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Vocabulario para aparejos-3D (sistemas de construcción con componentes-3D). 3D-bonding vocabulary (building systems with 3D-components).

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Resumen— **La producción de componentes-3D para la construcción industrializada ha ido en aumento en los últimos 20 años de manera constante y paulatina. Su presencia se tiene en cuenta tanto desde la producción industrial, como desde la enseñanza de la Arquitectura, pero casi siempre desde distintos puntos de vista e intereses. La industria suele valorar solo el factor económico en todo lo que produce sin atender completamente a otros requerimientos como la calidad espacial o el aspecto simbólico, etc. Y la Universidad plantea tanteos y experimentos creativos que, sin dejar de tener su interés, se alejan de unos procedimientos y metodologías capaces de ser asimilados por la mayoría (como sí de hallazgos continuos se tratasen). El presente artículo trata de poner de acuerdo ambos campos atendiendo a un análisis y clasificación de casos de agrupación-composición de componentes-3D (aparejos-3D), de manera que una posible nomenclatura, y un reconocimiento de lo más utilizado, sirva para poner en común una tecnología que debería llegar a ser convencional, y ofrecer buenos resultados de Arquitectura siguiendo estas pautas automáticas.**

Palabras clave— Aparejo / cadena de montaje/ componente industrial, unidad 3D, 3D-wagen, 3D-cápsula.

***Abstract*— The use of 3D-components for industrialized construction has been steadily and gradually increasing during the last 20 years. It is present both in the industrialized production and the Architectural education, but almost always from different points of views and interests. From one hand, the industry values the economic factor in everything it produces without get to attend all spatial or symbolic values fully. And from the other hand, Universities' projects often management exercises and experiments looking for a creative solution that are far away from procedures and methodologies be able assimilated for everybody (standard for industry). The present article tries to reunite both worlds (industrial and academic) from an analysis and classification of bonding cases. The most used procedures and the proposed names (operations designation) achive to link the conventional and standardized technology with correct spatial and compositional results.**

Index Terms— Bond; assembly line, industrial component, 3D- unit, 3D- wagen, 3D- pod.

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I. Introduction

The “modular construction” of buildings by 3D-components has been steadily settling down for 20 years (at least within a developed industrial market; Japan, EU, USA). This confirms the prediction that R.B Fuller, together with the first manufacturers of the mobile-home in USA, anticipated regarding an important sector of the worldwide building production in the 30’s. R.B Fuller and the first manufacturers of the mobile-home in USA foresaw a mass production of fitted volumetric parts (3D-components) whose final location would be different from one to another.

And, if we look back, the industrial architecture is the one that allowed us to reach the most characteristics buildings of the last two centuries, due its development was starting around 1850 (The Paxton`s Cristal Palace was built in 1851 for the first “Universal Exhibition of the Works of Industry” in The Hide Park at London):

XIXth Century: The “large voids” that Paxton start with The Cristal Palace had a continuation in all the train stations built afterwards and leading to the big covered spaces that nowadays populate the urban world of the contemporary inhabitant.

XXth Century: The “large heights” starting with first skyscrapers in Manhattan will characterized the skyline of the main cities of the World.

21st Century: This century should be the century of buildings made with 3D-components from “big-series”, continuing with the previous two. The big-series of 3D-components are waiting for their turn to empower their own part of the history in the coming decades.

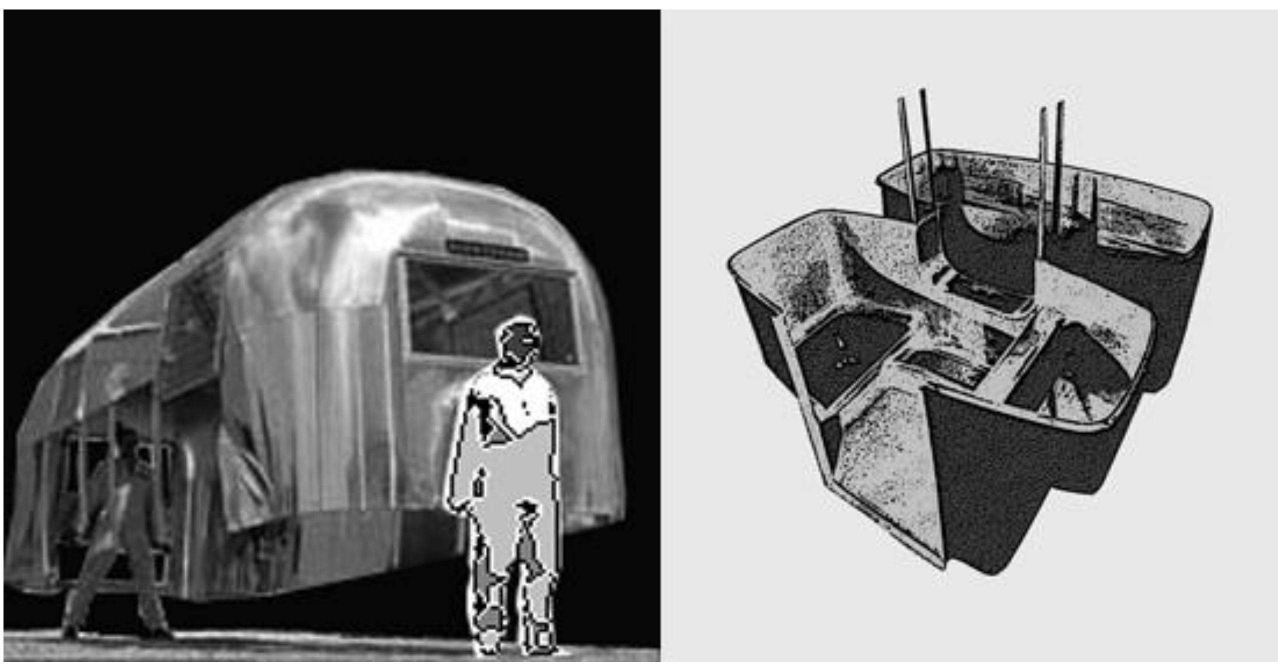
The difference between the two first centuries mentioned and the last one is that, in the first two, the components of each build (surfaces or lines) were manufactured in industrialized series but the assembly line was located in the same place where the building would be constructed. Then, the building itself is the one that work as an assembly line; sometimes horizontally (naves and warehouses) and others vertically (towers). This process is possible due to the human’s wit, and a with a lot systematization during construction (automation processes).

However, in the case of the big-series of 3D-components the assembly line is in an "off-site" factory. And completed parts of the building are transported from one place to other efficiently.

This can be achieved, simply if we conceive the production of building spaces in the same way that humanity manufactured many objects during the last Century (cars, trains, ships, planes, and electronics): Engineering has always preceded Architecture from the XIXth Century.

All that is said above don`t discover something new in this start of the 21th century; Le Corbusier or W. Gropius already wraited about this in the 20s, but Fuller is the only who try to carry out it (patent included) on his Dymaxion House (1929-40).

