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Architectural and construction solutions for the technological spaces of agricultural clusters located in an arcology skyscraper

Yanko Aleksandrov

University of Structural Engineering and Architecture "Lyuben Karavelov", 1373 Sofia, Bulgaria
Corresponding author: yanko.aleksandrov@live.com

Abstract

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Agricultural clusters are a new and specific form of meeting the fruit and vegetable needs of the inhabitants of arcology skyscrapers. The technological spaces of these clusters require a shell-protected volume structure against external influences with a specific functional purpose, according to the specifics of the production in them. This envelope should allow architectural execution in different geographical areas, including those with harsh climate. Innovative technical solutions with an inventive step (protected by patents for inventions) are a prerequisite for ensuring a microclimate with precisely defined parameters. The high competitiveness of agricultural production will depend on the way, in which selected varieties (e.g. tomatoes, peppers, or cultivated blueberries, raspberries) are grown. The location of the technological spaces of the clusters can be on an open roof, in separate one or two floors with a prefabricated structure, also located on the roof, or in the last floors of the arcology skyscraper – for example greenhouses with shelves. The construction of the clusters and the arcology skyscraper must guarantee resistance to wind, earthquake and fire. With increased consumption of certain varieties, in two or three neighboring skyscrapers can be concentrated their production in other similar agricultural clusters.

Keywords: new solution; architectural and construction solutions; technological spaces; agricultural clusters; arcology skyscraper; patents

Introduction

An arcology skyscraper is a super tall building that is an integral part of urban aglomerations with relatively small territories (e.g. Hong Kong), in which various agricultural activities, related to the feeding of the inhabitants are concentrated. The use of clusters, but located at the height of the building, on the top floors, or on the roof, is a new approach to the operation of their areas, determined according to the tasks assigned. Their capacity is proportional to the modular coordination of dimensions within the absolute dimensions of the skyscraper.

The main goal of the research is related to the solution of architectural, constructive, technological problems of the agricultural clusters located in skyscrapers.

The subject of this study are clusters built on a modular basis, where each cluster is collected from the areas of several modules. The architecture and construction of these modules shape the vision of each cluster.

Various aspects of innovative solutions are addressed in the work of the author "Innovative molding of architectural structures. Theory of innovation steps: problems, searches, solutions." 2021. Arcology skyscrapers, as a new architectural structure, have a significant distinctive characteristic – clusters formed from modular forms with their own construction, subject to modular coordination of dimensions in construction.

The design methodology includes the collection, research, analysis and synthesis of innovative achievements worldwide. The innovative design of new architectural struc-

tures is the result of innovative design, without inventive step and innovative design with inventive step. The second type of design results in patented solutions, distinguished by novelty, inventive step and industrial applicability, and their patent purity is guaranteed by the state expertise of the Patent Office.

Clusters interpreted with a certain number of modules give a new specific characteristic of the structure of the skyscraper. It is the modules that can be regarded as composed of new technical signs, which in combination with the known signs of the previous level of technique, lead to a positive technical effect greater than or at least equal to the one already existing in the world.

In this regard, creating clusters with new elements, for example to collect rainwater for drip irrigation of plants, can guarantee high productivity and competitiveness. On the other hand, using the space of clusters for other purposes, for example medical, expands their application. The multiplier effect in the operation of cluster spaces is their essential advantage over other traditional solutions.

Effectiveness of the cluster approach

The cluster approach is an effective tool for improving the microeconomic and social environment of a certain geographical region. Clusters prove that their use can turn disadvantaged regions into prosperous ones. They allow to accelerate the process of technology transfer in related economic sectors, which increases their innovation and competitiveness (Markov, 2014). The horizontal organization of agricultural clusters is typical for settlements and areas with a high concentration of type of production. In Bulgaria such clusters are located in Ruse – for agricultural machinery; in Silistra – for cereals; in Dobrich – for honey, bread and confectionery (Zakova, 2007) Agricultural biodiversity and economic productivity (Antoh et al., 2019), is essential for the organization of production in agricultural clusters. According to the specifics of high-rise buildings, the vertical organization of clusters requires concentrated production, as well (for example, in one or two separate floors, located on the roof of the arcology skyscraper), processing of agricultural products (on the top floor, and storage under certain refrigeration requirements of the already processed agricultural products (in a warehouse located on a selected floor or in warehouses located on more floors of the building). The examples with "agricultural clusters of small and medium enterprises" (Vlasarev, 2018) are suitable for adaptation in high-rise buildings. It is expedient to develop 1, 2, or 3 types of unified format of agricultural productions in each type of skyscraper. The needs of the inhabitants in all types of skyscrapers are met through trade exchange with the help of drones. Concentrated production is according to the number of inhabitants in the settlement.

