United States Patent

Zeischegg

[15] **3,659,360**

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[54] **REGULAR AND SEMI-REGULAR POLYHEDRONS CONSTRUCTED FROM POLYHEDRAL COMPONENTS**

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[30] Foreign Application Priority Data

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[52] **U.S. Cl.**.......................................**35/72,** 46/17, 273/157

[51] **Int. Cl.**...**A63h 33/14**

[58] **Field of Search**..............................46/17, 16; 35/72, 34

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Primary Examiner—F. Barry Shay

Attorney—McGlew and Toren

[57] **ABSTRACT**

A construction set, for building structures assembled from geometric parts having plane surfaces, comprises a plurality of geometric parts including at least one group of equal pyramids each having three, four, or five equal side faces and at least one part in the form of a semi-regular or regular polyhedron having at least one plane of symmetry. This latter part can be assembled from partial bodies, such as base-abutted pyramids, or may be a single unitary body. Adhesive means are provided to interconnect the geometrical parts selectively in either face-abutting or articulated edge-abutting relation.

10 Claims, 26 Drawing Figures

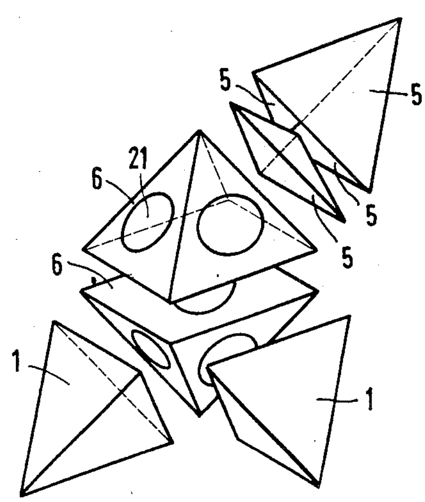


Fig.1

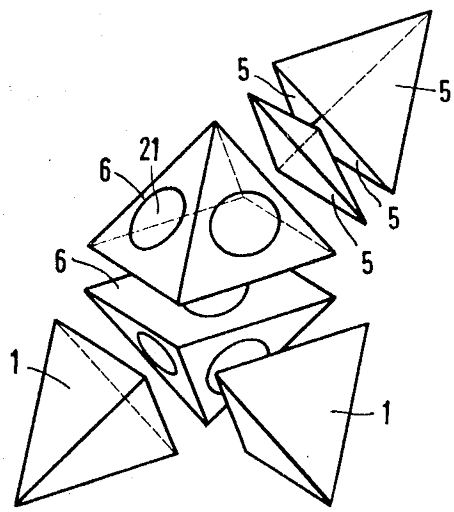


Fig.2

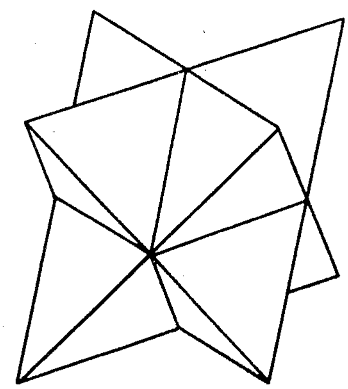


Fig.3

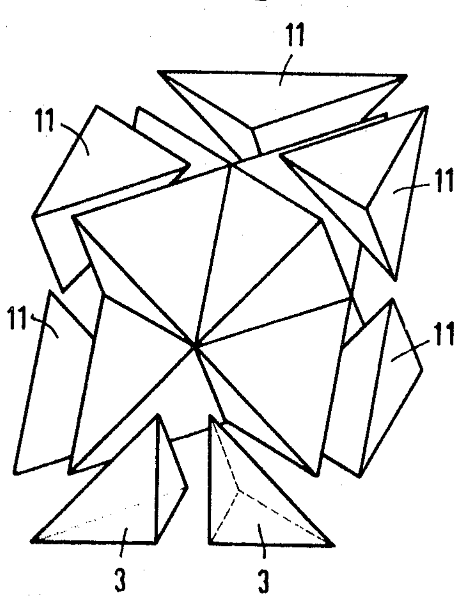
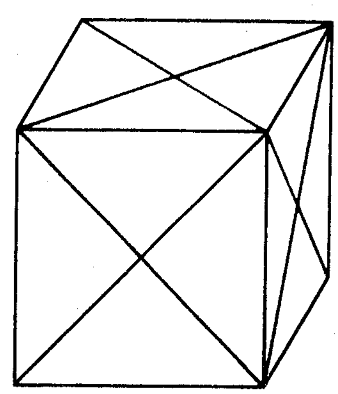