Thus, current 3D-components have antecedents along the whole XXth Century, in the same way the skyscrapers have it



(a) (b)

Fig. 1. (a) mobile-home Air stream [light test] (1933). (b) dymaxion-bathroom R.B. Fuller (1933).

too in the Chicago's School, Eiffel's office, or the train stations has it in correspondence with the greenhouses of the Age of Enlightenment. Step by step, pioneers on this field get accumulate their experiences showing up the path to be followed without give any opportunity to old technologies.

II. Backgrounds

Air-stream (1933) (fig.1a) launched their first mobile-homes while Fuller patented the stainless steel bath-capsule for the Dymaxion (1930-40) (fig.1b). These basic housing units were produced and thought in the same way as if they were cars. In fact, they also have wheels and their weights are very well valued. It is in these first living spaces-wagons where are found the first basic properties of industrialized 3D-components: manufactured in assembly line and easy to transport, (light construction, transportable volumes, systems of construction transferred from other 3D-units already industrialized.

The boom of the mobile-home started in that times but it stayed related to a socio-cultural situation: the fragility after the Crash of 1929 or the economic expansion of the "new-deal", always to look for a better work situation somewhere in USA.

Le Corbusier, as usual, picks up any important event of his time and transforms it into a premonition, as we can see in his Unite d'Habitation (1947): a conceptual hand appears holding the whole volume of one of the dwellings inside a spatial net. It is a conceptual operation (there was no machine able to do such movement at that time), but it is also a totally far-sighted definition if we understand where it comes from.

J. Prouvè, follower of the Master, but closer to the reality from his workshop works, is able to make up a lean "humid-cabin" fitted with kitchen and bathroom (with all equipment properly working and installed) on the foundations of the Maison for Aboot Pierre (1956) (by that time, Fuller had realized the first elevation and transport of one of his first geodesic domes using a Sikorsky helicopter: an important impact to the rest of industrial designers).

In the 60s, almost the whole "pop" generation feels identified with these premises and with the first general proposals of "prêt-a-porter" architecture (or ready-made architecture). One of the most known proposals from this time is the Archigram Plug-in-city (1967). Capsules, masts and cranes reminds the first ideas of Fuller and his "4D time-look" (1927) or the Vesnim's brothers works (made during the same period of time).

Japanese metabolism works in the same direction. K. Kurokawa designs the Nagakin hotel (1974) after his great success on the Osaka's EXPO also applying an overlapping of "plug-in" capsules around two masts. These capsules were metallic, like the proposals from the previous solutions: light materials, plastics, metallic alloys and aluminium.

Orthogonal geometry of 3D-components could remind also to Habitat`67 by Shadfi, able to claim many of the principles from the TEAM X, but however, this using an image of

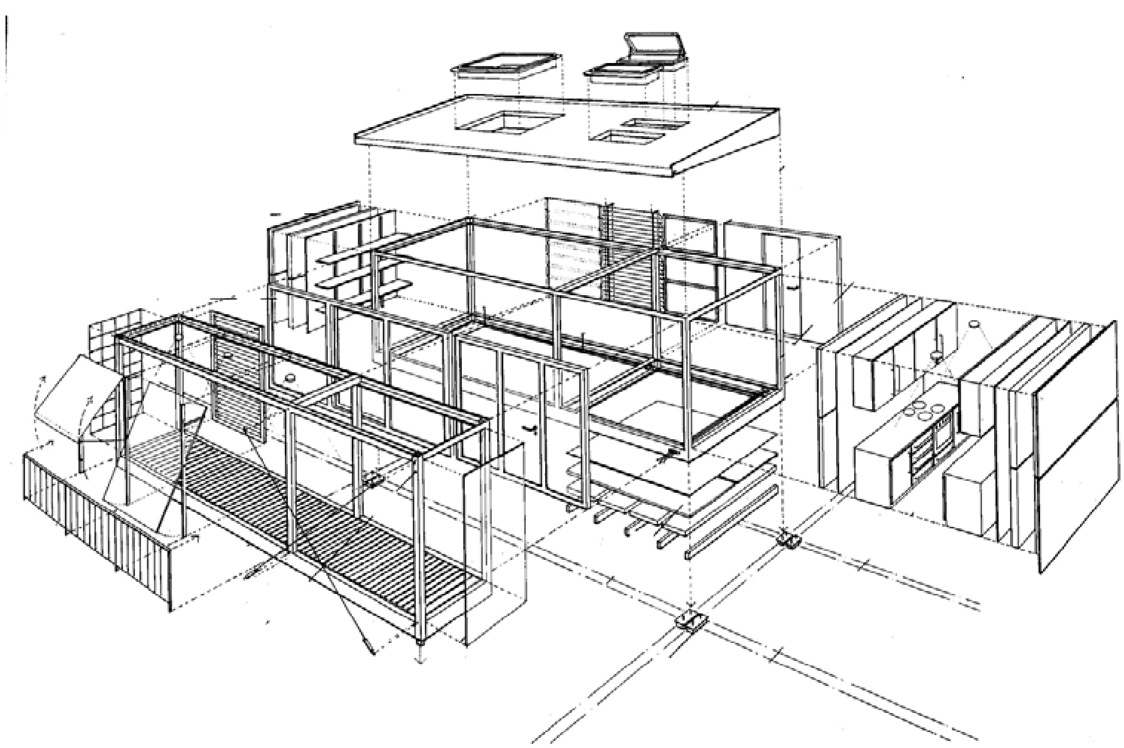


Fig. 2. **3D-wagen fitting,** (Toyota,1992) [components assembly].

“Mediterranean solidity” far away from the “pre-a-porter”. Habitat`67 was built using big 3D-units of reinforced concrete, direct influence from the URSS mass-housing construction. Reinforced concrete is an economic material but, due to its weight, difficult to be transported efficiently (except by the “Fife year plans” of Politburo). The energy required to transport and to place the concrete 3D-units at site is only possible under an economy of these characteristics).

Then, until finish the 80s this kind of making architecture is not recognized at World level in the Lloyd’s of London, and all the statements of its precedents are reflected on the facilities towers and services of this exemplar building. It is easy to identify the capsules and cranes from Archigram or the stainless steel from the Dymaxion on the Lloyd’s 3D-units, raising it level after level. Influences finish at this point and the cultural acknowledgment of the 3D-components’ serial production starts being possible and applied to any opportunity without distinction of use or purpose.

Schools, hospitals, laboratories and hotels embrace the serial production during the last decades (even we can find it in housing sometimes) and it travels around the EU from one country to another. The Lloyd’s of London building proofs that this language, often used regrettably in emergencies and precariousness occasions, can also be incorporated to the world of the symbolism and meaning in a positive way.

At last, the big series produced for the industrialized construction are manufactured like cars and by the same companies who produce them, as RB. Fuller previously announced. This is exactly what happened in Japan during the 90s and nowadays more than 70% of the detached houses in this country are produced in that way (Toyota is one of the most known brands in the detached housing market from 1992).

In last 20 years, many architects have approach and played with this field, but often in punctual manner, with some discoveries, and looking sometimes like risk challenges or trivial tries.

Meanwhile, 3D-components massive production is managed by corresponding systems engineers into each factory, and it doesn’t become automatically into architecture while it is used with other purposes.