The combined production of, for example, valuable flowering honey-bearing plant species with technologies for the production of honey and copper products is particularly effective. «Clusters are like an oasis in the desert. If well managed, they can also exist in regions of the world where natural and economic conditions are very harsh (Markov, 2014).

Material and Methods

Research, analysis, synthesis and approbation /stages in the research, conducted by the author in participation in international architectural competitions, have led the projects to the status of finalists in Hong Kong, Singapore, London, Toronto and others. The reorganization of the architectural cloud, as a concentrated chaos of known technical features, through the use of combinations with new technical features, which combinations are located in the characterizing part of patent claims (first independent and one, or more dependent) is the result of using the method of innovation design with an inventive step, developed by the author in his dissertation.

Innovative solutions with an inventive step of elements for the implementation of storage chambers and cold stores (Aleksandrov, 2012-2022). However, analysis of clusters in order to derive basic design principles, as well as analysis of architectural and structural elements necessary for their implementation, is essential for the modern solution of skyscrapers, as an agricultural type.

Agro-industrial clusters are a type of industrial clusters, uniting the goals of farmers and the food industry to achieve greater competitiveness in food production (Markov, 2014). In this regard, in high-rise buildings are needed area for growing, for example, fruits and vegetables, as well as premises for their processing, and a storage base for storage of finished products before shipment to consumers. Construction of these clusters requires meeting the specific requirements of the technological spaces for each type of agricultural activity. This construction can be: traditional, monolithic or prefabricated elements.

Methods for implementing clusters in the skyscraper

This refers to construction technologies for the preliminary execution of the walls, floor and ceiling of each cluster on the floor slabs of the skyscraper, located on formwork platforms, which rise from a number of elevators suitable to floor level. After fixing the slabs to the core of the skyscraper with the help of the same elevators (lower extractors and upper extractors) the formwork platform of spatial primary elements returns to the starting position (on the field /for

raising the next floor platform), patent № 67106/16.06.2020 and reg. №1119997/29.04.2015 (Aleksandrov, 2022) (Figure 1). Innovative solution – elevator technology for lifting the chambers where fruits and vegetables are cultivated and stored, implemented in a project – Toronto. (Aleksandrov, Y. (2020). Aleksandrov Y. and all., (2015a), Patent reg. №111997 of 29.04.2015), (Figure1), (Aleksandrov Y. and student M. Mihailova, Toronto).

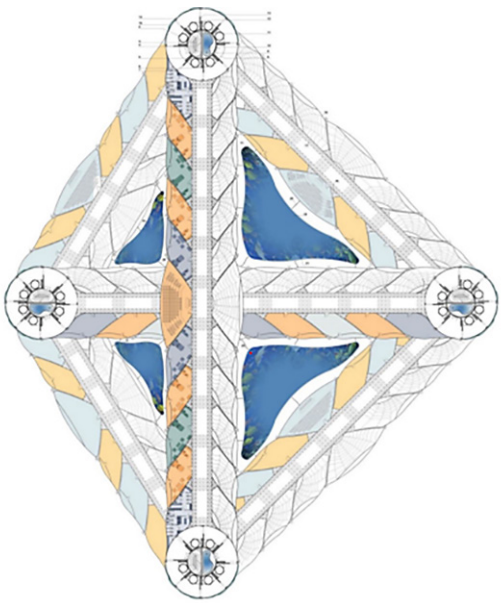


Fig. 1. Patent № 67106 / 16.06.2020 and registration №1119997 / 29.04.2015. Fisheries with storey aquariums. The cultivation of fishery products is integrated with floor clusters for processing, storage and transport by drones

The other possibility is also related to the elevator lifting of the floor slabs with parts of the clusters located on them. After rising to the floor level, these floor slabs are mounted once to the outer wall of the skyscraper, which is a kind of bearing ring. And the second time, each floor slab is fixed to the fronts of the slabs of the central stairwells. Aleksandrov Y. and all., (2015b), (patent reg. №112075 of 07.08.2015), (Figure 2)

According to Figure 2, seven cylinders of different sizes are located on the floor. Each cylinder is divided into sectors according to the nature of the cluster.

