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FABRICATION OF LIGHTWEIGHT COMPOSITE SANDWICH BY GRANULAR MOLD

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13. ABSTRACT *(Maximum 200 words)*

Although the sandwich panels fabricated of honeycomb core bonded between two face-sheets are very weight-efficient, their application causes many problems such as moisture retention, extensive corrosion, ineffective edge seals, unbonding of face-sheets, and time consuming and expensive repair. In an attempt to eliminate these detrimental factors, new sandwich structural concepts and their fabrication methods are introduced. These structural concepts include offset-corrugated, and cross-corrugated sandwich. They are variations of corrugated sandwich.

The new features of all the sandwich are the provision of passageways from cell to cell for moisture drainage to reduce corrosion, and they can be fabricated of fiber-reinforced composite materials in single cure operation without any secondary bonding.

Sample specimens of unidirectionally-corrugated, offset-corrugated, and cross-corrugated composite sandwich have been fabricated by utilizing granular mold mixture. The mold mixture is environmentally safe, non-toxic, non-reactive, and reusable.

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FOREWORD

This work was performed initially under 6.1 funding, no. R023001, work unit no. DG690 followed by NADC (presently NAWCADWAR) Independent Research (IR) funding, task area no. R00N0000, work unit no. HA695, and NADC (presently NAWCADWAR) Independent Exploratory Development (IED) funding, task area no. R00N0000, work unit no. IEA09. The author greatfully acknowledges R. Cline, M. Bosak, and C. Grubb for helping in fabrication.

LIST OF FIGURES

LIST OF FIGURES

1. INTRODUCTION

Sandwich construction employing honeycomb core is very weight-efficient for aerospace applications. But its application in the primary and secondary structures of Navy and Air Force airplanes and helicopters has resulted in severe maintenance problems. During twenty years of service experience, very high repair frequency has been reported due to problems in honeycomb sandwich construction such as moisture retention, extensive corrosion, ineffective edge seals, and unbonding of face-sheets from the core. During repair work, further unbonding of face-sheets from the core could occur due to high vapor pressure generated by the heating process used to cure the repair materials. Therefore, any comparable substitute to honeycomb sandwich construction, that eliminates or reduces the moisture and unbonding problems, will be extremely beneficial for aerospace structural applications.

In an attempt to eliminate these detrimental factors, new sandwich structural concepts are presented in Reference 1. These include bidirectionally-corrugated, lattice-core, offset-corrugated, and cross-corrugated sandwich. All of these sandwich structures are variations of corrugated sandwich construction. In the proposed sandwich structures, unlike honeycomb, the cells of the cores are open. These designs allow the panels to dissipate moisture, which minimizes or eliminates corrosion and premature failure of the component. The damage tolerance is expected to improve due to flexibility and discontinuity of the core. The presence of passageways and curing without any secondary bonding will eliminate or reduce the tendency of unbonding of face-sheets from the core due to formation of steam during the repair process.

The methods of fabrication of these concept sandwich are described in Reference 1. The bidirectionally-corrugated sandwich construction can be fabricated of fiber reinforced composite materials with cocuring of the two face-sheets and the corresponding corrugations producing two halves. The two halves can be adhesively bonded together to obtain the final form of the sandwich. The lattice-core, offset-corrugated, and cross-corrugated sandwich have the added advantage of being constructed by cocuring without any secondary bonding. In all the designs, cores are formed by wrapping materials around solid mandrels which maintain the shapes of the core.

In this report, methods of fabrication by utilizing granular mold mixtures are described. The mold mixture is environmentally safe, non-toxic, non-reactive, and reusable.

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2. MOLD MIXTURE

The mold mixture for fabricating the composite sandwich consists of glass beads as the base material, and either corn starch, calcium silicate, or polytetrafluoroethylene (PTFE) powder as a binder. Twenty four mixtures were made by mixing different combinations of ingredients in various proportions. These mixtures were examined for their suitability in fabricating the composite sandwich. Among all the mixtures, the one with approximately two parts of glass beads and one part of PTFE powder, by volume, provided the best results in fabricating small samples. Figure 1 shows a photomicrograph of granular mold mixture. The mixture of glass beads and PTFE powder is environmentally safe, non-toxic, nonreactive, and reusable. When solid mandrels are used for fabricating a sandwich, parting lines (tool mark-off) are produced in the face-sheets of sandwich located between the mandrels. These parting lines (tool mark-off) are usually eliminated by utilizing appropriate filler materials, thereby obtaining smooth face-sheets. But the addition of filler materials increases the weight of the sandwich. The use of a granular mold mixture in fabrication provides smooth face-sheets in the sandwich without increasing its weight.

3. UNIDIRECTIONALLY-CORRUGATED AND CROSS-CORRUGATED SAMPLES.

In order to find the appropriate proportions of glass beads and PTFE powder needed for the granular mixture, three samples were fabricated by using varying proportions of the ingredients. All three samples were assembled and placed in a closed cavity prior to the curing process. Figure 2 shows a unit cell of composite cross-corrugated sandwich fabricated by using a granular mixture composed of three parts of glass beads and four parts of PTFE powder (by volume). The height (distance between the face-sheets) of the sample is reduced from its precured size due to the presence of voids in the compacted mixture. Another unit cell of composite cross-corrugated sandwich (Figure 3) was fabricated by using only PTFE powder without the addition of any glass beads. In this case the height of the sample is excessively reduced from its precured size due to the presence of excessive voids in the compacted PTFE powder. Figure 4 shows a unit cell of composite unidirectionally-corrugated sandwich where a mixture of two parts of glass beads and one part of PTFE powder by volume was used for fabrication. The height of the sample remained almost the same as its precured size. It appears that a larger proportion of glass beads and a smaller proportion of PTFE powder is needed in a mixture to maintain the desired shape and size of a sandwich. Therefore, all the subsequent samples were fabricated by using a granular mixture containing two parts of glass beads and one part of PTFE powder by volume.

