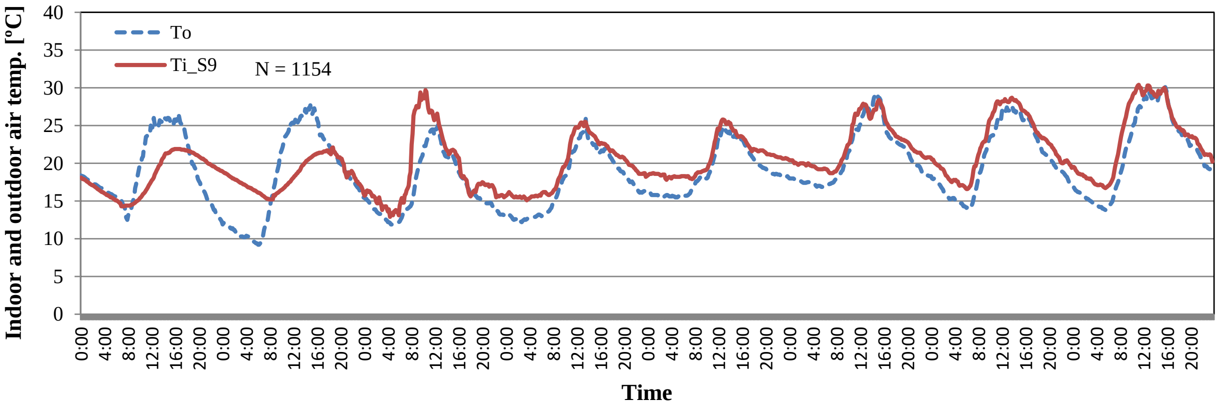
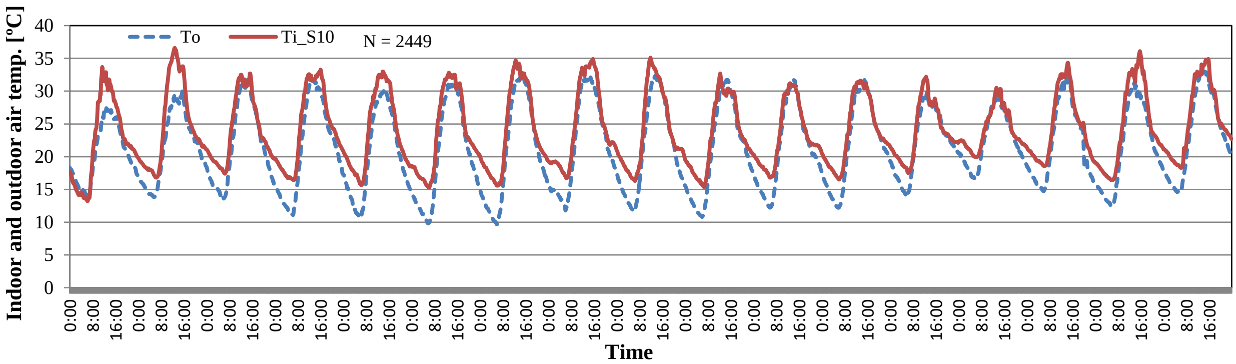


Fig. 2.24 continue….

(c) S9



(d) S10



(e) S11

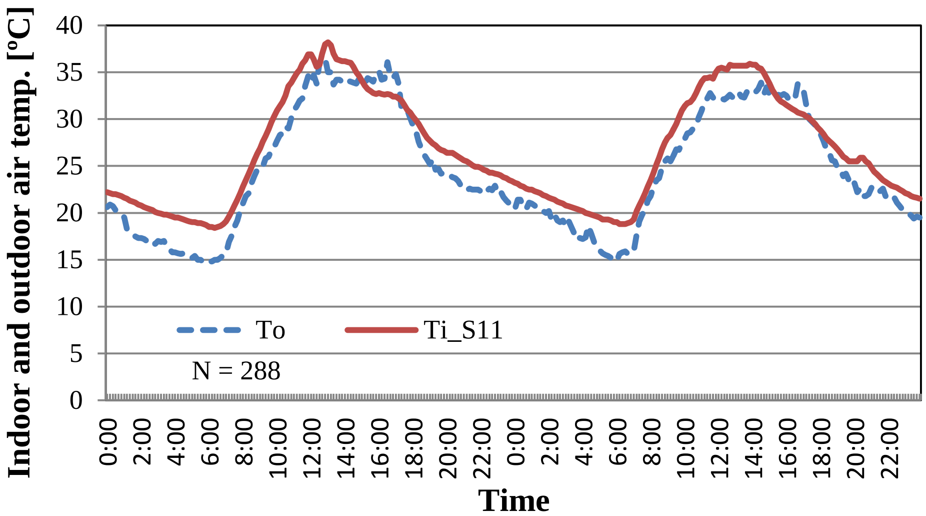
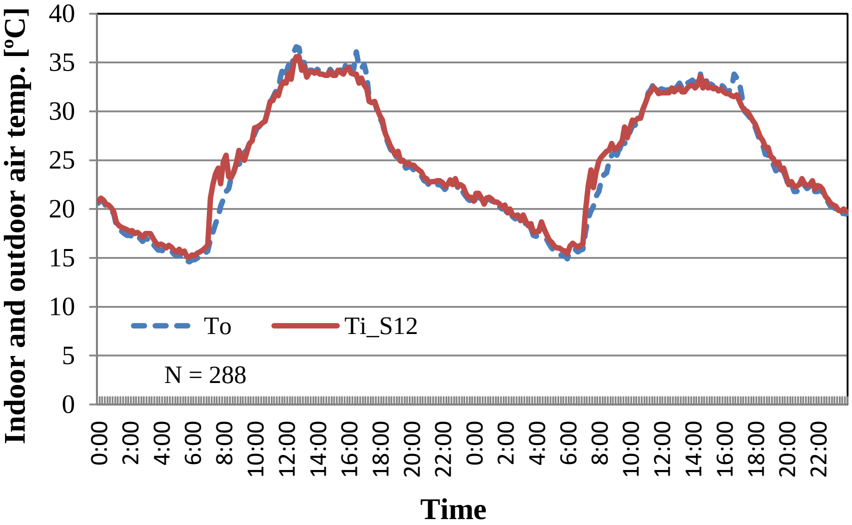
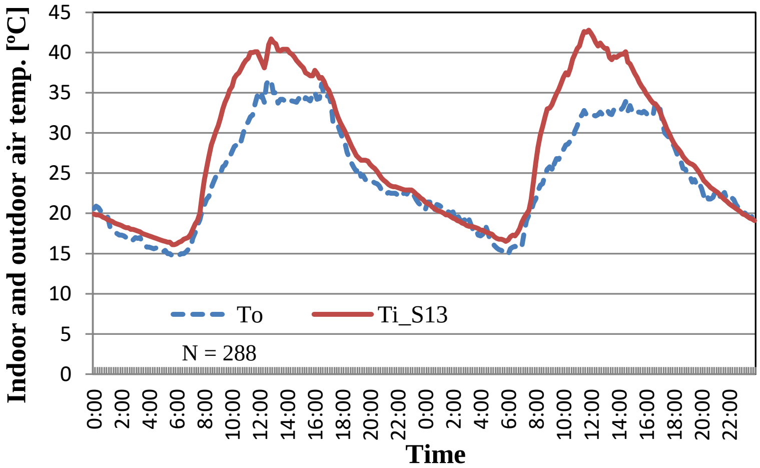


Fig. 2.24 continue….

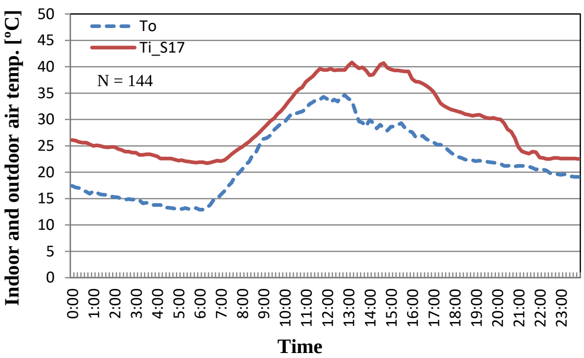
(f) S12



(g) S13



(h) S17



(i) S18

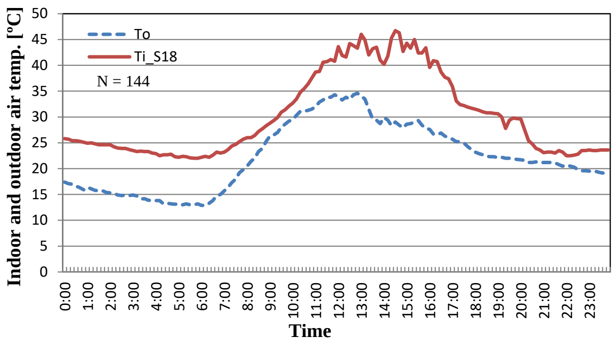


Fig. 2.24 Variation of indoor and outdoor air temperature of S7, S8, S9 and S10 in Lalitpur, S11, S12 and S13 in Shindhupalchowk and S17 and S18 in Gorkha for summer.

2.7.2 Relationship between indoor and outdoor air temperature

Fig. 2.25 shows the relationship between indoor and outdoor air temperature of three shelters for all 24 days. The indoor air temperatures for all shelters are highly dependent on outdoor air temperature. These results suggest that where there is no ventilation, the indoor air temperature tend to be higher than outdoor air temperature. To improve the indoor environment in summer, it is necessary to bring fresh outdoor air at lower temperature by natural ventilation. Here, we have obtained the following regression equation of three shelters to predict the indoor air temperature by outdoor air temperature.

S1 $T_i = 0.760T_o + 5.9$ (N = 3368, $R^2 = 0.937$, S.E. = 0.003, $p<0.001$) (2.7)

S2 $T_i = 0.861T_o + 3.8$ (N = 3368, $R^2 = 0.979$, S.E. = 0.002, $p<0.001$) (2.8)

S3 $T_i = 1.096\ T_o + 0.48$ (N = 3368, $R^2 = 0.893$, S.E. = 0.007, $p<0.001$) (2.9)

Where, N: number of sample, R^2: coefficient of determination, S.E.: standard error of the regression coefficient, p: significance level of the regression coefficient.

The slope of equation (6), 0.760 is slightly lower than equations (2.7) and (2.8). It suggests that S1 indoor air temperature is better than other two shelters in summer.

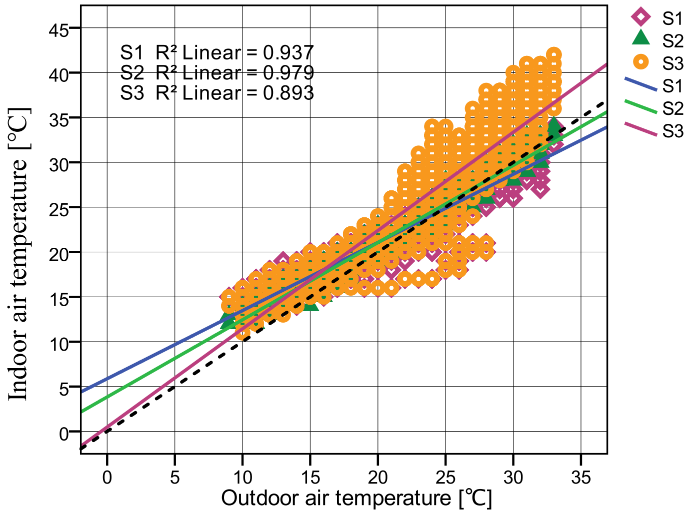


Fig. 2.25 Relationship between indoor and outdoor air temperature (Summer).

2.7.3 Mean temperature of day, night and sleeping time

Table 2.7 shows the result of overall monthly mean indoor and outdoor temperatures and also mean indoor and outdoor temperatures of day time, night time and sleeping time. The monthly mean indoor air temperatures of three shelters are similar to each other but standard deviations are quite large in between them. The result of monthly mean indoor air temperature of S1 and S2 are 21.6 °C (S.D. = 4.7 °C) and 23.1 °C (S.D. = 7.0 °C) in summer. The mean day time indoor air temperature of S1 is 27.1 °C which is 4.1°C lower than S3 in summer. The S3 mean indoor air temperature range between 17.2 and 31.2 °C is close to previous research of traditional houses (17.8 to 32.0 °C) in Nepal (Rijal et al. 2010) and in temporary shelters (25 to 30 °C) built after Wenchuan earthquake in China (Huang et al. 2015).

Table 2.7 Mean indoor air temperature and standard deviation in winter.

S.C.	Variables	Monthly mean [ºC]			Day time (6:00~17:50)			Night time (18:00~5:50)			Sleeping time (21:00~5:50)		
		N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
S1	T_i [ºC]	3368	21.6	4.7	828	27.1	3.3	864	17.3	1.8	1278	17.3	1.8
S2			21.6	5.2		28.1	3.3		16.9	1.9		16.9	1.9
S3			23.1	7.0		31.2	5.3		17.2	2.1		17.2	2.1
All Shelters	T_o [ºC]	3368	20.7	6.0	828	28.0	3.3	864	14.7	2.3	1278	14.7	2.3

S.C.: Shelter code, N: Number, S.D.: Standard Deviation [ºC], T_i: Indoor air temperature [ºC] , T_o: Outdoor air temperature [ºC]

2.7.4 Summer water vapor concentration

As can be define that, water vapor is the gaseous phase of water. It is one state of water within the hydrosphere. Water vapor can be produced from the evaporation or boiling of liquid water or from the sublimation of ice. Water vapor is transparent, like most constituents of the atmosphere. Water vapor is a relatively common atmospheric constituent, present even in the solar atmosphere as well as every planet in the Solar System and many astronomical objects including natural satellites, comets and even large asteroids. Likewise the detection of extrasolar water vapor would indicate a similar distribution in other planetary systems. Water vapor is significant in that it can be indirect evidence supporting the presence of extraterrestrial liquid water in the case of some planetary mass objects.
(https://weatherstreet.com/weatherquestions/What_is_water_vapor.htm).

Fig. 2.26 shows the summer water vapor concentration for all investigated shelters in Lalitpur, Fig. 2.27 for Shindhupalchowk and Fig. 2.28 for Gorlkha district. In the three investigated regions, the estimated indoor water vapor concentration seems higher than oudoor water vapor concentration. However, the estimated indoor water vapor concentration seems lower than outdoor water vapor concentration in Shelter S7 and S10 for Lalitpur. Maybe, it depends on the external heat transfer from wall. In real case materials of housing, wall material defines what amount of heat is transferred inside. In this condition, the reason might be inside these respective shelters indoor have much moister.

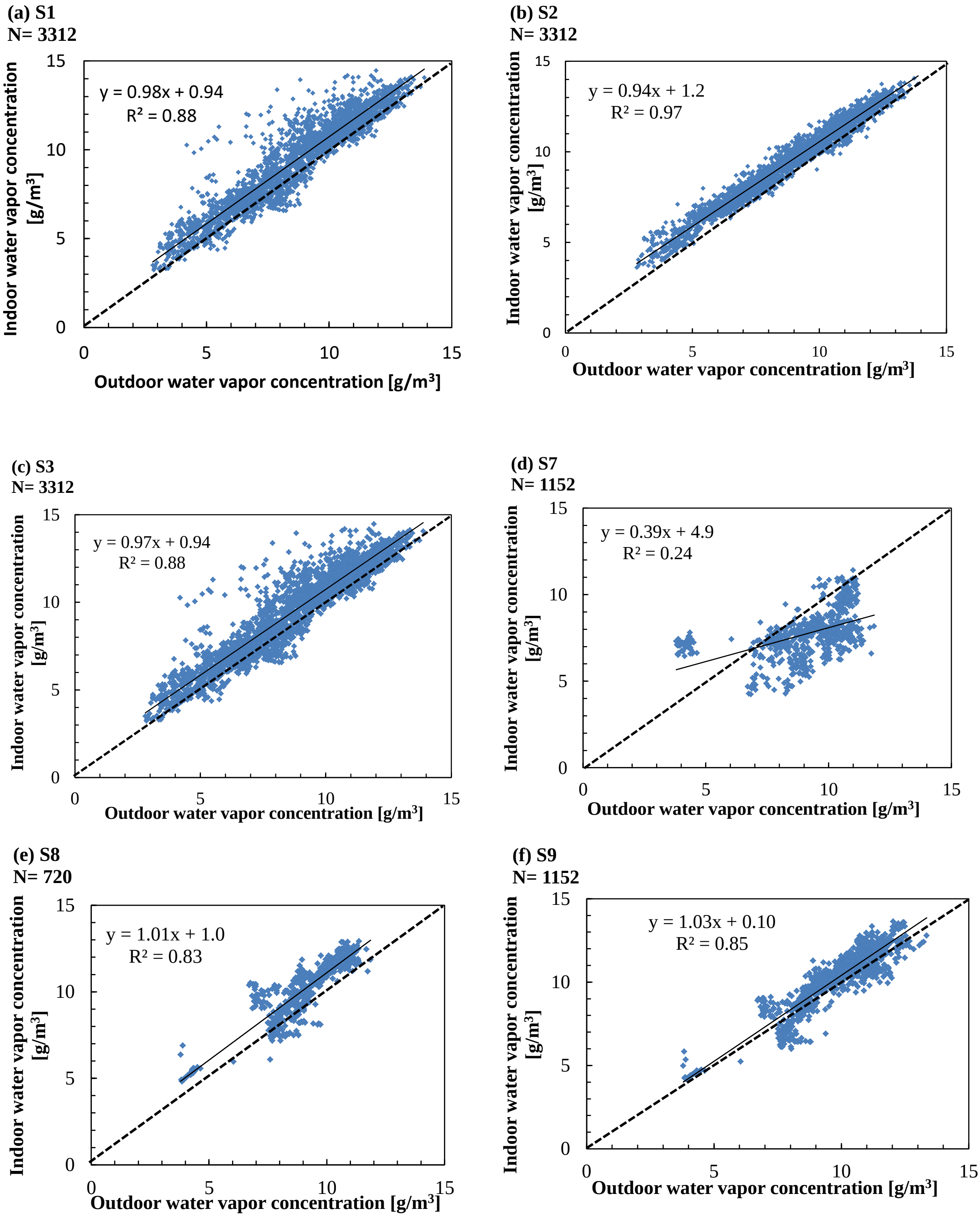


Fig. 2.26 continue….

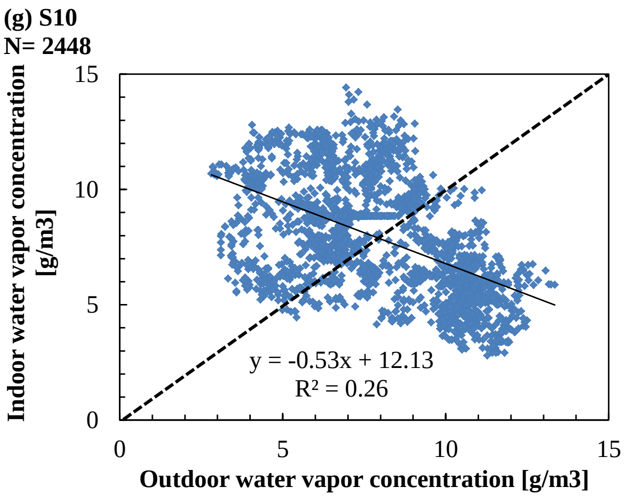


Fig. 2.26 Summer water vapor concentration for all investigated shelters in Lalitpur.

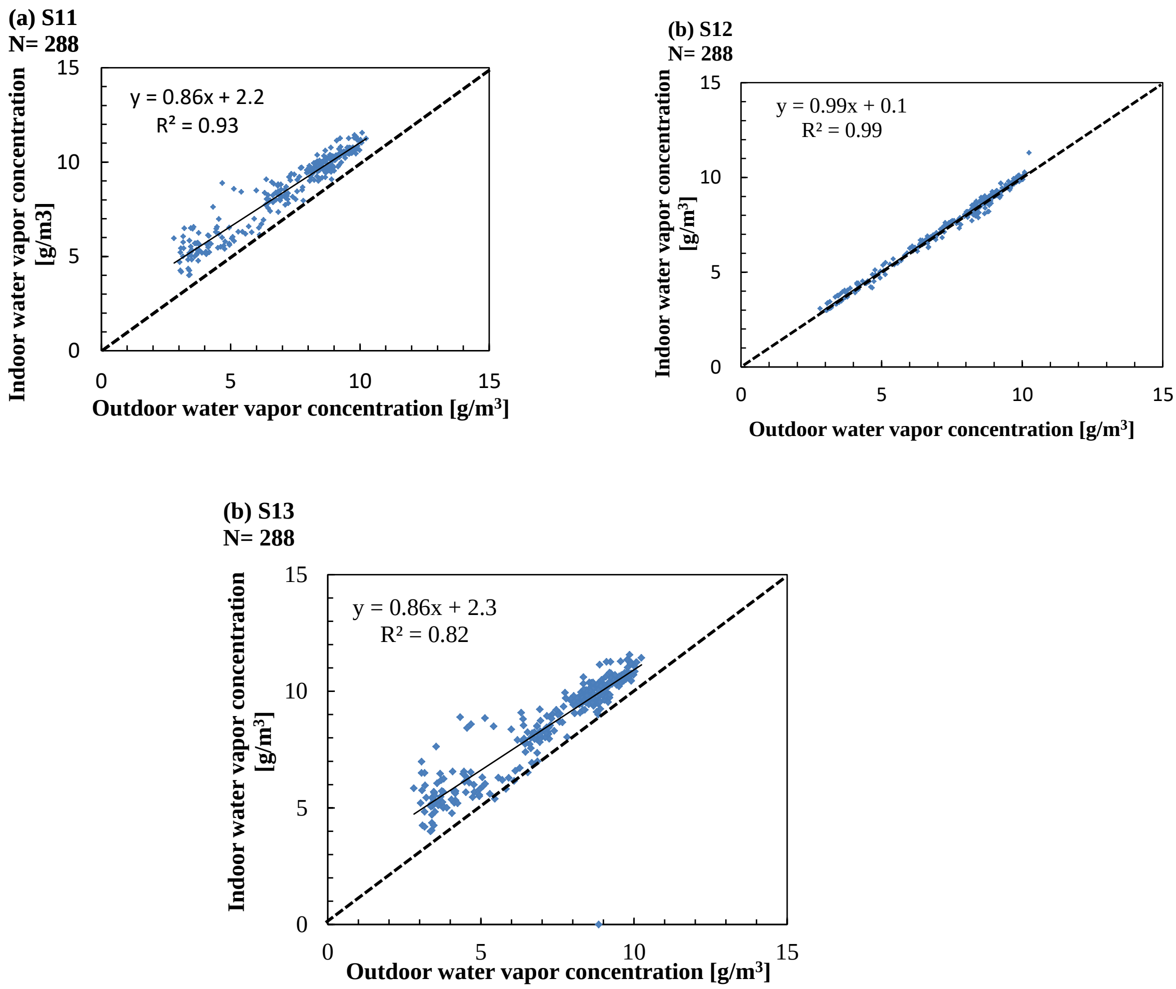


Fig. 2.27 Summer water vapor concentration for all investigated shelters in Shindhupalchowk.

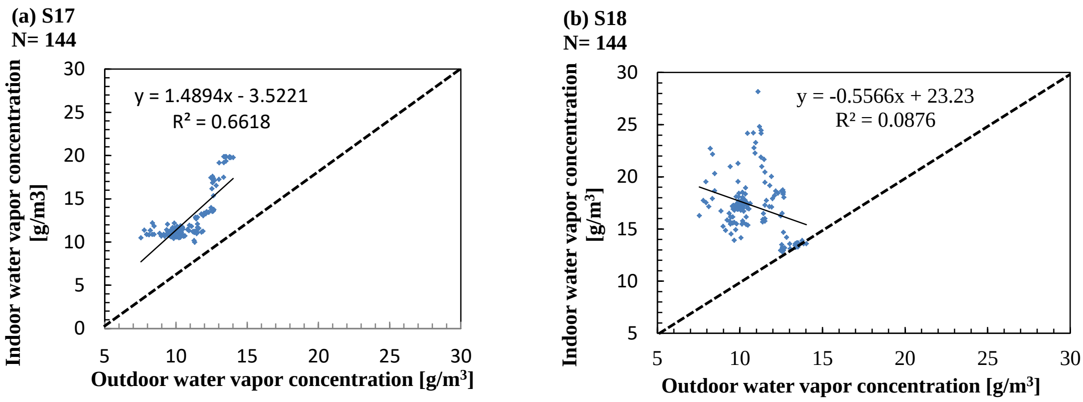


Fig. 2.28 Summer water vapor concentration for all investigated shelters in Gorkha.

2.8 Compare wintry and summer indoor thermal environment

2.8.1 Distribution of indoor air temperature of all investigated shelters in three districts

The measurement was performed in winter and summer for three investigated districts, i.e. Gorkha, Shindhupalchowk and Lalitpur. Table 2.4 shows the detailed information of field measurement. Environmental parameters such as indoor air temperature (T_i), indoor relative humidity (RH_i) and outdoor air temperature (T_o) were measured by data loggers at the interval of 10 minutes.

Fig. 2.29 shows the distribution of indoor and outdoor air temperature from S1 to S18 for winter and summer by boxplots. The indoor air temperature ranges from 2 to 32 °C in winter and from 9 to 47 °C in summer. Most of the whiskers coming out of the top of the box are longer than those at the bottom in both seasons; this suggests that the fluctuation of indoor and outdoor air temperatures. The distribution of S3 (Dome-shaped) indoor air temperature during daytime is much more than during night time in both seasons which indicates that there must have been quite problem in comparison to others shelters. The indoor air temperature of S11, S16 and S17 are very high during summer. As a general tendency, investigated shelters have more problems in winter than summer. The reason might be that these shelters applying thermally very conductive thin materials which cannot protect sufficiently from outdoor environment. So, we need to require some affordable methods for improvement which should be proposed for avoiding the harsh environmental conditions. As overall conclusion from this box plot, winter season were staying in very harsh indoor condition and it’s directly affects the people health. So, concern about people health and their thermal comfort we need to improve these extreme conditions of indoors.

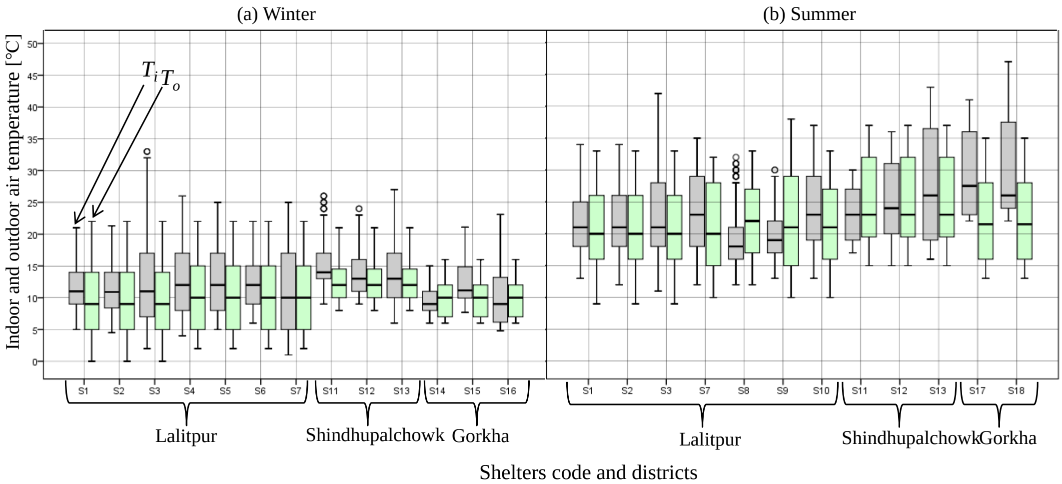


Fig. 2.29 shows the distribution of indoor and outdoor air temperature.

This session tries to evaluate the indoor thermal environment in winter and summer in the same shelters (S1), where people are adapting their thermal environment by taking different behaviors according to the change of season. The investigated shelter (S1) is built by people themselves without using scale (Fig. 2.6). The height of shelter was 2.1m, width 3.5m and depth 5m respectively, and thickness of zinc sheet was 0.26 mm. The shelter is rectangular shape made of zinc roof and surrounded by zinc sheet all round. The brick and mud wall around 60cm built up to floor level. The door was in south side and three small sizes of windows in east-west and south directions for ventilation. The shelter has two rooms: one for living and sleeping purpose and the other for kitchen.

The straw put on roof and clothes or black/white foam are used under the celling to protect it from solar radiation in both seasons. Different materials were used as insulations, not so changed in winter and summer. People used plastic sheet to cover the window from outside to save indoor heat during winter and cover windows with net to protect indoor space from insects during summer.

The measurements were conducted 26 days (January 20th to February 14th, 2016) in winter and 24 days (March 29th to April 21st, 2016) in summer. Environmental parameters such as indoor air temperature (T_i), indoor globe temperature (T_g) indoor relative humidity (RH_i), outdoor air temperature (T_o) and indoor surface temperatures were measured by data logger at the interval of 10 minutes as shown in Fig. 1.13

Fig. 2.30 shows the frequency distribution of indoor thermal environment of S1 in two seasons; i.e. winter and summer. The variation of S1 for winter is range between 6 to 23 °C whereas 13 to 34 °C for summer. The indoor thermal performance is varying according to season change.

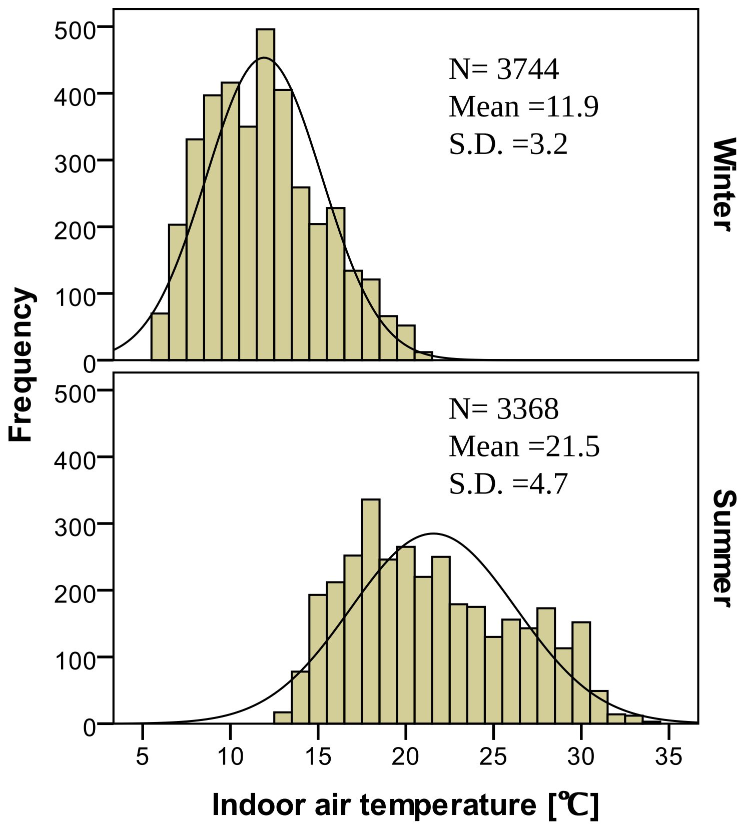


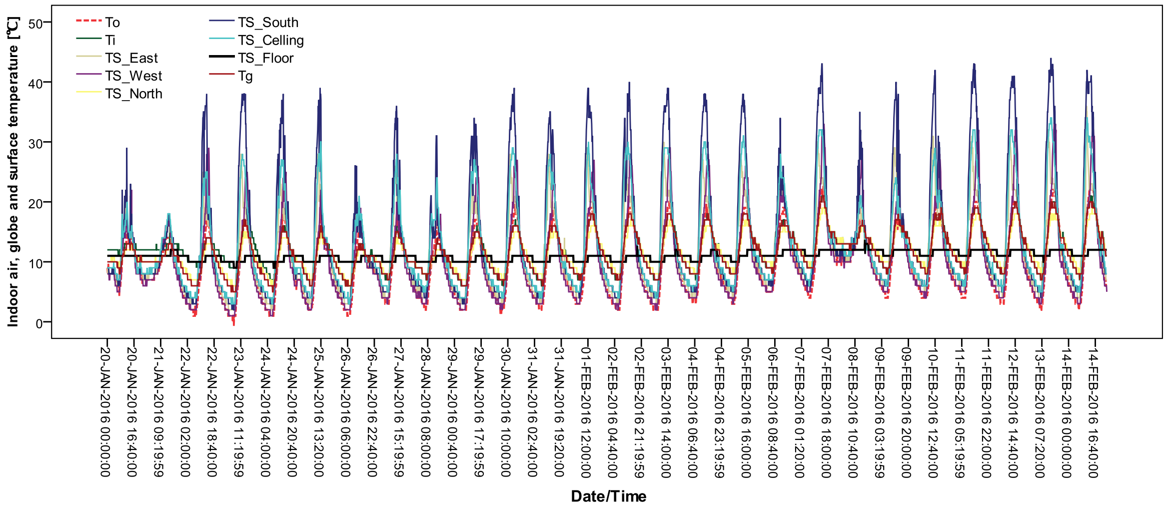
Fig. 2.30 Distribution of indoor thermal environment of S1 for winter and summer.