In the contour of the building of the sectors and of the seven cylinders are accessible by paths for the controlled production of the agricultural produce. Access from the outside for the import of raw materials *seeds, seedlings and other species, as well as for the size of the finished product, is through elliptical elevators located above the street network. Cultivation of algae, aquatic species – mussels, fish and others is part of the cylinder sectors. The highest sectors are used to extract energy by osmosis – mixing sweet purified rainwater with salt water obtained by salting with rock salt. The grid is located between them. Part of the cylinder sectors are used for sports purposes in some of the floors of the building (Aleksandrov, 2018b). New solution – cultivation and storage of soft fruits and vegetables in chambers of the "containers" type with positive temperatures (Container Skyscraper, Mumbai, India). Aleksandrov, Y. (2018a), (Figure 2), (Aleksandrov Y., Mihailova M. (2015).

Particularly promising are modern technologies: – building modules, consisting of prefabricated single foundations, columns, capitals, beams and slabs (Figure 3); – from containers (Aleksandrov, 2018a), or other type of bulk cells (Aleksandrov, 2017) and – from prefabricated chambers)

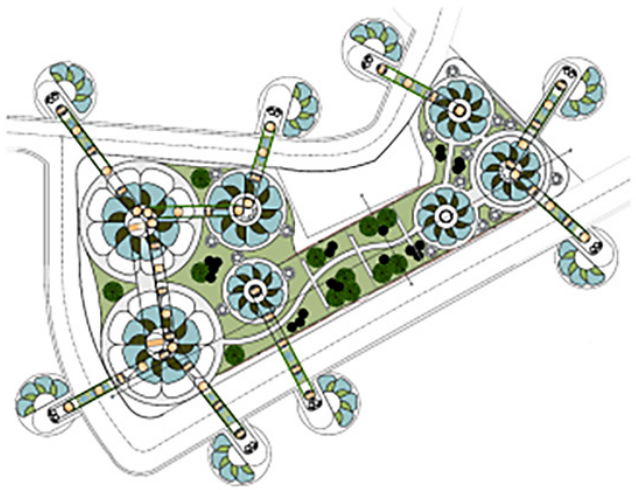
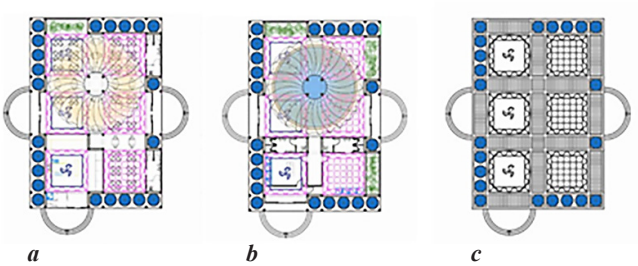


Fig. 2. Patent №67704 / 05.2020 and reg. №112075 / 07.08.2015. The fishery is located in multi-storey clusters of cylindrical bodies with different diameters of the plan and with separate sections for growing different species of fish, mussels, algae. Project Mumbai, India



a ***b*** ***c***

Fig. 3. Multiplier effect. Adaptation of 6 modules for other purposes

a – kitchen with dining room; *b* – sports area – shallow pool with dressing rooms, *c* – roofing plan

(Aleksandrov, 2018b). They are designed for growing and storing fruits and vegetables. Some of the water vessels designed to collect rainwater can be treated as aquariums with fluorescent fish and algae (Aleksandrov, 2020).

Building modules, containers, bulk cells and prefabricated chambers in extreme situations can be adapted for secondary use in extreme situations, for example for medical purposes (Aleksandrova, 2008; Aleksandrova, 2016). According to the size of the building modules, they are suitable for operating rooms and operating rooms; containers – for storage of medical products – blood, blood plasma, points for rendering the first medical assistance, prefabricated – detachable chambers – according to the size of their constituent elements – for the deployment of a wide area of medical care (Aleksandrova, 2016).

Architectural and construction solutions of technological spaces for agricultural clusters. (Figures 4, 5, 6) 22 volume planning units with dimensions (210 cm + 630 cm + 210 cm) × (210 cm + 630 cm + 210 cm) in an exemplary unfolded position, are designed for a planning solution of a complex with an useful area (22 × 110.25 = 2425.25 m^2) The basement is adapted for copper production. There are spaces for its storage and space for containers required to store soft fruits and vegetables in an inert gas environment (Figures 4 & 5); (Aleksandrov Y. and all., (2016b). Of these 22 units, 6 are angular and 16 are intermediate (Figure 5). The intermediates include 8 end and 8 middle units. In the space of the end units there are gardens, bathrooms and water vessels for rainwater, intended for drip irrigation and household needs. Inland water vessels are used to grow fluorescent algae and fish. (Aleksandrov Y., Iuzeirova M. (2017).

