Circular Plans in Contemporary Housing Architecture

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Abstract. Residential buildings on the central plan are not constructed too often, however they are a part of architecture since prehistoric times. The aim of this article was to study already constructed contemporary single-family houses on circular plans (and circle derivatives) to create and systematize the typology of such buildings and to determine the methods for shaping the space of residential interiors as well as to investigate the reasons for using such a building shape. The study was carried out by analysing technical drawings, plans and sections as well as photographic materials. 24 buildings constructed in the last 8 years (after 2010) were examined. During the study, 7 basic types of buildings were defined, distinguished on the basis of the manner of their layout arrangement (1. Circle, 2. Deformed circle, 3. Circle with cut-out, 4. Circle with add-on, 5. Multiple circles, 6. Negative, 7. Arc, and also 4 ways of organizing the living space (O Orthogonal, R Radial, C Circle in circle, NP No partition). The following features of residential buildings on circular plans were noticed: most of the examined buildings are houses with a large living area, mostly located within the landscape or suburban area with low development density, the main reasons for using the plans in the form of a circle in the examined cases were: maximum outdoor view, fitting the building in the surrounding landscape and saving energy.

1. Introduction
The buildings on the central plan in the residential architecture are not a common solution, however they have been erected continuously since prehistoric times. Traditionally, many primitive nomadic tribes (regardless of the climate) lived in houses/tents/shelters with central plans (e.g. yurts, trulli, tepees, igloos and many others). It was facilitating the construction and covering the temporary structure or moving the whole construction to another place. A round shape of a residential building gives a sense of security as well as protects against external factors, such as weather conditions or e.g. earthquakes [2]. In the history of modern architecture the following architects have designed residential buildings based on central plans: Palladio (Villa Rotonda, 15th century), Arne Jacobsen (House of the Future 1927), Konstantin Melnikov (Melnikov House 1929), Frank Lloyd Wrigth (e.g. Friedman House 1940), Matti Suuronen (Futuro House – constructed in many places around the world – Finland, New Zealand, Australia, 1960), Richard T. Foster (Round House in Wilton, 1967), Antti Lovag (Palais Bulles 1970-1980), Roy Mason (Xanadu Houses in the USA, 1980), Mario Botta (many realised projects in Switzerland, e.g. Losone, Stabio in 1980-1990) or Kazuyo Sejima (Forrest Villa 1994). One of the most well-known examples of round residential buildings in Poland is the “igloo house” built in 1960s designed by prof. Witold Lipiński in Wrocław.
The buildings on the central plan were subject of the study of P. Steadman who was searching in his article of 2006 [4] for the reason for the dominance of a rectangle shape as a geometric figure in architecture (in plans and elevations). As the reasons he indicated the flexibility and ease of secondary divisions of floor plans based on rectangles. He also stated that non-orthogonal plans in architecture are the most common in very small buildings (with one room), primitive buildings or vernacular structures (usually they constitute also buildings with one main room), and in the case of bigger buildings with non-orthogonal plans, the internal division is most often orthogonal and non-orthogonal rooms are located only at the external walls of the building. Nevertheless, P. Steadman described in the article from 2015 [3], the analysis of various buildings on circular plans - mainly public, as hospitals, prisons or multi-level car parks. He created a typology and named the buildings with a plan consisting of two concentric circles an “architectural doughnut”; he distinguished two types – the “ring doughnut” (a building with an atrium in the centre) and “jam doughnut” (a building with an important room in the centre). Steadman noticed problems related to the design of buildings with circular plans, such as: difficulty with placing furniture near the walls, especially in small rooms, problems or impossibility of expansion of the building, construction cost. In turn, E. Attia compared in his text [2] a building on a circular plan to a building with an orthogonal plan and he proved its greater energy efficiency, lower construction costs, maximum use of daylight and greater flexibility in the division of the interior space. He also stated that the most effective is to combine a circular plan with orthogonally planned rooms inside. He distinguished between two solutions for designing buildings on circular plans (orthogonal and radial).

