Indian Journal of Fibre & Textile Research
Vol. 51, June 2026, pp. 199-209
DOI: 10.56042/ijftr.v51i2.23340

Design and development of the angular lenticular brick motif woven fabric panels by weaving, double-layering, stitching, and foam tube wadding techniques

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Received 2 September 2025; revised received and accepted 20 January 2026

Angular Lenticular Panel (ALP) technology enables the transformation of one figure into another based on the viewing angle, developed using optical lenses, painted relief surfaces, or folded paper constructions. Recent research has extended this concept to textiles through Angular Lenticular Woven Fabric Panels (ALWFPs), which predominantly relied on elastic yarns to induce surface curvature during weaving, leading to limitations related to material control, dimensional stability, and long-term durability. The present study introduces a novel structural approach for developing ALWFPs without the use of elastic yarns, thereby advancing material innovation in angular lenticular textiles. An analysis of four previously reported ALP technologies revealed three common developmental stages, viz., segmentation motifs of identical dimensions, formation of a curved surface, and alternate placement of segmented motif elements on that surface. Based on these principles, three new ALWFPs were designed and fabricated with brick motifs using conventional heald shedding and extra-weft figure techniques. In the proposed method, two motifs were alternately woven into a single fabric. After weaving, the motif fabric was double-layered with a plain backing fabric and stitched to form horizontal hollow cloth tubes. Expanded polyethylene foam (EPEF) tubes were inserted into these channels to generate stable and repeatable curved surfaces. Each panel exhibited a clear angular lenticular effect, wherein one motif was perceived from one viewing direction and the alternate motif from the opposite direction. The developed ALWFPs demonstrate improved structural stability, material flexibility, and design scalability, offering potential applications in functional textiles, interior surfaces, interactive displays, and architectural textile design.

Keywords: Angular lenticular woven fabric panel, Brick motif, Foam tube wadding, Heald shedding, Stitching, Textile surface design, Two images merging

1 Introduction

The integration of visual transformation effects within textile substrates represents an emerging area of functional and decorative textile research. Angular Lenticular Panel (ALP) technology enables the visual merging of two or more images such that different figures become visible when viewed from left-to-right" / "right-to-left angles. One of the earliest demonstrations of this principle is attributed to the French painter G. A. Bois-Clair in 1692[1]. Based on visual outcomes, lenticular systems are commonly classified into three categories: angular (or transforming) lenticulars, animated lenticulars, and three-dimensional (stereoscopic) lenticulars[2]. Angular lenticulars facilitate a transition from one image to another as the observer moves laterally or tilts the viewing plane, making them suitable for displaying multiple figures within a single surface. Animated lenticulars create an illusion of motion by sequencing images with incremental variations, while stereoscopic lenticulars provide a depth effect by presenting separate images to the left and right eyes.

Conventional lenticular printing technology employs lenticular lenses mounted over interlaced printed images[3,4]. These lenses diffract light such that only one set of image strips is visible at a given viewing angle. While effective, lenticular lenses introduce constraints related to material rigidity, cost, and fabrication complexity, prompting researchers to explore alternative media and surface-forming techniques.

Lens-free angular lenticular panels (ALFs) have been explored in non-textile media. Sergio Cadenas developed angular lenticular oil paintings by creating vertical curved ridges on canvas using paste, with

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paired image segments painted on opposite sides of each ridge[5]. This relief-based approach enabled angular image transformation without optical lenses. Another method involved angular lenticular paper panels, where alternately merged image strips were folded into zig-zag or 'V' profiles, allowing directional visibility through structural geometry[6].

The translation of angular lenticular principles to textiles marked a significant development. Daniels and co-workers[7] demonstrated Angular Lenticular Woven Fabric Panels[8](ALWFPs) with backed cloth weaves[9]using electronic jacquard weaving[10], in which interlaced image segments were woven with elastic (Spandex)[11] weft yarns to induce fabric folds during relaxation. Each fold acted as a curved surface carrying paired image segments, enabling angular transformation. However, existing textile-based approaches largely depend on elastic yarns to generate surface curvature, which introduces challenges related to yarn cost, long-term dimensional stability, and compatibility with conventional weaving systems.

The analysis of the above four Angular Lenticular Panels (ALPs) led to the identification of three common developmental stages: (i) selection of two motifs of identical dimensions and their division into equal segments, (ii) creation of a curved surface, and (iii) alternate placement of segmented motif elements on the curved surface. A comparative analysis of these four angular lenticular panel types also reveals that surface curvature is central to angular image transformation, irrespective of the medium. Earlier ALPs employed lenses, paste-based relief in painting, and folded paper to generate curvature. The fourth development—an Angular Lenticular Woven Fabric Panel (ALWFP) —used elastic yarn as weft to induce surface curvature during weaving.

The present research addresses the limitations of earlier types by developing a novel Angular Lenticular Woven Fabric Panel (ALWFP). The fabric was woven on a conventional heald-shaft loomequipped with electronic dobby[12]. The brick motifs[13]developed based on Extra-weft[14] principle, are usedtocreate horizontal segmentation on the woven fabric. The weave structures and their lifting plan graphs were designed using MS Paint[15]. Expanded Polyethylene Foam (EPEF) tubes[16] were used as the wadding material to generate the required curved surface, broadening the scope of angular lenticular applications in woven textiles. The present study builds on this understanding by proposing an alternative woven ALFP in which curvature is achieved through double-layer construction, stitching, and EPEF wadding, eliminating the need for elastic yarns. This material system enables the formation of controlled curvature using commonly available textile yarns, materials and conventional looms, thereby improving manufacturability and scalability. By integrating foam-based wadding within woven structures, the study introduces a hybrid textile composite approach that expands the functional capabilities of woven fabric panels for advanced surface design applications. The resulting panels are soft, flexible, and spongy, and demonstrate potential for functional and decorative applications in architecture, interiors, product design, fashion, and textile art.