Fig.4



INVENTOR
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Fig. 5

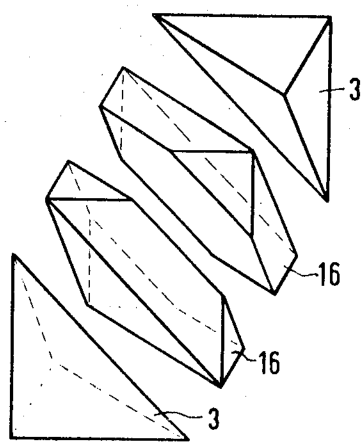


Fig. 6

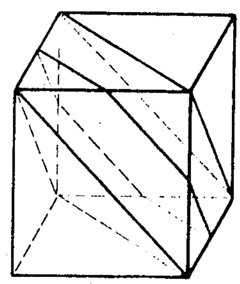


Fig. 7

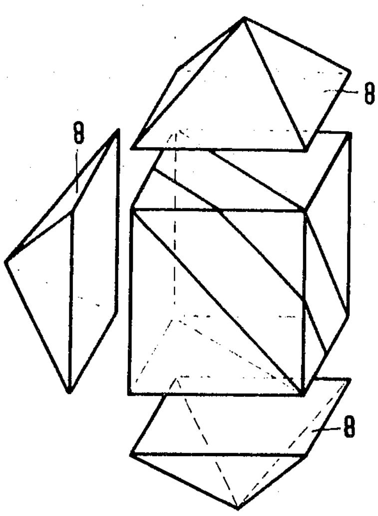
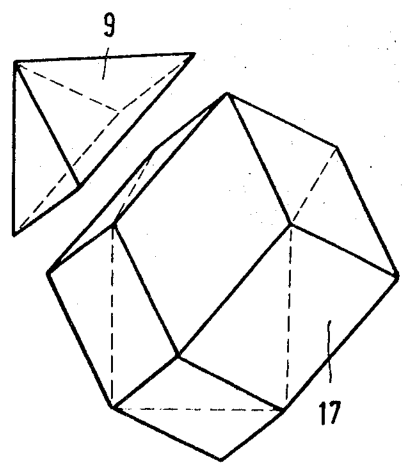