There is little documented research in the literature at residential buildings or any attempt to create a more accurate typology of buildings with central plans, taking into account not only the buildings on circular plans or circular plans with atrium. The aim of this article is to examine contemporary residential single-family buildings already constructed (containing one or two apartments where no more than 30% of space is used for additional purposes as per the Act of 7 July 1994 r. Building Law [5]) on circular plans and plans based on derivatives of a circle in order to find and systematize the typology of such buildings, to determine the methods of shaping living spaces and to investigate the reasons why buildings of such shape were constructed.

2. Research scope and methodology

This article is focused on contemporary residential buildings designed and constructed by architects (excludes buildings constructed using traditional techniques or without participation of an architect, it also does not take into consideration dome houses made of prefabricated materials which are very popular in the USA and Australia). The study covered 24 modern single-family residential houses on a circular plan and its derivatives, constructed after 2010. The studies were carried out based on the analysis of floor plans, sections, elevations and photographs. The examples were selected based on the designs available in the literature and websites, published drawings materials, photographs and design documentation. The buildings subject to the analysis are located in Japan (5), the Netherlands (3), Sweden (3), Czechia (3), Spain (2), the United Kingdom (2), Poland (1), Portugal (1), Chile (1), India (1), Vietnam (1) and the Republic of South Africa (1). Most often, circular buildings were constructed in countries that are associated with original and bold modern architecture (Japan, the Netherlands).

The selected buildings were analysed and compared in tables. The collected information was divided into groups: general information, basic data concerning the buildings (name, architect, year built, location, usable area), typology (in terms of geometric shape, way of use, program and location type), ways of solving the floor plan (how the central plan was used), the reason for designing a building on the central plan.
### Table 1. Researched circular buildings and their characteristics, own elaboration based on [6-29].

| Lp. | Name                | Architect                  | Realisation year | Location            | Floors b) | Usable space[m²] |
|-----|---------------------|-----------------------------|------------------|---------------------|-----------|-----------------|
| 1.  | 360 Villa           | 123DV                       | 2017             | Rotterdam, NL       | 1         | 85              |
| 2.  | Casa Kwantes       | MVRDV                       | 2016             | Rotterdam, NL       | 2         | 480             |
| 3.  | Dom TypOwy         | KWK Promes                  | 2009-2011        | Pszczyna PL/ second location in DE | 2         | 224             |
| 4.  | Duikklok            | Bedaux de Brouwer Architecten | 2011             | Tilburg, NL         | 5         | 576 a)          |
| 5.  | Exbury Egg         | PAD Studio, SPUD Group       | 2013             | Beaulier River, UK  | 1         | 17              |
| 6.  | Family House        | JRA Jarousek, Rochová Architekti | 2013           | Řevnice, CZ         | 2         | 198             |
| 7.  | Gumpha House        | Within N Without             | 2016             | Nashik, IN          | 1         | 111             |
| 8.  | House in Chiharada  | Studio Velocity             | 2017             | Okazaki-shi, JP     | 2         | 100             |
| 9.  | House in the Orchard | Šepka Architekti           | 2016             | Prague, CZ          | 3         | 80              |
| 10. | Hus-I               | Torsten Ottesjö              | 2012             | Bjällansás, SE      | 1         | 25              |
| 11. | Light Stage House  | Future Studio               | 2011             | Hiroshima, JP       | 2,5       | 104             |
| 12. | Light Valley        | Future Studio               | 2012             | Kyoto, JP           | 1,5       | 98              |
| 13. | Low Energy Family House | Caraa                     | 2014             | Prague, CZ          | 1         | 202             |
| 14. | Monte Do Córrego    | Atelier dos Remédios         | 2016             | Sào Domingos, PT    | 1         | 324             |
| 15. | Rode House          | Pezo von Ellrichshausen     | 2017             | Chiloé Province, CL | 1         | 200             |
| 16. | Solo House          | OFFICE KGDVS                | 2017             | Matarana, ES        | 1         | 452             |
| 17. | Stone House         | VTN Architects              | 2011             | Hon Cay, VN         | 2         | 290             |
| 18. | Tobogan House       | Z4Z4 AAA                    | 2015             | Madryt, ES          | 3         | 512             |
| 19. | Tree House          | Malan Vorster Architecture Interior Design | 2016 | Cape Town, ZA       | 4         | 117             |
| 20. | The Nutmeg House    | Barnaby Gunning Architects  | 2012             | Bridport, UK        | 1         | 290             |
| 21. | Villa Circuitus     | SAJT                        | 2016             | Vaxjo, SE           | 1,5       | 175             |
| 22. | Villa Nyberg        | Kjellgren Kaminsky Architecture | 2010            | Borlange, SE       | 1,5       | 156             |
| 23. | Villa Ronde         | Ciel Rouge                  | 2010             | JP                  | 2,5       | 1800            |
| 24. | Weekend House in Nasu | Minorou Masuda Architects and Associates | 2010 | Nasu, JP           | 2         | 139             |

