STARTING POINTS AND CREATION OF AUXILIARY SOFTWARE FOR DESIGNING CEMETERY COMPLEXES RELEVANT TO THE CURRENT NEEDS OF SOCIETY IN THE 21ST CENTURY IN THE CZECH REPUBLIC

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Abstract. *The main topic of the published research is the design of cemeteries in the context of social change in the 21st century in the Czech Republic. This is complex presentation of the principles of designing cemeteries and their auxiliary buildings. To this end, individual component researches were carried out, which captured the development of cemetery structures and crematoria in the Czech lands since the so-called Josephine reforms. At the same time, data were obtained from existing and historic cemeteries and buildings that have undergone a period of transformation over the last 100 years. The main output is a developed program called "HOK" in the MS Excel environment, which summarizes all the principles of research in the design of cemeteries and operations of the ceremonial hall or crematorium. The program's entire assembled environment is customized to be user-friendly and to provide practical designing benefits. The article introduces the key points of the research results and related analyses, and at the same time presents working with the newly developed software and its possible implementation in design practice focused in this article to the cemeteries.*

Keywords

Cemetery, columbarium, scattering meadow, funeral pyre, cremation.

1. Introduction

"Death is one of the crisis situations with which individuals and entire societies must come to terms." p. 57 [1] Therefore, every person and society has had to address the issue of "coming to terms with death". "For psychologists, death is the culmination of life, all of its developmental stages, and for theologians, it is the end of earthly life and the beginning of another. From a sociological perspective, we can view death as the final outcome of the course of a life." p. 35 [2].

This wide range of scientific disciplines also includes funerary architecture. Firstly, the topic under consideration can be divided into the liturgical ("spiritual") and the typological, which, unlike the first classification, is quantifiable and derivable from data. This is the spatial and dispositional design of cemeteries, crematoria or ceremonial halls. It involves not only calculations of the required minimum area and the number of new grave sites, etc., but also connections to existing settlement structures. In the case of cemetery complexes, we are also dealing with a way of looking at public space in the sense of understanding the cemetery either as a generally understood space (note: anchored in the municipal zoning plan), or public areas with links to and engagement in entire community or city structures. However, the current situation is often at odds with the above idea. Cemeteries are often located not only on the edges of settlements, but also on the periphery of public interest. Another element is the site of mourning ceremonies, the "ceremony", which is the result of a comprehensive transformation of the development of funeral services. "Completely new ways of burial have emerged along with the survivors' motives for these ways of burial. Today, people view death as a failure of medical science, not as a natural end to life. The culture of burial speaks volumes about the state of every society than we are willing to admit. Nowadays, almost all funeral arrangements have been taken over the funeral services, and the survivors do not come into contact with the deceased's body. Thus, all traditional funeral customs are irretrievably disappearing" p. 2 [1].
As a result of the development of funeral services, there is

no definitive specification of current typological principles for the possible future design of the cemetery environment. This is an opportunity to create a comprehensive typological plan that will respond to the current situation, including changes in society. This opportunity encourages the preparation of a methodological basis for the future design of the cemetery, which will result in the calculation of the minimum area of the cemetery. Another observed benefit of such a document is the method of processing (MS Excel program or any other application), where the result will be an adequate tool for designers or other users.

2. Methods

The aim is to bring a comprehensive typological view of the cemeteries in terms of typology and other specifications. The primary motivation was to create the "HOK" environment in MS Excel software, which in the future may be an adequate tool not only for designers but also other users (government) to determine the parameters of cemeteries and their accessories (minimum area, number of grave sites, ceremonial hall size, crematoria, operating diagrams, etc.).

The research published here had three parts: descriptive, predictive and comparative.

The descriptive part dealt with the collection and analysis of data from published outputs of the Czech Statistical Office—CZSO—terrain surveying, and evaluation of information from earlier, previous projects, assessment of the state of existing cemetery complexes and their buildings based on own acquired data (ČSÚ, map materials, on-site investigations, etc.)

In the predictive part, the possibilities of selected typological types were specified on the basis of observations, comparison of experiences and the obtained data were subsequently described.

Specifications and options were compared using comparative analysis with models that work/do not work in model implementation, mostly abroad.

Based on this experience, software was created, herein with the working title "HOK".

3. Introduction and perception of the cemetery complex of a public ecumenical burial ground of Central Europe

In the case of cemetery complexes, we are dealing with a complex ecosystem not only of the cemetery area itself, but also of a set of buildings dependent on the surrounding settlement. It is a comprehensive view that does not end with land use planning area. The individual buildings and functions of the cemetery area can be so interconnected that ignoring these links can have a negative impact on the overall use of the cemetery. It is also necessary to consider the diversity of individual cemetery complexes, which cannot always be unified by a calculation formula. The reason lies in the number of variables that enter the basic area calculation. A good example is the morphology of the terrain, complemented by the unmistakable character of the landscape, but where the total area can increase considerably. Therefore, to understand the whole issue, selected cemetery areas within selected regions were examined.

The cemetery complex is an independent ecosystem that contains, in addition to the cemetery area itself, a set of buildings. The most typical buildings are usually technical premises, such as a mortuary. This applies especially to older cemeteries built before 1945, which are attached to sacred buildings (churches, etc.). Due to growing secularization and the political background over the past century, mourning halls and crematoria have become part of cemeteries also. Other accompanying buildings, depending on the size of the settlement, are then public toilets, technical facilities for employees, technical yards (garages, temporary waste storage), columbarium buildings, parking lots, a flower shop, or cafe or restaurant.