Fig. 8



INVENTOR
WALTER ZEISCHEGG

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Fig.9

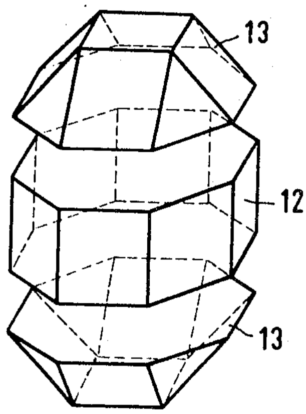

Fig.10

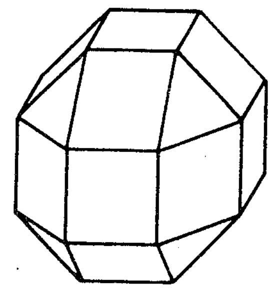

Fig.11

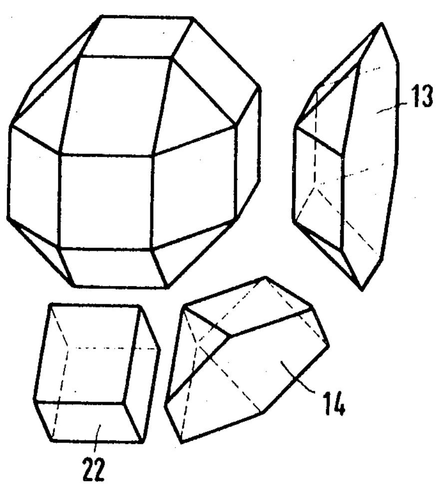

Fig.12

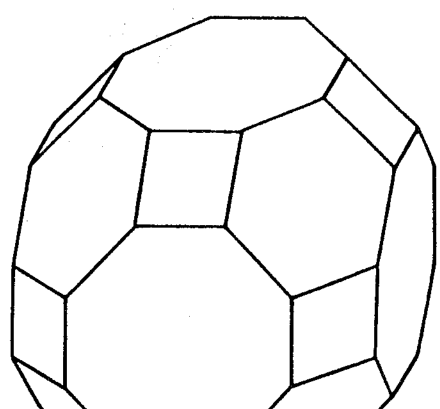

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Fig. 13

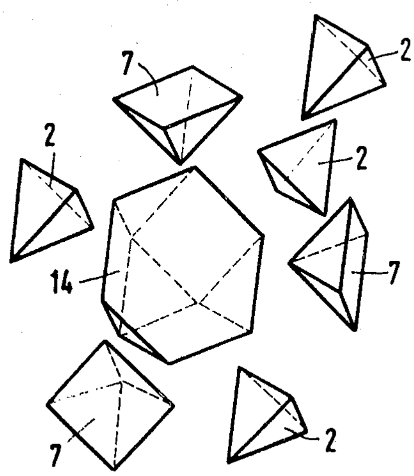

Fig.14

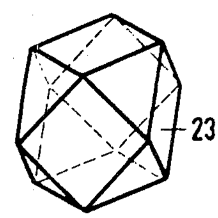

Fig. 15

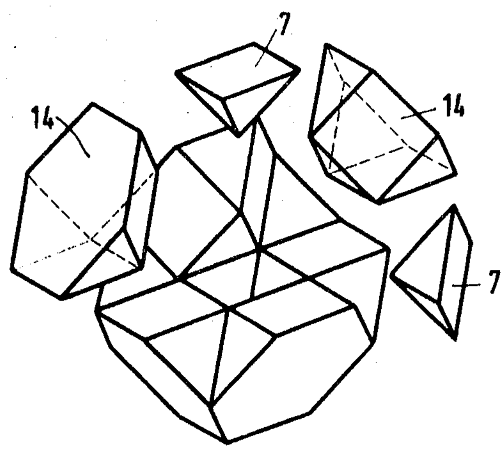

Fig.16

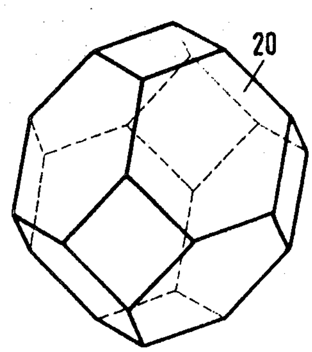

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Fig.17

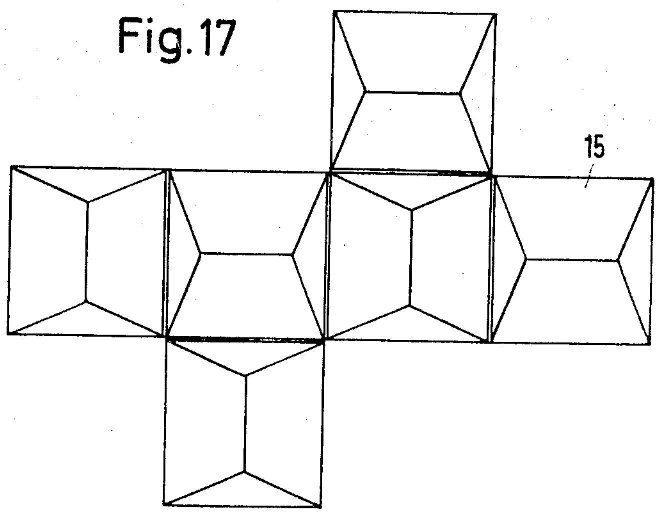

Fig.18

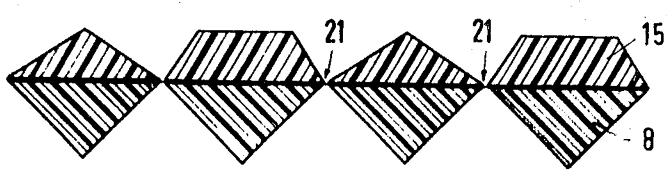

Fig.19

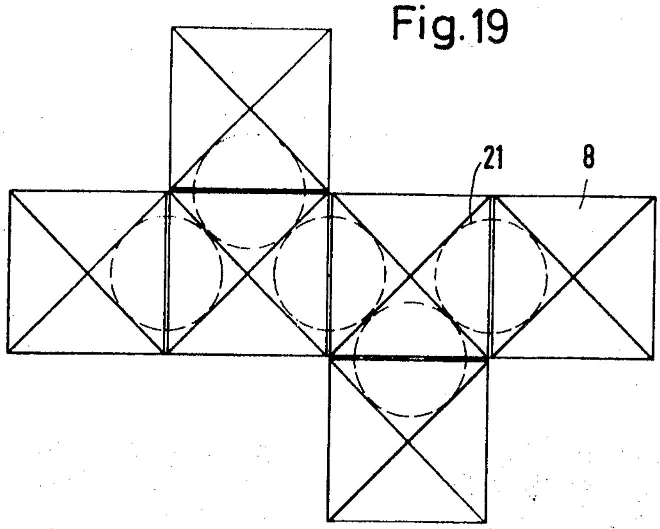

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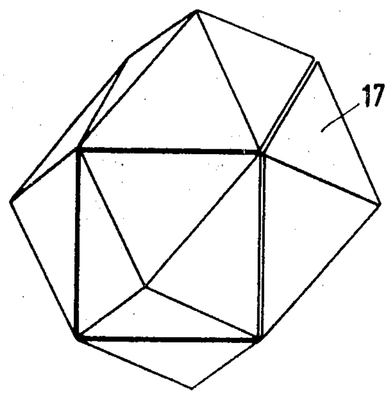
Fig. 20



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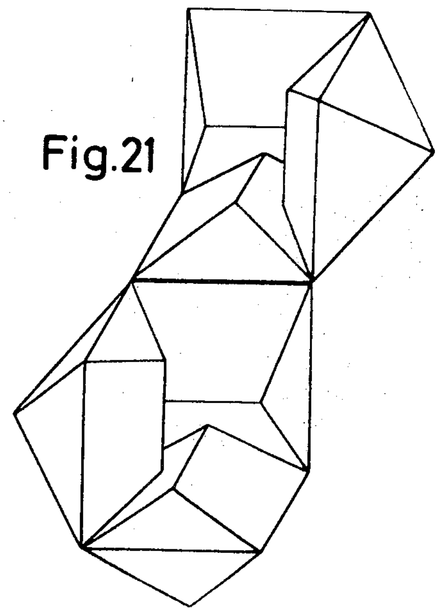

