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Weaving with Light: Exploring Shadow and Sunlight through Textile Thinking in Architecture.

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Abstract - This paper studies the influence of textiles on architectural responses to sunlight and shadow. In Indian textiles like *Bandhani*, *Ajrakh*, and *Patola*, the way light is modulated relies on thread density and the multiple layers of natural dyes. When these ideas are adapted to building design, they guide how façades filter daylight, form shadows, and affect the mood of interior spaces. The study suggests that light and shadow can be understood as interwoven elements that shape space, climate, and emotion. Through an analysis of literature and built examples, the study explores how textile-inspired façades and double-skin systems can produce breathable, climate-efficient, and aesthetically dynamic building envelopes that respond to the shifting path of the sun.

Key Words: – Weaving architecture, Gujarat traditional textiles, Textile-Inspired Façades, Sunlight, Shadow

1.INTRODUCTION

Textiles and architecture have always been connected through their use of structure, pattern, and surface. Both disciplines study how materials can shelter, filter, and shape the spaces people inhabit. Traditional Indian fabrics such as *Bandhani*, *Ajrakh*, and Patola show a deep understanding of light and climate. (Bordia, 2019) (Bharti, 2020) (Tolia-Kataria, 2012)The weaving of threads, the layering of dyes, and the repetition of patterns decide how sunlight filters through, how shadows appear, and how comfort is preserved in hot and dry climates. When applied to architecture, these textile concepts shape the way light and shadow move and interact on building surfaces. Features such as *jali* screens, perforated walls, louvers, and double-skin façades function like woven layers softening glare, enabling airflow, and producing dynamic light patterns that change with time. (Maurin, 2013) (Bharti, 2020) As the sun moves, these features make the building seem to change at times open and glowing, at other times calm and shaded. This study examines how concepts drawn from textiles can influence architectural design through the play of light and shadow. It highlights how features such as layering, porosity, and material density in fabrics can suggest methods to manage sunlight and heat within buildings. The research understands shadow not as darkness, but as a part of design that adds depth, feeling, and rhythm to a space.

2 OBJECTIVE

This study aims to understand how textile principles like weaving, layering, and openness can influence the use of light and shadow in architecture. It looks at how traditional fabrics handle light and comfort, and how these techniques can be adapted into building façades and spaces that filter sunlight, form patterns of shade, and respond to the surrounding climate.

3. METHODOLOGY

The research follows a qualitative and analytical approach to study how textile concepts can influence the use of light and shadow in architecture. It begins with a review of literature on textile logic, light behavior, and climate-responsive design. Traditional Indian fabrics like *Bandhani* and *Ajrakh* are studied to understand how the weave density, layering, and tiny openings control the passage of light and air. These insights are then applied to architecture to see how similar methods can be adapted in façades and building envelopes**.** The study seeks to translate textile qualities into architectural climate strategies, establishing a design framework where light, shadow, and material systems operate in a unified and responsive manner, similar to the interlacing structure of woven fabric.

4. HISTORICAL CONTEXT

In the history of architecture, textiles shaped some of the earliest ideas of enclosure. Woven skins and plant fibers used in primitive shelters created shade, ventilation, and filtered light, forming the basis for breathable and layered architectural surfaces. In Gujarat, this connection evolved further through rich textile traditions. (Patel, 2016) Techniques from *Bandhani*, *Ajrakh*, *Patola*, and *Tangaliya* demonstrated how material density and pattern control light, inspiring *jalis*, screens, and patterned façades that filter sunlight and improve comfort. (Bordia, 2019) (Bharti, 2020) (Tolia-Kataria, 2012) These crafts form an important historical foundation for light-responsive architectural design.

5. LITERATURE REVIEW

5.1 Early Textile-Based Shelter and the Origins of Architectural Thinking.

Textiles and architecture have been connected since humans began making their earliest shelters. Early forms of shelter, including tents, woven roofs, and reed huts, were largely built using textile-like methods. (Maurin, 2013) These fabric-based structures kept the interiors cool and airy by offering shade, reducing harsh sunlight, and allowing natural airflow. Over time, textile qualities such as porosity, layering, and rhythmic patterns started influencing the design of permanent buildings. As architecture developed, it began using textile-

inspired techniques to control light, airflow, and heat, while textile patterns also influenced building decoration. In this process, fabric shifted from being just a craft material to becoming a guiding idea for creating climate-responsive spaces.