Tab.1: Classification cemeteries according to purpose (Ondřej Juračka, source: [3])

Classification cemeteries according to purpose:	
1	Non-public burial grounds (exclusive) – pursuant to § 3 of Act no. 193/2017 Coll., on Funeral Services; mainly concerning the members of religious orders or other religious groups.
2	Occasional – these are mainly extraordinary events that require the establishment of a replacement burial ground (wars, natural disasters due to the large number of victims).
3	Public burial grounds (civil) – pursuant to § 17 of Act no. 193/2017 Coll., on Funeral Services

This paper only deals with public burial grounds (for more see Table 1) due to their majority representation. From the point of view of religion, these are "ecumenical, that is, for people of all religious faiths as well as for non-believers (civil cemetery)" [4]. Other types are exclusively specific burial sites that merit completely separate research.

To find the optimal ratio when designing individual types of grave sites, in the case of public (civil) cemeteries, it is necessary to take into account the prevailing method of burial in the given region. Despite the average percentage of cremation in the Czech Republic – about 80% (see Figure no. 1), there may be local variations according to the religiosity of the population, which generally affects the ratio of cremation to the total number of funerals. While in large cities and in specific regions with a low level of religiosity it is possible to expect stronger support for burial by cremation (approx. 98 % in Prague), in villages and regions with a higher level of religiosity, cremation is significantly less represented. The connection can also be seen in the degree of secularization, thus also the degree of keeping of traditions, which, for example, in South Moravia are strongly rooted, and therefore the traditional grave burial is preferred here.

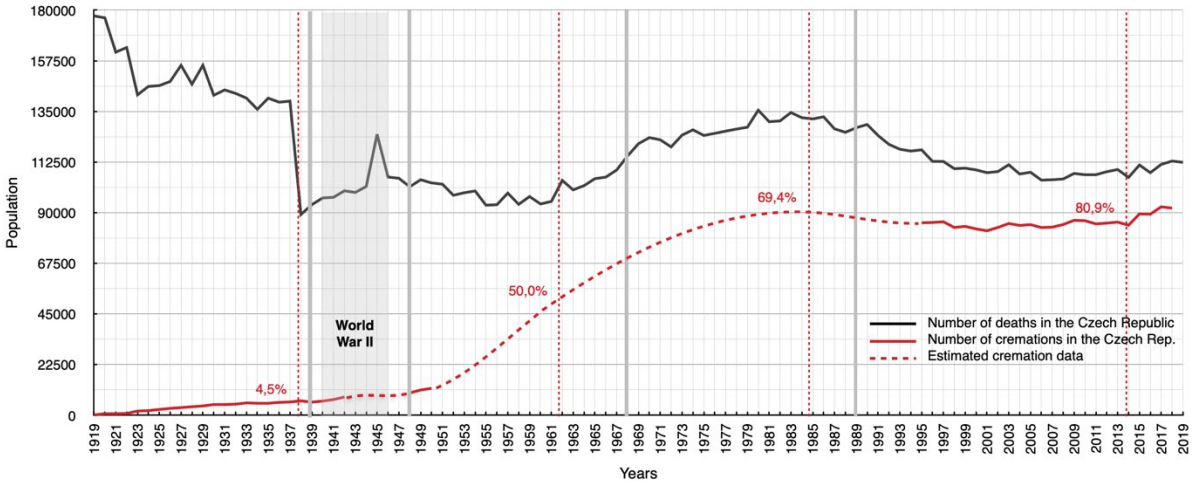


Fig. 1: Overview by year of the number of deceased vs. the number of cremations performed from 1919–2019 (Author: Ondřej Juračka; data from CZSO/Czech Statistical Office, publication of the Spolek přátel žehu/Association of friends of cremation [5, 6, 7, 8].

As regards legislation relating to cemetery sites, Act No. 193/2017 Coll., on Funeral Services deals with them only in Section 17 [3], where it sets out the authorities that issue an opinion from the point of view of public health protection, from the point of view of compliance with land-use planning documentation and from the point of view of the application of the objectives and tasks of spatial planning, and an opinion from the point of view of groundwater protection. It also mentions the need for hydrogeological surveys and comments on the establishment of graves, tombs and urn deposits [3]. In terms of the design of new cemetery sites, Act No. 183/2006 Coll., on Spatial Planning and Building Regulations [9], and the related Decree No. 501/2006 Coll., on general requirements for land use [10], are crucial. Act No. 183/2006 Coll. mentions burial grounds only in connection with § 80 [9], where in para. 2 it states, “Decisions to change the zoning are required by” letter (d) “public and non-public burial grounds.”[1]

A place must be chosen for the burial ground that meets hygienic, reverent and aesthetic requirements and which must be connected to the public transport network. Light, airy and permeable soil (hydrogeological survey) is required, and the distance of drinking water (determined by the hygienist) should not be less than 150 m. The terrain is recommended to be slightly elevated with a good possibility of run-off of surface and groundwater (not towards residential buildings) and outside an inundation area.

A general estimate of the size of the functional area of the burial ground, can be based on an average requirement of 3-5 m^2/person, regardless of the method of burial, including greenery, paths and other areas.

Other related laws for public cemeteries[2] are Act No. 372/2011 Coll., on Health Services and conditions of their provision [11] with effect from 01.04.2012, where §91 specifies in more detail “anatomical-pathological waste”. Act No. 240/2000 Coll., on Crisis Management and on the Amendment of Certain Acts [12] – effective from 01.01.2001, and where in §14 para. 3 it states: "Governor in times of crisis" in letter b. a) “coordinates rescue and liquidation work (§28 para. (3) the provision of health services, the implementation of measures to protect public health and the provision of emergency funeral services.” Furthermore, Act No. 122/2004 Coll., on War Graves and Reverential Places, and Act No. 256/2001 Coll., on Funeral Services [13, 14]. Related standards and decrees can be Act No. 20/1987 Coll., Act of the Czech National Council on State Monument Care, the CSN 73 6110 – Design of Local Roads standard and the Standard CSN 49 3160 – Coffins [15, 16, 17] and, of course, Decree no. 398/2009 Coll. On general technical requirements ensuring barrier-free use of buildings [18].