It is in this confused and exotic context in development, it looks convenient and necessary to try clarifying in a short way the kinds of available products already in used, and the possibilities that they can bring to architectural applications.

III. Possible Taxonomy

The purpose of the present analyze is to name and identify the 3D-components that nowadays can be found in the market, and then it is possible to compare them by setting down the advantages and disadvantages of each one depending on their programs, use and spaces. Initially, it can be determined 3 big groups:

3D-wagen /// 3D-pod /// 3D-compack

They can be defined as follows:

A. *3D-wagen (fig.2)*

They are 3D-components totally equipped in a parallelepipedal shape and proportion, elongated and easy to be transported.

Their structure is based on the edges of their geometry and it is made of light materials. The rest of pieces are standard pieces already found on the market (panels, frames, facilities etc).

Cross section of the unit usually depends on the international gauge of good’s transportation. Therefore, the measures are standard within an extended area of circulation.

3D-wagen units can be attached on the three spatial directions and can set up multiple spaces extracting common parts of the skin between two units.

This mean that different spaces can be generated adding units or doing a correct subdivision of the space to get bigger spaces.

These units are usually incorrectly associated with shipping containers normally used on ports due to their characteristics. Although they have many things in common, like their fabrication process and their dimensions, the services each product offers are very different.

The structure from the shipping container is prepared to support big weights but not necessarily the 3D-wagen’s one for architecture. The external enclosure for the first one just need to protect but the second’s one needs also to be equipped for comfort (isolation, waterproofing, facilities etc.). So, a shipping container can be reused as a 3D-wagen, but a 3D-wagen offers different benefits due to a totally different process of fabrication.

B. *3D-pod (fig.3)*

These are 3D components totally equipped and adapted to the purpose they are designed for.

Size is usually smaller than the 3D-wagen’s due to the specialization and adjusts to the different functions it contains.

That specialization leads to a strong ergonomic design in the interior.

It can be said that the pod suits the idea of a case (for example, violin’s case) and, on the other hand, the wagens match with the idea of a container (a neutral case for different contents).

The material fabrication of the pods (capsules) is usually continuous along the skin as a helmet: structure and enclosure go together. This shell is made by molding or cold stamping over the used material (stainless steel, reinforced PVC, GRP, synthetic materials etc). The full pod is made of two or more pieces that once joined shape the complete shell.

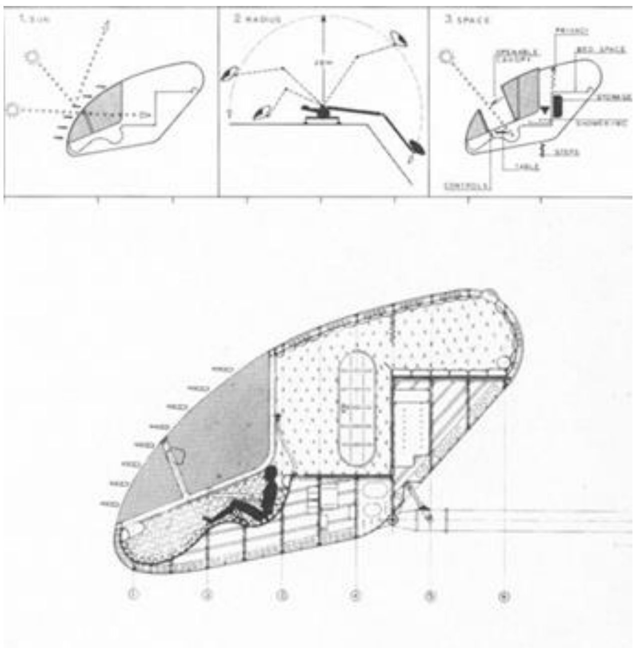


Fig. 3. Peanut FS [autonomy pod].

During shell's molding operation it can be included the installation of the special appliances that the pod will need in its interior: pipes, shelves, counter, etc.

The election of the inner function program implies the spatial release of the adjacent spaces to which it complements. This provoke that one or several pods in group do not respond in a very adequate architectural manner from the spatial point of view. A sequence of very specialized spaces results on a submarine, bunker, igloo, etc.

C. 3D-compact (fig.4)

These components can be defined as "furniture-appliance", able to easily transport technology and able to change the nature of the space where they step into.

The background theory of these components is based on the same reasons than the ones needed to understand work spaces inside the office towers from the XXth Century. Their shapes and technology depend on the use they support washing, working, rest, cooking, etc.

IV. Assemble and Systems For 3D-Wagen Units (3D bonds)

Once established the main differences between this three groups of 3D-components, we can focus on each of them individually. The 3D-wagen has different kinds of assembling depending on the shape of space and advantages we need.
The registered and more used types of assembly systems are the following ones:
stacked // plug-in // inside // in-between // deployed // isolate.

These types are defined and illustrated bellow with some highlighted examples of architecture extracted from dB alFA-G.100 research.

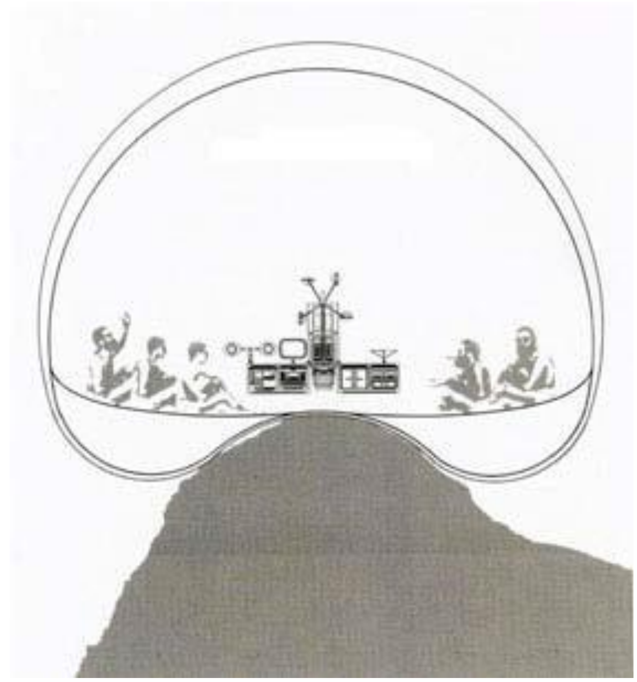


Fig. 4. Movable Standard-of-living package[multifunction compack].

A. Stacked bond (fig.5)

The units are displayed one next to the other along the three directions of the space, the edges of each unit work as the main structure of the total volume, supporting sometimes up to 4 or 5 levels.

In this case is important to point out how the lack of divisions (horizontal or verticals) leads to continuous spaces of any size (multiples with the chosen 3D-unit). This characteristic eliminates the idea from the non-specialists that 3D-units just produce spaces of the size of a single unit.

Being able to use totally equipped 3D-units, empty, or semi-equipped, let that the combination of them can create spaces of a great complexity. Therefore, the quality of these spaces depends on the skills of the designer of the system, no because we must be submitted on the monotony of an unnecessary repetition.

