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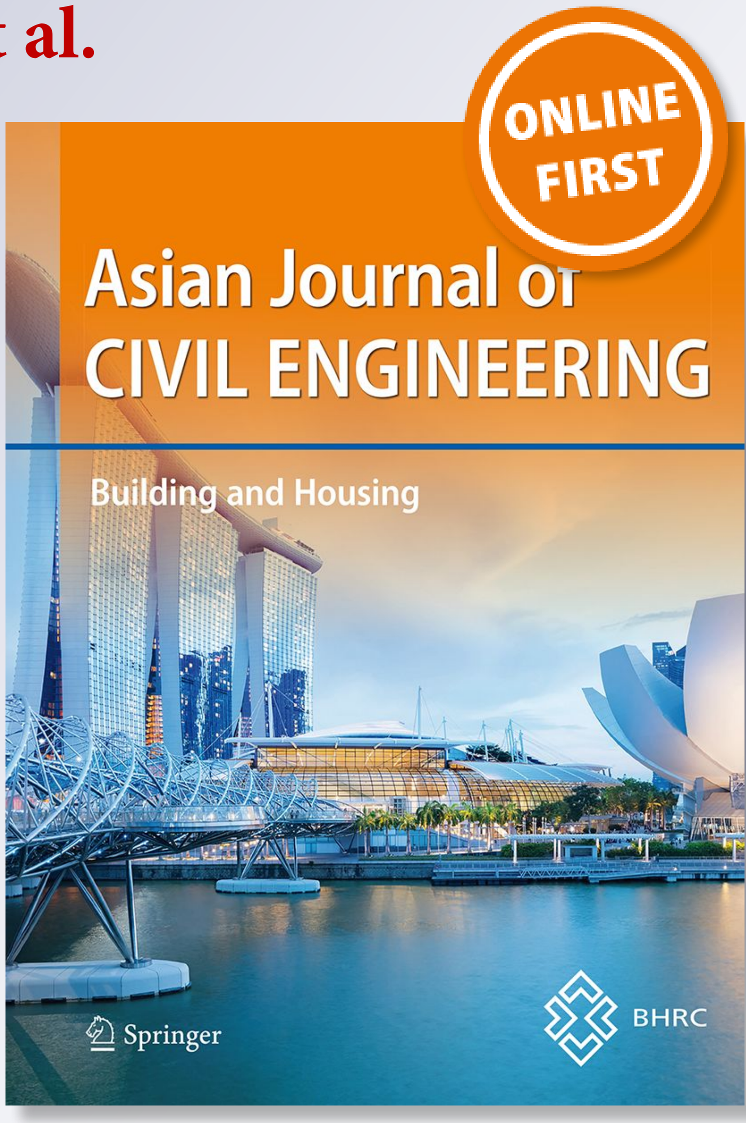

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ORIGINAL PAPER

An engineering approach towards the traditional beliefs in house construction

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Abstract

Although modern society is at the apex of science and technology, the shadows of traditional customs and beliefs in various fields can be seen. When the field of house construction is considered, traditional beliefs had been playing a considerable role which can be seen in Asian countries rather than European countries. Since hardly any engineering-based studies have been done to explore the significance of traditional beliefs in house construction, this paper tends to fill that gap and widen the thinking pattern of the society. The study reveals that 68% of stakeholders of house construction keep faith in traditional beliefs, while 32% do not. Among them, 81% accept not having three or more aligned openings in dwellings, 80.5% believe that it is not favourable to place ridge plate, beam or any load on top of the openings, 75.2% say that more west-facing windows are not suitable for houses while 65.7% say that west-facing verandas and balconies are not suitable for houses and 73.3% believe that using cross-walls for brick walls must be neglected. With respect to the engineering experiments done, not using cross-walls in brick wall construction was proven to be false with respect to the structural testing. Not having ridge plate, beam or any load on top of the openings was proven to be negligible in the presence of reinforced concrete (RC) lintel. But not having three or more aligned openings and not using west-facing verandas, balconies and more windows were accepted based on computational fluid dynamic (CFD) analysis and general explanations based on thermal comfort and structural behaviour of door and window frames. Hence, hasty neglection of traditional beliefs in house constructions by labelling them as superstitions should be changed. The acceptance or rejection of aforesaid beliefs has to be done with respect to the rational content of them, but not being blind slaves of them wasting both money and time.

Keywords Traditional beliefs in house construction · Superstitions in house construction · Feng shui · Vastu shastra · Cross-walls · West-facing houses · Aligned openings

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Introduction

Not only human beings but also all living beings from the tiniest insect which can hardly be seen with the naked eye to gargantuan creatures use safer places to live for mainly being protected from adverse climate changes and enemy attacks (Chandra et al. 2017). With the passage of time, the power of thinking of human beings gradually improved and made them superior to other beings and the master of them (Nehru 1930; Morris 1996, 1999). At the initial stage of human civilization, people used sheltered places like caves, dens and huts made on top of the trees as their dwellings. Eventually, people were nourished by the knowledge and attitude gained from nature. Then, they shifted their primary living places to well-prepared dwellings which were much more suitable for day-to-day lifestyle. These developed dwellings were called houses which are a place always suitable for human beings to live comfortably and a place that ensures an excellent balance between people and nature which brings about peace, happiness, health, wealth and prosperity to the inmates of the house (Patra 2006).

The house is the place where any family spends the most important, precious and valuable time of their lives. But it may not be the place where people spend the majority of hours of the day. For instance, doctors spend more than half a day at the hospitals, engineers spend weeks, months and years at their working sites and the professors spend most of their time at the universities. But none of those places are houses to any of them. Since the house is the place where people spend the most precious times of their lives with beloved family members, houses are considered sacred places like a shrine (Kithsiri 1995; Bhanumathie 1995). Hence, people have been making a huge effort to build their dream house that matches with each and every desire of them and their family members.

To achieve the goal of a properly built dwelling, people have been using various types of knowledge sources such as civil engineering and architectural knowledge as well as traditional knowledge in house construction (Chandra et al. 2017). Development of science and technology have influenced people to use civil engineering and architectural concepts for construction activities which refer to the science of construction, built environment, designation of space, creation and construction of the space required for making the day-to-day lives of people easy (Koranteng et al. 2015; Ulusoy and Kuyrukcu 2012).

Although construction materials such as concrete, cement blocks and bricks have been used from ages ago, modern technology seeks ways of improving the materials to make them more comfortable. In this phase, techniques such as building thermal insulation (Nandapala and Halwatura 2016; Chandra et al. 2019; Nandapala et al. 2018a; b; Silva and Chandra 2019), development of mew masonry concepts and sustainable building materials (Dehgan et al. 2018; Arooz et al. 2008, 2017, 2018; Jayathunge et al. 2019) and building information modelling (BIM) (Arunkumar et al. 2018) play a major role. Although the science and technology is in an extremely higher standard in the contemporary period, the shadows of traditional customs and beliefs can be seen in the fields such as building construction, town and country planning, as well as medicine. Thus, people have not totally abandoned their customs and beliefs in house construction, which are based on different fields like ancient architecture, astronomy, vastu shastra and feng shui (Chandra et al. 2011a, b, 2018). These beliefs in house construction have affected the lives of the people, have spread throughout society and have been lasting for years and years. And they continue to remain albeit with slight changes proving that they are inveterate in the society (Frenando 1998).

