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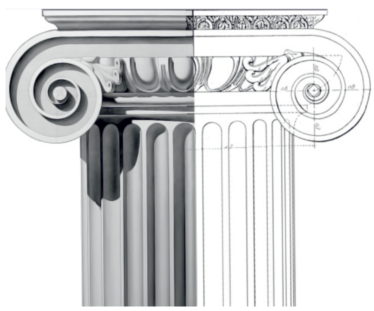

CONTENTS

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COLOR SCHEMES OF FACADE SYSTEMS IN NEW DORMITORY DISTRICTS OF SAINT PETERSBURG, RUSSIA

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Abstract

Fast and extensive transformation of cities is a quite widespread practice nowadays, but it has a disadvantage in affecting the quality of architectural spaces. The main task of architecture, i.e. space arrangement, shall address not only physical needs for comfort, but also visual ones. By means of facade color schemes, it is possible to make a positive impact on the human psychological condition and create a more favorable visual environment. A great number of developers also represents one of the main issues of such large-scale city transformation. At the design stage, the appearance of a new project is not always aligned with the appearance of the existing buildings.

Based on the experience of architects and theoreticians in coloristics and psychology of the spatial environment, modern districts of Saint Petersburg located both in the city and in its vicinity were selected for the analysis conducted in this paper. The study involves identifying the color schemes used as well as a possible impact of such choice on the community. Recommendations on improving the visual architectural space are given.

Keywords

Color environment, coloristics, psychology of the spatial environment.

Introduction

Nowadays, the rate of urbanization contributes to the intense modification of the city image, affecting the quality of the architectural space. Such city environment, in its turn, has a great impact on the psychological condition of its residents who have to witness every day too bright finish or, on the contrary, monotonous details or not details at all, too simple shapes or incommensurable height of erected buildings.

The architectural environment is a harmoniously created space. The primary task of architecture, i.e. space arrangement, shall address not only physical needs for comfort, but also psychological ones. The facade shall represent the value of a building, serve as a connective between inner and outer space, as well as coordination between old and modern design (Utaberta, 2012).

The organization of building facades in new residential areas is becoming one of the architect's ways to influence the image of the urban environment that people perceive on a daily basis. With the naked eye, it is noticeable that the constructive, volumetric and planning decisions of buildings in new residential areas are not just similar - each such building represents only a variation of one typology development - a multistory frame house, very often with a ventilated facade and a large glazing area of balconies and loggias.

Unfortunately, due to the peculiarities of the organization of the construction of buildings of this typology, the change in spatial planning decisions, a significant decrease in the number of storeys, as well as other methods for arranging a comfortable architectural environment do not find the necessary distribution - they are simply unprofitable, their application is connected with the monetary losses of construction organizations. Therefore, one of the real ways to use nowadays to organize a comfortable architectural environment is the

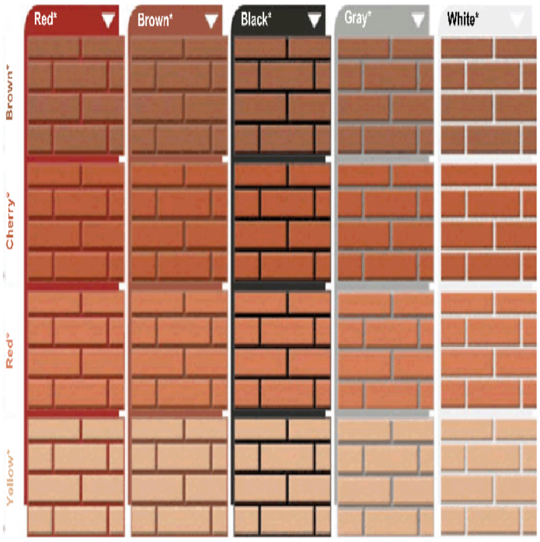

Figure 1. Brickwork color depending on mortar (http://arfaterm.com.ua/article.html?id=28)

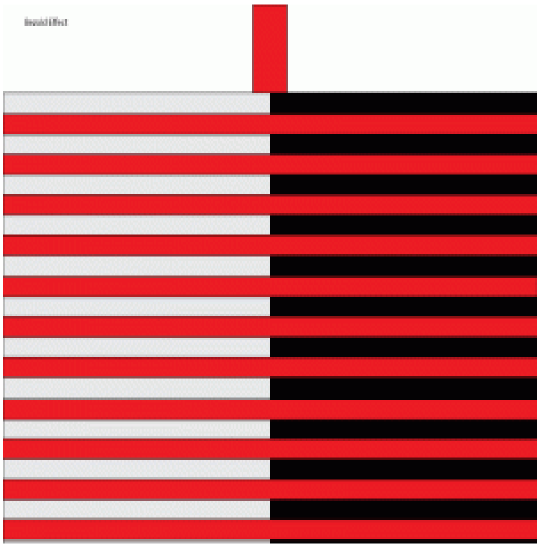

Figure 2. Bezold effect (https://openlab.citytech.cuny.edu/gchetram-eportfolio/2015/04/27/color-interactions/)

use of various color schemes for finishing the facades of buildings.

English architect Medd said that color is the only important factor that determines the character of a building (1949). Color can visually change dimensions: e.g. a black square looks smaller on white background than vice versa (Poling, 1975).

Such illusion can be observed when changing traditional colors of window frames in facades, the color of brickwork or panel mortar. It can be accompanied with the assimilation effect (Bezold effect).

Therefore, red bricks will seem lighter combined with white mortar, and darker combined with black mortar (Figures 1, 2).

Scientifically, color is an informative property of shape to reflect light rays of a certain wavelength, through which the eye perceives a variety of feelings (Efimov, 1990). Such feelings can change the general state and psychophysical well-being of a person. Color also performs a variety of other functions: it allows us to get out bearings, emphasizes certain elements, and shapes the urban landscape (Chechelnitsky, 2012).

According to the studies performed by Filin (1990), there are two types of the environment uncomfortable for the human eye: aggressive environment and homogeneous environment. An aggressive field is a field where a great number of similar elements are scattered, e.g. windows in the facade of a multi-story building. With a great number of similar objects in sight, it is difficult for a person to establish what objects he/she was focused on before and what after.

The eye starts to change focus very fast, and the time of its rest decreases. The optimum number of similar elements in sight in the urban environment is 5. 13 elements and more result in monotony (Filin, 1990).

In a homogeneous field, there are no visible elements or their number is minimal. In such case, an insufficient amount of information on the object observed is transmitted to the brain, which affects the nervous system and results in a sense of discomfort.

The idea to use color also became common outside Russia in the 1960s during the development of divided Berlin. In parallel with the criticism from pre-war architects who disregarded the use of color to improve mood and reduce monotony formed by large-scale prefabricated housing construction, it was stated that it was possible to "influence people's perceptions and feelings" through color (Pugh, 2014).

Color elicits a response in person, affecting the hormone system, and has either positive or negative effect. There are many typologies classifying colors based on their impact on people, but the generalized classification is based on wavelengths of the visible part of the spectrum.

1. Long wavelength part — 760...580 nm. Red, and orange colors belong to this category. They stimulate the brain, energize, and attract attention fast. Red color can symbolize both positive and negative emotions and attitudes, e.g. aggression or warning (see https://www.thoughtco.com/color-psychology-and-human-behavior-4151666). Besides, a red object always appears closer that it is (see https://medium.com/studiotmd/the-perception-of-color-in-architecture-cf360676776c). Orange color is not so strong in terms of the impact as red color; it has a less negative characteristic. However, it can stand out against the background and emphasize low-quality joints of elements, thereby reducing the visual value of a facade.

2. Medium wavelength part — 580...510 nm. Yellow contributes to high spirits and sociability, while green, the color, acts soothingly and is considered optimal from the position of favorable influence and when used as a background, creates the effect of increasing the space. Yellow, as a color closest to the sun color, has "a light nature and clarity", but makes "an unpleasant impression" being combined with a cold color or stain (Mesyats, 2012).

Green color is natural and soothing, it represents a balance between yellow and blue. It can be used

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in combination with dark blue, thereby smoothing out its coldness (see https://www.thoughtco.com/color-psychology-and-human-behavior-4151666; Mesyats, 2012).

3. Short wavelength part — 510...380 nm. Blue, purple and light blue belong to this category (Efimov, 1990, Mesyats, 2012). Blue color and its combinations with red in various proportions are sometimes associated with coldness and indifference (see https://www.thoughtco.com/color-psychology-and-human-behavior-4151666, Mesyats, 2012).

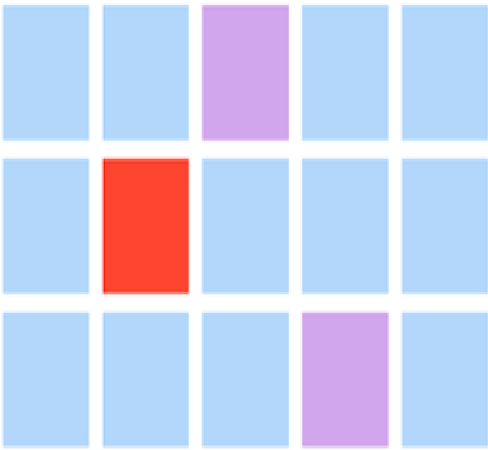


Figure 3. 60-30-10 color rule (http://www.eyequant.com/blog/2013/06/27/capturing-user-attention-with-color)

However, light-blue and blue also carry peace and in general are one of the most common colors. Purple is a combination of red and blue; light purple symbolizes power and spirituality (Efimov, 1990; see https://www.thoughtco.com/color-psychology-and-human-behavior-4151666). Such colors as brown and gray, black and white are classified separately. Brown represents order and stability, which is why it can be used to set accents, but in combination with gray it has an opposite effect (Poling, 1975; Chechelnitsky, 2012).

Cold gray does not irritate but brings instability and boredom. White color is light and noble. It also helps to set accents and is associated with cleanliness and clarity. Black color helps to concentrate and provides contrast but also brings frustration and dampens the mood (Frieling, 1973; Chechelnitsky, 2012; Rahmatabadi, 2011).

Thus, combining those individual colors with cold and warm hues, it is possible to create color balance having a positive impact on a person. Contrast and the environment shall also be taken into account. The use of cultural elements or patterns with details provides perception of hidden order of buildings, which favorably affects the need to feel safe (Azma, 2017; Feizi, 2013).

There are six types of contrast: dark-light, cold-warm, complementary, simultaneous, qualitative and quantitative. For example, it is possible to obtain two different hues of one color changing the background using simultaneous contrast.

And to compensate for a small volume of light yellow enlarging the space, a bigger area painted with lilac will be necessary (quantitative contrast) (Poling, 1975; Itten, 2013). Yoshizava took the property of simultaneous contrast as the basis for an analysis of "color pollution" in residential complexes of Japan (2007).

According to the results of his experimental research, a light building will better match with the environment of dark hues of the same color, but the existing background has pale hues, then it is necessary to choose a paler hue for a new building. According to the 60-30-10 color rule (Figure 3), balance is created using three colors where dominant color should be used 60% of the time, secondary color — 30% of the time, and accent color — 10% of the time. Typically, dominant color should be less saturated as compared to accent color (see http://www.eyequant.com/blog/2013/06/27/capturing-user-attention-with-color). There is a belief that, due to lack of sufficient light, north areas require self-luminous fluorescent coatings complementing city lighting (Efimov, 1990). On the other hand, where sunlight is scarcer, the colors wanted are softer, duller, and a greater preference for blue is noted. No shiny and strong colors are needed (Birren, 1945). Too bright or neon colors are associated with advertising or signs used to attract short-term attention of pedestrians, and they often do not cause any positive emotions. Initially, such approach became common in the 20th century in an American model of spatial organization in the city, but it was related to the focus on the fast-growing car industry and increase in the speed of moving from 5 km/h to 60 km/h (Banham, 1969; Gehl, 2006).

It is not recommended to apply color to vertical elements in vertical lines. Only transversal lines should be used. Individual elements should not be painted in individual colors: it is better to use similar balanced combinations for individual elements. If the shape of an object is complex, the color scheme should be simplified, and vice versa (Asgarzadeh, 2012; Ruskin, 2017).

Based on the experience of architects and theorists in the environment of color design of the architectural space, it is possible to distinguish a number of colors that positively influence the human psyche:

1. Red most effectively attracts attention and causes interest as a prerequisite for activity due to architectural organization (Zabelshansky, 1985). In this case, a large concentration of red color can displace all other colors, causing visual discomfort. It is recommended to use muted tones of red colors in order to take into account the small amount of sunlight in the city.

2. A saturated yellow color without cold shades. However, taking into account possible pollution due to frequent unfavorable weather conditions, it can produce an effect opposite to the "light nature" of the color. It is possible to use in small quantities as an accent color.

3. Blue and green colors and their light shades are well suited for northern regions. Also, the blue color, being a

color calm, can be used to visually increase the space when used as a background.

4. Brown or black can be used in small amounts for accents, it is not recommended to alternate with gray. White can be used as the main color in a quality performance, it will give lightness and expressiveness.

Subject, tasks and methods of the study

The objective of this study is to examine options in arranging the color environment of building facades positively or negatively affecting the human psychological condition, as exemplified by new housing construction in Saint Petersburg and the Leningrad Region.

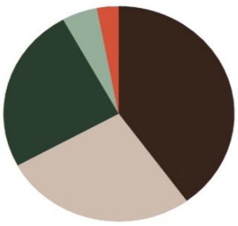
- **The subject of the study** is color schemes of facade systems of new housing construction.
- **Tasks of the study**:

1. To develop a method of choosing the color scheme positively affecting the human psychological condition, based on the national and international experience.
2. To identify advantages and disadvantages of the existing residential development in Saint Petersburg, make recommendations.

Methods

The method of investigation is the analysis of the color schemes of the facades of existing buildings by drawing

Table 1. Impact of the color scheme of facades in new housing construction in Saint Petersburg

№	Image. Color ratio diagrams	Dominant colors	Possible psychological effect. Color scheme analysis
1	 Figure 4. GreenLandiya residential complex (https://varlamov.me/2017/zap_murino/23.jpg)  Figure 5. GreenLandiya residential complex. Color ratio diagram	Dark brown basis with contrasting light color of window casings, changing in the middle of the facade. Color of balconies: several hues of green, sometimes with contrasting red inserts.	Combinations of brown and green are considered to be natural; such combinations shall include either warm or cold hues. It is not recommended to use several hues of green together with dark brown, otherwise, the basic color of the facade appears to be darker, and the facade appears to look bigger and more depressing. On the contrary, in the lighter part of the facade with dark brown window casings, the combination with green balconies does not create bad impression.
2	 Figure 6. Sily Prirody residential complex (http://vsenovostroyki.ru/novostrojki-sankt-peterburg/zhk-sily-prirody-15)	Gradients from light to dark of bright purple (lilac), cyan, blue and dark green-brown colors in different order relative to the neighboring parts of the buildings.	Such environment can be called aggressive as there are many similar windows located very close to each other. Smooth transitions and absence of boundaries between color spots highlight the similar simplistic windows in the facades. The colors, which almost not observed in nature are bright, contrasting with the sky and the ground.

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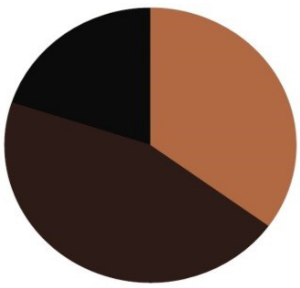
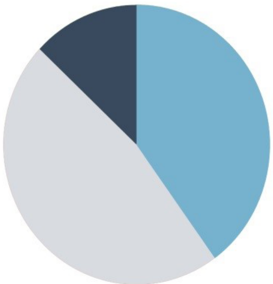
Continuation of table 1

	 Figure 7. Sily Prirody residential complex. Color ratio diagram		
3	 Figure 8. Novoe Murino residential complex (https://varlamov.me/2017/zap_murino/07.jpg)  Figure 9. Novoe Murino residential complex. Color ratio diagram	The dominant color is dark brown with orange-brown lines. The balconies, glazing, window casings, as well as the semi-basement are black.	Pairs of color combination horizontal divisions (black and brown, black and orange, brown and orange) elongate the building facade, which, in case of multi-story buildings, contributes to facade perception as continuous walls. Instead of accent highlighting, contrasting black and dark brown in the semi-basement part represent strength and inapproachability, separating the building with a clear boundary from the environment.
4	 Figure 10. Dominanta residential complex (http://aktiv-spb.ru/services/uslugi-v-sfere-nedvizhimosti/arenda-nedvizhimosti/torgovye-pomeshcheniia/arenda-pomeshchenii-tk-kosmos)	The dominant color is white with blue inserts. Mirror glazing of several hues of blue.	The environment is homogeneous due to the large amount of window glazing without much details. The combination of white and blue is considered to be visually pleasing and should be soothing, however, bathrooms in residential and public buildings usually have tiling of such blue color, and subconscious comparison of those hues results in the projection of the emotional attitude and generalization of the images. The mirror glazing causes discomfort: during the day, it reflects the interior imposed upon the reflection of the street or neighboring buildings (Lam, 1977)

Continuation of table 1

	 Figure 11. Dominanta residential complex. Color ratio diagram		
5	 Figure 12. Tsarskaya Stolitsa residential complex (see https://varlamov.ru/2502935.html)  Figure 13. Tsarskaya Stolitsa residential complex. Color ratio diagram	Alternation of vertical white and dark green lines made of panels different in size. Balconies and window casings are in black color.	The green-white range is based on the contrast of light and dark, where green color sets accents, causes a sense of rightness, in particular in combination with greenery nearby. Black color does not cause a feeling of heaviness. On the contrary, it darkens the elements of the balconies a bit. Differences in cladding depending on the color create a non-homogeneous field.
6	 Figure 14. Tsarskaya Stolitsa residential complex (see https://varlamov.ru/2502935.html)	Alternating vertical and horizontal pinkish and grey-brown lines. The lines are made of elements of different sizes. Balconies and window casings are in black color.	An aggressive field. Due to monotony in the alternation of the lines of different colors, no accents can be established. Sufficiently contrasting colors in terms of intensity create the ripple effect: pink appears to be brighter, while gray appears to be darker.

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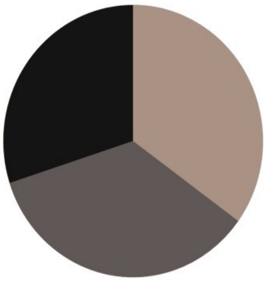
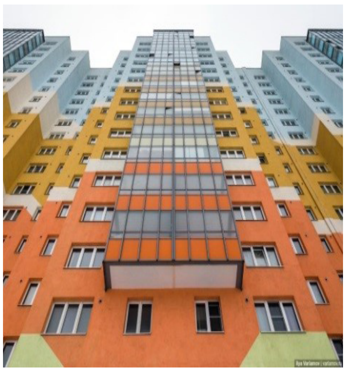
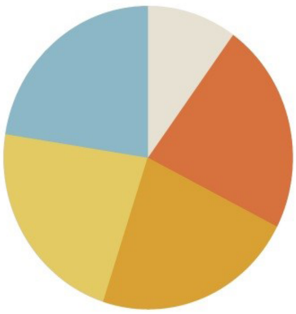
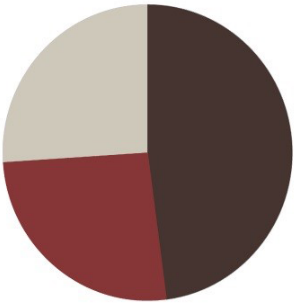
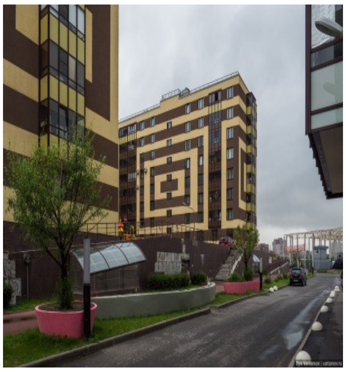
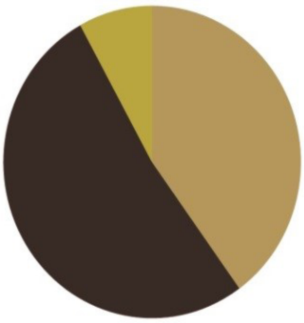
	 Figure 15. Tsarskaya Stolitsa residential complex. Color ratio diagram		
7	 Figure 16. Novaya Okhta residential complex (see https://varlamov.ru/2202685.html)  Figure 17. Novaya Okhta residential complex. Color ratio diagram	Alternation of lines with small geometric ornament of orange, yellow and light blue colors with separating light lines.	Almost equal in area in the visible field, color spots do not allow identifying the dominant and background colors. Absence of balance between the colors disorients and does not help the perceptive organs to determine fixation points.
8	 Figure 18. Novaya Okhta residential complex (see https://varlamov.ru/2202685.html)	The view of the lower floors: light yellow color of the plaster cladding.	The yellow plaster cladding with visible and inevitable dirtying creates an effect opposite to that of the color "light nature". Other color regions are not visible from places near the facade. The facade represents a homogeneous one-color environment with no appealing details.

Continuation of table 1

9	 Figure 19. Vena residential complex (see https://varlamov.ru/2511112.html)  Figure 20. Vena residential complex. Color ratio diagram	The ornament consists of square maroon and white elements on the dark brown basis.	The thick pattern makes the majority of windows hard-to-see, moves to the forefront and becomes an aggressive field. It would be better to leave bright enough red or white color (in minimum amounts) as accents according to the 60-30-10 color rule.
10	 Figure 21. Vena residential complex (see https://varlamov.ru/2511112.html)  Figure 22. Vena residential complex. Color ratio diagram	The view of the lower floors: light yellow color of the plaster cladding.	The yellow plaster cladding with visible and inevitable dirtying creates an effect opposite to that of the color "light nature". Other color regions are not visible from places near the facade. The facade represents a homogeneous one-color environment with no appealing details.

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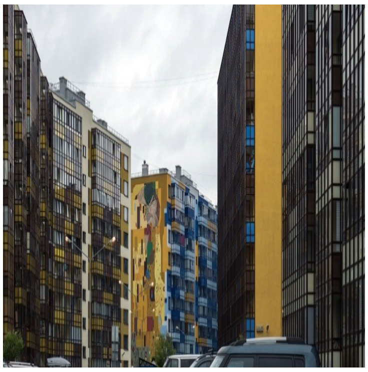
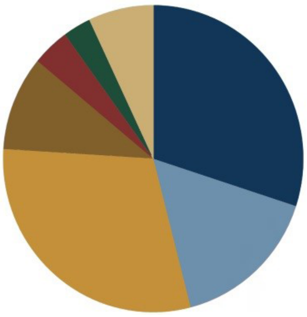
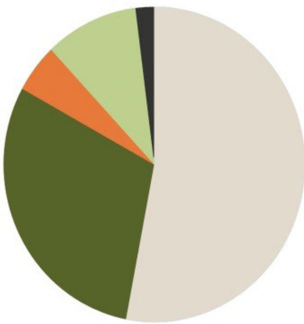
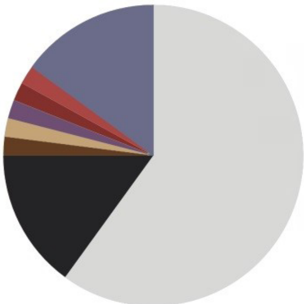
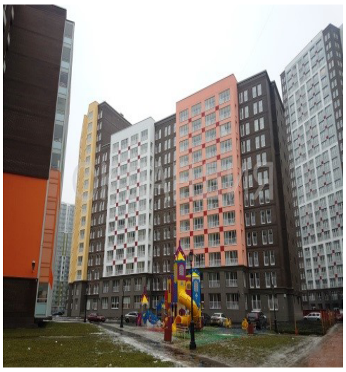
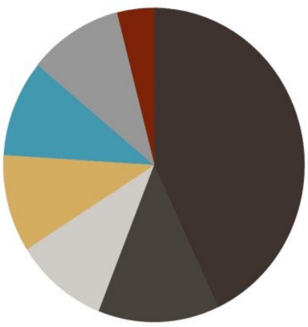
11	 Figure 23. Vena residential complex (see https://varlamov.ru/2511112.html)  Figure 24. Vena residential complex. Color ratio diagram	Alternation of bright blue and yellow colors in the facade and balconies, with blue transoms. On the side sides of this complex and neighboring buildings, works of art are depicted.	The combination of yellow and blue is considered to be trivial (Mesyats, 2012). Taking into account the wall painting, the color complexity of the main facades could be reduced (it is particularly evident in contrast with white cladding on the left). Colors cover almost equal areas, which does not allow paying attention to one of the spots as a visual center. Therefore, an aggressive visible environment is created. It is notable that the green element on the side wall is perceived as the center as the least used color is more easily detached from the background and perceived by an observer.
12	 Figure 25. Vena residential complex (see https://varlamov.ru/2511112.html)  Figure 26. Vena residential complex. Color ratio diagram	The dominant color is white. The pattern in the facade and balconies is in the form of vertical green lines of two hues with orange horizontal inserts.	Absence of hierarchy in the use of various colors of the same degree of contrast results in chaotic state. The bright outline elements create an aggressive visible environment rather than attract attention to the details.

Continuation of table 1

13	 Figure 27. Vernisazh residential complex (see https://spbhomes.ru/vernisazh)	The dominant color of the main facades is white; the side walls and semi-basement are black. The geometric pattern has several hues of red and brown colors.	Chaotic disposition of color spots against the white background is visually pleasing and reduces the likelihood of aggressive environment occurrence. The white and gray glazing against the light and bright background is inconspicuous. The colorful details against the black background include those surfaces into the main facade. No effect of individual continuous walls is created.
	 Figure 28. Vernisazh residential complex. Color ratio diagram		
14	 Figure 29. London residential complex (see http://oklandia.ru/zhk_london_zhk_7_stolic)	The dominant color is dark brown. Alternation of red, white, yellow and gray-blue bay windows with red inserts.	When using dark brown color highlighting lighter sections, a relation background/background instead of the relation background/accent appears due to the large area occupied by the projecting parts representing an aggressive environment.
	 Figure 30. London residential complex. Color ratio diagram		

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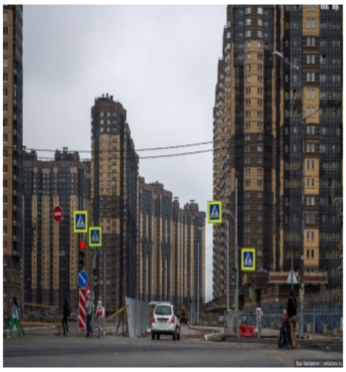
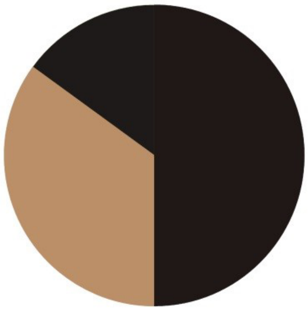
15	 Figure 31. Severnaya Dolina residential complex (see https://varlamov.ru/1873609.html)	The dominant color is brown with horizontal dark brown lines. The black vertical elements with windows alternate with the balcony elements.	Dark contrasting vertical lines visually reduce the length of the building, which has a positive effect. However, this effect is evident only in the light sections but completely disappears against the dark brown background.
	 Figure 32. Severnaya Dolina residential complex. Color ratio diagram		

up short color schemes for the main elements - the main color, the color of the basement, the framing of windows and balconies in the presence and their comparison with the studies of architects and theorists formulated in the literature.