2 Materials and Methods

2.1 Concept of Designing the Earlier ALP

Figure 1 illustrates the four angular lenticular technologies developed using different materials and processes. In all approaches, two figures (F1 and F2) of identical dimensions are divided into *n* equal vertical segments (P1–Pn) as shown in Fig. 1(a). Then these segments are arranged in the sequence of F1-P1, F2-P1, F1-P2, F2-P2 … F1-Pn, F2-Pn. (i) In lenticular lens-based printed panels [Fig. 1(b)], the segmented parts of both figures are alternately combined, printed and covered with lenticular lenses. The angular visibility of the figures depends on the observer's viewing direction. ii) The Spanish painter Sergio Cadenas developed angular lenticular oil paintings by creating thin vertical curved ridges using paste on canvas [Fig. 1(c)]. Each ridge carries paired segments from the two figures, resulting in an angular transformation as the viewer moves laterally. (iii) Another approach involves zig-zag folded paper panels, wherein alternately merged printed strips are folded into 'V' profiles, enabling directional visibility of the two figures[Fig. 1(d)]. (iv) Extending these principles to textiles, angular lenticular woven fabric panels were developed by Daniels using electronic jacquard weaving using weft-backed sateen and satin weaves. demonstrated angular lenticular effects in woven fabrics by combining interlaced motif segments and employing elastic (Spandex) weft yarns to generate curvature during fabric relaxation [Fig. 1(e)]. First, two figure graphs with two figures (letters) 'A' (F1) and 'B' (F2), are prepared for merging. Each figure graph is divided into 'n' vertical

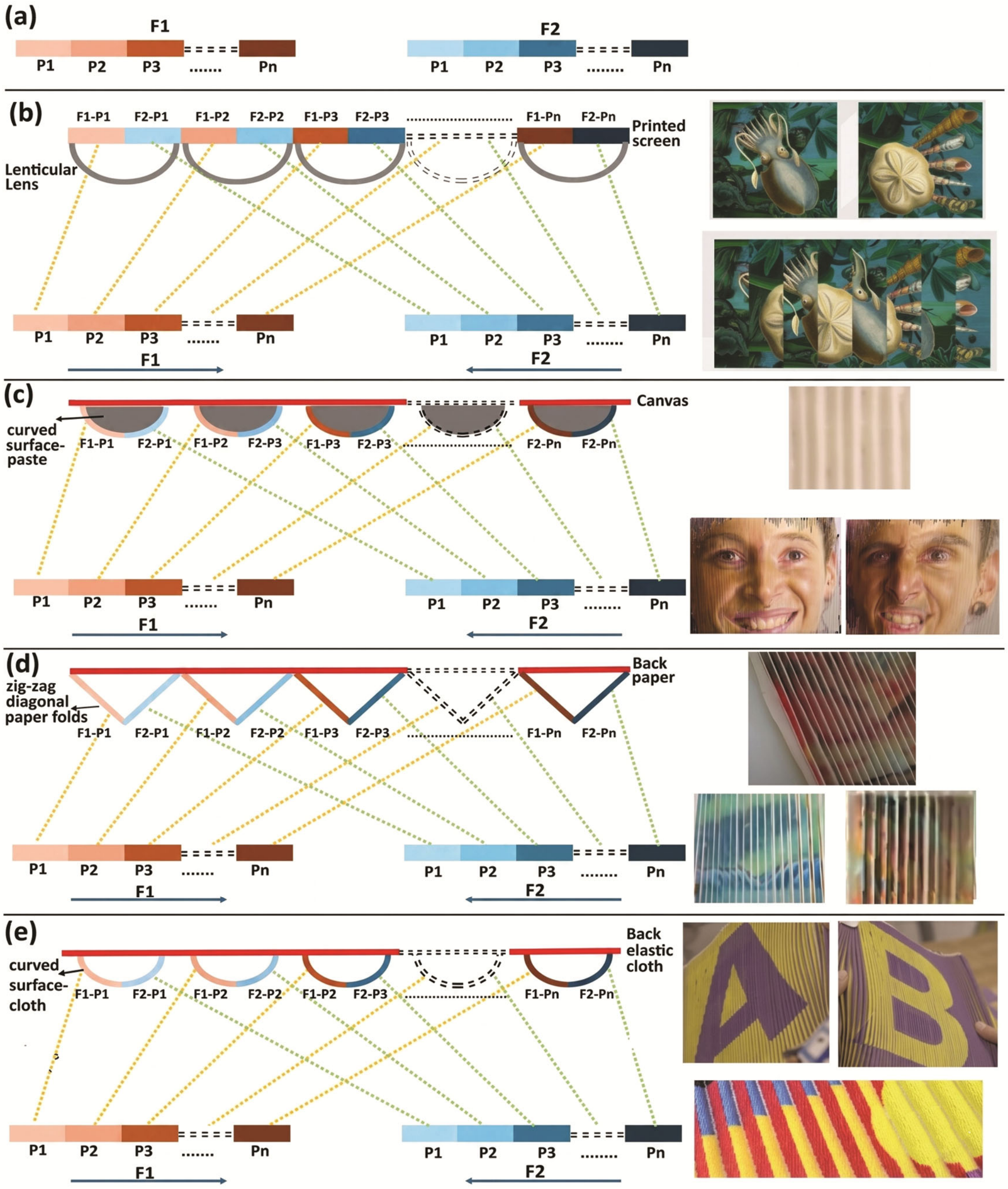

Fig. 1 — Different angular lenticular technologies developed, (a) two figures (F1 and F2) of identical dimensions, each divided into n equal vertical segments (P1–Pn), (b) angular lenticular panel developed by alternately printing segmented parts of Figures 1 and 2 and covering them with lenticular lenses, (c) angular lenticular panel developed by forming vertical curved surfaces using paste and alternately painting segmented parts of Figures 1 and 2, (d) angular lenticular panel developed by alternately pasting segmented paper parts of Figures 1 and 2 and folding them to form zig-zag diagonal profiles, and (e) angular lenticular woven fabric panel developed by alternately weaving segmented parts of Figures 1 and 2 and forming curved fabric surfaces using elastic yarn.

parts of equal ends. Then, the final digital jacquard graph is prepared for weaving by combining the two figure graph parts alternately, side by side, in the order F1-P1, F2-P1, F1-P2, F2-P2, F1-P3, F2-P3, …, F1-Pn, F2-Pn. The weft used is an elastic yarn (Spandex). Therefore, after weaving, when the fabric is relaxed, each fold forms a vertical curved surface. Hence, the letter ‘A’ becomes visible when observing it from left to right on the fabric panel. Again, the letter ‘B’ becomes visible when observing it from right to left on the fabric panel.