4. Methods of burial for the understanding of the needs of today’s cemeteries

The preferred methods of burial in a given locality – or their combination, has a significant effect on determining the size of the complex. The most basic classification of the method of burial is the division into decay and burial by cremation. The distinguishing factor is the decay time, which is closely related to finding suitable hydrogeological conditions. The resulting decay period can be 10 to 30 years, resulting in a burial cycle that limits site reuse during that time. In contrast to cremation burial, the time factor and the risk of groundwater contamination are completely eliminated. The end result is a set of advantages and disadvantages of cremation, which are described in the following table “Advantages and disadvantages of cremation”.

[1] From this law it can be surmised that in the case of a burial ground, we are not dealing witha building structure.

[2] Tomáš Kotrlý – Diagram of public burial ground (published prior to the amendment of the Act on Funeral Services) [19].

Tab. 1: Advantages and Disadvantages of Cremation (Author: Ondřej Juračka)

ADVANTAGES	DISADVANTAGES
+ hygiene (soil contamination)	– future archeological excavations
+ no location restrictions	– Christian tradition
+ space demands	– necessity for cremation equipment
+ technical demands of burial	

4.1. Burial by Cremation

The cremation burial itself contains a number of forms that, as a result of the development of society, have found their application in funeral practice. "After the transformation of the human body in a cremation facility, the persons bodily remains are placed in a so-called official urn with a height of about 20 cm and a diameter of about 15.5 cm (note: this is not further specified by any technical standard or law). Subsequently, these human remains are deposited in their final form with an emphasis on preserving the piety. According to the testimony of funeral and crematorium workers, close survivors do not pick up the urns of the deceased or these urns are kept in the home environment" [20]. After placing the human remains in the so-called official urn, there is a choice of final storage of the cremated material. However, in some forms, storage cannot, by its nature, be the final burial site. An example is not only the temporary or permanent storage of the urn in the home environment, but due to the chemical composition[3], it can also be the transformation of ashes into various souvenirs. However, this phenomenon is not in line with the position of the Roman Catholic Church, where "Besides avoiding any form of pantheistic, naturalistic or nihilistic misunderstanding, the dispersal of ashes in air, water, land or the conversion of ashes into souvenirs is not permitted" [21].

In the case of cremated human remains, we also distinguish whether they are public, anonymous or only partially anonymous. Due to the fact that we are dealing with a cremated remnant, where, for example, later identification is completely ruled out during scattering, there is a definitive loss of a specific burial location.[4]

Tab. 2: Methods of burial by cremation (Author: Ondřej Juračka)

Description	Dimensions [m]	Deposit sites per unit	Number of units	Area [m2]	Anonymity	Possibility of relocation
	Width	length				
Urn deposit site with epitaph plaque	1.0	1.0	1–5	1.0	NO	YES
Urn deposit site with small monument	1.0	1.3	1-3	1.3	NO	YES
columbarium (1x column)	0.6	0.6	1-5	0.4	NO	YES
Scattering meadow	-	-	-	-	YES	NO
Scattering meadow	-	-	-	-	Partial (cemetery register)	NO

4.2. Coffin burial

This is formerly a traditional method of burial, predominant in some localities, while almost unused in others. A benefit is the possibility of later archaeological research as it allows preservation of skeletal remains. On the contrary, the disadvantage is its demand for area as the area capacity of a cemetery is limited, as well the above-mentioned decay time. It is also necessary to consider the groundwater level, which is specified by law. Due to hydrogeological conditions, there are also limited placement options[5].

Tab. 3: Advantages and disadvantages of burials in coffins (Author: Ondřej Juračka)

ADVANTAGES	DISADVANTAGES
+ Christian tradition	– Correct hydrogeological conditions are required
+ future archeological excavations	– Space demands
+ Possibility of future exhumation	– Decay period (10-30 let)
+ Does not require cremation proceedings	– Technically demanding

Ground interment of the coffin is most basic and widespread burial method in the Czech Republic.

[3] Due to the transformation of human remains, we are dealing with carbon-based material; this interpretation may be inaccurate

[4] This is a phenomenon of the times in burials, when the places of one's "own" ancestors are not important.

[5] An example are the cemeteries in Ostrava in the Mariánské Hory/Marian Mountains, where due to unsuitable subsoil (clay soils) a ban was issued on burials involving decomposition.

Elsewhere, however, we can also see coffins in above-ground buildings (such as the cemetery in Bologna, Italy). However, there are alternative solutions, existing as a specific group, such as cryomation, where the remains are frozen at a very low temperature. In the cryomation cylinder, the human body is then shattered into dust, which is placed in the ground [22]. Current legislation [3], however, makes this method of burial in the Czech Republic impossible. Another way is cryonics (hibernation), where, unlike cryomation, the underlying assumption is the future revival of the human body, which was frozen during its lifetime [23]. A completely different approach is

the virtual area, where current technology allows for a virtual cemetery or holograms. These other ways may be closely related to the degree of secularization and the development of funerary architecture, where the sanctity of the cemetery area is no longer so important for modern man.

Another way of burying is the so-called cenotaph, which in literal translation can mean “empty”. This is a symbolic grave site that refers to a distant burial site. Usually, this is in the form of a real grave in a cemetery complex without the storage of human remains. An analogy are military graves in the form of a symbolic memorial, which is not related to the actual place of burial as a result of, for example, burial in the sea or another event of war conflict. These graves are also part of the cemetery grounds.