Almost all the customs and beliefs in building construction were nourished by vastu shastra, feng shui and various religious considerations of the society (Ranawaka Leelananda 2015). Vastu shastra which belongs to the period 1500–1000 BC is an ancient Indian knowledge as well as a science of architecture, planning and designing (Patra 2006). The word vastu originally was derived from the keyword "vas" that meant dwell or dwelling place (Arya 2000; Patra 2009). Hence, the term vastu conveys a place of human dwelling of more than a single household life. Feng shui is an ancient Chinese wisdom which literally means "wind and water" and it has influenced the layout and the design of cities and buildings (Koranteng et al. 2015; Huang 2012). The origination of feng shui was in China, then it spread to the western countries and can be seen all around the world now (Mak and Nag 2005).

The customs and beliefs which have been utilized in the field of house construction differ with respect to the climatic, religious and cultural parameters (Acharya 1946). Some of them have been labelled as superstitions and rejected by the society. But a considerable amount of them were transferred from generation to generation with slight differences and are still in practice. The superstitious influence in these beliefs can be a part of cosmology and myths such as para-religious and religious practices and beliefs embraced by people (Chandra et al. 2017). People are scared of these beliefs thinking that not obeying them would bring terrible results ending in death (Glazer 1978; Ofori et al. 2016; Rudski 2003). The most important thing is not "what other people believe" but "what is the rational basis of the beliefs and how they can be used in the real world". Hence, it is better to understand the rationality of these beliefs and use them in practical situations for the fruitfulness of the world.

A number of architectural and sociological studies have been done and explanations have been given for the traditional beliefs in house construction (Sarkar 2010; Chakrabarti 1998). But any deep investigation in terms of engineering and scientific context regarding the customs and beliefs in house construction can hardly be found. Therefore, it is necessary to launch a deep study as well as an analysis regarding these customs and beliefs and their engineering significance. When a civil engineer has a sound knowledge of these customs and beliefs as well as modern engineering technology, he would be able to cater a huge service to the society.

Structure of the article

The arrangement of the article is as mentioned below:

Section "Main objectives" contains the main objectives and specific objectives of the study.

Section "Identifying the most commonly used traditional beliefs in house construction and the reasons for admitting them" presents identification of the most commonly used traditional beliefs in house construction and the reasons for admitting them.

Section "Engineering approach towards key traditional beliefs in house construction" presents the approach towards the interpretation of the most commonly used traditional beliefs in house construction with respect to standard engineering experiments.

Section "Conclusions" contains the main conclusions which were achieved based on the current study.

Section "Recommendations and future works" describes the recommendations based on the current study and possible future works which can be done as extensions of the contemporary study.

Main objectives

The ultimate objective of the study is to analyse the behaviour of traditional beliefs in house construction with the aid of modern engineering technology and to discuss how meaningful beliefs can be used in modern construction fruitfully. The specific objectives are as listed below.

Specific objectives

- To identify the most commonly used traditional beliefs in house construction and the reasons for admitting them.
- To provide rational interpretations to the key beliefs using engineering technology.

Identifying the most commonly used traditional beliefs in house construction and the reasons for admitting them

Methodology adapted

The information regarding the commonly used traditional beliefs in the field of house construction was gathered from literature data of vastu shastra- and feng shui-related books, journals, newspaper articles and interviews which was done with the main stakeholders of house construction and ordinary citizens.

A detailed questionnaire survey was provided to the main stakeholders of house construction: civil engineers, architects, astrologers (experts of vastu shastra and feng shui), carpenters and masons covering all cultural, religious and locational variations of Sri Lanka. The questionnaire was carried out covering 75 in each category.

Most popular traditional beliefs in house construction were identified by means of the questionnaire and the reasons for the acceptance or withdrawal of them were identified. Then, the traditional beliefs which were of significant importance and needed to be analysed using the engineering technology were sorted out.

Results

Seven main traditional beliefs regarding house construction were identified and they are as listed below (Chandra et al. 2017; Ranawaka Leelananda 2015: Dayarathna 2010; Amarasooriya 2016);

- Not using cross-walls for brick wall construction.
- Not having three or more aligned openings (doors and arches) in the same row.
- Not disturbing the exact centre place of the house and the land plot.
- Not having more windows to the western direction.
- Not having west-facing verandas or balconies.
- Not having ridge plate, beam, etc., on top of the openings (doors, arches and windows).
- Not erecting walls, foundation, etc., on top of the ceremonial foundation stone.

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The usage of aforesaid beliefs was assessed by means of the questionnaire which was conducted in 2018. The questionnaire survey revealed that 68% of people believe in traditional concepts in house construction and 32% do not. This can be seen in Fig. 1.

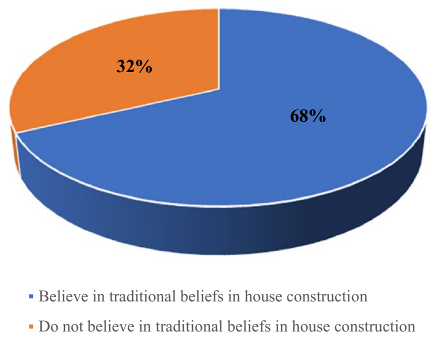


Fig. 1 Percentage of acceptance and withdrawal of traditional beliefs in house construction with respect to the whole sample

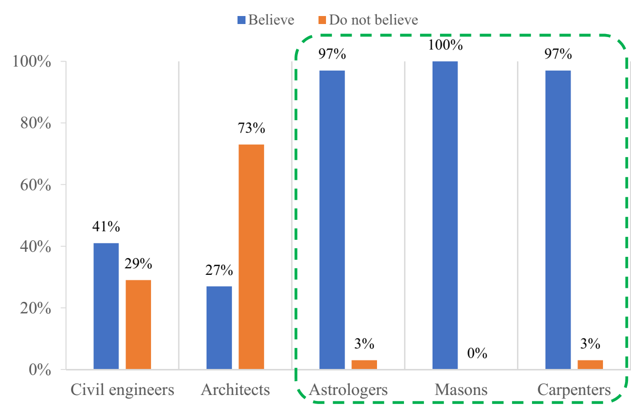


Fig. 2 Percentage of acceptance and withdrawal of traditional beliefs in house construction with respect to each category

Specifically, 61% of civil engineers, 27% of architects, 97% of astrologers, 100% of masons and 97% of carpenters have kept their faith in the traditional beliefs in house construction. The scenario is shown in Fig. 2.

In the questionnaire, some respondents have kept their faith in more than one belief and have mentioned more than one reason for admitting them. Each and every response was considered and the most commonly used beliefs among the society were sorted out; the ranking of them is as shown in Fig. 3.