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4. OFFSET-CORRUGATED SANDWICH

The offset-corrugated sandwich panels consist of strips of corrugations, offset by half a wave with respect to their adjacent strips, contained between two face-sheets (Figures 5). In this offset-corrugated sandwich the corrugated members are flat.

The method of fabricating the offset-corrugated sandwich with granular mandrels consists of wrapping each of the solid hexagonal and triangular mandrels (except the four outer triangular mandrels) with thin, stretchable release films made of plastic-type material and arranged as shown in Figure 6. Then the mandrels are wrapped with strips of uncured composite materials to form the corrugations. Next the face-sheets are placed on the top and bottom of the corrugations. In the figure, cross-sections of only two consecutive strips of corrugations are shown. The assembly of the solid mandrels, release films, face-sheets, and corrugations are placed inside a suitable stiff cavity with all its walls (or covers) properly secured except for the front cover which is removed (Figure 7). Then each of the solid triangular and hexagonal mandrels (except the four outer triangular mandrels) are removed one at a time without removing the release films, and the respective places are properly compacted with the granular mixture. After all the granular mandrels are formed, the front of the cavity is covered with soft uncured silicon-rubber type material. The front of the cavity containing the assembly is then properly closed by the front wall. Next the top cover of the cavity is unfastened from its secured condition and loosely placed on the assembly. Finally the entire assembly is cured. Upon completion of the cure cycle, the walls of the cavity are removed, followed by removal of the granular hexagonal and triangular mandrels, and the release films; thereby the offset-corrugated sandwich is made.

The advantages of the new method are as follows: (a) fabrication of the sandwich by one cocuring operation without any secondary bonding will eliminate problems related to secondary bonding such as unbonding of face-sheets from the core, (b) the method of fabrication provides passageways from cell to cell in the core, which allow moisture to be drained from the sandwich, (c) the damage tolerance is expected to improve due to the flexibility and discontinuity of the lattice core, (d) the presence of passageways and cocuring without any secondary bonding will eliminate or reduce the tendency of unbonding of face-sheets from the core due to generation of high vapor pressure during the repair process, (e) the method produces smooth face-sheets in the sandwich.

It is to be noted that the existing method of fabricating the honeycomb sandwich requires bonding of the face-sheets to the core. This increases the tendency of unbonding of the face-sheets from the core. Also, nonexistence of passageways from cell to cell in the honeycomb sandwich allows moisture to be retained in the sandwich, thus promoting corrosion.

The offset-corrugated sandwich panels with curved corrugations consist of strips of offset-corrugated core with curved members contained between two face-sheets (Figure 8). It is intended to provide curvature along the width of the strips of corrugations, and straight along their length. The method of fabricating the offset-corrugated sandwich with curved corrugations is similar to that of fabricating an offset-corrugated sandwich with flat corrugations except pieces of solid shaped inserts are placed between the mandrels (Figure 9 and 10). The advantage of providing curved members over flat members is to increase the strength of the members by virtue of so-called "plate action" as opposed to "beam action".

5. CROSS-CORRUGATED SANDWICH

The sandwich panels consist of cross-corrugated core contained between two face-sheets (Figure 11). In the figure shown, the corrugations are placed in both directions of the panel, and the corrugations in one direction are crossing the corrugations in the other direction. In a direction of corrugation, each strip of corrugation is offset by half a wave with respect to an adjacent corrugation.

The method of fabricating the cross-corrugated sandwich consists of wrapping solid rectangular and triangular mandrels with thin, stretchable release film made of plastic-type material and arranged as shown in Figure 12. Each of the rectangular mandrels is then wrapped with two strips of uncured composite materials in opposite directions, thereby forming corrugations along the length of the mandrels. The wrappings on the rectangular mandrels are such that a series of peaks is next to a series of troughs and vice versa. Then strips of uncured composite materials are wrapped around the rectangular and triangular mandrels as shown in Figure 12, thereby forming corrugations in the cross direction, that means in the direction perpendicular to the first direction of corrugations formed. The second set of corrugations (cross-corrugations) are such that a series of peaks are next to a series of troughs and vice versa. The assembly of the solid mandrels, release films, corrugations and face-sheets are placed inside a suitable stiff cavity with all of its walls (or covers) properly secured except for the front cover which is removed (Figure 13). Then each of the solid rectangular and triangular mandrels are removed one at a time without removing the release films, and the respective places are properly compacted with the granular mixture. After all the granular mandrels are formed, the front of the cavity is covered with soft uncured silicon-rubber type material. The front of the cavity containing the assembly is then properly closed by the front wall. Next the top cover of the cavity is unfastened from its secured condition and loosely placed on the assembly. Finally the entire assembly is cured. Upon completion of the cure cycle, the walls of the cavity are removed, followed by removal of the granular rectangular and triangular mandrels, and release films. Presence of cross-corrugations increases the strength of the cross-corrugated sandwich compared to that of offset-corrugated sandwich. Other features and advantages of the cross-corrugated sandwich are the same as that of the offset-corrugated sandwich.

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6. CONCLUSIONS

(1) The offset-corrugated, and cross-corrugated sandwich can be fabricated of fiber-reinforced composite materials in single cure operation without any secondary bonding.

(2) The new designs provide passageways from cell to cell for moisture drainage to reduce corrosion.

(3) Damage tolerance is expected to improve due to the presence of flexibility and discontinuity in the core.

(4) The presence of passageways and cocuring without any secondary bonding will eliminate or reduce the tendency of unbonding of face-sheets from the core due to generation of high vapour pressure during the repair process.

(5) The method utilizing granular mold mixture produces smooth face-sheets in the sandwich.

(6) The granular mold mixture is environmentally safe, non-toxic, non-reactive, and reusable.

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[3] Ray, H., "Offset-Corrugated Sandwich Construction with Curved Corrugations," Patent Application, Navy Case No. 75753, 7 September 1993.

