MATERIAL STUDY OF FOLDED PLATE STRUCTURE

Pallavi Bansode[1], Himani Dharmamer[2], Arya Ghosalkar[3], Aayushi Save[4], Mansi Thakur[5], Mohsin Khan[6], Pratik Katalkar[7]

1, 2,3,4,5 Student at VIVA School of Architecture

6, 7 *Assistant Professor at VIVA School of Architecture*

ABSTRACT

Folded structures are three-dimensional spatial structures that fall within the structural systems category. The term "folded structure" refers to a folded form of construction that includes constructions made up of elements that are joined together in space to form a folded structure. For a long time, this form of building was only possible in practice with reinforced concrete and on-site construction, which necessitated the use of a complex shell. The development of prefabricated buildings led to innovations in this style of construction, such that folded structures could be created by assembling prefabricated pieces and their relationships on site, resulting in monolithization. From the beginning of folded structure research to the present, it has followed the newest advances and developments in terms of applied materials and connecting methods. The desire for more cost-effective and faster building encouraged the use of folding reinforced concrete structures, leading to constructions made of wood, steel, and other modern materials that gradually expanded.

Keywords: architecture, building structure, folded plate structure, form-resistant structures.

INTRODUCTION

In terms of their forms and the materials used to make them, folded structures can be constructed in a variety of ways. The systematization of folded structures in terms of shape and geometry was done based on research and analysis of the formal possibilities of folded constructs. The phrase "folded structure" refers to a folded form of building that includes structures built of plates and structures made of sticks that are folded together in space.

It's worth remembering that the evolution of folded plate structures is intimately linked to the development of new building materials. Their application necessitates the use of new building techniques and opens up new structural possibilities. The development of folded plate structures was largely supported by concrete and fiber reinforced composites.

LITERTURE REIVEW

Folded structures made of reinforced concrete

The most typical material used for wrinkles is concrete. Folded construction is defined by a significant number of authors as a structure composed entirely of reinforced concrete.

The basis for this assertion is that this material is used in the majority of folded structures. The most frequent crease type is a "V" shape, whose static height varies according on the range and load. Wood is commonly used for folded board structures that require casing and are cast on site. When the plate slope is greater than 30 degrees, double plating is required. The dimensions of folded plates are not limited in this situation.

The use of reinforced concrete folded structures composed of composite slabs allows for the creation of

various fold shapes in reinforced concrete. The plating that is utilised while making elements in plants is fairly easy.It is important to connect plate joints on site during the folding process. Thin plates have more complicated monolithization of the joints due to a lack of room for their mutual connection, whereas thick plates have more complicated monolithization of the joints due to a lack of space for their mutual connection. Folded structures can

also be created by combining numerous smaller elements onto a single fold plane and monolithizing a larger number of compounds.

Truss folded structures of reinforced concrete

Reinforced concrete may be folded into truss structures. A folded hangar at Gatwick Airport in London is an example of a folded structure built in this manner. This structure is a trapezoidal folded structure, which means it is made up of three-band bars that are not placed next to each other but at a distance from each other, with purlins covering the gap between them. A trapezoidal crease in the cross section is generated by rods that are pre-stressed together to form a whole. It has a very exquisite appearance, with very thin rod cross sections and the appearance of a steel structure. This type of construction is not common for folded structures of reinforced concrete.[1]

Reinforced concrete folded structure performed in

combination of full-wall and lattice bearers

The building over the amphitheatre at Delft University, which was designed by Van den Broek , is an example of folded construction that is a combination of corrugated
board and lattice structure. The folded structure is built of a 32-meter-long cantilevered overhang. This design has made it possible to have a flexible space. It was done as a full-wall folded construction with a lattice structure above the supports. [2]

Metal folded structures

Trapezoidal sheet or truss can be used to create metal folded structures. Belts and diagonal bars of infilling make up folded metal, steel, or aluminium constructions. Formwork or powerful pumps are not required for the creation of such folded structures.
The relevance of deformation and stability in the design of metal truss constructions cannot be overstated. The size of a range that can manage its load capacity is affected by the height of a trapezoidal plate.

Floor folded construction of steel sheet

Because bridges constructed of steel structures have a low own weight, we tend to design light-weight floor . constructions for them. A trapezoidal sheet, folded as a trapezoidal fold, is one of the possible bearings of the bridge's floor design in this situation. Level sheet panels wearing course runs through them.[1]

Lattice folded structures of steel trusses

Steel trusses can be folded over a variety of bases to create folded structures. The building of boundary walls, like that of the roof, is done using a lattice folded framework. This style of structure can withstand a variety of conditions. They're used in the design of huge halls, sports facilities, and exhibition pavilions since they add to the object's aesthetic identity.