Results and Discussion

It should be noted that the number of stories in a building and its effect on the human psychological condition were not taken into account.

Despite the consequences of urban planning of the 20th century, when in 10–15 years high-rise residential blocks became problem areas that afterwards were demolished or neglected (Robin Hood Gardens, Holly Street Estate in London, Cabrini-Green Homes in Chicago, Ballymun Flats in Dublin, Toulouse-le-Mirail in Toulouse), currently, one-off building construction projects are uncommon or do no occur at all. According to Table 1, a trend to use dark hues of brown and black can be traced. Those colors shall be used rarely and only to create accents (so that not to construct a building which would have a negative effect on the human psychological condition in the absence of sunlight). When using large areas with bright colors, the combination of schemes is not always selected correctly, and the cladding material does not always match the selected color or the combination. In most cases, facades have many windows or large glazed surfaces, including mirror glazing.

The following recommendations can be made:

1. When designing high-rise brick blocks, it is recommended to use light brown bricks with white brick joints. Thus, each element will appear to be smaller, lighter in color and weight, and the whole composition will look less depressing.
2. When constructing high-rise residential buildings, it is not recommended to make them long. In such case, the light coming between the buildings can highlight visual characteristics of the facade (Figure 33).
3. When using white color as the basis in several buildings, one contrasting insert is enough (Figures 33, 35). Contrasting lines of different buildings shall match (Figure 34) in terms of intensity and cold/warm color palette: light hues of warm gray, pink, red and aquamarine are used.
4. In Figure 36, despite the great length of the building, concrete elements change geometrically. The building also has color inserts with geometric patterns on four sides of embeddings which mutually complement the facade material.
5. An aggressive field can be reduced by increasing the area of glazing and alternating rows of clearances of various shapes with windows and balconies embedded in the facade (Figure 37).
6. If each building has only one color, then it is recommended to paint the neighboring buildings with more or less intense hue of the dominant color. The color of the neighboring building can be used to set accents around windows or the entrance space (Figure 38).

Figure 33. Berlin, Germany

Figure 36. Unite d'Habitation. Berlin, Germany

Figure 34. São Paulo, Brazil

Figure 37. Paris, France

Figure 35. Berlin, Germany

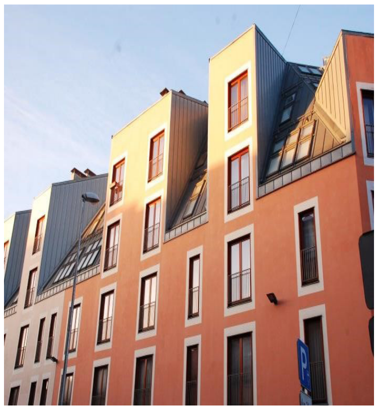


Figure 38. Riga, Latvia

Conclusions

The visual environment can vary even within one residential neighborhood. Due to this, it is necessary to coordinate the appearance of each residential complex with the neighboring ones, especially if they are built by different developers. In this case, the obvious difference in visually pleasing quality of the architectural space, where residents spend a lot of time and that, being on the outskirts of Saint Petersburg, represents the city identity for those driving by, can be reduced. Use of balanced color schemes, similar finish materials and details makes it possible to create residential neighborhoods having a unique single style and looking like a completed architectural ensemble.

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ACTIVE FAULTS AND CHARACTERIZATION IN OSAKA AND ALMATY BY BORING DATA BASE

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Abstract

The active fault in Osaka is known as Uemachi fault, which had been originally identified as geomorphological feature of the Osaka high terrace. However, the position of the fault line was corrected by geotechnical information during subway construction.

Later another active fault was identified by the continuous characteristics of geological formation which was later identified by seismic study.

Active fault lines in Almaty were identified based upon geomorphological feature and should be confirmed by underground information of boring data and seismic study.

Osaka and Almaty did not take any consideration of the active fault in the city except strong ground motions. In these cities, structural effects from fault displacements should be considered to not only independent buildings but also such lifelines of infrastructures of freeways, subway, and electric power as well gas lines. Especially, Almaty is the most dangerous situation. Geotechnical engineers in Kazakh should initiate the study of active fault and provide the damage potential and as well as effective countermeasures to protect the 1.5 million citizens in Almaty and to create resilient city.

Keywords

Boring data, active fault, hidden fault, Los Angeles, Osaka, Almaty.

Introduction

Basically active faults in Osaka area distribute along such lines of mountain foot as well as line of edges of terraces of recent young geological deposits. These are based upon geomorphological feature of the present mountains and terraces that have been made by fault movements as shown Figure 1.

In Figure 1, Uemachi fault is identified as the western edge of the Uemachi terrace in Osaka city. When a subway construction for Kintetsu-line that is crossing with the Uemachi-fault showed the geological section along the line as in Fig.2, it was found that the real fault is not on the edge of the terrace but some 500 m away to the west. The height of the western side of the ground is about +10m and that of the eastern side is about +20m.

The difference of 10m of the ground level had been considered as the fault displacement. In Fig.2, the boring samples were identified geological formation and shown as Ma number. Ma stands for marine clay deposit. The formation of Ma11 is found at the level of -15m in the western side and +10m in the eastern side. The difference of 25m is the fault displacement after the deposition of the Ma11 to the present time of about 210,000 years as shown in Table 1.

It is considered that the original cliff that had been created by the fault displacement was eroded away and the cliff was moved eastwards as shown at present. The return period of the Uemachi fault is estimated about 10,000 year. The anticipated vertical displacement for one fault movement is about 1.2m as shown in Table 1.

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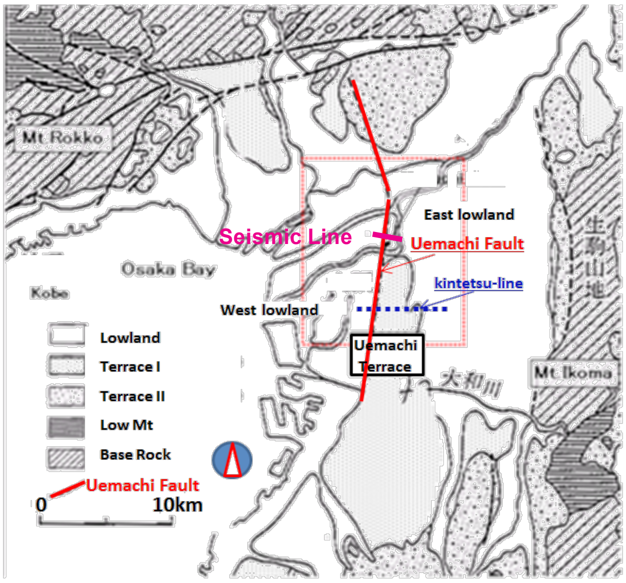

Figure 1. Uemachi fault identified along the edge of Uemachi terrace (1960)

A seismic reflection survey was performed along the seismic line in Fig.1. The result was shown in Figure 3. The underground feature of the fault was clearly identified by the reflection survey.

The depth of the base rock near the east and the west end of the surveyed line was about GL-800m and GL-1500m. The difference of the depths of the base rocks is considered as the fault movement in the past of 3million years from present.

Table 1. Geological formation and deposited period

Clay formation	geological age	vertical dip displacement	
	(ka)	(total/m)	(per event/m)
Ma12	130		
Ma11	210	25	1.2
Ma10	300		
Ma9	380		
Ma8	450		
Ma7	540		
Ma6	600		
Ma5	660		

From the information of study of surface to underground

Fault map in Osaka was revised after the recognition of the geotechnical study along the subway line as shown in Figure 4. The Uemachi fault was shown westwards in the geological map in 1980. At the same time, two additional faults lines were added as Fault 2 and 3. Fault 2 was estimated along the topological feature of the terrace in the south Osaka.

Fault 3 was estimated by not from surface topology but from the underground structure.

Geotechnical boring data system in Osaka began in 1980 and some special feature was recognized along the line of "Fault 3" in Figure 4.

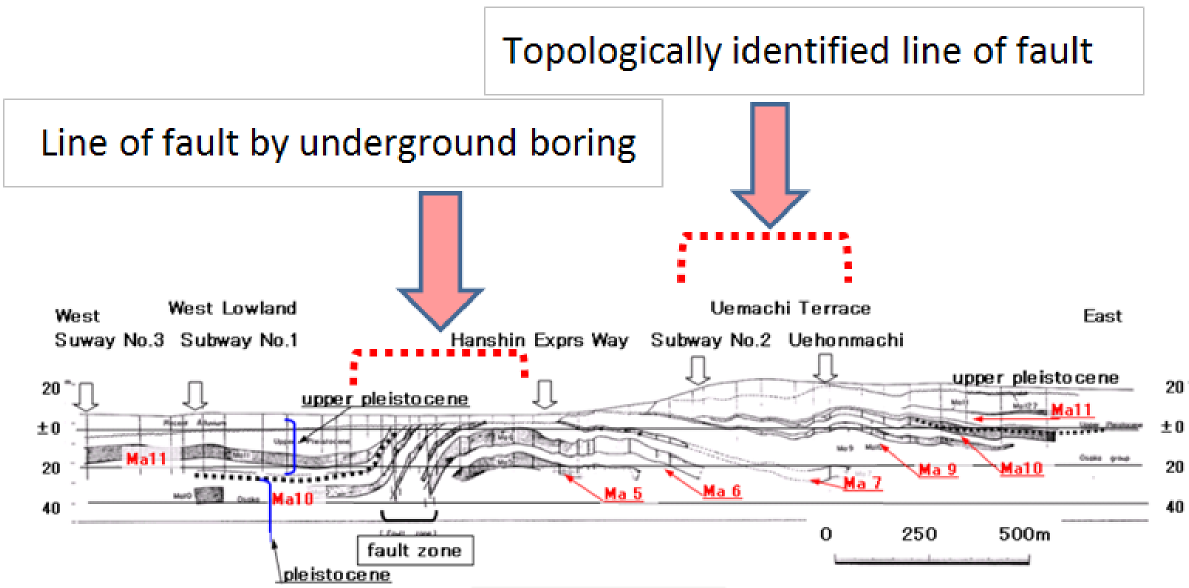

Figure 2. Underground structure along Kintetsu line

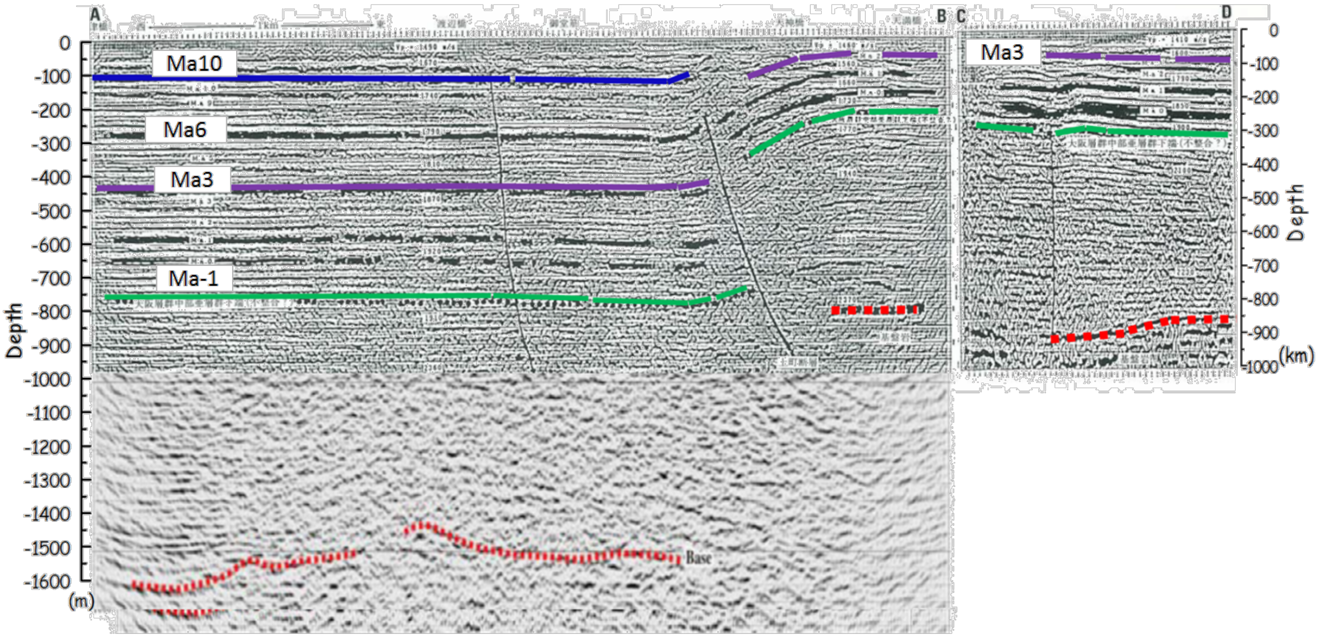

Figure 3. Nakanoshima seismic reflection line (1991)

Figure 4 shows a typical boring section along N-S line in Figure 3, where Ma13 of the recent deposit of clay layer is horizontal formation. Those layers of Ma11 and Ma10 are inclined towards north and the Ma12 is also inclined towards north but seems deposited horizontally at the north end. This unique combination of the horizontal layer of recent deposit with inclined formations of the earlier deposit was found along the fault line of "F3" in Figure 4.

After the Kobe earthquake of 1995, the author was asked where and how the fault should be studied in Osaka by the department of disaster prevention of Osaka city.

We recommended seismic reflection as well as deep boring including the line of N-S in Figure 5. The result is shown in Figure 7. The geophysical result shows the underground structure that was expected by geological study based upon geotechnical database.

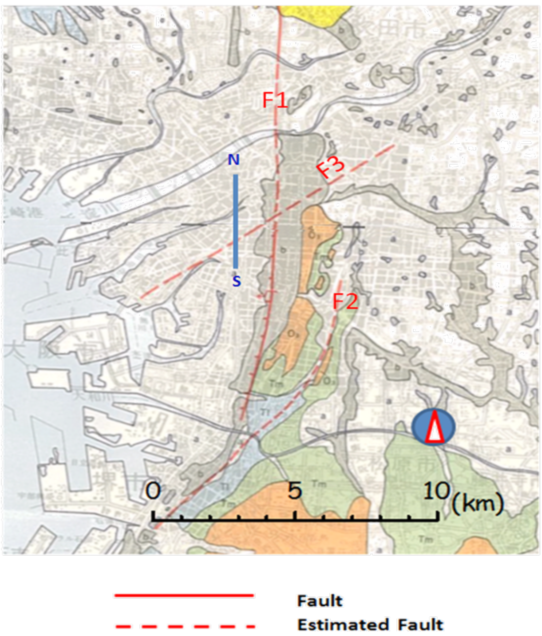

Figure 4. Fault map in Osaka in 1980

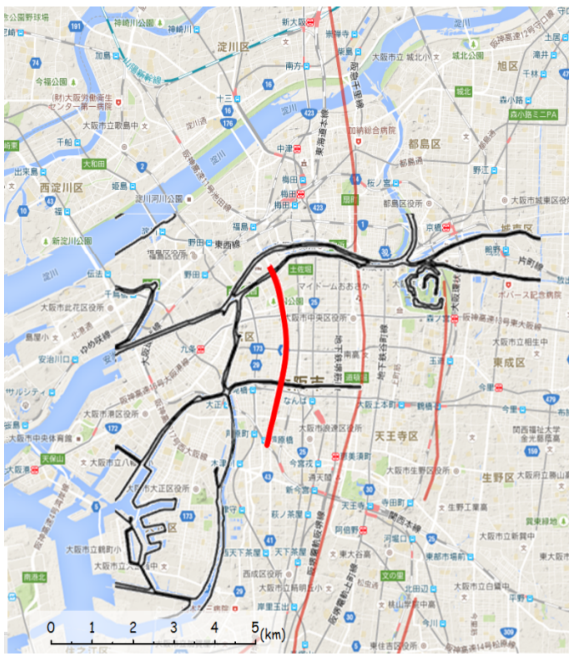

Figure 5. Seismic line along the fault

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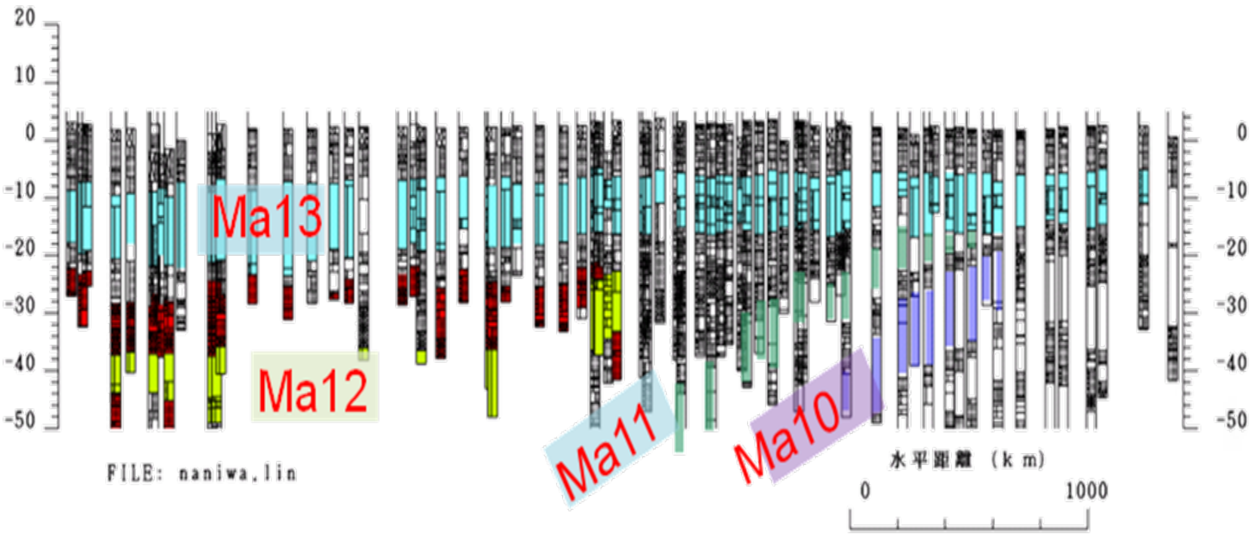

Figure 6. Geological section based upon geotechnical boring system in Osaka

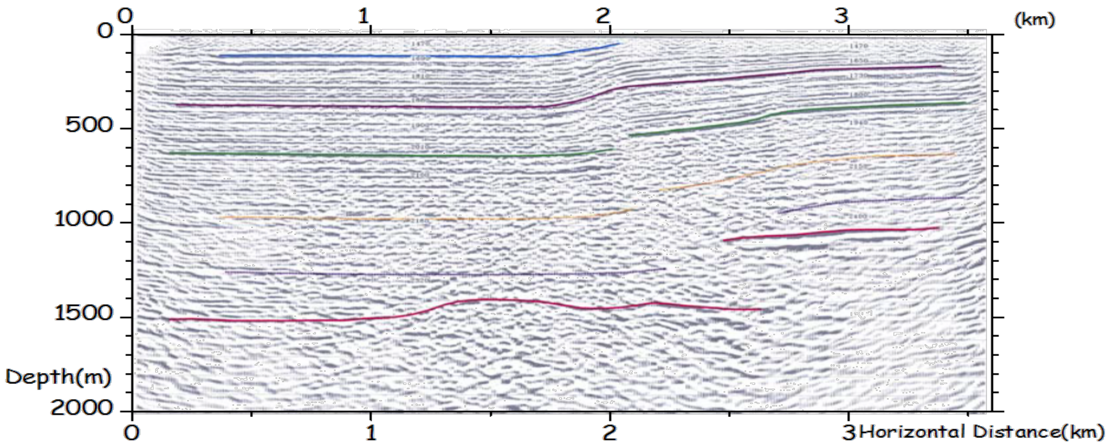

Figure 7. Seismic reflection along N-S line in Figure 5

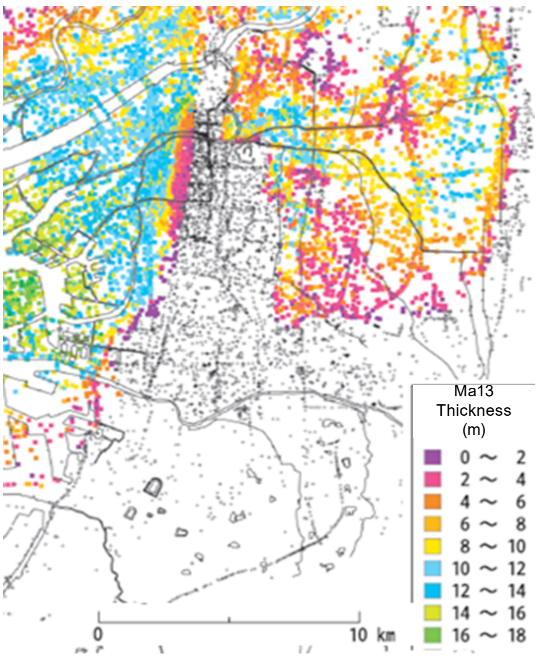

Figure 8. Thickness of Ma13

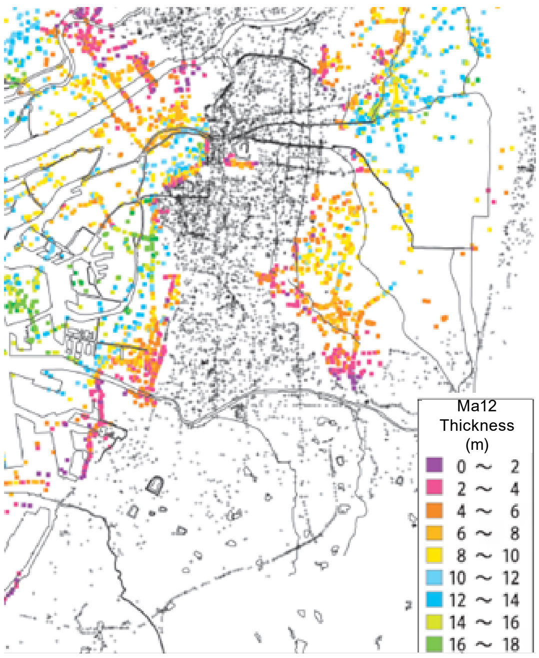

Figure 9. Thickness of Ma12

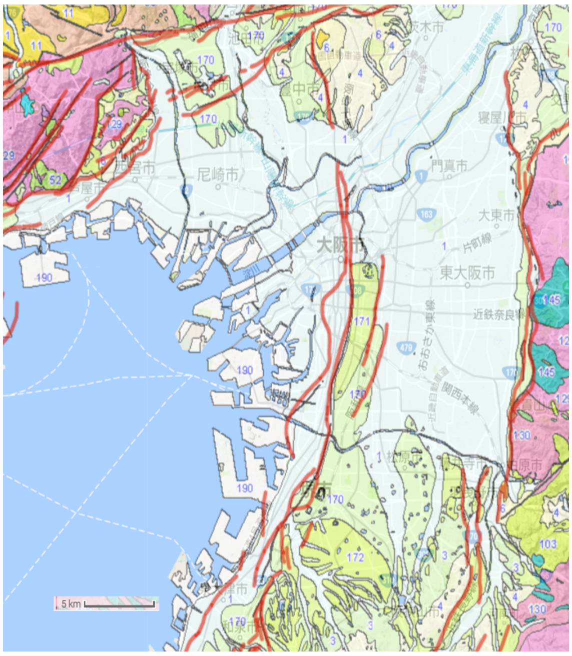

Figure 10. Active faults in Osaka (Geological Survey of Japan as of 2018)

Areal distribution of the thickness of Ma13 and Ma12 are shown in Figure 8 and 9. The thickness of Ma13 in Figure 8 is around 10-14 m in the western Osaka and decreases with eastwards and disappears at the west edge of the Uemachi terrace along the Uemachi fault. The thickness of Ma12 in Figure 9 is about 6-10 m in the western area in Osaka and then decreases towards east just like as Ma13. The difference is the disappearing shape of these geological formations. The shape of disappearing of Ma13 is rather straight line, but that of Ma12 is concaved curve.

The detailed study has revealed that the curvature is caused by another active fault structure named as "Sakuragawa Flexure".

Osaka 1-Line is in east-west direction at the south of the Osaka area, where several active faults are being crossed over. These active faults were estimated by geomorphological feature of the surface of the ground of the terrace and/or steps along the faults. The reflection image of Osaka 1-Line shows only continuous deformation of sedimentary layers with inclination towards to the east.

The base rock is clearly recorded by the survey and is shown at the GL-1,000m to 1,300m. The shape of the image does not show any fault gap of the displacement along the line, which contradicts the existence of the faults indicated by the geological survey of Japan. The faults in Osaka area are not strike slip with any vertical displacement but reversal dip slip with some vertical slip component.

