The Kashmir House its Seismic Adequacy and the Question of Social Sustainability.

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ABSTRACT :

The landscape and topography of the Kashmir valley has resulted in settlement and house forms that are of an isolated kind. A particular way of life and building develops from this isolation and maximizes the use of local resources.This paper discusses the house form in terms of the above mentioned way of life, but particularly in terms of available local materials and the distribution of these materials through developed construction techniques into a structural system that is flexible and has the potential for seismic resistance. Key construction techniques like the 'TAK' and the 'DAJJI DEWAR', will be dealt with in detail, while derstanding their role within an overall construction system. Through this particular case study the paper will discuss the limitations of the modern method of structural analysis, and the extensions required for a better understanding of traditional structures and construction. It will discuss a need to regain confidence in traditional construction techniques, with their ability to respond to a structural requirement (seismic resistance in this case), while simultaneously responding to other issues such as local availability of material, climate etc. The paper will bring out the inclusive way in which traditional buildings deal with issues of structure, rather than viewing them in isolation

INTEGRATED APPROACH TO SEISMIC DESIGN: Architectural Considerations and development of structural systems for earthquake resistant design

Structure is an integral part of architecture and both structure and architecture should be addressed to, simultaneously. The normal practice is to incorporate the structural design into an already developed architectural concept. Due to the special circumstance of the earthquake, an integrated approach to structure and architecture was envisaged. This paper highlights the process of design in an earthquake prone zone. The various stages of architectural and corresponding structural design shown in this paper demonstrate the tremendous potential of such an integrated approach to design. The process of designing modules and its various combinations allowed for a comprehensive and in-depth structural analysis of an individual module, enhancing the predictability of the structural behaviour of the building. Structural inputs were also extremely valid at the level of design detailing, an aspect which is often neglected in conventional design

Learning Earthquake Resistant Architecture: First Hand

The seismic performance was always looked as the primary responsibility of an engineer. The past earthquakes and research has shown that the roll of an architect is equally and sometimes more critical for seismic performance of the building. To inculcate this in the students mind, the learning from the real site of earthquake affected housing is a rare opportunity. The paper describes the result of studio conducted at Faculty of architecture; CEPT University, India after the high magnitude earthquake stuck the rural and urban areas equally. Studio started as a survey of damaged building in a village Kalyanpur in Kutchh.. The students were to develop the understanding of local materials and technology in addition to climate and socio-cultural aspects and design a housing for reconstruction of village with due consideration for social sustainability. The paper also talks about the innovative way of teaching structures and seismic aspects to the students of architecture at faculty of Architecture CEPT University India

KEYWORDS: Kashmir house, traditional construction, sustainability, seismic efficacy, modern analytical method.

1. THE CONTEXT

Fig 1. The hill settlements of the Kashmir Valley

Fig 2. The terraced hillsides along the Jhelum river

This paper discusses the house type that is commonly referred to as the 'Kashmir House'. This type is prevalent across the Kashmir Valley, with minor local variations. The consistency of use patterns, material use, and construction technique allow these houses to be categorised together. However the houses examined in this paper are of the Uri and Baramullah region of western Indian Kashmir, where stone is available. Examples of Brick construction from Srinagar, have also been discussed to explain the traditional construction systems of the 'Dajji Dewar' and the 'Taq'. In both these cases the houses are Multi Storeyed and are of greater import to this study. There also exists a single storeyed house, which is less refined in its making, the 'Gujjar House'. This has not been discussed here.

The houses have survived several earthquakes that have damaged many newer buildings that have been designed using the modern analytical method of structural design. Contemporary models of systemic behaviour, only partly explain the efficacy of these traditional structural systems. In addition to their structural soundness these traditional systems also follow a synthetic approach that looks at the structural issues in unison with issues of locality, lifestyle, usability maintenance and growth over time. These seem to be open ended systems which are able to absorb both the circumstantial variations due to locality and the growth and change of user needs.

The landscape of the region follows the Jhelum river as it flows from east to west, forming dramatic ravines which are upto 200m deep. The river flows with great speed and settlements are established some distance away on the steep slopes of the adjoining Pir Panjal Mountains.

The settlements along these valleys are spread out and in many cases are sparse, consisting of detached individual houses that are placed in small parcels of land, which are terraced for agriculture. Where the slopes are gentler the entire mountainsides are terraced for agriculture (fig 1 & 2). In this region the preparation of the ground, Its shaping and terracing becomes the first act of being able to position oneself in this harsh landscape

2. THE HOUSE.

Fig 3. The Kashmir house using Masonry and Timber construction

Fig 4. the Kashmir house in its landscape.

