Abstract

Space Crunch™ is a daily struggle in the life of majority of Urban Dwellers, more so for growing families to which they either respond with unique design solutions or compromise. Internal non load bearing walls occupying valuable floor space is one of the reasons contributing to this “Space Crunch™”. Thereby necessitating a study to explore transformations on the wall plane. This paper is a study of reconfigurable systems both on the wall as well as roof plane leading to an apt design solution for Reconfigurable, Internal Modular space dividers in Tensile Fabric. The paper would finally conclude with a conceptual design solution answering the “space crunch” issue enhancing functional efficiency of residential dwelling units with changing occupants.

Keywords:

Adaptive Environments, Spatial Adaptation, Reconfiguration

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pSpace Crunch : A by product of rising urbanisation

Migrating population is on the rise as cities offer lucrative employment opportunities. But work places go hand in hand with corresponding dwelling units, to house this growing populace. Land is limited and families still has the potential to grow. Predictably needs also grow and households need more space. This has been going on right from the time of Industrial Revolution and humans have always found a solution because they possess this incredible power to “Adapt” to changing situations, one of which is through “Spatial Transformation”.

Concept of Spatial Transformation

“Spatial Transformation” in this context is defined as any

- ALTERATION
- ADDITION
- EXTENSION
- MODIFICATION

Of Residential Interior Space Usage

It has been identified as an integral part of Inhabitation. In the context of self built houses in developing countries [1], as well as homes all over the world occupied by the Urban populace, studies show that there is an abundance of transformation incidents. [2].

Transformation in Interior walls is defined as Partition Level [PL] transformation, by the author T.H. Khan in his book Living with Transformation. Permanent construction works is involved as the Internal non load bearing walls are made of Bricks which is a rigid material.

Categories of Partition level Transformation

1. EXPANSION: The size of one unit is increased by devouring some space from adjacent units on the same floor. For eg : as families grow, a larger bedroom is required and a smaller dining space is acceptable as a compensation [Fig 1]

![Fig 1: Transformation by expansion](image)

2. REDUCTION : The size of one unit is reduced usually due to change of usage of part of any area into non residential activities. [2] For eg : the reduced part becoming office or storage space. (Fig 2)

![Fig 2: Transformation by reduction](image)

3. SUBDIVISION : It involves constructing or demolishing partition walls, or simply closing a door or two so that parallel private functions can be carried out in these subdivided areas. [2] (Fig 3)

![Fig 3: Transformation by subdivision](image)

These categories of transformation incidents are a common occurrence in small dwellings in urban areas causing “Space Crunch” due to rigid internal non load bearing walls occupying valuable floor space.
Internal subdivisions cause an increase in circulation space, thereby resulting in more wastage of space. (Fig 3)

As families grow, sometimes adjacent flats are purchased and merged into one and the internal circulation is reconfigured by shifting the position of few non-load bearing walls resulting in transformation by subdivision.
However not all the transformations follow basic architectural norms of space hierarchy. Examples of such transformations include entry to toilet through verandah, entry to a bedroom through another bedroom, multiple entry of a room to solve circulation, evolution of complicated circulation spaces etc. Using Gamma diagram it is found that the levels of depth increase after transformation, causing wastage of valuable floor space.

Thereby it is seen that there is scope for further research in the field of Lightweight Modular Walls Defining Flexible Internal Spaces Enhancing Functional Efficiency of Residential Dwelling Units with Changing Occupants.

Optimizing Space utilization

Considering the Housing scenario in India, the real estate prices in metro cities are as follows:

<table>
<thead>
<tr>
<th>City</th>
<th>Rate per Square feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mumbai</td>
<td>15,000 Rs.</td>
</tr>
<tr>
<td>Bengaluru</td>
<td>8,000 Rs.</td>
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</tbody>
</table>

The following table shows that residential spaces are becoming more and more unaffordable for the middle-income sector.