The fault lines have been estimated by topological features of straight lines with vertical steps for some

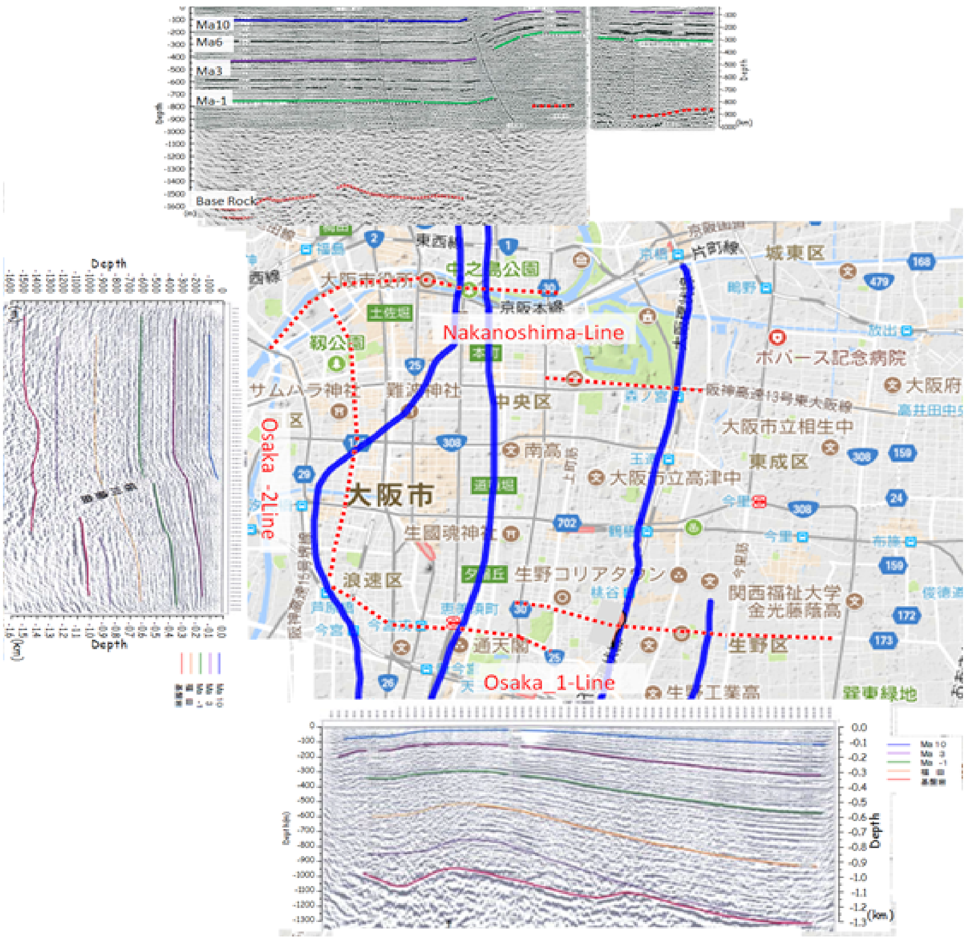

Figure 11. Seismic reflection results in Osaka

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continuous distance. However, the estimated faults should be re-evaluated and deleted at least beneath the survey line.

It may be clear that the "fault that is estimated by the characteristic elements of ground surface of fault" is not necessary to provide the correct information of fault existence.

Osaka 2-Line is in north-south direction at the west of the Osaka city, where the ground surface is flat and horizontal. The fault line was estimated by the boring data that show stepwise formation of underground layers.

The seismic reflection of Osaka 2-Line shows the clear fault structure of different depths of the rock. The depths of rock at the north and south sides are 1,500m and 1,000m.

Subway lines and faults in Osaka

At present in 2018, Geological Survey of Japan shows tectonic active faults as in Figure 10. Figure 11 shows some comparison between the active faults by Geological Survey of Japan(GSJ) in blue lines and seismic reflection results. It is found the estimated faults by GSJ do not correspond with the reflection survey. For an example, reflection line Osaka-1 show no deformation at four points where it crosses with the expected faults. We need to study more detailed structure to clarify the fault systems in Osaka.

Lifeline system and active faults

Subway metro is one of the important lifelines in urban area.

Figure 12 shows active fault lines and subway lines and indicates crossing points of the faults and subway lines. Figure 13 shows the distribution of boring points in the area and the selected zone along the subway line in the Figure 12. Figure 14 shows the characterization of fault movements as the flexure of two parameters.

The vertical displacement and the width of the fault as dip = 30 m and width =600 m respectively.

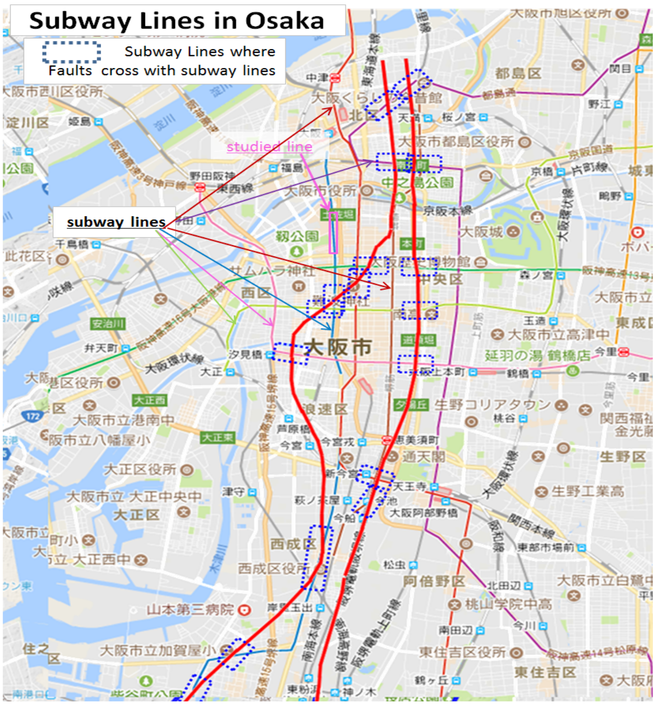

Figure 12. Subway lines in Osaka

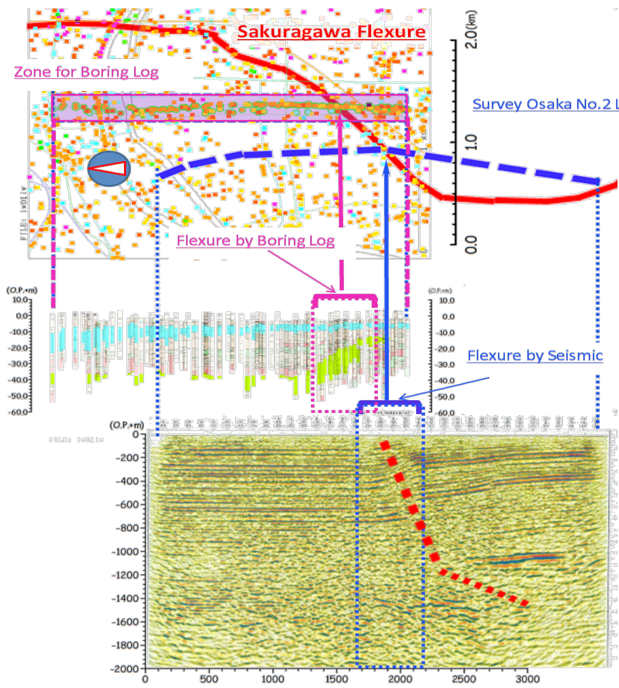

Figure 13. Boring data base along the studied line in Figure 12

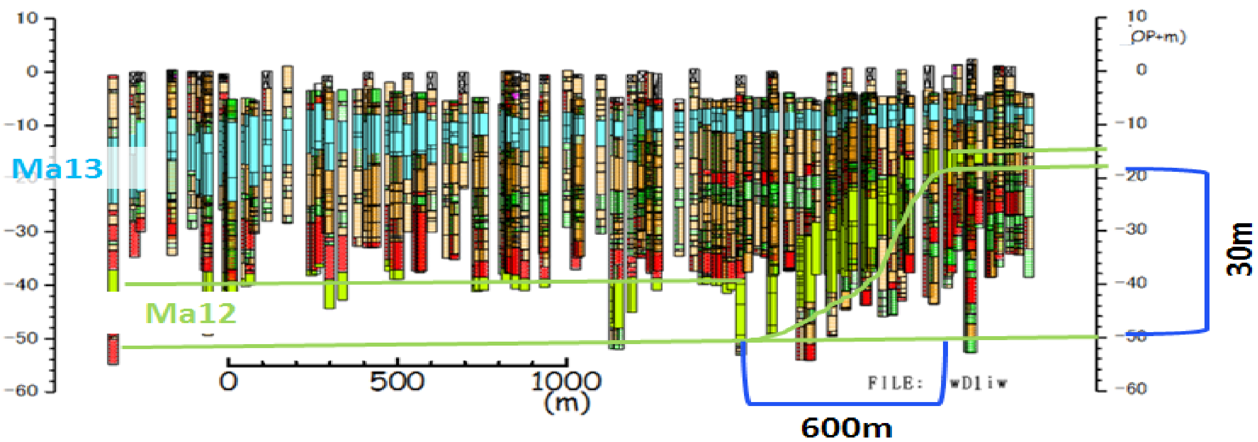

Figure 14. Characterization of the Fault movement of Ma12

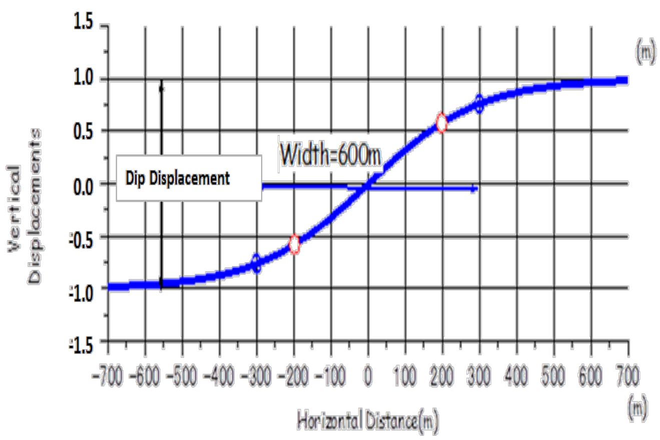

Figure 15. Anticipated deformation of the fault

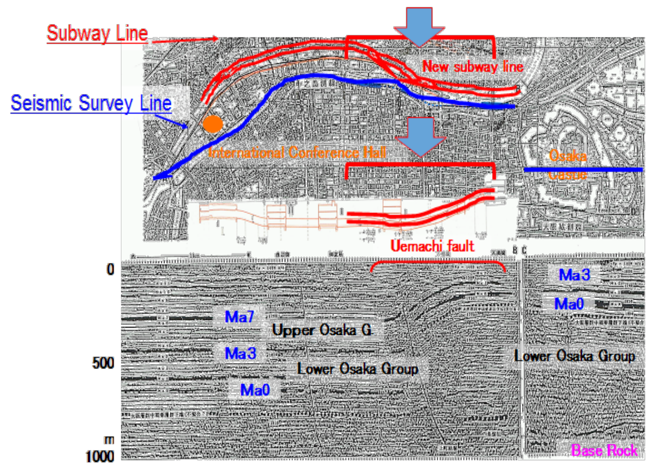

Figure 17. Section and Plan for subway extension of Keihan Line

The Ma12 is considered as the deposition during the geological period of 130,000 years before the present.

The anticipated deformation of the surface ground is shown in Figure 15.

Several important aspects of the fault displacements to the life line structure are 1 inclination, 2 flexure moments, 3 tension and compression strains caused by flexure mode of displacement, and overall compression strain caused by reverse fault.

The geological period of deposit of Ma12 is the late quaternary of around 120,000 to 130,000 of the sea water level near the present level as shown in Figure 6 of the change of the sea water level with the time of global climate history. The return period of the fault activity is estimated about 10,000 years, which results in 12 times of fault movements.

The maximum vertical displacement for one fault movement is estimated by dividing the total displacement of 30m by 12, which results in about 2.5m for the next earthquake displacement.

Aseismic Design for Subway line in Osaka

When a subway extension of about 2.9km from Tenmabashi to the west wards that crosses over the active fault, the anticipated displacement by the fault movement was applied to design the tunnel structure as aseismic capability.

Due to the bending deformation that is anticipated during the fault movement, the concrete segment of the shield tunnel was changed to the ductile steel segment was selected to protect the subway from the collapse of the train as the subway during Kobe Earthquake of 1995.

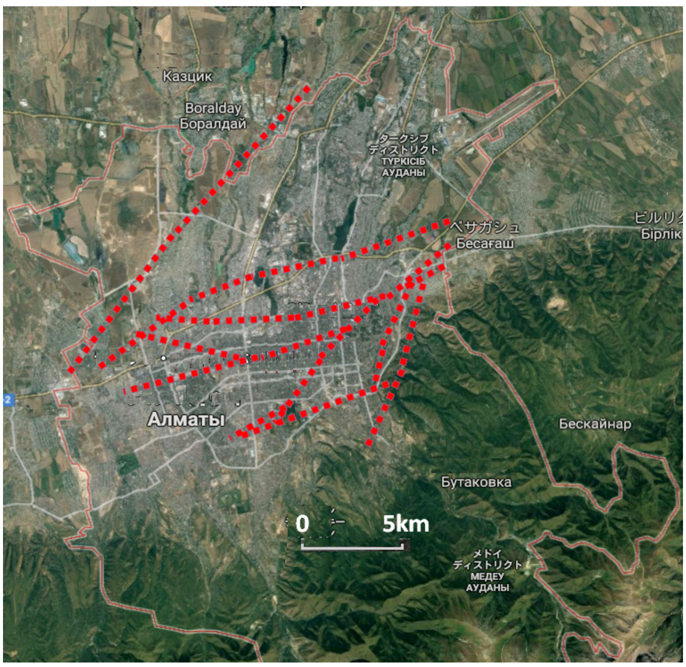

Figure 16. Fault Lines in Almaty (JICA (2009))

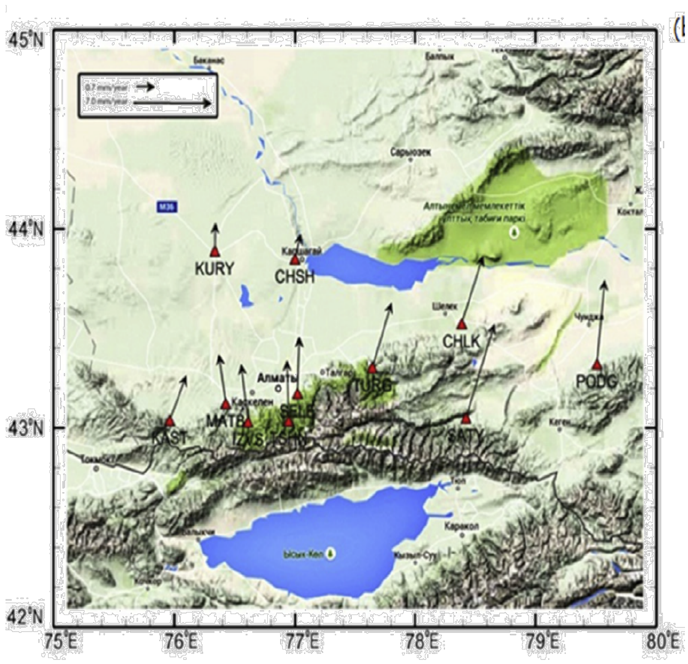

Figure 18. Crustal velocity by GPS monitoring (Vilaev (2017))

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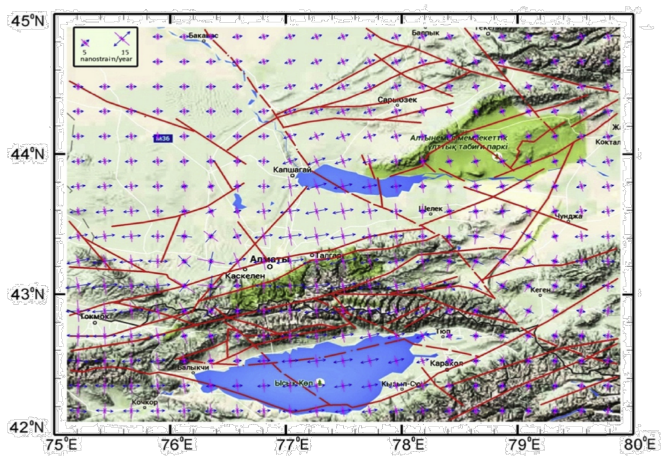

Figure 19. Distribution of ground strains in horizontal direction (Vilaev (2017))

Fmo	Fine-grained soil (high organic)	
Fms	Fine-grained soil (soft ground)	
Fma	Fine-grained soil	
Sa	Sand	
Ga	Gravel	
Gr(w)	Weathered granite	
Gr	Granite	

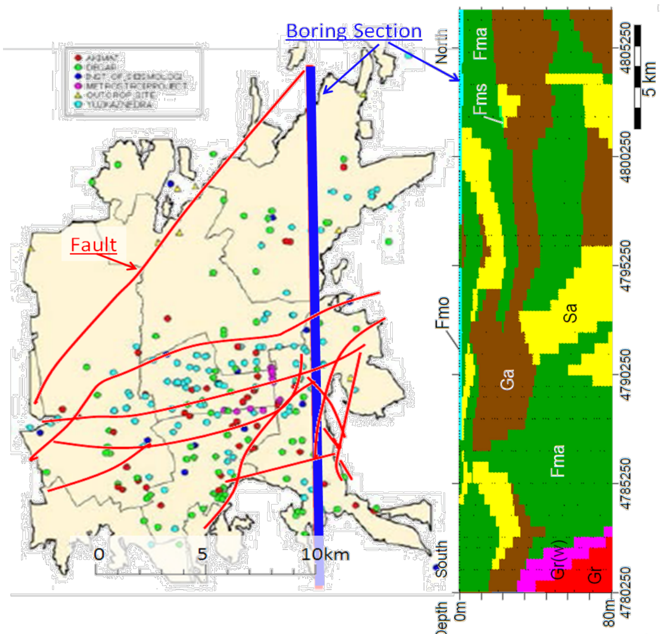

Figure 20. Example of geological section in Almaty

Active Faults in Almaty, Kazakhstan

The active faults in Almaty in Kazakhstan were studied by geomorphological character of the surface topology and shown as in Figure 17. Almaty area is located at the north of the Tien Shen Mountain that is tectonically very active being pushed by Indian continent.

As shown in Figure 18, GPS monitoring shows GPS movements in Almaty shows northwards displacement of about 7 mm/year, which results in compression strain in NS and expansion strain in EW direction that shall induce the reverse type of fault plane in EW direction as well as strike slip type of fault plane in about E30N or E120N direction. The fault directions in Figure 17 are consistent with what is expected by Figure 19.

JICA provided study of prediction of earthquake damage in Almaty and JICA made a study ground condition based upon boring data in Almaty and showed vertical section along NS direction as shown in Figure 20. The vertical section shows rather complicated structure than simple multi-layer.

JICA provided fundamental information of earthquake problems for Almaty. However, JICA did not study the long period problem caused by the very thick deposit of 3-4 km of the Almaty area and ground displacement effects from active fault.

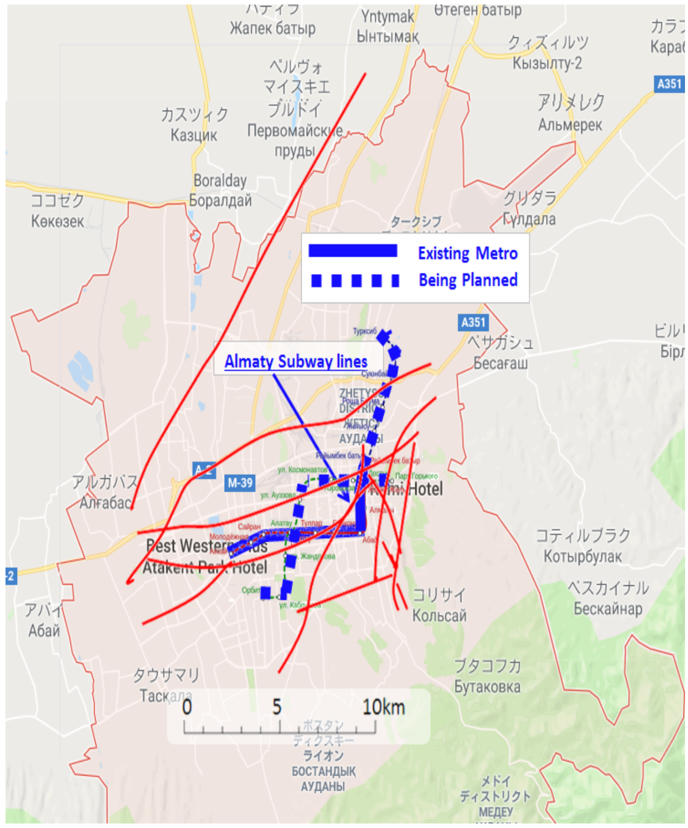

Figure 21. Subway system and fault lines in Almaty

Subway lines and active faults in Almaty

Figure 21 shows the subway system in Almaty as well as the anticipated active faults lines. The solid line for subway is under operation at present and the dotted line is being planned in the future.

The subway plan has been never considered the effects of the active faults in Almaty, which is rather common practice in the world. However, the professional people, especially the geotechnical engineers must give the information to the society on the situation of the present weak points of the preparedness for earthquake disasters.

Geotechnical engineering warning of dangerous situation and share the knowledge on the faults, develop preventive countermeasures to protect the people in Almaty.

Conclusions

Active fault system in Osaka based upon boring data system as well as seismic reflection is presented. Faults problems of Almaty in Kazakhstan, where active faults might result in severe disaster, are reviewed.

In Osaka area, geotechnical knowledge has been utilized to identify the position and characteristics of the ground deformation by the active faults. In Almaty, geotechnical boring logs should be compiled as the fundamental data base to provide very basic geological setting, ground zoning, including fault structures.

As shown for predicted active fault based upon only surface geomorphology does not necessary true, the underground structures should be confirmed by such survey of seismic reflection and/or geological borings.

Almaty is the most dangerous situation among three cities.

Geotechnical engineers in Kazakh should initiate the study of active fault and provide the damage potential and as well as effective countermeasures to protect the 1.5 million citizens in Almaty and to create resilient city for Kazakh.

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STAGES OF QUANTOMOBILE DEVELOPMENT

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Abstract

Physics advances of recent decades outlined the beginning of the formation of a new technological paradigm based on anti-gravity principles of object movement and propulsive drive. The article provides an engineering (simplified) view on the main conceptual features of the theory of Superunification that help to overcome the forces of gravity and inertia. It also considers schemes and propulsive mechanisms of thrust formation in quantum engines.

A concept of a quantomobile is introduced. A strategy of sequential R&D activities to design a quantomobile is developed. Removing wheels for quantomobile movement modes leads to a concept of a flying car.

Keywords

Automobile, quantum engine, quantomobile, flying car, R&D activities, development stages.

Introduction

Efforts of scientists in search of a new paradigm of energy supply for humanity in the 20th century (Einstein (1963), Davies (1985), Tesla (2009), Parker (1991), Veinik (1991), Puthoff (2010), Nikitin (2016) and others) were crowned with unveiling of the Unified Field, the structure and energy density of the physical vacuum, super-strong electromagnetic interaction (SEI).

An insight into the above-mentioned entities, their identification, content, systemic interconnection of functions and other features are with high confidence provided by the theory of Superunification suggested by Russian scientist Leonov V. S. at the turn of the 20th and 21st centuries (Leonov, 1996, 1997, 2010a, 2013, 2016, 2017a, 2017b, 2017c, 2018). This theory supported by a number of patents granted to Leonov on corresponding objects (Leonov, 2002) and results of experiments involving those objects (Leonov, 2009, 2010b, 2018, Petrov, 2015) provides the key to mastering the ability to draw energy from the global physical vacuum.

The number of studies in this field performed by other authors and research teams (Shawyer, 2006), McCulloch (2014), Fetta (2014), Tajmar (2018) and others) is also growing.

Practical implementation of the above-mentioned ability will result in a new technological paradigm involving the transport sector as well. And then, quantum engines will replace internal combustion and jet engines, new propulsion devices and transport routes will appear, the existing propulsion devices, transport routes and transport infrastructure in general will improve. The transport industry should begin relevant preparations.

An author's publication (Kotikov, 2018), firstly, addresses initial assumptions of the theory of Superunification suggested by Leonov V. S., secondly, covers concepts of quantum engine development, and, thirdly, anticipates features of cars with quantum engines (quantomobiles). The author is aware that the research is hypothetical due to weak verification of the physical theory involved. However, the readiness of the transport industry to accept new physical realities both in terms of time and the accumulated technology potential shall be noted.

The three-pronged goal of the article is to broaden understanding in this promising field: firstly, to provide an engineering (simplified) view on the main conceptual features of the theory of Superunification that help to overcome the forces of gravity and inertia; secondly, to present the concepts of thrust formation in quantum

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engines; and, thirdly, to present a strategy of sequential R&D activities to develop prototypes and produce batches of quantomobiles.

The main goal of the first subgoal is the formation of a compact conceptual essay based on dozens of publications (including more than 700 pages of the main publication only (Leonov, 2010a)) to get an insight into the mechanisms of thrust formation in quantum engines at the engineering level, i.e. to ensure the subsequent solution of tasks at the level of the second subgoal.

Successful solution of the tasks within the third subgoal will depend on the level of understanding and mastering the foundations of the theory of Superunification, i.e. comprehension of the first two subgoals. Therefore, in the author's opinion, the interpretation of the foundations of this new and difficult physical theory at the engineering level will be quite appropriate. It is possible to consider this simplified representation as an initial part of the future Quantomobile Theory.

It should be noted that the concept of the Quantomobile class (as the heir to the Automobile superclass) with a quantum engine/propulsor using energy of the quantized physical vacuum is justified.

Within this framework, the author of this article argues that it is inappropriate to use the Quantomobile term for an electric car with flow (liquid) batteries produced by NanoFlowcell company (https://www.drive2.ru/b/2849445/) or the Quantomobile.ru domain name (https://www.runfo.ru/quantomobile.ru).

An engineering (simplified) view on Superunification theory concepts ensuring overcoming forces of gravity and inertia

A quantum model of gravity in the theory of Superunification

The theory of Superunification (Leonov, 2010a) considers the process of Einstein’s space-time quantization. Quantization is an energy process related to filling space with quantons. A quanton includes four whole quarks: two electric (+1e and -1e) and two magnetic (+1g and -1g) quarks forming a tetrahedron with two orthogonal dipoles — electric and magnetic. Those two dipoles form an electromagnetic quanton quadrupole. The four mentioned quarks making up a quanton combine electricity and magnetism in the form of a unified electromagnetic substance, the carrier of which is the four-dimensional quantized space-time (QST).

The global physical vacuum (including material insertions) is densely filled with multiple mobile quantons representing a "boiling bouillon" Quantons interact continuously due to their proximity, charge sign in adjacent quarks of neighboring quantons and orientation of dipole axes (see diagrams and figures in the corresponding works (Leonov, 2010a, 2013; Shkrudnev, 2017; Kotikov, 2018).