The first five beliefs were the most popular in contemporary society. Out of them, not having more windows to the western direction and not having west-facing verandas and balconies were categorized together as, not having west-facing verandas, balconies and more west-facing windows.

Further, the reasons for embracing the selected beliefs were arranged with respect to the questionnaire results. Considering each response, the reasons for the acceptance of each belief were arranged as a percentage of each category.

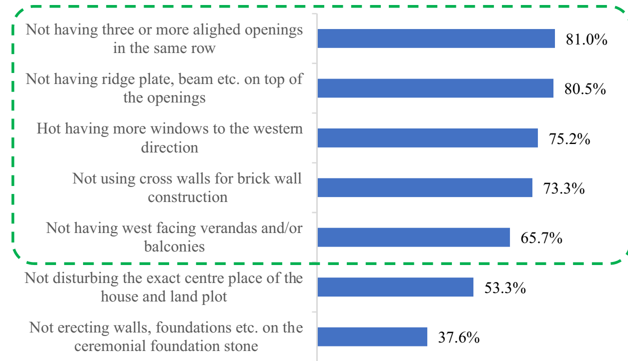


Fig. 3 The descending order of the beliefs in house construction with respect to the whole questionnaire results

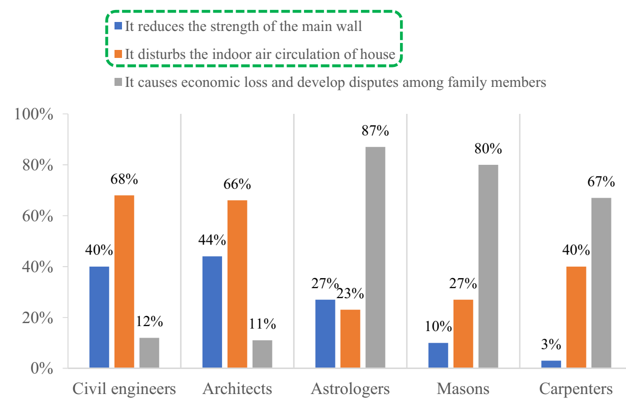


Fig. 4 Reasons for the acceptance of not having three or more aligned openings in the same row

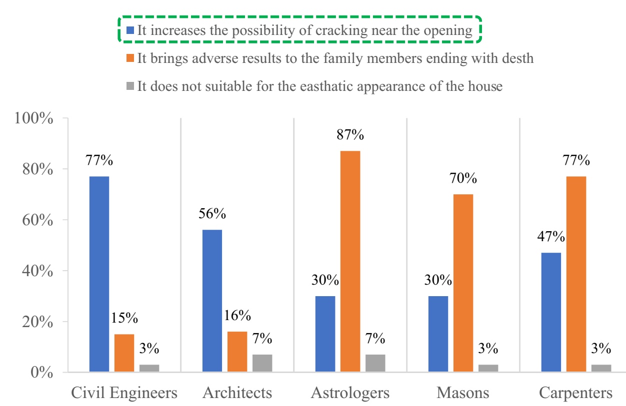


Fig. 5 Reasons for the acceptance of not having ridge plate, beam, etc., on top of the openings

The reasons for the acceptance of not having three or more aligned openings in the same row are as shown in the graph in Fig. 4.

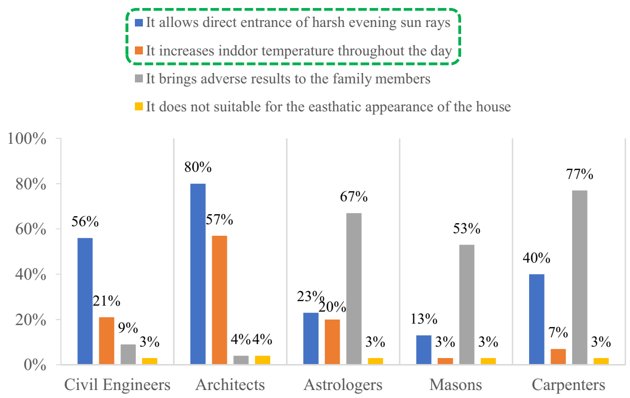


Fig. 6 Reasons for the acceptance of not having west-facing verandas, balconies and more west-facing windows

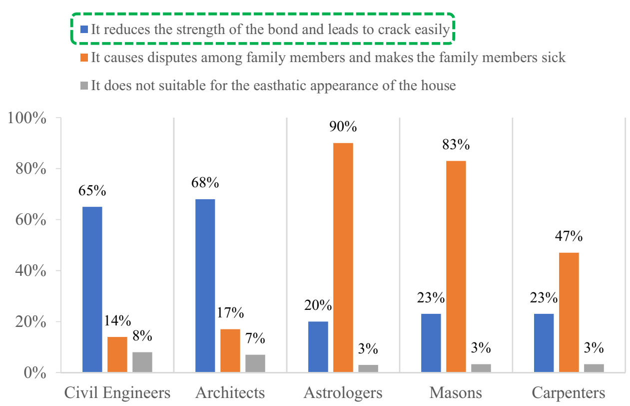


Fig. 7 Reasons for accepting not using cross-walls for brick wall constructions

The reasons for the acceptance of not having ridge plate, beam, etc., on top of the openings are as shown in the graph in Fig. 5.

The reasons for the acceptance of not having west-facing verandas, balconies and more west-facing windows are as shown in the graph in Fig. 6.

The reasons for the acceptance of not using cross-walls for brick wall constructions are as shown in the graph in Fig. 7.

Interpretations based on results

Among the sample of 375 stakeholders, civil engineers and architects were graduates in the fields of civil engineering and architecture and some had doctorates also. Some of the astrologers were graduates in arts subjects and the educational status of rest of them were in between ordinary level and advanced level, but the masons or carpenters would have hardly gone through at least secondary education. This reveals that civil engineers and architects are the people in the selected sample who have been nourished with theoretical as well as practical knowledge in the field of house construction. Hence, they have found the explanation to the considered traditional beliefs with respect to their technical knowledge. The highest percentage of highlighted responses, which have rational explanations in Figs. 4, 5, 6 and 7 was given by civil engineers and architects. Astrologers, masons and carpenters are responsible for the other unhighlighted responses which are based on the knowledge that were transferred from generation to generation mainly nourished by vastu shastra and feng shui.

Figure 2 clearly indicates that almost all the astrologers, masons and carpenters kept their faith in traditional beliefs in house construction. But being blind slaves of these beliefs will lead to the loss of both precious money and time. For an instance, the responses of majority of the astrologers, masons and carpenters indicate that not trusting the traditional beliefs will cause an economic loss in the family, will develop disputes among family members, will make family members regularly sick and will cause adverse effects ending in death. But, they are not providing any rational value and completely depend on the occult behaviour of vastu shastra and feng shui (Chandra et al. 2017; Ofori et al. 2016; Coote 1883; Ranjeet et al. 2016). The best option is choosing the traditional beliefs with significant importance and using them in real-world applications considering the rational explanations for accepting them.