It is easy to generate terraces or porches with just set units in a gradate shape, add some canopies or protective cover in certain places, or leave absence of built in some areas of penthouse.

The stairwells are usually 3D-units too, but un-enclosure. Then it can be included within the building or on outside as a compositional element to consider. Outer-galleries can be attached as volumes to the main building body, or we can get

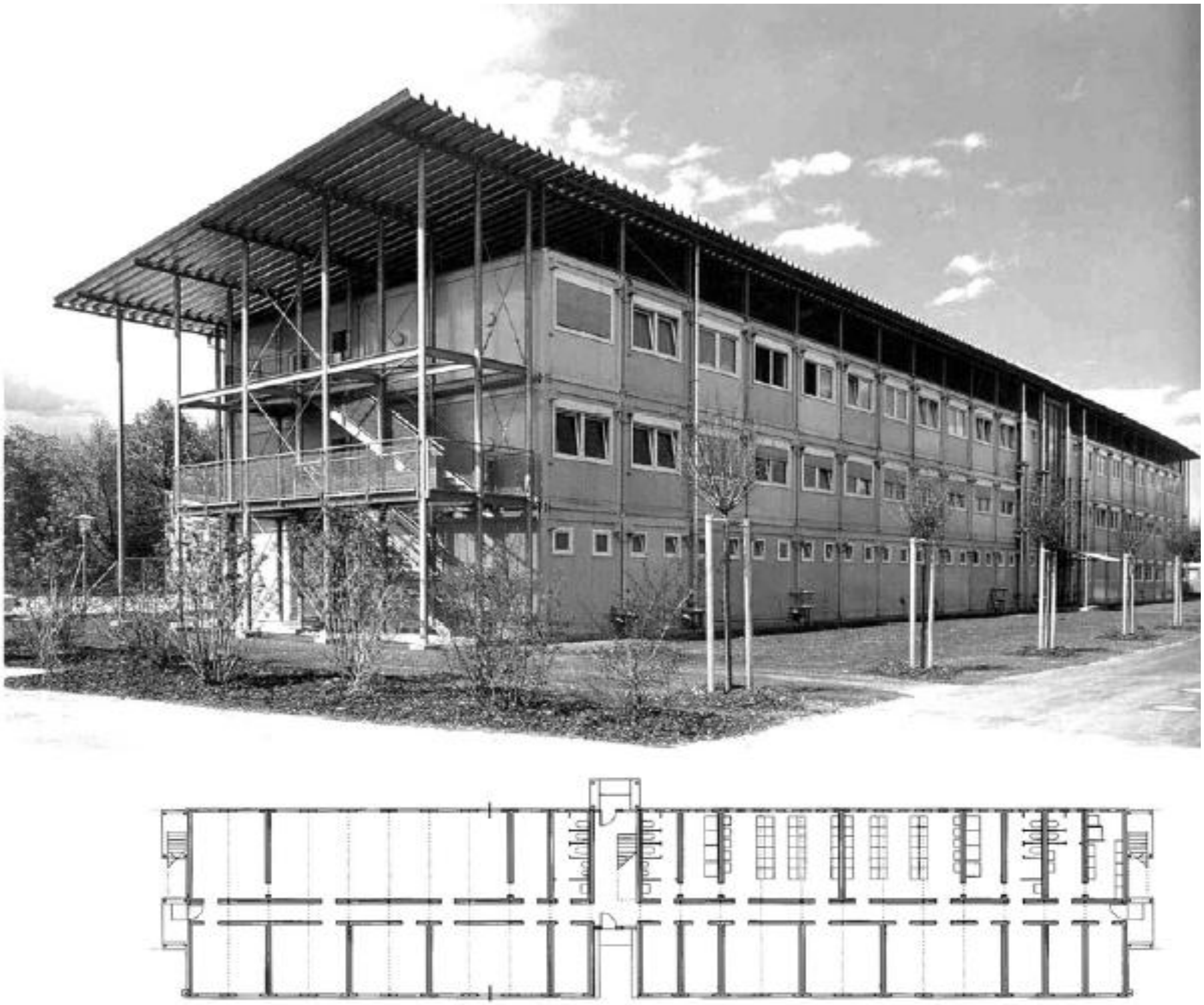


Fig. 5. Offices at Munich (Guggenbichler + Netzer,1996) [stacked wagen]

its by simply setback units.

The horizontal sliding between the units, induces special volumes and very interesting space compositions, and this is used by prominent architects (Lot-ek, architects, UCH-team: winners at SDecathlon-europe competition)

B. Plug-in bond (fig.6)

These units are usually independent ones from the others (regarding structure and installations) and they are connected to other spaces with other characteristics: vertical or horizontal spines of installations or circulations, or to bigger volumes to whom they complement.

The possible structural redundancy that can take place in these cases can be avoided with a correct design but can be also compensated with the independency of the 3D-units that allows an easy exchange of the units. It is easy to appreciate the differences between the spatial flexibility of this system and the previous.

In plugged systems, units can be replaced including the interior equipment and on the previous system is only possible to change finishes (partitions or surfaces).

For this reason, they are used primarily to accommodate equipped spaces (kitchens, bathrooms, etc). Thus, plug-in system usually has more application on pods and cabs that on 3D-wagen.

In this last case spaces tend to be tighter and more specialized, but issues such as manufacture economy or assembly, may induce to include this kind of program within the 3D-wagen:

For all 3D-units, dimensions and modulation in building-site are more general (for manufacturing and assembly line is used same procedure). This keeps the same manufacturer for all units produced, while pods are manufactured by brands with very specific catalogues: this means that we would be closer to the closed-industrialization than the open-industrialization.