Fig. 22

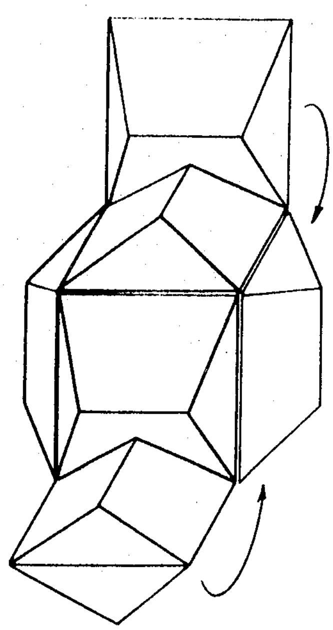

Fig. 23

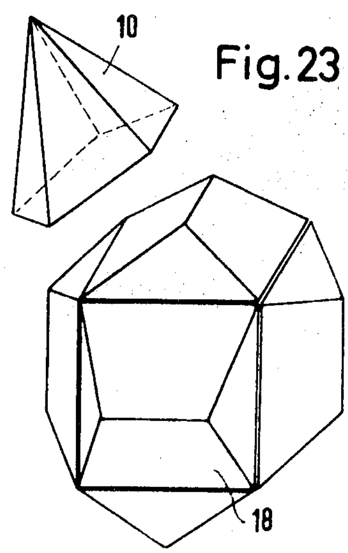

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Fig.24

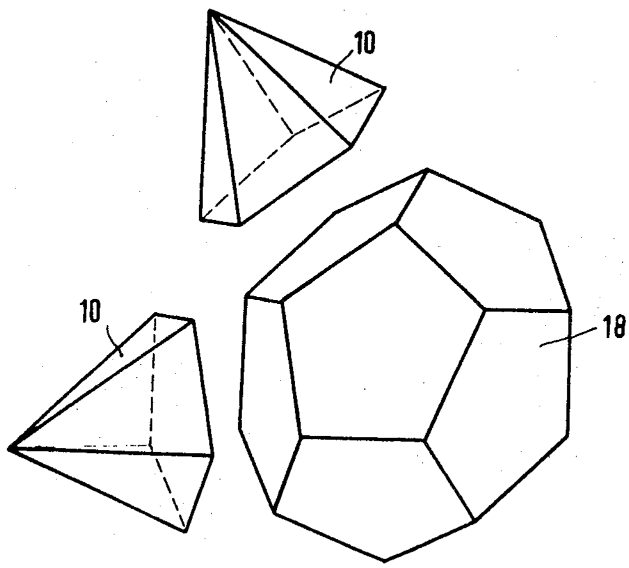

Fig.25

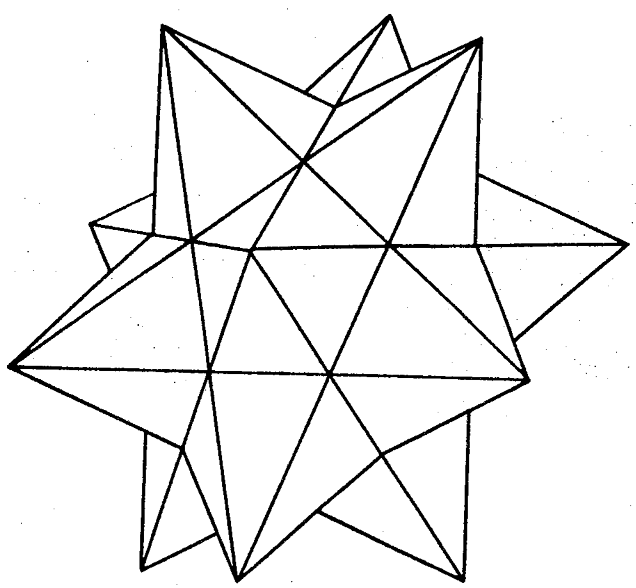

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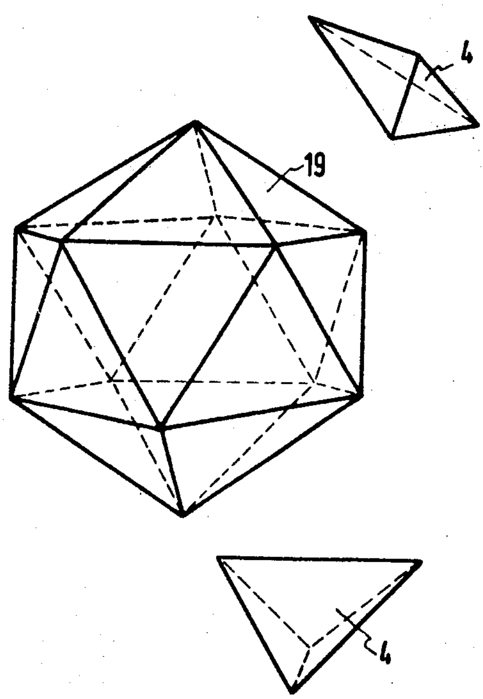
Fig. 26



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REGULAR AND SEMI-REGULAR POLYHEDRONS CONSTRUCTED FROM POLYHEDRAL COMPONENTS

BACKGROUND OF THE INVENTION

Construction sets of this type are widely known, such as the well-known "Erector" sets. There may be mentioned, by way of example, the cube sets widely used as toys and which comprise a plurality of identical cubes. All of these known construction sets have the disadvantage that their use is limited to toys. Furthermore, they are also limited in their possibilities of application since, if no special connecting means are provided, the possibility of assembling the individual parts to form complex bodies is rather small and, if connecting means are provided, these connecting means, such as pins to be inserted into holes, limit the assembling possibilities.