5. Other aspects and Particulars of Burial Grounds

5.1. Lighting

An integral part of cemeteries is the way they are lit. This is especially important during the “Remembrance of the Departed” (popularly known as "All Souls Day") holiday, when cemeteries take on a mysterious appearance, and even Genius Loci, when many “little lights” are lit up over an endless area. It is therefore necessary to be mindful of designing the lighting of cemeteries in such a way that this image is not lost and which stills ensures maintenance of safety. The solution may be to illuminate at the pavement line, almost at ground level, so that the access road is well lit and the surrounding landscape remains unaffected. Conversely, for the main pathways, traditional streetlights that guide towards the egress, away from the cemetery grounds, are most appropriate. Daylight or artificial light can be an important architectural element in the overall composition of a design where cemetery buildings such as crematoria, ceremonial halls, columbarium buildings, etc., are part of the design. These provide an opportunity to create a so-called “play with light”, which can further refer to other symbolism used.

5.2. Roads and Paths

Being, in its essence, a public space, a cemetery must comply with numerous standards and decrees. When it comes to the design of roads and paths, this mainly concerns the following CSN Standard 73 6110 Design of local roads [16] and Decree 398/2009 the Decree on general Technical Requirements ensuring barrier-free use of buildings [24]. According to §4(1), the above-mentioned decree states that: “Sidewalks, public transport platforms, level and off-level crossings, sidewalks in orchards and parks and other walking areas must allow independent, safe, easy and smooth movement of people with reduced mobility or orientation and their passing of other pedestrians” [24]. This means, for example, that the minimum width of the road surfaces must be at least 1.5 m, including maximum height differences (20 mm) and slopes (longitudinal 8.33% – transverse 2.00%). Further, at least on the main routes through the cemetery, to allow for access by cemetery administration or funeral service vehicles. In relation to this is the connection of the cemetery grounds to the transport network, including the resulting number of parking spaces for visitors to the cemetery grounds. No less important is the forecourt of the cemetery complex. This may include services such as florists, restaurants, cafés, etc. It includes not only roadways, but above all parking spaces (see [16]). In the case of a proposed cemetery area of approx. 25,000 m^2 (catchment area of 17,000 inhabitants), this is approximately 26 parking spaces (100% of which are short-term). It should be taken into account that the area can be more than doubled while maintaining the same catchment area and thus the number of parking spaces increases proportionally.

To the resulting parking area, it is also necessary to add reserved parking spaces for vehicles transporting severely disabled persons, pursuant to Decree 398/2009 Coll. §4(2) [24]. In the case of the above-calculated 26 parking spaces for the cemetery area, 2 reserved parking spaces will be added. Besides motor vehicles, it is necessary to consider the parking of bicycles, etc. This applies not only to the cemetery complex in a village landscape, but also in the urban environment. This includes, first of all, suitable shelters for bicycles that will fit into the concept of the cemetery design. Other factors for determining the number of spaces depend on the connection with the existing bicycle route network, etc., where the probable number of cyclists can be calculated. The choice of the material used for pedestrian roads also plays a big role, which again should contain elements resulting from the above decree, solutions for the visually impaired, at least in demarcation of a route crossing the complex, or the main road areas. This can be achieved by choosing different materials that will delimit the main routes of the area from the secondary ones. For example, the transition from the large-format paving of the main road to the local roadway with a fine gravel surface will be noticeable. However, this again depends on the specific architectural composition of the design. At present, it is possible to find earlier recommendatory texts for the correct design of cemetery

areas, but it is necessary to consider the relevant period and standards.

Tab. 4: Recommended fundamental indicators of the anticipated number of stopping and parking spaces pursuant to CSN 73 6110 [16].

Types of buildings	Special purpose unit	Number of dedicated units per parking space	Of the total number of parking spaces	
			Short-term %	Long-term %
Funeral ceremony hall, crematorium	seats	5	100	0
Restaurant	area for guests m^2	6	70	30
Cemetery	area m^2	1000	100	0
Park	area m^2	10000	-	-

5.3. Furnishings

Furniture is an integral part of the cemetery complex. “There should be benches for the survivors, especially the elderly, to rest in the urn grove area. The most suitable location is usually at the staging areas in front of the scattering meadow and along the park paths, which are lined with epitaph plaques. Because benches are not designed for extended resting, the main consideration in their design is the aesthetic effect of this element in the urn grove, not comfort.” s. 7 [25]. However, it is necessary to consider the visual axes, especially in complex morphologically rugged terrain, where a view of the wider landscape can be beneficial. It is advisable to place benches in these areas, especially facing the direction of the view. Another necessary furnishing element may be various directional indicators. But the best solution is to design a cemetery layout that is sufficiently intuitive so as to not require additional markings. On the contrary, already applied QR codes on graves and tombs can be an interesting addition. These may be modifications of Jewish tombstones, which usually contained a similar biography of the deceased. Although the designer's goal is to design the cemetery complex in such a way that it is as intuitive as possible, the design cannot do without various direction indicators. However, this presupposes a sensitive and inventive approach on the part of the graphic designer, who will be designing and placing the directional signs. Another common piece of furniture is most often a waste receptacle, whether it is traditional, sorted, or communal. In many cases, it is a large container for waste flowers, etc. Associated with this is a source of water for the routine maintenance of the grave site.