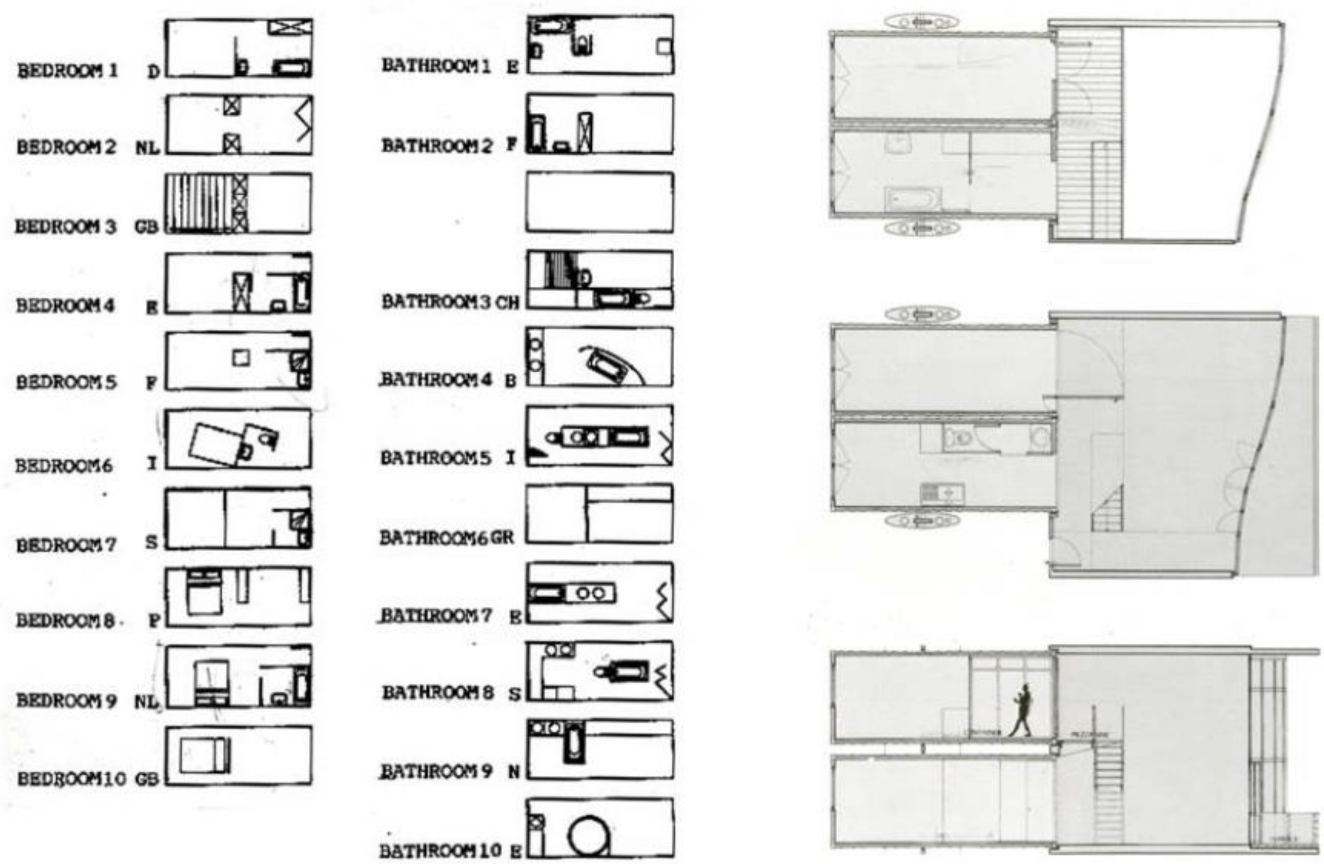


Fig. 6. Containerdim (Daridan et alt - europan-1, 1989) [plug-in 3D-wagen catalogue].

C. *Inside bond* (fig. 7)

These units are located inside a bigger space. This allows the units to behave in different ways, together or independently, but always inside a superior level space where they are connected to each other.

This case takes place when there is a space of a great size in a superior level due to the size the 3D-units already have. 3D-units can be displayed on the three directions of the space when the outer space is big enough and the small units have a second level of structure that supports them up to a certain level.

All over makes the 3D-units be protected by the same common environment, so their own enclosure can have a low level of isolation even if they are only under a roof, a glasshouse or under any other kind of shelter depending on the geographic location. Even more, waterproofing problems and constructive lace are also greatly simplifying, because we always get shelter with main skin.

In this case it is very advantage install small bearings lower 3D-units that are supported directly on a continuous pavement (to get certain freedom to move them on this surface).

Thus, the structure of the main nave facilitates changes and movement under it. Changes in distribution and therefore the spatial flexibility they have a very favourable field in this application.

However, the weight of each unit hampers its possible displacement by few people. The solution for this is usually: apply lanes, motorized bearings, or lighten the structure by wood, aluminium, or plastic.

Well known examples are Robo-house (R. Herron, 1987), Belgium Pavilion (Sevilla Expo'92), Naked house (S. Bhan, 2002), but that really they try is apply the theory both van der Rohe as RB Fuller defend since the middle of the XXth. Century. The first with The "Universal-Container " (Crown-Hall, Chicago 1947), and the second with The Biosphere 1 (Montreal Expo'67), with the following difference between both: the movement in the case of van der Rohe is limited in a horizontal level of space, while the vault of the second allows development in all directions of space (within it, with platforms and stereo-reticules that are ideal complement for the 3D-unit that can be placed between the interstices).

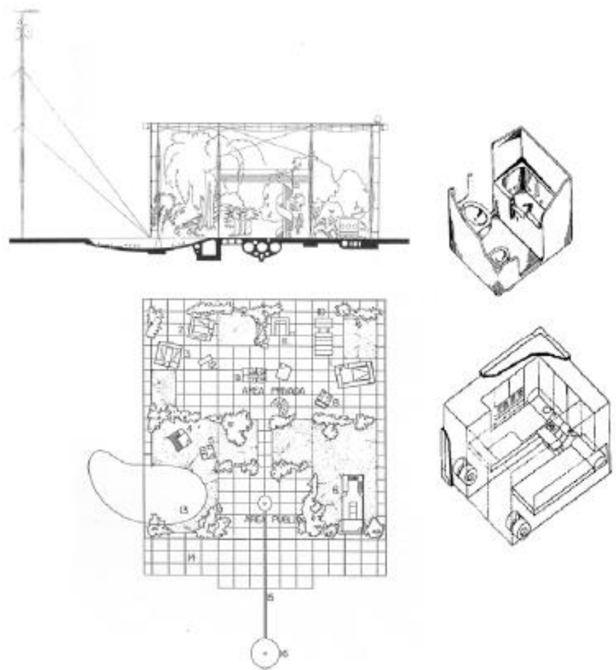


Fig. 7. Casa del Paraíso (JM de Prada Poole, 1991) [pods+ wg inner greenhouse].

D. *In-between bond (fig. 8)*

In this assembly type the 3D units are located crossing the spatial envelop were they are partially introduced.

That situation can be understood as a hybrid or mix of the previous ones:

3D-units can be used as plug-in pieces whilst they are half-protected by the skin, they are crossing

The external part of the units can stay overhanging and the interior built-in creating a plug-in with an efficient structural effect and maybe with a less compromised joints.

As an intermediate situation that is, this case serves to coexist with any of the previous 2: can be complemented with a nave full with other 3D-units exempt or stacked, or may be compatible with plug-in pods to take their place in the exterior when this kind of units are removed.

The horizontal sliding of these units by lanes, or its greater or lesser length, can also result in space situations with a strong metamorphic character, due to its ease of displacement once solved the crossing of 3D-wag through the skin of main building to which it is plugged.

E. Deployed bond (fig. 9)

This type of units unfolds part of their content once installed increasing the available space.

These operations can be made using different kinds of mechanism: swing platforms, extensible ceilings from the top (canopies, fabrics, etc) telescopic volumes.

Mobility is currently more associated to these units than to the rest of types bonds Its installation over wheels and its performance as tows are the most possibilities used but they have other applications as well.