Thus, for example, a part with a projecting edge cannot be inserted, by means of a pin, into the groove terminating a recessed edge of another part and be secured thereto. Furthermore, the known construction sets cannot be used, or can be used to only a limited extent, for complex geometric bodies, such as a demonstration model. This is due to the fact that, on the one hand, they do not lend themselves to complicated assemblies, due to their limitation to block-shaped or cube-shaped parts, and, on the other hand, the difficulties characteristic of known connecting members hinder such an assembly, as mentioned above.

SUMMARY OF THE INVENTION

This invention relates to construction sets and, more particularly, to a novel and improved construction set for building structures assembled from geometric parts having plane surfaces.

A construction set in accordance with the invention does not have the shortcomings of known construction sets. It permits the assembly of even very complicated structures from individual parts. It is suitable not only as a toy but also as a teaching aid and for research purposes, since it permits the reproducible representation of very complicated three-dimensional structures, using simple means, and this was not possible, up to the present, in practice, with known means because of the very high energy expenditure required.

A construction set in accordance with the principles of the present invention is characterized in that it contains at least one group of equal or identical pyramids with three, four, or five equal lateral faces, as well as at least one part in the form of an at least semi-regular polygon which can be assembled from partial bodies, such as abutting pyramid bases, or to a pyramid, this latter part having at least one plane of symmetry. The parts can be connected to each other by adhesive joints at their abutting faces or can be connected to each other in an articulated relation along abutting edges by the adhesive joints.

With such a construction set, it is possible to produce even complicated structures from simple parts, as will be described more fully hereinafter. In addition, it is possible to disassemble simple symmetrical bodies, such as cubes, into a plurality of other geometric parts. The adhesive joint between the parts can be effected, for example, by magnets imbedded in the surfaces of the parts or according to the principle of the bur lock. Preferably, however, areal elements are provided for the adhesive joints. The adhesive joints preferably are detachable, since this permits the reuse of all parts. As areal elements, there are preferably used foils provided on both surfaces with an adhesive. However, the term "foil" is not used here in the narrower sense, and may comprise, for example, thin fabrics or fleeces or other areal structures suitable as adhesive carriers.

The foils preferably have the form of circular sheets, and this form as the advantage that a special orientation of the foils is not required. The diameter of the circular sheets should be, at the most, equal to that of the circle inscribed in the smallest surface of a part. Under different circumstances, it may be necessary to work with either larger or smaller circular sheets.

The hinge connections when the parts are arranged in edge-to-edge relation are preferably foils having one surface provided with an adhesive coat, and here, too, the term "foil" is not used in a narrower sense but rather in the wider sense, as explained above.

Due to the use of adhesive-coated foils for joining the individual parts, the geometry even of complicated assembled structures is not changed, as long as care is taken that an adhesive foil is provided between all surfaces that are in contact with each other. Using adhesive foils as hinge connections provides a substantially volume-free joint, which does not hinder the geometry of the assembled structure if used correctly. A preferred pyramid form is that of a three-sided pyramid where all surfaces are equilateral triangles. Such a pyramid is, at the same time, a tetrahedron of equal face areas, and hence a regular body.

Another preferred form of pyramid is a four-sided pyramid with a square base, and whose side faces are congruent with those of the three-side pyramids. Two such four-sided pyramids can be assembled, for example, to form an octahedron as a regular body.

Another preferred embodiment of a four-sided pyramid is characterized in that its opposite side faces are arranged in planes intersecting each other at a right angle. Such pyramids can be assembled, for example, with a cube to form a semi-regular structure whose opposite rhomboid end faces extend parallel to each other.

A further preferred type or form of pyramid is a five-sided pyramid with a pentagonal base, whose triangular side faces lie in the extensions of the faces of a dodecahedron, which adjoin a lateral face of the dodecahedron forming the base of the pyramid. These pyramids can be assembled with a dodecahedron so that each edge of the dodecahedron is aligned with a lateral edge of a pyramid.

Although the parts assembled to form an at least semi-regular body need not be bounded on the surface, preferably these bodies are bounded by plane surfaces. Due to this plane-surface design of the parts, the latter can also be assembled again as elements to form the pyramids and regular and semi-regular bodies, so that the possibility variation is substantially increased and the representation of complicated geometric structures using the construction set embodying the invention.

An object of the invention is to provide a construction set for building structures assembled from geometric parts having plane surfaces.

Another object of the invention is to provide such a construction set wherein a plurality of geometric parts include at least one group of equal pyramids each having at least three equal side faces and at least one part in the form of an at least semi-regular polyhedron having at least one plane of symmetry.

A further object of the invention is to provide such a construction set in which the polyhedron can be assembled from partial bodies.

Another object of the invention is to provide such a construction set in which the polyhedron can be assembled from base-abutted pyramids.

A further object of the invention is to provide such a construction set including adhesive means effective to interconnect the geometric parts selectively in either face-abutting or edge-abutting relation.