5.4. Vegetation

Vegetation is an important building element of cemeteries. “This may partly be due to the “burial in nature” trend, the final manifestation of which is the park or garden-like appearance of the cemetery. But vegetation plays an important role even in traditional composition designs. It is also due to the construction of scattering and backfill meadows, where it is necessary to plant permanently maintained lawn or potentially ensure the optical separation of these areas by suitable vegetation (e.g., shrubs). Greenery, especially the planting of trees along the main pathway axes, is the best indicator of direction. The resulting layout can be the transformation of the cemetery space into a friendly garden area, even with all the possible nearby elements. “To increase the effectiveness of the urn grove, it is appropriate to include a water surface in its composition as a calming and soothing factor. It is possible to create a natural pond or pool, especially in large urn groves. In combination with suitable greenery on its bank, or a grouping of stones or a suitable sculpture, such a water surface can be a significant element of the urn grove” p. 8 [25]. Care must be taken, however, in choosing the appropriate type of tree or shrub and its location so as to avoid future damage to grave sites or paths by tree roots or excessive leaf falls, etc. Since the owner of the grave facility is the tenant, while the landlord (the cemetery manager, i.e. the municipality) is responsible for the greenery, inappropriate conflicts can and do occur when the grave site is disturbed by roots of mature trees

5.5. Symbolism and Funerary Sculpture

The added value of the cemetery complex is its so-called "funeral sculpture", which can reflect on contemporary society and its culture or the artist’s intent. “To emphasize the importance of the urn grove and for its visible demarcation in the surroundings, the significance of the most important part of the burial ground—the scattering meadow—is usually designed to complete the space aesthetically. A symbol can be a suitable sculpture – even a modern, simple stone pylon or Greek fire.” p. 7 [25]. It is significant that after the change of political regime in 1948 in Czechoslovakia, everything related to any church institution (e.g., registries, wedding or funeral ceremonies) was replaced. “The long-standing conservatism resulting from the entrenched tradition of church ceremonies has not yet been overcome and it is difficult to promote simple civilian forms of burial. Therefore, it is necessary to support the interest in the current expansion of funerals by cremation and the construction of urn groves even more emphatically. To this end, the Government of the Republic adopted Resolution No. 1093 on 14 December 1960, on the prospect of the construction of cremation facilities in the Czechoslovak Socialist Republic.” p. 4 [25]. It is a paradox that, after 1989, the symbolism of Christian Hope subsequently began appearing in the original compositions of the ceremonial halls, which were supposed to help replace the church tradition. These are most often symbols of the cross, which, depending on the artistic design, are less in tune with the original design composition.

6. The "HOK" Software Diagram

The aim of the software diagram (Fig. 3) is the creation of an intuitive environment for users. Selected research findings were processed in MS Excel software (hereinafter "HOK[Chyba! Záložka není definována.]"). so that it is possible to practically determine at least the approximate area of the designed cemetery complex and then the construction program of the ceremonial hall or crematorium. For greater clarity, the program was divided into several basic sheets ("Input Sheet", "Cemetery Design",), which were then interconnected. The principle of user simplification works in such a way that the whole system initially offers only a few necessary items (catchment area, number of services in the cemetery area, type of cemetery, "demand class" of the crematorium with the ceremonial hall, etc.). The user is systematically navigated through the user settings using hyperlinks. Only after obtaining further details is it possible to intervene in individual items (size of the cemetery area, distance of individual grave sites, etc.). The key to the final setting is again the input sheet entitled "Cemetery area", where all the key results were incorporated.

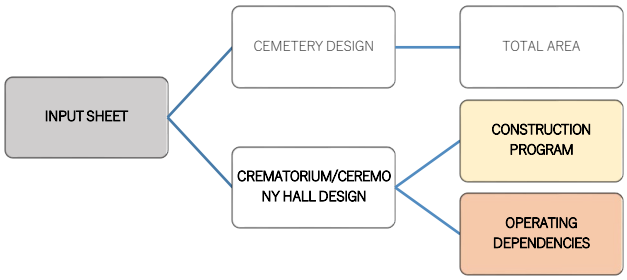


Fig. 2: Software diagram (Author: Ondřej Juračka)

6.1. Designing Cemetery Complexes

An important prerequisite for the proper design of a cemetery space is to determine what type of cemetery it is. Whether the area is regularly or irregularly structured; what is the preferred method of burial (percentage of burial by cremation vs. traditional ground interment); what is the terrain profile or, depending on the preferred method of burial, what will be the expected number of individual types of grave sites. These characteristics are then also modified by the delimiting of a catchment area with a specified population. These basic determining inputs affect the total area of the cemetery space, whether we are dealing with an existing or a new state. Another influence is the invention of the designer/architect himself, in terms of how he or she will eventually compose the cemetery space.

6.1.1. Calculating the Cemetery Area

"The process of drafting a zoning plan on the basis of an approved assignment is usually based on the average typological indication of three to five square meters per inhabitant, including roads, greenery and other areas. According to Václav Vejroch, the burial area (Pp) depends on the prospective population (O) on the mortality process per year (Ú = 1-1.5%), and on the type and average size of the grave (H = 3–3.6 m^2)" p. 77 [26]. See equation no. 1.

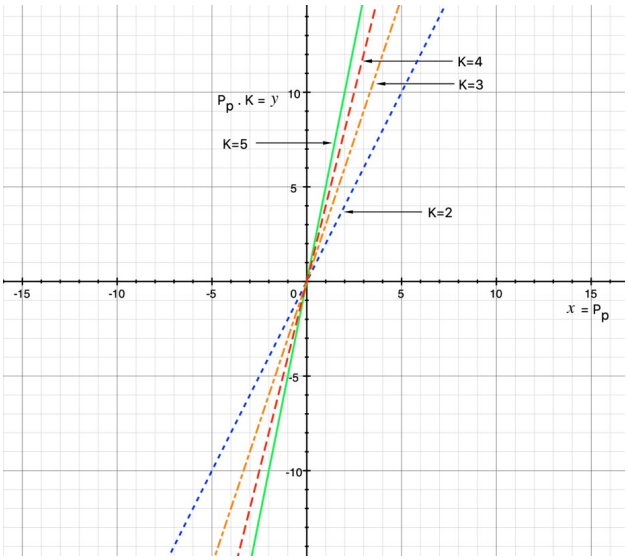


Fig. 4: Graphic depiction of the dependency on the K coefficient (Author: Ondřej Juračka, using the Grapher program, source: [26])