[4] Ray, H., "Cross-Corrugated Sandwich Construction," Patent Application, Navy Case No. 75754, 7 September 1993.

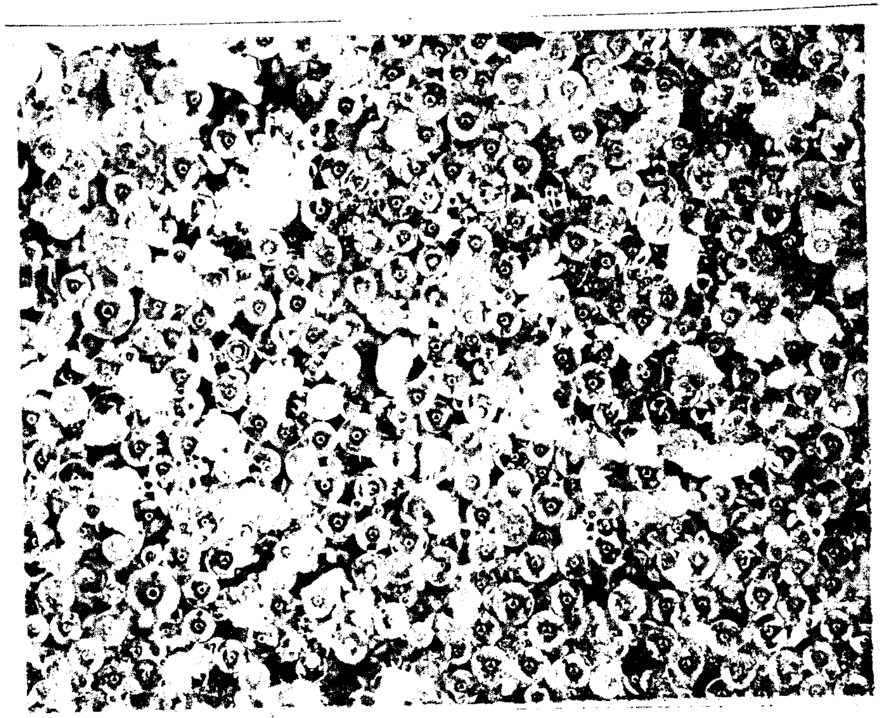

Figure 1. Photomicrograph of granular mixture containing glass beads and polytetrafluoroethylene (PTFE) powder, 50X.

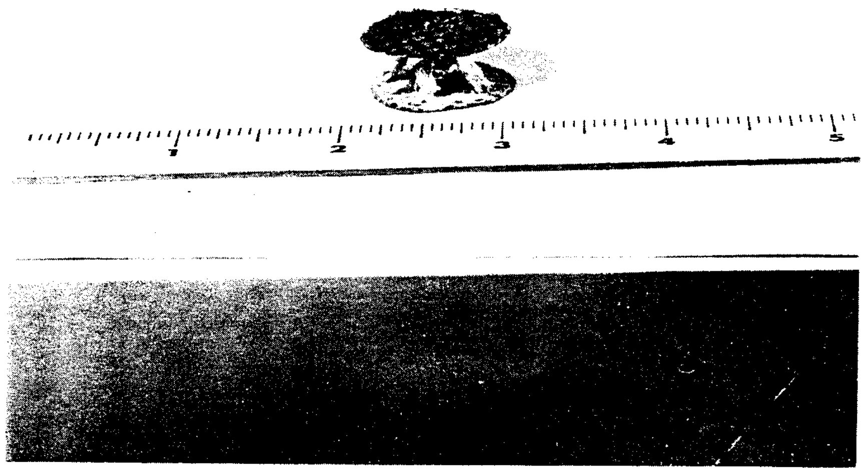

Figure 2. A unit cell of cross-corrugated sandwich. (Three parts of glass beads and four parts of PTFE powder by volume used for granular mixture.)

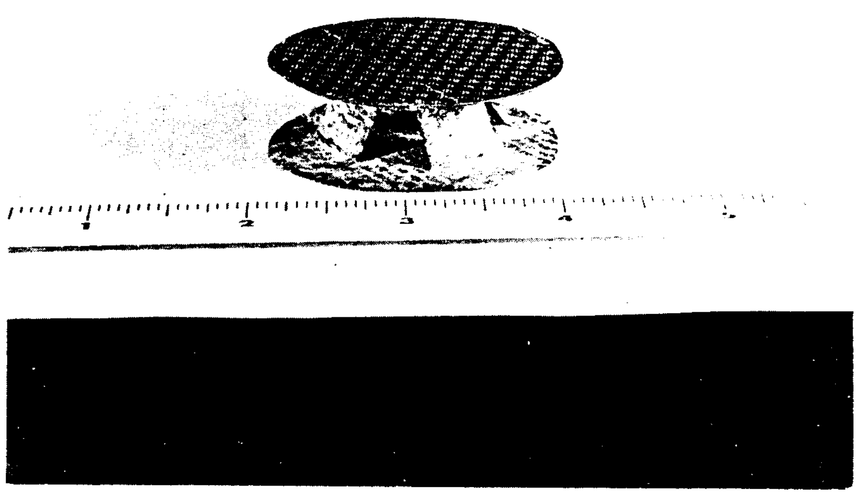

Figure 3. A unit cell of cross-corrugated sandwich. (Only PTFE powder used as a granular mixture.)