The cutting of the hillside to create flat ground for both the building as well as agriculture yields both the stone which is used in the construction of the walls of the house and mud which is used both as a mortar, and with animal dung, as a Plaster. The plinth is constructed as a platform in stone (Fig 5). The traditional stonework of the area is semi-coursed, but one finds that care has been taken in the cutting of the stone to ensure good bonding. Where the ground slopes steeply, the front of the platform may become high enough to accommodate functions (Fig 9). These cave like spaces in the plinth are usually allocated for animal shelter and grain storage.

Fig 5. The Kashmir house with its distinct plinth, body and roof.

2.1 ThePlan

The Kashmir house consists of an extremely simple square plan (Fig 6 & 7). The distribution of function is symmetrical, normally resulting into a quadripartite division of the overall square. The staircase is usually placed at the centre. '*Symmetry is a basic principle for earthquake resistance, as symmetrical buildings respond with regular displacements along height and almost negligible floor rotations due to insignificant torsional effects*'.[1]

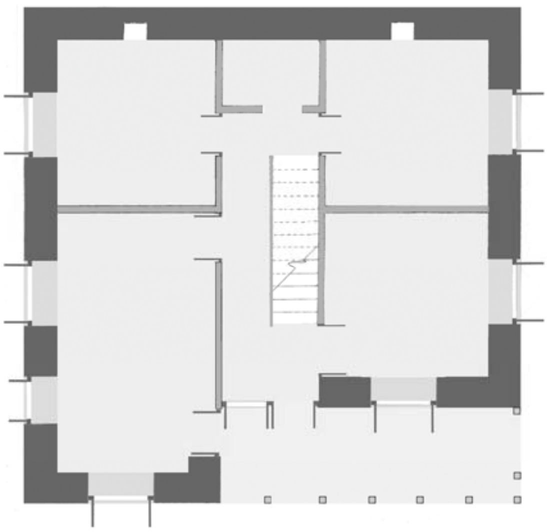

Fig 6. Typical ground floor plan.

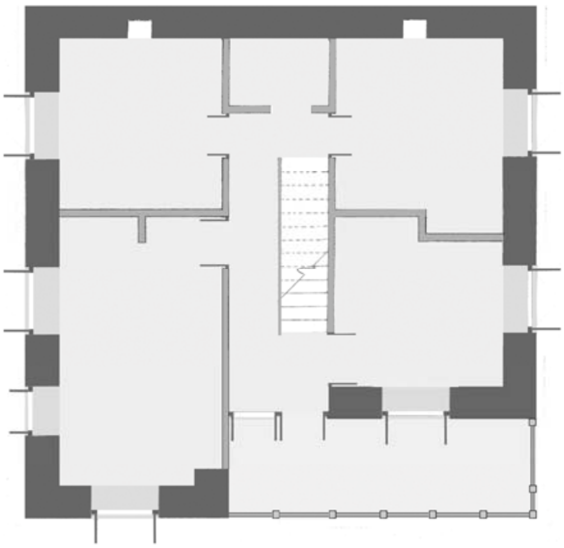

Fig 7. Typical first floor plan

The outer wall of the overall square is constructed as a heavy stone masonry wall, for both structural and climatic purposes.

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1 Modan, Akbar Nazim, Chhaya Neelkanth & Vinod Shah, (2006), Analysis of the System of Construction in the Traditional Ahmedabad Houses: Query in Seismic Resistance.

Internal divisions consist of thinner partition walls often of wattle and Daub, made from timber framing, in-filled with reeds and plastered with a mix of mud and animal dung. In reality the verticals of the timber frames are the columns that support the upper wood floor structure. Such internal walls have little structural importance, however in cases where the columns are in-filled with brick/masonry they may have some damping effect.

This plan configuration follows a complete masonry box system. 'Heavier walls help to apply compression to brickwork (masonry) in lower level, and the resultant of horizontal forces are taken care by thick walls.'

The diaphragm in the Kashmir house is almost completely continuous with the exception of the stair cut-out which is small in area in comparison with the overall plan area. Thus there are no abrupt discontinuities or variations in stiffness in the diaphragms of the 'Kashmir House'. This is good in terms of seismic design and is recommended by almost all international codes of practice.