2.2 Materials and Methods of Developing the New ALWFP

2.2.1 Materials Used

Yarns: The fabrics were woven using commercially available non-elastic yarns suitable for conventional weaving. Cotton yarns were used in both warp and weft directions due to their good tensile strength, flexibility, ease of processing, and compatibility with post-weaving stitching operations. The absence of elastic yarns ensured the dimensional stability of the woven structure. It facilitated controlled surface formation through structural means rather than yarn elasticity.

Fabric specifications: The fabric was woven on a conventional heald-shaft loom equipped with electronic dobby. The brick motifs based on extra-weft principles were used to develop weft-wise segmentation on the woven fabric, allowing accurate placement of motif strips alternately during the weaving process. A plain-woven fabric of identical construction, yarn type, and dimensions was used as the backing layer.

Foam wadding material: Expanded Polyethylene Foam (EPEF) tubes were used as the wadding material to generate the required curved surface. EPEF was selected due to its low density, flexibility, resilience, and smooth surface characteristics. The foam tubes exhibited good compressibility and shape recovery, enabling stable curvature without imposing excessive stress on the woven fabric. The diameter of each EPEF tube was selected to match the internal diameter of the corresponding hollow fabric tube, ensuring uniform curvature across the panel and consistent angular visual transition.

2.2.2 Methods Followed

Figure 2 illustrates the methods followed in developing the new ALWFPs.

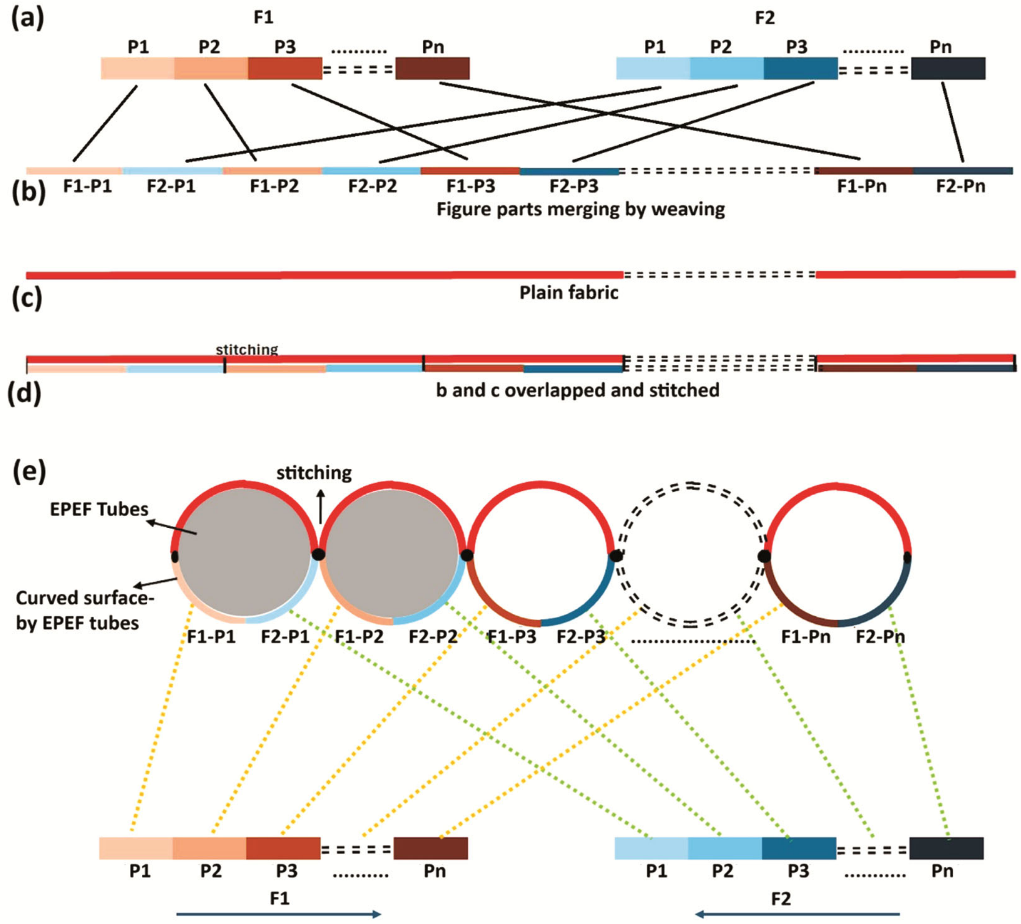

Fig. 2 — Principle of development of the new angular lenticular fabric panel (ALWFP) (a) two brick motifs (F1 and F2) of identical dimensions, each divided into n equal vertical segments (P1–Pn), (b) woven fabric produced by alternate merging of segmented parts of brick motifs 1 and 2, (c) plain woven fabric of dimensions equal to the motif fabric, (d) double-layer fabric assembly formed by stitching the motif fabric and plain fabric at predetermined intervals to create n hollow fabric tubes, and (e) insertion of n Expanded Polyethylene Foam (EPEF) tubes into the hollow fabric tubes to generate curved surfaces.