Engineering approach towards key traditional beliefs in house construction

As shown in Fig. 2, not having three or more aligned openings in the same row, not having ridge plate, beam, etc., on top of the openings, not having west-facing balconies, verandas or more west-facing windows and not using cross-wells for brick wall construction are some of the most commonly used traditional beliefs in house construction. Hence, they were selected to be investigated with respect to engineering technology.

The approach towards "not having three or more aligned openings in the same row"

Methodology adapted

The models with aligned and non-aligned openings are as shown in Fig. 8.

The reasons for not having three or more aligned openings in the same row were gathered using field interviews and different literature sources such as journal articles, books and local newspaper articles (Chandra et al. 2017; Ranawaka Leelananda 2015; Sarkar 2010; Dayarathna

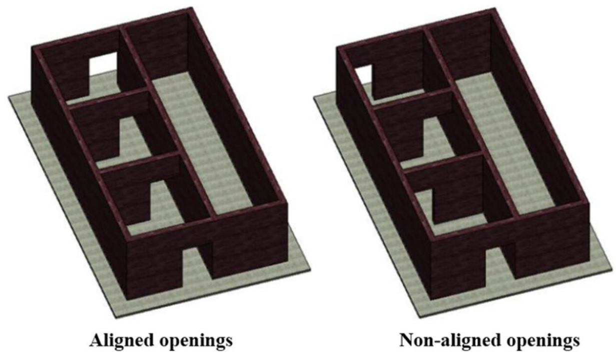


Fig. 8 A model with aligned openings and a model with non-aligned openings

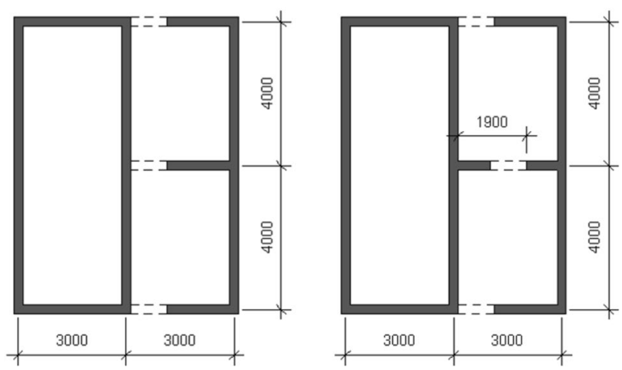


Fig. 9 Models with 4 m spacing between each opening

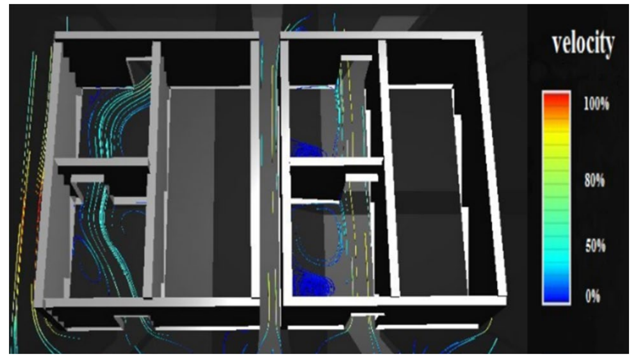


Fig. 10 Indoor air circulation with respect to 1 m/s wind velocity

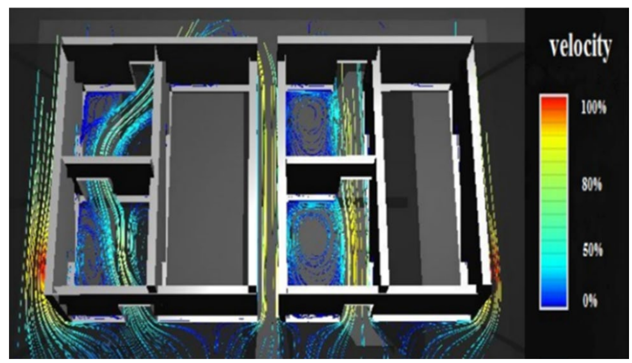


Fig. 11 Indoor air circulation with respect to 14 m/s wind velocity

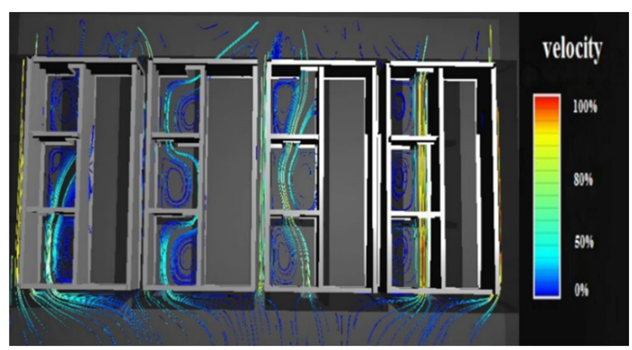


Fig. 12 Indoor air circulation of a model with four openings with respect to 4 m/s wind velocity

2010; Amarasooriya 2016). The most common cases were accessed with respect to the questionnaire survey. The results are as shown in Fig. 4.

Among them, only two reasons, reduction of the main wall strength and disturbance to the indoor air circulation had certain scientific backing. The most opted reason, causing an indoor air circulation issue was further investigated using Autodesk flow design and computational fluid dynamics (CFD) software. The analysis was done with respect to various wind velocities that lie between 1 and 14 m/s which cover the minimum and maximum wind range of Sri Lanka (Wind Colombo, Wind speed Sri Lanka, Weather Online 2016; World Weather, Local Weather Forecast 2016). Based on the general arrangements of dwellings, room sizes are 10 m × 12 m, 12 m × 14 m, 13 m × 15 m and the opening sizes are about 1.2 m × 2 m. The computer simulation was done representing aforesaid scenarios and a plan view of the sample model is as shown in Fig. 9.

Results

The experiment was done for wind velocities from 1 to 14 m/s using the models having 3 m, 3.5 m, 4 m and 4.5 m space between each opening. The indoor air circulation status of the models with three openings having 4 m spacing between two openings with respect to 1 m/s and 14 m/s wind velocities is as shown in Figs. 10 and 11.

Further, the indoor air circulation status of the models with four openings with 4 m spacing between two openings with respect to 4 m/s wind velocity was accessed. The scenario is as shown in Fig. 12.

Interpretation based on results

When the openings are aligned in a row, flow lines rushed through the openings and resulted in a lack of airflow in other spaces. Since flow lines with sufficient wind speed hardly circulate through other spaces of the house, those places become less ventilated.

When the openings are not aligned, flow lines get obstructed by walls and circulate with turbidity. It allows the circulation of flow lines with more than 50% of the original wind velocity to other spaces. Since the flow lines sufficiently circulate through other spaces of the house as well as through the openings, the whole house becomes properly ventilated.

When wind speeds approach higher values, some amount of flow lines circulate through other spaces even when the openings are aligned, but it is not a satisfactory situation which can be compared with air circulation when the openings are not aligned.

When there are more than three openings, the results are clearly verified. Flow lines with considerable velocities can be seen in every part of the model when the openings are not aligned. But when the openings are aligned, a rush stream of flow lines can be seen through aligned openings and flow lines which can be seen in other the spaces of the house contain nearly zero velocity.