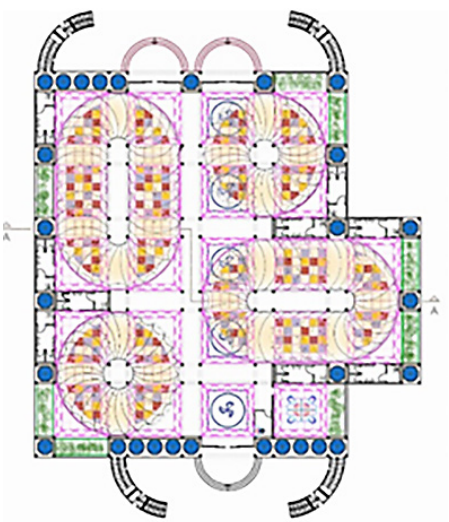


Fig. 4. Architectural and construction solutions of technological spaces for 22 agricultural clusters. Exemplary planning decisions for the cultivation of certain oil crops, soft fruits and vegetables in an autonomous environment. The example also includes vertical green walls for hanging plants

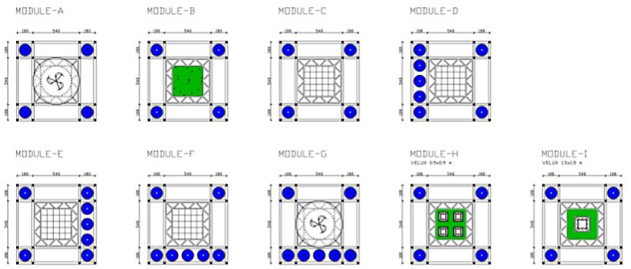


Fig. 5. 9 units. Schematic plans

Fig. 6. A food-agro complex of modules located on the roof of the skyscraper in an environment close to the natural

Sample production suitable for clusters of copper and copper products (Aleksandrov, 2018a).

This production is particularly suitable to be carried out in clusters of skyscrapers located in tropical climates. There the temperature does not fall below + 10°C. “Mumbai has a tropical climate. When compared with winter, the summers have much more rainfall. According to Köppen and Geiger, this climate is classified as Aw. The average annual temperature is 26.8°C in Mumbai. In a year, the average rainfall is 2386 mm.” [https://en.climate-data.org/asia/india/maharasl-htra/mumbai-29/, 2020. The areas for production of honey plants in the cluster are located horizontally, on the roof and vertically under elliptical gondola lifts. The bee colonies are located on the top floor of the middle part of the skyscraper (Figure 7). Aleksandrov Y., Mihailova M. (2015)

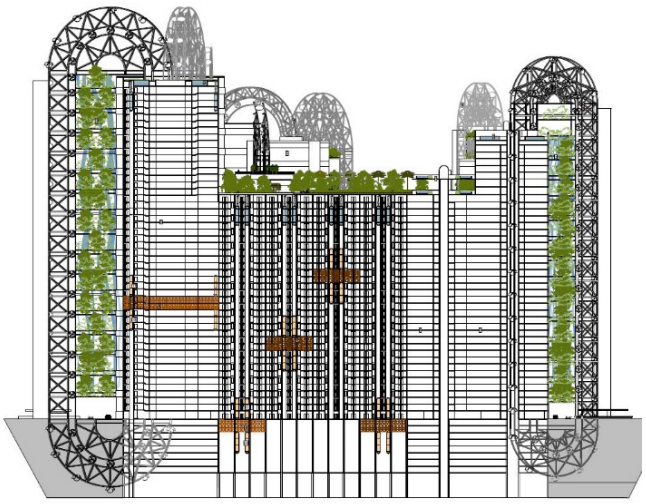


Fig. 7. Section (innovation conceptual design, Steel city – Container Skyscrapers, Mumbai, 2015) The clusters are located in bulk cells from containers

Rainwater collection

The modules are equipped with water containers for storing rainwater for irrigation of oil crops and for domestic purposes. The vessels are evenly distributed along the periphery of the complex. The area of a module is (210 cm + 630 cm + 210 cm) × (210 cm + 630 cm + 210 cm) = 1050 cm × 1050 cm = 110.25 m^2, × 3, or × 4, or × 5 = (110.25 × 3 = 330.75 m^2) or (110.25 × 4 = 441m^2) or (110.25 × 5= 551.25 m^2)