(i) Selection and preparation of motifs: Two brick motifs (F1 and F2) of identical dimensions were selected for angular lenticular formation [Figure 2(a)]. Each motif was digitally prepared and divided into n equal vertical segments of uniform width. The segmented parts were designated as F1-P1 to F1-Pn and F2-P1 to F2-Pn, respectively. (ii) Weaving of segmented motif fabric: The segmented brick motifs were alternately combined in the sequence F1-P1, F2-P1, F1-P2, F2-P2 … F1-Pn, F2-Pn and woven as a single fabric using non-elastic yarns on a conventional heald-shaft loom. The brick motifs of the plain-weave extra-weft structure were employed to ensure uniform interlacing and clear motif definition. The resulting fabric contained alternating horizontal strips corresponding to the two motif s[Figure 2(b)]. (iii) Preparation of backing fabric: A plain-woven fabric of identical dimensions, yarn type, and weave structure as the motif fabric was separately woven to serve as the backing layer [Figure 2(c)]. (iv) Formation of double-layer fabric assembly: The motif fabric and the backing fabric were superimposed with the motif fabric facing outward. The two layers were aligned accurately to ensure uniform strip widths across the panel. (v) Stitching to form hollow fabric tubes: Full-width stitching was carried out perpendicular to the warp direction at predetermined intervals corresponding to the boundaries between successive motif segments [Figure 2(d)]. The first stitch was placed at the beginning of F1-P1, and subsequent stitches were placed between F2-Pi and F1-P(i+1), forming n parallel hollow fabric tubes. Each tube enclosed one pair of motif segments (F1-Pi and F2-Pi). (vi) Insertion of foam wadding: EPEF tubes of predetermined diameter were inserted into each horizontal hollow fabric tube. The diameter of the foam tubes was selected to match the internal diameter of the fabric tubes. A total of n foam tubes were inserted [Figure 2(e)]. (vii) Formation of angular lenticular surface: Insertion of the EPEF tubes generated stable curved surfaces across the length of the panel. In each curved unit, the F1-Pi segment occupied the left face of the curved surface, while the corresponding F2-Pi segment occupied the right face. (viii) Evaluation of angular visibility: The completed ALWFP was visually examined by viewing the panel from left-to-right and right-to-left directions. Angular transformation of brick motifs was confirmed by the selective visibility of motif F1 from left-to-right viewing direction and motif F2 from the right-to-left direction, as shown at the bottom of Figure 2.

Figure 3 shows a comparative flowchart outlining the technologies used in the development of four earlier Angular Lenticular Panels (ALPs) and contrasts them with the process adopted in the present research for developing a novel woven Angular Lenticular Fabric Panel (ALWFP).

3 Results and Discussion

The experimental investigation was structured around the development and evaluation of three angular lenticular woven fabric panels (Panels 1–3) designed using a common structural principle but differing in motif complexity and visual resolution. All three fabrics required for developing the panels were produced with brick motifs on conventional looms using heald shedding with extra-weft figuring principle, followed by a uniform post-weaving process involving double-layering, stitching, and insertion of EPEF tubes to generate controlled curved surfaces. Panel 1 focuses on establishing the basic feasibility of the angular lenticular effect through colour-based stripe and cross-over motifs. Panel 2 extends this approach to icon-based brick motifs, requiring greater precision in motif segmentation and alignment. Panel 3 further advances the method by incorporating high-density letter-based brick motifs to assess the scalability and clarity of the lenticular effect with increased segmentation. Together, these panels enable a systematic examination of how motif structure, segmentation density, and fabric construction influence angular visibility and image transformation in woven lenticular textiles. The experimental development of three Angular Lenticular Woven Fabric Panels (ALWFPs) is presented in Figs. 4 and 5, illustrating the weave design, fabric construction, stitching strategy, and angular visual behaviour.

3.1 Development of ALWFP With Cross-Over and Stripe Effects (Panel 1)

In the first phase of the study, woven fabrics incorporating brick motifs were used to develop ALWFP). The motifs were produced using heald shedding by combining plain weave and extra-weft figure weaves. The warp yarns were arranged in a single series. In the plain weave regions, the weft was inserted as a single series, while in the figured regions two weft series were employed, comprising a ground weft and an extra weft inserted in a 1:1 sequence. The details of the yarns and weaving parameters are given in Table 1.

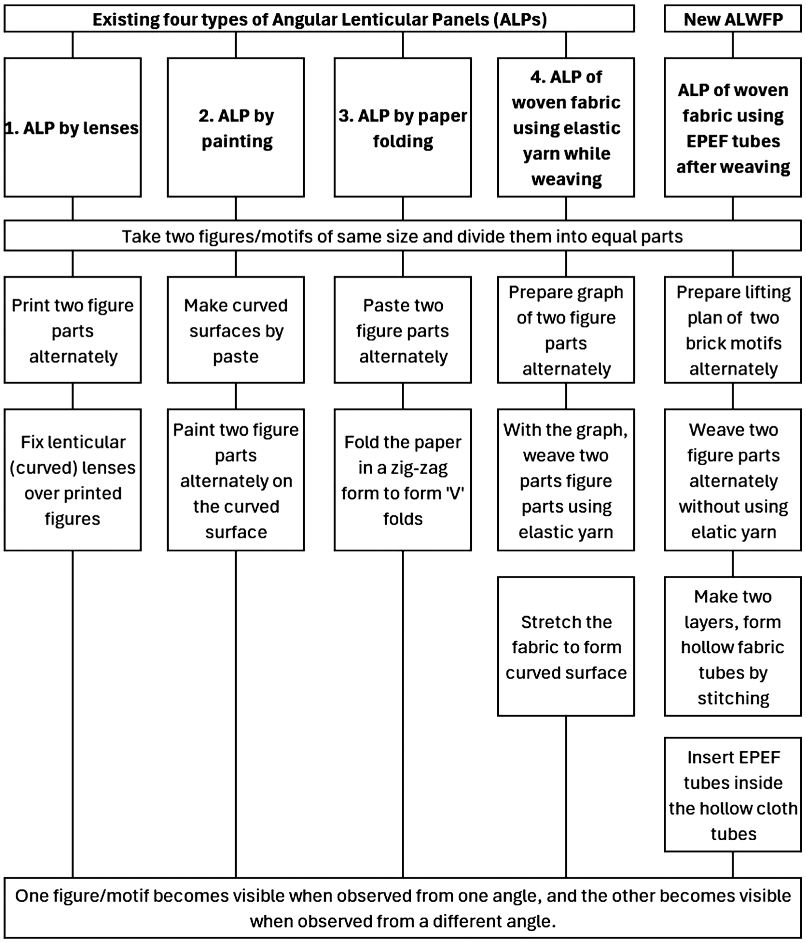

Fig. 3 — Comparative flowchart outlining the technologies used in the development of four earlier ALPs and the present research for developing a novel ALWFP.