The QST in the equilibrium state is an electromagnetic static field which is a carrier of super-strong electromagnetic interaction (SEI) — the fifth fundamental force. SEI is that Unified Field combining gravity and electromagnetism, anticipated by Einstein in his general theory of relativity (GTR) (however, he failed to combine those at the time). As a carrier of SEI, the QST possesses great energy density of approximately 10^{73} J/m^3 (Leonov, 2013).

The equilibrium state of a QST fragment implies that the resultant vectors of axial forces of quark dipoles are equal to zero in any direction (zero vectors). Throwing a material object (containing a lot of free quarks) into the fragment perturbs the electromagnetic field, bending it relative to the initial equilibrium state (in this case the resultant force zero vector acquires magnitude and direction). Control of free quarks' introduction allows affecting changes in the vector (Leonov, 2010a).

The discovery of the quanton in the form of a four-dimensional particle of a space-time quantum made it possible to give the GTR a quantum character. It also allowed V. S. Leonov to develop a quantum theory of gravity proceeding from the Einstein's concept of curved four-dimensional QST as the basis of gravity (Leonov, 2010a).

Leonov experimentally ascertained a ponderomotive (force) interaction between electromagnetism and gravity. Anti-gravity effects were discovered. According to the results of experimental studies, external fields can interact with the QST structure, resulting in stable anti-gravity effects. We can consider the outer space as an elastic super energy-dense medium having an electromagnetic structure with overall support and sufficient energy. We should learn how to interact with the medium and manage this interaction (Leonov, 1997).

The theory of Superunification also states that weightless QST penetrates all weighable (material) bodies. In this case, all weighable bodies represent an integral part of weightless QST. The body mass is formed as a result of the spherical deformation (bending according to Einstein) of weightless QST by elementary particles making up the body. In this case, the body mass represents an integral part of the elastic quantized medium, its energy cluster (Leonov, 2010a).

Spherical deformation of QST according to Einstein is curvature of its "density", which can be represented by Lobachevsky spheres of various curvature, strung one

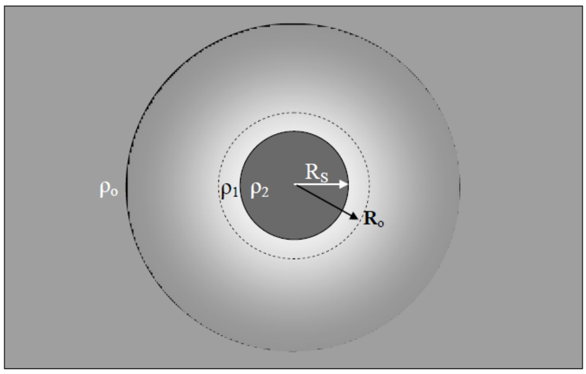

Figure 1. Modeling an elementary particle in the form of areas of spherically deformed QST: R_S — gravitational medium interface; ρ_1 — tension field (light-colored), ρ_2 — compression field (dark-colored) (Leonov, 2010a)

upon another at unequal distances (see Figure 1) (Leonov, 2010a).

If we throw an electric charge into QST, quantons will be attracted to this electric charge, compressing QST close to the charge and extending QST at a distance from the charge. A gravitational boundary forms between the compression and tension fields. A process of spherical deformation of the quantized medium occurs (Leonov, 2010a).

Leonov denoted the maximum gravitational potential of the unperturbed QST as C_o^2, and the gravitational action potential of the perturbed QST —as C^2.

QST can be characterized as a scalar field with the distribution of the medium quantum density *ρ (x, y, z)*. Thus, the process of medium compression/tension from the perspective of vector analysis (in Heaviside's notation (Heaviside, 1893)) can be represented by the divergence of the gradient of the QST quantum density (Leonov, 2010a):

$$\mathrm{div}\left(\mathrm{grad}\rho\right) = \mathrm{k_o}\rho_{\mathrm{m}} \tag{1}$$

where k_o — proportionality coefficient;

ρ_m — matter density, kg/m³.

The grad*ρ* gradient which is a part of (1) represents the medium deformation vector ***D*** when the scalar field *ρ (x, y, z)* is used to create a vector field upon deformation, characterizing gravity emergence (Leonov, 2010a).

Gravity and inertia

The following distribution of the Newtonian gravitational potential φ_n is known to be characteristic of a spherically symmetric system:

$$\varphi_n = -\frac{Gm_1}{r} \tag{2}$$

The theory of Superunification shows that the Newtonian potential φ_n is fictitious, and the action potential $C^2 = C_0^2 - \varphi_n\,\gamma_n$ is present in QST (where γ_n is the so-called normalized relativistic factor that changes its value depending on approximation to the speed of light). The gravitational force in the theory of Superunification is expressed through the action potential C^2 at $\gamma_n = 1$ in the following way (Leonov, 2010a):

$$\mathbf{F_m} = m_2 grad(C_0^2 - \varphi_n) = G\frac{m_2 m_1}{r^2}\mathbf{1_r} \tag{3}$$

where $\mathbf{1_r}$ is the unit vector along the radius (specifying the direction for the force $\boldsymbol{F_m}$).

Leonov expresses the force of gravitation (3) through the deformation vector ***D*** of QST:

$$\mathbf{F_m} = \frac{C_0^2}{\rho_0} m_2 grad\,\rho = \frac{C_0^2}{\rho_0} m_2 \mathbf{D} \tag{4}$$

The deformation vector ***D*** in (4) is an analogue of the gravitational field strength vector ***a*** (where ***a*** is free-fall acceleration):

$$\mathbf{a} = \frac{C_0^2}{p_0}\mathbf{D} \tag{5}$$

Figure 2 shows the trial mass m_2 in the heterogeneous gradient field of the Earth. The quantum density *ρ* (action potential C^2) weakens at the surface of the Earth. However, they do not determine the gravitational force. It is determined by their gradient (4), i.e. deformation ***D*** of QST. According to the theory of Superunification, gravity cannot emerge outside QST, and it is based on the real deformation of QST.

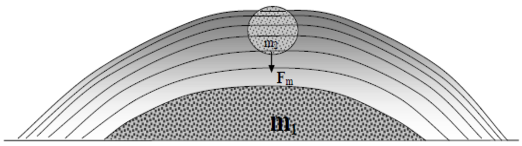

Figure 2. Gravity force $\boldsymbol{F_m}$ affecting the mass m_2 in the field of the perturbing mass m_1 (Leonov, 2010a)

A gravitational pit forms around any object having a perturbing mass. Figure 3 shows that formally the trial mass m_2 affected by the gravity force $\boldsymbol{F_m}$ rolls down into the gravitational pit to the perturbing mass m_1, ensuring their mutual gravitational attraction.

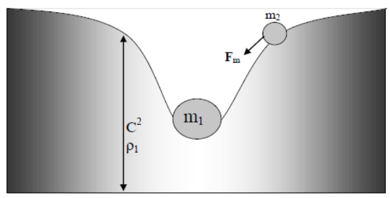

Figure 3. Presence of a gravitational pit in QST around the perturbing mass m_1 illustrating the effect of the gravity force $\boldsymbol{F_m}$ on the trial mass m_2 (Leonov, 2010a)

For clarity, Leonov transfers the trial mass m_2 out of the gravity field of the perturbing mass m_1 (Figure 2) to a separate figure (Figure 4) leaving the heterogeneity of the gravity field inside the gravitational boundary of the trial mass unchanged. The deformation vector ***D*** is provided with indices *i* (inertia) and 2 (deformation of the field inside the trial mass m_2) — $\boldsymbol{D^i_2}$. In this case, the trial mass will be affected by the accelerating inertia force $\boldsymbol{F_i}$, irrespective of the fact that the surrounding QST is not deformed.

The quantum density of the medium inside the trial mass m_2 (Figure 4) increases from ρ_2^{i1} to ρ_2^{i2}, forming the gradient of the medium quantum density within the body, which determines the direction and magnitude of the deformation vector $\boldsymbol{D^i_2}$ and the effect of the accelerating force $\boldsymbol{F_i}$ (Leonov, 2010a):

$$\mathbf{D_2^i} = grad(\rho_2^i) \tag{6}$$

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$$\mathbf{F_m} = m_2\mathbf{a} = m_2\frac{C_0^2}{\rho_0}\mathbf{D_2^i} \quad (7)$$

$$\mathbf{a} = \frac{C_0^2}{\rho_0}\mathbf{D_2^i} \quad (8)$$

The equivalence of gravity and inertia is determined by the capability of QST to be deformed, in the presence of which an unbalanced gravity or inertia force emerges. The difference between gravity and inertia lies in the fact that the deformation of the field inside the trial mass under the effect of gravity is due to the external perturbing field, and in case of inertia — due to the effect of the perturbing force (Leonov, 2010a).

Concepts of thrust formation in quantum engines

With an insight into the quantum nature of gravity in the theory of Superunification, the technology of creating an artificial gravity force has gotten real. It has already been implemented by Leonov V. S. in a number of designs of quantum engines that generate a thrust impulse due to the interaction of operating elements of quantum engines with quantized space-time without the ejection of the reactive mass (Leonov, 2009, 2010b, 2016, 2017d, 2018).

The gravitational field of the Earth creates the gravity force $\boldsymbol{F_m}$ for the trial mass m_2 (Figure 2). A body having the mass m_1 inside QST forms a gravitational pit into which the trial mass m_2 is "rolling down" (Figure 3). This is only the outer side of gravity, nature of which lies in the fact that the gravitational field of the Earth represented by a gravitational pit in this area is gradient (curved, deformed), and its strength decreases in process of advancement to a surface of the perturbing mass.

This corresponds to the main provisions of the field theory, when the direction and magnitude of the force vector $\boldsymbol{F}$ (the latter being determined by the spatial gradient (grad) of energy W) (in Heaviside's notation (Heaviside, 1893)), are oriented towards a decrease in energy (Leonov, 2018):

$$\mathbf{F} = gradW \quad (9)$$

Equation (9) is the main equation in the theory of Superunification to calculate the force. Other equations for the calculation of forces, including gravity forces, are derived from this equation. Differentials in energy levels in space determined by the energy gradient (9) lead to the emergence of a force, to force interaction.

If the global energy field W is a scalar field, then the gradient (9) describes a vector force field having the direction and magnitude of the fastest change in energy W in partial derivatives and can be written with the use of the Hamiltonian operator (Leonov, 2018):

$$gradW = \nabla W = \frac{\partial W}{\partial x}\mathbf{i} + \frac{\partial W}{\partial y}\mathbf{j} + \frac{\partial W}{\partial z}\mathbf{k} \quad (10)$$

where ***i, j, k*** are unit vectors along the *x, y, z* axes, respectively.

Equation (10) of the classical field theory (Heaviside, 1893) is valid only in case when energy diffuses in space in the form of an energy field. The absence of energy level differentials in a homogeneous energy field can be described by the following condition:

$$W = const \quad (11)$$

In accordance with the condition (11), the energy level remains constant regardless of the coordinates *x, y, z* in space. As it is known, the derivative of a constant is equal to zero:

$$gradW = \frac{\partial(W = const)}{\partial x}\mathbf{i} + \frac{\partial(W = const)}{\partial y}\mathbf{j} + \frac{\partial(W = const)}{\partial z}\mathbf{k} = 0 \quad (12)$$

If we need forces to emerge, it is necessary to create energy level differentials in the energy field, when W ≠ const. As far as the gradient (10) is a vector function, its force modulus is determined by the following equation:

$$\left|gradW^2\right| = \sqrt{\left(\frac{\partial W}{\partial x}\right)^2 + \left(\frac{\partial W}{\partial y}\right)^2 + \left(\frac{\partial W}{\partial z}\right)^2} \quad (13)$$

The direction of the unit gradient vector (force direction) ***n*** is determined by the ratio of the function (10) to its modulus (13):

$$\mathbf{n} = \frac{gradW}{\left|gradW^2\right|} = \frac{\frac{\partial W}{\partial x}\mathbf{i} + \frac{\partial W}{\partial y}\mathbf{j} + \frac{\partial W}{\partial z}\mathbf{k}}{\sqrt{\left(\frac{\partial W}{\partial x}\right)^2 + \left(\frac{\partial W}{\partial y}\right)^2 + \left(\frac{\partial W}{\partial z}\right)^2}} \quad (14)$$

Equations (9)...(14) represented by Leonov in Heaviside's notation (Heaviside, 1893) are valid for calculations of the force when the function of energy distribution in space *W = f (x, y, z)* is known, i.e. energy diffuses in space unevenly and energy differentials are observed.

The vector ***n*** (14) of the Earth's gravitational force is directed towards the center of the Earth (Figure 2). The theory of Superunification provides the scientific basis for the creation of an artificial thrust (changing the direction of the force vector ***n***), regardless of the effect of external gravity.

Then, using equation (9), Leonov formulates the Earth's gravitational force $\boldsymbol{F_n}$ through the energy gradient for the trial mass m situated in the gravity field with the gravitational action potential C^2 (Leonov, 2018):

$$\mathbf{F_n} = gradW = grad(mC^2) \quad (15)$$

Equation (15) reflects the fact that the Earth's gravity field leads to the gradient redistribution of energy within the trial mass m and creation of a force in accordance with the Newton's law of gravitation. The deformed QST (according to Einstein) with the gradient gravitational action potential C^2 serves as a mediator in the creation of the gravitational force.

To create an artificial thrust $\boldsymbol{F_T}$ in the absence of external gravitational perturbation, it is necessary to artificially create an energy gradient within the trial mass m (Figure 5).

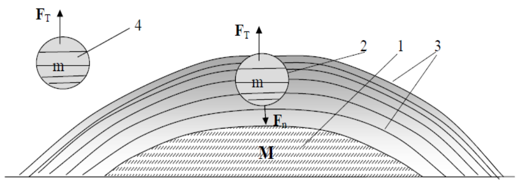

Figure 5. Creation of an artificial thrust $\boldsymbol{F_T}$ due to the creation of an energy gradient within the trial mass *m* (4) (Leonov, 2018)

The trial mass (body) m (2) in Figure 5 is turned around by 180° vertically, with initial gradient distribution of energy, gravitational potentials and medium quantum density inside the body. Then the trial mass (4) is removed from the picture to understand the formation of the basis for the development of a quantum engine with the thrust $\boldsymbol{F_T}$, where the direction ***n*** (14) of its vector can be changed in any way, including opposite to the Earth's gravitational force.

Thus, in order to create an artificial thrust, it is necessary to create an energy gradient inside the body (operating unit) due to the redistribution of the medium quantum density (Leonov, 2018). In 2002, in his patent, Leonov created an energy gradient (Leonov, 2002) due to the use of the conic shape of the operating unit and the effect of an external electromagnetic field with crossing electric and magnetic fields on the conical operating unit.

So far, he has implemented a dozen of methods to create an artificial thrust in various designs of quantum engines: with rotating operating units (conical, disk, linear, magnetic and non-magnetic, etc.), as well as with non-rotating operating units (conical, linear, with the supply of electromagnetic energy in a wide frequency range, SHF energy, thermal energy, with matter gradient density, etc.) (Leonov, 2018).

The justification for the operation of the EmDrive engine designed by R. Shawyer (Shawyer, 2006) can serve as an example of Superunification theory application to the analysis of the structural design of the quantum engine. The principle of engine operation (Figure 6) is associated with the creation of an energy gradient (9) in a conical operating unit, which determines the direction of thrust towards the area of decrease in energy concentration.

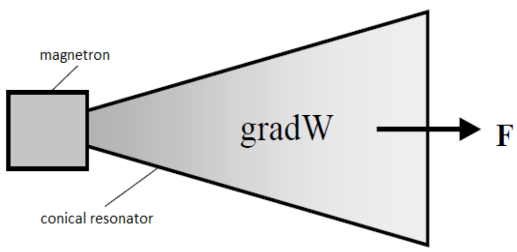

Figure 6. EmDrive microwave quantum engine with a conical resonator (Leonov, 2018)

The thrust ***F*** is created due to the interaction of the gradient SHF field with QST. At the same time, the gradient SHF field creates a gradient of the medium quantum density and energy inside the conical resonator (Leonov, 2018).

Both the magnetron, and conical resonator represent an integral part of QST freely penetrating those. Under the influence of the gradient field, the effect of the "drawing-in" of QST quantons in the diffuser of the conical resonator is observed. Since QST is stationary, the "drawing-in" effect manifests as the movement of the quantum engine in space under the influence of the thrust ***F*** (Figure 6). It turns out that the quantum engine, creating the thrust ***F***, kind of moves in QST (in the front), pushing off this space as from an elastic quantized medium (in the back).

The thrust direction in Figure 6 is conventional. It can vary and even become reverse, depending on the design of the resonator, placement of channels leading from the magnetron to the resonator, characteristics of the SHF field (McCulloch, 2014; White, 2017). This is calculated analytically with the use of equations (9)...(15).

Despite the fact that the theoretical concepts considered in the article still require comprehensive technical approbation and verification from the scientific community, a growing number of patents and operating laboratory prototypes of anti-gravity devices with quantum thrust already give confidence in the appearance of cars with quantum engines – quantomobiles — in the foreseeable future. This determines the need for the automotive industry to consider the following reciprocal actions: to carry out computational and experimental research of thrust in quantum engines, areas of quantum engines' installation in/on the vehicle body, forecasting of quantum engines' multi-functionality and their management.

Let us to attempt to plan R&D activities for the early stages of the creation of quantomobiles: studying the formation and application of the quantum engine thrust, installation of one or several quantum engines.

Stages of conducting R&D activities for the creation of prototype models and batches of quantum cars

Table 1 shows the main layout and time characteristics of those stages.

Table 1. Main layout and time characteristics of stages of conducting R&D activities

Stage	Number of quantum engines in a quanto-mobile	Installation options	Estimated date of the beginning of experimental works
1	1	1–9	First decade
2	2	10–15	Second decade
3	3	16–27	Third decade
4	4	28–35	Fourth decade
5	N	On a random basis	Fifth decade +

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Stage 1 — testing the first prototype thrust quantum engines and diagrams of installation of those quantum engines on automobile chassis of the existing car designs.

Stage 2 — elaborating suspension configuration of a quantomobile with two thrust quantum engines.

Stage 3 — elaborating suspension configuration of a quantomobile with three quantum engines (thrust quantum engines with horizontal vector control).

Stage 4 — elaborating suspension configuration of a quantomobile with four quantum engines (thrust quantum engines with horizontal and vertical vector control).

Stage 5 — elaborating concepts of quantomobiles based on quantum engines of various functionality.

Available space will be surely needed to move and install quantum engines, test various installation diagrams, place laboratory equipment and personnel. Therefore, it is reasonable to use mobile laboratories mounted in a truck (especially at the initial stages).

Figure 7. KamAZ-4911 Extreme vehicle

To represent the conceptual aspects of advancement through the stages, we have chosen the following basic vehicle: KamAZ-4911 Extreme, the one designed for the Dakar rally (see Figure 7). Moreover, the Kama Automobile Plant, with its powerful production and R&D facilities, advanced technologies, inquisitive minds and ambitious aspirations of its team of engineers, can certainly become one of the first manufacturers of future mass-scale quantomobiles.

Stage 1 — testing the first prototype thrust quantum engines and diagrams of installation of those quantum engines on car chassis of the existing automobile designs.

This initial stage will involve the first attempts to design and manufacture prototype quantum engines for cars; attention will be paid to the solution of layout issues, search for optimum main circuits of general-purpose quantomobiles, calculation of overall thrust dynamics,

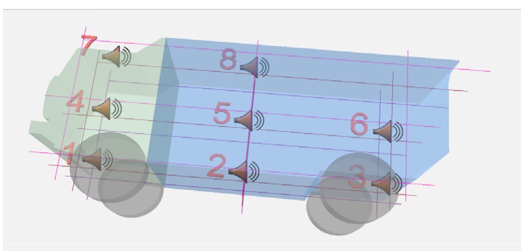

Figure 8. A matrix of the experimental layout for areas of the installation of a single quantum engine

consideration of the vehicle oscillatory system, key issues of ensuring the vehicle steerability and movement safety, as well as the safety of personnel.

Of course, we should start from one quantum engine per car and only with horizontal thrust. The installation of a single quantum engine shall be tested and studied analytically and experimentally at three horizontal levels: in the plane of the wheel axes, in the plane of the floating center of gravity, at the highest point of quantum engine mounting. I

t is also reasonable to test and study the installation of quantum engines in three vertical sections: in the plane (and/or in the front) of the front axis, in the plane with the floating center of gravity, in the plane (and/or in the back) of the rear axis.

Those are presented in Figure 8 in the form of a conventional matrix of analytical and experimental works. Obviously, a single quantum engine should be installed in the central longitudinal-vertical plane. Point 9 is absent as there is no sense to install an engine in that place due to the occurrence of the overturning moment (although it may make sense for a road train).

Stage 2 — elaborating suspension configuration of a quantomobile with two thrust quantum engines.

At this stage, further attempts will be made to design and manufacture prototype quantum engines for cars; attention will be paid to the solution of layout issues, search for optimum main circuits of quantomobiles, calculation of thrust dynamics, consideration of the vehicle vibration system, key issues of ensuring the vehicle steerability and safety issues.

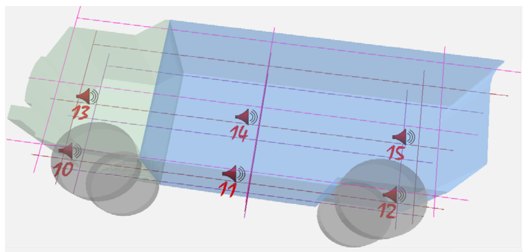

Figure 9. A matrix of the experimental layout for areas of the installation of two quantum engines

As two co-axially installed quantum engines (in comparison with a single quantum engine) improve the longitudinal stability and flexibility of load distribution along the vehicle axes, and provide the possibility of lateral yawing motion of the thrust vector, such issues are added to the aspects of the first stage. A concept of a quantum engine with horizontal vector control is introduced.

The installation of engines shall be tested and studied analytically and experimentally at two horizontal levels: in the plane of the wheel axes, in the plane of the floating center of gravity.

It is reasonable to test and study the installation of quantum engines in three vertical sections: in the plane (and/or in the front) of the front axis, in the plane with the floating center of gravity, in the plane (and/or in the back) of the rear axis.

The Figure 9 shows a matrix of experimental installation areas for quantum engines. Various options (at least 12) can be chosen. Obviously, both quantum engines should be installed in the central longitudinal-vertical plane.

At stage 2, When the soundness of the quantomobile will be fundamentally proved, based on the results of works at stage 1, it is necessary to start early R&D activities in the construction of quantum engines and quantomobiles, and their engineering support.

Stage 3 — elaborating suspension configuration of a quantomobile with three quantum engines (thrust quantum engines with horizontal vector control).

At this stage, R&D activities are continued, with the detailed elaboration of the issues generated at stages 1 and 2. More detailed studies of the longitudinal stability are performed. Studies of the lateral stability start. One of three quantum engines is allocated for controlling the trajectory movement.

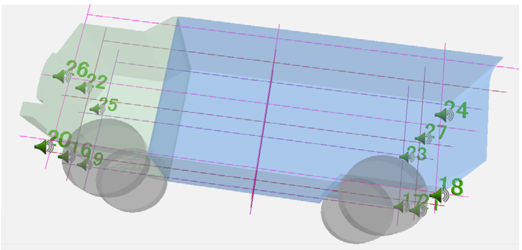

Figure 10. A matrix of the experimental layout for areas of the installation of three quantum engines

The experimental installation layout for three quantum engines consists of four triangles (see Figure 10): 16-17-18; 21-19-20; 22-23-24; 27-25-26. In each of those four junctions, the location of the acute angle of the triangle (located on the longitudinal axis of a car) is foremost in relation to two side locations.

Possibilities of horizontal vector control by means of quantum engines mounted on the longitudinal axis of a car are studied. It is possible to study the partial suspension of a car by horizontal thrust vectors of lateral quantum engines.

Stage 3 requires to continue R&D activities concerning the construction of quantum engines and quantomobiles, and their engineering support.

According to the results of stages 1–3, it is also advisable to prepare monographs, study guides, special training courses for engineers and teachers in this new field.

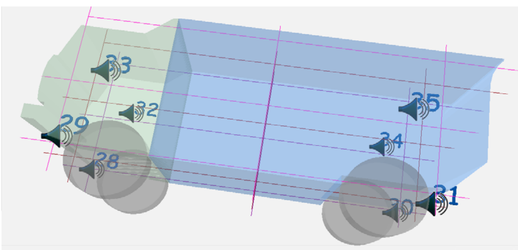

Figure 11. A matrix of the experimental layout for areas of the installation of four quantum engines

Stage 4 — elaborating suspension configuration of a quantomobile with four quantum engines (thrust quantum engines with horizontal and vertical vector control).

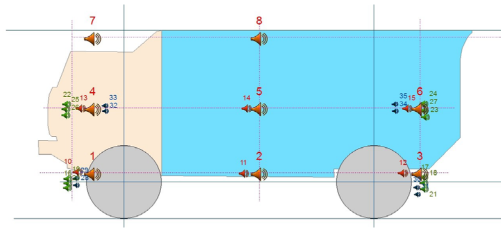

Figure 12. An overall picture of the layout for quantum engine locations for all four stages of R&D activities (lateral view)

Objectives of R&D activities at this stage are as follows: the use of the knowledge accumulated at the previous three stages for the creation of a quantomobile with partial or even complete replacement of the wheel assembly, with the implementation of longitudinal thrust, trajectory and lateral control, as well as the possibility of hovering. Refinement of the quantum engine system (thrust engines with horizontal and vertical vector control) is also provided.

A matrix of the experimental layout is shown in Figure

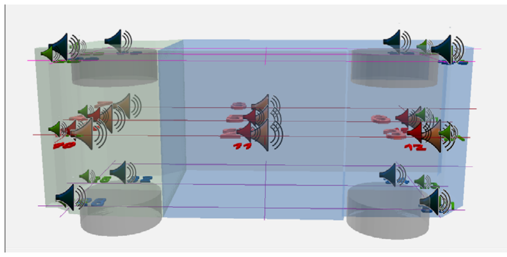

Figure 13. An overall picture of the layout for quantum engine locations for all four stages of R&D activities (bottom view)

11. An overall picture of the layout for quantum engine locations for all four stages of R&D activities is shown in Figures 12 and 13.