2.8.2 Seasonal surface temperature of S1 for winter and summer

Fig. 2.31 shows the result of indoor air temperature, globe temperature, surface temperature and outdoor air temperature of 26 days for winter and 24 days for summer. Fig. 2.32 shows the one-day variations for a typical one day, i.e. 25th January and 15th April. The indoor air temperature is close to outdoor air temperature in both seasons. The reason for this is that the shelter is made of zinc sheet, whose thermal resistance is very small.

According to the present study, the indoor air temperature are found ranging between 6~21°C in winter and 12~34 °C in summer.

(a) Winter



(b) Summer

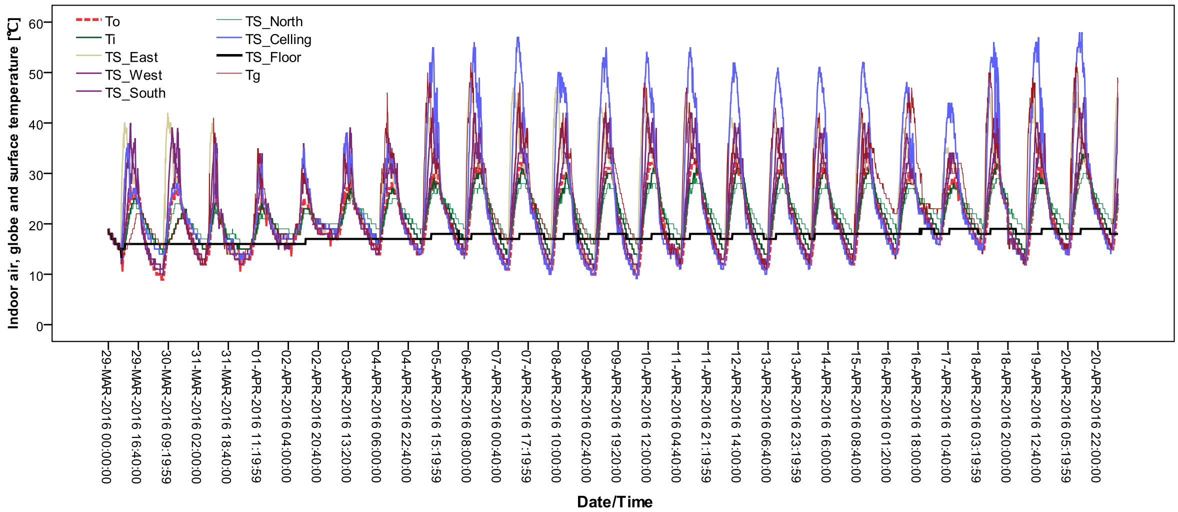


Fig. 2.31 Variation of indoor, globe and surface temperature of S1: (a) Winter and (b) Summer.

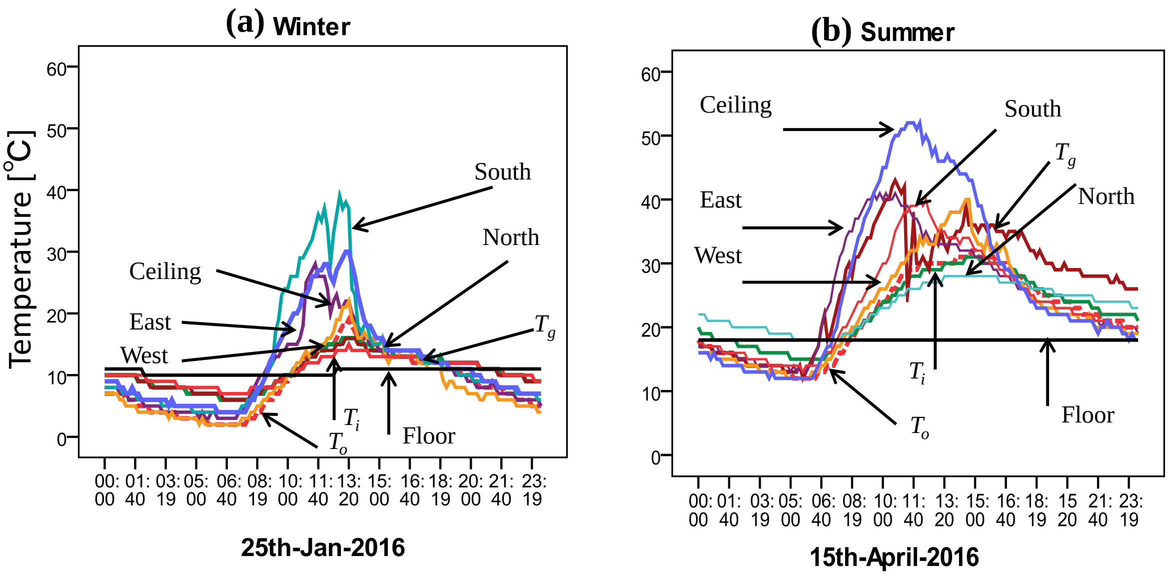


Fig. 2.32 Variation of indoor, globe and surface temperature of S1 for typical one day: (a) Winter and (b) Summer.

Cumulative frequency curve (Fig. 2.33. a) shows that about 50% of total time in winter remains below the acceptable range, which was found 11~30 °C in previous research but in summer only 5% of time remains above the acceptable range (Fig. 2.33. b). From this result, we can conclude, this shelter is not good for winter and creates several problems related to coldness.

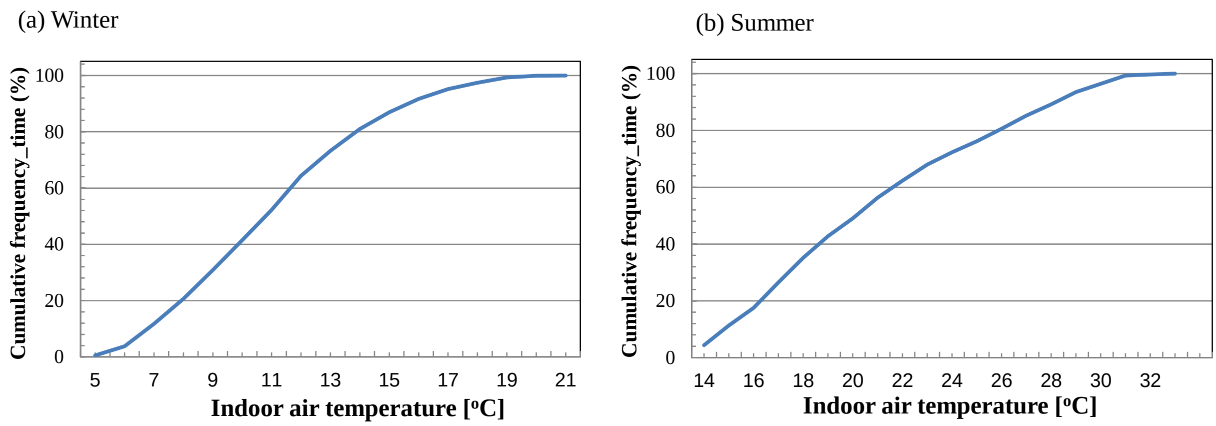


Fig. 2.33 Cumulative frequency curve of S1: (a) winter and (b) summer.

2.8.3 Sleeping time temperature

Table 2.8 shows the 26 and 24 days mean indoor air temperature is 11.9 °C in winter and 21.6 °C in summer and, thus seasonal difference is 9.7 K, which is close to the previous research of traditional houses in Nepal [Rijal et al. 2010]. The people are sleeping at 21:00~5:50 in Nepal, where such a low temperature minimum 6 °C during winter, and maximum 18 °C during summer. The result suggested that the winter is more terrible than the summer. To consider the people health, we need to improve the winter case soon than summer.

Table 2.8 Sleeping time indoor air temperature.

Season	Variables	Sleeping time (21:00-5:50)				
		N	Min	Max	Mean	S.D
Winter	T_i	1297	6.0	15.0	10.1	1.7
	T_o	1297	1.0	12.0	5.7	2.3
Summer	T_i	1278	13.0	24.0	18.3	2.3
	T_o	1278	9.0	23.0	15.9	2.9

2.9 Conclusions

In this research, we measured the thermal environment in the temporary shelters for three seasons, i.e. autumn, winter and summer and found the following results.

1. The daytime indoor air temperature is 18.7 °C which is similar to indoor globe temperature. The mean nighttime indoor air temperature is 15.2 °C which is also similar to indoor globe temperature.
2. Respondents slept where the mean indoor air temperature is 14.3 °C which is 5 °C higher than outdoor air temperature. The result showed that indoor air temperature is significantly higher than outdoor air temperature at night time.
3. The indoor air temperatures for all shelters were highly dependent on outdoor air temperatures, but the results indicate that the shelter S3 indoor air temperatures was approximately 9 °C and 6 °C lower than shelter S1 in winter and summer at day time. The results found that the shelters applying good thermal insulation is used to protect from outdoor environment comparison to poor thermal insulation in winter and summer.
4. The result of monthly mean indoor air temperature of S1 and S3 are 11.9 °C and 13.1 °C in winter and 21.6 °C and 23.1 °C in summer. The indoor air temperature differences of S1 and S2 are 1.2 °C in winter and 1.5 °C in summer.
5. The mean indoor air temperatures during the sleeping time of S1 is 10.1 °C which is 1.9 °C higher than shelter S3 in winter, however almost similar to each other in summer. The people in these shelters were sleeping in the indoor temperature at only 2.5 °C higher than outdoor air temperature at 5.7 °C in winter and 14.7 °C in summer**.**
6. The indoor air temperatures for all shelters are highly dependent on outdoor air temperature, but S3 is approximately 6 K higher than outdoor air temperature during the day time.

7. The overall mean indoor air temperature is also higher than outdoor air temperature during the sleeping time for all shelters. It means that the people sleep in the indoor environment at 2.6 K higher than outdoor air temperature.
8. The regional and seasonal differences of both indoor and outdoor air temperature were found large. This indicates that there must be quite a problem for residents' health.
9. Most of the shelters' indoor air temperatures are found to be lower than the lower limit of acceptable temperature at 11 °C in winter and fewer shelters are upper limit of 30 °C in summer. It seems that the winter is more problematic than summer.
10. The surface temperatures of south wall in winter and celling temperature in summer are sharply increasing during the noon.
11. The mean indoor air temperatures are 11.9 °C in winter and 21.6 °C in summer.
12. The indoor air temperature remains 50 % of time below 10 °C in winter and only 5 % of time in summer above 30 °C.
13. The people are sleeping at such a low temperature: i.e. minimum 6 °C during winter and maximum 18 °C during summer. The result suggested that the winter is more terrible than the summer.

Chapter 3

Thermal comfort of people in temporary shelters

3.1 Introduction

Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (ANSI/ASHRAE Standard 55). The human body can be viewed as a heat engine where food is the input energy. The human body will generate excess heat into the environment, so the body can continue to operate. The heat transfer is proportional to temperature difference. In cold environments, the body loses more heat to the environment and in hot environments the body does not exert enough heat. Both the hot and cold scenarios lead to discomfort (Yunus 2015). Similarly, thermal comfort of a person is also dependent on his/her physical characteristics such as their fitness level, size and weight, age, sex, etc. Environmental factors Atmospheric temperature or air temperature will decide how hot or cold we feel, but so will do other factors such as radiant temperature, humidity and air velocity.

Two different thermal factors that affect the temperature of the room and human comfort; they are physical and personal factors. The physical factors include; air temperature, mean radiation temperature, relative humidity and air velocity. The air temperature inside of a building will change depending on the temperature outside the building and the k-values of the materials used to build the walls and insulation. K-values are the values that all materials have which shows how good insulators the materials are, the lower the k-values the more affective the materials are at retaining heat. The u-value is what overall heat resistance of the materials are. Air temperature is also affected by the people inside the building and they activity they are doing. The mean radiant temperature also affects the human comfort; mean radiant temperature is the radiation that is coming into the building from windows and walls, balanced against the radiation given off by the human body. The relative humidity is another factor that affects the air temperature; the relative humidity is the percentage of water vapor saturation that is in the air. The final physical factor that affects human comfort is the air velocity; this is the movement of the air throughout a building or a room. This can be affected by the convection in the room, the warm air enters a room and rises to the ceiling, pushing the cold air downwards and draught also changes the air velocity, the cold air flows into the room and makes the temperature of the draught path colder that the room temperature.

There are also personal factors that can affect the human comfort, they include; age, gender, state of health, clothing and the level of activity. The age of a person greatly affects the temperature of a room; older people give off less heat then younger people. Gender is also a factor that affects the temperature given off by people, females give off less heat than males, and they give off 85% of what the male body gives off. The state of health of the person also affects the heat that they give off and the temperature of the room, a person who is sick or has an illness gives off less heat that a person who is physically healthy. The clothing you are wearing also affects the temperature that you need to be comfortable; depending on the weight of the clothing you will need different temperatures to feel comfortable. The level of activity you are doing also affects the heat that you give off and the temperature needed to feel comfortable.

3.2 Method of thermal comfort survey

A series of survey on indoor thermal environment and comfort was conducted three seasons: in autumn, winter and summer in Lalitpur, Shindhupalchowk and Gorkha and twice in Kathmandu in winter and summer as shown in Table 2.2 and Fig. 2.3 In all of the investigated districts, altogether 855 temporary shelters were randomly selected and data were collected from 1407 persons (547 males; 860 females) aging between 13 to 81 years at 6:30 to 20:00. We measured the thermal environmental parameters; i.e. indoor air temperature, surface temperatures (celling, floor and walls), globe temperature, relative humidity, air movement, outdoor air temperature and relative humidity by using sensors with digital recorders. Table 2.2 shows the sensors used for this survey; Table 3.1 shows the details of thermal comfort survey and Fig. 3.1 shows the photographs of field survey. Similarly, Table 3.2 shows the seasonal, the average age, height, weight, body surface area and clothing insulations. The physiques of the Nepalese people look similar to Japanese people; thus body surface temperature were estimated by the formula for the Japanese (Kurazumi et al. 1994).

During the thermal measurement, the people were asked individually about the thermal sensation vote (*TSV*), thermal preference (*TP*) and thermal acceptance (*TA*) as listed in Table 3.2. We spent 10 to 30 minutes for measurements of various physical quantities, while the same time they were interviewed about their thermal perception. The purpose of the questionnaires was explained in advance to all the respondents individually. We used modified Thermal Sensation Vote (*mTSV*) (Thapa et al. 2018) and translated them into Nepalese language (Rijal et al. 2010). The checklist of clothing was used to record the clothes worn by the respondents during the field survey. The corresponding clothing insulation value in the unit of ‘clo’ was determined in accordance with the values given by ISO 2003 (Havenith et al. 2003), and for “saree” traditional clothes (worn by female) value was taken from (Kimura et al. 2011).

Table 3.1 Details of thermal comfort survey in four districts in three seasons.

Season	Survey period			No. of shelters visited and No. of subjects asked									
	Start date	End date	Total days	Lalitpur		Kathmandu		Shindhupalchowk		Gorkha		Total	
Autumn	2015/10/23	2015/11/21	28	148	85	-	-	29	17	25	18	202	120
Winter	2016/1/20	2016/2/16	26	165	104	280	188	150	74	100	61	695	427
Summer	2016/4/2	2016/4/19	17	50	32	150	116	150	86	160	74	510	308
Total			71	363	221	430	304	329	177	285	153	1407	855

Table 3.2 Outline of the investigated people.

Season	No. of subjects		Age		Height (cm)		Weight (kg)		S (m^2)		I_{ci} (*clo*)	
	M	F	M	F	M	F	M	F	M	F	M	F
Autumn	86	116	41.1	36.7	160	151.8	60.2	53.5	1.6	1.5	0.6	0.7
Winter	224	471	39.6	37.1	162.5	155.2	58.3	53.2	1.6	1.5	1.0	1.2
Summer	237	273	33.3	31.8	163.4	156.6	54.7	52.4	1.6	1.5	0.5	0.6
Total	547	860	114	105.6	485.9	463.6	173.2	159.1	4.8	4.5	2.1	2.5

M: Male, F: female, S: Body surface area ($S= 100.315W^{0.383}H^{0.693}$), W: Weight (kg), H: Height (cm), I_{ci} : Clothing insulation

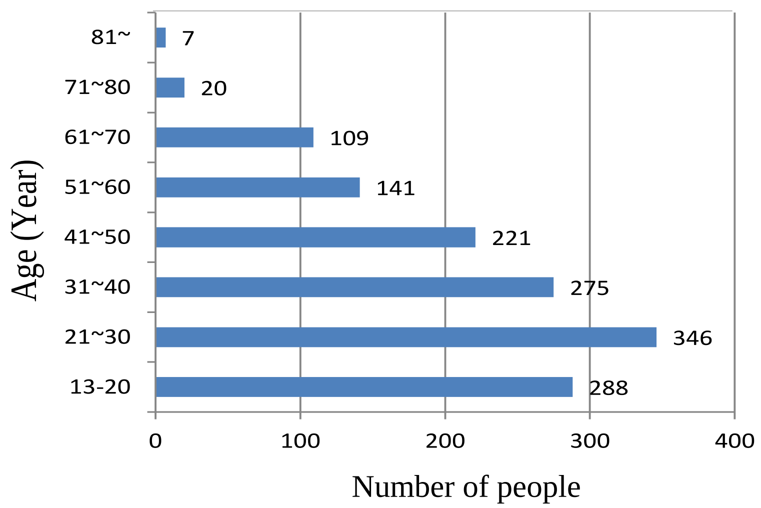


Fig. 3.1 Distribution of age group.

(a) Autumn (b) Winter (c) Summer

Fig. 3.2 Some scenes of the field survey conducted.

Table 3.3 Scale of thermal comfort survey (Rijal et al. 2010).

English	Transalated into Nepalese language
Modify Thermal sensation vote (mTSV)	**चिसो तातोको अनुभव**
1. Very cold	१. जाडो
2. Cold	२. चिसो
3. Slightly cold	३. अलिकति चिसो
4. Neutral (Neither cold nor hot)	४. ठिक्क (चिसो पनि छैन तातो पनि छैन।)
5. Slightly hot	५. अलिकति तातो
6. Hot	६. तातो
7. Very hot	७. गर्मी
Thermal preference 2. Now, how do you prefer?	**तापक्रम को चाहना** अहिले कस्तो चाहना गर्नु भएको छ ?
1. Much warmer	१. धेरै न्यानो चाहिन्छ।
2. A bit warmer	२. अलिकति न्यानो चाहिन्छ।
3. No change	३. एतिकै ठिक्क छ।
4. A bit cooler	४. अलिकति शितल चाहिन्छ।
5. Much cooler	५. धेरै शितल चाहिन्छ।
Thermal acceptance 3. Can you accept the present thermal environment?	अहिले जाडो /गर्मी वातावरण खप्न सक्नु हुन्छ कि हुदैन ?
1. Acceptable	१. खप्न सक्छु।
0. Unacceptable	०. खप्न सक्दिन।

3.3 Analysis methods applied

Here, in this section, the formulae applied to the present analysis. To estimate the acceptable indoor temperature, range in temporary shelters, the logistic regression method was applied for the probability of acceptance estimated from the distribution of *mTSV* in association with the bins of globe temperature.

3.3.1 Estimated mean radiant temperature

The mean radiant temperature, T_{mr} [°C] was estimated from a formula given in [Thorsson et al. 2007]. The materials used in the temporary shelters are thermally very conductive, which could not protect from the extreme cold in winter and unnecessary heat gains in summer. The calculation of *Tmr* is to confirm how much the radiation effect is inside the shelters in each season.

Where, T_g is the globe temperature [°C], v is the air velocity [m/s], T_i is indoor air temperature [°C], d is the diameter of globe (= 0.075 m), ε is the emissivity of globe surface (= 0.95). We did not measure the air movement in autumn survey. Therefore, we assumed 0.10 m/s of air velocity as the minimum value.

3.3.2 Estimation of comfort temperature

In this research, the focus is on acceptable temperature, but it is not possible to estimate directly the values of acceptable temperature so that we used the concept of comfort temperature to be estimated either by the regression method or Griffiths' method. In the regression method, the comfort temperature is estimated by substituting "4. Neutral" to the linear regression equation obtained from the relationship between the measured indoor globe temperature and the thermal sensation vote. However, the estimation of the comfort temperature by this regression method may not be suitable in the field survey, and thus the comfort temperature was also investigated by the Griffiths' method (Griffiths 1990 and Humphreys et al. 2013).

$$T_c = T_g + (4\text{-}C)/a^* \qquad (3.1)$$

Where, T_c indicates comfort temperature to be estimated [°C], T_g is the indoor globe temperature when votes are recorded, C is the thermal sensation vote and a* is regression coefficient assumed. We have used three values of regression coefficient (0.25, 0.33 and 0.50) to calculate the comfort temperature. In applying the Griffiths method, Nicol 1996, Rijal et al. 2010, and Humphreys et al. 2013 used regression coefficient of 0.25, 0.33 and 0.50 for seven-point thermal sensation scale. According to Nicol et al. 1996, the coefficient of 0.25 is often obtained in field survey. According to climate-chamber, the coefficient was 0.33 experiment performed by Fanger 1970.

3.3.3 Estimation of thermal acceptability

The logistic regression was applied to predict the thermal acceptability, which is calculated from the binary data: "1. Acceptance" and "0. Unacceptance", as a function of the indoor globe temperature (Nicol et al. 2004, Indraganti et al. 2014 and Indraganti et al. 2015). The relationship between the thermal acceptability and indoor globe temperature is expressed as;

$$\text{Logit}(p) = \ln\{p/(1-p)\} = bT_g+c \quad (3.2)$$

where, p is the probability of thermal acceptance, b and c are the constants obtained from the regression analysis on the values of probability of acceptability as the linear function of globe temperature as can be seen in Table 3.3.

3.4 Autumnal thermal comfort during voting time

3.4.1 Evaluation of thermal environment

The mean indoor temperature, humidity and clothing insulations are shown in Table 3.4. The mean indoor air temperature is 21.1 °C, which is similar to the globe temperature, mean radiant temperature and operative temperature. This supported by T_g value which is higher than T_i. Thus we get this result because of surrounding surfaces have radiative effect. The mean indoor relative humidity is 58%.

Fig. 3.3 shows scatter-plot between T_i and T_g during the voting. There is almost no difference between them. They are interrelated to each other except the T_i is low nearly 19 °C compare to T_g due to cold surface of temporary houses. From regression analysis we obtained the following equation to predict T_g by T_i.

$$T_g = 0.985T_i+0.635 \quad (3.3)$$

(N = 202, R^2 = 0.94, S.E. = 0.018, P<0.001)

N: Number of sample, R^2: Coefficient of determination, S.E: Standard Error of the regression coefficient, *P*: Significant level of regression coefficient.

Table 3.4 Mean and standard deviation of temperatures during voting time.

Seasons	Survey areas	N	T_o [ºC]		T_i [ºC]		T_g [ºC]		T_{mrt} [ºC]		T_{op} [ºC]		RH_i [%]		I_{ci} [*clo*]	
			Mean	S.D.	Mean	S.D.	Mean	S.D	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Autumn	Lalitpur	148	-	-	20.6	3.4	20.8	3.5	21.0	3.7	20.8	3.5	59	14	0.65	0.18
	Shindhupalchowk	29	-	-	24.1	1.9	24.6	2.0	24.9	2.2	24.5	2.0	52	5	0.59	0.15
	Gorkha	25	-	-	20.9	3.1	21.4	3.2	21.9	3.3	21.4	3.2	64	11	0.6	0.19
	All	202	-	-	21.1	3.4	21.4	3.5	21.7	3.7	21.4	3.5	58	13	0.63	0.18

N: Number of samples, T_o: Outdoor air temp., T_i: Indoor air temp., T_g: Globe temp., T_{mrt}: Mean radiant temp., T_{op}: Operative temp., RH_i: Indoor relative humidity, RH_o: Outdoor relative humidity, S.D.: Standard deviation. I_{ci}: Clothing insulations.

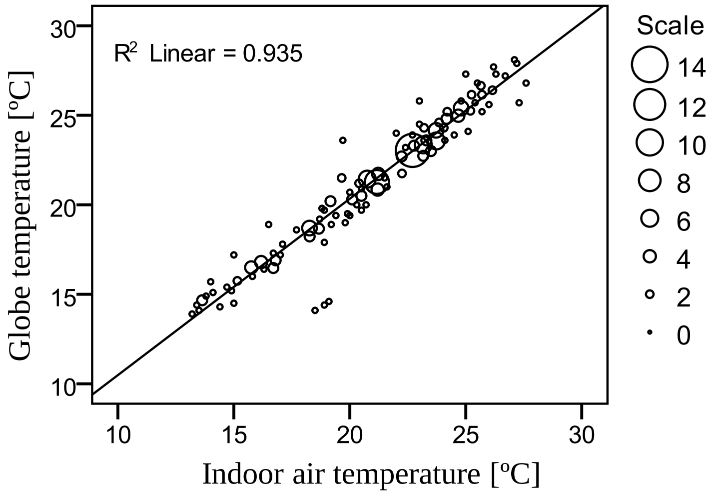


Fig.3.3 Relationship between the indoor globe and indoor temperature during voting time.

3.4.2 Subjective evaluation

(a) Thermal sensation

Table 3.5 shows the percentage of thermal sensation vote in three districts. When result from three district are added together, the relative frequency is 25.7 % for 'neutral' and 38.0 % for 'thermal comfort zone' (votes 3 to 5). The percentage of cold side (votes 1 to 3) is 64.8 % and the percentage of hot side (votes 5 to 7) is 9.4 %. This might be the reason of zinc sheets are radiative in nature and so the cold sensation as outdoor temperature drops. The results showed that most of residents were feeling cold in the temporary shelter houses. These trends are similar in three districts.

(b) Thermal preference

People always prefer to live comfortably in terms of temperature. They want to be neither hot nor cold. When results from three districts added together, the relative frequency is 18.8 % for 'No change' and 78.2 % for warmer side and 3.0 % for cooler side (Table 3.6). Most of residents prefer a bit warmer temperature compare to a bit cooler. As we know that the zinc sheets are radiative in nature and so the cold sensation as outdoor temperature drops. There was no one residents who prefer the much cooler air temperature. This might be the human nature. One saying that people are never satisfied what they have, they prefer more and more.

(C) Thermal satisfaction

An ideal thermal comfort level is preferred by people living in their shelters. In temporary shelters occupants are finding it difficult to attain thermal satisfaction. The thermal satisfaction in this research has been defined as feeling of people regarding the temperature. The thermal satisfaction vote is 26.7 % and un-satisfaction vote is 73.3 % (Table 3.6). The result showed that most of residents felt unsatisfied in staying in temporary shelters. No one answered ‘very satisfied’.

(d) Overall comfort

The comfortable vote is 25.7 % and thermal uncomfortable vote is 74.2 % (Table 3.4). The results showed that most of residents felt uncomfortable during their stay in temporary shelters. During the interview, we noted the residents reminiscing about their past houses destroyed during the earthquake and were noted to be emotionally disturbed. Understandably, temporary houses could not create a comfortable environment.

Table 3.5 Subjective evaluation of residents.

District	Scale	TSV		TP		TS		OC	
		N	P [%]	N	P [%]	N	P [%]	N	P [%]
Lalitpur	1	40	27.0	48	32.4	0	0.0	0	0.0
	2	40	27.0	64	43.2	23	15.5	18	12.2
	3	13	8.8	30	20.3	29	19.6	32	21.6
	4	40	27.0	6	4.1	40	27.0	45	30.4
	5	8	5.4	0	0.0	33	22.3	33	22.3
	6	3	2.0	-	-	23	15.5	20	13.5
	7	4	2.7	-	-	-	-	-	-
	Total	148	100	148	100	148	100	148	100
Gorkha	1	15	60.0	13	52.0	0	0.0	0	0.0
	2	5	20.0	9	36.0	0	0.0	0	0.0
	3	0	0.0	3	12.0	2	8.0	2	8.0
	4	3	12.0	0	0.0	5	20.0	9	36.0
	5	2	8.0	0	0.0	10	40.0	10	40.0
	6	0	0.0	-	-	8	32.0	4	16.0
	7	0	0.0	-	-	-	-	-	-
	Total	25	100	25	100	25	100	25	100
Shindhupalchowk	1	4	13.8	13	44.8	0	0.0	0	0.0
	2	13	44.8	11	37.9	0	0.0	0	0.0
	3	1	3.4	5	17.2	0	0.0	0	0.0
	4	9	31.0	0	0.0	7	24.1	7	24.1
	5	1	3.4	0	0.0	6	20.7	9	31.0
	6	1	3.4	-	-	16	55.2	13	44.8
	7	0	0.0	-	-	-	-	-	-
	Total	29	100	29	100	29	100	29	100
All	1	59	29.2	74	36.6	0	0.0	0	0.0
	2	58	28.7	84	41.6	23	11.4	18	8.9
	3	14	6.9	38	18.8	31	15.3	34	16.8
	4	52	25.7	6	3.0	52	25.7	61	30.2
	5	11	5.4	0	0.0	49	24.3	52	25.7
	6	4	2.0	-	-	47	23.3	37	18.3
	7	4	2.0	-	-	-	-	-	-
	Total	202	100	202	100	202	100	202	100

TSV: Thermal sensation vote, TP: Thermal preference, TS: Thermal satisfaction, OC: Overall comfort, N: Number of sample, P: Proportion.

3.4.3 Relationship between the thermal preference and thermal sensation

To analyze the characteristic of words used in the thermal comfort survey, the regression analysis of thermal preference and thermal sensation was analyzed as shown as the Fig. 3.4. It showed as the occupants vote for cool sensation, they prefer warmer sensation condition and vice versa. The correlation coefficient of thermal preference and thermal sensation is 0.55. The correlation coefficient is not very high because residents prefer 'slightly warmer' even though they voted neutral on the thermal sensation scale. It might be due to the low indoor and outdoor temperature during investigated period and the residents preferred a 'warmer' environment. Even though subjects reported 'neutral' on the thermal sensation (n = 52 votes), 27 (52.0 %) of the votes for 'slightly warmer' in the thermal preference scale. According to an earlier study (Rijal and Yoshida 2006), the reason might be; 1) the subjects would prefer a warmer environment in the winter. 2) They experience a very cold outdoor environment in their preference in their everyday life and would like to secure a warmer environment. 3) While they are satisfied with the current conditions, they would prefer a warmer environment if possible; a natural desire for most people.