5.2 Gujarat's Textile Traditions as Environmental Knowledge Systems

In India, the textile–architecture connection is especially strong in Gujarat. The region's diverse crafts—*Bandhani*, *Ajrakh*, *Patola* and *Tangaliya*—demonstrate a high level of understanding of how material behaviour affects both climate performance and visual effect.

a) ***Bandhani*** uses tiny tied knots that produce micro-perforations, controlling light and ventilation. (Bordia, 2019)

b) ***Ajrakh*** employs multiple resist-dyeing and printing layers, forming surfaces with varied light absorption and reflection. (Bharti, 2020)

c) ***Patola*** uses dense double *ikat* weaving that creates layered depth and shadow. (Tolia-Kataria, 2012)

d) ***Tangaliya*** incorporates raised dot patterns that catch light and create textured shadows.

Historically, this textile knowledge influenced architectural elements such as stone *jalis*, carved screens and patterned façades, which used similar ideas of porosity and repetition to manage daylight and reduce heat gain. (Guy, 1998) (Patel, 2016) Textile trade from Gujarat also contributed to an ongoing design dialogue, where techniques and visual systems moved between textile craft and building construction.

5.3 Weaving Logic and Architectural Interpretation

As architectural theory progressed, scholars began linking textile thinking directly to architectural form-making. Gottfried Semper located the origins of architectural enclosure in the "woven wall," while 20th-century experiments in tensile and membrane structures like Frei Otto's form-finding work repositioned textiles as active structural materials. (Maurin, 2013) Maurin and Motro's research on textile architecture highlights how tension, curvature and pre-stress generate structural behavior similar to woven cloth. Membrane structures gain stiffness from double curvature just as woven fabrics derive strength from the interplay of warp and weft. Through these studies, textile logic shifted from metaphor to method, giving architecture a vocabulary of pattern, seam, flattening and assembly that echoes garment construction.

5.4 Textile-Inspired Façades and Building Skins

Contemporary literature identifies several approaches through which textile ideas influence façade design:

a. Perforation and Pattern

Patterns derived from textiles such as *Bandhani* and *Ajrakh* inspire perforated screens that allow filtered sunlight and natural ventilation. (Bharti, 2020)

b. **Woven and Interlaced Surfaces**

Timber, metal or brick lattices replicate weaving logic, producing façades with depth and dynamic shadow patterns.

c. Layering and Double-Skin Systems

Architectural double skins adopt the textile idea of a base layer and an outer veil. The cavity between the two behaves like a breathable air gap that reduces heat and softens daylight.

d. Dynamic and Responsive Shading

Movable louvers, kinetic screens and fabric-based membranes use textile strategies to modulate light and airflow. Research on textile membranes and retrofit systems shows that lightweight, porous skins can improve thermal comfort and reduce energy use while adding minimal structural load.

5.5 Spatial and Structural Analogies: Warp–Weft Logic

The logic of weaving maps clearly onto spatial and structural systems.

a) The **warp**, which provides stability in fabric, corresponds to load-bearing elements like columns and structural walls.

b) The **weft**, which interlaces to create the surface, resembles flexible partitions, screens and secondary systems.

This analogy suggests architectural spaces that combine stable frameworks with adaptable, breathable layers. Textile compositions—especially the centre–field–border layout found in *Ajrakh*—translate naturally into spatial zoning, where a central activity space is framed by circulation zones and emphasized boundaries.

5.6 Textile-Inspired Façades and Building Skins

Textiles were designed for a hot and dry environment: breathable cottons allowed airflow, while denser weaves blocked sun and dust. These behaviors translate into architectural strategies:

a) *Bandhani*-inspired perforations can become façade openings for light modulation.

b) *Khadi*-like porosity informs breathable and ventilated wall systems.

c) *Ajrakh*-style layering inspires double-skin façades with shading and cooling benefits.

d) Changes in weave density mirror adjustable louvers and graded façade porosity.