The approach towards "Not having ridge plate, beam, etc., on top of the openings"

Methodology adapted

The view of the main door under the roof ridge and a door exactly under a beam is as shown in Fig. 13.

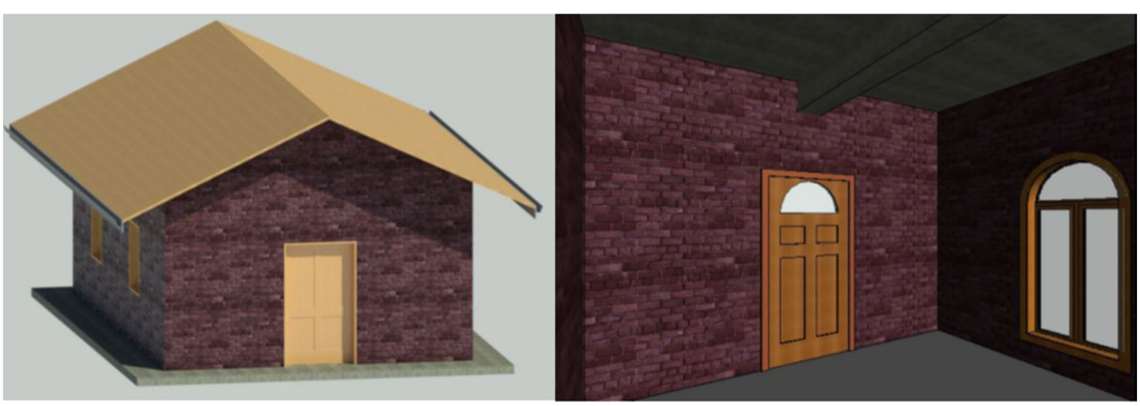
Similar to the previously described case in Sect. "The approach towards "Not having ridge plate, beam, etc., on top of the openings"", here also the main reasons for the adaption of the belief were lined up using a questionnaire survey. The outcomes are as shown in Fig. 5. The one and only response which had a rational explanation "increasing the possibility of cracking near the openings" was further investigated using the finite element modelling (FEM) software SAP2000.

For the FEM, a model with a plan area of 3.6 m × 5.0 m with an opening of 1.2 m × 2.2 m was selected considering the general room and opening sizes of a house. The model was prepared with 250-mm-thick membrane wall of brick masonry having a unit weight of 22 kN/m^3, elasticity modulus of 1×10^6 N/mm^2 and 0.3 Poisson's ratio. The FEM model was meshed into 0.2 m × 0.2 m meshing. The general 3D view and the model which was used in FEM are as shown in Fig. 14.

According to the structural calculations based on British standards (BS8110), the uniformly distributed roof load (UDL) acting on the ridge plate is about 3.5 kN/m. Hence, considering even the worst aspects loads from 3 to 7.5 kN/m within 0.5 kN/m intervals were used for the analysis. The loading was done for the three scenarios as shown in Fig. 15 such as, load is acting above the exact centre of the opening (1), the load is acting eccentric from the exact centre of the opening (2) and the load is acting away from the centre of the opening (c). Maximum compressive force (F22) which represents the maximum compressive stress at the critical regions of the openings was separately recorded with respect to the three loading scenarios and loading from 3 to 7.5 kN/m.

Results

Under the loading, critical stresses were observed near the regions marked in Fig. 16.



Main door under the ridge | There is a beam on top of a door

Fig. 13 Main door exactly under the roof ridge and a door under a beam

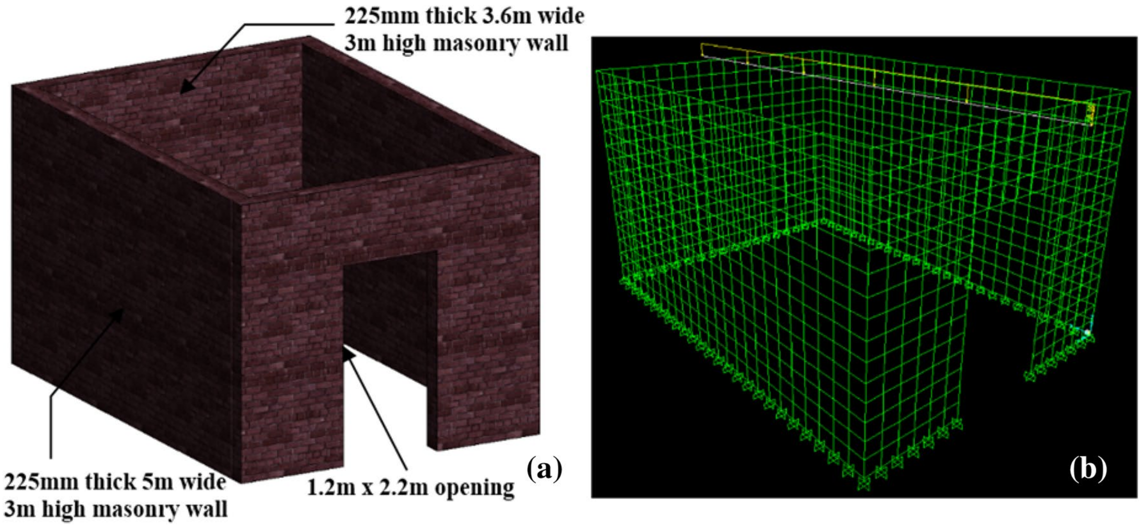


Fig. 14 3D view (**a**) and the analytical view (**b**) of the considered model

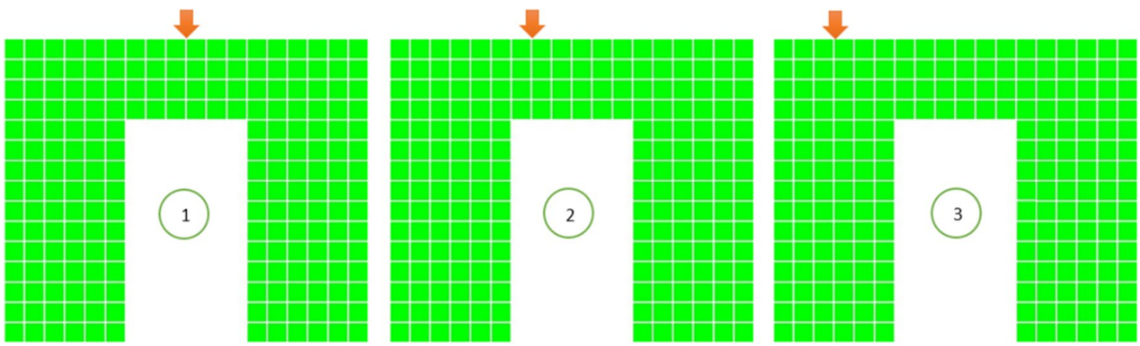


Fig. 15 Loads above the exact centre of the opening (**a**), loads act eccentric from the centre of the opening (**b**), load act away from the centre of the opening (**c**)