Table 1 — Details of the warp and weft used for weaving the brick motifs fabric samples for developing the ALWFP

Description	Panel 1	Panel 2	Panel 2
Count of warp	2/20^{S} Ne cotton - Half white		
Count of plain weave weft	2/20^{S} Ne cotton - Half white		
Count of extra figure weft	Ground pick - 10^{S} Ne cotton - Half white Extra weft pick - 10^{S} Ne cotton - Half white: Colour in 1: 1		
Healds used	4	8	
Draft order	1, 3, 2, 3 – 6 times; 1, 4, 2, 4 – 6 times.	1, 3, 2, 3 – 18 times; 1, 4, 2, 4 – 12 times; 1, 5, 2, 5 – 12 times; 1, 6, 2, 6 – 12 times; 1, 7, 2, 7 – 12 times; 1, 8, 2, 8 – 12 times; 1, 3, 2, 3 – 18 times;	
Picks sequence	Plain – 16 picks, Stripe – 20 picks (1 plain: 1 extra weft pick),	Plain – 40 picks, Each group – 40 picks (1 plain: 1 extra weft pick).	Plain – 24 picks, Each group – 32 picks (1 plain: 1 extra weft pick).
Weight – Grams per Square Yard	178	178	178

Figure 4 illustrates the successive stages involved in the design and development of Panel 1. The weave simulations selected for motif merging include stripe colour effect woven by alternate extra-weft-up and extra-weft-down weave [Fig. 4(a)], a cross-over colour effect woven by extra-weft-up weave [Fig. 4(b)], and a plain weave [Fig. 4(c)]. The combined graph design, draft, and lifting plans used