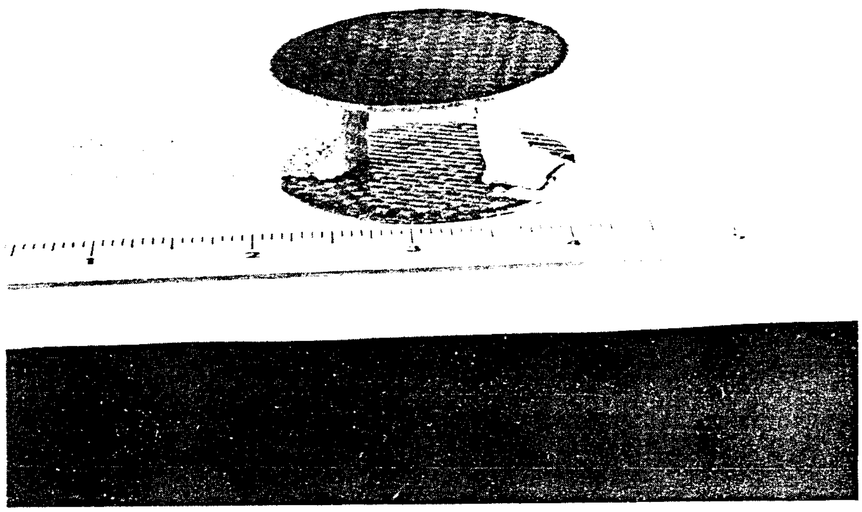

Figure 4. A unit cell of unidirectionally-corrugated sandwich. (Two parts of glass beads and one part of PTFE powder by volume used for granular mixture.)

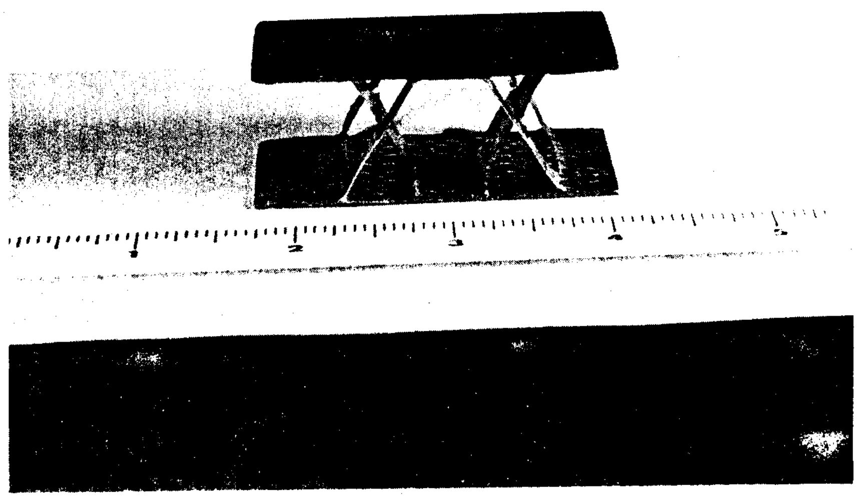

Figure 5. The offset-corrugated sandwich. (Corrugations with flat members.)

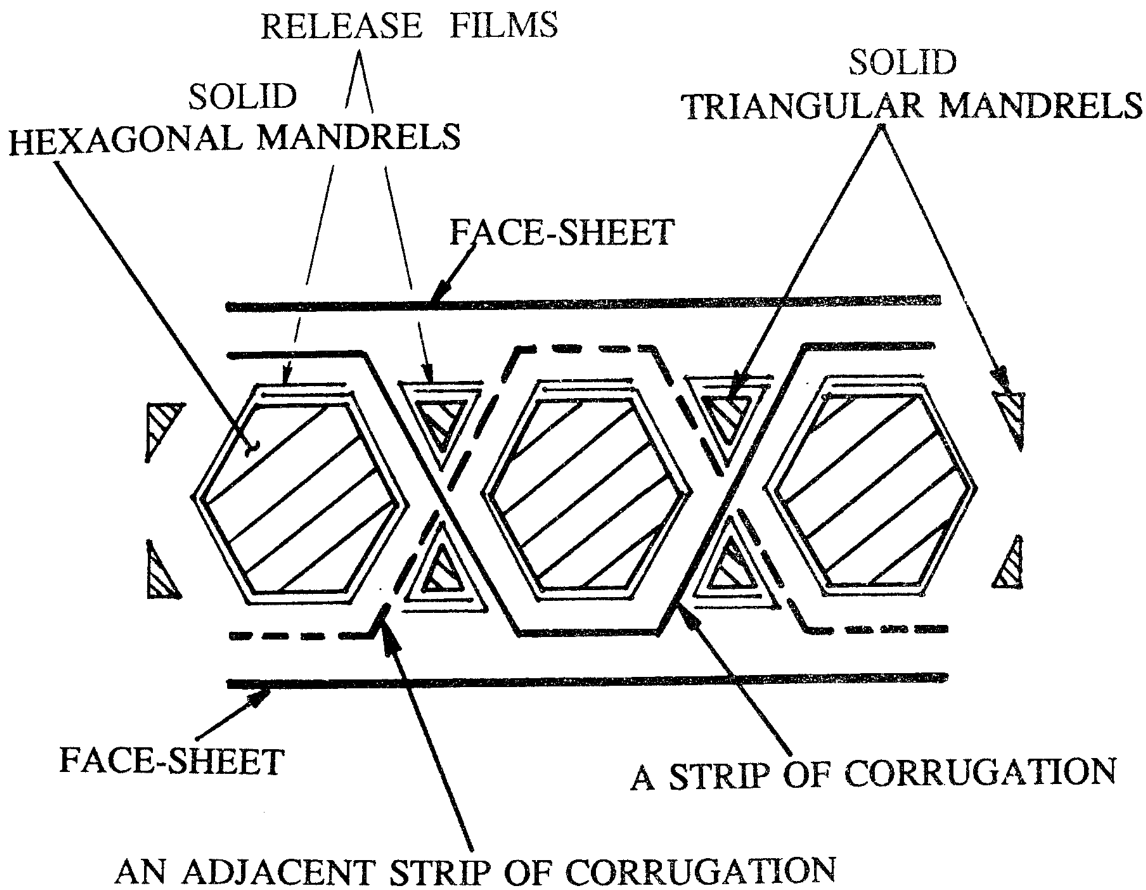

Figure 6. **Arrangement showing solid mandrels, release films, corrugations, and face-sheets for fabricating an offset-corrugated sandwich with flat corrugations.**