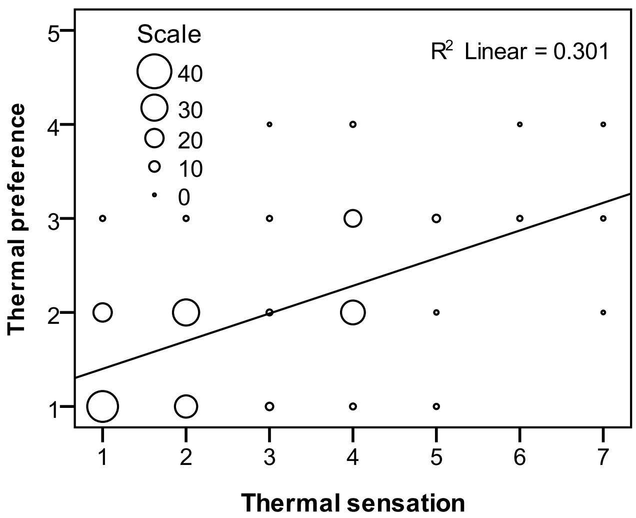


Fig. 3.4 Relation between the thermal preference and thermal sensation.

3.4.4 The comfort temperature

The ranges of temperatures recorded during the field survey were quite narrow. Therefore, it would be unreliable to use the regression method for calculating comfort temperature. Consequentially, we used 'Griffiths' method to calculate comfort temperature based on TSV (Griffiths 1990, Rijal et al. 2010, Humphreys et al. 2013).

$T_c = T + (4\text{-C})/a$ (3.4)

Here, T_c indicates comfort temperature [°C], T is the indoor air temperature or globe temperature or mean radiant temperature or operative temperature, C is thermal sensation vote and '4' is the scale point for 'neutral' condition. The constant 'a' indicates a constant rate of thermal sensation change with room temperature. In this case 0.5 is used as the constant, as applied by Humphreys et al. (2013) at 7-point thermal sensation scale.

The overall mean comfort air temperature is 23.9 °C, which is similar to the comfort globe temperature, comfort mean radiant temperature and comfort operative temperature. We found the comfort temperatures are highest in Shindhupalchowk, medium in Gorkha and lowest in Lalitpur.

Table 3.6 Comfort temperature and standard deviation

Variables	Lalitpur (N=148)		Gorkha (N=25)		Shindhupalchowk (N=29)		All (N=202)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
T_{ci} (°C)	23.1	3.5	25.1	2.5	26.6	2.8	23.9	3.5
T_{cg} (°C)	23.4	3.5	25.7	2.6	27.0	2.8	24.2	3.6
T_{cmrt} (°C)	23.5	3.6	25.9	2.6	27.2	2.8	24.3	3.7
T_{cop} (°C)	23.3	3.5	25.5	2.5	26.9	2.8	24.1	3.5

N: Number of person, S.D.: Standard deviation, T_i: Indoor air temp., T_{cg}: Comfort globe temp., T_{cmrt}: Comfort mean radiant temp. T_{cop}: Comfort operative temp.

3.4.5 Clothing insulations

People have a natural tendency to adapt to changing conditions in their environment. This natural tendency is expressed in the adaptive approach to thermal comfort. The comfort temperature is a result of the interaction between the subjects and the building or other environment they are occupying (Nicol and Humphreys 2002).

Due to the changing weather and different climate zone of Nepal, Clothing types and insulation level are varying. Temperature is very cold at an altitude above 3500 meters (Cold region), need thick and warm clothes. Temperature is extreme hot at an altitude of bellow 600 meters (Sub-tropical region), need thin and cool clothes. In general, the Nepalese men often wore western-style clothing such as T-shirts, shirts, jackets, and trousers, while women often wore traditional clothing such as saris, Nepalese blouses, and shawls. According to previous research (Rijal et al. 2010) reported that, in the cool climate, people wore layers of thick clothing and, until they went to bed, shoes indoors in winter. In the sub-tropical climate, people wore light clothing and men often wore only shorts in summer.

In this section we clarify about the clothing insulations in the investigated period of autumn season in three investigated districts. We took clothing value from ISC, 2003, as can be seen in Fig. 3.5 shows the mean clothing insulation with 95 % confidence interval for both genders. The mean clothing insulations noted in this study is 0.73 clo (standard deviation = 0.21 clo). The mean clothing insulation of female (0.81 clo) is significantly higher than that of male clothing (0.61 clo) (Fig. 3.6). This trend is similar to previous study (Rijal et al. 2010).

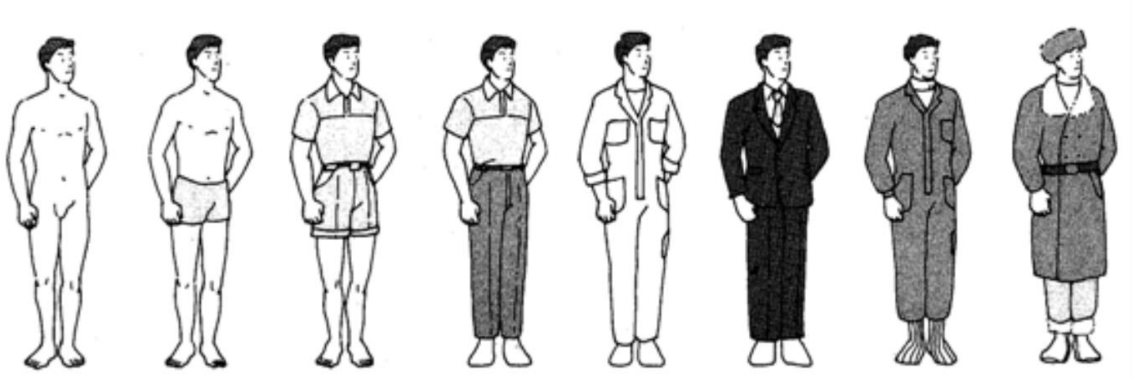


Fig. 3.5 Clothing value (ISO, 2003).

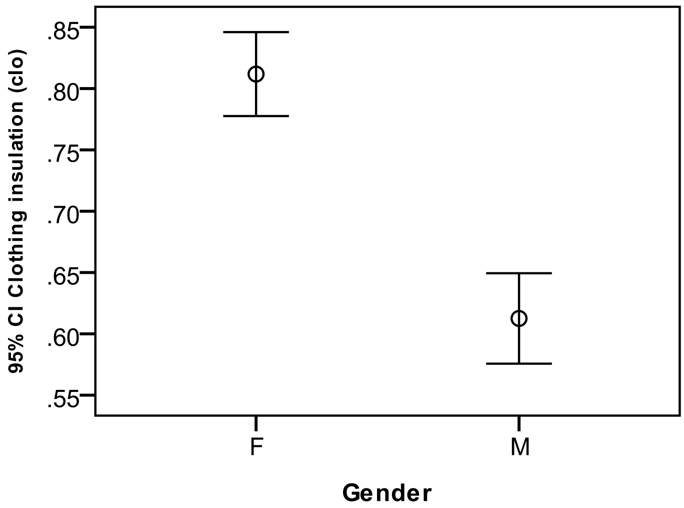


Fig. 3.6 Clothing insulations of female and male.

3.5 Winter and summer thermal comfort during voting time

3.5.1 Relationship between indoor and outdoor air temperature

The mean indoor temperature, humidity and clothing insulations are shown in Table 3.7. Fig. 3.7 shows the relationship between outdoor and indoor air temperature during the daytime of voting both in winter and summer. The indoor air temperatures are correlated very well with the outdoor air temperatures regardless of the seasons. The reason for this is that most of the shelters were made of zinc or tarpaulin sheet whose thermal resistance is very small. Indoor air temperature tends to be 2–5 °C higher than outdoor air temperature; this is due to internal heat generation and solar gain. The most of the data tend to be slightly above from the diagonal line. It seems that local and affordable materials are marginally useful as insulations for mitigating discomfort. Those living in temporary shelters tried to mitigate their problems and reduce discomfort of temporary shelters by using their own ideas and techniques as was mentioned in

Fig. 2.3. These thermal insulations are applying to the temporary shelters, where good insulation helps to reduce unwanted heat losses or heat gains in winter (Thapa et al. 2017) and vice versa in summer (Thapa et al. 2018).

Table 3.7 Mean, standard deviation, relative humidity, air velocity and clothing insulations during voting time.

Seasons	Survey areas	N	T_o [°C]		T_i [°C]		T_g [°C]		T_{mrt} [°C]		T_{op} [°C]		RH_i [%]		RH_o [%]		V [m/s]		I_{ci} [clo]	
			Mear	S.D.	Mean	S.D.	Mean	S.D	Mean	S.D.	Mean	S.D.	Mea	S.D.	Me	S.D.	Mean	S.D.	Mean	S.D.
Winter	Lalitpur	165	10.0	6.2	11.6	4.9	12.1	5.0	12.5	5.1	12.1	5.0	64	14	76	21	0.11	0.11	1.18	0.4
	Kathmandu	280	16.0	3.1	17.8	3.6	18.5	3.9	19.1	4.3	18.4	3.8	49	12	52	13	0.10	0.09	1.07	0.3
	Shindhupalchowk	150	14.8	4.6	16.3	4.6	16.6	4.7	16.8	4.8	16.5	4.6	59	16	67	19	0.11	0.21	0.84	0.4
	Gorkha	100	11.4	3.0	12.3	3.2	13.1	3.5	13.8	3.8	13.8	3.8	60	11	66	9	0.10	0.07	1.64	5.7
	All	695	13.7	5.0	15.2	4.9	15.8	5.1	16.3	5.3	15.7	5.0	56	15	63	19	0.10	0.14	1.13	2.2
Summer	Lalitpur	50	28.1	4.6	26.7	4.1	26.9	4.1	27.0	4.1	26.8	4.1	32	10	24	12	0.09	0.05	0.52	0.1
	Kathmandu	150	26.5	4.7	28.9	4.6	29.7	4.9	30.2	5.2	29.6	4.8	41	15	39	17	0.11	0.11	0.58	0.1
	Shindhupalchowk	150	29.7	5.6	29.7	5.2	30.6	5.3	31.2	5.3	30.4	5.2	27	15	25	14	0.14	0.19	0.54	0.1
	Gorkha	160	33.3	3.2	33.0	3.2	33.2	3.0	33.3	3.0	33.2	3.1	38	6	34	7	0.12	0.07	0.53	0.1
	All	510	29.7	5.3	30.8	4.8	30.8	4.8	31.2	4.9	30.7	4.8	35	13	32	14	0.10	0.14	0.55	0.1
Grand Total		1407	20.5	9.5	21.5	8.3	22.0	8.4	22.4	8.4	22.0	8.3	49	17	50	23	0.11	0.13	0.85	1.6

N : Number of samples, T_o : Outdoor air temp., T_i : Indoor air temp., T_g : Globe temp., T_{mrt} : Mean radiant temp., T_{op} : Operative temp., RH_i : Indoor relative humidity, RH_o : Outdoor relative humidity, V : Air movement, S.D.: Standard deviation. I_{ci} :Clothing insulations

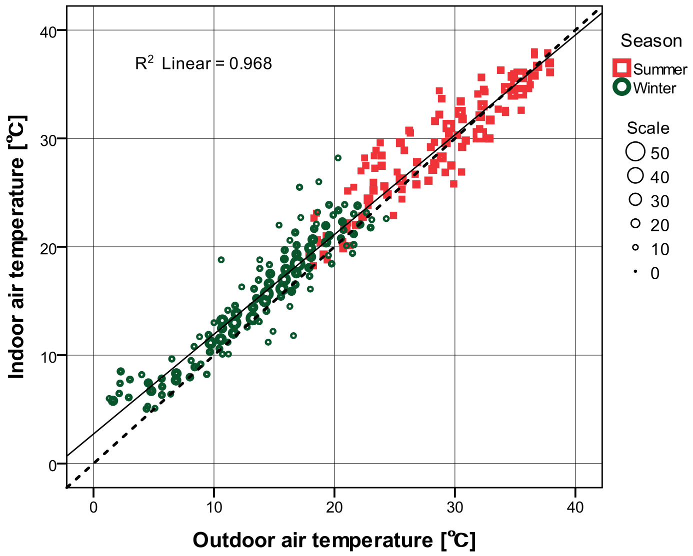


Fig. 3.7 Relationship between outdoor and indoor air temperature for all four districts in winter and summer.

3.5.2 Relationship between mean radiant temperature and indoor air temperature

Fig. 3.8 shows the relationship between mean indoor air temperature (T_i) and mean radiant temperature (T_{mr}) in all three seasons. Mean radiant temperature tends to be higher than indoor air temperature. The maximum and mean values of the differences between Tmr and T_i are more than 10 °C and less than 1 °C, respectively. This is probably due to the effects of solar radiation absorbed by the external surface from walls and roofs. Here, we have obtained the following regression equation.

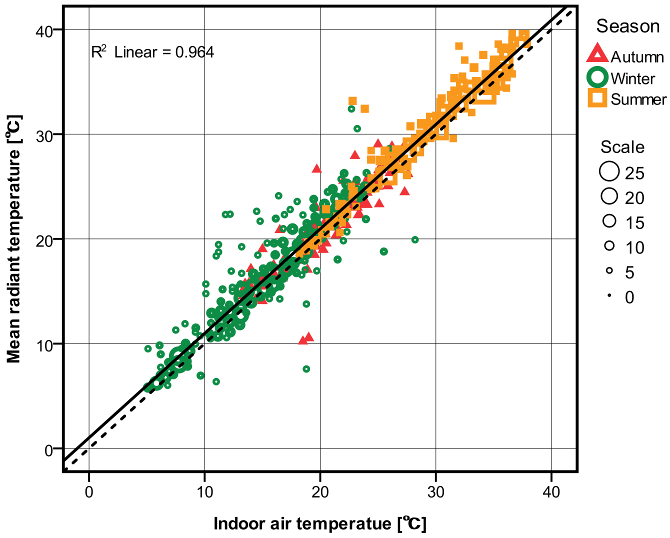


Fig. 3.8 Relationship between indoor air temperature and mean radiant temperature for all four districts and for three seasons.

3.5.3 Thermal responses during winter and summer

(a) Thermal sensation vote

Table 3.8 shows the numbers and percentages of thermal sensation votes and those of thermal preference in respective three seasons and four districts. If we define "comfort zone" as either of "3. Slightly cool", "4. Neutral" or "5. Slightly warm" out of the seven-point thermal sensation scale, the percentages of comfort zone were 38 %, 46 % and 40.2 % in autumn, winter and summer, respectively. The percentages of "cold discomfort" as either of "1. Cold" or "2. Cool" were 58 % and 54 % in autumn and winter, respectively, and "hot discomfort" as either of "6. Warm" or "7. Hot" was 58.3 % in summer. Thus, cold discomfort is high in autumn and winter, and hot discomfort is high in summer. This result confirms that the respondents were uncomfortable with their indoor thermal environment under the temporary shelters.

(b) Thermal Preference

According to Brager and de Dear (Brager et al. 1998) the thermal preference scale could be superior to measure the thermal comfort of people, since the “neutral” condition of TSV may not always represent the preferred condition. Referring to this thought, we have divided the five-point thermal preference scale into three categories: “prefer warmer” with either of “1. Much warmer” or “2. A bit warmer”, “no change needed” with “3. No change”, and then “prefer cooler” with either of “4. A bit cooler” or “5. Much cooler”. The percentages of “prefer warmer” were 79 % and 93 % in autumn and winter, respectively, and the percentage of “prefer cooler” was 67 % in summer.

Among the respondents’ votes as “4. Neutral” in the thermal sensation, the corresponding percentage of “prefer warmer” is 59.6 % (n = 31 votes out of 52 votes) in autumn and 78.1 % (n = 118 votes out of 151 votes) in winter. The reason for this could be that they usually experience very cold environment in their everyday life during winter and would like to have warmer time as can be imagined from the regression equations listed in Table 3.9, and also that, while they are satisfied with the current conditions, they would prefer a warmer environment if the preference was asked so that it came up as the portion of their consciousness. These trends and discussions are similar to previous studies (Singh et al. 2010, Rijal et al. 2006 and Rijal et al. 2010).

Table 3.8 Subjective evaluation of respondents during daytime.

Seasons	Scale	mTSV			TP		
		Number	Percentage (%)		Number	Percentage (%)	
Autumn	1	59	29	58	74	37	79
	2	58	29		84	42	
	3	14	7		38	19	
	4	52	26	38	6	3	
	5	11	5		0	0	
	6	4	2		-	-	
	7	4	2		-	-	
	Total	202	100		202	100	
Winter	1	90	13	54	196	28	93
	2	285	41		451	65	
	3	152	22		45	6	
	4	151	22	46	3	0	
	5	17	2		0	0	
	6	0	0		-	-	
	7	0	0		-	-	
	Total	695	100		695	100	
Summer	1	0	0		0	0	
	2	8	1.6		16	3	
	3	9	1.8		151	30	
	4	125	24.5	40.2	240	47	67
	5	71	13.9		103	20	
	6	60	11.8	58.3	-	-	
	7	237	46.5		-	-	
	Total	510	100		510	100	
All	1	149	11		270	19	
	2	351	25		551	39	
	3	175	12		234	17	
	4	328	23		249	18	
	5	99	7		103	7	
	6	64	5		-	-	
	7	241	17		-	-	
Grand Total		1407	100		1407	100	

mTSV: modified Thermal sensation vote, TP: Thermal preference.

3.5.4 The applicability of Griffiths' method

Thermal comfort is defined as ‘the state of mind, which expresses satisfaction with the thermal environment’; a definition easily understandable, but hard to capture in physical parameters while staying in temporary shelters for long term. In terms of shelters design and improve, an essential requirement for its fulfillment is providing good indoor air temperature regarded as satisfactory by the majority of occupants.

Thermal comfort has been defined as ‘that condition of mind which expresses satisfaction with the thermal environment'. The emphasis is on the condition of mind. It is therefore these two shelters improvements are ok for refer others because all the shelters materials were zinc sheet. The estimation of comfort temperature from the measured indoor temperatures and the corresponding “neutral” thermal sensation is one of the methods to evaluate the thermal comfort of respondents under a variety of actual thermal conditions. Since, comfort temperatures are usually estimated by two different methods; i.e. regression and Griffiths', we also try these two methods.

Here we apply these methods before determining the acceptable range of indoor temperature within temporary shelters. At first, the regression analysis of the thermal sensation and globe temperature was conducted to estimate the comfort temperature, and it was found that the regression coefficient and the coefficient of determination in summer is higher than those in autumn and winter. The comfort temperatures of autumn and winter were estimated outside the actual data points, and thus they are unrealistically high. This might be due to the problem of applying the regression method in the presence of adaptive behavior as has been found in previous research (Rijal et al. 2013, Nicol et al. 1994, Oseland et al. 1994 and Nicol et al. 1999). The estimated mean comfort temperatures were found to be similar to the mean globe temperatures when respondents were voting “neutral” as shown in Fig.3.9. Comfort temperature may have seasonal and regional differences (Table 3.10), and thus, we will further discuss about them in the following section.

Table 3.9 Comfort temperature estimated by the Griffiths’ method.

Regression coefficient	Total samples	Mean [°C]	Standard Deviation[°C]
0.25	1407	22.6	4.6
0.33	1407	22.3	4.6
0.50	1407	22.0	5.4

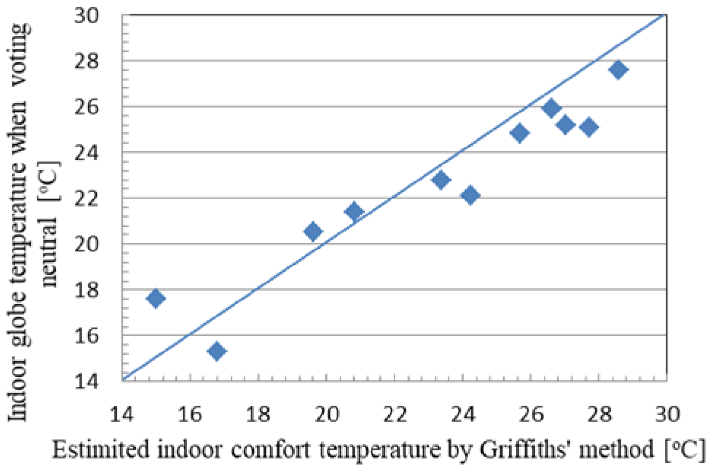


Fig. 3.9 Relation between mean indoor globe temperature when voting "Neutral" in TSV and indoor comfort temperature.

Table 3.10 Comfort temperature for all districts in three reasons.

Seasons	Survey areas	N	Comfort temperatures [°C]							
			T_{ci}		T_{cg}		T_{cmrt}		T_{cop}	
			Mean	S.D.	Mean	S.D	Mean	S.D.	Mean	S.D.
Autumn	Lalitpur	148	23.1	3.5	23.4	3.5	23.5	3.6	23.3	3.5
	Shindhupalchowk	29	26.6	2.8	27.0	2.8	27.2	2.8	26.9	2.8
	Gorkha	25	25.1	2.5	25.7	2.6	25.9	2.6	25.5	2.5
	All	202	23.9	3.5	24.2	3.6	24.3	3.7	24.1	3.5
Winter	Lalitpur	165	14.5	3.8	15.0	3.9	15.1	4.0	14.8	3.9
	Kathmandu	280	20.1	3.0	20.8	3.2	21.0	3.4	20.6	3.1
	Shindhupalchowk	150	19.3	3.8	19.6	3.8	19.7	3.8	19.5	3.7
	Gorkha	100	16.0	2.9	16.8	3.0	17.1	3.0	16.5	2.9
	All	695	18.0	4.1	18.6	4.2	18.8	4.3	18.4	4.2
Summer	Lalitpur	50	24.1	2.8	24.2	2.8	24.3	2.8	24.2	2.8
	Kathmandu	150	25.8	2.3	26.6	2.5	26.8	2.6	26.3	2.4
	Shindhupalchowk	150	26.9	3.1	27.7	3.2	28.0	3.3	27.4	3.1
	Gorkha	160	28.4	1.8	28.6	1.6	28.6	1.6	28.5	1.7
	All	510	26.8	2.8	27.3	2.8	27.5	2.9	27.1	2.8
Grand Total		1407	22.0	5.4	22.6	5.5	22.7	5.5	22.4	5.4

N: Number of samples., T_{ci}: Comfort indoor air temp., T_{cg}: Comfort globe temp., T_{cmrt}: Comfort mean radiant temp ., T_{cop}: Comfort operative temp., S.D.: Standard deviation.

3.5.5 Seasonal and regional difference in comfort temperature

Fig. 3.10 shows the frequency distribution of the estimated mean comfort temperatures. The values of mean comfort temperature vary by three seasons. The mean values are 24.2 °C, 18.6 °C and 27.3 °C in autumn, winter and summer, respectively. Thus, the seasonal difference is 8.7 °C, which is close to the value found in previous researches (Rijal et al. 2015, Rijal et al. 2013 and Rijal et al. 2010). Table 3.10 shows the seasonal and regional differences in comfort temperature obtained from Griffiths' method. The seasonal difference of comfort temperature can be seen in each district; it also shows the difference in comfort temperature to be given as a change of clothing insulation. The seasonal differences of comfort temperatures are 9.2 °C, 5.8 °C, 8.1 °C and 11.8 °C in Lalitpur, Kathmandu, Shindhupalchowk and Gorkha, respectively. In Kathmandu and Shindhupalchowk, the seasonal differences in comfort temperatures are smaller than in other two districts. The seasonal difference may be the reflection of the difference in clothing insulation. According to Nicol et al. (Nicol et al. 1994), the seasonal differences of 0.50 clo correspond roughly to the difference of 3.5–4.0 °C in comfort temperature. If the same value is taken to convert the seasonal difference in clothing insulation, then the seasonal difference in comfort temperature, for example, in Lalitpur turns out to be 5.4–6.1 °C.

As a whole, the temperature difference equivalent to clothing insulation is approximately 2.7–6.1 °C. We did not find the seasonal difference in air movement. However, the seasonal differences in comfort temperature still remain to be 1.6–5.8 °C, even though the effect of clothing insulation is excluded. This remaining difference may be due to the physio-psychological adaptive behaviors of the respondents emerging depending on the seasons. The regional mean comfort temperatures were found to range between 15.0 and 20.8 °C in winter and between 24.2 and 28.6 °C in summer. Thus, the regional difference is 5.8 °C in winter and 4.4 °C in summer. However, there is almost no difference in clothing insulations between four districts in summer; only the difference of 0.06 clo. With respect to winter clothing, there is a difference of 0.18 clo. This is equivalent to 1.3–1.4 °C. The remaining regional difference might be due to other thermal adaptation such as changing the place for stay, beverage, and so on.

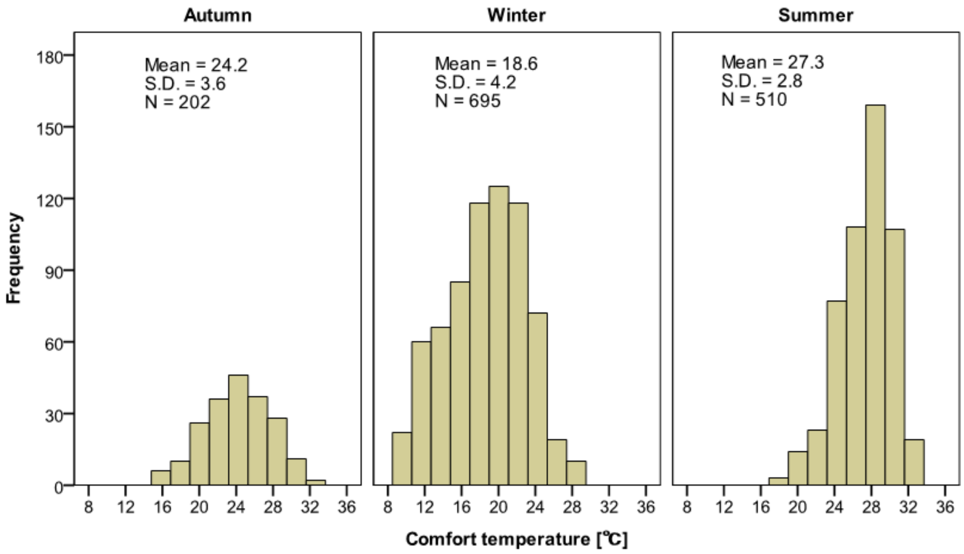


Fig. 3.10 Distribution of comfort temperature in three seasons.

Table 3.11 Seasonal and regional difference in comfort temperature, "clo" values and air velocity.

Descripition	Lalitpur	Kathmandu	Shindhupalchowk	Gorkha	Regional difference	Temperature difference equivalent to clo [ºC]
Summer [°C]	24.2	26.6	27.7	28.6	4.4	–
Winter [°C]	15.0	20.8	19.6	16.8	5.8	–
Seasonal difference (Summer-winter) [°C]	9.2	5.8	8.1	11.8		
Summer (clo)	0.52	0.58	0.54	0.53	0.06	–
Winter (clo)	1.29	1.11	0.93	1.26	0.18	1.3~1.4
Seasonal difference (Winter-summer) (clo)	0.77	0.53	0.39	0.73	0.12	–
Temperature difference equivalent to clo [°C]	5.4~6.1	3.7~4.2	2.7~3.0	5.1~6.0		–
Summer (m/s)	0.09	0.11	0.14	0.12		
Winter (m/s)	0.11	0.10	0.11	0.10		
Seasonal difference (Summer-winter) (m/s)	-0.02	0.01	0.04	0.02		

3.5.6 Relationship between the estimated comfort temperature and indoor globe temperature

Fig. 3.10 shows the relationship between the estimated comfort temperature and measured indoor globe temperature in three different seasons. The comfort temperatures (T_c) were higher than indoor globe temperature (T_g) in winter and vice versa in summer. The result indicates that people prefer higher temperature in winter or lower temperature in summer than the actual temperature. The comfort temperature changes according to the seasonal variation of globe temperature. The comfort temperature is, of course, highly related to the indoor globe temperature since the method used was based on eq. (2). This trend is similar to previous studies (Rijal et al. 2010, Indraghanti et al. 2010). We have obtained the following equation from the regression analysis.

For all season,

$T_c = 0.606T_g + 9.2$ (N = 1407, $R^2 = 0.854$, S.E. = 0.007, $P < 0.001$) (3.5)

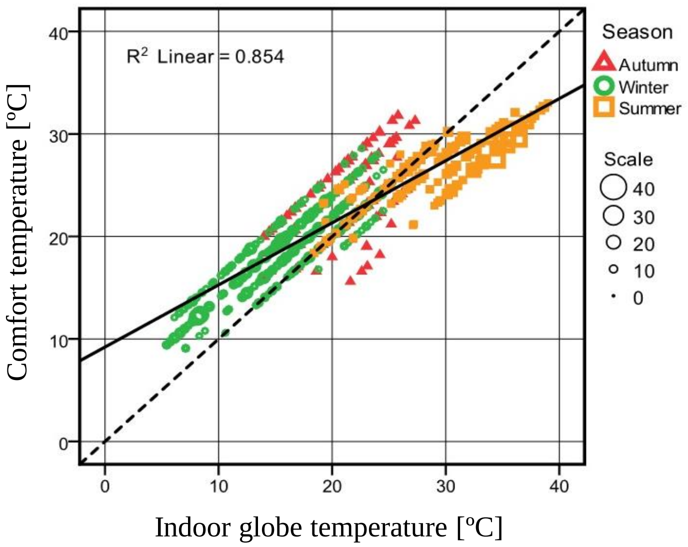


Fig. 3.11 Relationship between indoor globe temperature and indoor comfort temperature for all four districts and for three seasons.

3.5.7 Comparison of comfort temperature of present and previous researches

Table 3.12 shows the comparison of estimated comfort temperature by Griffiths' method so far obtained in the present research with those found in previous research. The comfort temperature obtained in this study is similar to the values in previous studies. We can say that, since the human beings, have to maintain the core temperature nearly at the constant level whether they are living in shelters or ordinary buildings, they always adapt more or less to the indoor environment by a variety of behaviors taken from physiological, psychological to physical.

Table 3.12 Comparison of comfort temperatures in winter and summer with existing research.

Countries	Areas	References	House type	Comfort temperature [ºC]	
				Winter	Summer
Nepal	Lalitpur, Kathmandu, Shindhupalchowk, Gorkha	This study	Temporary shelters	15.0~20.8	24.2~28.6
Nepal	Banke, Bhaktapur, Dhading, Kaski, Solukhumbu	Rijal et al. 2010	Traditional houses	13.4 ~ 24.2	21.1~30.0
Japan	Kanto region	Rijal et al. 2015	Japanese houses	17.6	27.0
Japan	Gifu Prefecture	Rijal et al. 2013	Japanese houses	15.6	26.1
Pakistan	Karachi, Multan, Peshawar, Quetta, Saidu	Nicol and Roaf, 1996	Homes, Naturally ventilated buildings	19.8~25.1	26.7~29.9

3.6 Applicability of adaptive model

People have naturally tendency to adapt to changing conditions in their environment. This natural tendency is expressed in the adaptive approach to thermal comfort. This session try to introduce the adaptive approaches of people residing in temporary shelters. This approach to the thermal comfort is based on the findings of surveys of thermal comfort conducted in field.