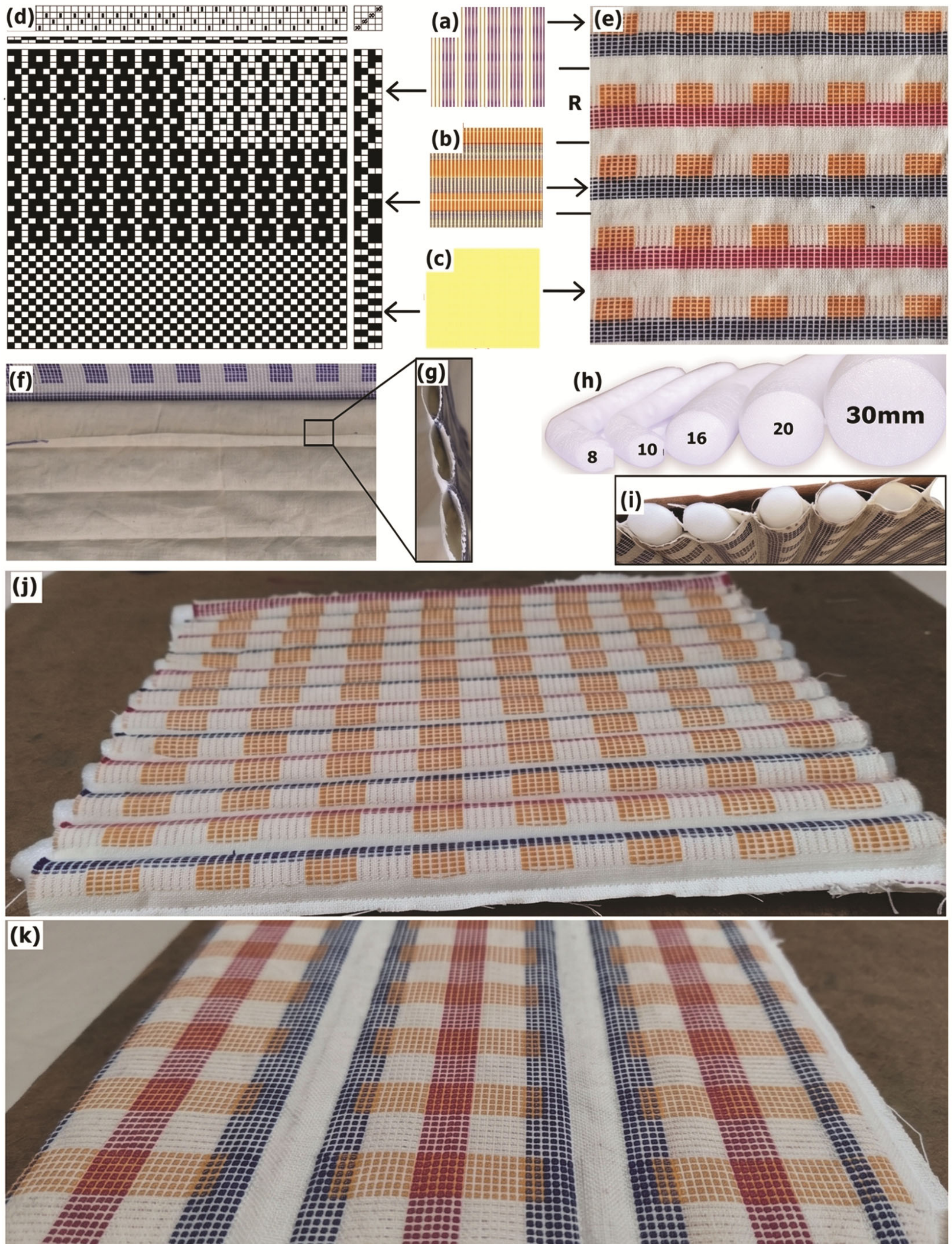

Fig. 4 — Designing and development of the angular lenticular woven fabric panel (ALWFP) with stripe and cross-over effects (Panel 1). (a) stripe colour effect woven by alternate extra-weft-up and extra-weft-down weave, (b) cross-over colour effect woven by extra-weft-up weave, (c) plain weave producing a single-colour ground effect, (d) graph design showing weave plan, draft, and lifting plan for the three weave effects (a–c), I fabric woven by sequentially combining plain, cross-over, and stripe weave effects, (f) motif fabric and plain fabric layered face-to-face and stitched, (g) formation of hollow fabric tubes between successive stitching lines, (h) expanded polyethylene foam (EPEF) tubes of varying diameters (8–30 mm), (i) insertion of EPEF tubes into the stitched fabric tubes to generate curvature and form the ALWFP, (j) orange and white stripe/cross-over effect visible when viewed from one angular direction, and (k) red and blue vertical stripe effect visible when viewed from the opposite angular direction.

to integrate these three effects are shown in Fig. 4(d). The upper, middle, and lower portions of the graph correspond to the stripe effect, cross-over effect, and plain weave, respectively, with appropriate pick repeats. The fabric woven according to the parameters given in Table 1 is shown in Fig. 4(e). Plain weave sections were woven for 16 picks, while each motif segment was woven for 24 picks using the extra-weft principle in a 1:1 sequence of plain and extra-weft picks.

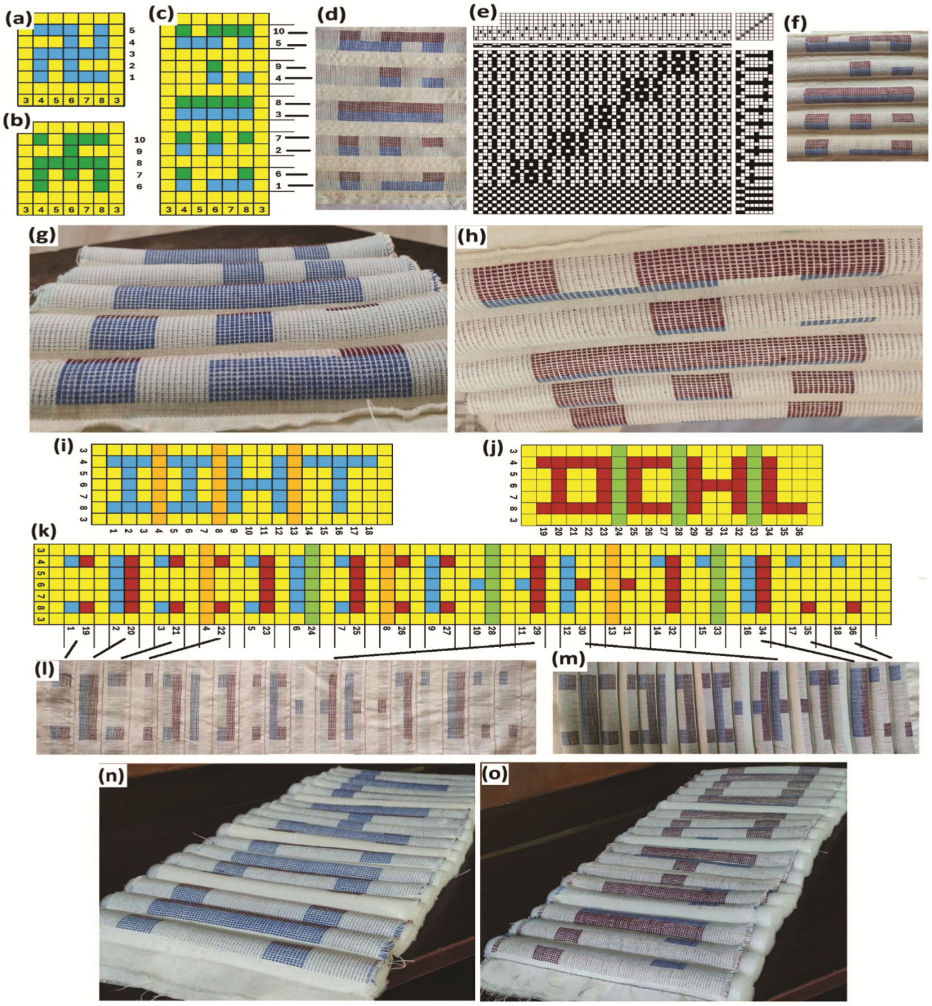

Fig. 5 — Designing and development of angular lenticular woven fabric panels (ALWFPs) with brick motifs (Panels 2 and 3). (a) first brick motif (Swastik icon) divided into five vertical parts, (b) second brick motif (Om letter) divided into five vertical parts, (c) alternate arrangement of motif parts from the two brick motifs with intermediate plain gaps, (d) fabric woven by alternately combining the brick motif parts using extra-weft figure, (e) basic graph design showing weave plan, draft, and lifting plan used for weaving the brick motif fabrics, (f) top view of the ALWFP after stitching and insertion of EPEF tubes, (g) Swastik motif visible when the panel is viewed from one angular direction, (h) Om letter visible when the panel is viewed from the opposite angular direction, (i) first brick motif composed of letters "IIHT", (j) second brick motif composed of letters "DCHL", (k) alternate arrangement of segmented letter brick motifs, (l) fabric woven by alternately combining the letter motif parts, (m) top view of the ALWFP after insertion of EPEF tubes, (n) "IIHT" letters visible from one angular direction, and (o) "DCHL" letters visible from the opposite angular direction.