a) There are two apartments in the building. The usable space in the table is the total space of the two apartments.
b) 1,5 are buildings with one full floor and one partial floor, analogous 2,5.

### 3. Results and discussions

#### 3.1. Size, location and function

Among the analysed structures, large and very large buildings are predominant and the average size of the analysed buildings is 281m². The biggest examined building is a house with an area of 1800m². Five buildings are bigger than 400m², five are smaller than 100m² (two of which are cabin-houses which are not the primary place of living with an area of 17 and 25m²). The analysed buildings are mainly all-year houses (18 cases), however there are also five residential buildings which are vacation houses and one experimental building. Most of the buildings are detached houses with one dwelling, except Duikklok which is very unique in this comparison and contains two apartments. It seems that it is easier to design a large building on a circular plan or a small building with a limited program (few rooms). The reason for that is that this way it can be avoided to design rooms with unusual shapes, difficult to furnish. The buildings subject to the study are located mainly in the open landscape (10 analysed cases) or in the
suburban area (single-family houses estates - 10 cases). Buildings with an unusual shape, such as a circle, have better chance of fitting into the location with low development density or not developed ones. In such a case, there is no clash between the existing orthogonal buildings and a new circle building.

3.2. Typology

After analysing the constructed buildings, it was possible to distinguish the following basic types of floor plans due to the geometric shape: 1. CIRCLE (on a circular plan, without deformations or only slight distortions having no significant impact on the shape of a building), 2. DEFORMED CIRCLE (ellipse, flattened circle, „egg” etc.) 3. CIRCLE WITH CUT-OUT (a circular plan with a cut-out or few cut-outs, including a floor plan in a shape of an arc of circle or circular segment), 4. CIRCLE WITH ADD-ON (a circular plan with a fragment designed orthogonally), 5. MULTIPLE CIRCLES (a plan consists of many circles/ellipses connected with one other or overlapping one other), 6. NEGATIVE (a plan in any orthogonal shape with a patio in the form of a circle, ellipse or a part of a circle etc.), 7. ARC (an elongated arc-shaped building, and in extreme cases the arc may have more than 360° and wrap around, so it forms a system of two storeys or more above each other). Combining the basic types allows to create mixed types. For example type 6. NEGATIVE can be combined with each of the other types to form a building with an atrium on a circular plan.

| NAME        | CIRCLE | DEFORMED CIRCLE | CIRCLE WITH CUT-OUT | CIRCLE WITH ADD-ON |
|-------------|--------|-----------------|---------------------|--------------------|
| SCHEME      | 1      | 2               | 3                   | 4                  |
| NAME        | MULTIPLE CIRCLES | NEGATIVE | ARC               |
| SCHEME      | 5      | 6               | 7                   |