As shown in Fig. 3.7, indoor air temperature was highly correlated with the outdoor air temperature and they were almost the same due to the highly conductive materials used for shelters. As was shown in Table 3.7, even in such conditions of temporary shelters, 40–46 % of the thermal sensation votes were either slightly warmer, neither warm nor cool, or slightly cool. Therefore, we thought that it might be possible to come up with an adaptive model [de Dear et al. 2002, CEN, 2007 and Humphreys et al. 2013, which is specific to temporary shelters.

At first we estimated the comfort temperature by using Griffiths' method as can be seen in subsection (Griffiths, 1990 and Humphreys et al. 2013).

Fig.3.12 shows the relationship between comfort temperature, T_c, and outdoor air temperature, T_o. The outdoor air temperature was not measured in autumn, and thus we have plotted only the winter and summer data. The comfort temperature is highly correlated with the outdoor air temperature. When T_o is lower than 25 °C, T_c is higher than T_o, and when T_o is higher than 25 °C, T_c is lower than T_o. The result indicates that the preference of respondents changes depending on outdoor air temperature. We have obtained the following equation from the regression analysis.

$T_c = 0.556T_o+10.9$ (N = 1205, R^2 = 858, S.E. = 0.007, $P < 0.001$) (3.6)

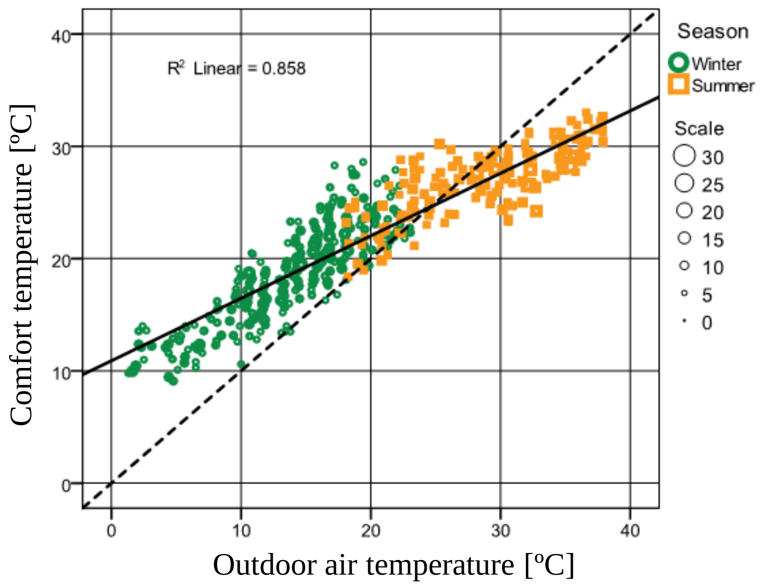


Fig. 3.12 Relation between comfort temperature and outdoor air temperature for all four districts and two winter and summer seasons during the voting time.

We also have seen the Nicol graph, where comfort temperatures were comparison with Rijal et al. 2010 (Fig. 3.13). There are two data can be seen in winter case and summer case. During winter, the mean outdoor air temperature at 10 °C where comfort temperature found 15 °C and during summer, mean outdoor air temperature at 21 °C where comfort temperature found 25 °C. Thus, this result shows that comfort temperature is higher than mean outdoor air temperature. However, Rijal et al. 2010, comfort temperature of winter is slightly close to Nicol outdoor air temperature and summer seems very similar.

$T_c = 0.534\ T_m + 11.9$ (3.7)

(T_c = Comfort temp., T_m = Monthly mean outdoor air temp.)

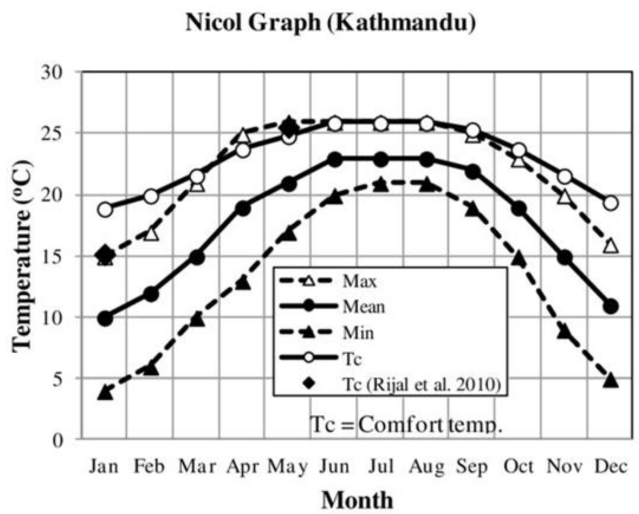


Fig 3.13 Comparison of the adaptive models found in Rijal et al. 2010 with Nicol (1994).

Table 3.13 shows the comfort temperature of this study compare with Rijal et al. 2010 for winter and summer.

Table. 3.13 Mean comfort temperature of Rijal et al. 2010 and Thapa et al. 2018.

To_Mean	Rijal et al. 2010 (Mean comfort temperature)					Thapa et al. 2018 (Mean comfort temperature)			
	Bake	Bhaktapur	Dhading	Kaski	Solukhumbu	Lalitpur	Kathmandu	Shindhupalchowk	Gorkha
3					13.4				
4									
5									
6									
7									
8									
9									
10		15.2				15			
11	16.2								16.8
12			24.2	18					
13									
14									
15					21.1			19.6	
16							20.8		
17									
18									
19				23.4					
20			29.1						
21									
22		25.6							
23									
24									
25									
26							26.6		
27									
28						24.2			
29									
30								27.7	
31									
32	30								
33									28.6

The Fig. 3.14 shows that the relationship between outdoor air temperature and comfort temperature in winter and summer. In winter case when the outdoor air temperature is 10 °C, the mean comfort temperature of Rijal et al. 2010 seems 15 °C. The study comfort temperature is slightly higher than Rijal et al. 2010, during winter and slightly lower during summer. The result suggests that people from temporary shelters within this study and people from traditional houses comfort temperature are not so difference.

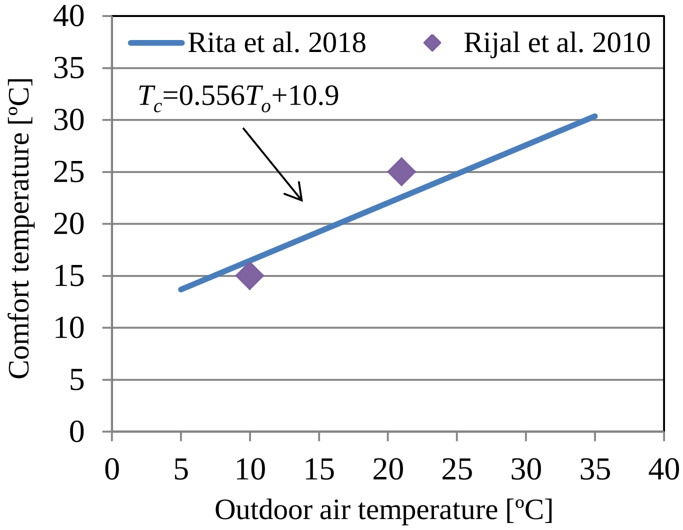


Fig. 3.14 Comparision between comfort temperature and outdoor air temperature of theis study and privious study for winter and summer.

Fig. 3.15 shows the relation between comfort temperature and outdoor air temperature for winter and summer. Here, we have compared the mean comfort temperature of Rijal et al. 2010 of five districts with row data of comfort temperature in winter (N = 695) and summer (N = 510). The result shows that the mean comfort temperature of Dhading district of both summer and winter are higher than other comfort temperature.

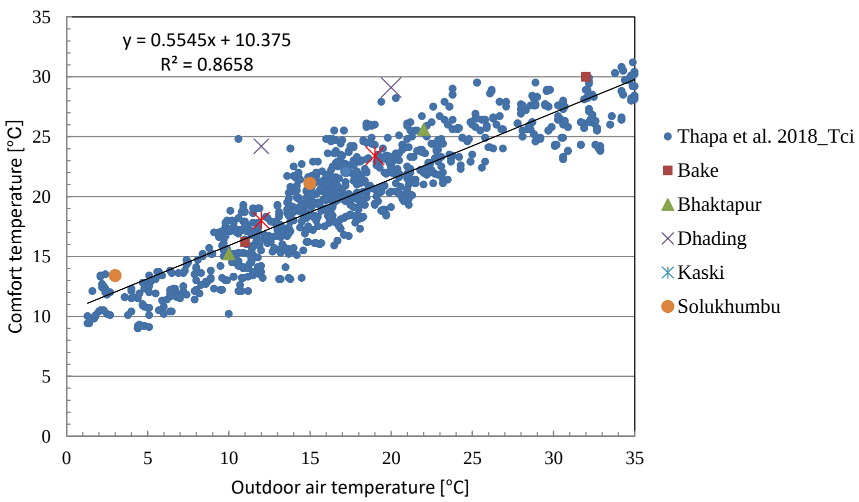


Fig. 3.15 Relationship between comfort temperature and outdoor air temperature (Comparison with Thapa et al. 2018 and Rijal et al. 2010).

Similarly, here we again analyzed the mean comfort temperature of this study and mean comfort temperature of Rijal et al. 2010 (Fig. 3.16). The result seems almost similar. The result suggests that people from temporary shelters within this study and people from traditional houses comfort temperature are not so difference. However, Dhading district of previous research mean comfort temperature for both seasons are slightly higher than this study cause due to firewood burning (Rijal and Yoshida, 2002).

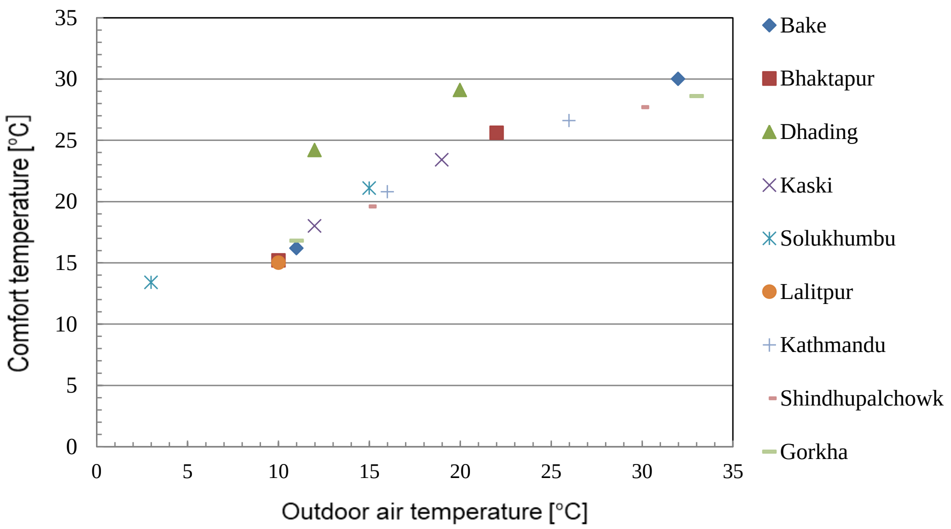


Fig. 3.16 Relationship between mean comfort temperature and outdoor air temperature (Comparison with Thapa et al. 2018 and Rijal et al. 2010).

Table 3.14 shows a comparison of the adaptive model generated from the data set used in the present research with those from the previous research. The slope of eq. (3.6), 0.556, is slightly larger than those values of 0.531–0.546 in previous researches. The constant (y intercept), 10.9 in eq. (3.6), is 2–3 °C lower. These tendencies are considered to reflect the characteristics of makeshift shelters; that is, the estimated comfort temperature is quite sensitive to a change in outdoor air temperature.

Table 3.14 Comparison of the adaptive model found in this study and those in previous research.

References	Mode	Regression equation
This study	FR	$T_c = 0.556T_o+10.9$
Rijal et al. (2015)	FR	$T_c = 0.531T_o+12.5$
Rijal et al. (2013)	FR	$T_c = 0.417T_{rm}+15.9$
Humphreys model (1978)	FR	$T_c = 0.534T_m+11.9$
Nicol (1994)	NV	$T_c = 0.38T_o+17.0$
Nicol (2012)	FR, MM, AC	$T_c = 0.36T_o+18.5$
Humphreys and Nicol (2002)	FR	$T_c = 0.546T_o+13.5$
ASHRAE standard 55 (2002)	NV	$T_c = 0.31T_o+17.8$
CEN standard 55 (2007)	FR	$T_c = 0.33T_{rm}+18.8$

T_c: Comfort temp., T_{rm}: Running mean outdoor air temp., T_m: Monthly mean outdoor air temp., T_o: Outdoor air temp., FR: Free running, NV: Naturally ventilated, MM: Mixed mode, AC: Air conditioned. All of their unit is [°C].

3.7 Determination of acceptable range of indoor globe temperature

As was shown in Table 3.3, we asked the thermal acceptance directly, that is, if the given thermal environment is acceptable to them or not. Fig. 3.17 first shows the percentage of thermal acceptance obtained from this direct question in each of three seasons. The percentage of acceptance is 90 % in autumn and it is even higher in winter and summer.

In this study, we just analyzed the thermal acceptance by total number of respondents in three seasons (N = 1407). However, we analyzed the gender wise thermal acceptance of respondents residing in temporary shelters (Fig. 3.17). These thermal acceptance votes were analyzed by the direct questions, i.e. Can you accept the present thermal environment? As was shown in Fig. 3.12, the indoor air temperature was very high in summer and very low in winter, but this result indicates that the respondents accepted the indoor environment within the shelters. At the first glance, it is rather surprising, but the likely reasons could be, 1). The respondents admitted the given conditions and were feeling rather lucky that they have been able to survive from the disaster, for which nearly 9000 people were killed. 2) The basic needs are food, clothing, sanitation and a place to live for resting rather than thermal acceptance. It means that they gave the first priority for their survival and safety and the second for health.

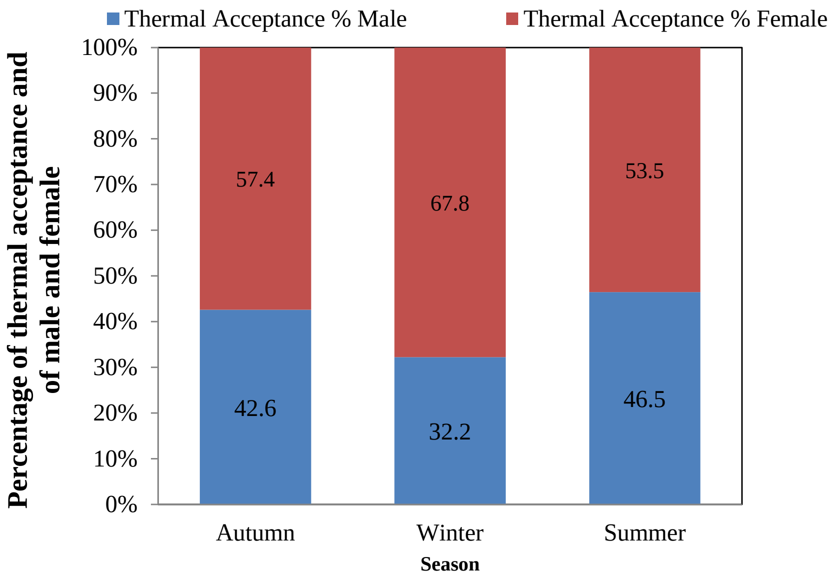


Fig. 3.17 Percentage of thermal acceptance for three season.

Since such high percentage of acceptance cannot be further developed for extracting the acceptable range of indoor temperature, we decided to make use of thermal sensation votes summarized in Table 1.20. We call what follows as indirect method for the estimation of the thermal acceptability of respondents. We define the central three categories as "Conventional Thermally Acceptable Zone" (CAZ): 3≤ TSV ≤ 5. The comfort temperature of the respondents living in temporary shelters seems close to ordinary situation as was found in Table 1.20, but, for the purpose of this paper aiming at the perspective of temporary shelters, we should know the indoor temperature range, with which people could avoid the harsh discomfort in winter and summer. For this reason, we have extended one more category, either "2. cool or 6. warm" of thermal sensation vote in both sides of comfort zone to define another acceptable range. Here, we call it "Wider Thermally Acceptable Zone" (WAZ): 2≤ TSV ≤ 6.

As can be seen in Fig. 3.18, the percentages of CAZ are 38 %, 46 % and 40 % in autumn, winter and summer, respectively. The CAZ falls within the thermal comfort zones, and thus the percentage of CAZ is lower than the value obtained from the direct analysis. The percentages of WAZ are 69 %, 87 % and 81 % in autumn, winter and summer, respectively. The results showed that the percentage of WAZ is higher than CAZ. As a whole, the thermal acceptance is the highest in direct question, the 2nd highest in WAZ and the lowest in CAZ method.

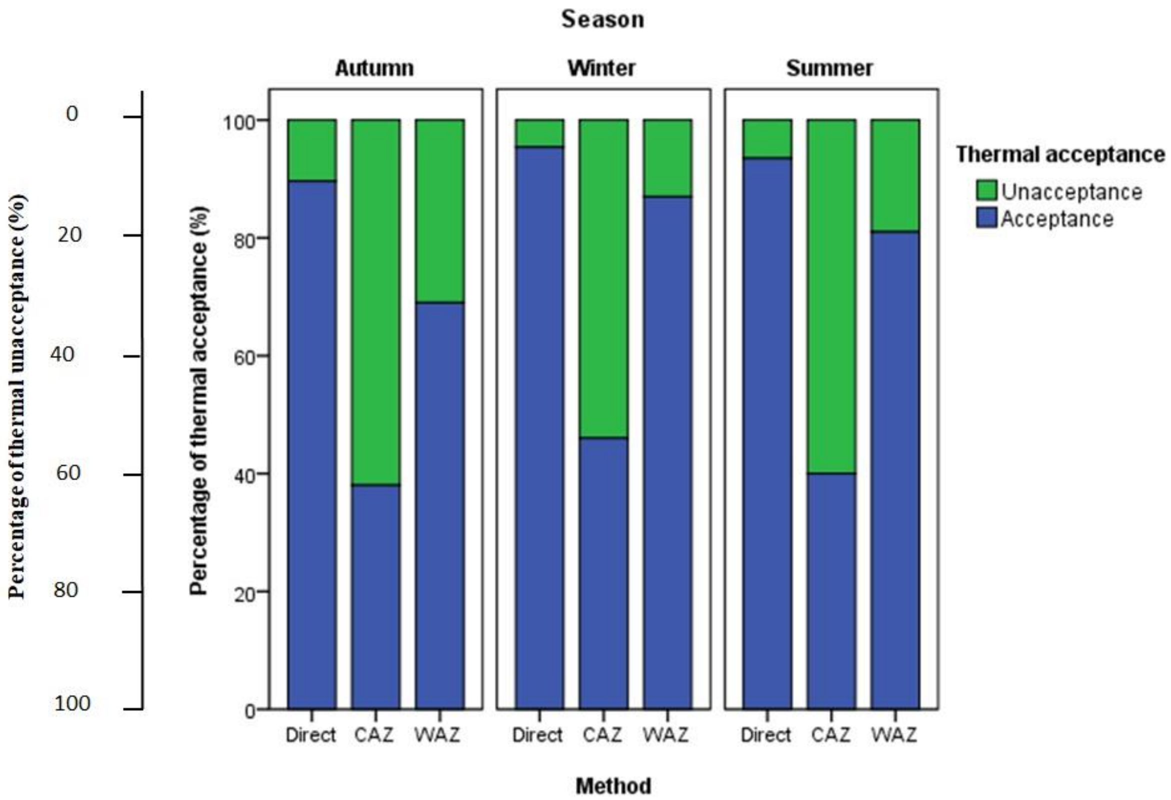


Fig.3.18 Comparison of the percentages of thermal acceptance according to the range of acceptability.

As mentioned in methodology section 2.3.3, we gain logistic equations of the thermal acceptability and globe temperature in each season and result can be seen in Table 3.16. In the course of analysis for autumn, we excluded four peculiar votes “6. warm” or “7. hot”. Similarly, we excluded eight peculiar votes “2. cold” in summer. The resulting coefficient of determination for CAZ was 0.62 in summer and 0.26 in winter. The reason for the low value of the coefficient of determination in winter might be that it is not only affected by temperature but also by other factors such as clothing insulation.

Table 3.15 Logistic regression equation of the thermal acceptability and globe temperature in each season.

Season	Discription	N	Equation	$R^2_{(Cox\ and\ Snell)}$	*S.E.*	*P*
Autumn	CAZ	194	Logit (p) = $0.223T_g$ - 5.3	0.12	0.050	<0.001
	WAZ	198	Logit (p) = $0.203T_g$ -3.4	0.10	0.047	<0.001
Winter	CAZ	695	Logit (p) = $0.261T_g$ -4.4	0.26	0.022	<0.001
	WAZ	695	Logit (p) = $0.162T_g$ -0.4	0.07	0.025	<0.001
Summer	CAZ	502	Logit (p) = $-1.114T_g$ +33.6	0.62	0.117	<0.001
	WAZ	510	Logit (p) = $-0.677T_g$ +21.6	0.52	0.058	<0.001

WAZ: Wider Thermally Acceptable Zone, CAZ: Conventional Thermally Accepatble Zone, R^2: Coefficient of determination, p: The probality of acceptance, N: Total sample, *S.E.:* Standard error, *P*: Significant level of the regression coefficient.

Fig. 3.18 shows the logistic curves representing the relationship between the proportion of thermal acceptance and indoor globe temperature based on the characteristics of CAZ and WAZ. As the temperatures were found to be 8.4–12.9 °C in winter and 30 °C in summer in traditional Nepalese houses (Rijal et al. 2006, 2010). Another recent research by Nicol [Nicol, 2017], has shown the 80 % of occupants in free running dwellings were comfortable at any temperature between 8 and 28 °C. According also to Albadra et al. 2017, the comfort temperature band ranged from 17.2 to 28.4 °C in desert refugee camps. The acceptable temperature of WAZ found here in this research is quite consistent with these recent findings. Thus, the acceptable range of indoor globe temperature as WAZ must be appropriate for the temporary shelters. Temperatures were found to be 8.4–12.9 °C in winter and 30 °C in summer in traditional Nepalese houses [Rijal et al. 2010 and 2012]. The acceptable range (WAZ) could be referred to develop thermally acceptable shelters to be prepared for a future disaster.

The acceptable limit of 11 °C found of four investigated districts within temperate climate. If we did research in other climatic region like cold and subtropical then, maybe we did not get the 11 °C limit of acceptable temperature due to altitude and climatic variations as can be seen in Fig. 1.1.

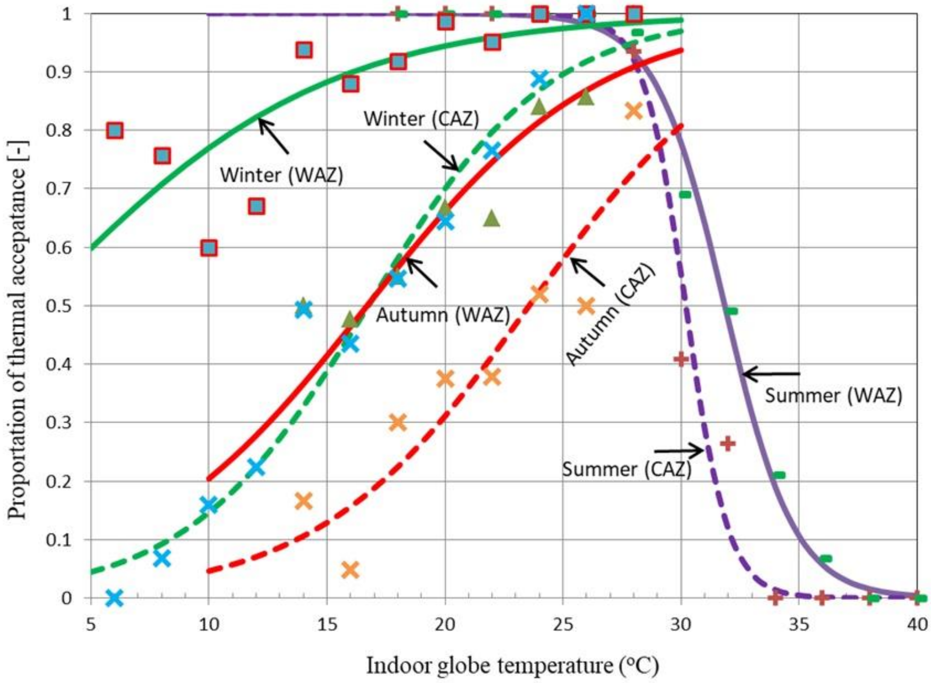


Fig. 3.18 Relationship between the proportion of thermal acceptance and indoor globe temperature.

Table 3.16 Mean globe temperature when voted “acceptable” in direct acceptability.

Season	Number	Mean [ºC]	S.D. [ºC]
Autumn	181	21.5	3.5
Winter	663	15.8	5.1
Summer	477	30.9	4.8

3.8 Conclusions

In this research, we measured the indoor thermal environment within temporary shelters and conducted thermal comfort survey visiting all together 855 shelters. The results found are as follows.

1. In autumn, the respondents felt cold and preferred to be much warmer. Similarly they were ‘slightly unsatisfied’ and ‘slightly uncomfortable’ with their present thermal environment. This might be the reason of zinc sheets are radiative in nature and so the cold sensation as outdoor temperature drops.
2. The mean comfort air temperature in the temporary shelter is 23.9 °C which is similar to globe temperature, radiant temperature and operative temperature.
3. The mean clothing insulations of the study is 0.73 clo. The result showed that female clothing insulation is significantly higher than male clothing.

4. The indoor and outdoor air temperatures are similar to each other during daytime in all four districts. Thus, the people are living under almost the same temperature conditions as outdoors.
5. The majority of the respondents in the survey reported that they found their shelters to be extremely hot in summer and extremely cold in winter, and thus most of the respondents were unsatisfied and highly uncomfortable with their thermal environment. Therefore, their preference is to make it warmer in winter and cooler in summer.
6. The mean comfort temperatures estimated from the measured data set are 24.2 °C, 18.6°Cand 27.3 °C in autumn, winter and summer, respectively. Thus, the seasonal difference (8.7 °C) is considered to be due to clothing insulation as adaptive behavior of the respondents depending on the seasons. The regional mean comfort temperatures were found to range between 15.0 and 20.8 °C in winter and 24.2 and 28.6 °C in summer; thus the regional difference of comfort temperature is 5.8 °C in winter and 4.4 °C in summer.
7. The comfort temperature was highly correlated with the outdoor air temperature. The tendency of estimated comfort temperature was quite sensitive to a change in outdoor air temperature in comparison with the previous studies.
8. The thermal acceptance was higher than 90 %, if the respondents were asked directly; this was considered due to the survival from the disasters. The logistic-regression analysis applied to quantify the relationship between the thermal acceptance and indoor globe temperature revealed that 80 % of the people would accept the indoor thermal environment if the indoor globe temperature is higher than 11 °C in winter and lower than 30 °C in summer in temporary shelters.

Chapter 4

Wintery thermal improvement of temporary shelters

4.1 Introduction

Temporary housing is defined as a place where families can re-establish household responsibilities and daily activities for an interim period until the permanent housing solution can be found (Quarantelli et al. 1995). Temporary shelters are the ones which present prompt solutions that emphasize the rapidity and the low cost. Therefore, they should be used only for a short period of time. Immediately after such a disaster, the major responsibility to be taken by the government is to provide temporary shelters. After a disaster, temporary shelters may have to be used for a longer period of time than to be used. Depending on the disasters' severity and the social conditions, they may need to be used for several months to several years. In 2011 Japan earthquake, Japanese government provided temporary shelters where all the basic facilities were available (Nobuo et al. 2011).

In 2008 Wenchuan earthquake in China, the Chinese government determined to adopt the program of interim settlements. One month after the earthquake, tens of millions of affected people were resettled in thousands of tents and then, two months later, the tents had been mostly replaced by portable housing (Jiuping et al. 2012). Permanent houses were designed and constructed and then most of people moved into those new houses by the end of 2008. But, in Nepal, three years after the devastating earthquake in 2015, the recovery is still very slow. Many families who lost their permanent houses are still living in temporary shelters due to various reasons such as: the lack of infrastructure, lands, manpower, economic condition, materials availability, and no formal rebuilding program has been commenced by the government. The

Nepal government had announced for initial relief with NRs. 15,000 (about USD 150) in cash for respective victim families that allow them to buy corrugated zinc sheets and other materials to build temporary shelters on their own (Koirala, 2015). But those makeshift shelters that they made can hardly provide with sufficient relief from hard rain, strong wind, scorching sun and biting cold because of their poor physical characteristics. What we should learn from these events is that a government has to be strong enough economically and to prioritize those who suffer most. Therefore, well before a next disaster may occur, the government is expected to establish national plans for temporary shelters, in which people can avoid a variety of discomfort as much as possible.

In this respect, temporary shelters need to be examined on their lightness, easiness of assembling and installation, thermally resistivity for providing minimal comfort. It is a well-known fact that basic designs of temporary housing have a direct impact on the residents' well-being and quality of life. Therefore, temporary housing designers must consider various properties of material and building structure to ensure occupants' overall well-being (FEMA 2009). Temporary housing should provide protection from the outdoor environment to secure personal safety, health and well-being until the permanent houses become available (Silva et al. 2007).

Several studies have been carried out focusing on the indoor thermal environment in temporary settlements (Shinohara et al. 2014, Huang et al. 2015). Thermal performance analyses of emergency shelter using dynamic building simulation have been performed to clarify the basic requirements of a better emergency shelter with simple materials (Cornaro et al. 2015). The case study on the life cycle performance of light-framed temporary housing with local technologies has been conducted in China (Song et al. 2016).

Some other researchers have focused on the design and construction to improve the temporary shelters (Abulnour 2014, Arslan et al. 2008, Cassidy 2007, Obyn et al. 2015, Salvalai et al. 2015 and Yu et al. 2016). But in the context of Nepal, after the massive earthquake, few researches have been conducted on this issue (Thapa et al. 2016 and 2018).

Our previous survey (Thapa et al. 2018) has found that the people residing in shelters were facing extreme coldness in winter and the lowest limit value of acceptable indoor air temperature of the respondents was 11 °C, which was identified from the daytime measurement of indoor temperature together with the survey of thermal comfort. The indoor temperature of temporary shelters during nighttime could be definitely below the lowest acceptable temperature value. With this likeliness in mind, the objectives of this paper are: (1) to evaluate the thermal characteristics of indoor thermal environment on the basis of materials used for the shelters; and (2) to examine the possible improvement of the shelters that can provide the occupants with a better indoor thermal environment.

We have analyzed the indoor air temperature variation and its relation to the overall heat-transfer characteristics of the makeshift shelters and thereby identify the affordable solution for the improvement.

4. 2. Method of thermal measurement

4.2.1 Selection of temporary shelters in Lalitpur

One of the severely affected districts, shown in chapter 2. Fig. 2.1, Lalitpur, has been chosen for field measurement. Originally, it was planned to investigate seven randomly selected shelters denoted from S1 to S7, for which six are rectangular-shaped shelters (S1, S2, S4, S5, S6 and S7) and one dome-shaped shelter (S3) as can be seen in chapter 2, Fig. 2.6. Regrettably, the sensors used in two shelters, S2 and S7, were found to have malfunctioned (Thapa et al. 2019). Therefore, these two shelters were excluded in the present study and we analyzed the thermal environment of five shelters.

As we can see the photos, plan and sectional views of five investigated shelters in Lalitpur in previous chapter 2, sub section 2.3.2, Fig 2.6 and composition of floor materials of five investigated shelters in Fig. 2.7. Each of these shelters has single room for living, sleeping and kitchen. The structure, size and materials used for insulation of the shelters are different from each other. People used local and affordable materials such as straw, tarpaulin sheets, cellular polyethylene foam, clothes and others on the interior and exterior sides of zinc sheets. No heating systems were used in all of the investigated shelters. We can see the the dimension of the shelters, the number of people living and the materials used in chapter 1, Table 1.1.