Perhaps were the first fast food street kiosks which relied on this technology for their purposes, this began to be extended also to the use of trailers for safaris across the landscape. But

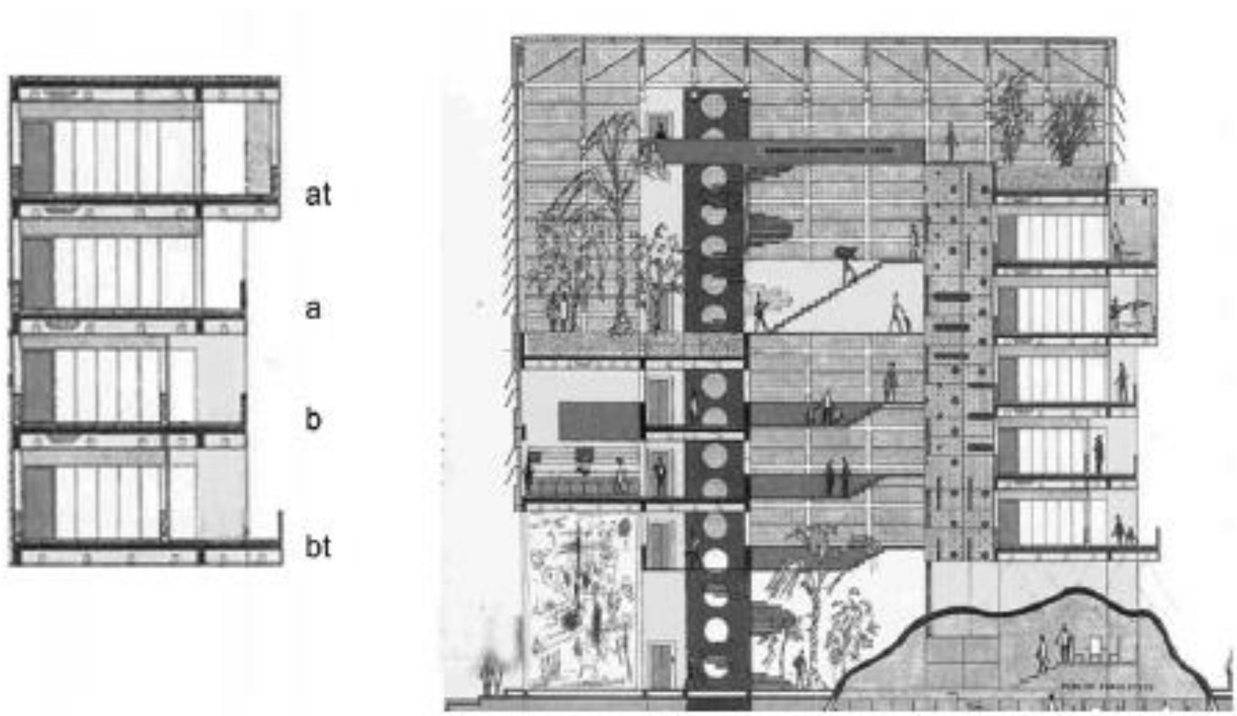


Fig. 8. Ocean - europan-3 (v. Der Broek, 1993) [3D-wg in-between]

really the circuses of all kinds (from the fairs for kids until the Formula One races) have been which give rise to the increased sophistication of these technologic resources.

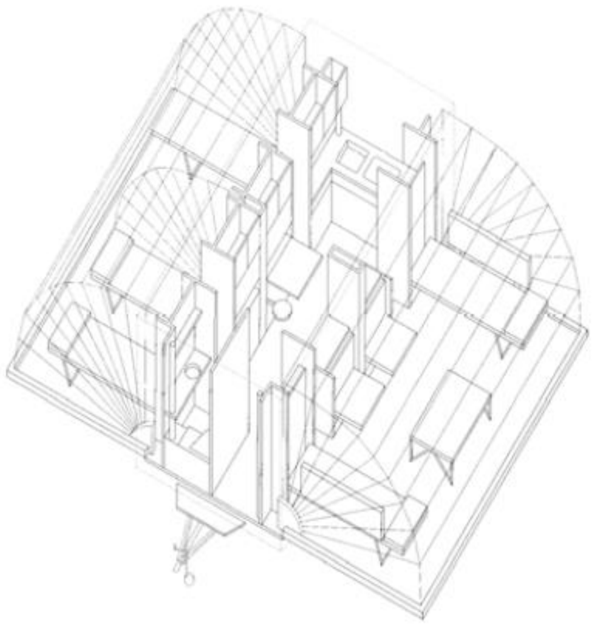


Fig. 9. Mobile home (E. Böhtlingk,1995) [3D-wg folding].

Their installation is usually separating one unit from another to allow the unfolding process. Nevertheless, their performance does not have to be independent so porches and patios can complement each other creating exterior spaces with own character.

In this sense, it is important to note as the transference of these resources to a more static buildings (without wheels) serve to transport in one truck two different kind of components: equipped 3D-units together with others that are empty but un-mounted, even as constructive complement ones for the others, with the consequent saving of transporting space.

Outstanding example in this approach is “system-3” of KFN (MoMA, 2008), and other with similar operation is “Cellophane house” (Timberlake, 2008), or “the smart citizens pavilion” (Vienna Council 2015).

F. Isolate bond (fig.10)

The last type bond takes place following the path from the big scale of the stacked units to the smallest scale: the single units.

Although 3D-units are separated one from another, this does not mean that they cannot generate groups of spatial interest.

The sculptural value of the units can be enhanced, and the interrelation between spaces can be routes or spaces of great importance.

This being the case less technically committed space and is the one that allows more freedom and therefore it tends to be the most used for the design of spaces with a certain symbolic value.

The orthogonal geometry itself and horizontality of 3D-wag (and their initial stacking), can be altered by all kinds of operations and plastics experiments: diagonals, vertical, hybridization with curves surfaces, etc, which are incorporated into the composition, while they bring a sudden feeling of dynamism to the grouping. This kind of effect can be accentuating even more with the use of ramps, advertising lights, colored spots, etc

Archigram group is good point of inspiration for all this, but today there are countless exhibition pavilions, for advertising, or urban information which will serve of these resources to get their message to the public (architects W. Muller, FOB Arch., or b_architecture among others are good examples of this).

Fig. 10. Casa del Prado, (Jones & partnes, 1992) [single 3D-wg combination].

V. Applications, Comparisons and Evaluation

If we review the 6 cases from figs. 11, 12 y 13, it looks like all of them belong to the same technology, and also that its shapes and appearance show us different kind of spaces more or less peculiars only because its designers have more or less own skills. First point is true, all of them belong to same kind of technology: Systems construction made by 3D-components through assembly line. Nevertheless, and after above classifications, it is very easy for us deduce what kind of spaces and appearance that each case generates (in correspondence with kind of 3D-bond that exist around components from each one of this six S.3c=Systems constructed by compatible components).

We can see how in figs.11a and 14a 3D-components are inn one wrap space and attached to inner skin face, and how they appear as very remarkable independents units. This is a clear example of plug-in connexion among 3D-components and general structure (how we had seen in figs 6 or The Lloyd´s of

(a) (b)

Fig. 11. (a) Extension office, Hamburg (Still K. & Keim Jochen 1997). (b) B2 at Barklays Center, Brooklyn (shop architects, 2016).

London): 3D-components sites are outside main building, also they are independents, and differentiated between them.