Fig. 8. Example arrangement of selected 22 volume planning modules on two floors. Multiplier effect. Adaptation of 22 modules for other purposes

(Figure 7, 8). The dimensions of the areas increase according to functional needs, for example, for growing soft fruits, vegetables, or plants used as spices. These sizes are also suitable for the construction of specialized botanical gardens in schools, or for kitchen, canteen and sports areas (Figure 8). Aleksandrov Y. and all., (2016a). (Aleksandrov Y. and all., (2016b). (Figure 9).

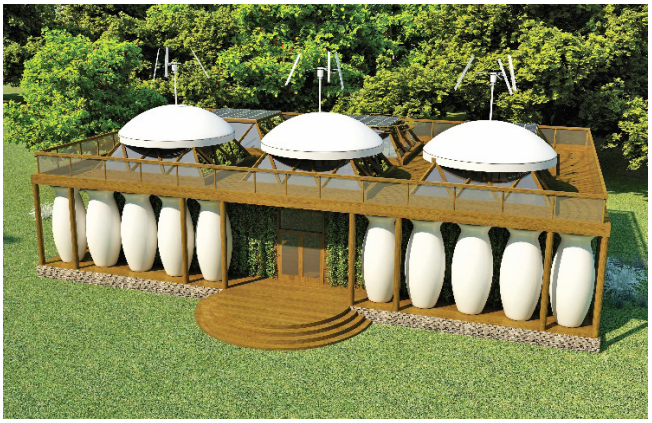


Fig. 9. Multiplier effect. Small primary school with classrooms to the complex; measurement of the modules (180 + 540 + 180) × (180 + 540 + 180) cm; and (210 + 630 + 210) × (210 + 630 + 210) cm

Results and Discussion

Multifunctional use of the volumetric modules, building the technological spaces of agricultural clusters, presupposes their functioning to be in accordance with the possibilities for secondary use for medical purposes in extreme situations. The dimensions and areas of the operating rooms and the other rooms of the operating room are decisive in the choice of the modular dimensions of the building block.

Architectural and construction solutions of technological spaces for agricultural clusters of building modules consisting of prefabricated single foundations, columns, capitals and slabs; technical characteristic of modules (Figures, 10, 11, 12, 13), (Aleksandrov Y., (2016).

A skeleton-free beam structure is mounted on a foundation bed consisting of a sand pillow placed in a flexible pillow and the step of the rigid foundation is located on the trough; circulation pumps are located on a stretched elastic conducting screen, stepping on an embedded embankment; friction between the screen and the embankment extinguishes horizontal vibrations from wind and earthquake, as well as from flickering equipment; the sandbox covers the vertical vibrations caused by the earthquake action, as well as the

vibrations of the circulating pumps at work; local lightning earthing in lightning storms by installing a grounding system.

Fire protection from lightning of agricultural clusters laid on the roof of the skyscraper

Reducing the electrical load (particular primary drawing) through local landing by means of implanting electrode in the earth, located between the complex foundations (Figures 10, 11, 12), (Aleksandrov Y., (2016.) "A cylindrical pool with a radius of 1 meter and a depth of 30 cm was excavated around the drive rod. Salt is served in this pool. The pool is then filled with water several times and the water is allowed to soak in the soil every time. In this way, the cylindrical space around the entire length of the drive rod is wetted with salt water. This significantly improves the earth's resistance to the rod (the electrode). In general, improved soil conductivity lasts many years. Recommends measuring the resistance of the electrode annually, or in half a year, and taking the necessary reprocessing action if the resistance increases above the desired value. (https://riverglennapts.com/bg/earthing/338-resistance-of- earth.html, 2020) Finally, the residual electrical load will be taken to the ground beneath the skyscraper's foundations.