At stage 4 it is necessary to implement pilot projects

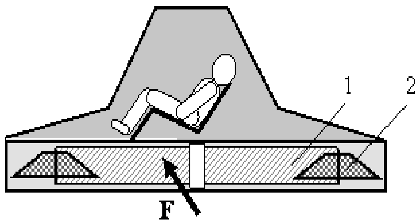

Figure 14. A layout of a flying car with a quantum engine (1); (2) — an activator deforming QST and creating the controllable thrust vector **F**

for the establishment of enterprises for the construction of quantum engines and quantomobiles, and their technological equipment. According to the results of stages 1–4, it is necessary to prepare monographs, study guides, training courses for engineers and teachers in the field of quantum car construction, to introduce relevant specialties in higher and vocational education institutions.

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Stage 5 — elaborating concepts of quantomobiles based on quantum engines of various functionality.

This is the stage of long-term prospects. R&D activities will be devoted to the sophisticated functionality of the quantum engine unit in a quantomobile, possible abandonment of supporting wheels, implementation of the concept of a flying car. This concept was suggested by V. S. Leonov (see Figure 14 (Leonov, 2010a)).

Conclusion

Despite the lack of experience in the field of creation of quantum cars quantomobiles in the world, the overview of the aspects of their staged formation and creation has proved to be possible. In the author's opinion, the tasks of achieving the three-pronged goal set at the beginning of the article have been solved at the conceptual level.

The comprehensive theory of Superunification, acting, among other things, to overcome gravity and inertia forces, will undoubtedly be further developed and improved, both structurally and descriptively. However, even now, after a series of experimental proofs of its provisions concerning the possibility of using the energy of the physical vacuum in technical prototypes and models, this theory can become the basis of computational techniques and engineering solutions for future quantum engines and "fuelless" vehicles, including land vehicles.

This gives an impetus to the permanent preparation of the transport industry for the appropriate re-equipment.

Within the framework of this preparation, the justified staging of R&D activities on the creation of a technical facility, which does not exist yet, is important. Therefore, based on his expertise level, the author made an attempt to present the sequence and contents of R&D activities on the creation of a future quantomobile.

This staged plan may seem too optimistic. But who knows?

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BASIC PRINCIPLES AND PLANNING TASKS OF THE LANDSCAPE AND RECREATIONAL ARRANGEMENT OF THE LADOGA LAKE COAST ATTRIBUTABLE TO AREA FEATURES

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Abstract

The paper discusses natural and climatic characteristics of Ladoga Lake coastal areas and their influence on the landscape and recreational arrangement of the coast. Basic principles of spatial arrangement are provided which are based on the continuity of the natural and environmental structure and the continuity of recreation areas and points of attraction backed by transport and pedestrian connections. The rugged terrain of Ladoga Lake coastal areas can and should be used as effectively as possible for creation of a landscape and recreational space. Due to climatic characteristics, special attention should be paid not to beach recreation but to other types of recreation and health improvement based on unique and diverse natural constituents of the Ladoga Lake coast. A spatial arrangement model of recreational functions should be able to transform considering the seasonal use.

By virtue of natural and climatic factors, terrain features, historical and cultural significance of the Ladoga Lake coast, nature tourism (eco-tourism) should become one of the basic directions for arranging recreation areas. Assurance of the preservation and sustainable restoration of natural resources (water resources, forest resources, etc.) through provision of an integral natural and environmental structure of the area gains paramount importance in the process of arranging the landscape recreation.

Keywords

Natural and climatic features, natural and environmental structure, landscape and recreational arrangement, Ladoga Lake coast.

Introduction

Coastal areas include historical types of landscape and have a significant natural and recreational potential. The Ladoga Lake coast is capable to stabilize ecologically a significant area, provide the population of the Leningrad Region and the Republic of Karelia with a wide range of recreational functions, a variety of recreational activities and types of recreation, health improvement and tourism.

Ladoga Lake is a major source of water supply being a part of the Volga–Baltic Waterway and the White Sea–Baltic Sea Canal. Processes of its active development trigger the need for the elaboration of new principles and foundations for the landscape and recreational arrangement of coastal areas, creation of specific models in conditions of the North-West of Russia. Those should be based on preservation and enhancement of natural constituents of the landscape, opportunities for improving the quality of the environment, arrangement of recreation areas, tourist routes, recreation centers.

To ensure efficient implementation of the basic principles and methods of the landscape and recreational arrangement of a large water body coast, a differentiated approach is required considering numerous conditions and factors, such as the area urbanization level, geographical, natural and climatic characteristics, cultural and historical image of the area.

By now, priorities of social and economic development for settlements in municipal districts of the Leningrad Region and the Republic of Karelia have been legislatively determined, general layouts and land-use planning

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schemes have been prepared. However, no coherence in planning and management with regard to the Ladoga Lake coast can be achieved. There is no long-term strategy and conceptual models for the development of coastal areas, no historical, urban-planning, theoretical, methodological or legal basis for the development and adoption of spatial planning solutions. The existing structure of recreation is characterized by disorganization, fragmentation and lack of uniformity, there is a tendency of linear development of recreation areas along the coastal lines with fragments of deep integration — perpendicular to the coastline, appearance of individual recreation centers in the form of holiday hotels and resorts, arrangement of seasonal tourist routes along the coast and islands of Ladoga Lake.

As for coastal areas, when arranging the landscape recreation, the "dominant resource type" (a term suggested by V. V. Vladimirov) is a water body itself the influence of which on the coastline is reflected in terrain and climate.

Theoretical and methodological background

In the course of any type of territorial planning, a number of tasks arise which are to be solved in various aspects of the territory development. Among such aspects in relation to the landscape and recreational arrangement of the coast the following can be distinguished: functional, cultural, aesthetic, ecological, territorial, environmental, social and economic aspects.

The functional aspect involves the formation of new ways of use and revitalization of coastal areas as a basis for the urban-planning arrangement of the environment, as well as the formation of new relations and point of attraction, buffer zones between sites of various purposes.

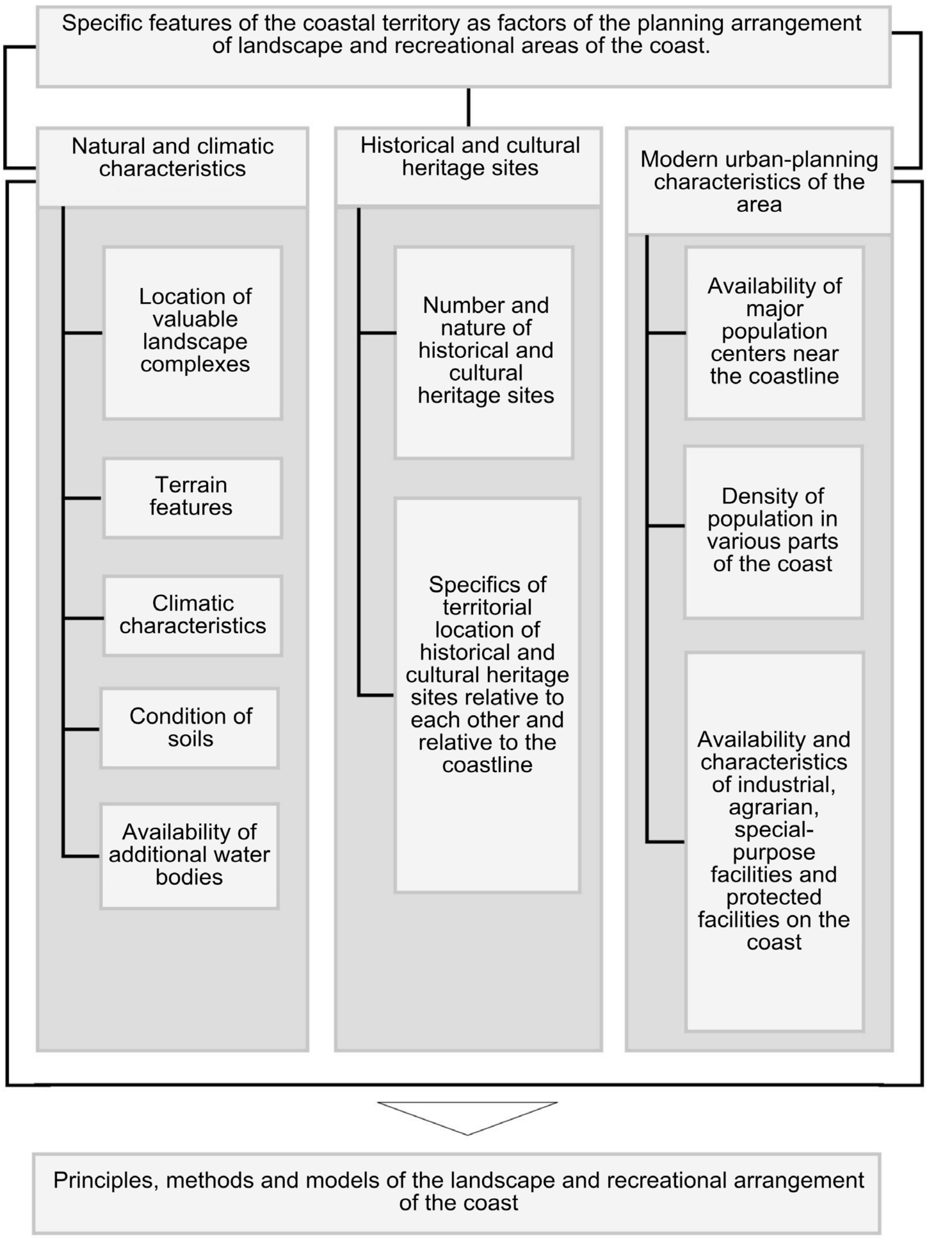

Figure 1. Specific features of the coastal territory as factors of the planning arrangement of landscape and recreational areas of the coast

Attention to the *cultural aspect* is evident in studies and restoration of traditions and cultural heritage, assurance of the historical connection of cultures. The creative potential of water spaces is unlocked by creating new forms of development and design of coastal areas with regard to latest trends and promising directions of cultural development.

When arranging the landscape recreation of the coast with regard to *aesthetic aspect*, the aims are to form new qualities and preserve the valuable existing features of the landscape image, draw attention to the importance of the natural constituent of the environment and enhance the role of the water space.

The ecological aspect consists of providing conditions for protection and sustainable use of natural resources, preventing the degradation of coastal landscapes under the influence of recreational activities through regulatory and legal control, approval of urban-planning regulations and protective measures, and implementation of environmental and biological measures.

The territorial aspect of the landscape and recreational arrangement of the coast implies the development and adherence to the principles of the arrangement of recreational facilities in conjunction with population centers, industrial, transport, engineering and other facilities, transport and pedestrian infrastructure, protected natural areas, as well as the arrangement of recreation areas of various use intensity, functions and specifics of seasonal activity if compared to each other.

The environment aspect implies the establishment of the favorable environment for the landscape and recreational arrangement through architectural and engineering structures, amenities. The variety of landscape recreation provides the conditions for the development of diversified recreational formations, thereby contributing to the implementation of the functional aspect of coast development (Pankeyeva, 2011).

The elaboration of models, principles and strategies for transforming the landscapes of coastal areas into recreational ones should be carried out by assigning and

Table 1. Landscape and geographical characteristics of the Ladoga Lake coast

Location of the Ladoga Lake coast	Landscape and geographical characteristics	Features of the coast having recreational value	Administrative affiliation
Northern, north-eastern, north-western coast	- a rocky coast with deep narrow bays (similar to Norwegian fjords in miniature); - granite and gneiss cliffs rising above the water; - small and high skerries abundant at bays and their outlets. Islets of skerries are always covered with pine forest.	- picturesque rocky esker hills covered with coniferous forest (Figure 2); - over six hundred skerries, the largest of which are Riekkalansari, Mantsinsaari, Lunkulansaari, Kilpola, Valaam, Konevets; - two gulfs: Lunkulanlahti and Uuksunlahti separated from the lake by one of the largest islands of the Ladoga — Mantsinsaari.	Republic of Karelia, Priozersky District, Leningrad Region
Eastern coast	- the coast is flatter than the northern one; - the rocks intersperse with sandy areas.	- wide sandy beaches including 50 m wide beach with dunes overgrown with pine forest, located in the area from the Olonets town to the Svir river outlet	Lodeynopolsky and Volkhovsky Districts, Leningrad Region
Western coast	- the coast is slightly indented; - dense mixed forest and shrubbery located close to the coastline along the boulder-strewn ground; - dangerous underwater shelves due to a ridge of stones stretching from the capes far into the lake.	- a variety of vegetation typical for zones of the middle and southern taiga; - a plain coast.	Priozersky and Vsevolozhsky Districts, Leningrad Region
Southern, south-eastern, south-western coast	- the coast is flat, slightly indented, covered with pebbles and boulders; - availability of wetlands since the coast is flooded due to the neotectonic submeridional distortion of the lake; - a large number of shelves, stony reefs and banks; - bed of rushes and reeds on the coast.	- three large bays: Svirskaya, Volkhovskaya and Shlisselburgskaya bays; - a plain coast (Figure 3).	Kirovsky, Volkhovsky and Vsevolozhsky Districts, Leningrad Region

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Figure 2. Rocky esker hills of the Ladoga Lake, a photo (https://sezony-goda.rf/Ladozhskoe%ozero.html)

solving issues within each aspect of spatial planning. In this case, the potential of the coastal area itself, its features and characteristics represent factors assessment and analysis of which allows determining methods for arranging the landscape recreation of the coast.

The ratio of landscape environment constituents varies from place to place, and such constituents become primary or secondary factors only depending on specific natural, social, urban-planning conditions (Figure 1).

Spatial planning tasks when forming a recreational structure of the area

The coastal line of Ladoga Lake is over 1000 km. When arranging the recreation of the Ladoga Lake coast, the availability of forest and lake landscapes at the places where rivers flow into the lake (more than 40 rivers in total) and just one river, the Neva, flows out, is of particular importance. The largest rivers flowing into Ladoga Lake: the Vuoksa, the Volkhov and the Svir.

Natural and landscape characteristics of the area are conditioned by its geographical location in the north-west of the European part of Russia. The border of the middle and southern subzones of taiga passes through the Ladoga area, the direction of this boundary is submeridional. The eastern and northern parts of the Ladoga area belong to the middle taiga subzone, and the north-western, western and southern parts of the Ladoga area belong to the southern taiga subzone. The convoluted history of the area development ¬at the junction of two tectonic structures¬ resulted in the formation of a large variety of landscapes (Table 1).

Typical features of the natural terrain of Ladoga Lake coastal areas include: 1) a diversity of terrain from plain one on the southern, south-western and south-eastern coast to rocky one, with pronounced layers and terraces, on the northern coast; 2) abundance of forest and river landscapes, including the places where the large rivers Svir, Vuoksa and Volkhov flow into the lake; 3) a developed network of ravines and draws in the places where rivers flow into the lake; 4) a significant number of wetlands, increasing towards the southern coast; 4) tectonic destruction; 5) availability of three large bays on the southern and south-eastern coast, as well as many narrow bays on the northern coast (Rumyantsev, 2012) (Alyabina, 2010).

In case of the rugged terrain, the development of recreational functions should consider the geomorphological parameters. Since the Ladoga Lake coast is characterized by the difference in elevation (from rocky hills to low flat areas of the coastline, it is reasonable to use the terracing method to perform space zoning with steps, landscaping of individual sections of horizontal shore cusps considering their features.

In order to develop a planning structure of the Ladoga Lake recreation in depth from the coastline, it is necessary to ensure cross-linkages: mountainous plateau–flat coast. At the places where the coast is flatter and terrain features are less pronounced, the spatial development of recreation areas is largely dependent on the functional-planning structure of recreation centers. When arranging the landscape recreation, the river terraces, which are abundant on the coast of Ladoga Lake, provide a high potential.

The natural structure of the Ladoga Lake coast is formed by areas with different functional purposes:

- federal, regional and local nature reserves;
- forest areas and protection forests;
- areas of lowland river landscapes;
- landscapes of open spaces and recreation areas, including agricultural and recreational areas.

In the territory of the Ladoga Lake coast, on the side of the Leningrad Region, such nature reserves (NAs) as the state Nizhne-Svirsky nature reserve and the state Kokkorevsky nature reserve are located. The Republic of Karelia hosts the Olonetsky state federal nature reserve, Tuloksky nature reserve, North-Ladoga state game reserve (faunal area), Sortavala botanical reserve, medicinal plants reserve (common bearberry) and other regional reserves (Vampilova, 2008).

In order to preserve the ecosystems of the lake water area coast, the Administration of the Leningrad Region intends to create a number of other regional NRs: Svir River mouth, Juniper communities of the Cape Shuryagsky, Southern Ladoga, Zelentsy Islands, Morye (Osnovnoy), Kuznechnoye, Motornoye–Zaostrovye (Government of the Leningrad Region, 2012).

NRs, both the existing and future ones, valuable forest and river landscapes impose certain restrictions on the recreational arrangement of the Ladoga Lake coast, however, they are the key to environmental stability and the basis for preserving the natural and landscape environment.

The specific character of seasonal recreational activity mainly depends on climatic features such as the duration of cold and hot periods, maximum temperatures, typical winds and humidity. The climate of Ladoga Lake is moderate, transitional (from moderately continental to moderately marine). This results from a relatively small amount of solar heat. A passage of a cyclone which determines the weather at Ladoga Lake is accompanied by the change of a south wind carrying heat to a cold north wind. Sometimes, when cyclones pass to the north, an anticyclone manages to wedge in. Then it is hot in summer and cold windless and sunny weather in winter.

Due to the small amount of solar heat, moisture evaporates slowly. In average, there are 62 sunny days per year. Therefore, during most of the year, cloudy days with scattered lighting prevail. The day length varies from 5 h 51 min during the winter solstice to 18 h 50 min during the summer solstice. "Twilight all night" can be observed over the lake during more than 50 days.

Due to climatic features, the coast of Ladoga Lake has seasonal arrangement of recreational activities. The summer period is characterized by increased intensity of using the coast for recreation, mainly in the areas of a flat coast with beaches, an increase of mobile recreation in the coastal area. In winter, recreational activities in the coastal area actually stop. Prime attention shall be given not to beach recreation but to the selection of recreation and health improvement types based on the variety of natural constituents of the Ladoga Lake coast and on the value and uniqueness of historical and cultural heritage sites.

Ladoga Lake and its basin host a number of monuments of history, architecture and culture attracting (or having the potential to attract) tourists. Among the monuments of architecture, the following can be mentioned: the Korela Fortress (13th–14th centuries), the Valaam Monastery (992), the Petrokrepost Fortress (1323), the Konevsky Monastery (1393), the first capital of Russia, Staraya Ladoga, etc. A number of historical monuments are located in the Karelian and Novgorod parts of the Ladoga basin. Tourist routes pass through Ladoga Lake to other regions.

The famous historical waterway "from the Varangians to the Greeks", connecting Northern Europe, the Baltic States and Veliky Novgorod with the countries of the Mediterranean region, passed through Ladoga Lake. As studies show, the greatest concentration of attractive heritage sites is located along the ancient water-and-portage routes and near water bodies. In the opinion of Yu. A. Vedenin, the ancient water-and-portage ways are the most valuable objects of natural and cultural heritage requiring in-depth study and protection (Vedenin, 2009).

Current activities on the coast of Ladoga Lake are related to the life of people in such cities as Priozersk, Novaya Ladoga, Syasstroy, Vidlitsa, Pitkyaranta, Impilahti, Sortavala, Lakhdenpokhya and others. Therefore, the arrangement of recreation areas within walking distance with horizontal connections, providing access to the coast and valuable landscape and recreational complexes of residents of nearby cities, is of particular importance (Zadvoryanskaya, 2009).

The main spatial and planning tasks for provision of the landscape recreation of the Ladoga Lake coast can be described as follows:

- a differentiated approach to the arrangement of the landscape recreation considering the complexity of the terrain structure, in particular, geomorphological parameters;

Figure 3. Southern coast of the Ladoga Lake, a photo (https://sezony-goda.rf/Ladozhskoe%ozero.html)

- arrangement and improvement of tourist routes allowing assessing the diversity of terrain and natural features of the coast in the most comprehensive way possible, increase the attractiveness of landscapes for studying;
- active participation of water resources in the formation of recreation areas, including through the use of additional utility systems and water transport;
- provision of year-round recreational activities through the formation of recreation areas considering the seasonality of their use and development of a flexible system of spatial arrangement which can be transformed depending on seasonal features;
- provision of infrastructure of indoor facilities for public and recreational purposes in the structure of green spaces and major tourist routes, including creating conditions for the development of winter recreation and active sports;
- arrangement of zones of various visiting intensity and functional use; sites aimed at more or less active types of recreation;
- creating conditions for exploring and studying historical and cultural monuments, artifacts of the cultural landscape by including them in pedestrian routes, arranging museum, educational and exhibition centers;
- alternation of recreation areas with the territories of specially protected and valuable natural complexes and nature reserves;
- preservation of the coastline for recreation by constructing the main roads no closer than 500 m from the water's edge with minimum traffic in the coastal area, limiting the development of the coastline with a width of 100 m;
- arrangement of a system of pedestrian spaces in the coastline and horizontal connections between the coastline and main roads;
- removal of industrial and agricultural enterprises and utility services, not related to water intake facilities, beyond the coastal¬ recreation area;
- saturation of coastal areas located near urban centers with recreation areas (Litvinov, 2011).

Assurance of the preservation and sustainable restoration of natural resources (water resources, forest

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resources, etc.) through provision of an integral natural and environmental structure of the area gains paramount importance in the process of arranging the landscape recreation of the Ladoga Lake coast. The valuable cultural and historical, scientific and educational, urban-planning objects and sights allow making the landscape recreation diverse and educationally interesting (Tukmanova, 2011).

By virtue of natural and climatic factors, terrain features, historical and cultural significance of the Ladoga Lake coast, creating the conditions for nature tourism (eco-tourism) may become one of the basic directions for arranging recreation areas. Nature tourism means visiting natural and cultural landscapes to explore geological and geomorphological as well as water objects, flora and fauna, monuments of nature, history and national culture for scientific and educational, nature protection and other purposes.

Some Russian regions have already created natural (ecological) routes and trails, for example, in the Baikal region, the Urals, the North Caucasus and the Krasnoyarsk Krai, etc. (the Silk Road, the Small Bear Trail, the Great Baikal Trail). However, in Russia, nature tourism has not yet become widespread due to the lack of long-term prospects for the development of tourist routes (Olifir, 2016) (Akhobadze, 2009). Natural aspects encouraging modern tourism on the coast of Ladoga Lake may be related to such directions as eco-tourism, agrotourism, rafting, diving, wildlife viewing, trekking, etc. Waterways near the northern islands are popular routes among tourists. The picturesque nature of Ladoga Lake (especially its northern skerry part) offers prospects for the development of recreation which can be combined with amateur fishing and other forms of active outdoor recreation.

In 2012, the State Program for the Development of Tourism in the Russian Federation for 2013–2020 was adopted. It provides for priority in the development of inbound and domestic tourism in comparison with international tourism. It is domestic tourism that is the basis for identifying and advertising exotic objects and tourist destinations. For this purpose, Russia offers favorable prospects and resources, and one of such resources is the largest water body in the territory of the Leningrad region and the Republic of Karelia — Ladoga Lake.

The lack of a sufficient legislative base in the field of ecology, legal regulation and control over the use of the resources of Ladoga Lake, as well as the lack of coordinated functioning of regional administrative, social and urban-planning institutions hamper the achievement of future sustainable development of the landscape and recreational arrangement of the coast.

Due to the existing system of economic development, economy structure, growth of population in the Leningrad Region, the coast of Ladoga Lake is subject to high human-induced impact. Meanwhile, Ladoga Lake as the largest freshwater body in Europe is of great importance for maintaining the ecological stability in the North-Western region and creating zones and centers for recreation and health improvement. The combination of diverse forest areas, vast water areas, upland and lowland bogs, rocky hills and beach areas of the coast determines the species wealth of flora and fauna, as well as the diversity of natural complexes.

The coastal landscape of Ladoga Lake has a number of features that, although causing a lot of difficulties in planning the routes, are interesting for creating broad prospects and memorable looks. As for natural and geographical features of the coast, ridge-hilly terrain predominates alternating with flat plateau, wetlands in the southern part, fjords and skerries in the northern part of the Republic of Karelia. Features of the coastal landscape should be used as effectively as possible in planning and creating a common landscape-recreational and spatial composition. Moreover, the model of the spatial arrangement of recreational functions should be transformable considering seasonal use.

The value of natural landscapes and historical and cultural heritage of Ladoga Lake coastal areas allows us to conclude that it is necessary to create a unique image of the coast for the purpose of forming a social space. This image can and should be based on nature (eco-) tourism in combination with other types of tourism (cultural and historical (educational), pilgrim (religious), archaeological, event, ethnographic, etc.).

This tourist destination will allow us to fully appreciate the diversity of terrain and unique natural features of the coast, increase the urban-planning importance of monuments of geology, history, culture, architecture. In the course of territorial planning and modeling of spatial development systems for recreational functions, it is necessary to consider the principles of environmental sustainability, allocating and arranging nature reserves and areas of specially protected natural monuments, landscape recreation and eco-tourism on the coast.

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STUDIES OF THE MORPHOLOGY OF WATERPROOF COATINGS BASED ON URETHANE ISOCYANATE, ALKYL-PHENOL-FORMALDEHYDE RESIN AND DIBUTYLTIN DILAURATE USING THE HIGH-RESOLUTION OPTICAL MICROSCOPY TECHNIQUE

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Abstract

A study of the morphology and structure of waterproof film coatings based on polyurethane isocyanate, alkyl-phenol-formaldehyde resin and dibutyltin dilaurate with finely dispersed iron-oxide filler depending on their production method (solution method or melting method) using the high-resolution optical microscopy technique was carried out. When obtaining polymer composites (films), the authors varied the ratio between the main components of the polymer matrix, urethane isocyanate and phenol-formaldehyde resin (1:2 or 1:3), and the content of the finely dispersed iron-oxide filler in relation to the polymer binding medium (0.1, 0.6 and 1.2 wt%).

In the modes of bright field, phase contrast and crossed nicols, the homogeneity of the obtained films, their structure, aggregation capacity and distribution uniformity of the powdered iron-oxide filler as a part of the polymer matrix, were investigated.

The obtained composite material in the form of film coating or adhesive repair compound can be used for waterproofing, repairs and corrosion protection as film coatings of water and underwater hydraulic structures.

Keywords

Waterproof film coatings, urethane polymers and co-polymers, solution and melting methods of film production, iron-oxide filler, microscopy, morphology, structure.