For an understanding of the principles of the invention, reference is made to the following description of typical embodiments thereof as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIGS. 1 and 3 are exploded perspective views and FIGS. 2 and 4 are assembled perspective views illustrating a construction set using an octahedron as a regular basic geometric part;

FIG. 5 is an exploded perspective view, FIG. 6 is a perspective view, FIG. 7 an exploded perspective view, and FIG. 8 a partially exploded perspective view illustrating a construction set including a multiple-part cube as a basic geometric body;

FIG. 9 is an exploded perspective view, FIG. 10 a perspective view, FIG. 11 a partially exploded perspective view and FIG. 12 a perspective view illustrating a construction set including a semi-regular basic geometric body;

FIGS. 13 through 16 are, respectively, exploded perspective, perspective, partially exploded perspective and perspective views illustrating the combination of a basic geometric body with pyramids;

FIGS. 17, 18 and 19 are, respectively, top plan, side elevation and bottom plan views of basic geometric bodies and pyramids articulated with each other in edge-to-edge relation;

FIGS. 20 through 23 are perspective views illustrating the possibilities of folding the articulated elements shown in FIGS. 17 – 19 to form geometric bodies;

FIGS. 24 and 25 are, respectively, a partially exploded perspective view and a perspective view showing the assembly of a so-called Keppler star body from a dodecahedron and polygonal pyramids; and

FIG. 26 is an exploded perspective view illustrating an icosahedron and two pyramids.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Since the dimensions are of great importance for the combination possibilities of the various bodies, a review of the bodies shown in the different embodiments, and their dimensions and relations to each other, will be helpful. The side lengths of the bodies are indicated starting from a unit length 1.

The tetrahedron **1** is a regular tetrahedron which is bounded by equilateral triangles and which has the side length $\sqrt{2}$.

The smaller tetrahedron **2** is likewise a regular tetrahedron, bounded by equilateral triangles, but having the side length of ½ the $\sqrt{2}$.

The portion **3** of an octahedron is a three-sided pyramid whose base is an equilateral triangle with the side length $\sqrt{2}$. Each of the lateral edges intersecting the apex of the pyramid is perpendicular to the opposite side face having the side length **1**.

The icosahedron pyramid **4**, shown in FIG. **26**, is a three-sided pyramid whose base is formed with an equilateral triangle having the side length **1**. The inclination of the three side faces of this pyramid is such that, when the pyramid is placed with its base on an end face of equal size of an icosahedron, the three side faces of the pyramid lie in planes with the respective adjoining end faces of the icosahedron.

The tetrahedron **5** is a three-sided pyramid whose base is an equilateral triangle with the side length $\sqrt{2}$, while the length of the sides meeting at the apex of the pyramid is ½ $\sqrt{3}$.

The octahedron half **6** is a pyramid with a square base having the side length equal to $\sqrt{2}$, and with the side faces of the pyramid being equilateral triangles.

The smaller octahedron half **7** is likewise a pyramid with a square base, and all of its sides have the length ½ $\sqrt{2}$.

The pentahedron **8** is a pyramid with a square base. The side length of the base is **1**, while the length of the side faces is ½ 3. In this pyramid, each side face is perpendicular to the opposite side face.

The rhomboid dodecahedron twelfth **9** is a four-sided pyramid with a rhombic base whose side length is ½ $\sqrt{3}$. The longer side edges have the length **1**, while the two shorter side edges have the length ½ $\sqrt{3}$.

The dodecahedron ten is a pentagonal pyramid whose base is a regular pentagon with the side length ½ $\sqrt{5-1}$), while the length of the side edges is **1**.

The octahedron quarter **11** is formed from the octahedron half **6** by a plane section through the apex and two opposite corners of the base of the pyramid forming the octahedron half **6**.

The octagonal prism **12** has a base surface and a top surface, each of which is in the form of a rectangular octagon with the side lengths ½ $\sqrt{2}$. The height of this prism is likewise ½ $\sqrt{2}$.

The octagonal cap **13** is so derived that, by placing a cap **13** on each side of the octagonal prism **12**, the latter is complemented to form the semi-regular body shown in FIG. **10**.

The hexagonal cap **14** has a base in the form of regular hexagon with the side length ½ $\sqrt{2}$. Adjoining this hexagon are squares and equilateral triangles alternating with each other and having the side length ½ $\sqrt{2}$. The top surface of hexagonal cap **14** is at equilateral triangle with the side length ½ $\sqrt{2}$.

The hip roof **15** has a square base with the side length **1**. Two opposite sides of this base adjoin triangular side faces, and the other two sides of the base adjoin trapezoids. The inclination of the triangular side faces and the trapezoids is such that, when the hip roofs are placed with their bases on the six faces of a cube with the side length **1**, so that the ridges of adjoining hip roofs are perpendicular to each other, the trapezoidal and triangular faces complement each other to form regular pentagons which form overall a dodecahedron. The pentagons are equal to the base of the dodecahedron pyramid **10**.

The hexagon disk **16** is formed from a cube having the side length **1**, with the cube being bisected, on the one hand, by a plane section intersecting all six sides uniformly, to yield a separating surface in the form of a regular hexagon, and then the triangular pyramid is separated from this half once again by a section parallel to the hexagonal surface and extending through the corners of the cube.

The rhombic dodecahedron **18** is a regular dodecahedron. The side lengths of its pentagons is ½ ($\sqrt{5-1}$). The pentagons are equal to the base of the dodecahedron - pyramid **10**.