2.2The Section

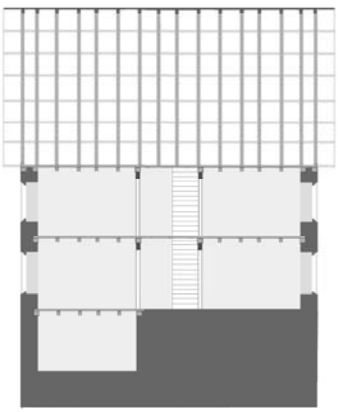

Fig 8. Typical section of a Kashmir House

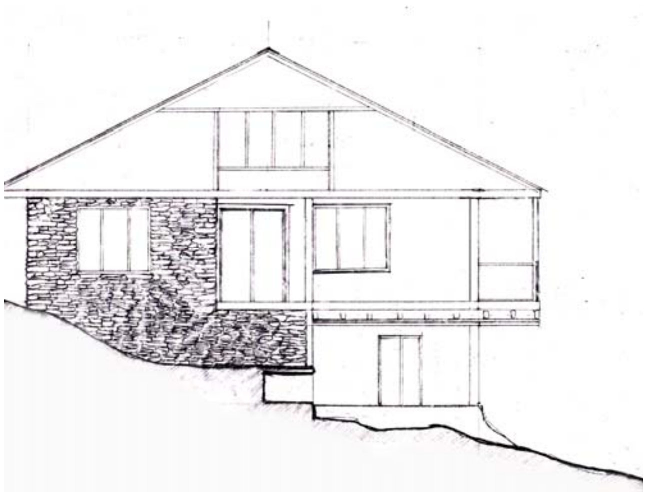

Fig 9. Section of a Kashmir House on a hill slope

'Structural symmetry in section is very important as an earthquake resistance principle. Because a building possessing symmetrical conditions responds with regular displacements along height and almost negligible floor rotations due to insignificant torsional effects, in consequence their deformation pattern is well distributed among the structural elements.'[2]

As mentioned above the lower level consists of a masonry platform which may be occupied for animals and for grain storage. The ground floor is usually a masonry box divided as described above to accommodate the functions of cooking, dining and living. Here the internal walls are partition walls. It is common to find timber balconies at this level which further serve to lighten the structure. The uppermost level is an attic like occupation of a light weight

[2] Modan, Akbar Nazim, Chhaya Neelkanth & Vinod Shah, (2006), Analysis of the System of Construction in the Traditional Ahmedabad Houses: Query in Seismic Resistance.

timber roof. This area is usually used for storage and on major family occasions (marriages etc.) as a social space. It is clear that as one moves upwards the structure becomes lighter. The lower levels are made with heavier masonry walls where as upper levels become composite with the use of timber and masonry together, terminating in the roof made only of timber. As one moves upwards the structure becomes lighter (Fig 10 & 11). This strategy not only reduces the dead load on the structure, it also balances the structure in the event of horizontal forces.

For earthquake resistant design, it is important that center of mass and center of rigidity of building is nearly coincident. If it is not so, the distance between center of mass and center of rigidity will cause torsion in the building. Center of mass and center of rigidity for the 'Kashmir House' are very close to each other. In addition to this the configuration of the house has a very low eccentricity.

2.3 Materials Used.

'Earthquake forces are, proportionate with the weight of the structure. Elastic properties of materials allow uniform deformation and absorb more energy during the earthquake. If the energy affecting the structure during the earthquake is equal to this energy area of the structure, the structure will have no damage. The ductile material deforms more, have more power of absorbing energy. Materials used should have the capacity to resist tensile forces, as the horizontal ground shaking is very likely to induce net tensile stresses.'[3]

The heavy stone walls that form the masonry box at the lower level are tied horizontally at various levels with timber bands. These bands are usually at sill and lintel level. These bands bind the masonry box having particular importance at the corners, where the perpendicular planes of masonry have a tendency to separate out on the application of horizontal forces. In addition to this the timber band breaks up the effective height of the wall into smaller panels of masonry whose height to width ratio decreases.

Timber as a material itself is suited to absorb seismic forces.