$$P_p = 0 \cdot \frac{\mathrm{U}}{100} \cdot C \cdot H \qquad (1)\ [26]$$

However, the resulting calculation of the cemetery area does not include green areas and roads. In the case of an irregular cemetery design, there may be an increase of up to four or five times the originally calculated area. Therefore, the following formula is presents itself:

$$P_c = P_p \cdot K \qquad (2)\ [26]$$

"The total area of the burial ground P_c, including greenery, roads and other facilities, is calculated according

to the formula by multiplying the burial area P_p by the coefficient K (2–5), … In the case of a regular burial ground, the burial plan represents 20-30% of burial area, of the park or forested type, and we count 50–70% of the area, (i.e. K = 2–3) for greenery, roads and paths. The burial plan of an irregular burial ground represents 20-30% of the burial area of the park or forest type, we count 70-80% of the area for greenery and roads, (i.e., K = 3–5)" p. 77 [26]. To obtain the total area of the burial ground P_c by multiplying it by the coefficient K, a wide variance of the final result applies. This difference is exacerbated by the fact that the coefficient K is entered in the range of 2–5 and its input can be more a matter of feeling. The solution may be a more detailed calculation of the minimum area, such as roads, etc. In principle, it is true that each grave site has associated with it a part of the road or path area. Together with the grave site, these will form the basic unit of calculations. The next stage will be individual segments composed of a specific number of these basic units, to which another communication area will be calculated, usually in the perimeter of this area. This will then be added to each such segment. Only finally will the basic area of the cemetery area be determined, from which the basic axes will be derived and added, including the areas of the crematorium or other services. However, this calculation procedure applies to the regular layout of a cemetery space. The terrain profile also contributes to the calculation of the area, when even in the case of a regular arrangement, it is necessary to count on a further increase of the area. The amount of greenery and thus the total area of the cemetery can also be affected by new methods of burial, so-called "interment in nature", where a tree is planted in place of the tombstone. The whole area later takes on the character of a park.

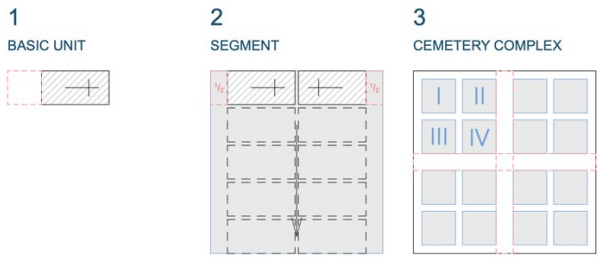


Fig. 5: Solution for calculation of the minimum paved area of a regularly arranged cemetery, depending on the number and type of grave sites (Author: Ondřej Juračka)

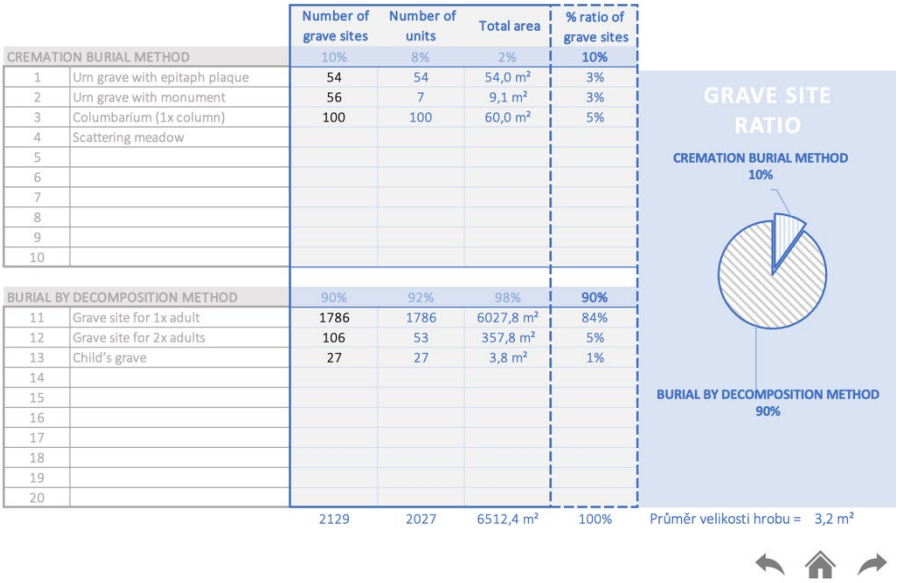
6.1.2. HOK for calculation of the Cemetery Area

Program layout

This section loosely builds on the chapter entitled "HOK Software Diagram", which describes the input parameters for the calculation of the cemetery area and a construction program, and potentially the operating continuities for the design of a funeral ceremony hall and crematorium. After completing the "Distribution list" sheet, the MS Excel file is moved (hypertext arrows) into the continuing sheets, which exclusively deal with the parametric settings of the cemetery area:

- Type of grave site (worksheet "Grave site type")
- Percentage representation of grave site type (sheet "%ratio")
- Cemetery area calculation (sheet "Cemetery area")
- Calculation of the minimum area for pedestrian roads (sheet "Road area")

In the settings section for grave site type, a user-prepared drop-down list is pre-prepared for each item, which can be added using a hyperlink. In the basic table, the individual parts are separated according to the method of burial. The resulting division is "cremation burial" and "cremation burial", where each part natively contains 10 lines. Subsequently, the basic dimensions (width, length of the grave) are further edited for each type of grave site. As the unit (grave site) may also contain a different number of interment of human remains, it is also necessary to indicate the maximum number of interments for each item (see "grave sites per unit"). Each item is subsequently confirmed by the user – see the "YES" or "NO" column. Scattering meadows are a unique feature, where due to the specifics of the method of burial it is not possible to determine the maximum number of grave sites. The size is usually 1/10 to 1/8 of the total area of the urn grove.