Figure 1 International Convention and Exposition Centre, Nanning, China

Source- *arch da*

Folded structures of wood

Due to the limited possibilities to overcome the large distribution areas and the reduction in the global supply of wood, wood was restricted by other materials (steel, reinforced concrete) in the early second half of the 19th century.
The application of modern technological solutions eliminated the weaknesses of the material and made possible a great use of wood and wood products in a contemporary building. Wood Folding Frames are easy to transport, handle and assemble.
This type of prefabricated pleats based on the primary support structure of a pleat segment can be divided into: panel and truss.

Panel folded constructions of wood

Folded constructions made of wood are usually formed as a panel. The wooden panel structures folded, according to their main structure, can be divided into:

- Full wall panels
- Panels with grid supporting structure
- Panels with framework (panel) supporting structure
- Panels with arch supporting structure.

The joints between the wooden panels are hinged, so it is necessary to install additional reinforcing elements of the membranes, which can be realized as full-wall wooden elements or rods (wood or metal).

Full-wall panel folded constructions of wood

The elements of the foldable construction of the complete wall panel are constructed as compact solid wood elements or plywood elements and the frame construction
of the panel is covered with veneer panels. Solid wall element consists of cross laminated wood panels. Based on laboratory tests and investigations; Using recently acquired knowledge, the church prototype was built in, consisting of 110mm thick panels. Chapel St. Loup, Vaud, Switzerland, was designed by Danilo Mondada in 2007. The joints between the panels are made with the reinforcement plates and wood screws. The elements under construction with wood joints can also be formed from the panels, which consist of a wood box lined with veneer panels on both sides.
The role of the plywood is to assume the transverse force in the folded construction, while the elements of the frame construction in take the deflections and the hips absorb the tensile and compressive forces. One possibility of creating joints between the panels as undercut elements is with "L" metal profiles and screws. "Trofdek" is a folding wooden construction with a low folding height. This folded structure is a trapezoidal pleat with sides made of plywood (ribs) and the top and

bottom tape is made of solid wood and is used to connect between the folding elements. "Trodek" is the trade name for this design, which is patented in England. This type of construction is used as a mezzanine and roof. [4]construction, but is also used as a cladding in the preparation of reinforced concrete rib constructions. The "Kielsteg" mezzanine construction is

Panel folded construction with lattice, frame and arched supporting structure of wood

The folded panel structure element can have a lattice, frame and arch structure as a support structure. With this type of panel element, both sides must always be placed over the entire surface of the support structure. The connections between solid wall panels as supporting elements of the folding construction can be made by connecting two panels: with bolts, screws indirectly through the wooden element , screws indirectly through the metal fittings.

Folded construction of wooden trusses

The elements of the folded structure could be formed from wooden frames. Combining the beams we can obtain different forms of folded structures. The trusses are connected at location. The slat bars at the deflections and hips of the folding construction and the filler bars are made of solid wood or glued laminated wood. The choice of the dimensions of the cross section of the wooden frame bar is influenced by: the area, the load, the shape and the dimensions of the element of a bend. Static calculation determines the exact dimensions of each bar in the truss of a wood element. When installing, the packages are formed on the ground. One package consisted of two truss girders, each connected by bars along the lower wing. [1]

Figure 2Mounted prototype of cylindrical folded structure formed by using wooden trusses as the elements of folded structure

Source-arch daily

Lattice folded structures can be made from glued plywood bars. They are used for large spans, even over 30 m. For such structures it is necessary to design and prepare a special shackle to connect wooden elements

a folding mezzanine construction. The "Kielsteg" element consists of top and bottom strings of solid wood and the frames with "V" folds of plywood or OSB composite. With the use of "Kielsteg" elements, ranges from to 30 m can be bridged. This type of construction can be implemented as a mezzanine for single-family homes and as a roof.
when forming the roof structure. The peculiarity of this type of truss structure is that there is no duplication of bars as elements of the adjacent fold planes that they contain the louvers at the deflection points and the hip. Characteristics of such folded structures are the large cross sections of the tape rods (hip and deflection). This type of construction is assembled from individual elements and on site. The formation of folded structures with wooden beams is a modern technical and technological solution that overcomes the shortcomings of spatial concrete structures. Folded constructions made of wooden trusses can meet high aesthetic requirements. As a natural material, meets the high environmental requirements that a modern design must meet, and with regard to the extraction of natural materials as energy efficient products and its possible recycling, which correspond to the current trends of sustainable development. The roofs thus formed as three-dimensional roof structures are realized by the installation of prefabricated wooden truss elements with uniform connections, and enables the industrial production of wooden trusses as elements of the folding structure. The search for such an economical and rational construction led to the choice of wood as a construction material with excellent physical, mechanical and aesthetic properties. The installation of structures with these lightweight elements allows to work comfortably on.