Introduction

Building structures, reinforcement elements and constructions of dams and bridges, supports of submerged pipelines, areas of periodic wetting of port facilities, etc. are constantly subjected to external adverse factors, moisture and water, which contribute to their early destruction (Alkhimenko, Zastrizhnaya, 2016).

It is very important to provide protection of structures against destructive effects of water and moisture at the stage of construction or repair works, as well as during the use of construction facilities. Waterproof coatings made of solid waterproof polymer films, as well as waterproof coating materials and rolled materials are used for this purpose. Works to ensure the safety of structures through overhaul are constantly performed at most important hydraulic facilities (Baydukov, 2017; Balakin et al., 2017; Matveeva et al., 2016). Depending on the conditions of operation and purpose of structures, various waterproof materials creating a solid and reliable waterproof layer are used to protect the facility against destruction. In building structures, waterproofing protects external surfaces of walls, foundations, basements and underground structures contacting with water or soil. Underwater sections of hydraulic facilities and structures in constant contact with water are of special concern and need special protection.

To perform repair and restoration works (sealing of cracks and joints of structures, repair and arrangement of an additional protective layer, etc.), it is important to select proper materials. There is a number of requirements to properties of materials. First of all, those are: high adhesion, compatibility with old materials, ability to solidify under water, corrosion stability, cold-resistance, waterproofing, strength, resistance to shrinkage and some other properties.

New effective materials and techniques of their use allow not only extending the operational lifetime of built hydraulic structures, but also designing and constructing concrete and reinforced-concrete facilities with significantly extended operational lifetime and less operating costs (Matveeva et al., 2016, Belan, 2017; Scientific & Production Center for Materials and Additives, 2017).

Polymer film materials and coatings based on such materials belong to the category of penetrating waterproof materials. In most cases, those are liquid polymer compositions applied to the surface being protected against water to ensure structure waterproofing and sealing.

Polymer compositions based on polyurethanes are the most efficient due to a complex of chemical, as well as physical and mechanical characteristics, adhesion strength, reliability and durability (Matveeva et al., 2016, 2017; Scientific & Production Center for Materials and Additives, 2017; Meier-Westhues, 2009).

Additional chemical or physical and chemical modification of polyurethane elastomeric materials, as well as co-polymerization with other functional monomers and compounds allows improving the operational characteristics of waterproof polyurethane compounds and extend the scope of their application in construction (Meier-Westhues, 2009; Matveeva et al., 2016).

Experimental procedure

To obtain protective film coatings, the following primary components of the composite material were used:

– urethane isocyanate (Trifor), oligomeric product produced by the Research Institute of Synthetic Rubber (FGUP NIISK), Saint Petersburg, according to Specification 38.433809–95 (TRF);

– alkyl-phenol-formaldehyde resin (PFR), a product of condensation of liquid alkylphenols with formaldehyde in the alkaline environment; Specification 2228-352092208–96;

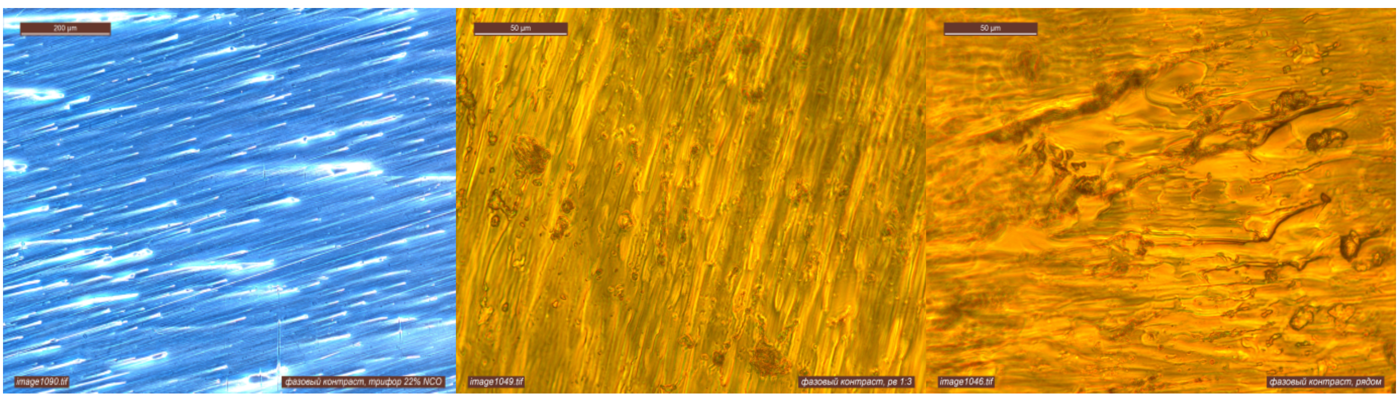
– iron-oxide concentrate (IOC) with a mass fraction of Fe2O3of at least 96%; dispersity — 25 μm max; State Standard GOST 18172–80;

– dibutyltin dilaurate (DBTDL), a synthetic organotin compound produced by FOMREZ CATALYST SUL-4"; CAS No. 77-58-7. Appearance: light yellow viscous homogeneous liquid, no sediments or foreign substances; mass fraction of tin, % — 18.2–18.9; at 25–30°C, viscosity is 35–60 cP; density at 20°C — 1.05 g/cm^3. DBTDL is used in the catalysis of adhesives, sealing materials and silicone polymers vulcanized at room temperature. It is also often used for polyurethane-based paint systems.

Film coatings represented mixture composites based on urethane isocyanate (Trifor) with 22 wt% of NCO-groups, alkyl-phenol-formaldehyde resin (PFR), and dibutyltin dilaurate (DBTDL), with iron-oxide finely dispersed filler depending on the ratio of the main components TRF:PFR — 1:2 or 1:3, and content of the filler IOF — 0.1, 0.6 and 1.2 wt% in relation to the polymer binding medium.

For studies of the morphology and structure of waterproof film coatings, an instrumental analytical complex based on a research optical microscope *Leica DM–2500*, digital camera with Peltier cooling *Leica DFC–420C* capturing high-resolution color images, and a special computer station were used. Image capturing, archiving and quantitative processing were performed with the use of the relevant software — *Leica Las*.

Samples were represented by polymer films with a thickness of 0.25–0.5mm laid between the object plate and cover glass. The films were produced by the following methods: 1) solution method, i.e. by combining components in an inert solvent environment; 2) melting method, i.e. preliminary heating until viscosity is reduced and components transfer to a state of viscous flow with subsequent mixing. The samples were studied using the method of high-resolution optical spectroscopy in the transmission mode using bright field, phase contrast and crossed nicols. The study results were obtained as high-resolution color microphotographs.



a b c

Figure 1. a) TRF, phase contrast mode; b) PFR + TRF solution, phase contrast mode; c) PFR + TRF melting, phase contrast mode

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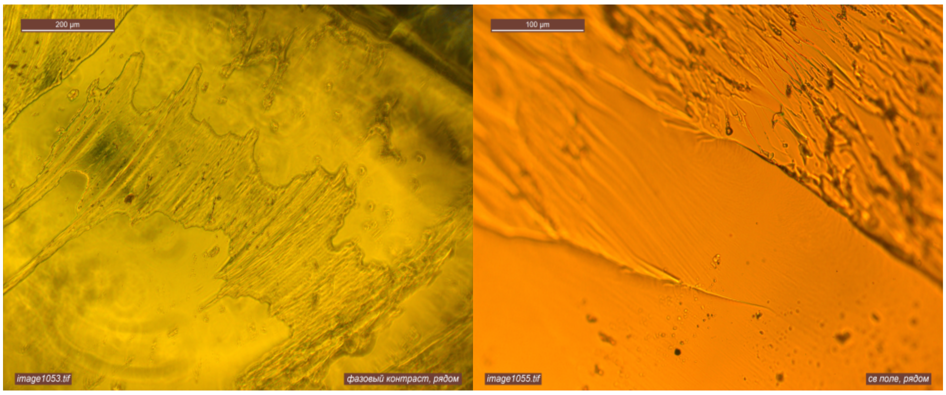

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Figure 2. Microphotographs of films produced by the melting method:
a) phase contrast mode; b) bright field mode

In total, in the course of the study, 66 images (pictures) with a total volume of 632 MB were obtained. They reflected both primary components of the compound and film coatings with various ratio of primary components of the material, obtained using different methods.

Discussion

The morphology of most mixtures of two polymers depends on the structure of primary components and an interphase transition layer formed as a result of diffusion of macromolecule parts in the polymers in contact. When two polymers are in contact, due to diffusion of individual parts of macromolecules, a transition layer can form. Its thickness depends on the interacting force of component molecules and some other factors.

If the interaction between macromolecules of different polymers is stronger than the forces of intermolecular interaction in individual components, then the probability of the formation of a homogeneous one-phase system with a corresponding technique of mixture production will be rather high.

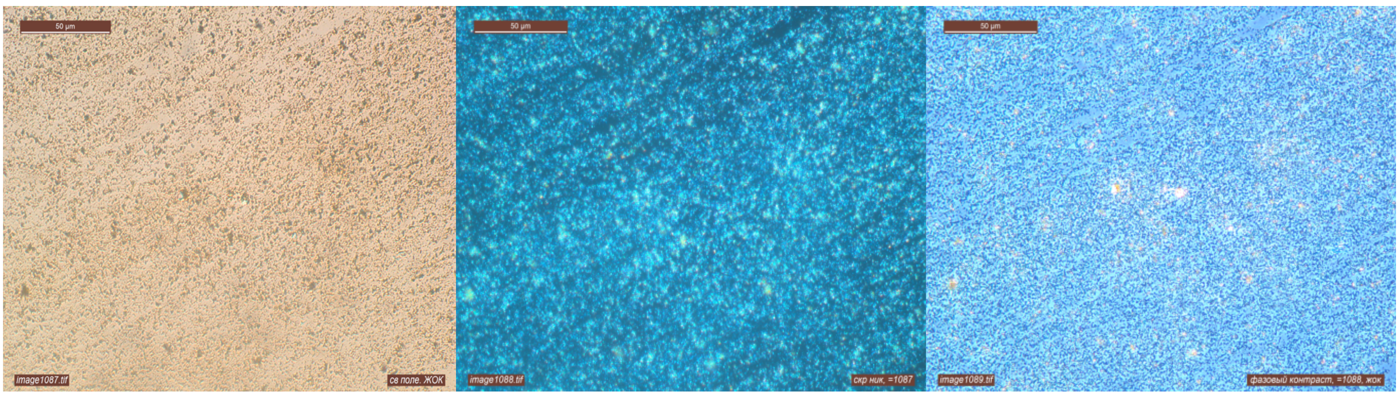
Otherwise, if the forces of intermolecular interaction of individual parts (components) of molecules are stronger than the forces of interaction between molecules of different polymers in the mixture, then the system will be heterogeneous and two-phase. Completely homogeneous mixtures of polymers are quite rare (Kuleznev, 1980; Tkhakakhov, 2013).

In the course of data processing and analysis, it was established that the main primary component (Trifor) and compounds based on it had a layered structure in the absence of the filler (Figure 1a). Individual internal layers can be easily detected, their sizes are from 0.2 to 5 μm. The most uniform alteration of PFR and TRF layers is provided by the solution method when films are produced using toluene solvent at the of ratio 1:2 to the total mass of the compound (Figure 1b). In case of the ratio of 1:3, layering of films does not decrease; polymer clots and pile-ups are also observed in the film structure (Figure 1c).

The compounds produced by the melting method are characterized by a noticeable gradient of concentration of primary components throughout the whole volume (Figure 2a, b) as is evidenced by lines and spots, non-homogeneous in thickness, in optical microphotographs in the phase contrast mode.

Apparently, such method of compound production does not provide uniform distribution of components in the mass and formation of a homogeneous film coating.

The iron-oxide concentrate (IOC), in the absence of binding components, has a finely dispersed structure, with



a b c

Figure 3. Microphotographs of polymer films filled with the IOC based on PFR + TRF in the mode of: a) bright field); b) crossed nicols; c) phase contrast

a size of particles of 25–45 μm and low tendency to the formation of aggregates.

Introduction of the IOC into the polymer compound PFR + TRF is accompanied by the increase of the volume fraction and size of the optically dense dispersed phase with apparent diffusion boundaries (Figure 3a–c). The range of aggregate sizes varies from 3 to 108, 120, 343 μm depending on the content of IOC (0.1, 0.6 and 1.2), respectively.

The studies of waterproof film coatings using the method of high-resolution optical spectroscopy in the transmission mode using bright field, phase contrast, and crossed nicols have shown that the most regular and homogeneous in terms of volume morphological structure of compounds occurs during formation of polymer films by the solution method with the mass ratio of the components PFR:TRF — 1:2.Introduction of the finely dispersed iron-oxide filler into the polymer matrix results in the formation of a heterogeneous structure of films with the aggregate sizes from 0.3 to 7 μm, with the filling degree of 0.6 wt% (Figure 3a).

The sizes of the dispersed phase increase symbatically with the increase in the content of the iron-oxide filler in the system, distribution of the IOC in the volume of the polymer matrix obtained by the solution method is quite uniform (Figure 3a–c), and the structure of the film is quite homogeneous.

Conclusions

As a result of the studies, it has been established that when preparing a waterproof (or adhesive) mixture composite material based on a polymer matrix composed of PFR, TRF and IOC filler, and subsequent formation of film coatings, the solution method shall be preferred. S

Since it provides composition which is more homogeneous in volume with relatively uniform distribution of the heterogeneous phase — iron-oxide filler. The optimum ratio of the polymer matrix components PFR + TRF shall be 1:2.

The amount of the iron-oxide filler affects the viscosity (consistence) of the compound and determines the purpose of the compound (covering, adhesive repair, crack sealing compounds, etc.) in the set range of concentrations of 0.1, 0.6 and 1.2 wt%; the filler is distributed in the volume of the polymer matrix quite uniformly. It can be expected that the distribution uniformity of the compound components and, respectively, the heterogeneity of the formed films will help ensure reliability and sufficiently long operational lifetime of the waterproof protective coating (or adhesive coat) in the conditions of active water environment influence.

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CONCERNING OPTIMIZATION OF THE SYSTEM MANAGING OPERATING AND TECHNICAL TRAFFIC MONITORING MEANS

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Abstract

Relevant issues of transport machinery functioning when using operating and technical monitoring means in the field of traffic safety assurance are revealed. Methodological approaches allowing determining the implementation degree of management functions assigned to the traffic monitoring system in a particular region are proposed.

A stochastic model for the evaluation of performance efficiency of the subdivisions, institutions and organizations ensuring the implementation of monitoring functions using automated traffic enforcement systems (ATES) is determined. Results of the study conducted include developed models, as well as a method and algorithm for optimizing the structure of the system managing operating and technical means of transport machinery traffic monitoring.

Keywords

Management systems, operating and technical monitoring means, efficiency evaluation criterion, optimization algorithm.

Introduction

The underdevelopment of traffic management systems applied in regions of the Russian Federation when using operating and technical monitoring devices, insufficient qualifications of experts ¬trained in this field, and the limited number of persons capable of determining the ideology of solving tasks for managing the agencies and institutions ensuring the operation of automated traffic enforcement systems (ATES) in regions of the Russian Federation prove the significance of the gap between management practice and theory and, thus, reveal the need to develop a method for the evaluation of functional efficiency of the system managing operating and technical means when using ATES.

The professional literature does not contain any works on the theory of traffic management using operating and technical monitoring systems, based on the description of their functional properties. Developments related to design and intended application of organizational structures ensuring the operation of automated traffic enforcement systems as well as quantitative evaluations of functional efficiency of such structures and numerous subsystems are poorly represented. However, the following general issues were studied in great detail: design of management systems and evaluation of their properties (Popov, 1988); systems for monitoring of dynamic systems (Evlanov, 1972); automated system analysis (Stabin et al., 1984); systems science and potential efficiency of complex systems (Fleishman, 1982), information reliability in such systems (Melnikov, 1973); structure evaluation (Tsvirkun, 1982), and structural analysis (Nechiporenko, 1977). The corresponding developments were implemented in various fields and can be used as a scientific base for studies on the issue discussed in this article.

Main Part

A concept as a system of views, ideas and principles constituting a general methodology for control over a complex systemic object applied to an ATES system is based on the following provisions:

- recognition of traffic safety as a property of a purposefully functioning ATES, and recognition of managing this property as elimination of the possibility for system operation in modes that do not comply with the standards and lead to road accidents;
- recognition of the following as the main monitoring tasks defining the management structure of the corresponding monitoring subsystem: obtaining information on the

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actual state of all ATES components, calculating the subsystem state parameters and corresponding quality indicators on the basis of such information; making decisions on their compliance or non-compliance with the regulatory requirements to system functional performance; determining causes for non-compliance and corresponding remedial measures;

- recognition of monitoring as a necessary price for obtaining information ensuring purposeful functioning of the entire ATES and implemented on the basis of the corresponding financial, physical and other resources;

- recognition of automating the processes of the system managing operating and technical monitoring systems by means of improving the quality and efficiency of the monitoring subsystem without changing its functions.

Activities of organizations in the field of managing operating and technical traffic monitoring systems represent a set of interrelated procedures aimed at achievement of a specific goal. Ordered actions aimed at solving the task of traffic monitoring with the use of automated traffic enforcement facilities to a specified level represent the procedures. Work as a procedure with tangible results is expressed by the following tuple (equation 1):

$$x_i = (a_i, b_i, T_i) \quad (1)$$

where *i* — work (procedure) index;

$a_i = (a_{i1}, a_{i2}, ...)$ — vector of the parameters characterizing the work result;

$b_i = (b_{i1}, b_{i2}, ...)$ – — vector of the resources allocated for work performance and achievement of the result;

T_i — time required for work performance.

Adverse events characterized by ATES failures and defects as well as erroneous actions and violations of regulatory documents can occur upon performance of monitoring functions. Indicators describing those events represent the initial information for analysis, evaluation and study as well as development of activities and decision-making.

The evaluation of the performance efficiency of subdivisions, institutions and organizations ensuring the implementation of traffic monitoring using ATES is carried out according to such generalized criterion as the level of traffic safety P_{TS}. A method for the evaluation of the performance efficiency of subdivisions, institutions and organizations ensuring the implementation of traffic monitoring using ATES represents an established sequence of activities.

To evaluate the impact of the automated traffic enforcement system on traffic safety, it is necessary to conduct studies at several levels: at the first level, it is necessary to give an absolute estimate to the road accident; at the second level, it is necessary to analyze the impact of the automated traffic enforcement system on the number of road accidents, taking into account the accident place and type.

Information about each road accident suitable for the evaluation of system performance includes the following:

- the name of the section where the road accident was recorded;
- the date and time of the road accident;
- the place of the road accident;
- the lane where the road accident occurred and direction of the traffic;
- the road accident cause;
- the state of the road surface at the moment of road accident occurrence;
- weather conditions observed at the moment of road accident occurrence;
- the description of the road accident.

At the second level, the evaluation shall be based on the analysis and comparison of the traffic situation before and after the start of traffic enforcement system operation. Information about each road accident suitable for the evaluation of system performance includes the following:

- the date and time of the road accident;
- the place (kilometer point) of the road accident;
- the road accident direction;
- the description (type) of the road accident;
- the number of people killed and injured as a result of the road accident.

The best option of the automated traffic enforcement system shall be selected using the methods and software implementing the systemic criterion (the level of traffic safety). The process of creating anthologies (sets of information system objects and their classes which determine object behavior and changes together with the fundamental properties and interrelations between such objects) is greatly simplified in information systems designed for application in the organizations, activities of which are governed by laws and regulatory documents. Upon system formation, it is reasonable to use the following:

- a single hardware and software technological complex ensuring the unification of all procedures for information exchange between organizations and interacting subdivisions;
- a single system of regulatory documents ensuring the unification of the accounting items of public importance by the main attributes.

The level of traffic safety (TS) is determined by the optimum combination of the estimates for the efficiency of the functions implemented and their actual values for a specific period. To assess this level, the following model for evaluating the functional efficiency of organizations was developed:

$$P_{TS} = P(\upsilon, Q_f, Q_s, H_f, H_s, F_k, Z_f, D_f) \quad (2)$$

The following designations are accepted:

U — management function (activities);

H_f — a criterion for evaluating the implementation of the organization management function related to data processing in a region for a specific period of time;

Hs — a criterion for evaluating the implementation of the organization management function related to the implementation of administrative punishments;

Q_s — an optimization criterion related to the implementation of administrative punishments;

Q_f — an optimization criterion related to the functional efficiency of data processing.

The accepted factors are basic, but their list is not exhaustive. Their qualitative and quantitative composition depends, first of all, on the problem statement. Dependence of the level of traffic safety on various indicators can be represented as follows:

$$P_{TS} = P(Q_f, Q_s, H_f, H_s, U) \quad (3)$$

The stated optimization task is considered multi-criterion. To solve it, we should choose restriction criteria.

The method developed allows determining the implementation degree of functions assigned to the traffic safety management system in a particular region.

The criteria developed make it possible to determine the generalized criterion (the level of traffic safety).

$$P_{TS} = M\left[P_i\right] = \sum_{i=1}^{1} (P_{ki} \times H_{ki}) \quad (4)$$

Based on the maximum value of the traffic safety level when using ATES, the optimum structure of the system managing operating and technical traffic monitoring means is established.

The evaluation of management system performance when using ATES facilities is carried out according to the level of traffic safety. The studies conducted revealed the following systemic factors:

- the efficiency of the management function at each level of system activity;
- the implementation degree of the management function in a particular region for a specific period of time.

The number of the criteria taken into account and their weightage for a particular region shall be determined by experts.

The efficiency of the management function is evaluated according to the following dependence:

$$P_{ki} = P(U; Q_f; Q_s) \quad (5)$$

The actual evaluation of function implementation is carried out in accordance with the following equations:

$$H_f = H_c(n, C) \quad (6)$$

$$H_s = H(S, S_n, W, W_f) \quad (7)$$

where n is the number of ATES, pcs.;

C is the number of issued orders, [*orders/year]*;

S is the amount of penalties paid within a year, *[RUB/year]*;

S_b is the amount of penalties, *[RUB/year]*;

W – the number of cases filed, [*cases/year]*;

W_f is the number of actually paid proceedings, [*cases/year*].

Taking into account equations 6 and 7, equation 3 can be rewritten as follows:

$$P_{TS}F(\nu_k) = \max\left[F(\nu_k)\right] = \max\left[\sum_{i=1}^{y} P_{ki}H_{ki}\right] \quad (8)$$

In case of stochastic nature of the criteria for evaluating the level of traffic safety, it is necessary to consider a stochastic single-objective problem (Table 1). Let us assume that the number of possible activities and the number of traffic safety estimates for each activity are finite.

This condition corresponds to reality as the evaluation process requires the use of random events characterizing traffic safety. It is convenient to perform the analysis in accordance with the recommendations given in work (Safiullin, Kerimov, 2016).

The left column of the table represents activities in the form of a function, U_1, U_2,....U_k,....U_t and the top line represents types of events (causes — factors). The useful effect of ATES operation mainly resides in the social

Table 1. A stochastic model for evaluating the performance efficiency of subdivisions, institutions and organizations ensuring the implementation of traffic monitoring using ATES

Activities, management functions	Evaluation of the function efficiency *(P)* and function implementation *(H)* for various structures			Traffic safety indicator
	1	*i*	*R*	
Functions of the first level U_1	P_i / H_i	P_{1i} / H_{1i}	P_{iR} / H_{iR}	$P_{TS1} = \mu[P_{1i}] = \sum_{\upsilon=1} P_{1i}H_{1i}$
Functions of the second level U_2	P_{ki} / H_{ki}	P_{ki} / H_{ki}	P_{kR} / H_{kR}	$P_{TS2} = \mu[P_{2i}] = \sum_{\upsilon=2} P_{2i}H_{2i}$
Functions of the third level U_3	P_{ti} / H_{ti}	P_{ti} / H_{ti}	P_{tR} / H_{tR}	$P_{TS3} = \mu[P_{3i}] = \sum_{\upsilon=3} P_{3i}H_{3i}$
Efficiency evaluation	P_{ti} / H_{ti}	P_{ti} / H_{ti}	P_{tR} / H_{tR}	$P_{TS}F(\nu_k) = \max\left[F(\nu_k)\right] = \max\left[\sum_{i=1}^{y} P_{ki}H_{ki}\right]$

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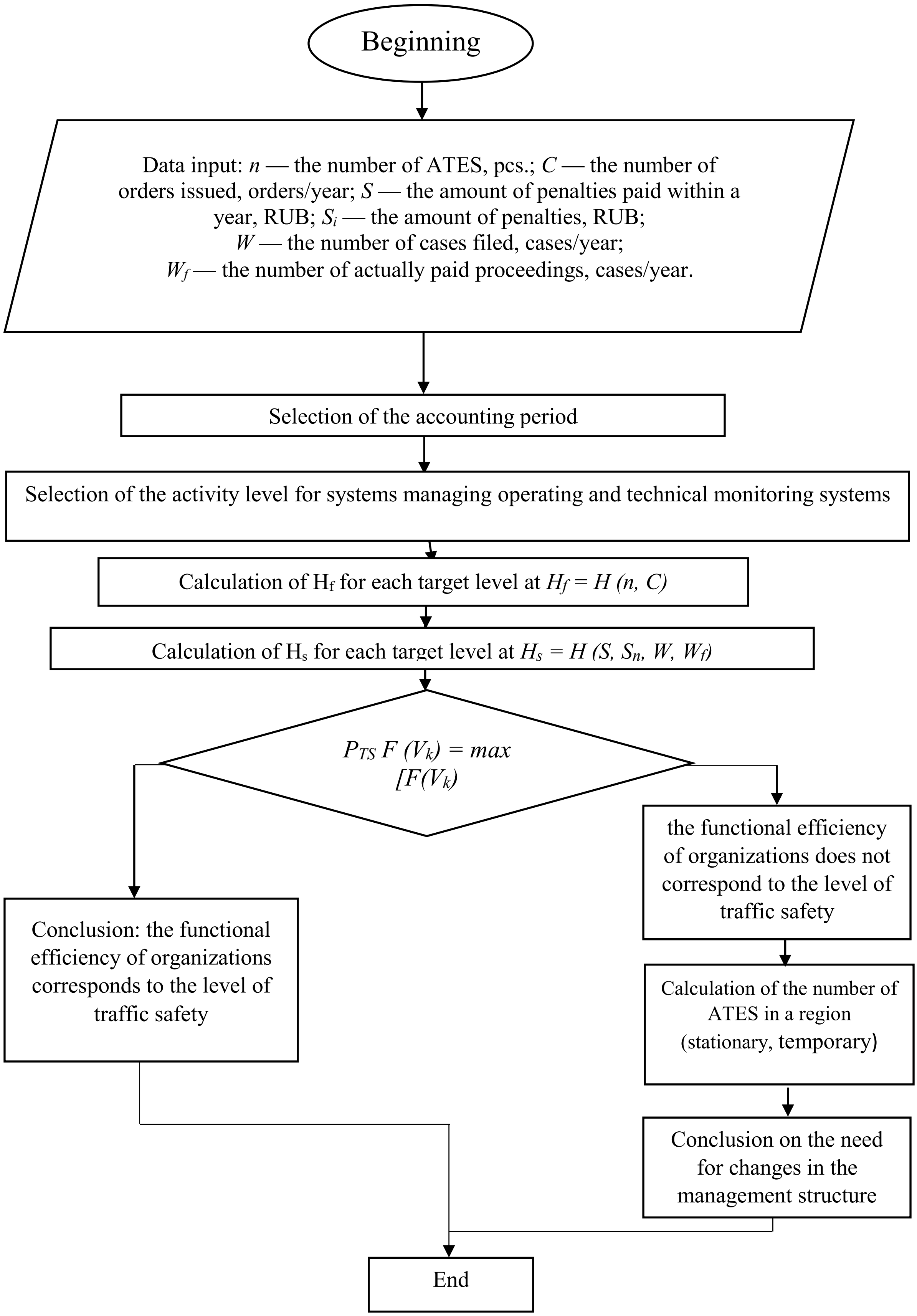

Figure 1. An algorithm for optimizing the system managing operating and technical traffic monitoring means

significance of the complexes' functioning results, which can be evaluated by the indicator of a decrease in the accident rate on the monitored section of the street and road network ("accident cluster").