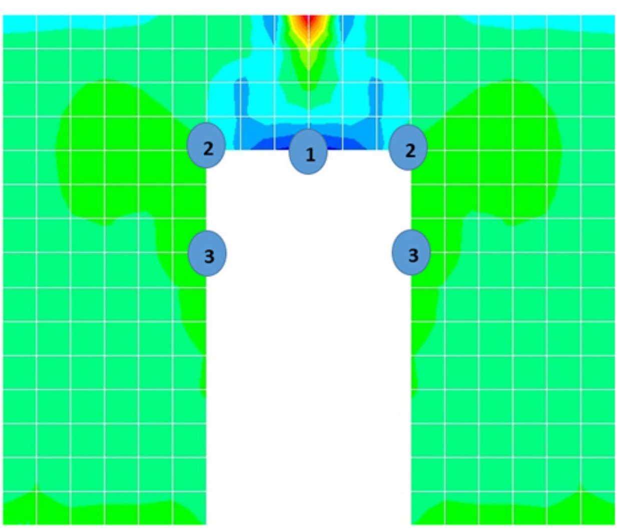


Fig. 16 Regions where the highest stress values were observed

Scatter diagrams which represent the maximum compressive force vs applied load when the loads acted at the exact centre point, eccentric from the centre and away from the centre are as shown in Fig. 17.

Since the maximum compressive force was observed due to the eccentric loads from the exact centre of the openings, the investigation was extended to figure out the exact loading point which provides the maximum stress. For that, 4kN/m load was applied from the exact centre place of the opening to the corner of one edge of the opening. The results are as shown in Fig. 18.

Interpretation based on results

The structural effect of having a beam or a ridge plate on top of the openings is the load transformation through the openings. The belief says not to place beam, ridge plate or any loading member exactly above the centre of the opening.

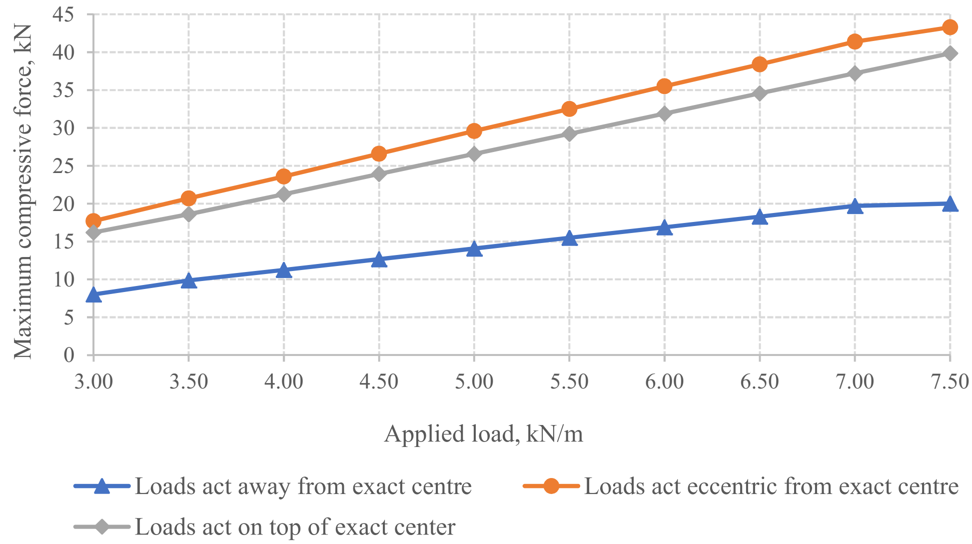


Fig. 17 Compressive force at critical regions of openings vs applied load

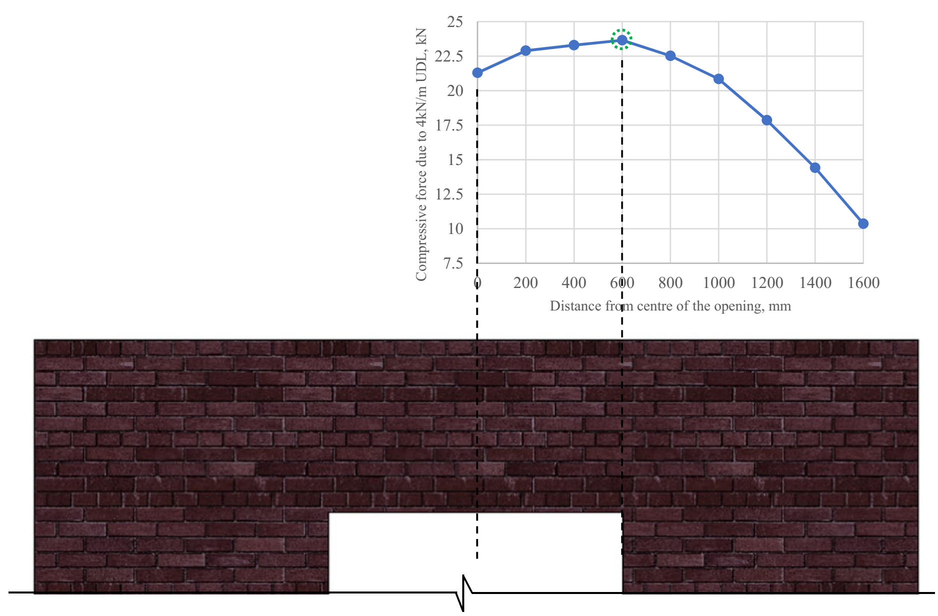


Fig. 18 The variance of compressive force vs distance from the centre of the opening due to 4 kN/m UDL

But as shown in Fig. 18, FEM results clearly show that the maximum stress develops near the openings when the load acts at the edge of the opening. Further, the intensity of the stresses decreases when the load gets away from one edge of the opening. But in the presence of reinforced lintel (RC lintel), no excessive stresses will be attributed to the openings.

The approach towards "Not having west-facing balconies, verandas or more west-facing windows"

For this aspect, no engineering experiment was adapted, since the scenario could be explained with general knowledge. In most of the houses, verandas and balconies are not placed facing to the western direction and hardly any west-facing window is used. The belief says, when the verandas, balconies or windows are placed facing west, it will adversely affect the family members by making them easy victims of illnesses, creating mortal accident situations, etc. It is very obvious that these explanations cannot be given any engineering rationale. But, the rule should have certain hidden meanings.

Usually, family members get together at evening and spend their leisure time in balconies and verandas. But when those verandas and balconies are west-facing, harsh evening sun rays will disturb the people who spend time in those places. And also, when the window frames are made of timber, they may be severely twisted due to the harsh evening sun rays. And also, evening sun rays enter the house through west-facing windows creating a warm building interior. It causes a thermally discomfort condition inside the house even during late evening hours making the inmates uncomfortable.

The approach towards "Not using cross-walls for brick wall construction"

Methodology adapted

The appearance of a brick wall with a cross-wall and a brick wall without a cross-wall is as shown in Fig. 19.