Wood: "Timber structures have a well-deserved reputation for high resistance to earthquakes. Particularly the high strength-to-weight ratio of timber and also its enhanced strength under short-term loading and the ductility. Timber is an organic material and their cellulose fibre makes them highly effective to undertake tensile stresses."[4]

The bonding materials used for masonry is a mixture of mud and cow-dung which has adequate bonding properties with stone and brick. The weak mortar perhaps allowed a certain degree of movement and plasticity in total wall. Though the materials used for construction are brittle with lean mortar with the use of timber, Dr. Arya's (the well known Indian Earthquake Engineer) research shows that the Damping in this type of construction is 20-25% against 5% for concrete. Due to increased damping such structures dissipate energy faster.

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[3] Modan, Akbar Nazim, Chhaya Neelkanth & Vinod Shah, (2006), Analysis of the System of Construction in the Traditional Ahmedabad Houses: Query in Seismic Resistance.

[4] Dowrick,D.J. Earthquake resistance design for engineer and Architect, *Second edition*

Fig 10. The Upper levels of the house are constructed of lighter material.

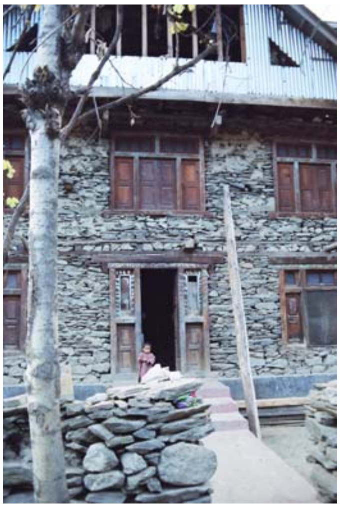

Fig 11. The skilled use of traditional stone masonry

2.4 Method of Construction

1.4.1 The 'Dajji Dewar'.

The 'Dajji Dewar' is a much thinner and lighter form of wall construction it consists of timber framing with in fills of brick, (Fig 12, 13) and in a few cases stone masonry. In the case of the 'dajji dewar', walls will have greater ductility and damping. In addition to this the horizontal and vertical cage formed by the timber are braced diagonally against shear. This cross member is usually at the corner, but lends the entire framing a resistance against shear. The closely placed timber studs prevents propagation of shear cracks. This framing also results in breaking up the upper level masonry walls into smaller multiple panels, each of which are independent. The collapse of any one panel will not result in the complete collapse of the wall, and therefore the structure. Small masonry panels surrounded by timber elements have greater safety against out of plane collapse.

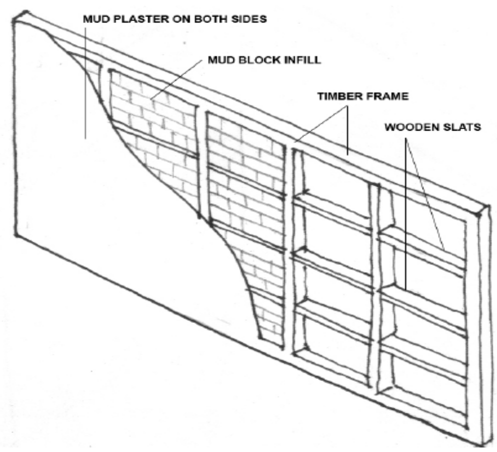

Fig 12 The details of a 'Dajji Dewar'

Fig 13. 'Dajji Dewar' in a typical Kashmir house

1.4.2 The'Tak'

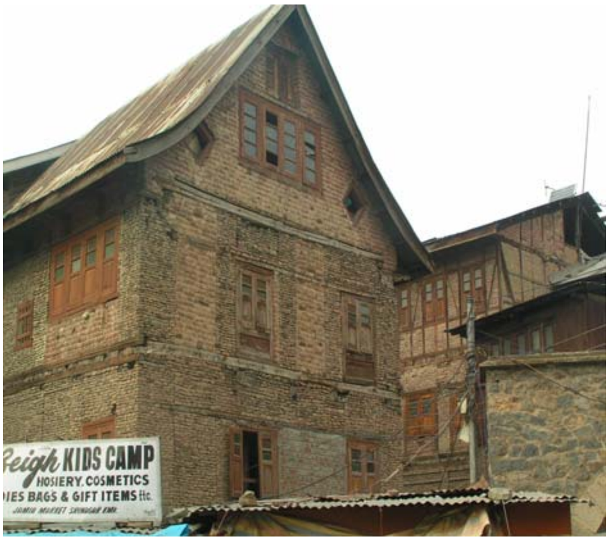

Fig 14. The 'Tak' construction technique

Tak, refers to load bearing masonry piers with infill walls. In many cases these are expressed by a different use of material. The piers may be made of stone and the infill walls of brick. Timber runners at each level tie the walls. The infill walls have timber embedded in them to increase their elasticity (Fig 14).