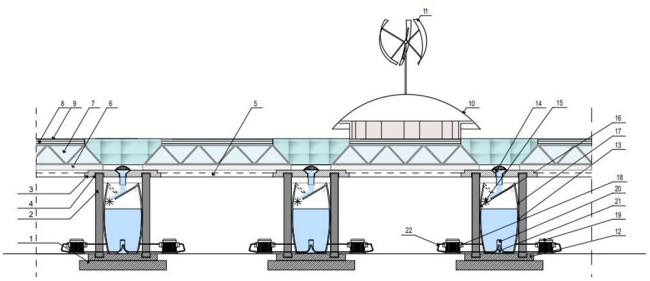


Fig. 10. Modules without a basement. Cross section through three water vessels

1 – foundation; 2 – columns; 3 – capital; 4 – open; 5 – roof panels; 6 – board beams; 7 – inclined trapezoidal farms; 8 – roof slab; 9 – photovoltaic elements; 10 – dome; 11 – wind turbine; 12 – foot foundation; 13 – water vessel; 14 – water receiver; 15 – hole for a water turbine; 16 – inclined surface; 17 – wall of the water vessel with integrated floating hose for irrigation of plants; 18 – first circulator; 19 – second circulation pump; 20 – overflow; 21 – discharge of circulator pumps; 22 –pipe

Figure 10

Figure 11

Figure 12

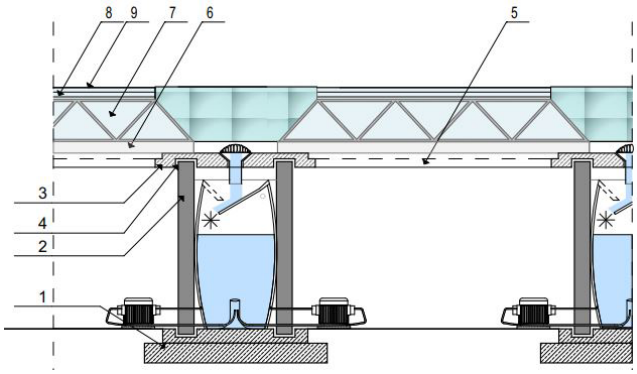


Fig. 11. Modules without a basement. Fragment 1 of section

1 – foundation; 2 – columns; 3 – capital; 4 – open; 5 – roof panels; 6 – board beams; 7 – inclined trapezoidal farms; 8 – roof slab; 9 – photovoltaic elements

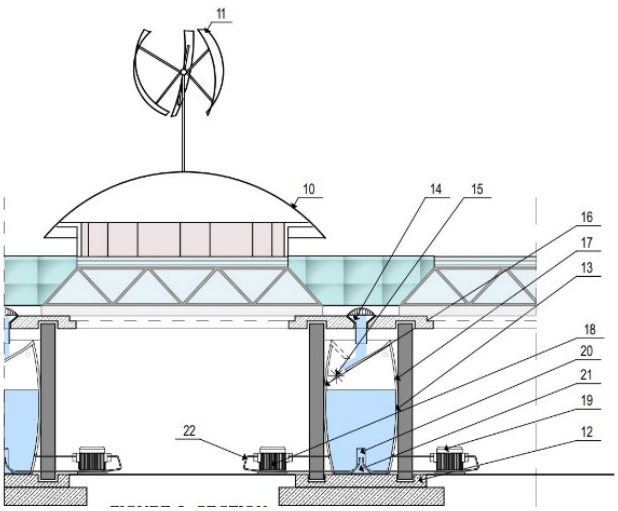


Fig. 12. Modules without a basement. Fragment 2 of the section

10 –dome; 11 –wind turbine; 12 –foot foundation; 13 – water vessel; 14 – water receiver; 15 – hole for a water turbine; 16 – inclined surface; 17 –wall of the water vessel with integrated floating hose for irrigation of plants; 18 – first circulator; 19 – second circulation pump; 20 – overflow; 21 –discharge of circulator pumps; 22 – pipe

Patents

– from volume cells; innovative solutions with inventive step to be used in the production of refrigerators for fruits and vegetables with transparent elements

The triangular panels 5 situated on the walls and the ceilings are transparent; the connections are gas-impermeable. The chambers and the containers with transparent walls and

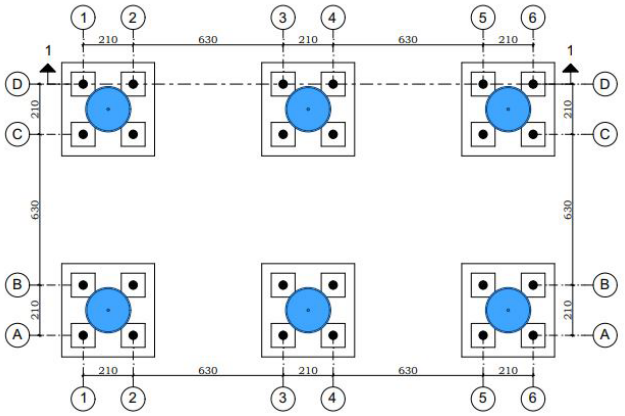


Fig. 13. Modules without a basement. Plan of foundations. Six pieces of single foundations with four more steps for four columns in each single element

ceilings are situated over a base of channels, formed under them, whereas this base is situated directly on a rotating ring. The channels allow the air conditioning of the bottom of the chambers and the containers, in the case when they are used for refrigeration of fruits and vegetables **(**Patent BG63644 (B1) (Aleksandrov, 2017) (Figure 14).