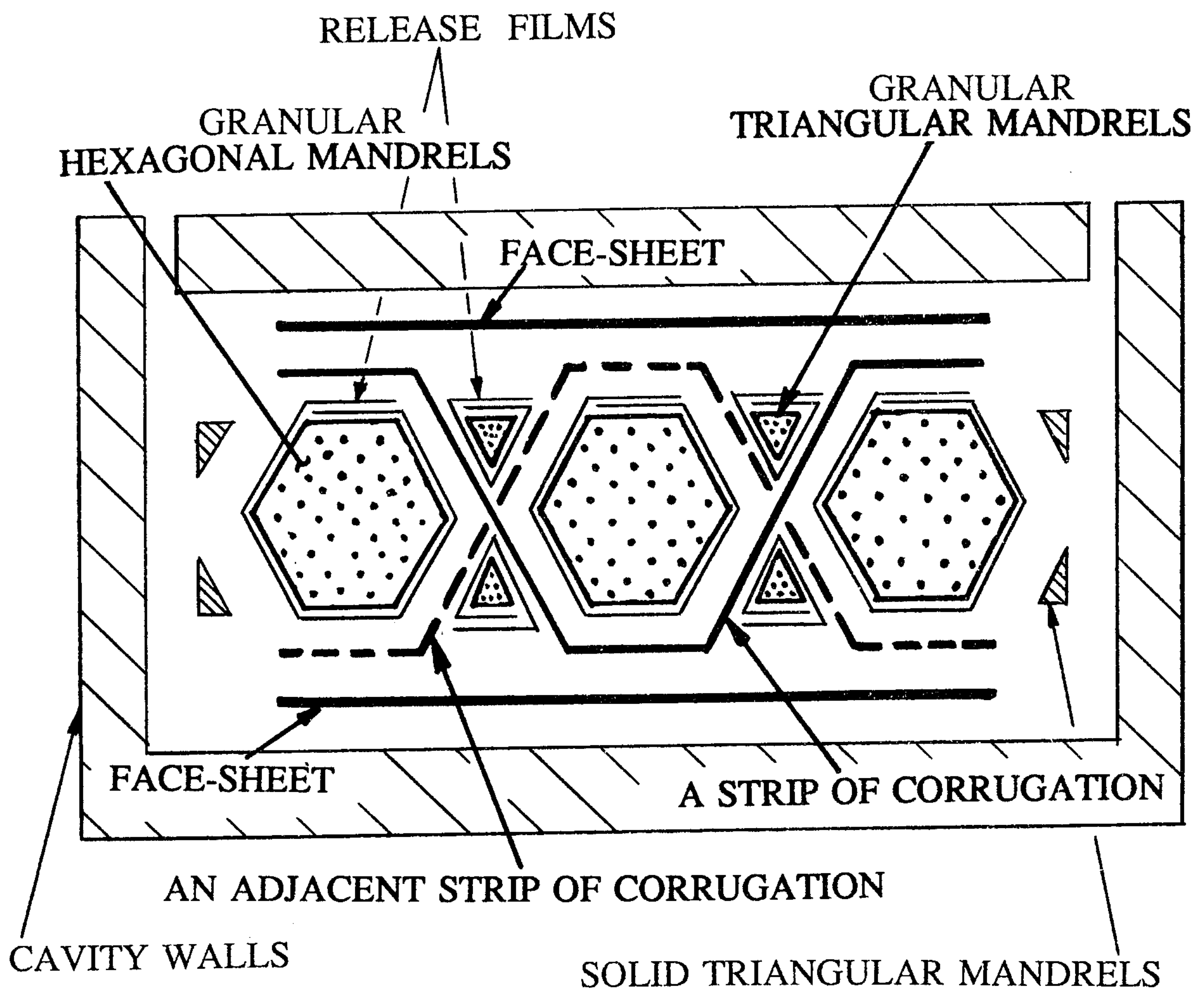

Figure 7. **Arrangement showing granular mandrels, release films, corrugations, and face-sheets placed inside a closed cavity for fabricating an offset-corrugated sandwich with flat corrugations. (Front and rear covers of the cavity are not shown.)**

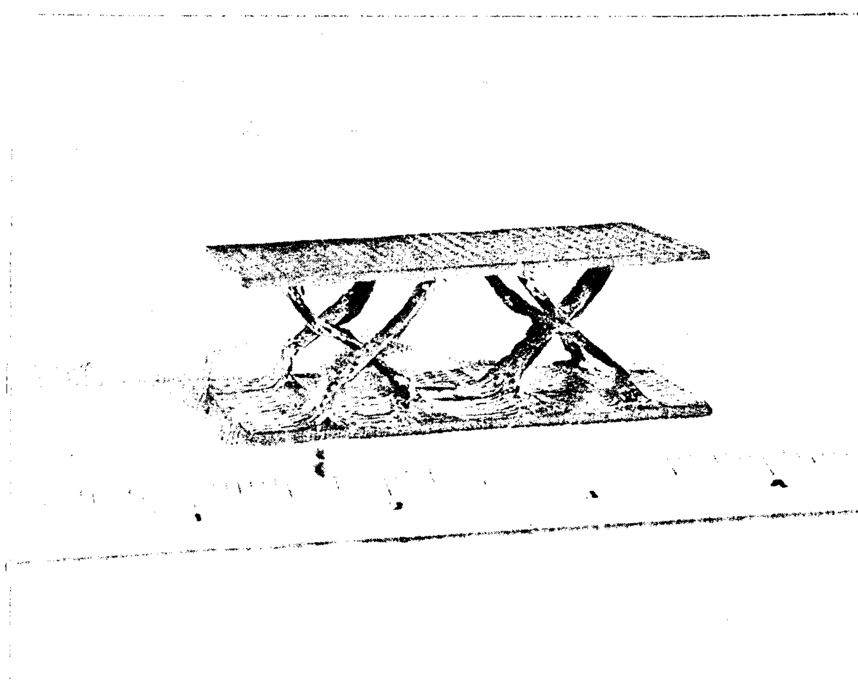

Figure 8. The offset-corrugated sandwich. (Corrugations with curved members.)