Scientific studies on knitted canopies, mesh shading, and translucent membrane roofs confirm that textile geometry and layering significantly affect illumination, heat gain and comfort.

(Maurin, 2013) This positions textile knowledge not only as a cultural reference but also as a climate-responsive toolkit.

5.7 Material Translation: From Craft Techniques to Building Technology

Techniques from textile craft—cutting, flattening, seaming and assembling—now have direct architectural equivalents through digital fabrication. CNC cutting, penalization, seam welding and folded plate construction mirror garment-making methods. Advanced 3D textile technologies, spacer fabrics and technical knit composites expand the role of textiles into insulation, light diffusion, structure and shading. These developments show how textiles can serve as high-performance building envelopes.

5.8 Case Studies as Evidence of Textile–Architecture Interaction

Built examples illustrate how textile thinking operates in practice.
The Weave House uses interlaced timber and patterned brickwork to create filtered light and ventilation, echoing weaving logic. (Studio., 2022)
Chinar Textile Studio applies brick *jalis* and layered spaces to control daylight and temperature, reminiscent of textile workshops. (Studio, 2021)
The Passive House demonstrates layering as a thermal and environmental strategy, where outer skins, insulation and air cavities work together like a multi-layered textile envelope. (Institute., 2015)

These projects show that textile ideas are adaptable across climates, functions and materials.

5.9 Gaps in Existing Literature

Although many scholars discuss textiles in relation to structure, ornament or membrane systems, there is a significant gap in how traditional textiles are connected to architectural behavior specifically through sunlight *and* shadow. Much of the literature focuses either on the cultural symbolism of motifs or the engineering of textile membranes, without exploring how the porosity, layering, pattern density and light-handling qualities of traditional textiles—especially those from Gujarat—can be directly translated into façade design and environmental performance.

There is also limited research linking textile motifs with measurable daylight and shadow effects, or connecting traditional craft logic with contemporary parametric façade design that responds to solar exposure.

This study addresses these gaps by analysing how textile behaviour can inform architectural strategies for filtering light, shaping shadows and improving climatic comfort.

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6. STUDY OF TRADITIONAL TEXTILES

Gujarat's textile heritage provides a valuable basis for understanding how variations in material density, color, layering and perforation can direct sunlight and generate shadow effects. Although originally developed for cultural and utilitarian needs, these crafts demonstrate an advanced environmental intelligence closely aligned with architectural performance. Each textile embodies distinct methods of regulating light, air, heat and visual depth—insights that become crucial when translated into façade systems and architectural shading strategies.

6.1 *Bandhani* (Tie-Dye as Micro-Perforation Logic)

Bandhani is created by tightly tying small portions of cloth before dying, resulting in thousands of tiny resist points. These tied sections, when opened, leave lighter dots on the dyed surface. While this is primarily a decorative method, it demonstrates an important environmental behavior:

a) The tied knots create minute air pockets,

b) The resist points act like micro-perforations,

When sunlight falls on a *Bandhani* cloth, the variation in dye density and dot spacing produces a rhythmic light texture. This effect parallels façade systems where small perforations or repeated openings modulate daylight. The scattered visual texture of *Bandhani* can be seen as the earliest analogue to architectural perforated screens—filtering light gently, reducing glare, and maintaining airflow.

Figure 1 Bandhani print

Figure 2 Perforated Facade

6.2 *Ajrakh* (Layering, Repetition & Color Response to Heat)

Ajrakh textiles from Kutch are known for their geometric symmetry, deep indigo shades, and multiple stages of resist-dyeing. *Ajrakh's* construction reveals important insights:

a) Multiple layers of dye create depth and absorb or reflect light differently,

b) Dark indigo absorbs heat, while white resist motifs reflect it,

c) Repetitive geometry influences how shadow falls across the cloth,

d) The layered printing produces subtle shifts in tonal value under sunlight.