		Number of grave sites	Number of units	Total area	% ratio of grave sites
CREMATION BURIAL METHOD		10%	8%	2%	10%
1	Urn grave with epitaph plaque	54	54	54,0 m²	3%
2	Urn grave with monument	56	7	9,1 m²	3%
3	Columbarium (1x column)	100	100	60,0 m²	5%
4	Scattering meadow				
5					
6					
7					
8					
9					
10					
BURIAL BY DECOMPOSITION METHOD		90%	92%	98%	90%
11	Grave site for 1x adult	1786	1786	6027,8 m²	84%
12	Grave site for 2x adults	106	53	357,8 m²	5%
13	Child's grave	27	27	3,8 m²	1%
14					
15					
16					
17					
18					
19					
20					
		2129	2027	6512,4 m²	100%

Fig. 7: Sheet "%ratio" (Author: Ondřej Juračka, HOK – MS Excel)

The contents of the associated sheet "%ration" are the monitoring of two goals, which are necessary for further solution. These are percentage representation of individual types of grave sites and the total ratio of grave sites according to the method of burial.

6.1.3. Average Grave Size

These items are recalculated based on the data entered in the side control panel, where the number of units is entered by the user. From this, in parallel, the percentage of each grave site can be derived. These percentages can be recalculated from the maximum burial area ("Cemetery area" sheet), where in the case of confirmation in the control panel, the total area on the "% ratio" sheet is recalculated. Otherwise, the formula for calculating the burial area can be bypassed and the total burial area can be obtained based on the entered values from the control panel. To monitor the percentage according to the method of burial, the sheet is supplemented by a pie chart, where these two methods are shown graphically. The usual proportion of cremation burials is about 80%, but it is necessary to take into account the religiosity of the place, where there may be conflicting information figuring in the observed ratio – see further details in the chapter 3.2 "Burial Methods". Last but not least, the monitored element is the average size of the grave, which is recalculated from the specified percentage. This is indispensable data for the subsequent calculation of the burial area.

The key worksheet of the compiled program is the "Cemetery Area" sheet. Here you'll find the calculation formula for burial area and other monitored goals:

- Burial area
- Overall area of burial ground
- Coefficient K

The burial area draws on previous sheets of items such as "population of the settlement" (sheet "Catchment area" - see chapter Entry sheet") and "type and average size of the grave" (sheet % ratio, usually 1.5 to 3.6 m^2). Subsequently, it is necessary to add the "percentage of mortality per year (usually 1 to 1.5%) and the length of the burial cycle", which is determined by the hydrologist (approximately 10 to 20 years). The "burial area" is recalculated from this data – see item P_p z equation no. 1 [26]. Subsequently, the burial ground P_c (Equation no. 2) works with the coefficient K. The reverse method of calculation is used in the developed program, where the coefficient K is not used for calculation, but is calculated in order to obtain information about the type of burial plan of the burial ground. The user enters the percentage of the other area $P_{c'}$ to the burial area P_p, assuming that the "Total burial area" represents 100% – see graphic pie chart (ratio of P_p and $P_{c'}$). The resulting value of the other area $P_{c'}$ is the sum of P_p and P_c; to obtain the total area of the burial ground Pc - see equation:

$$P_c = P_p \cdot K = P_p + P_{c'} \qquad (3)$$

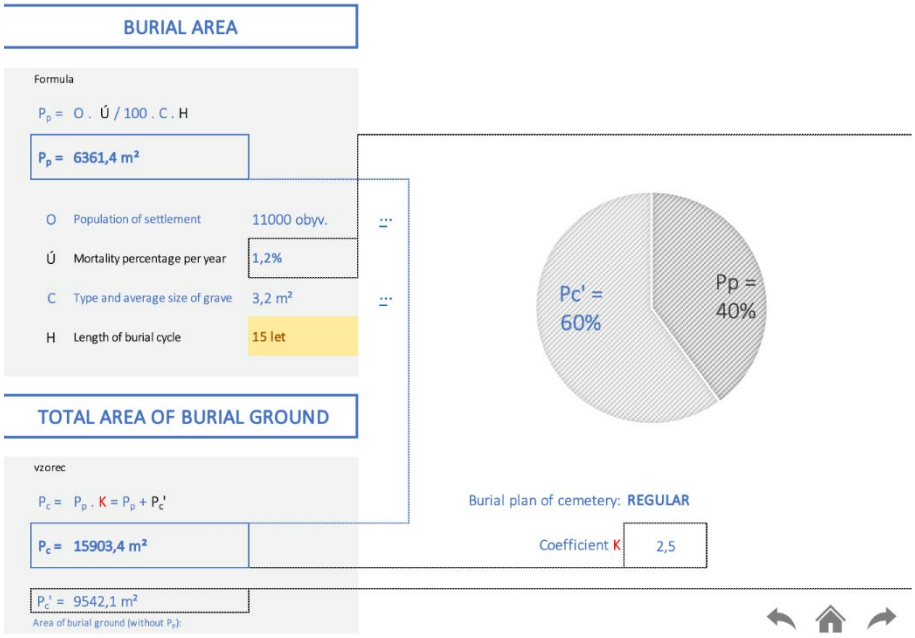


Fig. 8: Sheet "Cemetery Area" (Author: Ondřej Juračka, HOK – MS Excel)

Additional parameters needed to be compiled in connection with the issue of the accuracy of the coefficient "K", which represents the remaining parts of the cemetery (road and path areas and green areas). Therefore, for the purpose of a better calculation, I inserted a follow-up sheet entitled "Road area". This is the principle described in Chapter 0 "Calculation of the cemetery area", where it is assumed that each cemetery unit must have a part of the road area. Then, by adding up all cemetery units, it is possible to know the area of all access roads to individual grave sites. A by-product is also the area of greenery, which arises during the calculation in connection with setting the spacing between grave sites. The goal is the following goals:

- Total minimum area of access roads - see P_{KOM}
- Total minimum green area - see P_G

These results include only the minimum, i.e., necessary, area that can arise, assuming the ideal layout of the cemetery area:

- Geometric shape (cemetery area in the shape of a rectangle, square)
- Terrain plane (clear plane)

It is also appropriate to multiply these results by a possible factor of 1.5 in order to make a reserve. For the user interface, it is necessary to enter the proposed width of roads – see b_{kom} and the distance between individual grave sites - see b_{DIST}. From these quantities, together with the data of the previous sheets, the area of access roads $P_{KOM\,n}$ and the area of green P_{Gn} for each cemetery unit are calculated separately. Subsequently, the total monitored areas are calculated, for which the following relationship applies:

$$P_{kom} = \sum(P_{kom\,1} + P_{kom\,2} + \cdots P_{kom\,n}) \quad (4)$$

$$P_G = \sum(P_{G\,1} + P_{G\,2} + \cdots P_{G\,n}) \quad (5)$$

In practice, this can be an area that can be separated from the total cemetery area. Therefore, in order to further refine the cemetery area, the solution is to calculate other sub-segments, such as the area of the crematorium and the ceremonial hall - see the following chapters. Although these are almost a percentage item, the assumption will be an increasingly accurate picture of the future cemetery area. On the contrary, due to the absolute originality of each grave site (layout, morphology and other conditions), they achieve 100% accuracy.

7. Conclusion

The aim of the paper was to research the ways of designing cemetery complexes in the context of social changes in the 21st century in the Czech Republic. Within the framework of the given topic, research was earlier carried out on the development of cemeteries and funerary architecture in its transformations from the period since the so-called Josephine reforms in the Czech lands.

The last but not least result of the research is the practical use of the adopted equations [4], which were incorporated into the HOK in MS Excel. It was found that these equations may exhibit inaccuracies in the design of the burial area and the total burial area. The reason for this is the selected coefficient K (determines the irregularity and regularity of the cemetery structure), where there is a broad interpretation of the selected value (2–5) – see Chart no. 3. A more specific calculation of the minimum access areas at each grave unit has partly eliminated this inaccuracy described above. The HOK program was also practically used to retrospectively examine the design of the Bruntál cemetery complex [27], where the specification of each

type of grave space used in the design corresponded to the calculation of the burial area with the input data corresponding to the year 2005. The error rate of the burial area calculation was less than 1%, "Calculation of the cemetery area using HOK". Conversely, the calculation of the total burial area differed from the original proposal. On retrospective review, a correction was made to take into account, for the first time, the sloping terrain of the cemetery site design. The result was subsequently satisfactory. Several systematic adjustments were made to the calculation equations in the HOK design. For example, for the first time the coefficient K is not entered by the user in the MS Excel environment, but calculated retrospectively based on the setting of the percentage of the other cemetery area. The result of these modifications is greater convenience in the calculation.

A component question of the research was the assumption of burial method in the future and the subsequent readiness of cemeteries and related funeral facilities. Given the development of cremation burials and the current stable burial ratio of 80%/20% (in favor of cremation), a steady or increasing interest in cremation can be expected. The reasons lie mainly in the following parameters, such as the ecological parameter (soil contamination), economic parameter (space requirements, long-term care), demographic parameter (population aging) and social parameter (individualism vs. traditional family).

These parameters speak in favor of burial by cremation. The current amendment to the law does not allow other methods, such as cryomation, cryonics. These alternative methods of burial can only be speculated on (ethical, ecological, economic issues, etc.). Rather, the advent of new ways of storing human ashes can be expected (e.g., the forest of memories, etc.).

The practical contribution of the research for implementation in practice or for further development of the scientific field is the compiled HOK program in the MS Excel environment. It is a comprehensive form of all formulas, typology and other experiences used in the course of designing. The name HOK is an abbreviation of the first letters of the words "cemetery", "ceremonial hall" and "crematorium" in Czech, in which is possible to determine the necessary cemetery area, the construction program for the crematorium and the ceremonial hall, including the context. During the development of the program, this practical result was preceded by several other versions. This resulted in modifying the experience, making it more user-friendly. Previously extensive tables have been reduced to several basic queries that gradually open up for HOK users and do not overload them unnecessarily. In this program, equations were transformed into graphical output (e.g. pie charts, etc. instead of "unknown" coefficients). This program is also the culmination of the entire paper, which can be used in practice in design activities.

At the same time, this practical result observes the further possible development of a computer program, which already requires working with IT skills. Specifically, this could be a separate software application (outside the MS Excel environment), where it will be possible to parametrically compile a specific operating diagram. The results of our work enable further development. The recommended areas of possible follow-up research are the historic cemetery areas; improvement of calculation parameters of cemeteries or operations of crematoria and mourning halls in connection with the search for a new typology of funeral buildings.

All research, including component steps, is now being prepared for comprehensive publication in a professional publication, including a QR code, that will make the software itself available to potential interested members of the professional public.

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About Authors

Klára PALÁNOVÁ works as an assistant professor, leads architectural design studio and participates in theoretical lectures on typology and theory of architecture. Original research was dedicated to aspects of minimal housing; follow-up projects were focused on “living for eternity” - burial and funeral architecture and on the conversion of former mines and subsequent colony buildings. They are heading mainly for the sustainability of funeral and mining areas in the context of urban and suburban structure.

Ondřej JURAČKA currently works as an architect in the KJJ-Architects group. Previously, he studied at the Mining University - Technical University in Ostrava, where he finished his doctoral studies with the defence of his dissertation on the topic "Research of the design of cemetery grounds in the context of social changes in the 21st century in the Czech Republic". This was preceded in 2016 by his master's thesis "Crematorium with an Innovative View of Funeral Culture", at that time supervised by his current co-author Klára Palánová.