**Figure 1.** Typology of round buildings according to the shape of the floor plan, own elaboration.

The most common basic typology is CIRCLE and DEFORMED CIRCLE, and both typologies occurred both 4 times each in the examined cases. The next ones were CIRCLE WITH CUT-OUT, MULTIPLE CIRCLES and NEGATIVE (3 buildings), and the NEGATIVE type also occurred often as part of a building in a complex typology. CIRCLE and DEFORMED CIRCLE seem to be slightly more popular typologies, but the remaining typologies occur more or less equally often. That suggests that none of the typologies has considerable advantages over others and their choice is related mostly to the individual concept of the building and its program.

3.3. Means of creating interior space

Four ways of organizing the living space were distinguished 1. ORTHOGONAL (internal walls of the building are designed on an orthogonal grid, the rooms have at least 3 straight, perpendicular or parallel walls, only external walls are curved) 2. RADIAL (walls are designed perpendicularly to arched walls, like cutting a cake into pieces, rooms have two straight walls which, however, are not perpendicular to
each other; the larger is the size of the building, the more rectangular the rooms are). 3. CIRCLE IN CIRCLE (spaces are separated by smaller circles or parts of arches), 4. NO PARTITION (no partition in particular circles, each circle is a separate room). Sometimes, several ways of shaping the space are used in one building.

### Table 2. Analysis of the chosen examples of circular buildings, own elaboration based on [6-29].

| Lp. | Name                  | Locationb) | Functione) | Typologyd) | Interior spacee) | Reasons for using circular plan | URBAN | ECO | OTHER |
|-----|-----------------------|------------|------------|------------|------------------|-------------------------------|-------|-----|-------|
| 1.  | 360 Villa             | L          | W          | 1          | R                | view                          |       |     |       |
| 2.  | Casa Kwantes          | U          | H          | 6          | O                | privacy protection             |       |     |       |
| 3.  | Dom TypOwy            | SU         | H          | 1          | R                | fits in every plot             |       |     |       |
|     |                       |            |            |            |                  | energy saving                 |       |     |       |
| 4.  | Duikkoik              | U          | H          | 4          | O                |                               |       |     |       |
| 5.  | Exbury Egg            | L          | E          | 2          | O                | water inspired shape          |       |     |       |
| 6.  | Family House Revnice  | SU         | H          | 6          | R+O              |                               |       |     |       |
|     |                       |            |            |            |                  |                               |       |     |       |
| 7.  | Gumph House           | SU         | H          | 5          | NP               | fitting in the landscape       |       |     |       |
| 8.  | House in Chiwarada    | SU         | H          | 1          | O                | contrasting the context       |       |     |       |
| 9.  | House in the Orchard  | SU         | H          | 4          | R+O              | fitting in the plot with trees |       |     |       |
| 10. | Hus-i                 | L          | W          | 7          | R                | fitting in the landscape       |       |     |       |
| 11. | Light Stage House     | U          | H          | 2          | O                | contrasting the context       |       |     | use of daylight |
| 12. | Light Valley          | U          | H          | 7          | O                | privacy protection             |       |     | use of daylight |
| 13. | Low Energy Family House | L          | H          | 2          | O                | view                          |       |     | energy saving |
| 14. | Monte Do Córgrego     | L          | H          | 6          | O                |                               |       |     | special interior effect |
| 15. | Rode House            | L          | H          | 3          | O                | view                          |       |     | wind protection |
| 16. | Solo House            | L          | W          | 3          | O                | view                          |       |     |       |
| 17. | Stone House           | SU         | H          | 2+6        | R                | contrasting the context       |       |     |       |
|     |                       |            |            |            |                  | creating a private garden     |       |     |       |
| 18. | Tobogan House         | SU         | H          | 5          | O                |                               |       |     |       |
|     |                       |            |            |            |                  | contrast forms for different floors and functions |       |     |       |
| 19. | Tree House            | SU         | W          | 5          | O                | view, fitting in the plot with trees |       |     |       |
| 20. | The Nutmeg House      | L          | H          | 2          | O                | view                          |       |     |       |
|     | Villa Circuitus       | SU         | H          | 1          | R+C              |                               |       |     | energy saving |
| 21. | Villa Nyberg          | L          | H          | 1+6        | R                | view                          |       |     | energy saving |
| 22. | Villa Ronde           | L          | H          | 4+6        | C                | view, fitting in the landscape |       |     | wind protection |
| 23. | Weekend House in Nasu | SU         | W          | 3          | O                | view                          |       |     |       |