Ajrakh fabrics demonstrate how surface layering and geometric repetition can influence light behavior. When interpreted in architecture, *Ajrakh* suggests how double skins, patterned screens, and façade layering can soften harsh light, create patterned shadows, and reduce solar heat gain. The center–field–border layout, common in Ajrakh, also translates well into spatial zoning and façade composition.

Figure 3 Ajarakh pattern

Figure 4 double skin pattern facade

6.3 *Patola* (Density, Precision & Visual Depth)

Patola, the famous double-*ikat* weave of Gujarat, is constructed with dyed warp and weft threads aligned with extreme precision. Its characteristics are vital from an architectural perspective:

a) Dense weaving reduces direct light penetration,

b) Color intersection creates depth similar to layered shadows,

c) Sharp edges of woven motifs influence the sharpness of shadow patterns,

d) Double-sided patterning resembles façades that function similarly from inside and outside.

The nature of *Patola*—rich colour, high density, and intricate intersections—suggests façade strategies where opacity and transparency are carefully balanced. *Patola's* ability to create depth despite being a flat fabric parallels how layered façades and textured screens can produce dynamic shadows inside a building.

Figure 5 Patola print

Figure 6 colourful textured facade

6.4 *Tangaliya* (Raised Texture & Shadow Play)

Tangaliya weaving incorporates small bead-like dots created by twisting colored yarn into the warp. These raised knots create a textured surface that behaves uniquely under light:

a) The raised dots catch sunlight, creating fine shadow points,

b) As the cloth moves, the shadows shift direction,

c) The surface appears three-dimensional even though it is woven flat.

Tangaliya's light-catching texture is a direct parallel to architectural surfaces that use projection, relief, or depth to manipulate sunlight. This technique suggests design ideas for façades that rely on textured materials, patterned brickwork, or carved screens to create delicate shadow patterns that animate interior spaces.

Figure 7 Tangaliya pattern

Figure 8 patterned brickwork facade

7. ARCHITECTURAL ANALYSIS

Textiles and architecture connect through how they manage light, heat, and airflow. Textile qualities like porosity, pattern, layering, and color translate into *jaalis*, perforated screens, and double-skin façades that filter daylight, soften shadows, and reduce heat. Techniques seen in *Bandhani*, *Ajrakh*, and Patola inspire shadow patterns, while weaving logic reflects the

relationship between a building's fixed structure and its flexible shading systems. Overall, textile principles help buildings act like breathable, responsive skins that enhance comfort and spatial experience.

7.1 Warp–Weft as Structural Logic

Textile weaving offers a structural analogy for building systems. The rigid warp threads act like the building's structural frame—columns, beams, and the primary grid that holds the form together. The flexible weft threads parallel the secondary elements such as louvers, screens, shading devices, and lightweight partitions. This relationship shows how buildings can combine stability with adaptability: a strong load-bearing structure paired with a responsive façade or envelope that adjusts to light and climate. This structural reading strengthens the link between textile logic and architectural performance.

7.2 Structural Behavior of Layered Façades

Layered textiles like *Ajrakh* and *Patola* reflect how layered building façades work structurally. The outer screen acts as a lightweight, non-load-bearing layer fixed to the structural frame through brackets or a secondary steel system. The inner wall carries the load, while the cavity between the two layers allows heat to escape and air to circulate. This structural arrangement mirrors textile layering, where each layer serves a different function protection, depth, and breathability without compromising the core fabric.

7.3 Structural Patterning Using Textile Geometry

Textile patterns can guide modular structural systems. Repeating motifs found in *Ajrakh* or *Tangaliya* can be translated into modular panels, terracotta blocks, or precast screens that follow a structural rhythm. When aligned with the building grid, these patterns create both aesthetic order and structural clarity. This approach shows how craft-inspired geometry can become a repeating construction module that is efficient to produce, easy to install, and climatically effective.

8. CASE STUDIES

8.1 The Weave House, Navsari (India)

The Weave House explores how a building façade can behave like a woven textile. The design takes inspiration from the interlacing of warp and weft, translating it into a façade made of brick screens and staggered wooden members. The exterior skin is not a flat surface; instead, it shifts in density and layering, similar to how fabric changes thickness and openness in a woven cloth.