Unlike, the 11-b skin appears as a continued surface, sometime broken or folded (as happen in fig.5). This is a clear example of staked bond between the juxtaposed 3D-components of system. While in the previous case, complete 3D-units can change its own position, and also to be combined between them, now the combinatory is between skin panels. Total continue stacked volume could be broken because one 3D-wg is absent, or because sliding is provoked between units (pointing out edges from prisms, but with clear orthogonal discontinuity between all surfaces of the system, so for observer is very difficult to suppose any mechanic independence between 3D-units).

The 3D-wg are supported on spatial reticule at fig 12-a, justly in correspondence with "inside" bond type. In this case, the relation between units is trough fluid space generated around them. This is a protected and continuum space, fully enclosure that could have stairs, catways, or platforms that connect different building zones. All cases included in this kind of relation (like fig 7) they are clamming for RB. Fuller

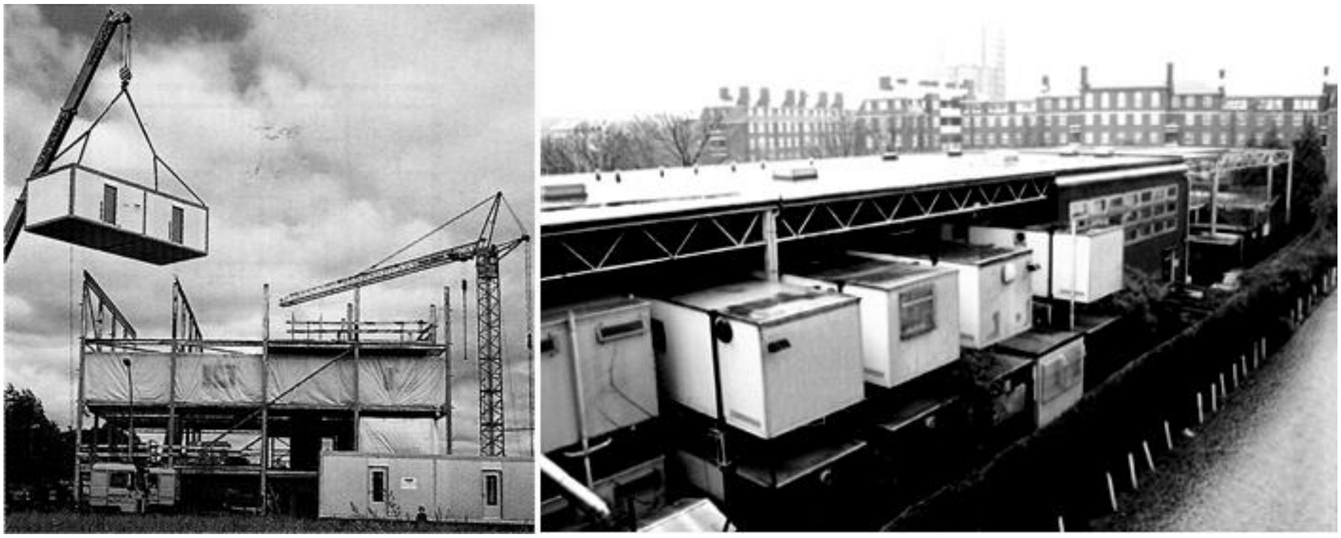
Theory: thus artificial environment conditioning of inner space under general domes. This reason, these cases have great spatial flexibility since all possible mechanic operations have weather protection, and they independent of overall envelope structure...

If this kind of spatial relation hasn't one stereo reticule to support the 3D-units, then these components lay on floor directly. So, 3D-units can roll, and they get fluids from tech-floor or hanging-net (like happen at fig. 7 or Robo-House respectively). These cases are treated how a complex of construction under nave, so its continue skin don't let us read directly the inner components that could be inside, from outside.

Figure 12b show us a similar situation than previously, but with total skin no fully closed. At Action Centre (C. Price, 1972) we can see how one spatial reticule define the structural operation field, but ceiling and vertical enclosure cud be missing along certain areas. For this reason, we can identify the units from outside of complex like happen in fig 8. These two cases show us certain kind of plug-in 3D-components from outside; but its relation with the continuous and unitary space (covered or semi-closed) indicates us they belong to "in-between" bond kind (as really it is).

With "plugged" and "stacked" bonds happen the same that with "in-between" and "inside of": the available continuous space is complementary for the quantum spaces from 3D-units, but they are following different kinds of configurations.

In "plug-in" bond 3D-units are complementary with adjacent spaces only by floor levels, and they are connecting to void space free of services, galleries, or installation vertical nucleus... This kind of 3D-bond let us high flexibility by 3D-



(a) (b)

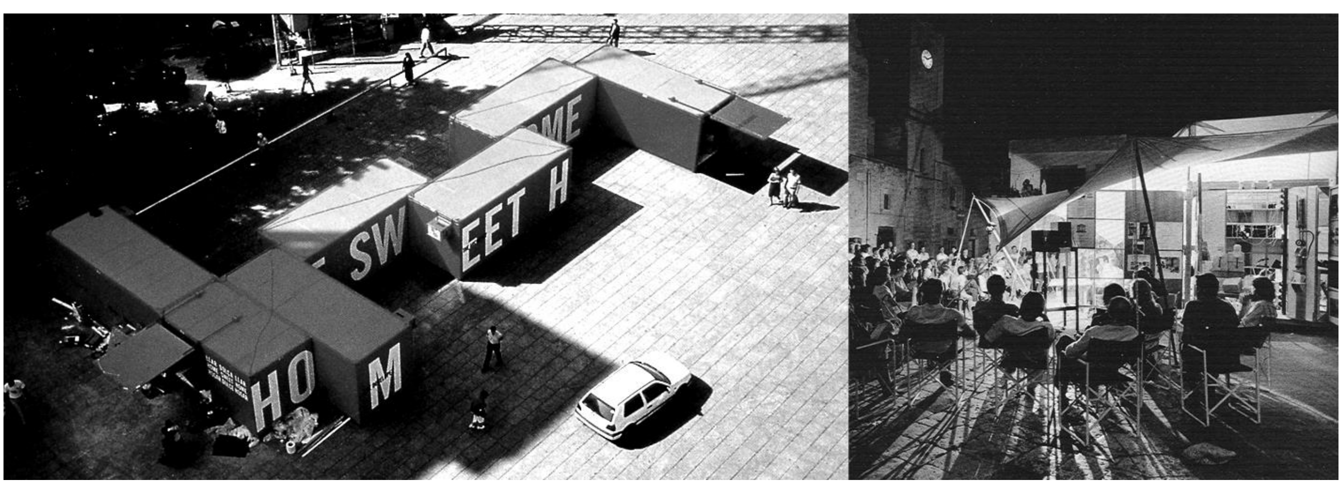
Fig. 12. (a) Offices, Stuttgat (Dullman & partners, 2000). (b) Action Center, London (C. Price, 1972).

units permutation or substitution (easier with 3D-caps, than 3D-wg, because of weight and sizes). Unlike, "stacked" bond: it don`t let us remove each unit independently of each others (maybe except at some penthouse that provide this). This last case gets the spatial flexibility through remove adjacent surfaces of juxtaposed prisms (as we can prove at fig 5 and 11-b cases).