4.2.2 Thermal measurement

The continuous thermal-environment measurement was performed for 16 days from 30th January to 14th February 2016. Indoor air temperature, outdoor air temperature, indoor globe temperature, indoor relative humidity and outdoor relative humidity were measured by respective sensors with data loggers at the interval of 10 minutes. Table 2.3 shows the instruments used in this field measurement. The data loggers were placed in the middle or the corner of respective investigated shelters; they were set 1m above the floor level as shown in Fig. 2.8. As we mentioned in chapter 2, sub-section, 2.4, the outdoor air temperature was measured just outside the shelter S1. Thus, we assumed the same outdoor air temperature for other investigated shelters because all of the investigated shelters are located only 50 m to 5 km away from shelter S1.

4.3. Evaluation of the investigated shelters based on measurement

Fig. 4.1 shows the measured indoor air temperature of the five shelters for 16 days together with the outdoor air temperature. The indoor air temperature fluctuates very sharply every day in all of the five shelters. The amplitude ranges from about 12 °C at the minimum to about 20 °C at the maximum. The daily lowest indoor temperature is 2 to 3 °C higher than the outdoor air temperature. This difference must be caused mainly by the internal heat generation. During daytime, some shelters have the indoor air temperature higher than the outdoor air temperature and some others lower than the outdoor air temperature. The former must be definitely due to the solar radiation absorbed by the shelter's roof and walls; on the other hand, the latter must probably be due to the combined effect of little solar radiation for the shelter location and the coldness stored by the ground, above which the shelters are formed.

The horizontal dashed line represents the lowest acceptable indoor temperature found in our previous research (Thapa et al. 2018). In all of the shelters, the indoor air temperature during nighttime becomes lower than 11 °C. The mean indoor and outdoor air temperatures from 18:00 to 5:50 are 10.3 °C and 7.6 °C, respectively. Such low temperature must affect very much on the people's health. According to the previous studies (Rijal et al. 2010 and 2012), Nepalese people are exposed to extreme cold in everyday life during winter seasons. The results showed that the discomfort, illness and death may cause by the indoor air temperature about 6.5 °C, during wintry nighttime in traditional houses located in Solukhumbu (Himalayan region). It is close to the result in this study, although the climatic condition in Lalitpur is much milder than Solukhumbu.

Fig. 4.2 shows cumulative frequency of indoor air temperature of the five shelters for 16 days. About 50 % of the time, the indoor air temperature remains below 11 °C. According to a recent experiment on corrugated cardboard temporary shelters (Nakaya et al. 2018), the indoor temperature dropped as low as outdoor temperature during nighttime. This is considered to be comparable to what happened in the investigated shelters in this study.

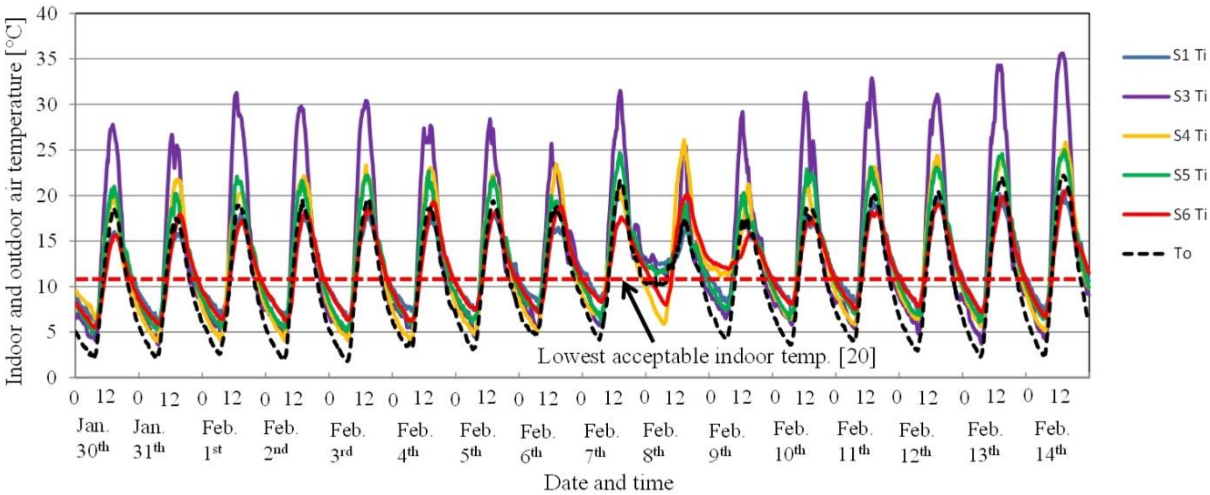


Fig. 4.1 Distribution of indoor and outdoor air temperature of five investigated shelters in 2016.

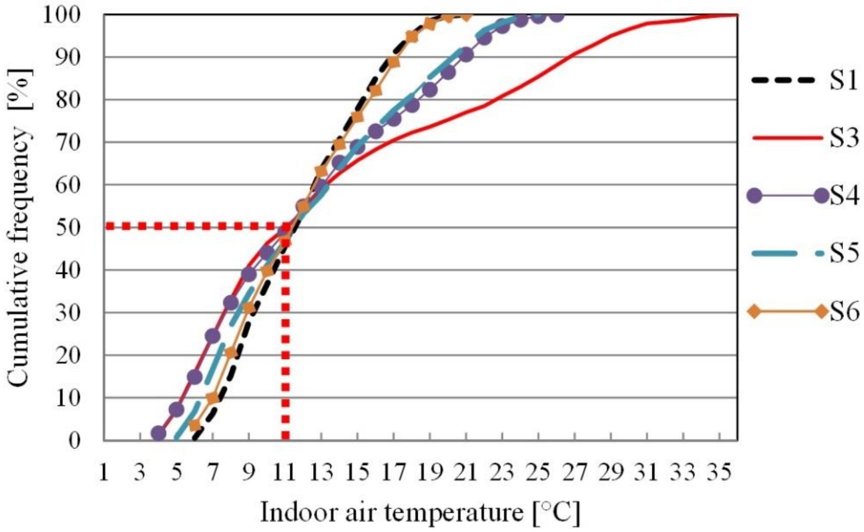


Fig. 4.2 Cumulative frequency of indoor air temperature of five investigated shelters.

4.4 Improvement of temporary shelters based on simulation

4.4.1 Energy balance equation set up for simulation

In order to assess the possibility of improvement, we use simplified mathematical modeling for the calculation of indoor air temperature. First, we set up the energy balance equation to be expressed as [Thermal energy input] = [Thermal energy stored] + [Thermal energy output] (Shukuya, 2013).

Focusing only on nocturnal energy balance of a shelter, thermal energy input may be regarded consisting of the thermal energy emission from the human body and some other miscellaneous heat sources. Its portion is partly stored by the room air and other things inside the shelter and partly outflows by heat transmission and infiltration. In order to avoid unnecessary complexity of calculation and develop a reasonably simple mathematical model, we ignore the effects of miscellaneous heat generation and infiltration and the heat flow towards the floor; in other words, we assume that they can be left out from the energy balance equation to be used in the present investigation.

Then the energy balance equation can be expressed as follows.

$$H\mathrm{d}t = C\rho V\mathrm{d}T_{ei} + \sum_{i=1}^{5} A_i\, U_i\, (T_{ei} - T_{eo})\, \mathrm{d}t \,, \qquad (4.1)$$

where *H* is the rate of human-body heat generation [W], d*t* is the infinitesimally short period of time, *t* [s], *C* is specific heat capacity of the space inside a shelter [J/(kg·K)], *ρ* is the density of air [kg/m^3], V is the volume of shelter space [m^3], dT_{ei} is an infinitesimal increase of indoor operative temperature [°C], A_i is the area of " i " th walls and roof (i = 1, 2, . . 5) [m^2], U_i is the heat transmission coefficient of " i " th walls and roof (i = 1, 2, . . 5) [W/(m^2·K)], T_{ei} is the indoor operative temperature [°C], and T_{eo} is the outdoor operative temperature [°C].

Fig. 4.3 schematically shows the relationship between the external and internal surrounding conditions and the heat flow. Theoretically speaking, the operative temperature is the weighted average of radiant temperature and air temperature (Shukuya, 2019) and we need to know both value of radiant and air temperatures, but here we assume both are equal to each other. This is for simplifying the calculation and also for applying the measured indoor and outdoor air temperatures.

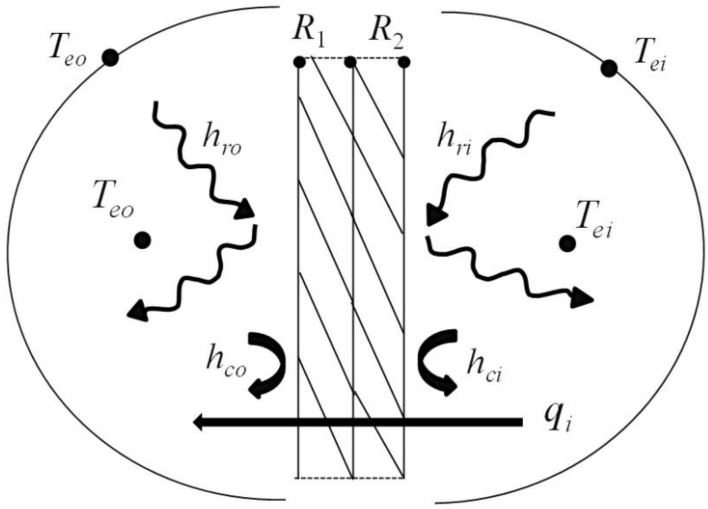


Fig. 4.3 Schematic image of heat flow q_i through " i " th wall.

In the present study, the value of heat transmission coefficient, U_i, is determined from the following equation.

$$U_i = \frac{1}{\frac{1}{h_{ro}+h_{co}} + R_1 + R_2 + \frac{1}{h_{ri}+h_{ci}}} , \qquad (4.2)$$

where h_{ro} and h_{ri} are radiative heat transfer coefficient at the external and internal surfaces, respectively [W/(m^2·K)], h_{co} and h_{ci} are convective heat transfer coefficient along the external and internal surfaces, respectively [W/(m^2·K)], R_1 and R_2 are the resistance of two materials in " i " th wall [(m^2·K)/W]. In the calculation of U_i, we referred to thermal conductivity data of the solid materials available from [Shukuya, 2019 and JSME data book, 1987] and we assumed the values of radiative and convective heat transfer coefficient to be as follows: h_{ro}= h_{ri}= 5.2 W/(m^2·K), h_{co}= 12 W/(m^2·K) and h_{ci}= 3 W/(m^2·K).

The heat flow, q_i [W/m^2], through "i" th wall may be expressed as

$$q_i = U_i (T_{ei} - T_{eo}). \quad (4.3)$$

The investigated five shelters are different with respect to the size and the materials used, so that we calculated the areas of four walls and roof (A_i) and respective corresponding heat transmission coefficients (U_i).

Once the values of heat loss coefficient ($\sum_{i=1}^{5} A_i U_i$) are estimated, the unknown variable left in eq. (1) becomes the heat capacity, $C\rho V$. In this study, the value of $C\rho V$ is estimated by approximating equation (1) with the finite differential equation. The calculation of $C\rho V$ is made from

$$C\rho V = \frac{[H - \sum_{i=1}^{5} A_i U_i \{T_{ei}(n) - T_o(n)\}] \Delta t}{T_{ei}(n) - T_{ei}(n-1)}, \quad (4.4)$$

where Δt is the finite period of time, $T_{ei}(n) - T_{ei}(n-1)$ is the finite temperature change from $(n-1)\,\Delta t$ to $n\Delta t$, where, n is integer (n = 0, 1, 2, …..).

The values of $C\rho V$ obtained for each time interval, Δt, are averaged to determine the single value of $C\rho V$. Once we come to know the values of total heat loss coefficient ($\sum_{i=1}^{5} A_i U_i$) and heat capacity ($C\rho V$), the indoor air temperature, $T_{ei}(n)$ may be simulated by the following equation.

$$T_{ei}(n) = \frac{H\Delta t + C\rho V\, T_{ei}(n-1) + \sum_{i=1}^{5} A_i U_i\, T_{eo}(n)\, \Delta t}{C\rho V + \sum_{i=1}^{5} A_i U_i \Delta t}. \quad (4.5)$$

4.2.2 Description of investigated shelters in terms of heat transmission coefficient, total heat loss coefficient and heat capacity estimated

Table 4.1 shows the wall and roof areas (A_i), their corresponding heat loss coefficient values (U_i), total heat loss coefficient $\left(\sum_{i=1}^{5} A_i U_i\right)$, and finally the estimated heat capacity ($C\rho V$). The total heat loss coefficient per floor area of the five investigated shelters are from 11.3 to 15.2 W/(m^2·K). The average heat capacity estimated per floor area are from 56.6 to

141.1 kJ/(m^2·K). These heat capacity values are 16-40 times larger than the heat capacity of air alone about 3.6 kJ/(m^2·K). This is because the estimated heat capacity includes the effects of various things inside the shelter space and a part of the ground as floor. We calculated the heat loss coefficient of the floor by assuming the thickness of ground is 3 m and found the heat loss coefficient is 0.60 W/(m^2· K).

Table 4.1 Description of investigated shelters in terms of heat transmission coefficient, total heat loss coefficient and heat capacity estimated.

S.C.	Wall area [m^2]	Roof area [m^2]	Floor area [m^2]	Total surface area (wall + roof) [m^2]	U_i for wall [W/(m^2·K)]	U_i for roof [W/(m^2·K)]	Total heat loss coefficient [W/K]	Total heat loss coefficient per floor area [W/(m^2·K)]	Total heat loss coefficient per surface area [W/(m^2·K)]	$C\rho V$ [kJ/K]	$C\rho V$ per floor area, [kJ/(m^2·K)]
S1	35.7	17.5	17.5	53.2	5.6	1.2	220.9	12.6	4.2	1918	109.6
S3	11.6	15.1*	9.3	26.7	5.6	2.6	104.2	11.3	3.9	526	56.6
S4	67.2	36.3	35.8	103.0	5.6	3.8	514.3	14.4	5.0	4770	133.2
S5	79.0	49.7	49.4	128.6	5.6	3.8	630.1	12.8	4.9	5051	102.2
S6	25.6	9.1	9.1	34.7	4.4	2.8	138.1	15.2	4.0	1284	141.1

S.C.: Shelter Code, $C\rho V$: Specific Heat Capacity, *: Roof area is calculated for whole dome-shaped shelter.

4.5 Comparison of simulated indoor air temperature with measured indoor air temperature

Fig. 4.4 shows the comparison of simulated indoor temperature obtained from equation (14) and the measured indoor air temperature during nighttime (18:00 to 5:50) for 16 days. The correlation coefficient in the case of S3 and S5 are extremely high and those in the cases of S1, S4 and S6 are also very high, though the discrepancy of simulated and measured temperature becomes large in some period of time.

These comparisons as a whole indicate that the present simplified simulation can well reproduce the indoor air temperature with the assumed values of heat loss coefficient and heat capacity. Thus, we determined to apply the simplified energy balance equation developed so far to the investigation on the possible improvement.

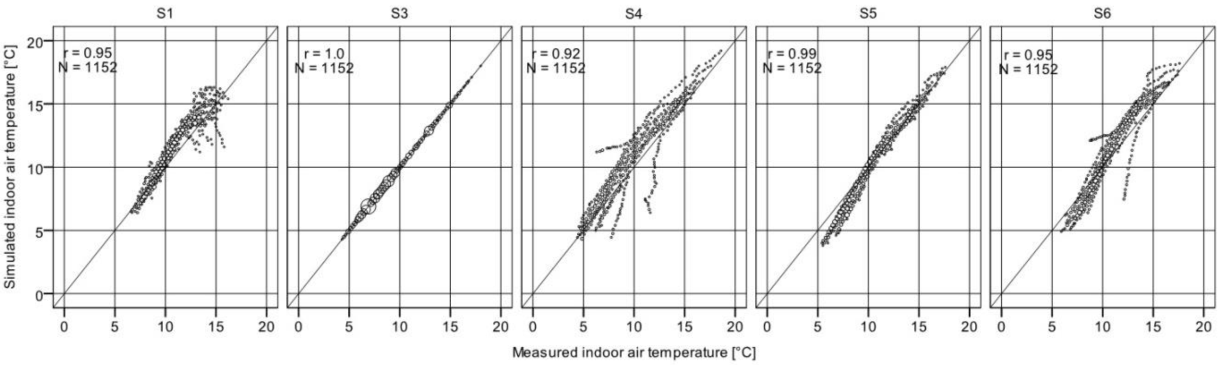


Fig. 4.4 Relationship between simulated and measured indoor air temperatures.

4.6 Reduction of heat loss coefficient for the possible improvement

Fig. 4.5 shows the relationship between the heat loss coefficients calculated per floor area for each shelter tabulated in Table 3 and its corresponding percentage of time during nighttime being higher than the lowest limit value of acceptable temperature, 11 °C. As can be seen, the high values of heat loss coefficient in the five shelters result in 42 to 52 % of time during nighttime for being higher than the acceptable temperature. This result is of course consistent with what can be seen in Fig. 4.3.

The percentage of indoor air temperature higher than 11 °C being only 42 to 52 % is not sufficient. Therefore, how much of reduction in the total heat loss coefficient can bring about a higher percentage of indoor air temperature higher than 11 °C is examined. We assume the value of percentage to be either 70, 80 or 90 %. If our focus is on ordinary buildings, then the percentage should be 80 or 90 % (de Dear et al. 2002, Mohammad et al. 2013), but the focus in this paper is makeshift shelters so that we assume 70 % rather than 80 or 90 %. The temporary shelters do not need to follow strongly about the permanent housing standards because these shelters are to provide the occupants with the minimum requirements of living.
The heat loss coefficient of S4 and S5 has to be significantly lowered by the improvement because of the percentage of the time higher than 11 °C is the smallest among the five shelters. On the other hand, in the cases of S1, S3 and S6, the improvement required is rather moderate.

Here, we just improved the two shelters where is added little bit insulating materials (S1) and another for none (S5). Maybe these two shelters improvements are ok for refer others because all the shelters materials were zinc sheet. Maybe these two shelters improvements are ok for refer others because all the shelters materials were zinc sheet. The reason for these differences is that the surface areas of S4 and S5 are larger than the other three investigated shelters as can be seen in Table 1.28. To achieve the 70 % of the nighttime in which indoor air temperature is higher than the 11°C, the total heat loss coefficient needs to be reduced to about 2~7 W/(m^2·K).

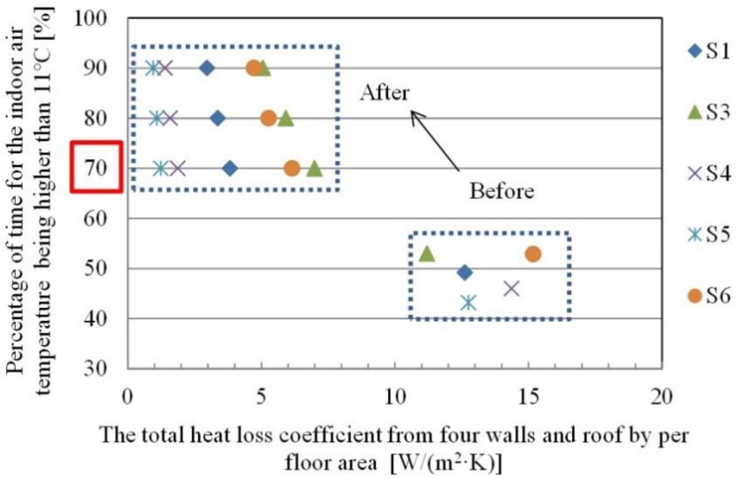


Fig. 4.5 Relationship between total heat loss coefficient per floor area and the percentage of time for the indoor air temperature higher than 11 °C.

In Table 4.1, the value of total heat loss coefficient at present and those to be reached for 70 % of nighttime for higher indoor air temperature above 11 °C are tabulated. In the case of S1, the reduction of total heat loss coefficient from 12.6 W/(m^2·K) to 3.8 W/(m^2·K) is required; this is 70% [= (1-3.8/12.6)100] of reduction.

Table 4.2 The percentage of reduction required for the indoor air temperature higher than 11 °C.

Shelter code	Total heat loss coefficient per floor area [W/(m^2·K)]		Percentage of reduction required [%]
	Before	After	
S1	12.6	3.8	70
S3	11.3	7.0	38
S4	14.4	1.9	87
S5	12.8	1.2	91
S6	15.2	6.2	59

Fig. 4.6 shows two examples of affordable improvement for the wall and roof in the cases of S1 and S5. In S1, the heat loss coefficients of four walls and the roof at present are 5.6 W/(m^2·K) and 1.2 W/(m^2·K), respectively. Addition of tarpaulin (2 mm) and cellular polyethylene foam (12 mm) results in the heat loss coefficient of the walls to be 1.4 W/(m^2·K). The heat loss coefficient of roof, 1.2 W/(m^2·K), is small enough so that no improvement is needed. In S5, the heat loss coefficient of the walls and roof are 5.6 W/(m^2·K) and 3.8 W/(m^2·K), respectively. The same addition for S5 as for S1 results in the heat loss coefficient of the walls

to be 1.4 W/(m^2·K). The heat loss coefficient of roof, 3.8 W/(m^2·K), is quite high so that addition of cellular polyethylene foam (12 mm) and clothes (5 mm) are made so that it is reduced to 1.2 W/(m^2·K). Addition of the sheets of tarpaulin or cellular polyethylene foam is considered to be not different even under urgent conditions.

The temporary shelters are not suitable for long term living (Felix et al. 2013). Several researches have suggested that the shelters are preferred to be designed as foldable and movable unit (Sagiroglu et al. 2018). The sheets proposed here could fit such requirement. Previous research (Asefi et al. 2012) proposed that shelters should be innovative, lightweight, and transformable whose size and materials can be different for different applications. Desirable temporary shelters should be able to be made with local materials by local people. Reuse of the materials from destroyed buildings should also be considered. As an example, rubbles from destroyed buildings were used after Gujarat earthquake while beer crates were used after Kobe earthquake with the foldable temporary housing system, the shelters could be built within 4 hours (Felix et al. 2013).

According to a previous field survey made after Lushan earthquake (Yu et al. 2016), the thermal performance in winter for two kinds of temporary shelters made of bamboo and prefab and the result found that very low indoor temperature at 8 °C. So, they carried out different insulations for walls and roof experimentally and they recommended the use of air-bubbled polythene sheet for the insulation of walls and fiberglass cement for roof. This is considered to be similar to what we have found in the present analysis. In summary, we can improve the walls and roof rather easily by adding locally available materials as thermal insulation i.e., cellular polyethylene foam and clothes to make the indoor air temperature become higher than 11 °C for 70 % of the wintry nighttime.

This type of research on the affordable improvement is also considered to be necessary for finding effective solutions for the preparation to be made before a disaster to occur in the future. Thus, it hopefully helps to make policies for the government.

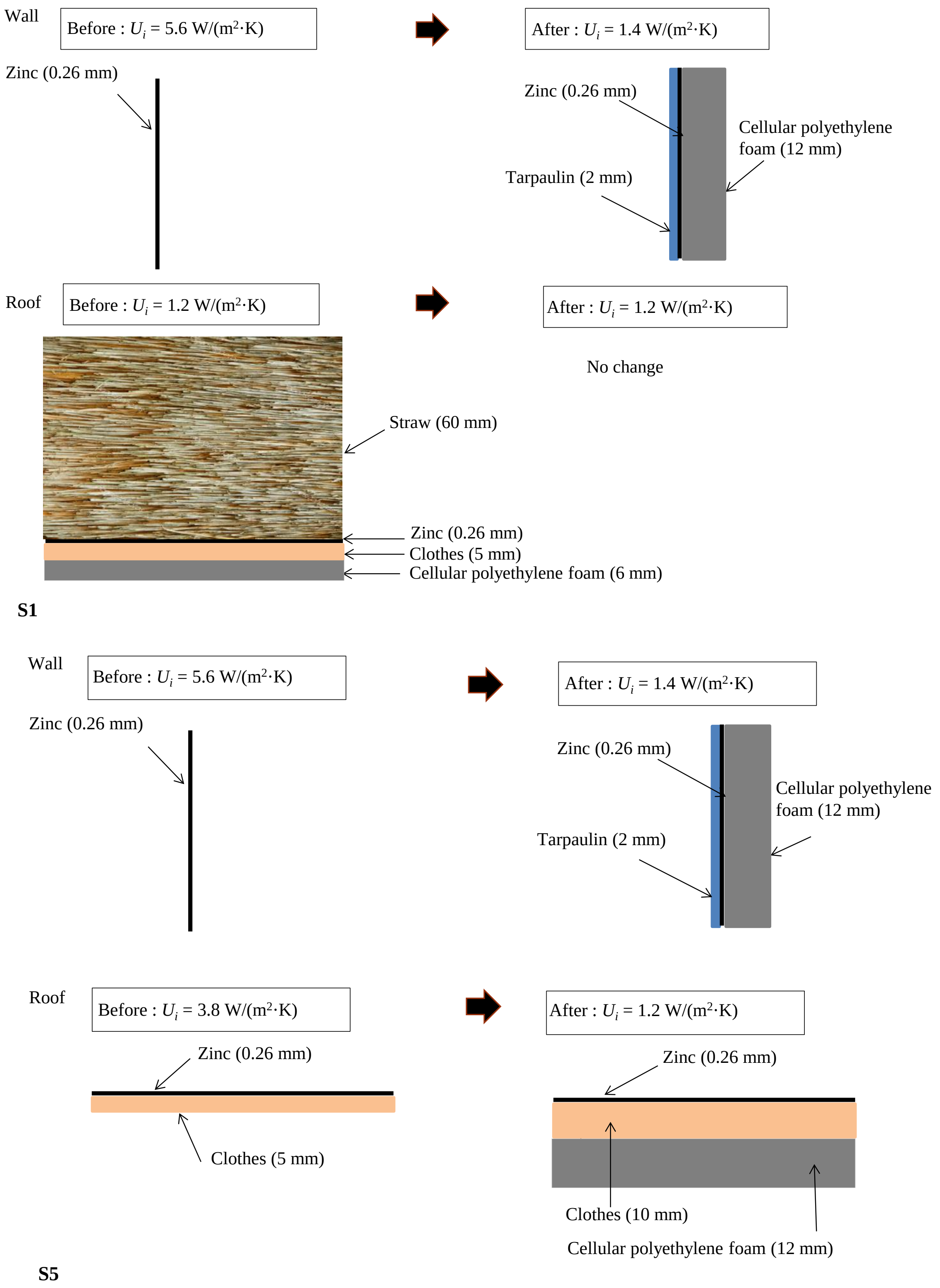


Fig. 4.6 Shelter improvements.

Here, as an example of proposed materials are shown in Fig. 4.7. These materials could find easily in local markets with regional price.

(a) Cellular polyethylene foam (12 mm) (b) Tarpaulin sheet (2 mm) (c) Fabric (10 mm)

Fig. 4.7 As an example of proposed materials for improving temporary shelters (Source: Fig. a photo taken by author itself and Fig. b and Fig. c are form website: https://www.google.com/search?q=Tarpaulin+sheet+and+fabric).

4.7 Conclusions

Since the last big earthquake, 83 years have passed but there were no such historical records of victims and their living conditions. There is a need for good planning before any kinds of disasters to come in the future. For this reason, this study focused on the present conditions of temporary shelters built after earthquake 2015 and tried to identify the problems and the possibility of improvement. We have come to the following conclusions based on this study.

1. The indoor air temperatures for all shelters are highly dependent on outdoor air temperature. Especially during nighttime, the indoor air temperatures were much lower than those during daytime.
2. About 50 % of the nighttime remained below the lowest acceptable temperature, 11 °C, in the five shelters investigated. This must cause quite a serious problem in residents' health.
3. The total heat loss coefficient per floor area needs to be reduced down to the range of 2 to 7 W/(m^2·K) in order to realize the indoor air temperature well above 11 °C for 70 % of time during wintry night.

4. The reduction of heat loss coefficient may be achieved by adding cellular polyethylene foam of 6 to 12 mm and clothes of 5 to 10 mm for the walls and roof of temporary shelters for the requirement of indoor air temperature higher than 11 °C for 70 % of the whole nocturnal hours.

What has been found in this study should be hopefully applied to actual improvement of indoor thermal environment in existing shelters and also to the development of the possible preparation for the future disaster.

Chapter 5

Gorkha earthquake 2015: Social life and environmental factors

5.1 Introduction

The earthquake of 1934, 1980, 1988, 2015 and the flood of July 1993, 2008, 1913, 2014 and 2017 AD are the most destructive disasters which not only caused heavy losses to human lives and physical properties but also adversely affected the development process of the country. The lessons of the earthquakes of 1988 and 2015 and the floods and landslides of 1993, 2008, 2013, 2014 and 2017 have cautioned the concerned authorities and agencies for a coordinated disaster preparedness and response mechanism (Subedi and Chhetri 2019). Climate change, on the other hand, has become 'extreme.' Nepal is ranked as the fourth most climate vulnerable country in the world in the climate change vulnerability index (Ulaanbaatar, Mongolia; 2018).

Temporary shelters play a vital role in large-scale disasters and are an important part of disaster response and recovery. In general, shelters are used to provide private and secure places for people to live who have left or lost their usual accommodations as a result of some form of disaster. A lack of adequate consideration with regard to climatic conditions, locally available materials and on traditional skills, cultural and social issues, has been used for making temporary shelters in Nepal after massive earthquake 2015.

Temporary shelters are also considered vital for personal safety, climate protection, security, and resistance to disease and ill health (IFRC/RCS 2013). Such types of temporary shelters are commonly used until a displaced people could be shifted new permanent accommodations. The provision of shelters is widely accepted as a necessary component of response and recovery following disasters such as earthquakes, hurricanes, tsunamis, and floods, it is not yet clear which type of shelter is most appropriate given various circumstances that can occur in practice. As a result, the provision and performance of shelters in certain cases has been hindered by inappropriate climate, cultural differences, poorly located settings, social issues, expenses, overcrowding, poor services, and delays (Barakat 2003, Nigg et al. 2006, Johnson et al. 2006, El-Anwar et al. 2009, Félix et al. 2013b). Previous researches have reported that the design of shelters may potentially overlook locally available skills and materials (Johnson 2007b, Hadafi and Fallahi 2010), and shelters may provide an acceptable standard of living where the higher limit of acceptable indoor temperature was 11 °C in winter and 30 °C in summer (Thapa et al. 2018).

Adequate shelter has a significant impact on human survival in the initial stages of a disaster (The Sphere Project 2011). A shelter requires more than just a roof for a space to be habitable. People living in a shelter must have enough clothing, blankets, mattresses, stoves, fuel, and access to services such as water and sanitation (Ashmore 2004). In general, we understand that shelters mean offers a safe and secure area to live within immediately following a disaster; houses include daily household responsibilities and work routines (Johnson 2007b, Félix et al. 2013a). But in the contest of Nepal, four years after the devastating earthquake in 2015, the recovery is still very slow. Many families who lost their permanent houses are still living in temporary shelters due to various reasons such as: the lack of infrastructure, lands, manpower, economic condition, materials availability, and no formal rebuilding program has been commenced by the government.