Another component of the useful effect is the number of administrative offences detected by the ATES facility. To evaluate the efficiency of system functioning, it is proposed to use an algorithm for optimization of the structure for managing operating and technical traffic monitoring means, which is shown in Figure 1.

Conclusions

The concept of the "optimum structure" for managing operating and technical traffic monitoring means should be considered as the best concept in the narrow sense, defined by the accepted optimization criterion. In this case, the level of traffic safety serves as such criterion.

Based on the studies conducted, it is possible to distinguish the following basic directions for improving the structure of the system managing operating and technical traffic monitoring means. Improvement of procedures related to management and technologies of processing data on recording of administrative offenses, modernization of the regulatory framework regarding recording of traffic violations when using technical monitoring system.

Typization of displaying information on objects of traffic violations, development of a hardware and software complex and equipment of the street and road network with the required amount of traffic enforcement facilities.

The efficiency of the management system operation is determined by the level of its interaction with concerned organizations and institutions, and, to a large extent, depends on the availability of the corresponding infrastructure and regional investment policy.

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TYPES AND SPECIFICS OF CONSTRUCTION MACHINES USED IN ROAD PAVEMENT DISMANTLING

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Abstract

Road construction is a number of activities including engineering, actual construction of road pavements, as well as maintenance and repair of roads of various purposes. An important area in intensification and acceleration of scientific progress in road construction is a wide use of construction and road machines. Road machines are designed to mechanize road construction works.

Maximum road construction mechanization is reached by using special road equipment including dozens of machine types. Use of special equipment reduces the share of manual labor (used only for patch work) and prime cost of road construction. The article discusses types of road construction machines most frequently used in dismantling of road pavements (road grader, excavator, loader, tractor, bulldozer and recycler), their purpose and specifics.

Keywords

Construction machines, design, equipment, road.

Introduction

Construction machinery consists of an internal combustion engine, a transmission, an undercarriage, and implements. It is equipped with one or several operating elements (implements) and a control system to execute process operations in construction as well as in road construction in accordance with the machine's purpose and area of application. Construction machinery can also be mounted with replaceable implements to expand the application area of special machinery.

The parameters of construction machines include: mass; dimensions; operation and transportation speed; performance characteristics of operating elements. In terms of nature of operation, road construction machines are divided into continuous and cyclic machines. Continuous machines such as compactors operate continuously, and cyclic machines such as excavators have the operating process consisting of repeated cycles that include several different operations.

Road construction machines have two modes: operation and transportation. The operation mode is characterized by higher total resistances and low speeds. In this mode, pulling properties of road construction machines are used to the fullest extent. Road construction machines are usually classified into groups using a technological principle (by purpose of functions performed).

For instance, they can be classified into preparation machines (for preparatory road construction works: grubbers, rippers, etc.), earth machines for road bed construction (bulldozers, road graders, etc.), machines for construction of artificial structures (hammers, pile-drivers, etc.), machines for base course and wearing course soil compaction.

They also can be classified into other types of road construction machines by purpose of functions performed. It should be noted that there are three types of capacity of road construction machines.

Firstly, it is design capacity characterized by design parameters and properties of the environment.

Secondly, it is technical capacity defined by multiplying the design capacity by a number of coefficients with account for respective losses (power losses, speed losses, etc.). In other words, it is the extent to which implements are used (trip overlap, bucket fill factors, etc.).

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Thirdly, it is operational capacity defined by multiplying the technical capacity by the machine use coefficient in time and by the coefficient taking into account the operator's qualification (Dobronravov and Galperin, 1985).

Subject, Objectives and Methods

The subject of the study is represented by types and specifics of construction machines used in road pavement dismantling.

The objectives of the study are the following:

- to review types of construction machines used in road pavement dismantling;
- to analyze specifics of construction machines.

The methods used to achieve these objectives include the study and analysis of characteristics of construction machines used in road pavement dismantling.

Results and Discussion

A roadway is a system of structures designed for comfortable and safe all-year-round traffic of automobile transport at rated speeds and loads. Structurally, a roadway is characterized by transverse and longitudinal profiles (Figure 1).

In accordance with operating requirements, prior to construction (or road construction), a road construction machine shall be selected with respect to machine purpose. Most practical operation modes of road construction machines are selected. Soil categories at the place of operation shall be taken into account.

A special group of road construction machines is used for road construction, which is divided into groups by functions performed:

1. Equipment for preliminary preparation works:

Grubbers are used for grubbing, removing bushes, tree trunks, and boulders.

Brush cutters are used to remove underwood and bushes.

Rippers are designed for preparation of frozen and packed soil.

2. Digging machines:

Excavators are used for earth moving.

Bulldozers are used for ground surface leveling, digging and earth moving. Nowadays, it is common among many enterprises to rent bulldozers (http://dorstroy.su/arenda_buldozera.php).

Scrapers are used for soil layer cutting and earth moving.

Graders are designed for road bed leveling and grading.

3. Asphalt spreaders distribute and compact asphalt-concrete mixes over the prepared road bed.

4. Soil compacting machines:

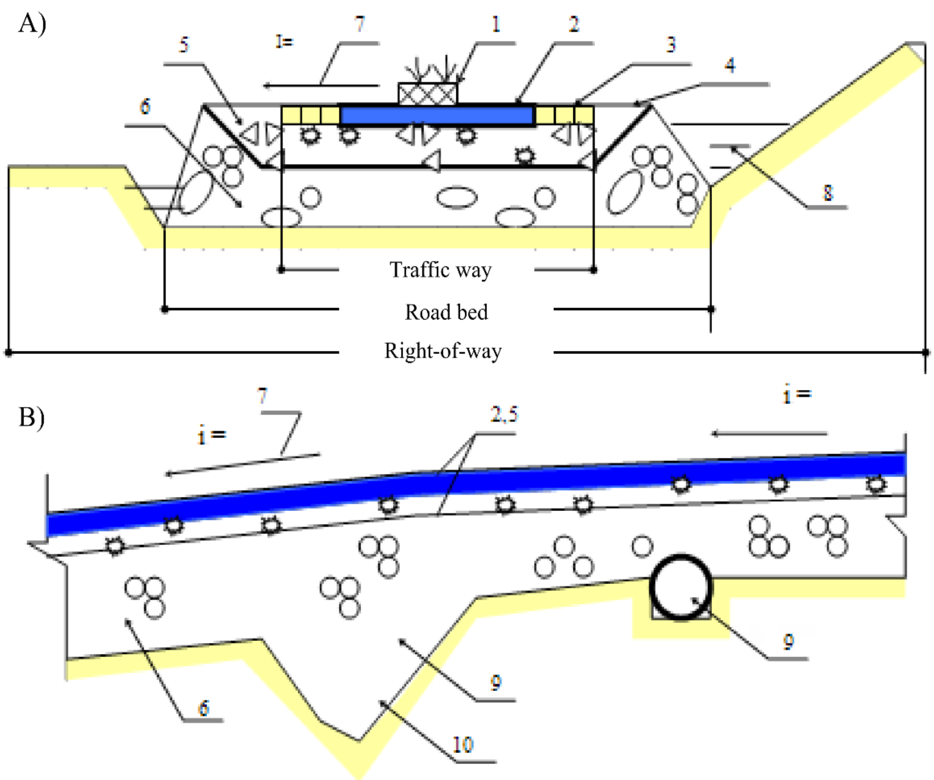

Figure 1. Roadway profiles:
A) transverse profile; B) longitudinal profile; 1 — dividing strip, 2 — road pavement, 3 — margin strip, 4 — shoulder, 5 — road bed, 6 — earth fill, 7 — slopes (transverse and longitudinal), 8 — ditch, 9 — area of concentrated construction works, 10 — natural ground profile

Rollers are machines used for asphalt compaction and tamping.

5. Road construction machines for production and transportation of concrete mixes:

Concrete mixers are used to produce concrete mixes.

Bulk cement trucks transport cement.

Concrete pumps intake concrete mixes and supply them to the concrete placement site (Volkov D., Aleshin N., Krikun V. et al., 1985).

Let us discuss types of road construction machines most frequently used in road pavement dismantling, namely: grader, excavator, loader, tractor, bulldozer, and recycler.

A hydraulic revolving crawler excavator is designed for excavation of non-frozen soils (category I–IV) as well as preliminary loosened rocky and frozen soils with the chunk size of no more than 300 mm.

It is used in developing open pits, digging excavation pits, trenches and channels as well as in other activities.

Such excavator consists of a revolving platform, supported by a crawler truck (undercarriage) through a swivel bearing, and of implements including a boom, a dipper, and a bucket.

The revolving platform accommodates:

- a power unit;
- a hydraulic motor with a swing drive and a braking mechanism;
- a hydraulic pump with a drive;
- a hydraulic tank;
- a fuel tank;
- distribution and valve devices;
- piping and other elements of hydraulic equipment.

A hydraulic lock is usually used as a service brake of the platform swing system, and a multi-disc mechanical brake is used as a retaining (blocking) brake. The revolving platform also accommodates an operator's cabin where controls are located and a counter-weight and implements are secured.

Both the running gear drive of the hydraulic revolving excavator and controls of excavator implements are usually hydraulic. A hydraulic revolving crawler excavator is usually equipped with electrical systems of lighting, ventilation, signaling, heating, diesel engine startup, and power supply.

As a rule, excavators are transported with heavy-duty semi-trailers.

Graders are designed for earth digging and leveling in construction including road construction.

Graders are also designed for works related to urban communal services, repairs, summer and winter maintenance of streets, sidewalks and squares in cities and other localities, and for maintenance of roadways.

Graders are able to level slopes, excavations, earth fills, ditches, clear roads from snow, remove icing from road pavements, move and mix materials with additives and binders on the road pavement, rip asphalt pavements, stone pavements and heavy soils.

A grader is a self-propelled wheeled machine, which usually has three axles and a leveling blade located between the front and middle axles. It also usually has a bulldozer blade located in front of the machine and a ripper located in the rear of the machine.

The leveling blade can usually rotate in the horizontal plane through 360 degrees. It can be placed vertically to the left or right from the grader, protract to the left or right from the grader, and rotate around its cutting edge.

Graders consist of an undercarriage including an articulated (back bone) frame, a wheel travel device including the front axle and balancers, as well as a full revolving leveling blade and rear implements.

The back bone frame accommodates: an engine; a transmission; a hydraulic pump and its drive; hydraulic cylinders (including hydraulic cylinders rotating the grader); hydraulic distribution valves with manual and electromagnetic control; valves and other elements of hydraulic equipment; a cabin with controls.

Bulldozers are designed for earth digging and leveling in construction including road construction.

During the working travel, the bulldozer excavates soil using a blade located in front and pulls the soil wedge forming in front to the backfilling area. At the backfilling area, the bulldozer stops to unload the soil. Its blade raises by approximately 300 mm. Then the bulldozer moves backwards (idling) at a higher speed as compared to the working travel.

The bulldozer ripper located in the rear is designed for layer-by-layer ripping of hard soils, which are difficult to excavate with a blade, for further excavating and moving.

The bulldozer includes a frame, an undercarriage, a front blade and a rear ripper (implements).

The frame usually accommodates: a power unit; a hydraulic gear pump with a drive to control rear and front attachments; a hydraulic vane pump to drive two hydraulic motors each of which drives a side track; distribution and valve devices; piping; a hydraulic tank and other elements of hydraulic equipment; a fuel tank. The frame also accommodates an operator's cabin where controls are located.

Both the undercarriage drive and controls of bulldozer implements are usually hydraulic.

The bulldozer uses electrical systems of lighting, ventilation, signaling, heating, diesel engine startup, and power supply.

A hydraulic revolving wheeled excavator is designed for excavation of non-frozen soils (category I–IV) as well as preliminary loosened rocky and frozen soils with the chunk size of no more than 300 mm.

It is used in developing open pits, digging excavation pits, trenches, channels as well as in other activities (Drozdov N. et al., 1988).

This excavator has an articulated boom. It should be noted that the articulated boom has an additional section and an additional hydraulic cylinder designed to make the additional boom section rotating.

The bulldozer includes a revolving platform, an undercarriage and implements consisting of a monoblock boom, a dipper and a bucket, a blade, and folding supports.

The revolving platform accommodates:

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- a power unit;
- a hydraulic motor with a swing drive and a braking mechanism;
- a hydraulic pump with a drive;
- a hydraulic tank;
- a fuel tank;
- pneumatic braking system units;
- distribution and valve devices;
- piping and other elements of hydraulic equipment.

A hydraulic lock is usually used as a service brake of the platform swing system, and a multi-disc mechanical brake is used as a retaining (blocking) brake.

The platform also accommodates an operator's cabin where controls are located and a counter-weight is secured.

Both the running gear drive and control of excavator implements are hydraulic.

The excavator uses electrical systems of lighting, ventilation, signaling, heating, diesel engine startup, and power supply.

In road pavement dismantling, lifting machines are used for handling construction materials, assembling structures, loading/unloading operations, installing and maintaining process equipment during its operation.

These machines are of cyclic action. The main parameter of lifting machines is their lifting capacity which means the maximum permissible load mass including the mass of the removable hoisting gear. The lifting capacity is expressed in mass units (kg, t).

The main classification feature of lifting machines is their similarity in design. Depending on the purpose, area of application and functions performed, loading machines are classified into the following categories: lifting mechanisms; cranes; lifters; industrial robots. Jacks are designed to lift loads to a small height (up to 0.7 m), primarily for assembly and repair.

By design, they are divided into the following categories: rack jacks, screw jacks, hydraulic and pneumatic jacks. Rack jacks are mainly used during installation when it is necessary to handle parts and assemblies of machines or light-weight structures with no accuracy of operations required. Rack jacks with a capacity from 0.5 to 10 tons are the most common.

Screw jacks are used for jacking of machines during preventive maintenance and repair when it is necessary to move parts and assemblies of machines slightly, when placing machines into storage, when lifting and lowering light-weight span structures onto supports, etc. They have a capacity from 2 to 50 tons. Hydraulic jacks are used to lift and lower extra heavy loads. Loads are lifted when pressurized liquid is supplied to the jack's cylinder, and it is lowered when this liquid is discharged through a drain channel. Hydraulic jacks with a capacity from 3 to 200 tons and a lifting height of 0.15–0.4 m, and special jacks with a capacity up to 750 tons are most common.

Hoists are designed to lift loads in confined spaces and applied in construction and installation, repair of machines in the field and in workshops as well as during other activities. Hoists are small lifting machines with simple design suspended from highly located supports. They can have a manual drive or a geared motor drive. As a rule, manual chain or rope hoists with a worm or gear lifting mechanism are used.

A wheeled tractor with excavator and bulldozer implements is designed for the following operations to be performed by excavator implements: digging trenches, channels, excavation pits with soil unloading into the dump pit or transportation vehicles; simple clean-up works; loading/unloading of loose materials and materials with low specific mass.

A wheeled tractor with excavator and bulldozer implements is designed for the following operations to be performed by bulldozer implements:

- trench backfilling;
- cleaning of debris;
- clearing roads from snow.

Use of replaceable equipment makes it multi-functional. The following replaceable implements are usually used:

- a clamp;
- a hydraulic drill;
- hydraulic shears.

Wide wheels facilitate its movement and insignificant pressure on the surface allows it to move over public roads. It consists of a utility tractor, a rotating column with excavator implements, and bulldozer implements.

A utility tractor accommodates:

- a power unit;
- hydraulic pumps;
- a hydraulic tank;
- a fuel tank;
- distribution and valve devices;
- piping and other elements of hydraulic equipment.

It also has a swiveling seat for the operator. The geared hydraulic pump (designed for the implements drive) is driven by the power take-off connected to the tractor transmission. The running gear drive is mechanical and has an external planetary gear unit. The implement controls are hydraulic. The wheeled tractor with excavator and bulldozer implements uses electrical systems of lighting, ventilation, signaling, heating, diesel engine startup, and power supply. It is usually used in construction (including road construction) and loading/unloading operations. They move at a speed of up to 20 km/h. Their capacity is around 900 kg (including the counter-weight).

The tipping load is about two times more than its load capacity.

This is a mini-loader with skid steering (right-side and left-side wheels are driven by individual hydraulic motors). For purposes of operation, wheels on one side are blocked or wheels of opposite sides rotate in opposite directions.

Usually, mini-loaders are all-wheel-driven and wheels of each side are driven by the hydraulic motor shaft (one per side) using chain transmission. There are mini-loaders with a hydrostatic drive; each wheel is driven by its own hydraulic motor, and braking is carried out by hydraulic locks of the hydraulic system.

It should be noted that there are mini-loaders wheels of which rotate together with the rotary link of the articulated frame when hydraulic fluid is supplied from the power steering to steering hydraulic cylinders.

A wheeled loader is designed for earth moving and loading/unloading operations during construction (including road construction). Usually, single-bucket frontal loaders are used for stacking or loading of loose and lump materials into vehicles, for clean-up and leveling.

These loaders can have boom or telescopic attachments and use the following rotation methods: rotation using two semi-frames; rotation of controlled wheels; full rotation (rotation of front and rear wheels); skid steering (left-side and right-side wheels are driven with individual hydraulic motors and can rotate in opposite directions).

A wheel loader usually consists of a wheel undercarriage, an articulated frame consisting of two links, and implements. The frame usually accommodates a power unit, a transmission, a hydraulic pump with a drive, a hydraulic tank, a fuel tank, distribution and valve devices, piping and other hydraulic equipment elements.

The frame also accommodates an operator's cabin where controls are located. The implements drive and their controls are hydraulic. The wheel undercarriage is driven by an internal combustion engine through a gearbox, axle gear units and wheels. The loader usually rotates using hydraulic cylinders. The wheeled loader uses electrical systems of lighting, ventilation, signaling, heating, diesel engine startup, and power supply (Galperin M., Dombrovskiy N., 1980).

Recyclers are designed for cold recycling or milling of road pavements. During cold recycling, the recycler's cutting system cuts (mills) about 300–350 mm of road pavement (asphalt, concrete, etc.). Then the recycler mixes this milled material with an emulsion (binder, foamed bitumen, cement grout, etc.) and this newly produced mixture (e.g. asphalt and concrete mixture) is placed as a road pavement on the ground or loaded into the asphalt spreader.

The recycler is loaded with a binder (binding emulsion) from a tank truck. The recycler capacity depends on the cutting width which is usually 1.2–3.8 m depending on its dimensions and design. The power unit capacity varies from 300 to 950 hp. The power unit ensures the operation of hydraulic pumps and motors, as well as recycler's hydraulic cylinders. The milling drum is usually driven by a V-belt drive and has a safety coupling.

Recycler implements

The recycler implements usually include the following:

- a power unit;
- a control system;
- a transmission;
- a track undercarriage;
- a milling drum (cutting drum);
- a rod with spray nozzles;
- a conveyor system;
- a vibratory screen;
- a roller breaker;
- a batch
- a weigher;
- a mixer (usually double-shaft);
- a system to supply mixture to the ground for its further tamping.

The recycler's conveyor system has a hydrostatic drive (using axial hydraulic motors). The milling (cutting) drum gear unit has a shearing safety coupling. The milling drum is usually driven by a V-belt drive. The milling drum has a planetary gearing. The mill can rotate in both directions. The mill rotation speed during operation is about 20 rpm. The recycler's operation speed is about 50 m/min. The milling depth is controlled by a hydraulic cylinder and is about 300–350 mm of the road pavement depth (asphalt, concrete, etc.). The cutting drum has quick-detachable teeth.

The rod with spray nozzles for binder (binding emulsion) batching and adding to the mixture is usually located next to the crushing plate in the upper part of the drum housing.

Mill cooling is usually carried out with water or binding emulsion. The recycler is loaded with a binder (binding emulsion) from a tank truck. In case the recycler moves forwards, the rear gate located in the drum housing is lowered using the hydraulic cylinder and the front gate is raised, the material can be supplied to the dump truck. The recycler conveyor can usually rotate approximately 60 degrees in both directions, which allows loading dump trucks both on tight curves and when moving along an adjacent lane.

In case the recycler moves backwards, the cutting drum (mill) knives cut the road pavement moving downwards. The mill can crush any hard-surface pavement to the size of crushed stone used in such pavement. Then the milled material is mixed with a binding emulsion (and cement grout, if necessary) and loaded into the asphalt spreader.

It should be noted that the front blade (the gate located in the drum housing) of the recycler, located next to the mill and lowered using the hydraulic cylinder, can be used instead of the asphalt spreader to level the recycled road pavement.

The recycler can also operate as a grader. In this case, the upper conveyors are turned off and the lower conveyor is turned off and raised using hydraulic cylinders to prevent its contact with the milled material. The rear gate is raised and the milled material remains on the ground. Recyclers usually use both contact and non-contact slope control means for leveling, e.g. MOBA Sonic-Ski and automatics (Germany).

A loader with a telescopic boom is a universal soldier of modern small and medium enterprises. Such loaders were invented during the World War II to replace the manual labor of men who went up the line and became a real help for agriculture both in that period and in the following years.

The telescopic loader is equipped not only with forks but with other types of attachments, which makes it an irreplaceable at factories, warehouses and during outdoor work.

Unlike the fork-lift loader, this loader is equipped with a two-section (or sometimes three-section) boom. The first section moves in two planes and serves as the base.

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The second section (or sometimes the third section) is flexibly connected with the base and telescopically retracts from the first section using a hydraulic mechanism, though in some options a chain mechanism is used as a more reliable method. At the end of the end section, a fork mechanism is secured along with an excavator clamp bucket, a lifting platform, etc.

It should be admitted that the term "loader" is not completely accurate. It is derived from the original agricultural purpose of such machines. Nowadays, customers have a wide range to select from: a telescopic boom of a small but powerful electric or gasoline loader can be equipped with forks or a fork grip, an excavator bucket, a grab bucket, a lifting platform or a man rider for works at height, a grip for pipes and tanks, as well as other mechanisms.

Depending on the operations area, the telescopic loader can have an electrical motor or an internal combustion engine (depending on indoor or outdoor application). Modern fork-lift loaders as machines used to transport and load small cargoes appeared in the USSR and the USA in the period between World Wars during active industrialization and, therefore, due to the need to replace the manual labor with a more productive system (Dobronravov, 2003).

Types of fork-lift loaders:

1. Classical electric loaders.
2. Narrow-aisle trucks with decreased clearance, side loaders, reach trucks.
3. Stacker trucks designed to place cargo and pallets in stacks.
4. Off-road loaders representing a special type of equipment intended for outdoor operation (for instance, during site improvement), on native soils, including in bad weather (rain, snow, etc.).

It should be taken into account that the fork-lift truck is designed for lifting and moving of pallets with cargo or just cargo of specific dimensions and weight, with a flat bottom.

For other loading operations, either additional attachments (for rolls, drums, tires) or improved lift masts are required. Furthermore, the operations area should be taken into account since a high-capacity loader with diesel or gas power unit is completely unsuitable for warehousing operations. A compact electric loader with small-radius tires can be used outdoors with the same result.

Conclusions

Modern construction of roadways moves onto a new level: at the present time, it is almost completely automated and mechanized. This allows reducing the duration of road construction works to the maximum extent and improving the process using special road equipment.

In accordance with operating requirements, road construction machines and most practical operation modes shall be selected prior to road construction. Soil categories at the place of operation shall be taken into account.

In this study, the classification of road construction machines and their basic types were reviewed. Characteristics, purposes and specifics of road construction equipment were considered.

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DETERMINING CHARACTERISTICS OF DIFFERENT FILTER MATERIALS TO REMOVE VOCS (MAINLY FORMALDEHYDE) IN THE BUILDING ENVIRONMENT

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Abstract

Volatile organic compounds (VOCs) are inseparable part of the building environment. As a result the health and well-being of the occupants is at risk because the concentration of these compounds is often times above the standard levels. As a result the occupants are unknowingly exposed to these harmful compounds. Recently, there have been developments on the ways of solving this problem.

The existing heating, ventilation and air conditioning(HVAC) systems offer a solution but often times have some drawbacks in operation. Some techniques are effective but not very feasible for cleaning indoor air while others are very sophisticated. One of the smart ways to reduce the levels of VOCs in the buildings is to use air filters. VOCs are almost always present indoors; however, their concentration in the ambient air can be controlled by use of air purification process and can be brought down to acceptable levels.

One of the major compounds found in buildings is formaldehyde, which is emitted by substances used daily to day life. In the long run, formaldehyde has adverse health effects on the occupants. The principal focus of this article is to determine and compare the efficiency of different filter materials like granulated carbon, carbon+ion-exchange and ion exchange in removing the major quantified compound i.e. formaldehyde. Also another important criteria in the selection of a filter material is pressure drop, hence the performance of each filter with respect to pressure drop has also been shown.