Among the responses of the questionnaire, the rational reason for not using cross-walls for brick wall constructions is the reduction of the strength of the bond leading it to be cracked easily. To check the structural behaviour of cross-wall junctions and non-cross-wall junctions, previously done test results (Weerasinghe et al. 2011) by one of the authors were used.

In this study, bricks which were manufactured satisfying the SLS 39:1978(2) were used, with mortar joint of 15 mm thickness and 1:6 cement–sand ratio that had been selected according to the BS 5628-1:1992; Table 1. Test panels of seven bricks long and ten bricks high as shown in Fig. 20 were selected according to the BS 5628-1:1992, Appendix A.2.2 which mentions "panels should be from 1.2 to 1.8 m in length with a minimum cross-sectional area of 0.125 m^2 and from 2.4 to 2.7 m in height. But, in special cases, it is required to test panels having dimensions outside these limits".

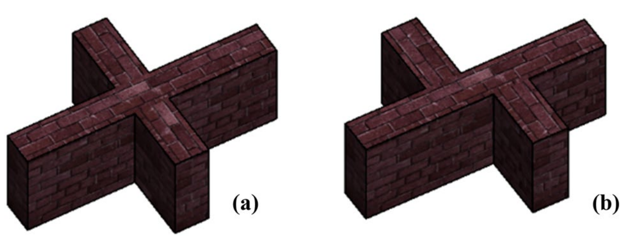


Fig. 19 A brick wall with a cross-wall (**a**) and a brick wall without a cross-wall (**b**)

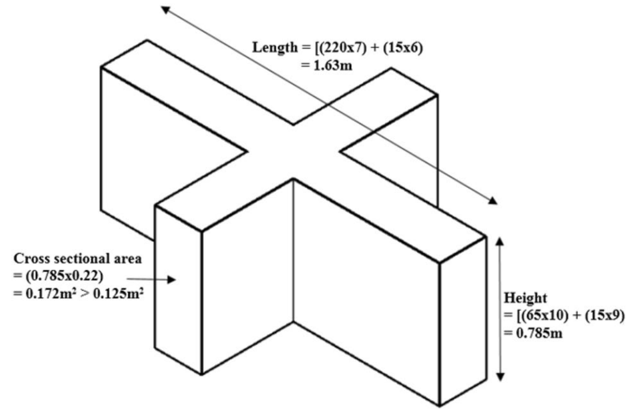


Fig. 20 Dimensions of the test panel

The prepared test panels are as shown in Figs. 21 and 22.

The physical testing was done in two sessions according to the BS 5628-1:1992, A.2.6. with a curing period of 28 days. The brief methodology of two test seasons is as mentioned in Table 1.

The loads were applied using the structural testing machine with the maximum capacity of 50 kN and the loads were equally distributed over the top surface of the main wall through three 25-mm-thick steel plates and one 50-mm timber plate as shown in Fig. 23.

Results

Test results of both tests regarding crack initiate load and failure load are as listed in Table 2.

Further, load reductions during every 1 min of rest time after application of a load of 10 units were observed using test no-02 and corresponding results are as shown in the scatter diagram in Fig. 24.

Interpretations based on results

In test 01 and test 02, crack initiate load differences between wall panel with a cross-wall and wall panel without a

Table 1 The brief methodology of two loading tests

Test no-01	Test no-02
1. Tests were carried out after 28 days of curing period	1. Tests were carried out after 28 days of curing period
2. Loading was continued until initial crack forming and continued until the failure stage of panels	2. Load of ten units was applied once and waited for 1 min without a load and again a load of ten units was applied and waited 1 min before the assignment of next ten loading units
3. Loads were applied only along the main wall for both types of test panels	3. Loads were applied only along the main wall for both types of test panels
4. Initial crack forming load and the failure loads were observed	4. Load reductions after every 1 min of rest time after application of loads of ten units was observed and crack forming load and the failure loads were also observed

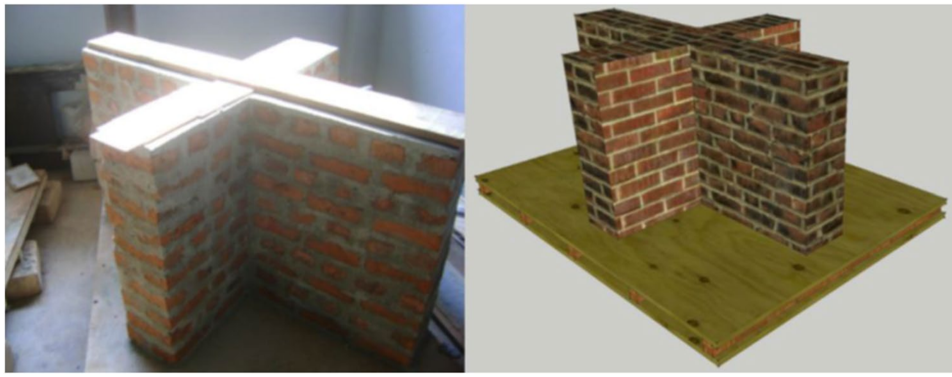


Fig. 21 A brick wall panel with a cross-wall junction (Weerasinghe et al. 2011)

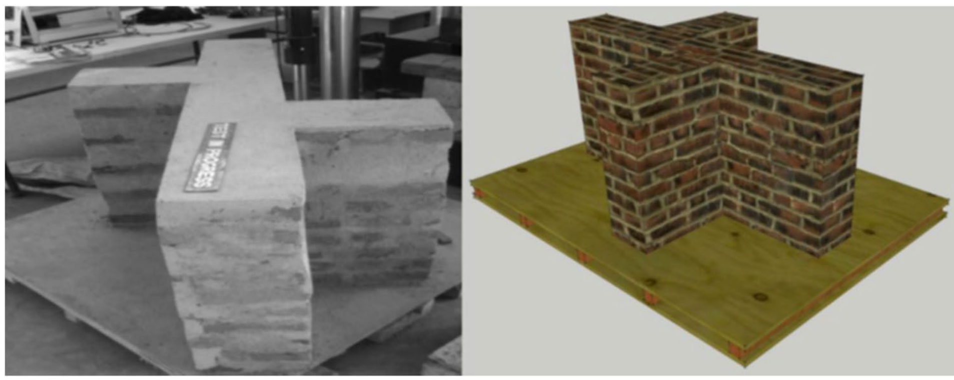


Fig. 22 A brick wall panel without any cross-wall junction (Weerasinghe et al. 2011)

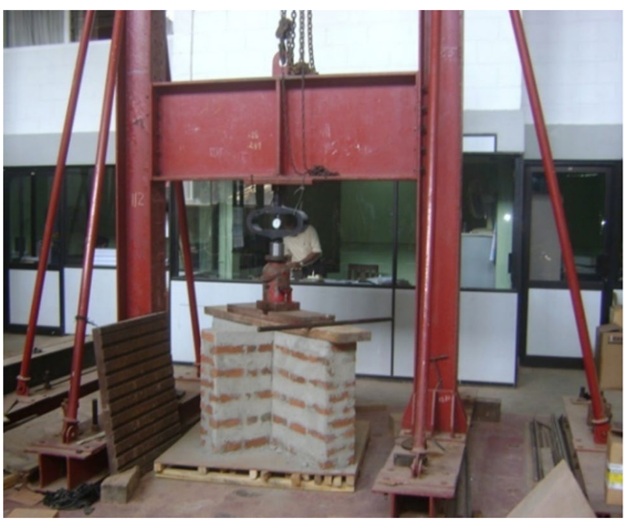


Fig. 23 Applying the loads through the structural testing machine (Weerasinghe et al. 2011)

cross-wall were 4.42 kN and 1.35 kN, but the failure load differences were 0.43 kN and 0.57 kN. The wall panels without a cross-wall attributed higher strength situation. But since the crack initiate load contained a relatively higher value than the value of wall panels with a cross-wall, the ultimate strength of both types of wall panels can be considered to be approximately similar. The failure loads being very closer values further verify the rationale.