Thus, this paper focused to evaluate that how Gorkha earthquake impacts on social life and other miscellaneous environmental factors and also understand the lessons learnt from this disaster. Here in this research, we tried to examine the extent to which environmental, economic, technical, and sociocultural criteria affect the people residing in shelters, and how such factors might be good record for future generation as well upcoming researcher. Thus, these following objectives are obtained in this research;

1. To find out, how Gurkha earthquake impacts on social life and other miscellaneous environmental factors.
2. To make this harsh disaster to be learnt for lesson and keep records for the future generation.

5.2 Methodology

5.2.1 Research area and climate

According to World Health Organization, total of 35 districts have been affected, 14 severely: Gorkha, Dhading, Rasuwa, Sindhupalchok, Kavre, Nuwakot, Dolakha, Kathmandu, Lalitpur, Bhaktapur, Ramechhap, Okhaldunga, Sindhuli and Makwanpur. Among them 14 severely affects districts; Gorkha, Shindhupalchowk, Dhading and Lalitpur have been chosen for the field survey. Nepalese climatic conditions vary from one place to another in accordance with its geographical features. These four districts are located within temperate climate region. In chapter 2, Fig. 2.1 shows the map of Nepal with these four investigated districts.

5.2.2 Details of field survey

The field survey was performed in autumn, winter and summer for 424 households on 2015 and 2016 (Table 5.1). The perspectives of people are represented here in this study as respondents (Fig. 5.1). The district wise numbers of male and female respondents are separately presented in Fig. 5.2 and Fig. 5.3 shows age distributions of family members in respective districts. Questionnaires related on: Social life of peoples' living condition and thermal perception during Gorkha earthquake in Nepal and damage looks and other miscellaneous environmental factors have done after Gorkha earthquake 2015 (Questionnaires are given in Appendix A1).

Table 5.1 Details of field survey.

Season	District	Date	Day	Place	Total
Autum	Gorkha	2015/11/03	1	Pipalthok VDC, Gorkha Durbar	22
	Lalitpur	2015/10/25 to 2015/10/28	4	Dukuchhap VDC, 4	47
		2015/10/29 to 2015/10/30	2	Mahalaxmi muncipality (Bishnudol and Jyagata)	23
	Sindhupalchok	2015/2/11	1	Chautara, Sangachowk muncipality	32
Winter	Gorkha	2016/01/25 to 2016/01/26	2	Pipalthok VDC	91
	Lalitpur	2016/02/02 to 2016/02/05	4	Mahalaxmi muncipality (Bishnudol and Imadol)	46
	Sindhupalchok	2016/01/22 to 2016/01/24	3	Melamchi muncipality	71
Summer	Dhading	2015/5/20 to 2015/5/22	3	Jyamrung VDC	53
	Lalitpur	2016/04/04 to 2016/04/07	4	Mahalaxmi muncipality (Lubhoo)	39
				Grand total	424

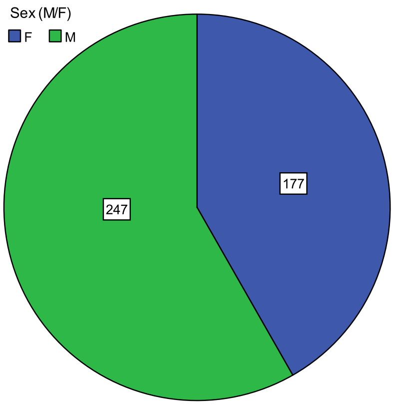


Fig. 5.1 Total number of people in four investigated districts.

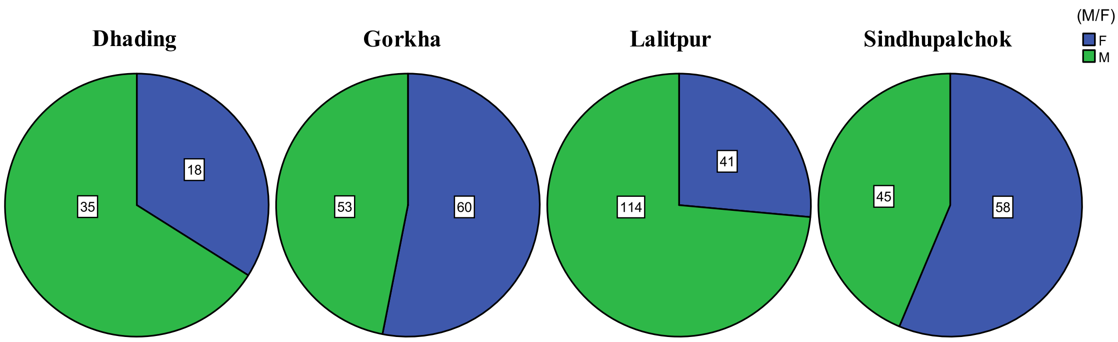


Fig. 5.2 Number of male and female members in four investigated districts.

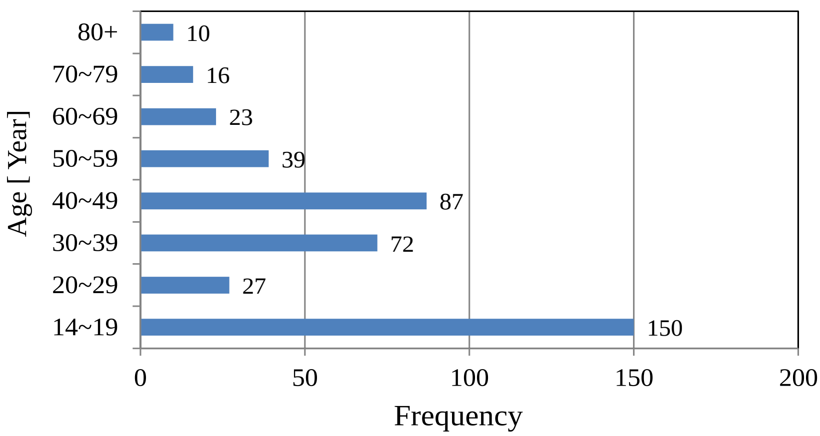


Fig. 5.3 Age distributions of members in four investigated districts.

5.3 Evaluation of peoples' living condition, activities and their experienced during earthquake occurred

(a) Living condition

We asked to peoples' living conditions while earthquake occurred. On that time, they remembered and answer us in different place. We have got multiple answer and we categorized them by respective indoor and outdoor place into 6 types of place i.e. court yard, field, forest, inside the house, market and on the way. Fig. 5.4 shows that more than 50% people were stayed in inside the house because of that 25th April was on Saturday (holiday) and also in lunch time. The 7.8$_M$ earthquake of 25th April 2015 killed about 9000 people because it occurred on a Saturday and so many buildings that collapsed, such as schools and municipal buildings were empty reducing the death toll.

In addition, the epicenter of the earthquake was in a rural setting, so the worst hit districts had low population densities and most of the population was outside when the earthquake hit. If the earthquake had occurred at night or during the working week, when many more people were inside vulnerable buildings, the death toll would have likely been much higher or out of imagination.

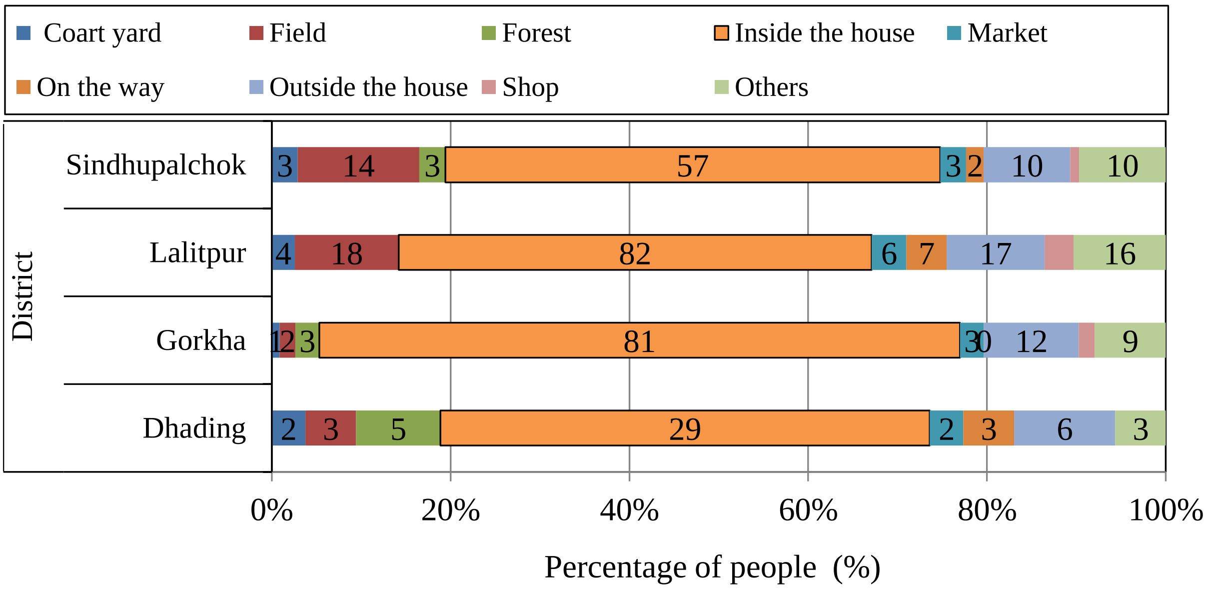


Fig. 5.4 Peoples' living place while earthquake occurred.

(b) Activities done

We should know the peoples' activities while earthquake took place because we would like to record these evidences for future generation. Fig. 5.5 shows that 50 % people were involved in household works in each district. Very few people were involved in official work because as we discussed in previous session that 25th April was on holiday day.

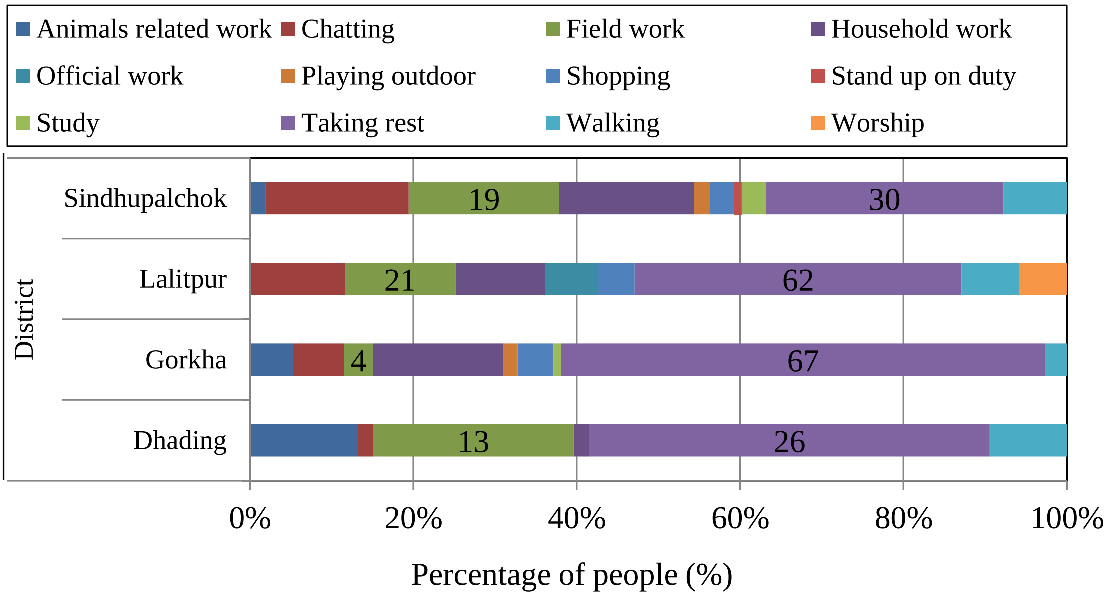


Fig. 5.5 Peoples' activities while earthquake occurred.

(c) People's experience

We analyzed people's experience while earthquake occurred (Fig. 5.6). We found that nearly 50 % people were in absolute fear felt and sad. They were nervous and disorientated (confused). We also found nearly 50 % people were felt strange. The people of Dhading district were not able to figure out what has happened (can't imagination that what was happened); it means they were in the state of unconsciousness during earthquake period.

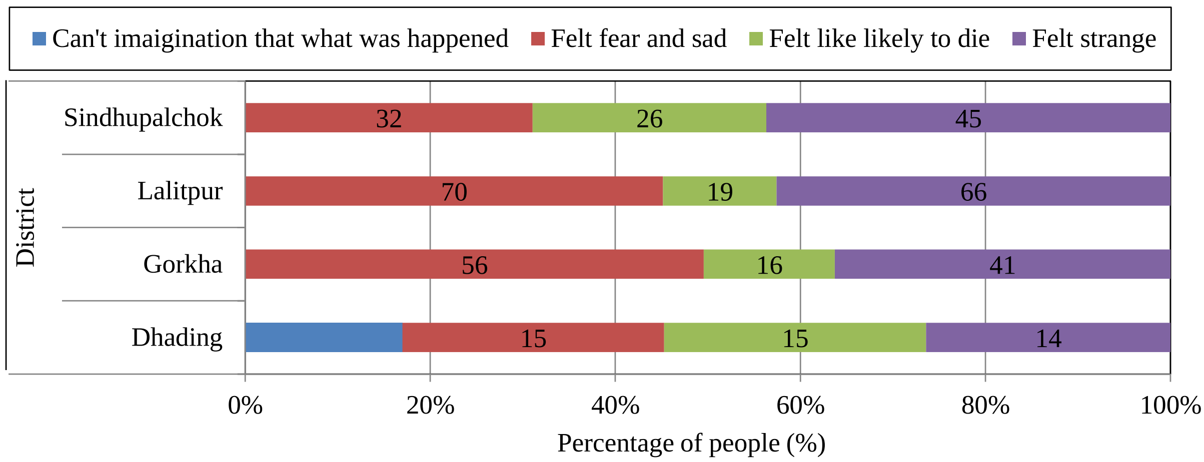


Fig. 5.6 Peoples' experienced while earthquake occurred.

5.4 Damage after earthquake 2015

The earthquakes destroyed 604,930 houses completely and 288,856 houses were partially damaged. It is estimated that the total value of the damages caused by the earthquakes is NPR 706 billion or equivalent to US$ 7 billion (Government of Nepal, National Planning Commission (NPC) 2015). Around 800,000 people displaced by the earthquake in Nepal were struggled to survive in a context of persistent, a severe lack of safe and adequate housing (Amnesty International Nepal, Earthquake Recovery Must Safeguard Human Rights. London; 2015). We can see the damage condition in four investigated districts in chapter 2, Table 2.1. Fig. 5.7 shows the results about damage looks in four investigated district (N = 424). People were also asked about their house condition after earthquake. In Shindhupalchowk, more than 60 % of houses were fully collapsed. In Lalitpur, more than 50 % of houses were fully collapsed. However, in Gorkha in Dhading, there is less than 50 % of houses were fully collapsed while in Dhading 30 % of houses were totally crack. It means people doomed to leave their permanent houses and shifted in temporary shelters.

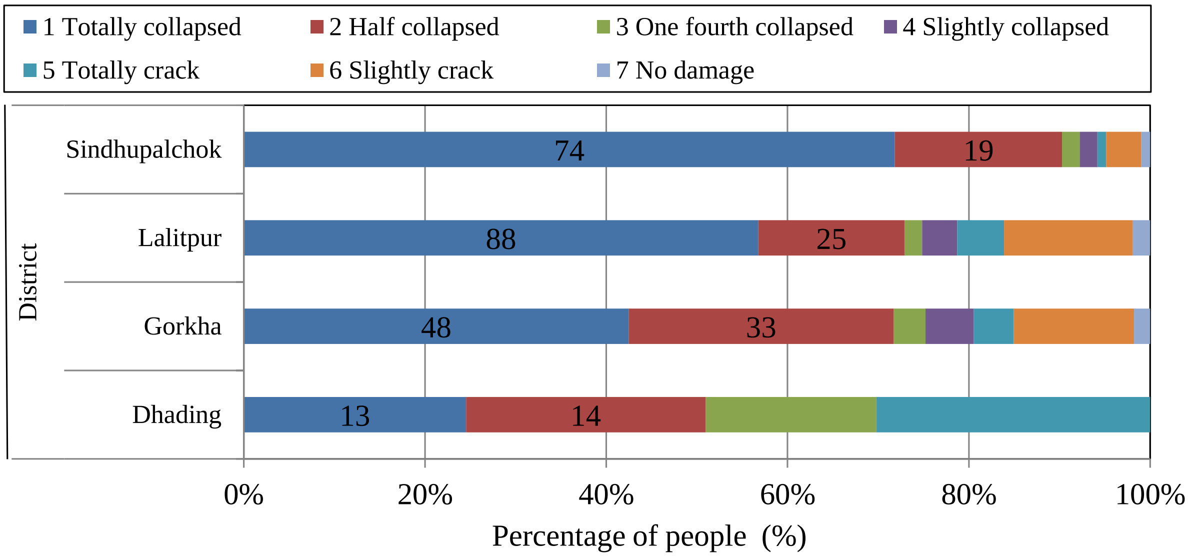


Fig. 5.7 Percentage of damage condition after earthquake in four investigated districts.

5.5 Living condition after earthquake

25th April, 2015, Gorkha earthquakes, a large number of houses were fully damaged as can be understood by Table 5.2. Thus, people were forced to live in temporary shelters. As can be seen in chapter 1, in Fig 2.1, we observed seasonal and regional living condition of people. Fig 5.8 shows that, immediately, after earthquake 25th April, in Dhading district more than 80 %

people started to live in tent. In Lalitpur (next year after earthquake) nearly 40 % people were settled in their own houses and tent where about 25 % of people lived in temporary shelters.

In autumn, Shindhupalchowk (about 78 %) and Gorkha (about 65 %) people were settled in temporary shelters. However, in Lalitpur, about 50 % people were settled in tent house. In winter, more than 65 % people were settled in temporary shelters in Shindhupalchowk and Lalitpur. However, in Gorkha, more than 65 % people were settled in tents.

An overall result showed that most of the people were doomed to live in temporary settlements and return their normal life. Many people were exposed to risks due to poor shelter, poor hygiene. Moreover, people did not receive recovery support immediately, and had to spend monsoon season without a house. Since political commitment has always been weak in Nepal, leaders often focused on party politics and direct their effort to change the government (Bhujel 2017). Consequently, weak government and leadership have direct effect in the reconstruction and recovery efforts (Subedi and Poudyal Chhetri 2019).

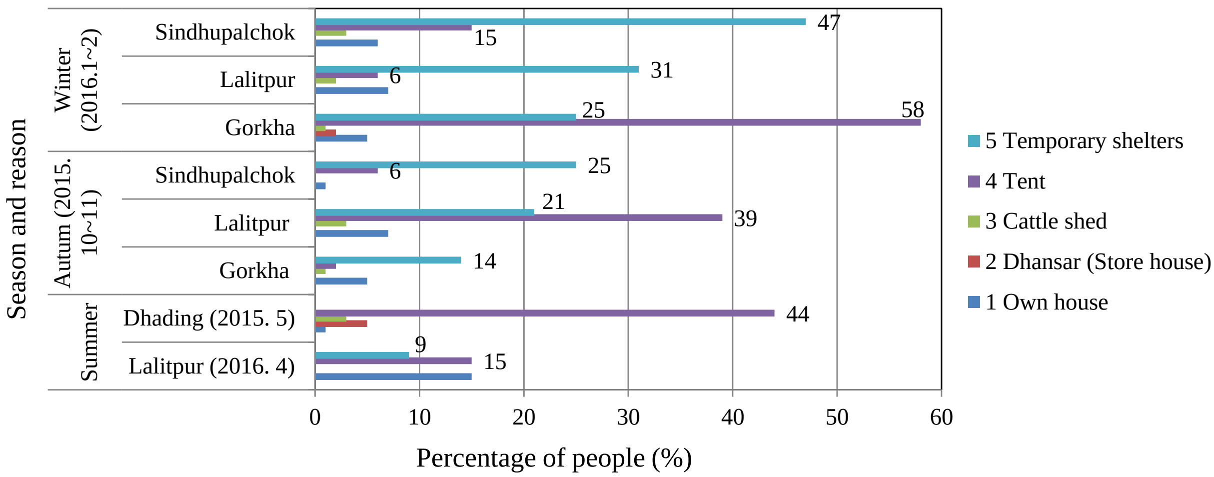


Fig. 5.8 Seasonal and regional living condition after Gorkha earthquake.

5.6 Other miscellaneous environmental factors impact by Gorkha earthquake

(a) Brightness condition

It is important to analyze brightness in the living space or work place. Thus session tried to analysis the brightness condition of people living in present conditions after Gorkha earthquake 2015. Fig. 5.9 shows the seasonal and regional brightness condition over there living space. In summer, Dhading district, about 42 % living place seems dark where as in Lalitpur district about 70 % living place seems slightly light. In autumn, three investigated districts; more than 50 % living places seems that slightly bright. In winter also three investigated districts, more than 50 % living places seems that slightly bright. Thus, overall result shows that the present living places are not well bright.

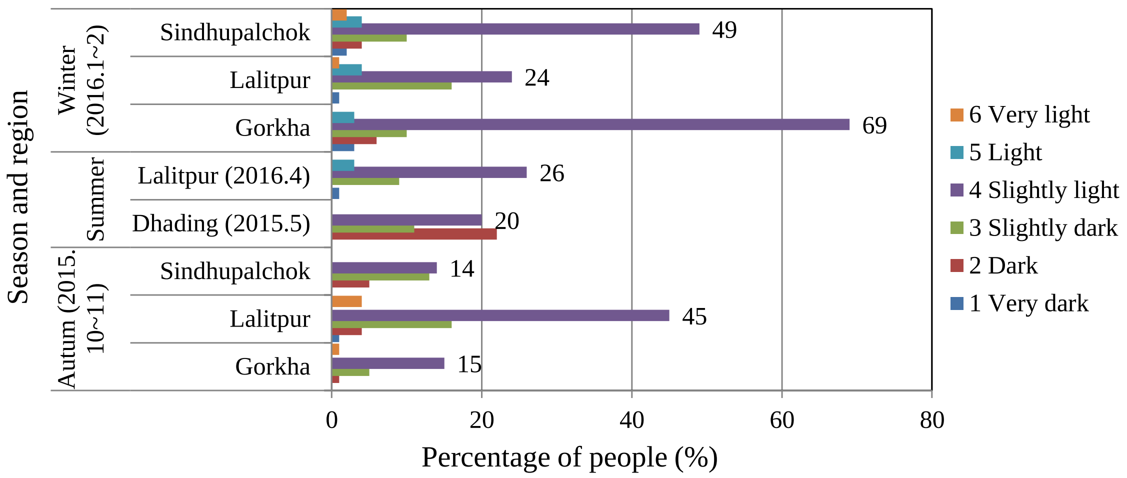


Fig. 5.9 Brightness condition.

(b) Air quality

80-90 % of humans spent most of their time in indoors. Therefore, it is obvious that indoor air quality is highly importance for the health and wellbeing of the people. Here in this session we tried to analyze the indoor air quality of those places where people currently living. People were asked the question about their indoor air quality. We found that seasonal and regional differences in indoor air quality of investigated areas (Fig. 5.10). It seems that, current living places are not so good condition for living.

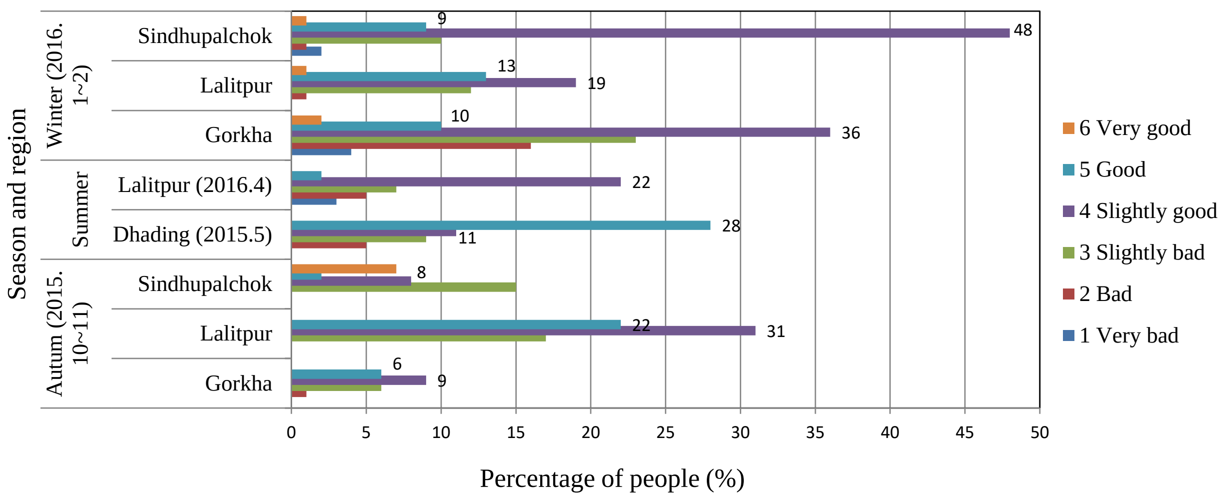


Fig. 5.10 Seasonal and regional air quality condition.

(c) Noise pollution

Sound is an important and valuable part of everyday life. But when sound becomes noise, it can negatively affect our mental and physical health. We found that noise pollution condition in four investigated areas. In three seasons, three investigated districts (Shindhupalchowk, Lalitpur and Gorkha) have found slightly peace (Fig. 5.11). It seems that, current living places are not so good condition for living.

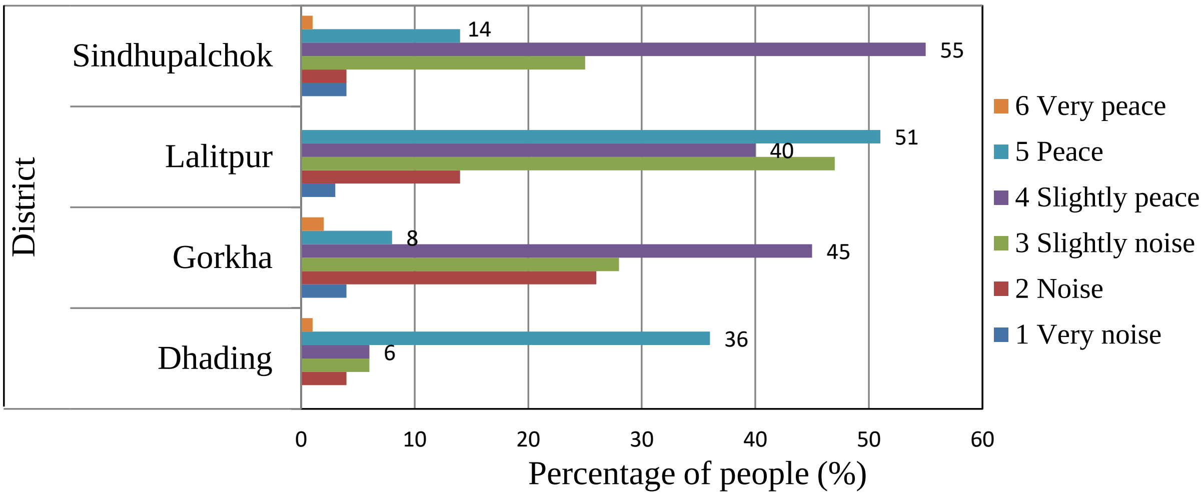


Fig. 5.11 Noise condition of investigated districts.

(d) Felt fear during nighttime

During the survey time, respondents reported us about their outdoor environment condition where drunkard people walked up to midnight and made noise and sometimes they quarreled with each other. Sometimes they started thrown stone over the shelters. These kind of naughty activities were done by drunkard people in Nepalese society. We concerned these matters, respondents were asked about their fear condition during nighttime. Thus, this session tries to analyze the fear condition about their present settlement after earthquake 2015 (Fig. 5.12). The overall resulted suggested that, outdoor environmental is not well safe. Fine and fear votes seem higher than other votes.

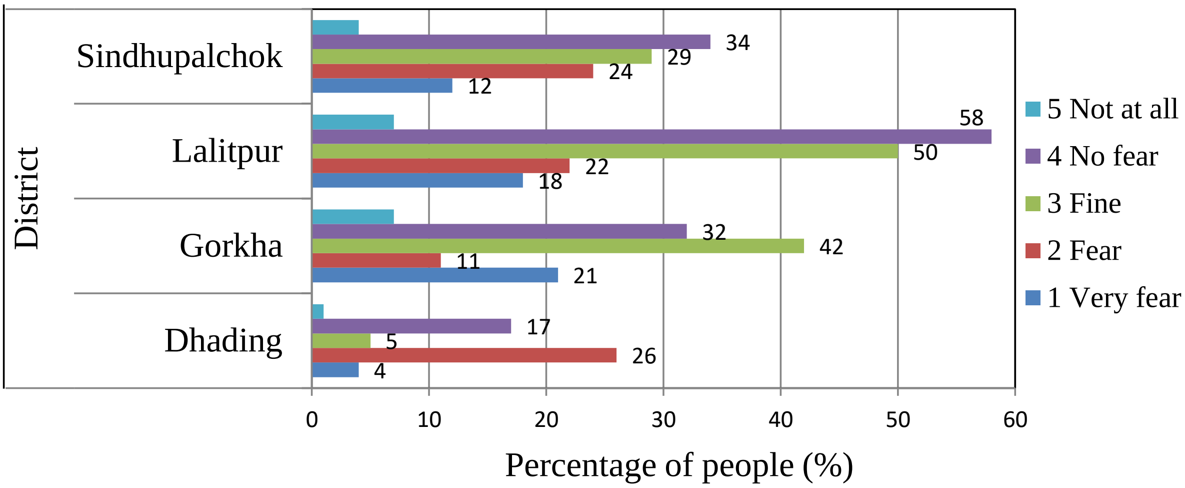


Fig. 5.12 Fear condition during nighttime in all four investigated districts.

(e) Privacy condition

Privacy is essential, as human beings, and we make decisions about it every single day. It gives us a space to be ourselves without judgement, allows us to think freely without discrimination, and is an important element of giving us control over who knows what about us. Therefore, in this session, respondents were asked about their privacy condition in their present living space in four investigated districts. Fig. 5.13 shows that the privacy condition seems just fine. This resulted suggested that their privacy condition does not seen fine.

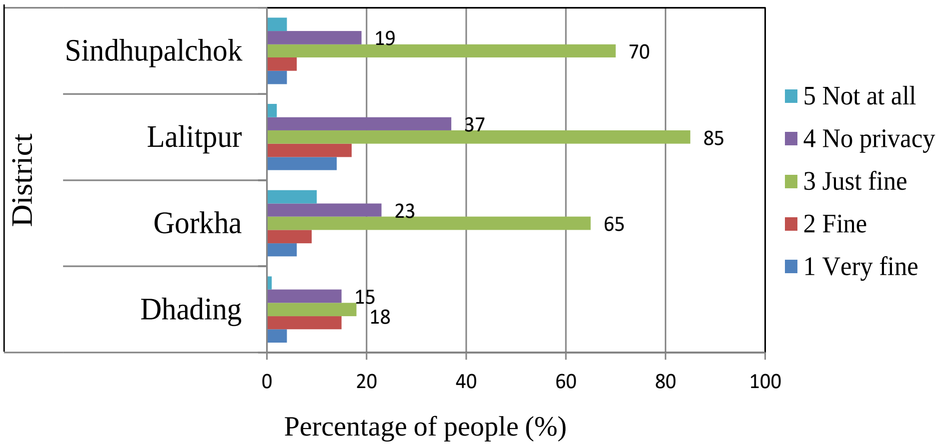


Fig. 5.13 Privacy condition during nighttime.