A general trend in India, shows that home buyers pay more for considerably lesser space that they effectively occupy. Home buyers pay for a total built up area whereas they occupy only the carpet area.

For Example:

Carpet area = 900 sq. ft (Area occupied)

Loading factor = 25% [125]

Built up area = Carpet area + Loading factor

= 1125 sq.ft.

Therefore, Carpet Area = 80% of Built up Area

Balance 20% is profit for the builders.

Out of the above mentioned 80%, rigid space divisions in the form of internal walls, further reduces maximum space utilization.

Actual space utilized = 70% of Built up Area

In such a scenario, Reconfigurable Modules of Tensile fabrics can greatly reduce space wastage by an astonishing 20%, as there is reduction in area covered by fixed walls, and the reconfigurable nature of tensile modules makes multiple internal wall configurations easy, thereby achieving optimum space utilization.

Reconfigurability on the wall and roof plane: Built examples

This study was undertaken to understand the design characteristics of reconfigurable modules. Even though majority of the featured projects show reconfigurability on the roof plane, their analysis led to the kinematic development of the conceptual design of Lightweight modular walls.

Project: ROOF OVER SWIMMING POOL in Unterluss, Germany.

References


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Photographs: Courtesy the author.
Conceptual Design Solution

Fig 4: Internal View of Swimming pool showing double layered membrane roof [barrel form].

COMPLETE RECONFIGURATION


Reconfigurability Analysis: Double Layered membrane = good design for reconfigurable modules

From the point of view of reconfiguration, if a module consists of 2 layers of fabric, with an intermediate air space of minimum 3 cm. The internal pressure in the double layered skin can be used to control the foldable structure, which gives it stability in a reconfigured position. This concept is in tandem with Stromeyer & Co., whose internal envelope for the swimming pool at Unterluss, Germany.

Project: CANOPIES FOR SHADING COURTYARD OF PROPHETS MOSQUE

This design would be a lightweight modular, light transmitting alternative to conventional architectural form. BuroHappold, 1972: "It is highly advantageous in comparison to the above modules with an inherent design兵on of folding folding action via "Spatial Transformation".

The project described above [Fig 5] is of 17 X 92 m envelope of umbrellas atop of Babylon, used for shading the courtyard of the palace of the kings. For non-circular buildings, this double layered structure can be deployed partially, thereby saving on circulation spaces. [Fig 5] Below of deployment the cantilevering arms of an umbrella like structure a shift from vertical to a horizontal position, thus creating a considerable volume of unobstructed space. (Fig 21)

FURTHER RESEARCH

Reconfigurability Analysis:

Year: 1972


Reconfigurability Analysis: Double Layered membrane = good design for reconfigurable modules

From the point of view of reconfiguration, if a module consists of 2 layers of fabric, with an intermediate air space of minimum 3 cm. The internal pressure in the double layered skin can be used to control the foldable structure, which gives it stability in a reconfigured position. This concept is in tandem with Stromeyer & Co., whose internal envelope for the swimming pool at Unterluss, Germany.

Conclusion & Scope for Further Research

"Space Crunch" issue through design.

Value:

Maximum utilization of space, thus allowing maximum utilization of space, thus enhancing functional efficiency of residential spaces.

Shreya Sen

Adaptive Environments: Spatial Adaptation By Reconfiguration

SCOPE FOR FURTHER RESEARCH

“Space Crunch” issue through design.

Temporary, semi-permanent, permanent, thereby saving on circulation spaces. (Fig 21)

FURTHER RESEARCH

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Conceptual Design Solution

Fig 4: Internal View of Swimming pool showing double layered membrane roof [barrel form].

Fig 5: Closed to open position showing folding action of the umbrellas [clockwise from top left].
Reconfiguration Principle

<table>
<thead>
<tr>
<th>Design</th>
<th>Material</th>
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<tbody>
<tr>
<td>• Skeletal frame</td>
<td></td>
</tr>
<tr>
<td>• Double layered membrane forming each module</td>
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Adaptability to indigenous climate and day-lighting strategies, using high fire rating, fire-resistant fabrics with high fire rating. Prevents tear propagation.