Keywords

Volatile organic compounds, formaldehyde, heating, ventilation, and air conditioning (HVAC), air filter, ventilation.

Introduction

Nowadays, environment of buildings has become a topic of main concern as more people are experiencing problems associated with quality of indoor air. This is the reason for a transition of research which was initially focused mainly on outdoor environment contamination to indoor air quality within buildings. Many researches are extensively being conducted to address the issue of quality of indoor environment. People tend to spend most of their time indoors at home, at work or travel.

Despite many regulations are still based on outdoor air pollution with little attention is paid to indoor quality. Hence, its necessary that people are aware of quality of air they are breathing and take appropriate measures to reduce the sources of pollutants. Recent studies have shown that the pollutants in the indoor air are higher than expected.

Since it has been found out that the health related problems are caused by exposure to pollutants overtime, so indoor atmosphere requires more study and understanding. Studies have shown that the contamination of building atmosphere has been linked to several building materials and consumer products that are used in everyday life. Emissions are pronounced in newly built apartments (Jo and Shin, 2012).

In short we are unknowingly polluting our known habitat and eventually breathing in the polluted environment. Our activities have direct impact on temperature, gases, humidity, odor, volatile organic and inorganic gases, and most importantly the particulate matter.

Although structures are designed to protect people from adverse climate and to provide higher level of comfort but on the contrary we have spoiled this environment and introduced a variety of contaminants into the indoor atmosphere that have a potential to cause moderate to severe health risks. They include inorganic compounds like lead, radon and asbestos and organic compounds like formaldehyde, which is found in higher concentration as compared to other pollutants (Goodman et. al., 2017).

The pollutants of major concern are radon and formaldehyde as they are found in more quantity and therefore can pose grave health problems. The focus of this article is to present the efficiency of different filter materials to remove most quantified organic compound i.e. formaldehyde and also to measure the pressure drop across three different filters.

Volatile organic compounds (VOCs) are the major pollutants in indoor air, which significantly impact indoor air quality and thus adversely affecting human health (Karakitsios et al., 2011). VOCs are the inherent part of the building atmosphere which are generated from indoor sources. They are organic chemicals that have high vapor pressure but low boiling point. This property causes large number of VOCs to evaporate from liquid or solid form and enter into surrounding air. Such a unique behavior is called volatility.

Everything we do in daily life results in the release of organic chemicals to the atmosphere ranging from driving a car, painting the house, cooking, making a fire etc. all of these processes result in the emission of organic compounds such as carbonyls, alcohols, alkanes, alkenes, esters, aromatics, ethers and amides. Studies have shown that formaldehyde is the most frequently quantified compound. It is the best known organic compound found in every building atmosphere.

The contamination of indoor air is common to every built environment. It starts when inhabitants start complains of discomfort, headaches, nausea, dizziness, sore throats, dry or itchy skin, sinus congestion, nose irritation or excessive fatigue. These are only the beginning symptoms and are almost always followed by long term conditions. Sick building relates to the condition that an occupant experiences during the course of his stay in the building. It does not mean that the building is sick and uninhabitable. There have been reports from the occupants who complained about symptoms, such as irritation or dryness of mucous membranes, burning eyes, headache or fatigue.

These symptoms are termed as Sick-Building-Syndrome (SBS)(Takigawa et al., 2012). A common related problem is Building Related Illness (BRI). BRI is considered as a building associated, diagnosable disease. If signs of actual illness are present and can be linked to a condition in the facility, the concerned building can be classified as BRI. The key point of difference between Sick building syndrome (SBS) and Building Related Illness (BRI) is that particular contaminants resulting into SBS may not be known.

VOCs are of utmost importance because they are mainly responsible for causing long term adverse health effects. Studies have also found that some VOCs are even neurotoxic (Fournier et al., 2017, Liu et al., 2008).

Home ventilation plays a significant role in keeping the indoor air clean and to check the level of pollutants. Adequate ventilation facilitates supply of fresh air which also helps in removing the pollutants. But opportunities for ventilation may be limited by weather conditions or by contaminants in the outdoor air. Countries which are located on more northern latitudes have low temperatures which in turn do not allow free natural ventilation.

The efficiency of ventilation for controlling VOC concentrations depends upon the operation of the building, the pollutant sources and the physical and chemical processes affecting the pollutants. Thus, a combination of methods to reduce the concentration is suggested (Fisk, Mirer and Mendell, 2009).

Artificial ventilation in the form of air-ventilation systems are the only viable option. Sometimes the systems are not efficient enough to remove all pollutants. The buildings in cold countries tend to have more closed spaces and have lack of natural ventilation. As a result, air may have more concentration of VOCs (Salthammer 2017).

It has also been observed that presence of organic compounds in buildings, offices and other places of work affect the performance of people using the building. It has also been seen that reducing air pollutants in the buildings is more energy efficient that to provide outdoor supply of air (Salonen et al., 2009).

The quality of working environment with less concentration of pollutants provides satisfaction and increases the productivity of people (Frontczak et al.,2012; Lee and Guerin 2009). A well maintained air cleaning system can help in keeping the air clean and its also necessary to minimize the use of materials that act as a source of pollutants in the buildings.

World health organization classifies organic compounds into the following classes (Table 1).

Table 1. Organic compounds classification into the following classes according to World health organization.

Description	Abbreviation	Boiling Point range	Example
Very volatile (gaseous) organic compounds	VVOC	<0 to 50-100	Propane, butane, methyl chloride
Volatile organic compounds	VOC	50-100 to 240-260	Formaldehyde, d-Limonene, toluene, acetone, ethanol (ethyl alcohol) 2-propanol
Semi volatile organic compounds	SVOC	240-260 to 380-400	Pesticides , fire retardants

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Formaldehyde is a volatile organic compound (VOC) found in the building atmosphere emitted from a wide range of building materials and products of daily use (Salthammer, Mentese and Marutzky, 2010).

It belongs to a group of one-carbon saturated aliphatic aldehydes with chemical formula - HCHO. Due to such a molecular structure it is highly reactive with compared to other aldehydes like acetaldehyde, acrolein, glutaraldehyde etc. It is useful in industrial and commercial process because of its high thermal stability. Formaldehyde is a colorless, gaseous substance with a strong, pungent odor.

On condensation it forms a liquid with a high vapor pressure that readily forms a part of the air. Owing to its high reactivity, it rapidly changes to form paraformaldehyde. Hence, liquid formaldehyde must be held at low temperature or mixed with a stabilizer (such as methanol) to prevent/minimize polymerization.

Formaldehyde is commercially available in the form of paraformaldehyde, which has multiple lengths of HCHO molecules. It is a colorless solid that slowly decomposes and vaporizes into HCHO at room temperature. It is used in a variety of deodorizing commercial products.

It is also available as formalin, an aqueous solution containing 37 to 38% HCHO by weight and the rest 6 to 15% methanol. For the experiments conducted as a part of this thesis, formalin was used as a source of formaldehyde to have some recordable value with the available devices.

Urea-formaldehyde is a thermosetting resin which is used as adhesives for wood, in the production of pressed-wood products such as particle board, medium-density fiber board and hardwood plywood, finish coatings textile treatments and in the production of urea–formaldehyde foam insulation.

Table 2. Primary sources of formaldehyde in indoor environment.

Products	Examples
1) Combustion	Cigarettes, e- cigarettes, kerosene, natural gas,stoves and fire places, vehicle exhaust
2) Insulation	Urea formaldehyde foam insulation (UFFI)
3) Pressed-wood products	Pressed-wood products Plywood, particle board, decorative paneling
4) Daily products	Deodorants, perfume, cosmetics, disinfectants, insecticides, paints, dyes, shampoo, shower gel
5) Other sources	Floor covering, carpet adhesives, fire retardants

Urea formaldehyde wood adhesives are colorless and provide excellent bonding performance. However, this UF based adhesives is a potential source of free HCHO into indoor environments, particularly during the first months of usage and later on in the life of a product. Apart from these there are also phenol–formaldehyde resins used in buildings which also a source of HCHO.

Formaldehyde is also found in the deodorants, perfumes and cosmetics which are used on everyday basis (Lefebvre et al., 2012).

Formaldehyde levels in the indoor environment are significantly higher in residential, institutional, and commercial buildings. Pressed wood products are a major source of HCHO contamination in indoor environments. Particle board is used as underlayment in conventional homes; floor decking, furniture, and a variety of consumer products; and as well as decorative wall panels.

Another type used is hardwood plywood for decorative wall covering and as a part in cabinets, furniture, and wood doors. Medium-density fiber board has been used in cabinet, furniture, and wood door manufacture.

Scope, Objectives and Methodology

The main objective of the thesis is to find the efficiency of each filter against volatile organic compound (VOC) – formaldehyde and also to find the pressure drop across the three filters namely carbon + ion exchange, carbon only and ion exchange filter and finally make recommendations. To find pressure drop and efficiency, experiments will be conducted separately with each filter installed in the test setup. Its also vitally important to review the past results and research conducted in regard to the purification of indoor air. There are several methods adopted to keep the indoor environment clean and safe for inhabitants. However, these are not widely used over the lack of awareness about the quality of indoor air. A past study research conducted concerning VOCs by using photo catalytic oxidation (Wang, Ang and Tade, 2007). This method is one of the effective methods to control the amount of VOCs. One of the major drawback is that its commercially expensive.

Whenever the use of technology is concerned over a large scale it has to be affordable for the public. But photo catalytic oxidation is rather expensive. Another setback related to this method is the chances formation of carbon monoxide, CO (Pershin et al.,2017) as a byproduct. But since this method uses short-wave ultraviolet light to energize the catalyst, it has an advantage to be cost effective. Another study shows that there is possibility of formation of formaldehyde as result of photo catalytic oxidation. This technology is still on the nascent stage and needs to be optimized.

One more study was conducted to tackle VOCs by using coconut activated carbon shell. The filter was tested for VOCs removal efficiency. It gives promising results for the use of activated carbon filter but this study was focused on the use of one filter and does not make comparison of removal efficiency with respect to other filters, which are sometimes claimed to be effective (Gallego et al., 2013). Similar experimental study was made to remove VOCs using activated carbon-fiber (ACF) filter calcined with copper oxide (CuO) catalyst (Huang et al., 2010). When a choice is to be made while selecting an effective filter material it is necessary to give due consideration to parameters like pressure drop and standard removal efficiency of the filter material. This research is focused on the same objective to suggest the best filter in terms of pressure drop and efficiency.

It also possible that the Heating, Ventilating, and Air Conditioning (HVAC) system may promote accumulation of compounds like formaldehyde and acetone. Also, its possible that microorganisms may survive on filters giving rise to those compounds.

The use of electrostatic precipitators is one of the techniques to remove VOCs from indoor air. One study has incorporated the electrostatic precipitator-type small air purifier with a carbon fiber ionizer and an activated carbon fiber filter (Kim et al., 2018). Although it has shown to be efficient in removing the VOCs from the air, on the contrary there are possibilities of formation of ozone in the process, which is harmful to health.

VOCs are found in every human dwellings whether its home, office or shops. Apart from sources that are always present in the building, VOCs are also emitted from equipments used in buildings like printing machines, photocopy machines etc. (Destaillats et al., 2008; Sarkhosh et al.,2012). They are also found in hair saloons (Gennaro et al., 2014).

The one of the best way to analyze the relative performance of various air filters to clean indoor air is to make a comparative study with regard to their efficiency against most quantified and well known VOCs in the building i.e. formaldehyde. Pressure drop helps to choose the filter which offers less resistance to air flow and hence it more effective.

Formaldehyde, which is carcinogenic, is very harmful to human health. Hence, it is important to give more attention for removal of this compound from the building. Also, it is also possible to make recommendation and suggest practical implication of the results obtained from the experiments.

Methods

General set up

As shown in Figure 1, Pd is the pressure drop (in pascals,Pa) and Ps is the measured concentration of formaldehyde measured by gas analyzer (in milligram/m^3). The diameter of duct, used as passage for air flow, was 250mm. Small hole was made at equidistance in the input duct and the output duct to measure the pressure drop, velocity using differential manometer.

The change in air flow was created using combination of two devices namely frequency regulator and fan. By selecting different frequency values in the control panel of frequency regulator it was possible to create different velocity of flow. The filter was placed in the rectangular chamber to carry out the experiment.

Filter materials

For conducting the experiments, three different types of filter material were used. All readings were taken separately with each filter installed. Carbon and Ion exchange is a filter with carbon granules and ion exchange material in the form layers which imparts property of ion exchange material. Another filter material was carbon. The size of carbon granules was 4mm in diameter with density 550 gm/decimeter^3.

The ion exchange filter used was Panion 510, which is capable of removing organic compounds like formaldehyde, acetone, oxides of sulphur, benzene, tobacco smoke, organic acids and many other harmful compounds found in homes.

For conducting experiments, Sovplym laboratory, Industrialniy prospect was used.

The experiment involved the use of following:

1) Formalin – It's a solution containing 40% formaldehyde or 37% by mass. Since its highly volatile so it was used as a source of formaldehyde. It is very important to note that formaldehyde is certainly found in homes however the concentration is small. In order to successfully conduct experiments it was necessary to use an actual source of formaldehyde so that the gas analyzer is able to detect the presence of formaldehyde.

2) Gas analyzer – It is a device used for analyzing the presence of organic compounds in the air. It is able to record the concentration of carbon monoxide, sulphur dioxide, hydrogen sulphide, ammonia and organic compounds like formaldehyde and acetone. Gas analyzer used was geolan-1p.

3) Frequency regulator – It is used to vary the speed of the fan and in turn the air flow. It comes with a control panel giving option to select different frequencies. For the experiment the range of frequency was 20 to 50hertz. It

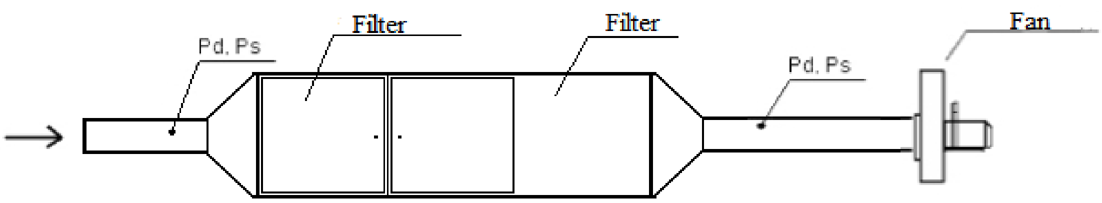

Figure 1. Experimental setup (set, installation)

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was connected to the fan and hence its possible to get different air flow through the duct.

The objectives of conducting experiments are:

1) To find pressure drop across three filters viz. carbon and ion exchange, carbon and ion exchange filter. In HVAC system, if a filter is installed, it will create some resistance to the air flow. This resistance results into pressure drop. The difference in air pressure on one side of filter versus other side is termed as pressure drop across a given filter. If there is more pressure drop, it indicates that there is too much resistance to air flow. This wastes energy and increases wear and tear. The aim is always to minimize pressure drop. In order to measure pressure drop, Testo 510 which is a differential manometer was used.

2) To find efficiency of each filter in removing formaldehyde. For each filter three readings were taken. Then, the final value of efficiency was calculated as an average of the three values. Then to check the result comparison was made. The first reading was taken before air passes through filter using gas analyzer and final value was recorded after the filter when air has been filtered out. Same process was repeated for each of the filter.

$$Efficiency = \frac{Initial\ value - Final\ value}{Initial\ value} \times 100$$

Results and discussions

The results are listed in the Table 3 and 4.

Table 3. Measuring instruments used in testing

№	Name of the measuring instrument	Account serial number	Certificate number about verification	Validity of verification
1	Differential pressure gauge digital Testo 510	38966834/012	0126441	23.08.2018
2	Pitot tube	52	1528-2016	02.08.2018

Table 4. Technical data on test equipment

Fan	Type	Diameter of duct, mm		Rotation frequency, min -1
	FS-4000	Ø250		2850
Electro-motor	Power, kW	Voltage, V	Nominal current, A	Rotation frequency, min -1
	1.5	380	3.46	2850

Efficiency – All values in milligram/m³. For measurement of efficiency the volume of flow was kept constant. It was kept at 1200m3/hr for recording the values of efficiency for all three filters. Here, Ps represents concentration of formaldehyde measured before and after filtration.

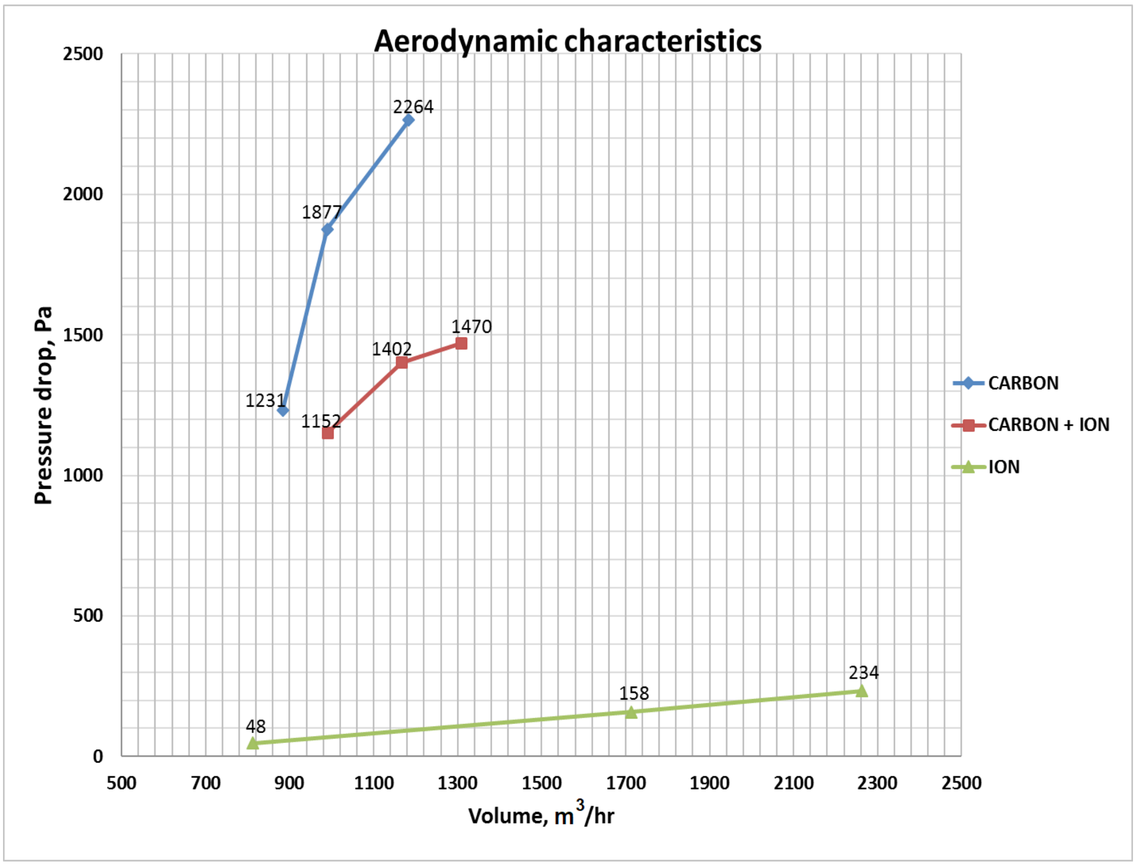

Figure 2. Pressure drop

Table 5. Aerodynamic performance with carbon+ion exchange filter

Frequency	Velocity	Average velocity	Volume flow	Pressure (Pd) before filter in pascals (Pa)	Pressure (Pd) after filter in pascals (Pa)	Difference in pressure in pascals (Pa) dPs, Pa
v,Hz	V, m/s	m/s	L, m³/h	Ps, Pa	Ps, Pa	dPs, Pa
36	4.5	5.6	989.5	38	1190	1152
	7.7					
	4.8					
40	7	6.6	1166.2	48	1450	1402
	8.5					
	4.5					
45	6.5	7.4	1307.6	50	1520	1470
	7.2					
	8.5					

Table 6. Aerodynamic performance with carbon filter

Frequency	Velocity	Average velocity	Volume flow	Pressure (Pd) before filter in pascals (Pa)	Pressure (Pd) after filter in pascals (Pa)	Difference in pressure in pascals (Pa) dPs, Pa
v,Hz	V, m/s	m/s	L, m³/h	Ps, Pa	Ps, Pa	dPs, Pa
36	4.6	5.0	883.5	24	1255	1231
	5.9					
	4.6					
45	5.4	5.6	989.5	43	1920	1877
	5.6					
	5.9					
50	6.7	6.7	1183.9	48	2310	2264
	6.9					
	6.5					

Table 7. Aerodynamic performance with ion exchange filter

Frequency	Velocity	Average velocity	Volume flow	Pressure (Pd) before filter in pascals (Pa)	Pressure (Pd) after filter in pascals (Pa)	Difference in pressure in pascals (Pa) dPs, Pa
v,Hz	V, m/s	m/s	L, m³/h	Ps, Pa	Ps, Pa	dPs, Pa
25	4.4	4.6	812.8	17	65	48
	4.8					
	4.7					
30	9.6	9.7	1714	96	254	158
	9.8					
	9.7					
35	12.7	12.8	2261.8	156	390	234
	12.6					
	13.2					

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1) Carbon.

Table 8. Efficiency for carbon filter

№	Initial concentration before filtration, Ps	Final concentration after filtration, Ps	Efficiency
1	110	44	60
2	108	40	62.9
3	105	34	67.6

Average efficiency = 63.5%

2) Carbon + ION.

Table 9. Efficiency for carbon+ion filter

№	Initial concentration before filtration, Ps	Final concentration after filtration, Ps	Efficiency
1	122	25	79.5
2	140	36	74.2
3	138	24	82.6

Average efficiency = 78.7%

3) Ion-exchange.

Table 10. Efficiency for ion-exchange filter

№	Initial concentration before filtration, Ps	Final concentration after filtration,Ps	Efficiency
1	102	21	79.4
2	152	26	82.8
3	97	18	81.4

Average efficiency = 81.2%

Conclusions

Based on the experiments conducted, following conclusions can be drawn:

1) Pressure drop is important criteria for choice of the filter. If filter has more pressure drop, it is not very efficient and results into more wear and tear of the filter. Also, more energy is consumed as a part of the filtration process which is not desirable. Hence, it is preferable to choose a filter with lowest pressure drop. From the performed experiments (Figure 2), filter with lowest pressure drop is ion-exchange and therefore its more efficient.

2) Filters used were able to remove the targeted organic compound i.e. formaldehyde. As seen from the tables 4,5 and 6, filter with highest efficiency is ion exchange filter (81.2%), followed by carbon+ion exchange (78.7%) and finally carbon with efficiency 63.5%.

3) Although organic compounds are almost invariably present in the ambient air, their true detection is possible through the use of sophisticated methods.

4) Air flow also affects the efficiency of filter and energy consumption. More the air flow, more will be the filtered compounds and particulates reducing effectiveness of filter to some degree. At the same time for higher air flow more power is consumed, which is not desirable.

5) In order to get recordable concentration of formaldehyde captured by the filter, it was necessary to use formalin as a source of formaldehyde. The use of filter will be beneficial in the long run that is, the filter will be able to remove generated formaldehyde and also other organic compounds from the household sources, printing press, offices etc.

6) In order to achieve acceptable indoor quality, mere ventilation is not enough. It is necessary to use an effective filter material like ion-exchange to trap the impurities in the air as a part of the HVAC system. This is essential if intensity of activities is more in the building. In addition, it is recommended to use a pre-filter to trap the particles of larger sizes, so as to increase life of the filter.

7) Ion-exchange filter can be used in HVAC system to solve the problem of organic compounds emissions in offices and residential places. This can be facilitated by periodic circulation of the indoor air through the filter. Similarly, in homes HVAC system of smaller capacity can be installed to tackle problem of organic compounds.

8) The use of Ion exchange filter will be particularly useful in cold countries where natural ventilation is restricted because of cold weather conditions resulting in closed spaces. Hence, to achieve the desired objective for better indoor environment some source control measures in addition to use of filter will be more effective.

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IN MEMORY OF PROFESSOR VALERY NEFEDOV

On 22nd May, 2018 the All-Russia scientific-practical conference "Problems of green architecture and sustainable development of cities", devoted to the memory of a doctor of architecture, professor, deserved worker of the higher school of the Russian Federation, member of the "Architecture and Engineering" journal Editorial Board Valery Nefedov (1949-2017) took place at the Saint Petersburg State University of Architecture and Civil Engineering.

Valery Nefedov was a unique creative and professional person. He was the author of the books "Landscape design and stability of environment" (2002), "City landscape design" (2012), "How to return a city to people" (2015) and more than 70 scientific articles on topical problems of architecture, urban planning and urban design.

As the head of the educational creative workshop, he has trained hundreds of qualified specialists working in St. Petersburg and in other cities of Russia and in different countries (China, Morocco, etc.) for dozens of years in the departments of Urban Development and Urbanistic and Urban Design.

Valery Nefedov relied on the experience of his western colleagues in his studies: he was on a course in Italy; he worked and conducted lectures in the US, France, China, Sweden, Germany at various times. For 18 years, Valery Nefedov acted as the coordinator of international educational programs and joint project seminars with universities in Germany, France, Italy. Being invited the professor gave lectures, held design seminars on architecture and design in educational institutions of China, the USA, France, Sweden. He made reports and participated in big scientific international congresses and conferences devoted to landscape architecture in Porto, Bergen, Zurich, Rio de Janeiro, and Venice.

In memory of the talented scientist, Saint Petersburg State University of Architecture and Civil Engineering held the conference that brought together 140 participants from three universities: Ural State University of Architecture and Art (Ekaterinburg), Saint Petersburg State University of Architecture and Civil Engineering (Saint Petersburg), Southern Federal University (Rostov-on-Don).

The conference was attended by representatives of the Kazan State Architectural and Construction University and the Magnitogorsk State Technical University, Scientific Research Institute of Theory and History of Architecture and Urban Planning, branch of the Central Institute for Research and Design of the Ministry of Construction and Housing and Communal Services of the Russian Federation, "Studio-44", Architecture and Urban Planning Committee of the Leningrad Region, METKEM LLC, Atomstroykompleks.

The scientific and practical conference became the basic platform for the development and comprehension of the scientific and creative ideas of Valery Nefedov in the field of "green architecture" and sustainable development of the urban environment. Being an innovator in architecture and design, he instilled in students a broad view of the problems of the big city, advocating that the urban environment was comfortable and suitable for life.

Organising committee
June 2018