3.0 SUSTAINABILITY.

The Kashmir house has developed with the use of local materials stone, and timber. These materials are readily available and can have been appropriated from the environment without excessive processing. Building is a community based activity. Families help each other build their houses. This community based organisation of labour is prevalent today and was visible after the earthquake for the repair and reconstruction of the damaged houses. Community labour facilitates the transmition and refinement of skill and the technique of building. Through this there develops an indigenous understanding of the material and methods of putting them together. This understanding is holistic and is connected to all the other aspects of living in the particular environment. Thus built into this approach are the checks and balances that prevent the exploitation of the landscape beyond the needs of its inhabitants. Structure too develops to optimise resources, as they have multiple uses. What can be saved from building can be used elsewhere.

The technologies that develop in this system are simple yet robust. They develop from the use of by-products of other life-processes. Thus the mud and dung mortar is a developed product from animal husbandry. This product can also be used for manure. Agricultural waste is often used for insulation, but is most often used for fodder. Stone and mud is a product of shaping the ground, terracing, in order to cultivate it. One understands that the activity of building is deeply woven into the survival of the family and the community.

At the heart of this community based system seems to be the doctrine of Reduce, Re-use, Recycle, which is also the slogan of our contemporary movements towards sustainability.

4.0 EXPERIENCE AND OBSERVATIONS.

Following the earthquake that hit Kashmir in October 2006, Several NGO's were involved in the process of rehabilitation of the region. One of the small initiatives was that of the Centre for Environment Education (CEE), through its Himalaya chapter. CEE Himalaya, under its long term rehabilitation project 'Rebuilding Trust'. This Project took up the reconstruction of seven Primary schools in the Baramullah and Uri Districts of Indian Kashmir. These were small village schools which prior to the earthquake had been simple two roomed structures with a common veranda, normally sitting on a playground area. However not all the schools had the luxury of open space, three of them were on constricted sites limited by the topography and the steepness of the ground. In short the schools were located on varying sites but there existed a typological consistency of a series of classrooms fronted by a linear veranda.

Fig 15. Typical collapse of buildings in the Kashmir earthquake

In every case, it was not possible to retrofit the damaged school buildings. The damage was such that complete reconstruction was required.

For the new buildings the design approach developed the existing typology and modified the details of material and construction in order to engineer the structure to be earthquake resistant.

During the field study of the damaged buildings, a survey was also carried out of traditional buildings using indigenous construction methods, which remained undamaged during the earthquake. It was found that the sudden introduction of a new modern material altered the behavior of the structure that was considered in the traditional system. A particular example is illustrated below.

In the traditional houses of Kashmir there are two interesting structural constructs that are used, that consider the behavior of the structure during earthquakes. The 'Dajji Dewar' (a timber braced wall) and the 'Tak' (a cantilevered window element that connects the horizontal structural elements of one floor to the other). Both allow for a greater ductility, which may be visualized as an allowance for controlled lateral displacement when seismic loads are at play. In the traditional houses of Kashmir the Timber joinery of the roof framing also takes into account the need for this ductile behavior. It should be noted that the traditional roofing material in these buildings was slate and tiles which would also allow for this behavior.

In recent times, due to issues of cost and maintenance, the roofing material has almost completely changed from the traditional slate and earth ware tiles to corrugated galvanized iron sheeting. The typical mode of fixing these sheets is to simply nail them firmly to the inclined members of the existing trusses. However it was found that this simple change from tiled roofs, i.e. loosely jointed modular units to a continuous sheet with great lateral stiffness changed the behavior of the traditional system, in a majority of cases leading to collapse and complete destruction of the structure.

In almost every case of destroyed buildings where galvanized iron sheets were used it was found that the roofs of the buildings remained intact. In fact this is the enduring image of the Kashmir earthquake, of complete roofs floating incredulously over dilapidated walls (Fig 15).

This is probably due to the lateral stiffness of the corrugated sheet roof for which lateral loads are ‘in-plane loads’. The sheeting ties together all the roof trusses causing them to behave as a singular structural module. The timber members in the ‘Dajji Dewar’ which are connected to the roof trusses are considered to withstand stresses at the level of an individual truss, which due to the loosely jointed tiles are seen to act independently. The stresses induced during seismic activity, between the wall members and the truss timber is distributed and seen to be resolved locally. When the trusses are tied by the membrane action of the corrugated sheet, the whole roof acts as one, creating stresses that are concentrated, and of a much greater magnitude, causing failure.