The icosahedron **19**, shown in FIG. **26**, is a regular icosahedron, and the side lengths of the twenty equilateral triangles forming its surface is **1**.

The quartodecahedron **20**, which is shown in FIG. **16**, is formed by eight regular hexagons and six square faces, with all sides having the length ½ $\sqrt{2}$.

Referring now to FIGS. **1** through **4**, the two octahedron halves **6** are first connected at their square pyramid bases with the imposition of a circular areal adhesive element **21**, so that a regular octahedron is formed. In the exploded view of FIG. **1**, the bases of these two pyramids are still spaced from each other. By means of an areal adhesive element, a regular tetrahedron **1** is attached on each of the eight triangular end faces of the octahedron, thus to form the body shown in FIG. **2**. This represents the penetration into each other of two regular tetrahedrons having the side length 2 $\sqrt{2}$. It should be noted that each regular tetrahedron **1** can be composed of four tetrahedron quarters **5**, as indicated in the tetrahedron shown at the top right in FIG. **1**.

The body shown in FIG. **2** can now be complemented by means of octahedron quarters **11**, in the manner shown in FIG. **3**, using areal adhesive elements **21** comprising a foil coated on both surfaces with an adhesive. This will form the cube shown in FIG. 4. The use of the areal adhesive elements **21** will not be mentioned hereinafter, since their use is effected always in essentially the same manner.

Instead of an octahedron quarter **11**, there can be used two octahedron eighths **3**. Naturally, the above-described construction of a cube is only one of many combination possibilities and application possibilities of the parts being used. From octahedron half **6** and tetrahedrons **1** there can be assembled, for example, plane layers whose thickness is equal to the height of the pyramid formed by an octahedron half. It is also possible to use, instead of the octahedron halves **6**, two octahedron quarters **11** or four octahedron eighths **3**.

FIGS. **5** and **6** show the assembly of a cube or hexahedron from two octahedron eighths **3** and two hexahedron disks **16**. FIG. **5** shows the individual geometric parts used, while FIG. **6** shows the assembled cube which is a regular body. This cube can be assembled, as shown in FIGS. 7 and 8, by placing hexahedron sixths 8 with their square bases on the square surfaces of the cube to form the rhomboid-dodecahedron 17 shown in FIG. 8. The rhomboid-dodecahedron 17 is a semi-regular body. On its rhombic end faces, there can be place rhomboid-dodecahedron twelfths, hence pyramids with a rhombic base. The rhomboid-dodecahedron twelfths must not be placed on all the rhombic surfaces of the rhomboid-dodecahedron 17. If the rhomboid-dodecahedron twelfths 9, which are at right angles to each other, are placed on only four surfaces of the rhomboid-dodecahedron 17, there is obtained a double pyramid.

FIG. 9 shows the assembly of the semi-regular body of FIG. 10, using an octagon prism 12 and two octagon caps 13. As can be seen from FIGS. 11 and 12, the semi-regular body with 26 faces shown in FIG. 10, and whose faces are formed by squares at equilateral triangles of equal side length, can be disassembled to the semi-regular body shown in FIG. 12, by using additional hexagon caps 14, as well as cubes 22, whose side length is equal to the side length of the square faces of the 26 face body.

FIG. 14 shows a semi-regular quartodecahedron 23, whose faces consist of squares and equilateral triangles of equal side length. The quatrodecagon 23 of FIG. 14 can be assembled from two hexagonal caps 14. It is interesting that, depending on the relative angular position of hexagonal caps 14 with respect to each other, the quatrodecagon 23 is formed, having each edge extending between a triangle and a square.

Quatrodecagon 23 also can be assembled, as shown in FIG. 13, from a rectangular cap 14, three smaller octahedron halves 7 and three small tetrahedrons 2. The small tetrahedrons and the small octahedron halves together form another hexagonal cap 14. On this there can be placed small tetrahedrons and small octahedrons, as pyramids.

FIG. 15 illustrates the assembly of the semi-regular quartodecagon 20 shown in FIG. 16, and which is bounded by eight regular hexagons and six squares, the member 20 being formed from hexagonal caps 14 and small octahedron halves 7. Of interest with respect to this arrangement is that a regular small octahedron remains hollow in the interior of quatrodecagon 20 assembled from the geometric parts 7 and 14. This hollow octahedron also can be filled by inserting two small octahedron halves 7.

In the examples described above, the production of complex and compact continuous bodies was dealt with. Accordingly, adhesive foil elements have been used to connect the coplanar contact surfaces disengageably with each other. At this point, it should be noted that the adhesive foil elements or areal adhesive elements should have only such adhesive power that the parts connected thereby can be manually separated without too great an effort. Regulation of the adhesive power is effected best by corresponding dimensioning of the adhesive foil elements, which means that they must not be too large.

It should further be pointed out that the preferred material for the various geometric parts of the construction set embodying the invention is a plastic composition material, and both thermoplastic and thermosetting materials can be used.