Folded structures of glass

Glass has been used extensively as a structural element in construction. Glass can be used alone or in conjunction with other materials to create wall, roof, and floor structures. Because an independent glass plate deforms when subjected to pressure, it flares up, we associate it with another element in order to prevent it from deforming.

If another glass plate is used to prevent deformation, the new feature is put at an angle to the base glass plate, resulting in a folds shape and achieving spatial stiffness of the glass element. Glass constructions for a cylindrical folded structure can be made up to a distance of 12 meters. This structure is made up of glass triangle parts linked together by metal braces. This sort of joint connection allows adjacent panels to stiffen each other.

Although the manufacture of folded glass structures is not widely used in practice today, there is study and development of experimental models that address this

issue.[1]

Folded structures of plastic materials

In the second part of the twentieth century, polyester resin-based products were widely employed. This material has also been used in the manufacture of folded structures. Individual flat plate elements or a combination of spatial elements of "V" or "" form folds with flat plate elements have been used to create folded buildings in the past. This sort of polyester resin-based folding structure.

Folded constructions made in combination of different materials

The development of folded structures led to the use of multiple materials in a single folded structure. Renzo Piano designed a series of temporary facilities in the 1960s using a combination of steel and orthorhombic folding spatial elements constructed of polyester resin. He was attempting to rationalize the construction on site by producing specific portions of the structure at the factory and realizing a more efficient design by picking the type of material and minimizing the weight of the elements. In the mine in Pomez, Italy, he experimented with the use of various materials in the construction of a dismantling structure for ore storage. This structure is constructed up of fractured rhomboid plates made of polyester resin and steel reinforcement. Screws were used for all of the connectors between the parts. This folded construction is partly transparent and provides for natural brightness and energy savings due to the type of material used – polyester resin.A test model of folded construction constructed of trapezoidal sheet metal and glass as a horizontal surface represents an example of producing the folded structure in combination of two materials (metal and glass). Special screws are used to connect these two materials. The sheet's perforations allow light to pass through and contribute to the artistic and aesthetic experience of space. [5]

CASESTUDY

U.S. AIR FORCE ACADEMY – CADET CHAPEL

Location: Colorado Springs, Colorado
Project Completion: 1963
Project Area: 54,870 ft2
Building Height: 150 ft
Market: Cultural, Education
Service: Architecture, Structural + Civil Engineering
CLIENT/OWNER-United States Air Force Academy
Built in-1959 – 1962
Height-45.72m
Width-26mLength-85m

Figure 3 View of USA Academy

Source-arch daily

Concept

- The Chapel was specifically designed to accommodate three distinct areas of worship under one roof.
- Inspired by Sainte-Chappelle chapel in France and the Basilica of St. Francis of Assisi in Italy, architect Walter Netsch stacked spaces on two main levels.
- The architect faced the challenge of bringing together under one roof different spaces for different faiths and creeds, while creating a national monument.
- For this reason he considered that a single needle involve a message of a single religion and a deck with
- Three towers would make no sense, in addition to a design that will leave no doubt that it was a place of worship without using traditional architectural exterior badges of any faith.

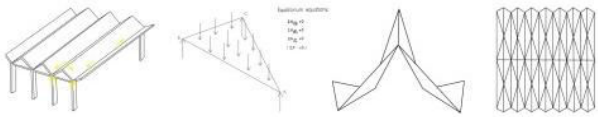

Figure 4 Folding patterns

Source-arch daily

Plan

- The main floor Protestant chapel is enclosed by the aforementioned tetrahedrons clad in extruded aluminum separated by continuous colored glass panels, with windows of special laminated glass.

- The terrace-level Catholic chapel is characterized by precast masonry forming the ceiling pattern, with side walls of amber glass and strip windows of faceted glass. The Jewish chapel is a circular room enclosed in cypress frames and stained-glass slabs, with a foyer of brown Jerusalem stone donated by the Israeli Air Force.

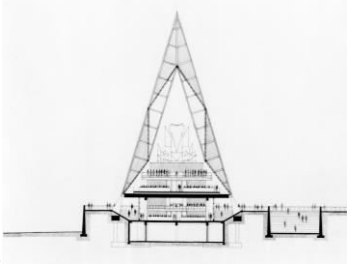

Figure 5 Section

Source-arch daily

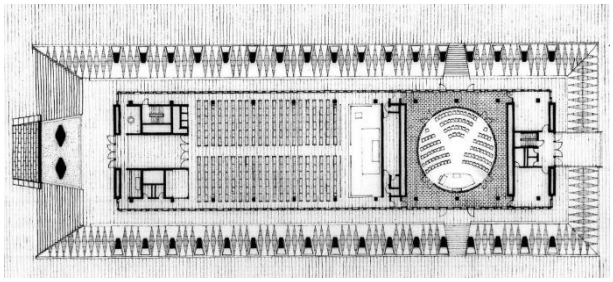

Figure 6Plan

Source-arch daily

Structure

- The building that houses the chapels rises 46m, has a length of 85m and a width of 26m.
- The most striking aspect of the chapel is its row of seventeen towers.
- In the original design nineteen needles were contemplated, but this number was reduced due to budget problems.
- The structure is a tubular steel frame consisting of 100 identical tetrahedrons, each 23m long and weighing 5tn, coated aluminum panels.
- Tetrahedrons 0,30cm are spaced from one another, creating holes in the frame are filled with stained glass 25mm thick.