c) L – landscape, SU – suburban, U – urban
d) H – all year house, W – weekend house, vacation house, E – experimental house
e) All numbers are according to the typology showed in Figure 1
f) All letters are according to the means of creating the interior space showed in Figure 2
Figure 2. Means of creating the interior space, own elaboration.

Taking into consideration the above-specified ways of shaping the space inside buildings, the most predominant are orthogonal solutions (14 of 26 examined cases), then the radial ones (5 cases). The rarest solutions are CIRCLE IN CIRCLE and NO PARTITION (only 1 case each). No PARTITION solution requires that a building is designed in MULTIPLE CIRCLE typology, so that each room with a different function was in a separate circle, and CIRCLE IN CIRCLE works only in very large buildings (e.g. Villa Ronde 1800m²) because with such interior solution the use of space is not efficient. The orthogonal solution is the most popular because it creates many straight, perpendicular and parallel walls which facilitates furnishing.

3.4. Reasons of using the circular plan

As declared by architects, the main reasons for applying the solution of buildings on the circular plan were: urban aspects, such as maximizing the view (10 examples), fitting the architectural form in the landscape (6 examples) as well as ecological aspects, such as energy saving (6 examples). Other most common reasons for designing buildings on circular plans included efficient use of daylight (3 examples) and contrasting with the surroundings (3 examples), Figure 3, 4.

Figure 3. Examples of chosen buildings in each typology and different means of creating the interior space – mixed types, own elaboration based on [6-29]
Figure 4. Examples of chosen buildings in each typology and different means of creating the interior space – basic types, own elaboration based on [6-29].
4. Conclusions

Residential buildings on circular plans are not popular nowadays. It results from design difficulties, technological difficulties as well as construction costs. Those which are constructed on a circular plan are individual designs, tailored to the needs of residents and intended for a particular location (here the exception is “dom typOwy” where the intention was to construct it on any plot). Even if a building is round from the outside, then the interior is usually based on an orthogonal plan. Most often, the buildings of central plans and their derivatives are used in two cases - due to ecological reasons (minimization of external walls while maintaining a large floor plan area, which gives material savings during construction as well as energy savings during maintenance of the building) and for urban reasons (attractive location and maximizing outdoor views from any place inside the building as well as fitting to the surrounding landscape).

The size and scope of the subject research was limited due to the access to graphic materials. Not all design companies publish their materials (e.g. floor plans) based on which the study could be carried out. Moreover, there is a large number of residential buildings which are constructed without an architect or with their very little involvement (in this case, these are mostly buildings having standard forms, so it can be expected that buildings on central plans are even less frequent). Therefore, the examined objects are rather luxury buildings where the investor had a large budget and ambitions of creating high-quality architecture and which have been published in architectural literature or media.

The article does not take into consideration buildings created in adapted non-residential spaces (e.g. in silos, old mills, forts etc.) despite the fact that there are many such examples. In these cases, the shape was imposed by the existing structure to which the residential function was prescribed, thus the shape does not result from the architect’s decision. The comparative analysis of buildings on circular plans which have been adapted in non-residential spaces with newly designed buildings would be an interesting development of this research. Another option for continuing the research concerning circular buildings could be the study of coverings typology (spatial forms) of such buildings - e.g. dome covering, flat roof, pitched roof and search for correlation between the shape of floor plan and the form of coverings.

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