After weaving, a plain-woven fabric of identical dimensions and thickness was prepared as a backing layer. The motif fabric and backing fabric were superimposed and stitched across the full width at the centers of successive plain weave regions, forming parallel horizontal hollow fabric tubes [Figs. 4(f) and (g)]. EPEF tubes of 8 mm to 30 mm are shown in Fig. 4(h). After stitching, the linear fabric length between two consecutive stitch lines (L) was measured accurately. This length corresponds to half the circumference of the hollow cloth tube formed by stitching. Accordingly, the total circumference (C) of the tube is given by C = 2L, and the corresponding tube diameter (D) was calculated using the relationship C = πD. That is (C = 2L; D = 2L/π). The diameter of the EPEF tube inserted into each hollow cloth tube was selected to match the calculated diameter of the fabric tube, ensuring a snug fit and stable curvature formation. Table 2 presents representative calculations relating the measured fabric length between stitch lines and the corresponding EPEF tube diameters. For the fabric illustrated in Fig. 4(e), the measured value of L was 1.26" (32 mm). The diameter (D) of the tube calculated from L is 20 mm.

Table 2 — Calculating the diameter (D) of the EPEF tube from the length (L) of fabric between the stitches

Sl. No.	Length, L of fabric between stitches in inches	Circumference, C of the cloth tube in inches	Diameter, D of the cloth tube = Diameter of the EPEF tube in inches
		$C =$ (2 x L) inches	D = $\frac{C}{\pi} = \frac{C}{22}$ x 7 inches (or) (2L/π)
1	0.906” (23 mm)	1.181” (46 mm)	0.591” (14.63 mm -15 mm)
2 (Panel 1)	1.260” (32 mm)	2.520” (64 mm)	0.787” (20.36 mm - 20 mm)
3 (Panels 2 and 3)	1.850” (47 mm)	3.700” (94 mm)	1.181” (29.90 mm - 30 mm)

Then EPEF tubes of 20 mm diameter are inserted in between each hollow fabric tube to generate curved surfaces [Fig. 4(i)]. This structural arrangement resulted in the orange stripe effect becoming prominent when viewed from left to right [Fig. 4(j)], while the red and blue cross-over stripes became dominant when viewed from right to left [Fig. 4(k)], confirming successful angular lenticular behaviour without the use of elastic yarn.

3.2 Development of ALWFP With Icon-Based Brick Motifs (Panel 2)

The second ALWFP was developed using two icon-based brick motifs, namely the ‘Swastik symbol’ (F1) and the ‘Om letter’ (F2), woven using heald shedding. Figure 5(a) and 5(b) show the colour simulations of these two brick motifs, F1 and F2. Each motif was constructed using six vertical groups and five horizontal groups. The six vertical groups corresponded to six design healds (Healds 3–8), while two additional healds (Healds 1 and 2) were used for plain weaving.

Each motif was divided into five horizontal segments. The segments of the first motif were designated F1-P1 to F1-P5, while those of the second motif were designated F2-P6 to F2-P10. Fig. 5(c) illustrates the fabric colour simulation showing the alternate arrangement of the two brick motifs with a plain weave gap between successive motif pairs. The sequence followed for weaving was: Plain, F1-P1, F2-P6, Plain, F1-P2, F2-P7, Plain, and F1-P5, F2-P10, Plain.

The corresponding graph design, draft, and lifting plan are shown in Fig. 5(e). Eight healds were employed in total, with the draft order arranged to activate the required vertical motif group through selective lifting of the design healds. The bottom portion of the graph represents the plain weave gap, while successive sections show the formation of extra-weft effects in the required group. The fabric was woven according to the specifications listed in Table 1. Plain weave sections were woven for 40 picks, while each motif segment was woven for 40 picks using the extra-weft principle in a 1:1 sequence of plain and extra-weft picks.

Following weaving, a plain backing fabric of identical size and thickness was prepared. The motif fabric and backing fabric were overlapped and stitched at the centres of successive plain weave regions, forming five hollow fabric tubes. Five EPEF tubes of 30 mm diameter (calculated as given in Table 2) were inserted into these tubes, generating five curved surfaces [Fig. 5(f)].As a result, the five segments of the Swastik motif occupied one side of each curved surface, while the corresponding segments of the Om motif occupied the opposite side. The plain weave regions remained in the recessed zones. Consequently, the Swastik motif became clearly visible when the panel was viewed from left to right [Fig. 5(g)], whereas the Om motif appeared when viewed from right to left [Fig. 5(h)], demonstrating effective angular lenticular transformation.

3.3 Development of ALWFP With Letter-Based Brick Motifs (Panel 3)

The third ALWFP was developed using brick motifs formed from letters, namely IIHT (F1) and DCHL (F2). Figures 5(i) and 5(j) show the colour simulations of these two motifs. Each motif consisted of six vertical groups and eighteen horizontal groups. The six vertical groups were woven using six design healds (Healds 3–8), along with two plain healds (Healds 1 and 2).The first motif was divided into eighteen horizontal segments designated F1-P1 to F1-P18, while the second motif was divided into eighteen segments designated F2-P19 to F2-P36. Figure 5(k) illustrates the fabric simulation showing the alternate arrangement of the two motifs with a plain weave gap between successive motif pairs, following the sequence: Plain, F1-P1, F2-P19, Plain, F1-P2, F2-P20, Plain, and F1-P18, F2-P36, Plain.

The fabric was woven using the same draft and heald arrangement as that used for Panel 2, with

Table 3 — Summary of the fabric size, number of EPEF tubes, diameter of EPEF tubes, and panel size of the three panels developed