The orientation of the house guided how tightly or loosely the façade was "woven." South and west sides have denser brick screens to soften the harsh afternoon sun, while the north and east sides are more open, allowing cooler daylight and ventilation. As sunlight passes through the brick pattern, it creates delicate, shifting shadows on the floors and interior walls. These shadows behave similarly to the light passing through *Bandhani* or woven fabric broken, rhythmic, and constantly changing throughout the day.

The house shows how textile ideas can shape architectural performance. The façade filters heat, enhances privacy, reduces glare, and ventilates the interior naturally. At the same time, the shadow patterns bring a visual warmth and cultural familiarity, echoing the textures of Gujarat's textile heritage.

8.2 Chinar Textile Studio, Jaipur (India)

Chinar Textile Studio is a working space for craftsmen where daylight, ventilation, and thermal comfort are essential. The building adopts the logic of traditional textile workshops, where light must be controlled to avoid glare on fabrics while keeping the workspace cool. This requirement influenced the entire form, beginning with its deep brick walls and carefully placed perforated openings.

The façade uses brick *jalis* arranged in patterns that recall block-printed textiles such as *Ajrakh*. The pattern density is varied based on orientation: areas facing direct sun have tighter *jalis*, while shaded sides remain more open. This creates a gentle gradient of light across the interior. The filtered daylight resembles the effect of holding a printed textile against sunlight—soft shadows, subtle patterning, and reduction of heat.

Courtyards and transitional spaces act as breathing zones, similar to air gaps in layered textile construction. These voids bring indirect light, create air movement, and reduce the temperature inside the workshop. The architecture here behaves like a fabric with multiple layers—an outer protective surface, an inner workspace, and ventilated pockets in between.

The project demonstrates how textile thinking can inform climate comfort: controlled porosity, rhythmic openings, and material layering come together to create a workspace where light and shadow are both functional and atmospheric.

8.3 Passive House, Darmstadt (Germany)

The Passive House represents a different yet complementary interpretation of textile logic. While it does not reference textile culture visually, its building envelope functions like a layered fabric system. The house uses three main layers—an outer protective surface, insulation, and an airtight inner layer—with an air cavity working as a thermal buffer. This arrangement mirrors how clothing layers keep the body insulated, ventilated, and protected from heat and cold.

Sunlight is carefully managed through high-performance glazing, shading devices, and precise window orientation. Instead of decorative shadows, the emphasis is on thermal performance: preventing excess heat in summer while capturing low winter sunlight. The façade composition filters and redirects daylight much like a tightly woven textile that blocks glare yet admits soft illumination.

Although the Passive House is technologically advanced, the underlying idea remains close to textile logic—layering, controlled porosity, and climate response. It shows that textile-inspired thinking can apply across cultures and climates, whether through craft-based patterns or through high-performance building skins.

9. FINDINGS

The study finds that the structural logic embedded in Gujarat's traditional textiles offers clear architectural value, especially for climate-responsive façade design. The porosity of *Bandhani* translates into breathable screens and *jaalis*, while the layered depth of *Ajrakh* and Patola aligns with double-skin envelopes that soften light and reduce heat. (Mehta, 2019) The warp–weft relationship reflects the balance between a stable structural frame and flexible secondary elements like louvers or shading panels, showing a direct mapping between woven order and façade organization. (Sharma, 2021) Repeating textile patterns also inform modular façade rhythms that shape controlled daylight and shadow quality. Overall, the findings show that textile behavior can significantly enhance environmental performance, yet this craft-based intelligence remains underused in contemporary architectural practice.

10. CONCLUSIONS

The study concludes that Gujarat's textile traditions offer more than aesthetic inspiration—they provide a practical framework for climate-responsive architecture. (Sharma, 2021) Techniques like porosity, layering, and weaving can guide façades, screens, and shading systems to control light, heat, and airflow. (Mehta, 2019)Translating textile behavior into architecture enhances daylight quality, reduces heat gain, and creates meaningful shadow patterns, bridging cultural heritage with environmental performance. By applying these principles, buildings can become adaptive, comfortable, and expressive, demonstrating that traditional crafts are valuable tools for sustainable, contemporary design.

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