Near to the end, fig.13-a is referring to a 3D-wg composition with units connected like change shape, while them keeping its exempt appearance and conforming important pores around. Clear example for "isolated" bond (as fig. 10 is too). This spatial case could be looks like "inside" bond when it is developed along only one flat level (because similar pores are generating). But now the continuity between 3D-components is necessary, contrary that is with "inside" bond (where artificial environment control is possible). For this reason, spaces around "isolated" bond must be more adjusted, limited, and separated.

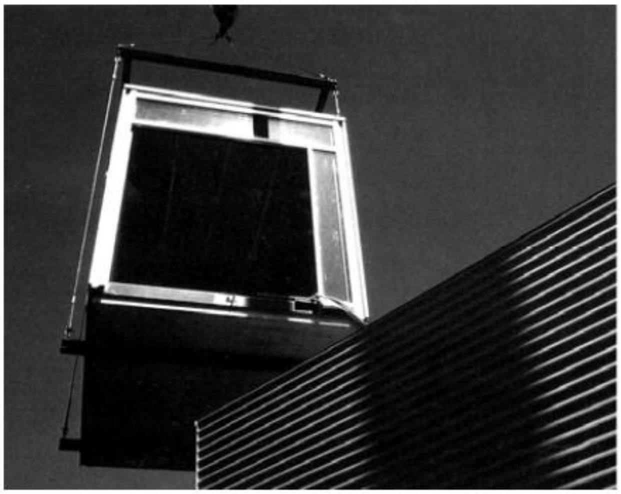
Figure 13-b case belongs to "deployed" bond (fig 9): expansion zones around are basic to understand this kind of proposals and its right work. This spatial characteristic is so main, that these transitional spaces could be very interesting like gardens between pavilions, porch between courtly yards, meeting urban places.

So, as we can prove after analysis of the 6 above samples (using classification from item-4): the 3D-units configuration shape of each system is in direct relation with its spatial organization implicit. And the two are determined by the bond type (assembly) that is applied at system components. The

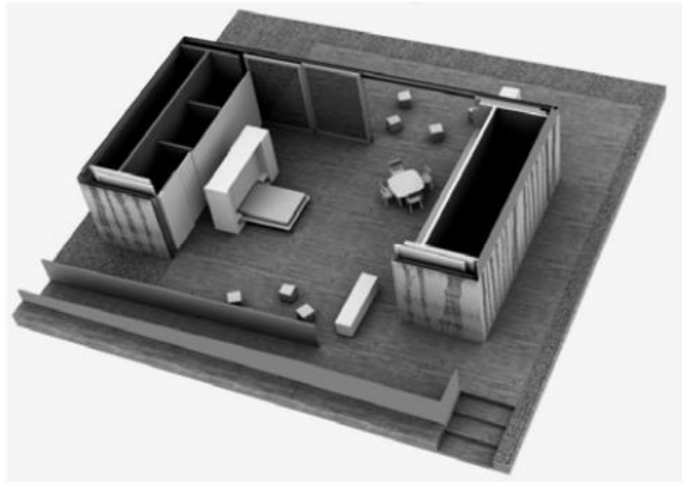


(a) (b)

Fig. 13. (a) Sweethome UIA-expo, BCN (Gili, Lelyveld, Schulzt 1996). (b) Lab. di Quartiere, Otranto (R. Piano1979).



(a)



(b)

Fig. 14. (a) extension office, Hamburg (Still K. & Keim J. 1997. (b) EKI house, Solardectahlon (EHU Team UPV, 2012).

same thing happens in traditional construction systems (with its own bond-names), but now this concept is applying to current systems composed by 3D-componentes make through "lane-production".

Start from this point, we can extend very easy the sample list, and using above 3D-bond classification, we can deduce directly what kind of spatial organizations must be better to favour its technical properties:

stack: Chantier AGV-, Edifuso, Terminal at Gijon, Gluck+,
….. (idem offices at Munich and B2)

Plug-in: Lloyds of London, Nagakin Hotel, d21 system,
Urbanautas, Urban Sets, Habitaclon,
INVISO,
(idem container-dim and extension offices at Hamburgo)

Inner : Las Harineras, Eurotravelroom, Robo House,
Green-machine … (ídem C. del Paraíso)

and so on with “in between”, “deployed”, and "isolate” type bonds (....using db alFA-G.100 for instance).

VI. CONCLUSIONS

The main conclusions are to recognize a specific vocabulary and to develop it for spatial and technologic flexibility. It seems mandatory that these bond types need to be considered and recognized by the society to coherently and normally operate (automatic) with 3D components.

That leads “modular construction” can adapt self to new technologies. Once the right parts are identified (including their characteristics and relations), then it is possible to operate with the corresponding system knowing its technical and spatial rules.

All of that allows us to experiment knowing the situation of each proposal regarding the systems explained. Experimentation will occur discovering and moving forward being aware of the different possibilities like in any investigation. In that way, we can anticipate mistakes and will recognize previous situations.

For instance, we can see how in fig. 11a 3D-units has been made as 3D-wg components, but its size and proportion are cubics not elongated shapes (fig 14-a). Also, its space is used as in capsules (pods) for special program: kitchen, archives, toilettes... (installations generally); but they have not been made as pods.

In the same way, the fig.14-b is made it by one hybrid solution with 3D-units+2D components (EKI house). This case looks like it is not including in the classification here brought; but this happen, only if we do fast review. Really, it can be easy include in “deployed-bond” type, if we consider 3D-unit expansion zone (Ze) not only toward exterior space (urban transition envelope), but toward inner living room band. So, this 14-b case is not one rare or strange invention outside of more used and recognized standard 3D-bonds by the general proposal.

From this 3D-wagen bond classification, we can see easily that composition possibilities of 3D-units are not only “stacked” (fg-5,11-b) or combined sculpturally using single units (as believed by the majority of the professionals that use this technology) (fig 10,13-a). Also, this units could be used in relation with another main architectonic spaces: fluids spine, large voids, or stereo grids … allowing us to get very efficient and spatially flexible architectures: plug-in, inside, in-between, deployed (fg. 6 to 9).

Maybe “modular architecture” is not best way to call with precision this specific architecture since 3D-units could be combined changing their size or shape. Nevertheless, a wide range of people believe “modular architecture” must be repetitive and boring when they hear something about this market.

The module must be implicit on the general definition of the system (30, 60, 90 ….cm) but it is not necessarily associated directly to any repetition of the 3D-units (material parts of the system). Regrettably, nowadays ordinary people confuse "modular-market housing" with modular-concept design.

From all the above, we get the vocabulary that favors the automatic rules of construction that any standard system needs. Thus, using this first approach vocabulary here brought, 3D-unbrought, brought, t, n (Systems of components for “modular construction”) can be used without risk of spatial or compositional error also from the technical point.

Acknowledgment

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References

Bergdoll B., Christiensen P. (2008), Home delivery, NYC: MoMa 248 p.

Detail Monographs (2009). Systems & Components. Munich: Brikhaüser 240 p.

Kronengburg R. (2002). living in motion.Basilea: Vitra Museum.