Description	Panel 1 (cross-over and stripe)	Panel 2 (icons)	Panel 3 (letters)
Fabric size (Width x Length)	8.50” x 12.25” (216 mm x 311 mm)	8.00” x 9.84” (216 mm x 311 mm)	8.00” x 33.31” (216 mm x 846 mm)
Number of EPEF tubes used	12	5	18
Diameter of EPEF tubes used	0.787” (20 mm)	1.181” (30 mm)	1.181” (30 mm)
Angular Lenticular Fabric Panel size (Width x Length)	8.50” x 9.45” (216 mm x 240 mm)	8.00” x 5.9” (216 mm x 150 mm)	8.00” x 21.26” (216 mm x 540 mm)
First stitch to last	(12 tubes x 20 mm) = 240 mm Length	5 tubes x 30 mm) = 150 mm Length	18 tubes x 30 mm) = 540 mm Length
Angular Lenticular Fabric Panel size, including extra on four sides (Width x Length)	9.00” x 10.45” (229 mm x 265 mm)	8.50” x 7.00” (216 mm x 178 mm)	8.50” x 23.00” (216 mm x 585 mm)

weaving parameters as given in Table 1. Plain weave sections were woven for 24 picks, while each motif segment was woven for 32 picks using the extra-weft principle in a 1:1 sequence of plain and extra-weft picks.After weaving, the motif fabric was combined with a plain backing fabric of identical dimensions. The two layers were stitched at the centers of successive plain weave regions, forming eighteen hollow fabric tubes. Eighteen EPEF tubes of 30 mm (calculated as given in Table 2) were inserted to generate corresponding curved surfaces [Fig. 5(m)].This configuration resulted in the eighteen segments of the IIHT motif appearing on one side of each curved surface and the eighteen segments of the DCHL motif on the opposite side. The completed panel exhibited clear angular lenticular behaviour, with the IIHT letters visible when viewed from left to right [Fig. 5(n)] and the DCHL letters visible when viewed from right to left [Fig. 5(o)]. A comparative summary of fabric dimensions, number of EPEF tubes, tube diameters, and final panel sizes for all three panels is presented in Table 3.

A comparative examination of the three angular lenticular fabric panels reveals a progressive increase in design complexity, motif resolution, and structural control achieved solely through heald shedding and post-weaving panel formation. Panel 1 demonstrates the fundamental feasibility of producing angular lenticular effects in woven fabrics using simple stripe and cross-over colour effects, where visual transformation arises primarily from colour dominance and surface curvature. In contrast, Panel 2 extends this principle to icon-based brick motifs with defined symbolic forms, requiring precise segmentation and alignment of motif parts to maintain recognizable imagery during directional viewing. Panel 3 further advances the technique by accommodating higher motif density and finer segmentation through letter-based brick motifs, thereby achieving sharper visual definition and improved readability across a greater number of lenticular segments. Across all three panels, the underlying structural principle—alternate arrangement of motif segments separated by plain weave gaps, followed by controlled formation of curved surfaces using EPEF tubes—remains consistent, confirming the scalability and adaptability of the approach. Importantly, the transition from colour effects (Panel 1) to iconographic (Panel 2) and typographic brick motifs (Panel 3) illustrates that increasing motif complexity does not necessitate additional weaving mechanisms, elastic yarns, or lenticular lenses. Instead, the study demonstrates that careful control of heald allocation, extra-weft insertion, and post-weaving structural manipulation is sufficient to achieve stable and repeatable angular lenticular behaviour in woven textile panels.

3.4 Future study

In the present work, Angular Lenticular Woven Fabric Panels (ALWFPs) were developed using brick motifs woven through conventional heald shedding, followed by post-weaving double-layering, stitching, and foam insertion to generate the required curved surfaces. The present study demonstrates a proof-of-concept approach for developing ALWFPs using post-weaving structural modification involving stitching and foam insertion, which may limit immediate scalability for high-speed industrial production. Building on the encouraging structural and visual outcomes obtained, the next phase of research will focus on implementing jacquard shedding to integrate the formation of hollow cloth tubes directly during the weaving process. This advancement is expected to eliminate secondary operations such as stitching, improve dimensional precision, and enhance production efficiency.

Further research will also investigate the development of multi-figure angular lenticular textiles. In particular, the concept of a Double Face Figured–Angular Lenticular Woven Fabric Panel (DFF-ALWFP) will be explored, wherein two distinct figures are positioned on one side of each curved surface and two additional figures on the opposite side. Such configurations are anticipated to expand the visual complexity and functional scope of lenticular woven fabrics.

Additionally, future studies will examine the influence of alternative yarn types, foam materials, and tube geometries on curvature stability, angular visibility, and tactile properties. These investigations aim to establish design guidelines for scalable manufacturing and broaden the application potential of ALWFPs in architectural textiles, interactive interior surfaces, and advanced decorative fabric systems.

4 Conclusion

This study successfully demonstrates a novel material–structural approach for developing Angular Lenticular Woven Fabric Panels (ALWFPs) without the use of elastic yarns. By critically analysing earlier angular lenticular panel technologies—including lens-based printing, painted relief surfaces, folded paper constructions, and elastic-yarn-based woven panels—three common developmental principles were identified: segmentation of two brick motifs of identical dimensions, creation of a curved surface, and alternate placement of motif segments on that surface. These principles formed the foundation for the proposed woven ALWFP concept. Three ALWFPs were developed using conventional heald shedding and extra-weft figure structure, incorporating stripe and crossover effects, as well as symbolic and typographic brick motifs. The introduction of post-weaving double-layering, controlled stitching, and the insertion of EPEF tubes enabled the formation of precise and stable curvatures independent of yarn elasticity. This approach ensured consistent angular visibility, wherein distinct brick motifs became dominant when viewed from opposing directions, confirming the effectiveness of the proposed structural method. Compared to earlier woven ALPs, the present technique offers enhanced dimensional stability, improved material control, and greater design flexibility. The use of readily available yarns, simple loom mechanisms, and lightweight foam wadding makes the process scalable and adaptable to diverse textile formats. The developed panels exhibit soft, flexible, and resilient characteristics, expanding the functional and aesthetic potential of angular lenticular textiles. Building on these outcomes, future studies will explore jacquard-based shedding for in-loom tube formation and the development of double-face figured ALWFP applicable in architecture, interior design, product design, fashion, and art. The developed ALWFPs demonstrate strong potential for practical application in architectural surfaces, interior partitions, and fashion or display textiles, where controlled directional visibility, tactile surface modulation, and material-driven visual transformation can be exploited for functional and aesthetic innovation.

Acknowledgments

The authors thank Balaji Nukella, of Weavers' Service Centre, Hyderabad, for his assistance in developing the samples.

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