Conceptual Design Solution
Adhering to these Specifications

Scale

Easy handling by home occupants

ERGONOMIC DESIGN
Considering the human height and scale of the room of a general apartment (2.7 M) in metro cities of India, the overall vertical height of the room can be divided into 3 zones. (Fig 21) below

CEILING LEVEL
The height of the ceiling is not only a factor in the design of the module but also in the design of the module itself. (Fig 20). The module is designed to fold along the ceiling channel, allowing for easy manipulation by the user.

Fig 20: Foldable module design fixed at the Ceiling.

Fig 21: Conceptual model of a reconfigurable wall module fixed at the roof level

Fig 22: Complete reconfiguration of wall module allowing barrier free zone on floor level

Fig 23: Preparation of a rough model
similar to the iris-type diaphragm of a camera (Fig 10). By rotating the ring the welded pieces push or pull the blades and the swivel diaphragms opening can work like the iris diaphragm. When this system is in its open position each blade overlaps the other during the deployment, as a result they are forced to operate on a sloped angle. The slope of the blades increases as they approach the closed position. This is more evident when the width of the blade is less. A combination of Swiveling action for the roof plane and lightness and strength qualities of nonwoven materials are more evident within kinetic devices due to their flexibility, nonwoven textiles like membranes used in context of this research are an apt choice for kinetic devices which reconfigure on a regular basis. 

Conclusion: Textiles and membranes are an excellent and new material for reconfiguration in transforming surface. Such condition restricts the range of reconfiguration in one plane, thereby controlling the amount of light entering that side of the building, according to the weather and seasonal conditions. This is a very high-tech and beautifully engineered solution for a transformable facade. Unfortunately, due to high maintenance and operational costs the rings no longer work. Commonly, the iris diaphragm is used with photographic cameras consists of number of very thin metal blades mounted on a base plate and membrane with a blade actuating ring that has a series of welded pieces (Fig 10). By rotating the ring the welded pieces can push or pull the blades and the swivel diaphragms opening can work like the iris diaphragm. When this system is in its open position each blade overlaps the other during the deployment; as a result they are forced to operate on a sloped angle. The slope of the blades increases as they approach the closed position. This is more evident when the width of the blade is less. A combination of Swiveling action for the roof plane and lightness and strength qualities of nonwoven materials are more evident within kinetic devices due to their flexibility, nonwoven textiles like membranes used in context of this research are an apt choice for kinetic devices which reconfigure on a regular basis.

Reconfigurability on the wall side of the plane: Conceptual Design

Reconfiguration Analysis: Modules with an inherent flexible geometry

Reconfigurability Analysis: Modules with an inherent flexible geometry

<table>
<thead>
<tr>
<th>Reconfigurability</th>
<th>Analysis</th>
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<td>Modules with an</td>
<td>inherent flexible geometry</td>
</tr>
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</table>
Adaptive concept has potential to be applicable as technology is not available. From the point of view of this area of research, this design concept has a potential to be applicable as reconfiguring it potentially enhances the performance of low-income families.

Disadvantage: the truss turns around on one fulcrum at three intervals, allowing the roof the span of being applicable to many different environments. This requires precision during fabrication. Therefore, any force applied to it's current geometry is needed to be reconfigured. The researcher J. Chilton has proposed an alternate design which facilitates the design in order to make the design more energy efficient and at the same time eliminating the gaps.

Fig 17 & 18: PROPOSED DESIGN of QI Zong Tennis centre, Shanghai and it's opening detail

Fig 16: BUILT DESIGN of QI Zong Tennis centre, Shanghai  Petal form of retractable roof (5)

be applied in areas where specialized technology is not available. From the point of view of this area of research, this design concept has a potential to be applicable as