As illustrated in Fig. 24, both initial cracks and ultimate failure occurred in wall panels with a cross-wall, earlier than in the wall panels without a cross-wall. But there is no significant strength difference between the two types of wall panels. Hence, it can be considered that the strengths of wall panels with a cross-wall and without a cross-wall are approximately the same.

When the walls become non-load bearing, the structural effects due to the imposed loads can be neglected. But there is a construction difficulty in erecting cross-walls due to the complexity of the cross-wall junction. In the presence of a reinforced concrete column at the crossing point as shown in Fig. 25, each and every inconvenience can be easily eliminated.

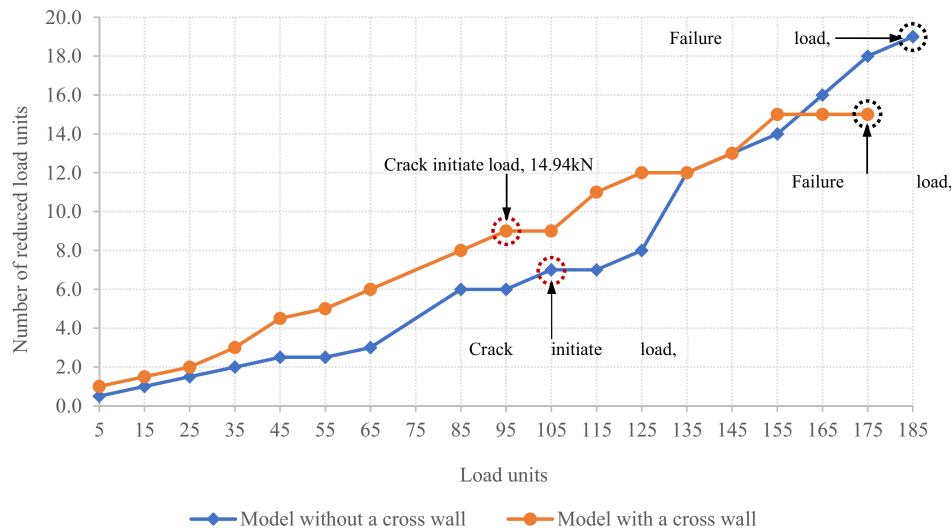
Conclusion

Traditional beliefs in house construction are one of the main knowledge heritages mainly nourished with vastu shastra, feng shui, religious considerations and faiths which have been transferred from generation to generation. The aim of the study was not to discriminate such beliefs or label them as superstitions. Instead, the study tried to provide rational

Table 2 Test results regarding crack initiate load and failure load

Type of wall panel	Crack initiate load (kN)	Crack initiate load difference (kN)	Failure load (kN)	Failure load difference (kN)
Test no-01				
Without cross-wall	16.51	4.42	27.75	0.43
With a cross-wall	12.09		27.32	
Test no-02				
Without cross-wall	14.94	1.35	27.04	0.57
With a cross-wall	13.59		26.47	

Fig. 24 The number of load units: reduced vs applied load units



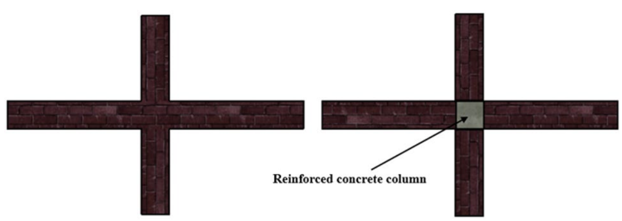


Fig. 25 A cross-wall junction without and with a reinforced concrete column

engineering explanations to selected traditional beliefs which can be studied with the aid of engineering technology.

The study reveals that the main reason for not having three or more aligned openings in a dwelling is the lack of sufficient natural ventilation in the house. And also, there can be issue for the privacy of inmates due to such opening arrangements. Hence, it is better not to have three or more aligned openings in dwellings as well as in any building.

Though the belief says not to place ridge plate, beam or any load on top of the exact centre point of openings, that aspect was proven to be wrong through the study, since the maximum stress development was observed when the load acted on top of one edge of the opening. In the presence of reinforced concrete (RC) lintel, every adverse effect gets eliminated. Since RC lintels are commonly used in present house constructions, this belief can be withdrawn.

West-facing verandas, balconies and windows create uncomfortable situations in terms of thermal comfort. It also leads to the twisting of window frames. Since there is significant importance in certain belief, it is better to admit these beliefs.

Through the final investigation, it was proven that there is no significant difference in structural strength between brick walls with and without cross-walls. When the walls become non-load bearing, every structural effect due to the imposed loads can be neglected. Hence, cross-walls can be used in brick wall construction in house constructions without having any dispute of structural strength.

The ultimate conclusion is that it is not better to withdraw the traditional beliefs in house construction by just labelling them as outdated pieces of information or be slaves of them wasting both money and time. The best idea is to accept or reject the traditional beliefs based on the rational explanations and utilize them in real-world applications when they are meaningful.

Recommendations and future works

The study was limited to a sample of 375 people for the questionnaire survey. But more elaborative responses can be achieved by expanding the sample size. And also the results can be further sharpened by extending the questionnaire to other countries also.

Physical model testing was only used for the cross-wall scenario. But the other three cases can also be physically tested using prototype models to obtain reliable outcomes.

If each and every traditional belief in house construction is withdrawn by labelling them as superstitions, the beliefs which contain rational explanations will never be extracted for use in real-world applications. These beliefs had been existing in the world long before the emergence of modern science. Even modern science has taken examples and guidance from them. In the past, traditional beliefs may have been introduced to ordinary people attributing them to occult repercussions of not obeying them, since the ordinary people did not have sound technical knowledge. Since they have been transferred from generation to generation, the occult behaviour may remain albeit with fewer changes and this could be the reason for questionnaire responses such as adverse effects ending in death, etc.

Hence, it is recommended to consider beliefs such as "not having three or more aligned openings" and "not having west-facing balconies and more west-facing doors and windows" which have rational explanations and engineering significance in real-world practices.

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Compliance with ethical standards

Conflict of interest All authors state that there is no conflict of interest.

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