(f) Tiredness condition

Physical and mental fatigues are different, but they often occur together. Respondents were asked their tiredness condition (physically and mentally) after Gorkha earthquake 2015.

The fine percentage seems higher in Gorkha district rather than rest of other districts (Fig. 5.14). Gorkha is epicenter districts and damage looks higher than other investigated districts even respondents' tiredness condition looks fine. The result might be they are fine and felt lucky and able to live after all this harsh disaster.

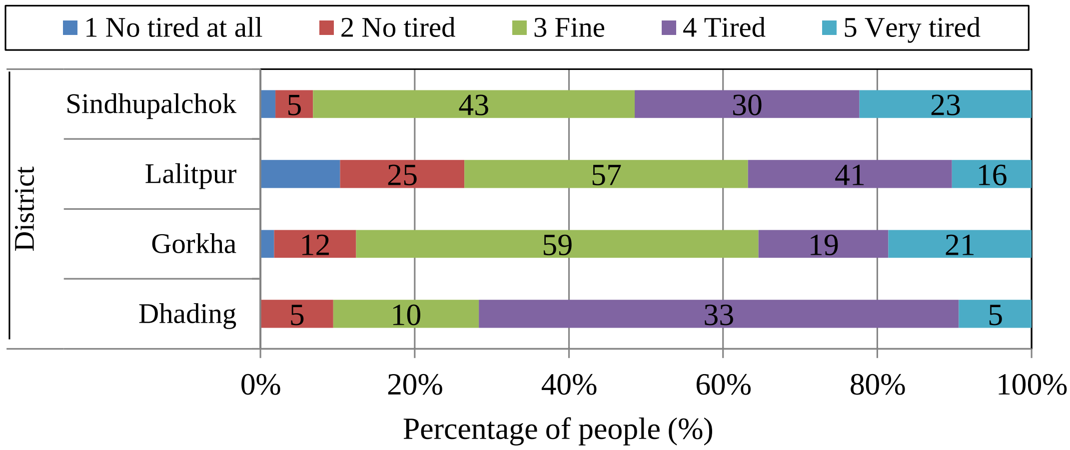


Fig. 5.14 Tiredness condition.

5.7 People's satisfaction level

(a) Staying in present condition

This session presents an investigation regarding the effect of indoor thermal environment to temporary shelters respondents' satisfaction level. Fig. 5.15 shows that the 'not fully satisfied' votes are higher than 'fine' and 'not satisfied'. We found that less than 5 % votes for 'very satisfied'. Thus, overall the result suggested that the people are not satisfied in their present living condition.

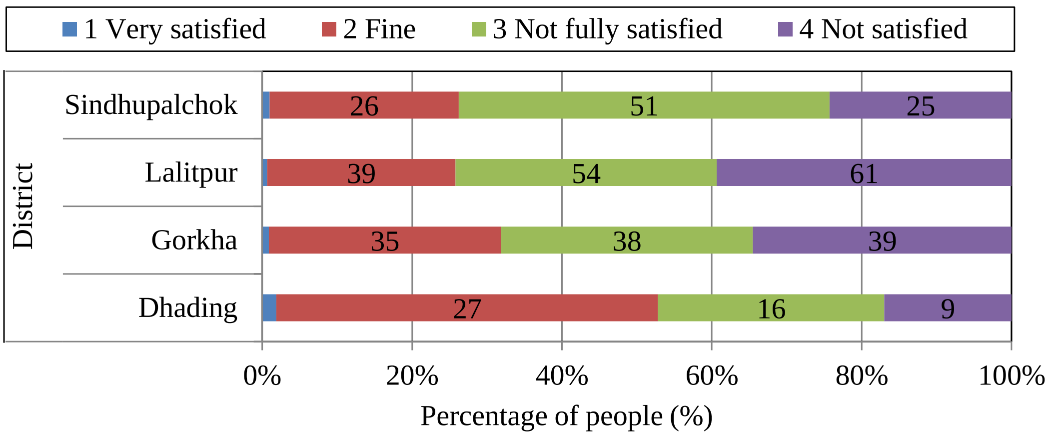


Fig. 5.15 Overall satisfaction level.

(b) Overall comfort condition

Fig. 5.16 shows the overall comfort level of respondents residing in their present conditions. The result shows that, the 'slightly comfortable' and 'uncomfortable' votes are higher than 'comfortable'. Thus, the result suggested that people are not satisfied in their present living condition.

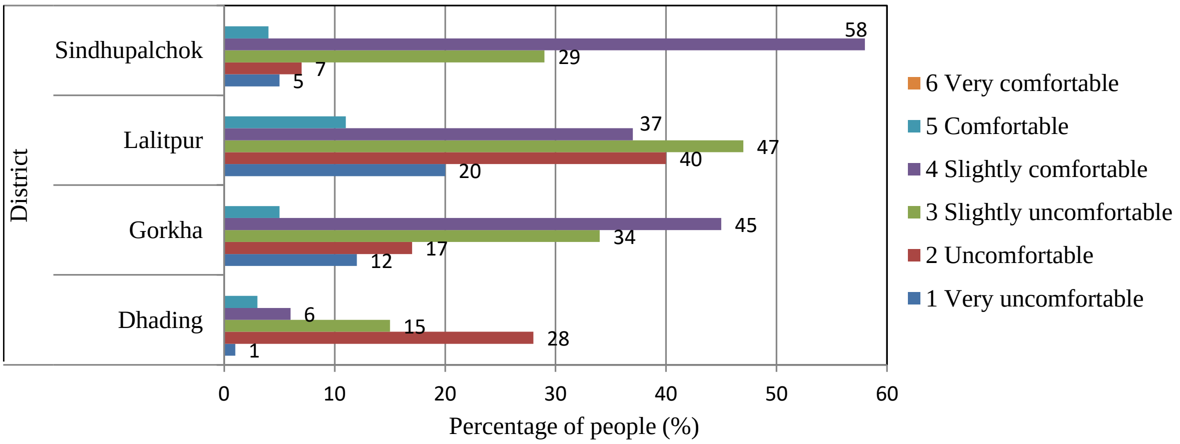


Fig. 5.16 Overall comfortable level.

5.8 Future adjustment

Respondents were asked about their future adjustment for their thermal comfort in season change. Table 5.2 shows that their future adjustment to mitigate their discomfort in different season. Especially they are planning to mitigate their harsh indoor conditions of their present settlement like tent and temporary shelters by adding additional materials as insulations. As a season change, they would like to wear warm clothes during winter and use other windows opening behaviors, poster change and so on during summer.

Table 5.2 Future adjustment for thermal comfort.

District			No. of votes
Dhading	Summer	To add some grasses and leaf materials on roof of shelters	8
		To do nothing special	1
		To maintain shelter	27
		To stay in shade place	2
		To wear thin clothes	15
		Total	53
Gorkha	Autum	To add some materials in shelters	4
		To do nothing special	3
		To drink hot drinks	2
		To wear warm clothes	13
		Total	22
	Winter	To take fire wood	10
		To add some materials in shelters	12
		Not mentioned	19
		To do nothing special	1
		To drink hot drinks	4
		To wear warm clothes	45
		Total	91
Lalitpur	Autum	To add some materials in shelters	15
		Not mentioned	8
		To do nothing special	12
		To drink hot drinks	4
		To wear warm clothes	31
		Total	70
	Summer	To fan Use	14
		To do nothing special	2
		To build new house	5
		To maintain shelter	17
		To wear thin clothes	1
		Total	39
	Winter	To add some materials in shelters	12
		To do nothing special	3
		To drink hot drinks	7
		To wear warm clothes	24
		Total	46
Sindhupalchok	Autum	To add some materials in shelters	5
		To do nothing special	4
		To wear warm clothes	23
		Total	32
	Winter	To add some materials in shelters	7
		Not mentioned	3
		To do nothing special	1
		To drink hot drinks	15
		To wear warm clothes	45
		Total	71

5.9 Conclusions

We interviewed 424 people, questionnaires related on their social life and other miscellaneous environmental factors impacts by Gorkha earthquake 2015, for three seasons in four investigated districts. The following results were found as follows;

1. Most of the people (about 60 %) were in indoor condition while earthquake occurred.
2. People experienced “felt very strange and fear” during earthquake occurred.
3. More than 50 % of houses were fully collapsed. More than 80 % of people shifted in temporary settlement.
4. More than 50 % of people were doing house hold work while earthquake occurred.
5. Other environmental factor seems very poor conditions during the staying in temporary settlement. Thus, people were not satisfied the present living conditions.
6. Furthermore, people used varieties of thermal adjustment to mitigate their discomfort.

Chapter 6:

Conclusions and recommendations

6.1 Conclusions of chapter 2

In this chapter, we measured the thermal environment in the temporary shelters for three seasons, i.e. autumn, winter and summer. The daytime indoor air temperature is 18.7 °C which is similar to indoor globe temperature. The mean nighttime indoor air temperature is 15.2 °C which is also similar to indoor globe temperature. Respondents slept where the mean indoor air temperature is 14.3 °C which is 5 °C higher than outdoor air temperature. The result showed that indoor air temperature is significantly higher than outdoor air temperature at night time. The indoor air temperatures for all shelters were highly dependent on outdoor air temperatures, but the results indicate that the shelter S3 indoor air temperatures was approximately 9 °C and 6 °C lower than shelter S1 in winter and summer at day time. The results found that the shelters applying good thermal insulation is used to protect from outdoor environment comparison to poor thermal insulation in winter and summer. The result of monthly mean indoor air temperature of S1 and S3 are 11.9 °C and 13.1 °C in winter and 21.6 °C and 23.1 °C in summer. The indoor air temperature differences of S1 and S2 are 1.2 °C in winter and 1.5 °C in summer. The mean indoor air temperatures during the sleeping time of S1 is 10.1 °C which is 1.9 °C higher than shelter S3 in winter, however almost similar to each other in summer. The people in these shelters were sleeping in the indoor temperature at only 2.5 °C higher than outdoor air temperature at 5.7 °C in winter and 14.7 °C in summer**.**

The indoor air temperatures for all shelters are highly dependent on outdoor air temperature, but S3 is approximately 6 K higher than outdoor air temperature during the day time. The overall mean indoor air temperature is also higher than outdoor air temperature during the sleeping time for all shelters. It means that the people slept in the indoor environment at 2.6 K higher than outdoor air temperature. The regional and seasonal differences of both indoor and outdoor air temperature were found large. This indicates that there must be quite a problem for residents' health. Most of the shelters' indoor air temperatures are found to be lower than the lower limit of acceptable temperature,11 °C, in winter and fewer shelters are upper limit of 30 °C in summer. It seems that the winter is more problematic than summer.

6.2 Conclusions of chapter 3

In this chapter, we measured the indoor thermal environment within temporary shelters and conducted thermal comfort survey visiting all together 855 shelters. In autumn, the respondents felt cold and preferred to be much warmer. Similarly, they were ‘slightly unsatisfied’ and ‘slightly uncomfortable’ with their present thermal environment. This might be the reason of zinc sheets are radiative in nature and so the cold sensation as outdoor temperature drops. The mean comfort air temperature in the temporary shelter is 23.9 °C which is similar to globe temperature, radiant temperature and operative temperature. The mean clothing insulations of the study is 0.73 clo. The result showed that female clothing insulation is significantly higher than male clothing. The indoor and outdoor air temperatures are similar to each other during daytime in all four districts. Thus, the people are living under almost the same temperature conditions as outdoors. The majority of the respondents in the survey reported that they found their shelters to be extremely hot in summer and extremely cold in winter, and thus most of the respondents were unsatisfied and highly uncomfortable with their thermal environment.

Therefore, their preference is to make it warmer in winter and cooler in summer. The mean comfort temperatures estimated from the measured data set are 24.2 °C, 18.6 °C and 27.3 °C in autumn, winter and summer, respectively. Thus, the seasonal difference (8.7 °C) is considered to be due to clothing insulation as adaptive behavior of the respondents depending on the seasons. The regional mean comfort temperatures were found to range between 15.0 and 20.8 °C in winter and 24.2 and 28.6 °C in summer; thus the regional difference of comfort temperature is 5.8 °C in winter and 4.4 °C in summer. The comfort temperature was highly correlated with the outdoor air temperature. The tendency of estimated comfort temperature was quite sensitive to a change in outdoor air temperature in comparison with the previous studies. The thermal acceptance was higher than 90 %, if the respondents were asked directly; this was considered due to the survival from the disasters. The logistic-regression analysis applied to quantify the relationship between the thermal acceptance and indoor globe temperature revealed that 80 % of the people would accept the indoor thermal environment if the indoor globe temperature is higher than 11 °C in winter and lower than 30 °C in summer in temporary shelters.

6.3 Conclusions of chapter 4

Since the last big earthquake, 83 years have passed but there were no such historical records of victims and their living conditions. There is a need for good planning before any kinds of disasters to come in the future. For this reason, this study focused on the present conditions of temporary shelters built after earthquake 2015 and tried to identify the problems and the possibility of improvement. We have come to the following conclusions based on this study. The indoor air temperatures for all shelters are highly dependent on outdoor air temperature. Especially during nighttime, the indoor air temperatures were much lower than those during daytime. About 50 % of the nighttime remained below the lowest acceptable temperature, 11 °C, in the five shelters investigated. This must cause quite a serious problem in residents' health. The total heat loss coefficient per floor area needs to be reduced down to the range of 2 to 7 $W/(m^2 \cdot K)$ in order to realize the indoor air temperature well above 11 °C for 70 % of time during wintry night. The reduction of heat loss coefficient may be achieved by adding cellular polyethylene foam of 6 to 12 mm and clothes of 5 to 10 mm for the walls and roof of temporary shelters for the requirement of indoor air temperature higher than 11 °C for 70 % of the whole nocturnal hours. What has been found in this study should be hopefully applied to actual improvement of indoor thermal environment in existing shelters and also to the development of the possible preparation for the future disaster.

In overall, our research has found two important points. One is, based on field survey; we have found acceptable range at 11 °C for winter and 30 °C for summer. This acceptable range can be used for guidelines and standard of temporary shelters.

Another one is energy balance equation which we set for mathematically calculation for improving indoor thermal conditions. We could say that these applied methods are very important and unique point of our research.

6.4 Conclusions of chapter 5

Lacks of adequate consideration with regard to climatic conditions, locally available materials and on traditional skills, cultural and social issues, have been used for making temporary shelters in Nepal after massive earthquake 2015. In this chapter 5, we tried to analysis the how earthquake impacts on social life and other miscellaneous environmental factors. Most of people were indoors condition while earthquake occurred. People experience during earthquake occurred in that time they felt very strange and fear. Most of the people doomed to live in temporary shelters after Gorkha earthquake 2015. About 60 % of people were in inside the house while Gorkha earthquake occurred. More than 50 % of people were doing house hold work while earthquake occurred. People 'felt fear and strange' during earthquake happened. More than 50 % of houses were fully collapsed. More than 80 % of people shifted in temporary settlement. Other surrounding environmental seems very poor conditions during the staying in temporary settlement. People were not satisfied by the present living conditions. People used varieties of thermal adjustment to mitigate their discomfort.

6.5 Recommendations

Our study will be a first step towards the research having newly constructed buildings where we could find the seasonal standard of comfort temperature and seasonal range of indoor temperature. The value of the total energy use of the house would not relevant for the energy performance of the building because the energy use may vary depending on the lifestyle of the occupants, appliances installed in the house and so on. These findings would help to make thermally comfortable housing. This research is useful to impacting to various fields:

Occupants: This research will benefit to make thermally comfortable housing. People would know the actual indoor environmental conditions and how harsh those indoor environments are affects their daily living life as season change. It can be lead to further improvement in energy efficiency too.

This research will benefit to improve temporary shelters with comfort and satisfaction in their surroundings. They could understand and could compare their previous shelters and improve shelters and experience the indoor environmental conditions. They will notice that how harsh those indoor environments would affect their daily living life.

It will be benefit by using this study and implements this theory and make new thermally comfortable housing with useful applications for considering cost, time and size of family. It can get record of the newly constructed housing and establish the seasonal and regional comfort range of indoor temperature. This study helps to report the buildings envelope parameters as guidelines to ensure the thermally comfortably houses for future.

This research will benefit to improve temporary shelters with comfort and satisfaction in their surroundings. They could understand and could compare their previous shelters and improve shelters and experience the indoor environmental conditions. They will notice that how harsh those indoor environments would affect their daily living life.

This research will be fruitful to make the thermally comfortable housing designers in future construction and good reference for researchers in coming days.

This research can contribute not only in terms of academic research but also in planning at national and international level. This research would benefit to follow the research methodology and would get the future references.

6.6 Lesson learnt from Gorkha earthquake 2015

Things we should consider about awareness, preparedness as well as coordination among disaster management are most. In overall conclusions from this chapter, the lessons we learnt from the Gorkha earthquake, 2015 are as follows (Subedi and Poudyal Chhetri, 2019);

- Weak law enforcement and monitoring of building codes and town planning and lack of training for professionals in earthquake resistant construction practices have been found as the major factors of infrastructure damage; lack of adequate preparedness and response capacity among various stakeholders.
- The biggest lesson is that to be safe from earthquake is to build earthquake resistant infrastructures. There should be no "COMPROMISE" in building compliance.
- Arrangement of appropriate and essential equipment/s based on the nature of disaster can assist for the quick search and rescue works.
- Modern technology and strategic communication/risk mapping/satellite mapping/ earth observation are also important tools and techniques in reducing the disaster risks; and in life-saving. All most all casualties were due to the collapsed infrastructures. This emphasizes the need for strict compliance of town planning bye-laws and building codes in Nepal.

Here we should like to add some more relevant points which are really need to consider for near future;

A natural disaster will certainly strike in the near future; the problem is that nobody knows exactly when. Thus, we need to be prepared for future disaster. There are four stages of housing in the recovery process (Quarantelli, 1995):

1) Immediate relief (within hours);
2) Immediate shelter (within a day or two);
3) Temporary housing (preferably within weeks); and
4) Permanent housing reconstruction (probably within a few years).

In Nepal, the construction progress has been painfully slow for families who have now spent four winter and summer without proper shelter. Many live in makeshift huts, temporary shelters (built from zinc sheet) and also bamboo tents. Preparedness planning before the disaster is necessary to find the 'best-fit' solution for temporary accommodation. Preparedness planning includes understanding: pre-disaster vulnerabilities; regional and local issues; climate; long-term effects of temporary accommodation; project procurement, planning and construction time; permanent reconstruction strategy and timing; and location. Matching these planning considerations with a type or combination of types of temporary accommodation will produce the 'best-fit' solution (Cassidy, 2002). The following things need to be considering;

- Problems on the ground have been identifying related on temporary housing.

- Materials and skilled workers needed for constructing earthquake resistant infrastructures.
- Governments, NGOs and aid organizations must take decisions quickly and immediately after the disaster in order to offer critical aid to feed, shelter (Planning a strategy for temporary accommodation) and treat the victims of disaster.
- Understand the economic, social, environmental and cultural vulnerabilities that exist prior to the disaster.
- Adopt long-term and sustainable efforts to mitigate the hazards.
- Disaster management and risk reduction may be considered expensive in view of the competing demands for resources in a developing country.

Regional and local issues are also need to be considered:

- How many families may need temporary accommodation?
- What are the cultural peculiarities?
- What percentage of the population are renters? What percentage are landowners? Will they need land for temporary accommodation or do they already have land?
- Will people tend to migrate away from the disaster-affected area in search of jobs and housing?
- Governments, NGOs and aid organizations must have knowledge of the regional and local issues that are specific to the particular disaster situation.
- Temporary accommodation necessary must be based on the specific regional and local situations.
- The climate of the disaster-affected area is a determinant for the type of temporary accommodation. Thus, the chosen type of temporary accommodation must provide adequate shelter from the elements.

6.7 Future work

Indoor environment has a significant influence on our comfort, health and wellbeing given that we spend 80 ~ 90 % of our time indoor. Health is one of the most important aspects that are affected by thermal comfort. There are found many research related to indoor thermal environment and peoples' thermal comfort in traditional houses (Rijal et al. 2012, Bajracharya 2013, Gautam 2018) and temporary shelters (Thapa et al. 2018, 2019), however there is still gap in thermal comfort studies in relation to build newly constructed housing after earthquake 2015 in Nepal. The earthquake followed by large number of significant aftershocks has created awareness among the people for the construction of earthquake resistant houses. A large proportion of energy is used for thermal comfort in buildings. Energy is a key component in any overall sustainable development strategy, and it is important to monitor the effects of energy policy on thermal comfort in the social, economic and environmental dimensions (Chwieduk, 2003). Energy efficiency of the house and the thermal comfort offered to the occupants is directly connected with the proper design of the building envelope functions (Healy, 2002). In

Nepal, electricity is major energy source where solar is secondary source of energy use. There is also fire wood energy has been used in remote areas for making food and space heating. Nepal is vulnerable to earthquakes in multiple reasons: geographical condition, building structure, economic condition and awareness of people. In the case of earthquake 2015, all over 755,000 houses were damaged (Newly constructed buildings accessed on: 2019/8/24). These were mostly traditional stone-mud and brick-mud structures built. The majority of these houses were non-engineered with little consideration of seismic risks. The earthquake followed by large number of significant aftershocks has created awareness among the people for the construction of earthquake resistant houses. JICA (Japan International Cooperation Agency) supported the Government of Nepal to develop an earthquake-resistant construction guideline for the reconstruction of housing based on Nepal's existing earthquake-resistance standards, and has been extending training for homeowners and masons on earthquake resistant houses (Gautam 2015).

Now a day, newly constructed housing are rising in earthquake affected districts. We should consider that what kinds of housing provide comfortable and healthy environment and what is the impact in energy use from different practices. Thus, in order to evaluate the indoor thermal environment and peoples' comfort level based on household energy use; we need to conduct this research. We also need to focus on the housing function on thermal comfort such as in newly constructed buildings considering national curricula, guidelines and also manuals for training individuals with earthquake resistance. It can contribute to a better understanding of how thermal comfort is related to and affects the energy use and environmental issues involving social-economic and climate change. This could have significant impact on the built environment as well as the energy use rate.

Consequently, there is a time gap that needs to be bridged over, and temporary housing seems to be the obvious answer. This 'answer', however, immediately raises a set of difficult questions, calling for informed decision making regarding: (Cassidy 2006)

1) What kinds of temporary housing?
2) Where should it be obtained from and how paid for?
3) Where should it be put?
4) How long is it supposed to last?
5) What happens afterwards?

We would like to suggest for constructing temporary shelters in open places surrounding by greenery. Temporary shelters need to build by considering natural ventilation.

On the other hand, the temporary housing program need to provide safe and comfortable (inclusion of bathrooms and kitchen in the units and provided privacy for families).

There are also many concerns in relation to the issue of culture and temporary housing. Cultural issues become more important in the rural areas where families have needs for additional space for belongings, animals and kitchen gardens. In settlement design, the safety and comfort of elderly, women and children are very important.

Here we can see the as an example of shelters within surrounding environment (Fig. 6.1).

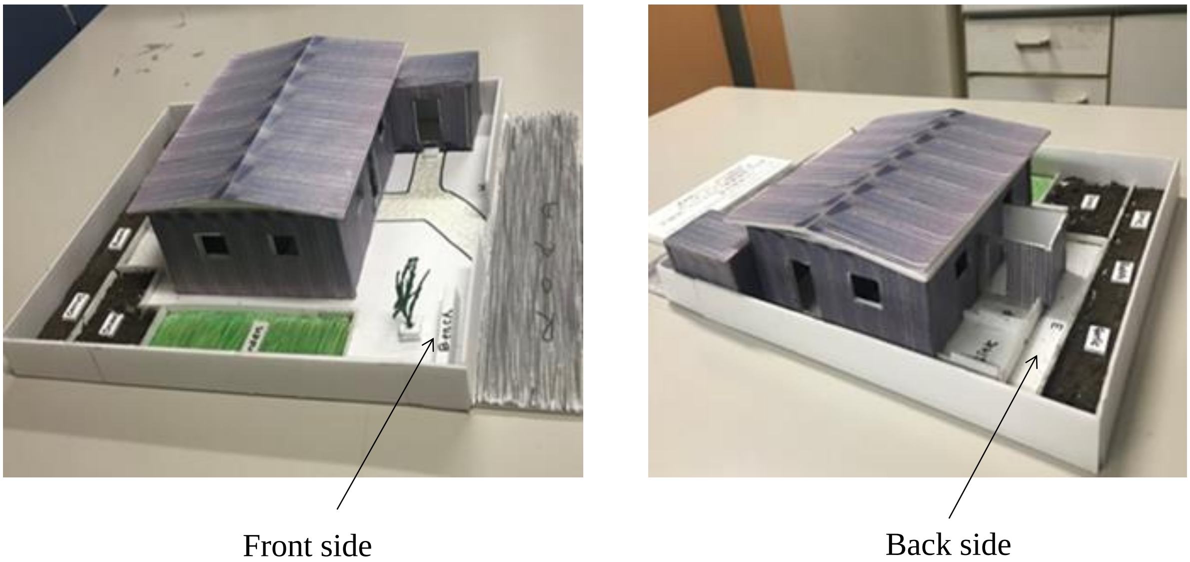


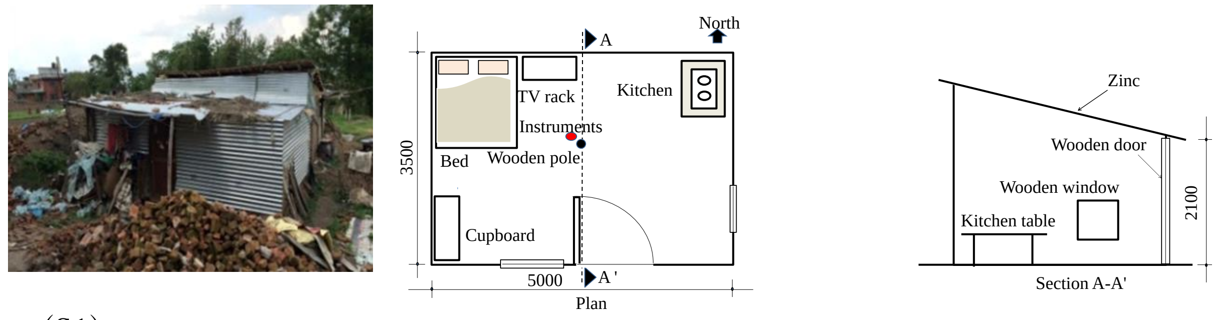
Fig. 6.1 As an example of improved temporary shelters.

Before improving the shelters, we need to consider the cost. Based on Table 4.1, here we are estimate the cost for S1.

Table 4.1 Description of investigated shelters in terms of heat transmission coefficient, total heat loss coefficient and heat capacity estimated.

S.C.	Wall area [m^2]	Roof area [m^2]	Floor area [m^2]	Total surface area (wall + roof) [m^2]	U_i for wall [$W/(m^2 \cdot K)$]	U_i for roof [$W/(m^2 \cdot K)$]	Total heat loss coefficient [W/K]	Total heat loss coefficient per floor area [$W/(m^2 \cdot K)$]	Total heat loss coefficient per surface area [$W/(m^2 \cdot K)$]	$C\rho V$ [kJ/K]	$C\rho V$ per floor area, [$kJ/(m^2 \cdot K)$]
S1	35.7	17.5	17.5	53.2	5.6	1.2	220.9	12.6	4.2	1918	109.6

Area	Materials
Wall	Cellular polyethylene foam, Tarpaulin sheet
Roof	Straw, Cellular polyethylene foam, fabric



(S1)

Fig. 6.2 Photo, plan and sectional view of the five temporary shelter: S1. The unit of length is mm. In sectional view, zinc sheets alone are shown.

Table 6.8 Estimated cost before improving considering following things:

Materials	Quantity	Price NRS	Remarks
Zinc sheet (12 Feet)	20 piece	21000	(12*2.5) Feet
Bamboo	10 piece	3000	
Nail (1 Inch)	2 kg	500	
G.I. wire (0.5 Inch)	5 kg	1000	
Window (Wood)	2 piece	3000	(3*2) Feet
Door (Wood)	1 piece	2500	(5*3) Feet
Wage	4 people	4000	per person 1000 per day
Estimated time	1 day		
	Total	35000	

Table 6.9 Estimated shelters by considering (adding) following things:

Materials	Quantity	Price NRS	Remarks
Cellular polyethylene foam (Indoor wall and ceiling) (12 mm)	29 piece	7250	(6*4) Feet (29*250=7250)
Tarpaulin sheet (Outdoor wall) (2 mm)	20 piece	6000	(6*4) Feet (20*300=6000)
Fabric (Celling) (10 mm)	9 piece	2700	(6*4) Feet (9*300=2700)
Straw (60 mm)	10 role	500	L=3 Feet (10*50=500)
Wage	2 people	2000	per person 1000 per day
Estimated time	1 day		
	Total	18450	

Note: Price would be slightly vary according to time and place, 100 USD = 11400 NRs.

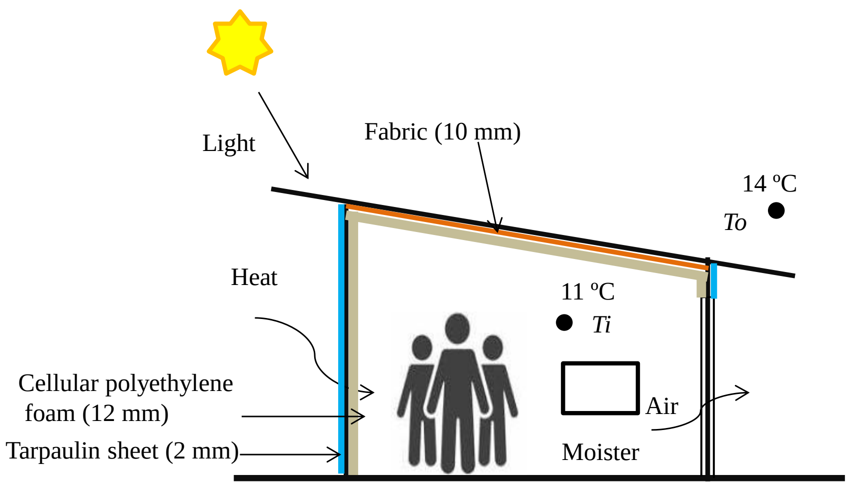


Fig. 6.3 Require materials in order to keep the indoor air temperature should be acceptable at 1111ºC for 70 % of the whole nocturnal hours.

6.8 Past research related to research plan

I would like to continue my past research as a part of my research continuously in future. As much as possible I would like to do following research together with what I purposed in above section. As we know in emergency situations, it is important to provide shelters to protect the population and the support against their environment and give them privacy. Nepalese government does neither have such recovery centers nor has future planning, and failed to save the earthquake affected people from monsoon rain, cold winter and hot summer [Koirala, 2015]. Government must need to know the condition of temporary shelters, which affects people's health for living in shelters for a long period of time. The materials used of temporary shelters are mostly zinc sheet which are good conductor materials as well as environmentally and ecologically sound.

I would conduct the field experiments survey to examine the real condition of temporary shelters for one year. I will set one improve shelter as can be seen in Fig. 6.3 (Additional insulating materials added for improving shelter suggested by previous research of Thapa et al. 2019) and see the one-year trend of indoor temperature variation.

I would compare the results of our previous study (simulated result) [Thapa et al. 2019] together with field experiment results. It will be important to collect the information that how people adapt to the outdoor temperature in their daily living life. It may be required that we need to explain them by behavioral, psychological, physiological and environmental adaptation. Then I should be able to write research paper on the basis of result comes from analysis, with literature review, discussion with other studies and forward to the conclusion.