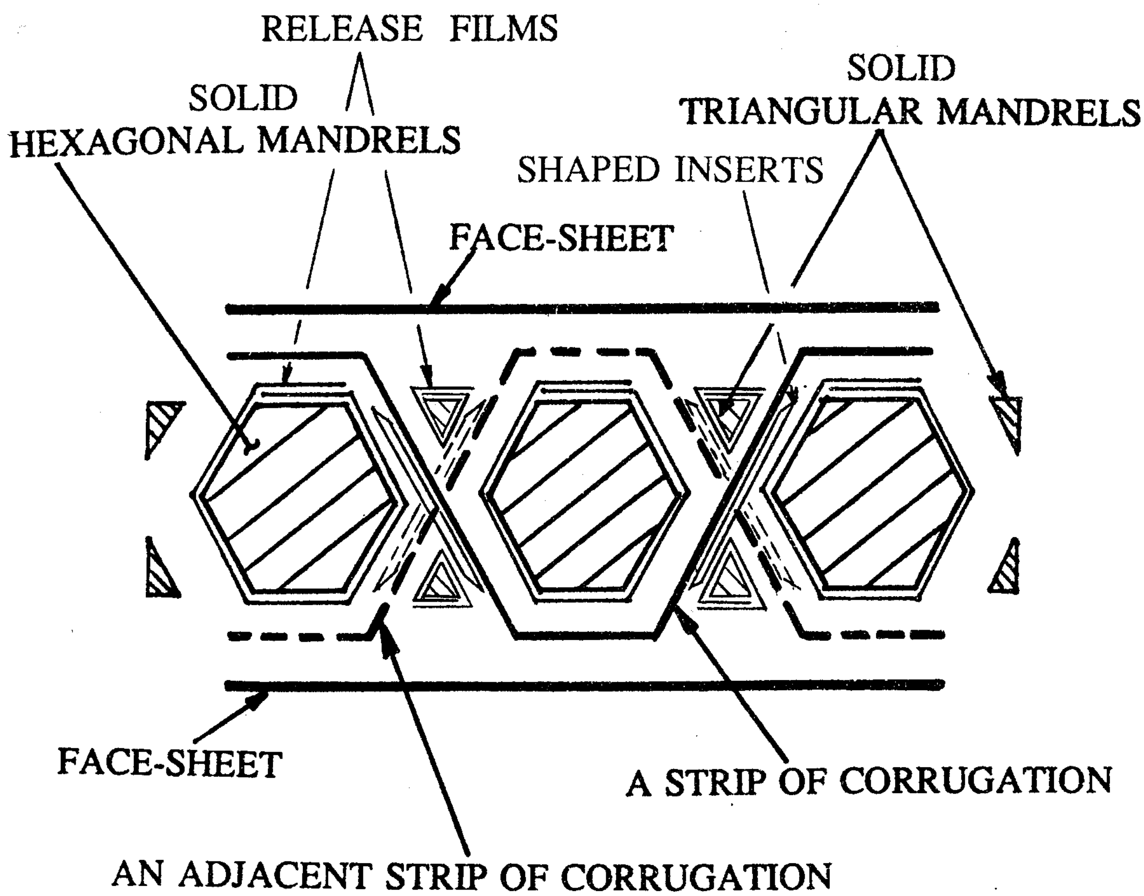

Figure 9. Arrangement showing solid mandrels, shaped inserts, release films, corrugations, and face-sheets for fabricating an offset-corrugated sandwich with curved corrugations.