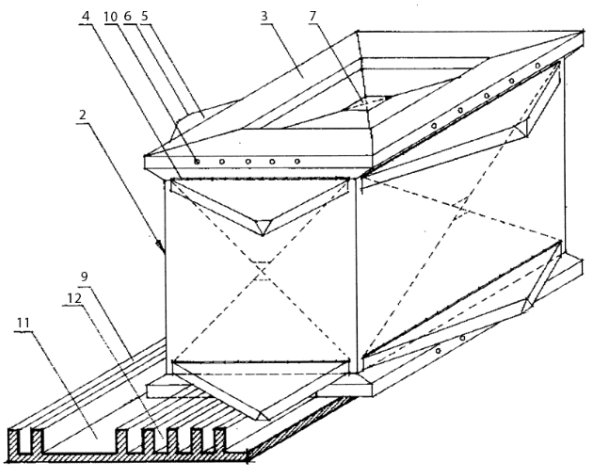


Fig. 14. Refrigerator for fruits and vegetables. General view. Patent for invention „Built-up refrigeration chamber“. Patent BG63644 (B1)

1 – four walls; 2 – chamber; 3 – beamed walls; 4 – horizontal pivotal connections; 5 – triangular panels; 6 – chamfered peaks; 7 – clamp; 8 – gas impermeable layer; 9 – rib; 10 – cylindrical channels; 11 – channel for foundation of the beamed walls; 12 – channel

– hybrid solutions from a container with an external supporting structure and from prefabricated-detachable wall and roof elements-panels for the implementation of cameras.

Moveable cold storage chamber for positive temperature. Patent № BG66823, reg. № BG111651 (A) (Figure 15). The angular two-plane elements used in the floor and the ceiling are transparent. The chambers and the containers can have one or two volumes. When they have only one volume, every first volume is used for cultivation and every second volume is used for storage of fruits and vegetables (BG111651 (A); (Aleksandrov, 2017).

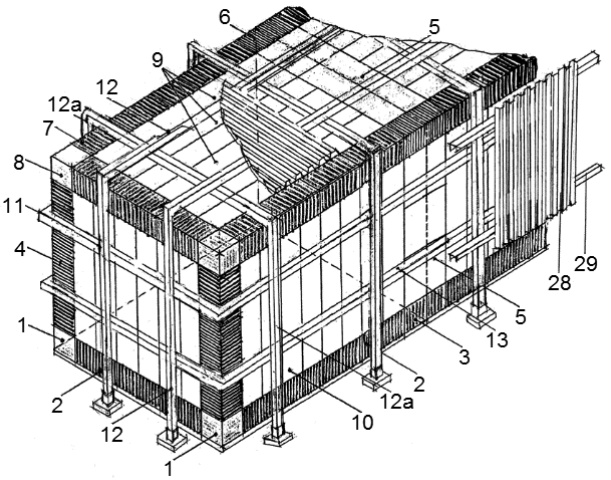


Fig. 15. Refrigerator for fruits and vegetables. General view. “Moveable cold storage chamber for positive temperatures”. Patent № BG66823, reg. № BG111651 (A)

1, 8 – three angular planar elements; 2, 7 – two planar elements; 3, 6 – „T“-shaped angular member; 4 – the vertical angular of two planar elements; 9 – not transparent ceiling panels; 10 – not transparent wall panels; 12 – a transverse transparent frames; 11, 13 – inside transparent guides

– type container with external supporting structure and with solar water heating system;

A system for solar heating of cooling chamber with positive temperatures. Patent № BG66742, reg. № BG111658 (A) (Figure16).