6.9 Propose research plan

For experiment, research area would be chosen for Lalitpur (Fig. 2.1). We will request to local people (earthquake victims) to live one year for those improved shelter. We will conduct the seasonal thermal comfort survey together continues measurement (Table 2.3). I will set the digital instruments indoor for summer and winter measurement. That data logger records the indoor thermal parameters at the interval of 10 minute.

Additionally, I would also provide the awareness preparedness program during the field visit in Nepal related about future disasters. Based on our research, I will also provide some creative and innovative ideas to build thermally comfort temporary shelters by using maximum local materials with low cost, short period and use local manpower with the fusion of hi-tech technology in climatic variations (seasonal change) and size of family. This study helps us to quantify the necessities of victim’s desires. After that, we could be able to provide require improvements as well as discussion with government to provide thermally comfortable for future disaster.

6.10 Expected results and impacts

These findings would help to make thermally comfortable shelters for future disaster. This research is useful to impacting to various fields:

1. Occupants: This research will benefit to improve temporary shelters with comfort and satisfaction in their surroundings. They could understand and could compare their previous shelters and improve shelters and experience the indoor environmental conditions. They will notice that how harsh those indoor environments would affect their daily living life.
2. Government: This research will benefit to improve temporary shelters with comfort and satisfaction in their surroundings. They could understand and could compare their previous shelters and improve shelters and experience the indoor environmental conditions. They will notice that how harsh those indoor environments would affect their daily living life.
3. Researcher: This research will be fruitful to make the thermally comfortable shelters designers in future construction and good reference for researchers in coming days.
4. Academics: This research can contribute not only in terms of academic research but also in planning at national and international level. This research would benefit to follow the research methodology and would get the future references.

References

Abulnour A., The post-disaster temporary dwelling: Fundamentals of provision, design and construction, HBRC Journal. 10 (2014) 10–24.

Albadra D., M. Vellei, D. Coley, J. Hart, Thermal comfort in desert refugee camps: An interdisciplinary approach, Jordan. Building and Environment 124 (2017) 460–477.

Albadra D., et al., Thermal comfort in desert refugee camps: An interdisciplinary approach, Jordan. Building and Environment. 124 (2017) 460–477.

Amnesty International Nepal. Earthquake Recovery Must Safeguard Human Rights. London; 2015. pp. 1-21. Available from: https:// www.amnestyusa.org/wp-content/ uploads/2017/04/p4583_report_-_nepal_report_on_earthquake_web. pdf_-_adobe_acrobat_pro.pdf, Appl. Therm. Eng. 82 (2015) 110–119.

Arslan H., Cosgun N., Reuse and recycle potentials of the temporary houses after occupancy: Example of Duzce, Turkey, Building and Environment. 43 (2008) 702-709.

Asefi M., Sirus F.A., Transformable shelter: Evaluation and new architectural design proposals, Procedia Social and Behavioral Sciences. 51 (2012) 961-966.

Bajracharya S.B., Investigation of thermal environment of the traditional houses of Kathmandu valley. AIJ Kanto Chapter Architectural Research Meeting. (2013)141-144.

Bajracharya S.B., The thermal performance of traditional residential buildings in Kathmandu valley, J. Inst. Eng. 10 (2013) 172–183.

Berlaer Van G., Staes T., Danschutter D., Ackermans R., Zannini S., Rossi G., et al. Disaster preparedness and response improvement: comparison of the 2010 Haiti earthquake-related diagnoses with baseline medical data. European Journal of Emergency Medicine. 2017; 24(5):382.

Bhujel R., Efforts made by government in post-earthquake reconstruction and recovery 2015. Research Gate. Lalitpur; 2017. DOI: 10.13140/RG.2.2.25158.27204. Available from: https://www.researchgate.net/ publication/317716970

Brager G.S., de Dear R.J., Thermal adaptation in the built environment: a literature review, Energy Build. 27 (1) (1998) 83–96.

Cassidy J., 2002, What the big deal about temporary housing? Planning consideration for temporary accommodation after disaster: Example of the 1999, Turkish earthquake. 2002

Cassidy J., Impacts of prefabricated temporary housing after disasters: 1999 Earthquakes in Turkey, Habitat International. 31 (1) (2007) 36–52.

Cassidy J., Lizarralde G., and Gavidson C.H., A systems view of temporary housing projects in post disaster reconstruction, Construction Management and Economics (April 2006) 24, 367–378.

Cassidy J., Strategic planning for post-disaster temporary housing, Article in Disasters 3I (4) (2007) 435–458.

Chen P.-T., Yao G.C., Yu C., Liu L.-F., Wen J.-H., and Huang C.-H., 2014. A comparison of residents' satisfaction with temporary housing: A case study of two temporary housing types in southern Taiwan. J. Chinese Institute of Engineers, 37 (5): 635-642.

Chwieduk D., Towards sustainable-energy buildings. Applied Energy, 76, 76:211-7, 2003.

Cornaro C., Sapori D., Bucci F., Pierro M., Thermal performance analysis of an emergency shelter using dynamic building simulation, Energy and Buildings. 88 (2015), 122-134.

de Dear R.J., Brager G.S., Thermal comfort in naturally ventilated buildings: revisions to ASHRAE standard 55, Energy Build. 34 (2002) 549–561.

Earthquake-Report.com, http://earthquake-report.com/wp-content/uploads/2015/04/Screen-Shot-2015-04-28-at-12 35.14.png, Accessed: 12 September, 2016,

European Committee for Standardization (CEN), EN 15251: 2007-08, Indoor Environment Input Parameters of Design Energy Performance of Buildings Addressing. Indoor Air Quality, Thermal Environment, Lighting and Acoustics, Committee European de Normalization, Brussels. (2007).

Fanger P.O., Thermal Comfort, Danish Technical Press, Copenhagen, 1970.

Felix D., J.M. Branco, A. Feio, Temporary housing after disaster: A state of the art survey, Habitat International. 40 (2013) 136-141.

FEMA (Federal Emergency Management Agency), 2009. Disaster housing plan, https://www.fema.gov/pdf/emergency/disasterhousing/FEMA2009HousingPlan.pdf (2009).

Gautam B., Rijal H.B., Shukuya M., Imagawa H., A field investigation on the wintry thermal comfort and clothing adjustment of residents in traditional Nepalese houses, 26, 100886, 2019.

Gautam D., Bhetwal K.K., Hugo R., Neupane P., Yasushi S., Observed damage patterns on buildings during 2015 Gorkha (Nepal) Earthquake, Center for disaster and climate change studies, Nepal, 2015.

Government of Nepal, Ministry of Home Affairs. Presented: National position paper on disaster risk reduction and management Nepal. (018). 03-06 July 2018. Ulaanbaatar, Mongolia; 2018. p. 1

Government of Nepal, National Planning Commission (NPC). Nepal Earthquake 2015-Post Disaster Needs Assessment; key findings. Kathmandu. p. 98. Vol. A. Available from: https://www.nepalhousingreconstruction.org/sites/nuh/files/2017-03/PDNA%20 Volume%20A%20Final.pdf

Griffiths I.D., 1990. Thermal comfort in buildings with passive solar features: Field studies. Report to the Commission of the European Communities. EN3S-090 UK: University of Surrey, Guildford.

Han J., Zhang G., Zhang Q., Zhang J., Liu J., Tian L., Zheng C., Hao J., Lin J., Liu Y., Moschandreas D.J., Han J., Zhang G., Zhang Q., Zhang J., Liu J., Tian L., Zheng C., Hao J., Lin J., Liu Y., Moschandreas D.J., Field study on occupants' thermal comfort and residential. Building and Environment; 42 (2007) 4043-4050.

Havenith G., Ergonomics of the thermal environment estimation of the thermal insulation and evaporative resistance of a clothing ensemble. ISO 9920, 2003.

Healy J.D., Clinch J.P, Fuel poverty, thermal comfort and occupancy: results of a national household-survey in Ireland. Applied Energy; (73) (2002) 329–43.

H.M.G, of Nepal. Climatological records of Nepal: Ministry of science and technology, Department of Hydrology and Meteorology, Kathmandu, 1991-1994.

https://www.jica.go.jp/english/news/field/2017/20180309_01.htmlNewlyconstructed buildings_Accessed on: 2019/8/24

https://www.goodvibeadventure.com/people-and-language-in-nepal.html, Accessed on: 2020/3/2

Huang L., Long E., Ouyang J., Measurement of the thermal environment in temporary settlements with high building density after 2008, Wenchuan earthquake in China, Procedia Engineering. 121 (2015) 95–100.

Humphreys M.A., Nicol J.F., Outdoor temperature and indoor thermal comfort: Rising the precision of the relationship for the 1998 ASHRAE database of field studies, ASHARE Trans. 106 (2) (2000) 485–492.

Humphreys M.A., Outdoor temperature and comfort indoors. Building Research and Practice. Journal of CIB. 6 (2) (1978) 92–105.

Humphreys M.A., Rijal H.B., and Nicol J.F., Updating the adaptive relation between climate and comfort indoors; new insights and an extended database. Building and Environment, 63 (5) (2013) 40-55.

Healy J.D., Clinch J.P., Fuel poverty, thermal comfort and occupancy: results of a national household-survey in Ireland, Applied Energy. 73, pp. 329-343, 2002.

Indraganti M., Ooka R., Rijal H.B., Thermal comfort and acceptability in offices in Japan and India: A comparative analysis, The Society of Heating, Air-conditioning and Sanitary Engineers of Japan (SHASE). Annual Conference, (2014) 17–20.

Indraganti M., Ooka R., Rijal H.B., Thermal comfort in offices in India: behavioral adaptation and the effect of age and gender, Energy & Buildings (103) (2015) 284–295.

Indraganti M., Using the adaptive model of thermal comfort for obtaining indoor neutral temperature: findings from a field study in Hyderabad, India, Build. Environ. 45 (2010) 519–536.

Japanese Society of Mechanical Engineers (JSME), Data book of Heat transfer, (1987) pp. 319.

Jiuping X., Yi L., Meta-synthesis pattern of post-disaster recovery and reconstruction: based on actual investigation on 2008 Wenchuan earthquake, Nat hazards. 60 (2012) 199–222.

Kimura K., Minka no shizen energy gijutsu (Transalated by authors: Natural energy technology of Japanese traditional house). Shokokusha, (2011), p. 42.

Koirala J., Government failure in disaster management; Evidence from Nepal earthquake. Author Orcid: (2015) Org/0000-0001-6711-828x 1–5.

Nobuo M., Kazuya Y., Seiki K., Hiromune Y., So K., Damage from the great east Japan earthquake and tsunami: A quick report, Mitigation and Adaptation Strategies for Global Change. 16 (2011) 803–818.

Ponni M., Basker R., A study on indoor temperature and comfort temperature, International Journal of Engineering Science International Journal of Engineering Science. 4 (3) (2015) 7–14.

Sagiroglu M., Memari A.M., learning from the experiences of using different types of temporary housing systems. 42 IAHS world congress, The housing for the dignity of mankind, Italy. (2018).

Shukuya M., Bio-climatology for built environment, CRC press, (2019) pp. 143, 254–258.

Manandhar S., Francis M., The official journal of the international association of lowland technology, Special issuee on: Nepal earthquake & disaster ISSN, 18 (2) (2016) 1344–9556. measurement and application of a multilayer insulator for emergency architecture,

Meteorological observatory, H.M.G, of Nepal. Climatological records of Nepal, Ministry of science and technology, Department of Hydrology and Meteorology, Kathmandu, 2015.

Meteorological observatory: H.M.G, of Nepal. Climatological records of Nepal: Ministry of Science and Technology, Department of Hydrology and meteorology Kathmandu, 2017.

Mohammad T., Martin T., Stanley K., Andy van den D., A review into thermal comfort in buildings, Renewable and Sustainable Energy Reviews. 26 (2013) 201–215.

Motra G.B., Performance of building during Gorkha earthquake 2015 and recent trends of repair/rehabilitation works. Department of civil engineering, Pulchowk campus, Nepal, Proceeding of IOE Graduate Conference, 2015, 1–5.

National Society for Earthquake Technology (NSET), Earthquake Preparedness hand Book, (2014).

Nicol J.F., Roaf S., Pioneering new indoor temperature standards: The Pakistan project, Energy & Buildings. 23 (1996) 169–174.

Nicol J. F., Jamy G.N., Sykes O., Humphreys M.A., Roaf S., Hancock M., A survey of thermal comfort in Pakistan toward new indoor temperature standards, Oxford Brookes University, School of Architecture, 1994.

Nicol J.F., and Humphreys M.A., Adaptive thermal comfort and sustainable thermal standards for buildings. Energy and Buildings (34) (2002) 563-572.

Nicol J.F., Humphreys M.A., A stochastic approach to thermal comfort: Occupant behavior and energy use in buildings, ASHRAE transactions 110 (2) (2004) 554–568.

Nicol J.F., Raja I.A., Allaudin A., Jamy G.N., Climatic variations in comfortable temperatures: The Pakistan projects, Energy Build. 30 (1999) 261–279.

Nicol J.F., Temperature and adaptive comfort in heated, cooled and free-running dwellings, Build. Res. Inf. 45 (7) (2017) 730–744.

Obyn S., Moeseke van G., Virgo V., Thermal performance of shelter modelling: Improvement of temporary structures, Energy and Buildings. 89 (2015) 170–182.

Ogawa H., Building Management Education Center, Tokyo, 15-17 (1999).

Olshansky R.B., Johnson L.A., and Topping K.C. 2006. Rebuilding communities following disaster: Lessons from Kobe and Los Angeles. Built Environment, 32 (4): 354-374.

Oseland N.A., A comparison of the predicted and reported thermal sensation vote in home winter and summer, Energy Build. 21 (1994) 45–54.

Quarantelli E.L., Patterns of sheltering and housing in US disaster, Disaster Prevention and Management. 4 (3) (1995) 43-53.

Rijal H.B., Humphreys M.A., Nicol J.F., Towards an adaptive model for thermal comfort in Japanese offices, Build. Res. Inf. 45 (7) (2017) 717–729.

Rijal H.B., Thermal improvements of the traditional houses in Nepal for the sustainable building design, Journal of the Human-Environment System. 15 (1) (2012) 1–11.

Rijal H.B., Yoshida H., Umemiya N., Seasonal and regional differences in neutral temperatures in Nepalese traditional vernacular houses, Building and Environment. 45 (12) (2010) 2743-2753.

Rijal H.B., Yoshida H., Winter thermal comfort of residents in the Himalaya region of Nepal, Proceedings of International Conference on Comfort and Energy Use in Buildings - Getting them Right, 27–30 April 2006, Windsor, U.K.

Rijal, H.B., Yoshida, H., 2002. Comparison of summer and winter thermal environment in traditional vernacular houses in several areas of Nepal, Advances in Building Technology, 2: 1359–1366.

Rijal, H.B., and Yoshida, H., 2005. Winter thermal improvement of a traditional house of Nepal. Building simulation, Ninth International IBPSA Conference, Montreal, Canada, 1035-1042.

Salvalai G., Imperadori M., Scaccabarozzi D., Pusceddu C., Thermal performance measurement and application of a multilayer insulator for emergency architecture, Applied Thermal Engineering. 82 (2015) 110-119.

Sanderson D., A. Sharma, J. Kennedey, J. Burnell, Lost in transaction: Principals, practice and lessons from Haiti for urban post-disaster shelter recovery programs, Asian J. Environ. Disaster Manag. 6 (2) (2014) 131–151.

Shinohara N., Tokumura M., Kazama M., Yonemoto Y., Yoshioka M., Kagi N., Hasegawa K., Yoshino H., Yanagi U., Indoor air quality and thermal comfort in temporary houses occupied after the great east Japan earthquake. Indoor Air. 24 (2014) 425-437.

Shrestha S., Bajracharya A.R., Bajracharya L., Shrestha N., Maharjan M., Earthquake damage assessment in the traditional town of Sankhu, Kathmandu, J. Inst. Eng. 12 (1) (2016) 27–38.

Shukuya M., Exergy-Theory and applications in the built environment, Springer, (2013) pp. 161–162.

Silva J.D., Quality and standards in post-disaster shelter, The Structural Engineer. (2007) 25–32.

Song Y., Mithraratne N., Zhang H., Life-time performance of post-disaster temporary housing: A case study in Nanjing, Energy and Buildings. 128 (2016) 394–404.

Subedi S and Poudyal Chhetri M.B., 2019, Impacts of the 2015 Gorkha Earthquake: Lessons Learnt from Nepal, DOI: http://dx.doi.org/10.5772/intechopen.85322,(http://creativecommons.org/licenses/by/3.0)

Thorsson S., Lindberg F., Eliasson I., Holmer B., Differenr methods for estimating the mean radiant temperature in an outdoor urban setting, Int. J. Climatol. 27 (2007) 1983–1993.

Ying Y., Enshen L., Yuan S., Hongxing Y., Assessing the thermal performance of temporary shelters, Procedia Engineering 159 (2016) 174–178.

Yu Y., Long E., Shen Y., Yang H., Assessing the thermal performance of temporary shelters, Procedia Engineering. 159 (2016) 174–178.

"What is Water Vapor?". Retrieved February, 10, 2020. https://weatherstreet.com/weatherquestions/What_is_water_vapor.htm

Appendix

"Gorkha Earthquake 2015: Social life and environmental factors"

Questionnaires_2015/2016

1. Detail Informations

Sheet no:

1.1 Name: ………………………………

1.2 Sex: Male ☐ Female ☐

1.3 Age: ………………..

1.4 Number of family: ………….

1.5 Address: ……………………….

2. The condition during the earthquake shakes 2015

2.1 Where were you living while earthquake occurred? : ……………………………………………

2.2 What were you doing while earthquake occurred? : ……………………………………………..

2.3 What you have experienced during earthquake occurred? : ……………………………………………….

(A) What your expression after earthquake? Please select one of them:

1. Very happy ☐
2. Fine ☐
3. Not so happy ☐
4. Very sad ☐

3.1 About damage your house condition; please select one of them.

1. Overall ☐
2. Half ☐
3. 4 in 1 ☐
4. Little ☐
5. Very scratch ☐
6. Little scratch ☐
7. Not at all ☐

3.2 Now, where are you living? Please select one of them.

1. Own house

2. Dhansar (Store house)
3. Cowshed
4. Tent
5. Temporary shelter

3.3 What types of goods were damaged? Please list them.

1. House hold goods: ……………………………………………………………………………………….
2. Please mention the price of predicated damage in Rs: ……………………………………………..
3. Name the list of cattle were died: ……………………………………………………………………..
   (If not mention just "No")
4. How much money did you lose from these cattle? ……………………………………………….
5. The name of damaged food grains: ………………………………………………………………..
6. What could be the cost of damaged food grains? ………………………………………………

(B) Are you satisfied after earthquake settlement? Please select one of them:

1. Very satisfied ☐
2. Fine ☐
3. Not fully satisfied ☐
4. Not at all ☐

4. About Health

4.1 Now, are you sick?

1. Yes ☐ 2. No ☐

(If you are sick, please mention the name of disease: ....

4.2 Now, are you still suffering from earthquake injuries?

1. Yes ☐ 2. No ☐

4.3 If you are injured then please mention the date by choosing one of the options;

1. Before 25th April ☐ 2. On 25th April ☐

3. After 26th April ☐

4.4 After 25th April, how many times did you visit the hospital? And also did you get the chance to check up?

1. Visit hospital: ………. 2. Chance to check up: ……………..

4.5 Have you felt tried (Mentally and physically)? Please select one of them;

1. No tried ☐ 2. Very tried ☐

3. Fine ☐ 4. Feeling tried ☐

5. Very tried ☐

4.6 Now are you feeling well?

1. Very healthy ☐ 2. Healthy ☐

3. Not healthy ☐ 4. Very bad ☐

5. About Pollution

5.1 Do you worry about pollution; please check (√) the following Table.

	1. Very worry	2. Slightly worry	3. Not so much worry	Not at all
Outdoor air pollution				
Garbage				
Sound pollution				
Drinking water				
Toilet				
Drainage system				
Electricity				

5.2 Do your family use toilet? Please select one of them;

1. Every day ☐ 2. Usually ☐

3. Not sure ☐ 4. Sometimes not use ☐

5. Never use ☐

6. About Environment

6.1 How about hotness and coldness during staying in this condition? Please select one of them;

1. Very cold ☐ 2. Cold ☐

3. Slightly cold ☐ 4. Neutral ☐

5. Slightly hot ☐

6. Hot

7. Very hot

6.2 How do you feel the humidity of the air? Please select one of them;

1. Very dry
2. Dry
3. Slightly dry
4. Neutral
5.Slightly humid
6. Humid
7. Very humid

6.3 How do you feel the quality of the air? Please select one of them;

1. Very good
2. Good
3. Slightly bad
4. Bad
5. Very bad

6.4 How do you feel the sound pollution? Please select one of them;

1. Very piece
2. Peace
3. Slightly Peace
4. Slightly crowed
5. Crowed
6. Very crowed

6.5 How do you feel the lighting condition? Please select one of them;

1. Very dark
2. Dark
3. Slightly dark
4. Bright
5. Slightly bright
6. Highly bright

7. Very bright

6.6 Have you felt fear during nighttime? For example, somebody throw the stone, thieves and drunkard people. Please select one of them;

1. Very frightened
2. Fine
3. No fear
4. Not at all

6.7 How do you feel the privacy? For example, you do not want to show valuable things and own behaviors to public. Please select one of them;

1. Very good
2. Yes, ok
3. Just ok
4. Never
5. Not at all

6.8 How do you feel the satisfaction? Please select one of them;

1. Very satisfied
2. Satisfied
3. Slightly satisfied
4. Slightly unsatisfied
5. Slightly satisfied

7. Daily living life

7.1 How many times did you take a meal in a day? …………………………………..

7.2 Have you take a balance food?

1. Yes
2. No

7.3 Is there is enough foods for eating?

1. Yes
2. No

7.4 Is there shop for buying goods?

1. Yes ☐ 2. No ☐

3. Little far ☐

7.5 Do your family have enough clothes?

1. Yes ☐ 2. No ☐

7.6 What do you use to keep your body comfortable during hot and cold weather/ condition? ....

7.7 Is there the facility of electricity? Please select one of them;

1. Yes, as it is ☐ 2. Yes, but little lower than before ☐

2. Not at all ☐

7.8 Do you use mobile phone?

1. Yes, as it is ☐ 2. Yes, but little lower than before ☐

3. Not at all ☐ 4. I donot have ☐

7.9 How did you know about the earthquake? Which media, please select by them;

1. By people talking ☐ 2. Radio ☐

3. TV ☐ 4. Newspaper ☐

5. Internet ☐ 6. No news from anywhere ☐

7.10 Now weather is changing, so, what kinds of planning are in your thought to mitigate such climatic conditions?……………………………………………………………………………………………

7.11 Is there anything hampering your son and daughters' study? Please select by them;

1. Damage the school ☐ 2. Lost the books ☐

3. There is no place for study in home ☐ 4. No money for buying copy and pencil ☐

5. Others ☐

8. About economic and work

8.1 Is there any effects on agriculture due to this earthquake?

1. Very bad effects ☐ 2. Minor Effects ☐

3. Its fine ☐ 4. No more effects ☐

5. Not at all ☐

If effects please mention the causes: …………………………………………………………………………….

8.2 Now what types of relief do you need? Please select three of them.

1. To construct new buildings ☐ 2. To construct new school ☐

3. To buy new books, copy and pencil ☐ 4.To buy food grains ☐

5. Other: ……………………………………………………………………………………………………

8.3 What are the things that make you feel worried for future? :………………………………………………..

8.4 How much cost, time do you need for constructing new buildings?

1. 1 month ☐ 2. 3 months ☐

3. 6 month ☐ 4. 1 year ☐

5. 3 year ☐

6. 5 Year ☐

7. More than 5 year ☐

Estimated amount: ………………………………………………………..

Publication Lists

(with review):

1. Thapa R., Rijal H.B.: Study on thermal environment and thermal comfort in autumn season of temporary shelters in Nepal after massive earthquake 2015, Lowland Technology International, vol.18 (2), pp. 119-128.

   (Available on: 28th, September, 2016)

2. Thapa R., Rijal H.B., Shukuya. M.: Field study on acceptable indoor temperature in temporary shelters built in Nepal after massive earthquake 2015, Building and Environment, vol. 135, pp. 330-343.

   (Available on: 7th, March, 2018)

3. Thapa R., Rijal H.B., Shukuya M., Imagawa H.: Study on wintry thermal improvement of makeshift shelters built after Nepal earthquake 2015, Energy and Buildings, 199, pp. 62-71.

   (Available on: 14th, June, 2019)

4. Thapa R., Rijal H.B.: Study on thermal comfort in temporary shelters in Nepal after massive earthquake 2015 The Seventh Nepal Academy of Science and Technology (NAST), Khumaltar, Lalitpur, Nepal, Abstract, p. 214. (2016.3)

5. Thapa R., Rijal H.B., Shukuya M.: Study on the summer thermal comfort in temporary shelters in Nepal after massive earthquake 2015, 17th Conference of the Science Council of Asia (SCA), Philippine International Convection Centre, Philippines. 14th-16th, June, 2017

6. Thapa R., Rijal H.B., Shukuya M., Imagawa H.: Study on regional thermal performance of temporary shelters built in Nepal after massive earthquake 2015, 18th Conference of the Science Council of Asia (SCA), Science Council of Japan (SCJ), Tokyo, Japan. 5th-7th, December, 2018

7. Thapa R., Rijal H.B., Shukuya M.: Evaluation of seasonal thermal environment of temporary shelters built in Nepal after massive earthquake 2015, The 10th Windsor Conference: Re-thinking comfort, Cumberland Lodge, Windsor, UK pp. 1202-1209. 12th-15th, April, 2018
8. Thapa R., Rijal H.B., Shukuya M.: Evaluation of seasonal indoor environment: The case study of temporary shelters built in Nepal after massive earthquake 2015, Grand Renewable Energy Yokohama, Japan, 17th-22th, June, 2018
9. Thapa R., Rijal H.B., Shukuya M., Imagawa H.: Study on winter indoor thermal environment of temporary shelters built in Nepal after massive earthquake, 4th International conference RETRUD, conference in Nepal, Kathmandu. 29th-31st, October, 2018
10. Thapa R., Rijal H.B., Shukuya M, Imagawa H.: Study on winter indoor thermal environment of temporary shelters built in Nepal after massive earthquake 2015, SBE19 Tokyo, Built Environment in an area of climate change, Venue: The University of Tokyo, Komaba Campus. 6th-8th, August, 2019
11. Thapa R., Rijal H.B.: Evaluation of thermal environment of the temporary shelter of Nepal after massive earthquake 2015, The NEAJ/NESAJ Symposium 2016 on Technologies and Development Policies, University of Tokyo, Komaba, Research Campus June 18th, 2016

Publications (without review):

12. Thapa R., Rijal H.B., Shukuya M.: Study on thermal comfort in temporary shelters build in Nepal after massive earthquake 2015, Abstract, Asia University (NEAJ/NESAJ Symposium), July 8th, 2017
13. Thapa R., Rijal H.B., Shukuya M., Hikaru I.: Field study on acceptable indoor temperature and wintry thermal improvement of makeshift shelters built after Nepal earthquake 2015, The NEAJ Symposium 2019, University of Tokyo, Komaba, Research Campus July 13th, 2019
14. Thapa R., Rijal H.B.: A thermal comfort survey in temporary shelters in Nepal after massive earthquake, 2015, AIJ Kanto Chapter Architectural Research Meeting, vol. 86, pp. 93- 96. 2016.3
15. Thapa R., Rijal H.B.: Study on thermal comfort and comfort temperature in temporary shelters in Nepal after massive earthquake 2015, AIJ Summaries of Technical Papers of Annual Meeting, Fukuoka, pp. 265- 266. 2016.8
16. Thapa R., Rijal H.B., Shukuya M.: Winter thermal comfort survey in temporary shelters in Nepal after massive earthquake 2015, AIJ Kanto Chapter Architectural Research Meeting, pp. 253-256. 2017.2
17. Thapa R., Rijal H.B., Shukuya M.: Comparison of Wintry indoor air temperature in temporary shelter in Nepal after massive earthquake 2015, AIJ Summaries of Technical Papers of Annual Meeting, Hiroshima, pp. 515-516. 2017.9
18. Thapa R., Rijal H.B., Shukuya M.: Evaluation of summer thermal environment of temporary shelters built in Nepal after massive earthquake 2015, AIJ Kanto Chapter Architectural Research Meeting, pp. 13- 14. 2018.3

19. Thapa R., Rijal H.B., Shukuya M.: Evaluation of seasonal and regional indoor air temperature of different types of temporary shelters built in Nepal after massive earthquake 2015, AIJ Summaries of Technical Papers of Annual Meeting, Sendai, pp. 543-544. 2018.9
20. Thapa R., Rijal H.B., Shukuya M, Imagawa H.: An investigation of thermal characteristics of temporary shelters in Nepal during wintry night time, AIJ Kanto Chapter Architectural Research Meeting, pp. 71-72. 2019.3
21. Thapa R., Rijal H.B., Shukuya M, Imagawa H.: Evaluation of summer indoor conditions of makeshift temporary shelters built after Nepal earthquake 2015, AIJ Summaries of Technical Papers of Annual Meeting, Kanazawa, pp. 381-382.2019.9
22. Shrestha M., Rijal H.B., Thapa R.: Literature review in various climates and thermal comfort survey in Nepalese schools, SHASE (The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan), pp. 5-8. 2017.9
23. Thapa R., Rijal H.B., Shakya L., Imagawa H.: Gorkha earthquake 2015: Its impacts on social life and environmental factors, AIJ Kanto Chapter Architectural Research Meeting, pp. 25-28. 2020.3

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Research Title

Study on Thermal Environment and Adaptive Thermal Comfort of the Occupants in Temporary Shelters in Nepal after Massive Earthquake

(ネパール大地震後の仮設住宅における温熱環境と熱的快適性に関する研究)

PROFESSIONAL EXPERIENCE

Research Assistant (Japan) 04/2017 - 03/2020

Responsibilities:

- Conduct thermal comfort field survey
- Prepare data and information
- Perform data analysis by excel and performed statistical data analysis using SPSS software

Teacher (Nepal) 06/2007 – 03/2014

Responsibilities:

- Taught Social studies in secondary level (Main subject)
- Taught computer in lower secondary level (Optional subject)

EDUCATION

Bachelor Degree of Education **2004 – 2007**

(Major of Population dynamic and foundation of health)

Sanothimi Campus, Tribhuvan University of Nepal

Master of Humanities and Social Science **2008 - 2011**

(Major of model of society and research methodology)

Thesis: "Study on Social, cultural and economic status of low ethnic group of Danuwar in Lalitpur district of Nepal".

Patan Multiple Campus, Tribhuvan university of Nepal

PhD of Environmental and Information Studies **2016 – 2020**

(PhD. Study on Thermal Environment and Adaptive Thermal Comfort of the Occupants in Temporary Shelters in Nepal after Massive Earthquake)

Tokyo City University, Japan

ADDITIONAL SKILLS

Languages

English : Business level

Hindi : Conventional level

Japanese : N2

Computer Knowledge : (Microsoft office package)

Statistical operation : SPSS software

Hobby

- Watching animated movies, Group discussion
- Drawing, Dance
- Visiting and observing developing countries (to gather knowledge about what kinds of researches are in needed and try to purpose the require improvement for making peoples' thermally comfortable in their respective built environment.)

Licenses

Teaching license for secondary level (Nepal)

Member **2016~**

Earth Tree Organization, Japan

Visiting junior high school of Japan once a year and conducting "Nepal work shop" and introducing Nepalese social life, cultural and sharing my research activities.

Award **07/2017**
Best doctoral presentation award

Scholarship: Heiwa Nakajima (PhD)
04/2019~09/2019
Foundation, Japan