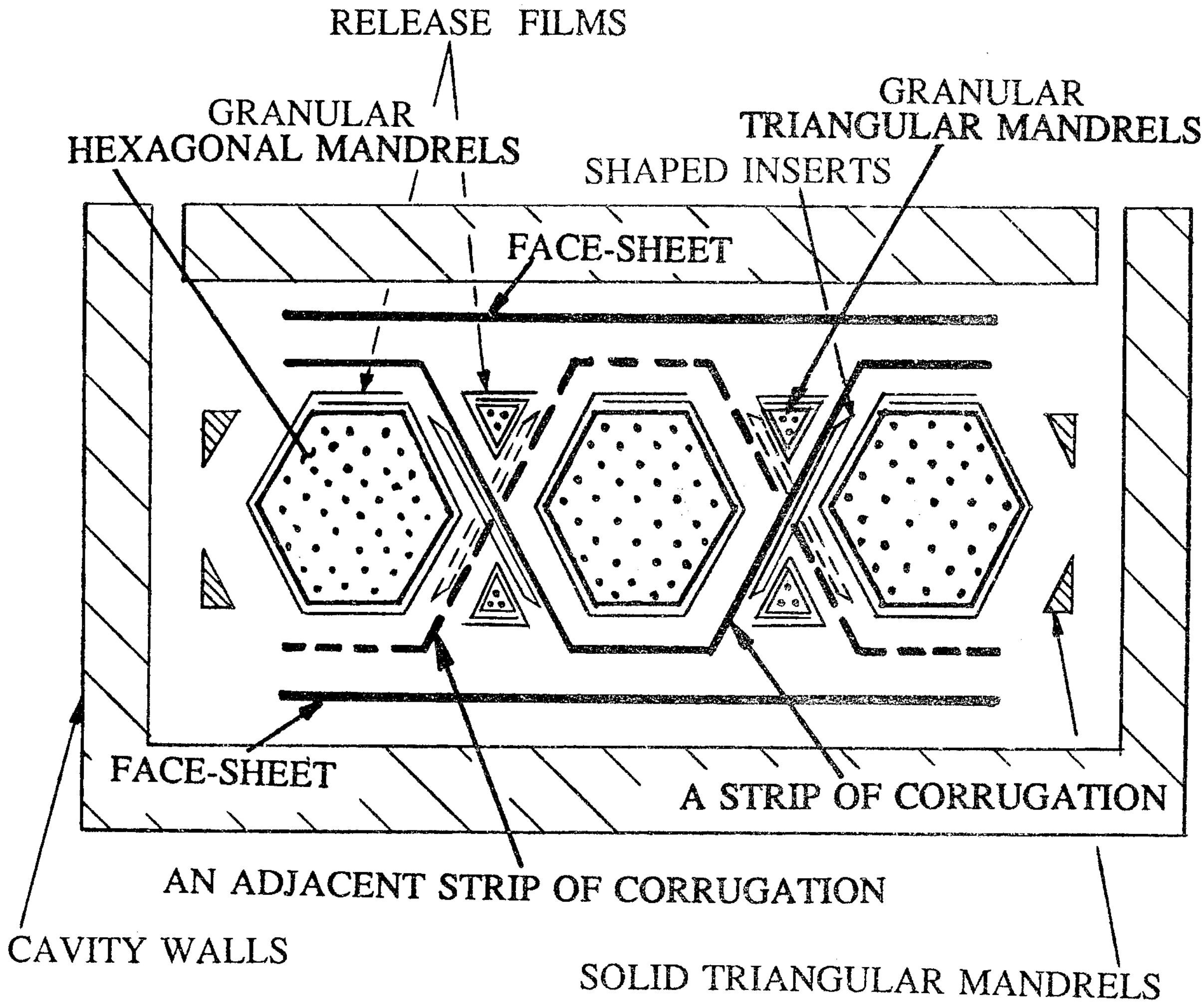

Figure 10. Arrangement showing granular mandrels, shaped inserts, release films, corrugations, and face-sheets placed inside a closed cavity for fabricating an offset-corrugated sandwich with curved corrugations. (Front and rear covers of the cavity are not shown.)

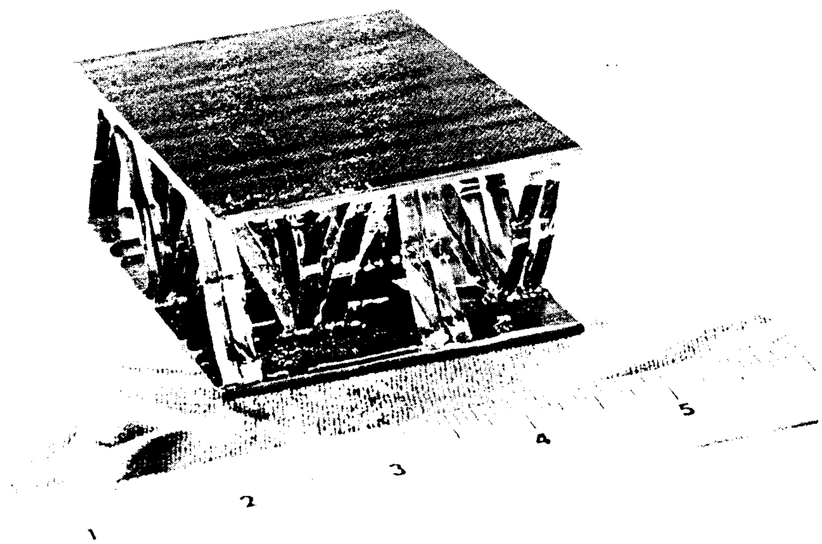

Figure 11. The cross-corrugated sandwich.