The transparent angular elements are combined with solar water collectors situated on the roof of the refrigerator. When the chambers and the containers have two volumes, the first volume situated on the ring, near the facade is used for cultivation of soft fruits and vegetables, and the other volume situated near the core of the skyscraper is used for their storage. The solar collectors are situated near the facade, whereas their back surface is heated by the sun rays, which

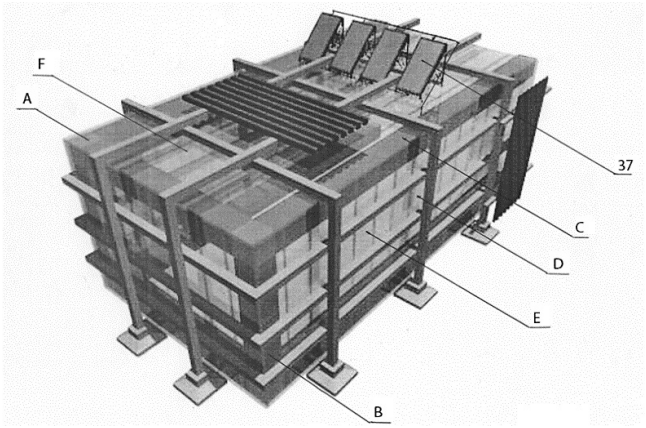


Fig. 16. Refrigerator for fruits and vegetables. Elevation. "System for solar heating of cooling chamber with positive temperatures." Patent № BG66742, reg. № BG111658 (A)

A – three flat corners; B – two flat corners; C – „T"-shaped three flat elements; D – „T"-shaped two flat elements; E – flat vertical elements; F – flat horizontal elements; 37 – collectors

are reflected by the horizontal reflective surface (Patent № BG66742, reg. № BG111658 (A) (Aleksandrov, 2017).

Each architectural idea is part of a space, idealized as an abstract cloud containing combinations of features (known and new).

The combinations of signs for survival in dynamic situations (COVID-19) make it possible to propose a new arrangement of the known signs (horizontal clusters) in a new skyscraper environment, such as vertical clusters. In an extreme situation, an additional important function is the adaptation of vertical clusters to new activities/educational, medical, sports, which in a pandemic crisis are essential for the survival of those living in the skyscraper.

Three-dimensional and two-dimensional shapes (volumes and areas), are an integral part of the development of agricultural clusters of the skyscraper.

Vertical clusters lead to savings in territorial areas, coordinate their operation at different heights in the skyscraper, and their unfolded area is a concentrated expression of their content.

The clusters can develop laboratories for the production of minimized plants (sprouts), which are especially in demand on the market due to their high level of energy.

Vertical clusters allow multiple repeatability of architectural and construction elements (columns, beams, load-bearing and partition walls, slabs), installations, modern construction technologies and others. Deciphering the cloud by introducing the feature vertical clusters, brings the functional solution closer to the execution of the architectural program of the task. Vertical clusters in the skyscraper allow us to gather useful space for new features by bringing together clusters of different sizes for secondary use for medical purposes.

The roof areas (horizontal and inclined) are suitable for the formation of cluster paths (beds) in the open for growing selected species of plants, soft fruits and vegetables and others.

Conclusions

The modules are of universal application, their area according to the functional purpose is decisive for their dimensions. The construction elements (1-base, 2- columns, 3-capitals, 5-roof panels, 6-bord beams, 7-sloped trapezoidal farms, 8- roofing plates of Figures 10, 11, 12,), are sized according to the spacing distances allowing the insertion of the respective manufacturing process.

The use of modules of different sizes, in accordance with the functional needs and technological features of plant species, allows the relocation of agricultural production with different specific characteristics. In arcology skyscrapers, by adding new areas from already selected and used modules, the production of agricultural crops can be expanded. The construction with containers for growing soft fruits and vegetables is recommended for skyscrapers, in which containers of the same type are used for the main housing unit.

Providing self-feeding opportunities from areas of agricultural clusters is of particular importance for the inhabitants of the skyscraper.

With the use of transparent parts of the containers, which aims to achieve a greenhouse effect necessary for the accelerated development of soft fruits and vegetables grown in them, water containers for storing rainwater for irrigation, solar water collectors for space heating of the containers, a solution is given to the requirements of the respective technological regimes – appropriate temperature, relative humidity, purity of the air. The high productivity of agricultural cluster production is guaranteed by the genetic characteristics of the seed, on the one hand, and on the other hand by the technology of their cultivation.

Their high quality is guaranteed in compliance with strict technological requirements in the storage areas located in selected floors of the skyscraper. The market exchange of agricultural products is in principle a market "from producer to consumer" and is carried out with the help of robotic drones between skyscrapers. Payment is by bank transfer, and social contacts between seller and buyer are avoided.

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