FIGS. 17, 18 and 19 illustrate articulated units each comprising a hip roof 15 and a hexahedron sixth 8, with the arrangement of the individual geometric parts being clear from the drawing. The bases of the pyramid-shaped hexahedron sixths 8 are cemented to the bases of the hip roofs 15. The hip roofs are arranged in the manner shown in FIG. 17, with the ridge of each hip roof being perpendicular to the ridges of adjacent hip roofs. In this example, areal adhesive elements 21, coated on both sides with an adhesive, are provided to obtain the hinge connection. At the contact point between two units, each comprising a hip roof 15 and a hexahedron sixth 8, there is arranged an adhesive element 21 in such a way that it has one half thereof extending into the joint between the hip roof and the hexahedron sixth and the other half into the joint between the corresponding parts of the adjacent unit.

If the joints are to be particularly durable, areal adhesive elements connecting the two units with each other are preferably not selected to be circular but rather to be rectangular, so that they extend over the entire length of the edges to be joined with each other. In the simplest case, however, the use of circular areal adhesive elements 21 is sufficient, as indicated in FIG. 17. If necessary, two such areal adhesive elements can be used in side-by-side relation.

As can be readily seen from FIGS. 17 through 19, the units, each comprising a part 8 and a part 15 with the units being pivotally connected with each other, can be so assembled that the squares connecting joints between the parts 8 and 15 form the edge lattice of a cube.

When the units are now so folded that the hip roofs 15 extend toward the interior of a cube while the hexahedron sixths 8 project to the outside, is shown in FIG. 21, the semi-regular rhomboid-dodecahedron 17 is formed, wherein two of the side pyramid faces of the hexahedron sixth 8, which lie in a plane and abut with their edges forming the pyramid base, together form a rhomboid surface. In this type of folding, an octagonal cavity remains in the interior, as can be seen from FIG. 21, and into which a corresponding body (negative dodecahedron) can be inserted.

However, if the units are folded with the hexahedron sixths extending toward the interior, as shown in FIG. 22, these parts 8 bear tightly on one another in the interior. The hip roofs 15 complement each other on the outside as can be seen from FIG. 23, to form a regular pentagonal dodecahedron 18.

The pentagonal dodecahedron 18 thus formed now can be complemented completely or partly to form a so-called Kepper star body, for example, by means of dodecahedron-pyramids 10 which have their pentagonal bases united to the pentagonal surfaces of dodecahedron 18. Such a Kepper star body is shown in FIG. 25, with FIG. 24 showing the parts partly assembled. Another possibility is to attach dodecahedron-pyramids 10 on only two opposite faces of dodecahedron 18, for example.

Only a few combination possibilities are represented in the above-described examples. Thus, for example, the bodies described with reference to FIGS. 1 through 16 can be assembled to form completely or partly articulated parts, by means of foils provided with adhesive on one side or surface only.

What is claimed is:

1. A construction set, for building structures assembled from geometric parts having plane faces, comprising a plurality of closed geometric parts including at least one group of equal pyramids each having at least three equal side faces and a base face; some of said geometric parts, including at least some of said pyramids with their base faces in abutment, being capable of assembly in abutting facial relationship into a geometric structure in the form of a polyhedron; said polyhedron including a plurality of outer faces at least one of which is congruent with one of the faces of said pyramids, and adhering means between opposing ones of said faces effective to interconnect said geometric parts selectively in face-abutting relation, said adhering means including individual adhering elements in the shape of circular discs, said discs covering coextensive circular areas on the respective ones of said faces.

2. A construction set, as claimed in claim 1, in which the interconnection provided by said adhering elements is disengageable.

3. A construction set, as claimed in claim 2, in which said adhering elements are sheet-like areal elements between opposing faces and coated on both surfaces with an adhesive.

4. A construction set, as claimed in claim 1, in which the diameter of each circular disk does not exceed that of a circle inscribed in the smallest surface of one of said geometric parts.

5. A construction set, as claimed in claim 1, in which said pyramids are tetrahedrons whose side faces are equilateral triangles.

6. A construction set, as claimed in claim 1, in which said pyramids comprise pyramids with four side faces and whose

opposite side faces lie in planes intersecting each other at a right angle.

7. A construction set, as claimed in claim **1**, in which said pyramids comprise pyramids with five side faces and whose side faces form extensions of those side faces of a dodecahedron which adjoin a face of the dodecahedron coplanar with the base of the respective pyramid.

8. A construction set, as claimed in claim **1**, in which the parts are assembled to form an at least semi-regular polyhedron bounded by plane surfaces.

9. A construction set as in claim **1**, wherein said adhering means includes bur-lock means on opposing ones of said faces.

10. A construction set, for building structures assembled from geometric parts having plane faces, comprising a plurality of closed geometric parts including at least one group of equal pyramids each having at least three equal side faces and a base face; some of said geometric parts, including at least some of said pyramids with their base faces in abutment, being capable of assembly in abutting facial relationship into a geometric structure in the form of an at least semi-regular polyhedron having at least one plane of symmetry; said polyhedron including a plurality of outer faces at least one of which is congruent with one of the faces of said pyramids, said polyhedron being composed of at least one partial body different in overall shape from said pyramids, and adhering means between opposing ones of said faces effective to interconnect said geometric parts selectively in face-abutting relation, said adhering means including individual adhering elements in the shape of flat sheet-like circular discs said discs covering co-extensive circular areas on the respective ones of said faces.

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