Program

- The main program requires three distinct and separate entrances chapels: a Protestant chapel with 900 seats, a Catholic chapel with 500 seats, and a Jewish chapel with 100 seats. Each chapel has its own entrance, and services can be maintained simultaneously without interfering with each other.

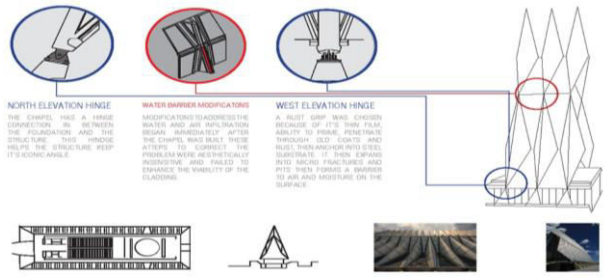

Figure 7 Structural System

Source-arch daily

Chapel protestant

- The main floor of the Protestant chapel, on the top floor, is enclosed by the extruded aluminum coated tetrahedral separated by continuous panels of colored glass and special laminated glass windows.

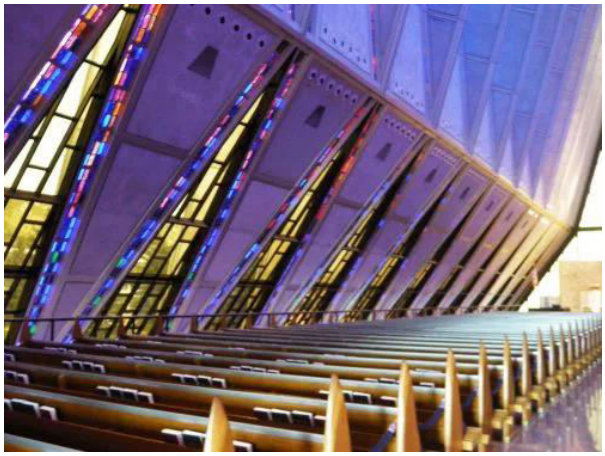

Figure 8 Protestant chapel

Source-arch daily

Catholic Chapel

- The terraced level of the Catholic chapel on the ground floor, is characterized by the prefabricated masonry forming the pattern of the roof, sidewalls with amber glass windows and rows of faceted crystals.

Figure 9 Catholic chapel

Source-*arch daily*

Jewish Chapel

- Jewish chapel is a circular room closed with cypress frames and slabs of colored glass with a brown lobby Jerusalem stone donated by the Air Force of Israel. It is located on the ground floor as well as the Buddhist shrine.
- The small Buddhist shrine, 27,87m2, was added in 2007 and in 2011 outdoor space known as Falcon circle, a circle of large stones and created for fans of "The Earth Centered Spirituality" was created.
- A little lower than the Buddhist Chapel some rooms for other possible services confessions were enabled, no special symbolism in order to be used by each and two conference rooms.

METHODOLOGY

- Description of the method This Article talks about different materials that can be used while constructing a folded plate structure. While reviewing others research papers it was observed that folded plate can be constructed using different materials which can act as monolithic structure.Taking inspiration from nature as well as origami various shapes of folded plates can be obtained.Structure load of different materials act as same as the load itself gets transferred through this folded plates.

FUTURE SCOPE

- After reviewing various research paper and materials used, we can state that there can be numerous ways for designing and constructing the folded plates structure, Different materials provide different aesthetical looks. Folded plates structural systemscan be used for various structures as it is very light form of construction. These types of structures reduce both materials and construction costs. Molding of concrete, joinery of timber, welding of steel and aluminum are ways in which design of folded can take place providing scope in the future.

CONCLUSION

- A folded construction is a spatial system of constructions made up of flat parts positioned at an angle to each other.
- First, folded structures are associated with reinforced concrete structures, and there has long been a misconception that this style of construction can only be done with that material.
- Folded structures were built of additional materials throughout the second half of the twentieth century, including steel, wood, polyester resin, and glass, as well as combinations of these materials.
- Using the principles of unification and systematization as essential structural elements, you may create a flexible system for producing folded structures in terms of technology and make the process of manufacturing, transporting, and installing folded structures easier.
- In terms of design and visual effect, folding structures with various materials can result in intriguing forms and design solutions. This distinguishes and distinguishes the structures created in this manner from other, less complicated spatial forms

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