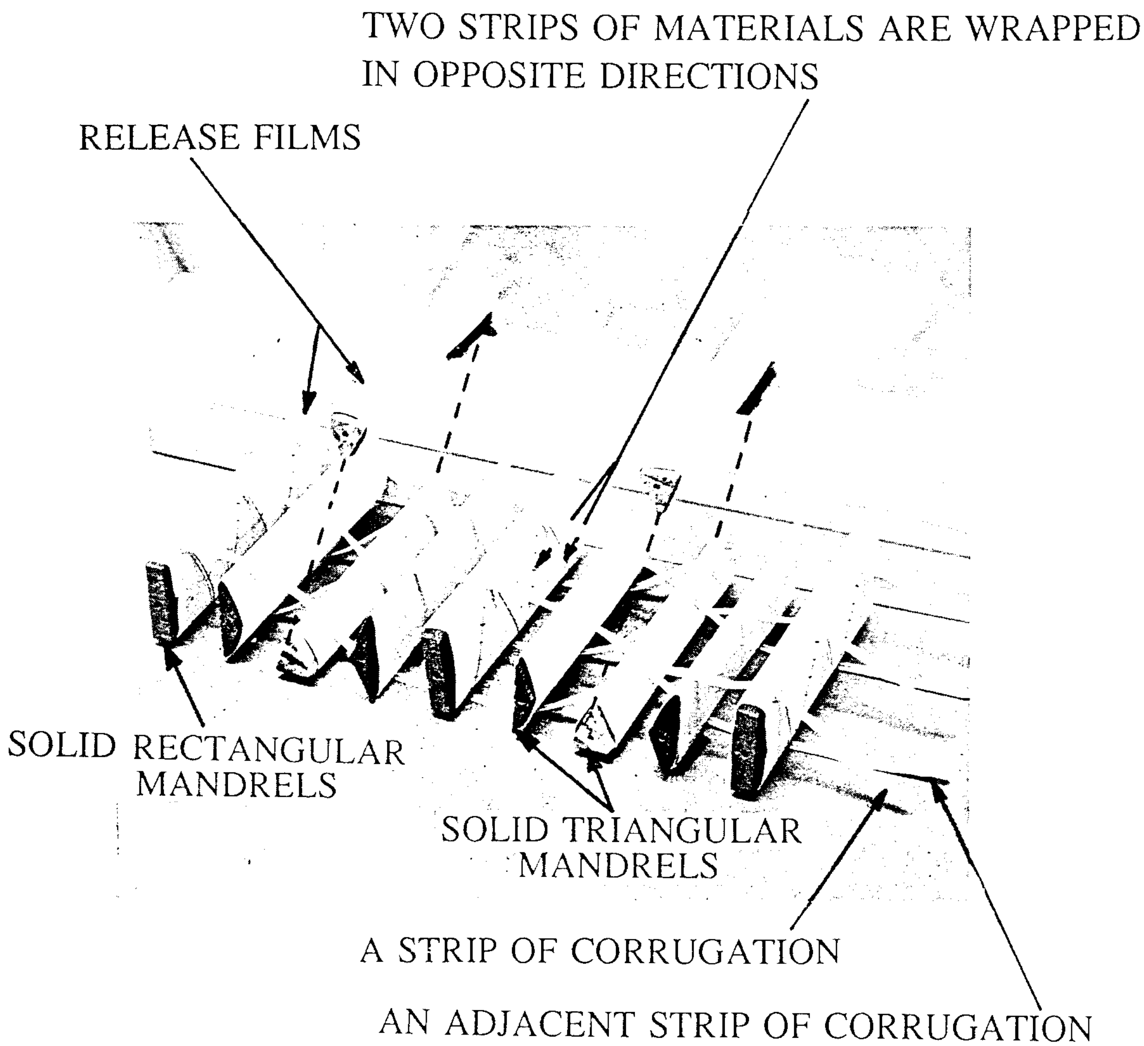

Figure 12. Arrangement showing solid mandrels, release films, and corrugations for fabricating the cross-corrugated sandwich. (Face-sheets not shown)

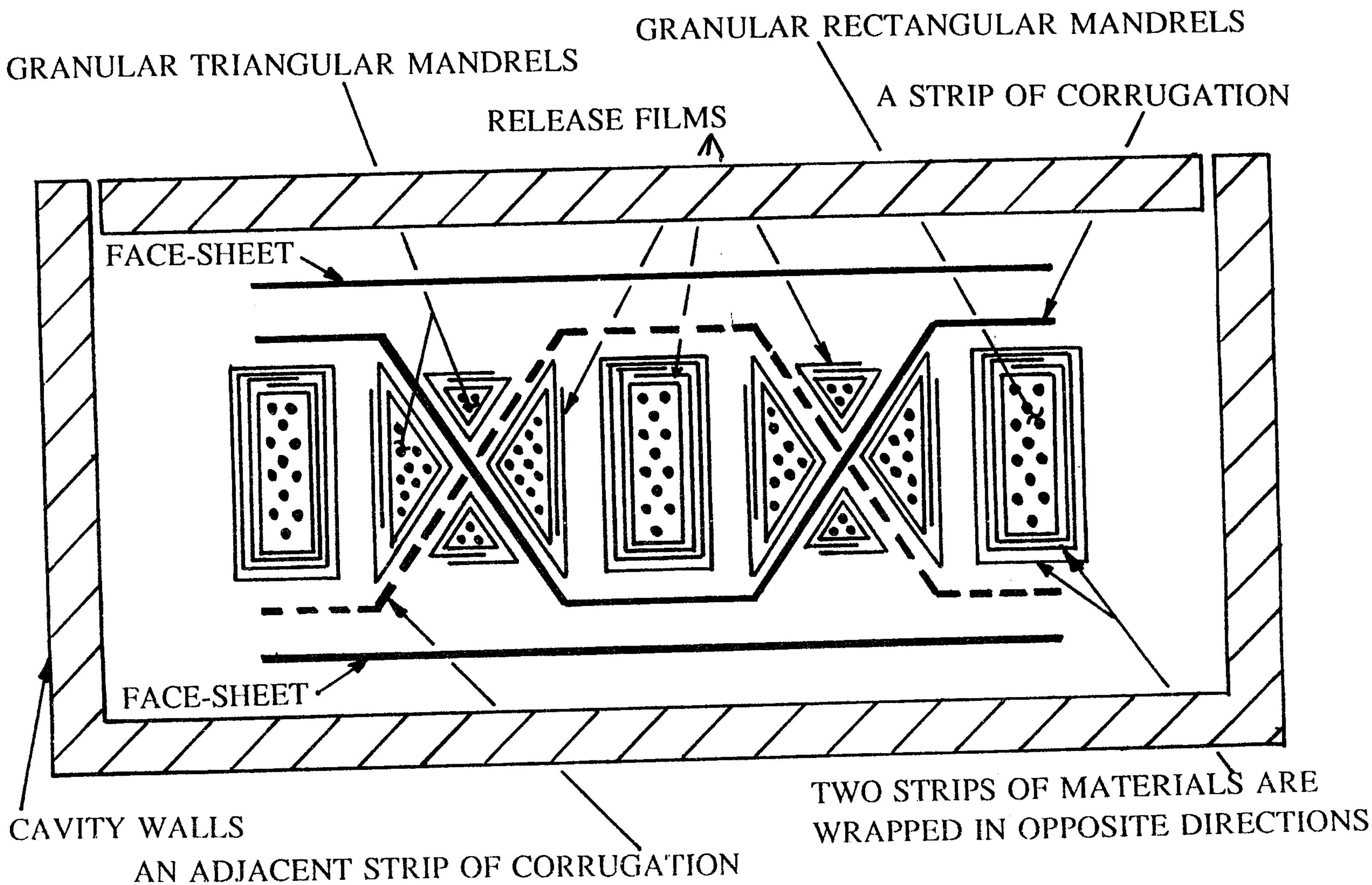

Figure 13. Arrangement showing granular mandrels, release films, corrugations, and face-sheets placed inside a closed cavity for fabricating the cross-corrugated sandwich. (Front and rear covers of the cavity are not shown.)

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