Considering budgetary limitations, the use of Galvanized Iron sheeting was a given for the reconstructed schools. The roof was designed as a singular structural construct resting on the load bearing walls of the classroom and the timber frame of the veranda. A simple strap detail between the timber members of the truss was used to simplify construction and joinery in remote places. In one particular school the timber members of the truss were nailed together without the straps. Using the modern analytical method, one would assume the failure of this roof due to the snow load, however the roof withstood over four feet of snow and survived the winter. Though the trusses have subsequently strapped, the question remains as to why the roof survived.

We conjecture that when it snows the first later of snow is compressed to form a slab of ice over the galvanised corrugated sheet. Subsequent snow load is now taken by this slab of reinforced ice. The pitched slabs of reinforced ice take a large portion of the load, transferring relatively minor load to the timber trusses. This is an example where the understanding of the structural behavior of a building as an isolated object limits the design. It is clear that a better understanding of snow would allow us to design far more efficient buildings.

This separation between the structure and its context, its surroundings and the behavior of all the elements that act on it, is at the root of the modern analytical method (Fig. 16). In the traditional systems one senses a greater continuity between the various factors that give rise to buildings. Material is sourced from the immediate landscape, stone from the hills, and timber from the forest. Structural elements rarely seem to have singular functions, like simply carrying load. They are articulated to incorporate various levels of use, like the ‘TAK’ which is articulated into a projected window, so characteristic of the Kashmir House. Over and above its structural function the timber members of the ‘Dajji Dewar’, set up the position and dimensions of openings. They also set up the articulation of the wall in terms of ornamentation. The functional, structural and aesthetic value of each element cannot be separated.

Though the typology of the school buildings were continued, it must be noted that the sizes of the classrooms in the original schools were very small, measuring 10’x12’ on an average, a space woefully small for 30 children. It was considered an opportunity to create better sized spaces for the classrooms. This was subsequently enforced by the district authorities. This directive, to have a minimum classroom size of 15’x18’ also had an impact on the design.

5. CONCLUSIONS

The Kashmir Earthquake has once again shown that traditional housing typologies that have evolved over time have a definite seismic resistance.

In order that the traditional methods and knowledge of building survive it is important that the faith of the people who live and use these structures is not only nurtured but is developed keeping in mind the larger issues of sustainability. In many cases natural disasters result in a loss of faith in the methods and techniques developed through generation, where a modern alternative is seen as the only ‘safe’ option. This option is then elevated to a level of a status symbol. The modern alternative is seen as something to aspire for. However, a study of the buildings that survived the Kashmir earthquake make it evident that the modern methods of analysis and design are limited for the complete comprehension of traditional systems. A new more integrated approach is needed to assess the seismic adequacy of vernacular structures. It may be suggested that this approach should integrate the analysis of structural elements as well as the processes and systems that they are a part of.

The modern method of analysis fails to determine the seismic adequacy of traditional buildings. From comparison table one can see the different approach that is followed for traditional and modern building construction. The difficulty with analytical methods is as follows.

1. Analysis of structure using scientific methods needs formulation of an idealized model capable of being analyzed along the known mathematical relationships.
2. Codes and engineering methods are designed to ensure predictable behaviour and therefore advocate simple and regular configuration closer to the idealized models. However, historical structures achieve non-predictable but definite firmness; such structures, because of their complexity and irregularity make it difficult to predict, and analyze behaviour.
3. The method fails to take into account contradictory, complex or unqualifyable characteristics of the combined action of wood and brick.

Ultimately, the main difficulty is that most analytical methods are based on the assumption that the structure is elastic. These fail to take into account the higher order of deformability and energy dissipation of traditional construction. The response of inelastic structures will be different from that of elastic structure and the seismic forces attracted are lower in the former than in the latter

	Traditional	**Contemporary**
Configuration	Plastic, Damageable	Stiff, Rigid
Material	• Circumstantial behaviour • Deformation	• Uniform behaviour • Measurable assessment
Construction Technology	• Qualitative experience based assessment • Durability contextual parameters • Performance based • Easily repairable	• Universal parameters • Non maintenance • Durability • Required complex process

Fig 16. Comparison between traditional and modern methods of structural design.

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