INTERNATIONAL SCIENTIFIC CONFERENCE
PEOPLE BUILDINGS AND ENVIRONMENT 2012
7.-9. 11. 2012, LEDNICE, CZECH REPUBLIC

AESTHETIC REQUIREMENTS FOR BRIDGE PIERS

Ilze Rozentale[1], Ainars Paeglitis[2]

Abstract

The bridge designers should try to find an ideal balance between structural integrity, economy, buildability, aesthetics and durability. Bridge's structures should harmonize with landscape.Today the bridge design features are mostly the topical issue of designers often not having instruments to estimate the real output related to visual qualities. Some methods have been developed to examine bridge interaction with landscape by 3D modeling and photomontage in landscape.

Transport infrastructure development usually must ensure decreasing of project costs, increasing the social and economic benefits and also reducing the negative impact on the landscape. During the last years the society has accepted documents giving procedures for evaluation of the structural appearance on surrounding landscape. The European Landscape Convention defines the landscape as a part of territory whose features draw from natural and anthropogenic factors and consequently, interrelationships. The Convention gives clear and objective methods to assess the landscape's visual quality.

This paper deals with aesthetic requirements for bridge piers, and according to the Convention analyzes two categories of piers: short piers and tall piers. The key to improve the appearance of a not tall pier is eliminating or minimizing the pier cap, minimizing the number of columns. Problems of short hammerhead piers can be minimized with appropriate proportions. Tall piers are easier to design because both structure and aesthetics point in the same direction: emphasizing vertical members. The paper presents the analysis of bridge piers built in Latvia in the last decade.

Key words

Aesthetic requirements, pier caps, pier shape, short piers, tall piers.

To cite this paper: *I. Rozentale, A. Paeglitis. Aesthetic Requirements for Bridge Piers, In Proceedings of International Scientific Conference People, Buildings and Environment 2012, Vol .2, pp. 737-746, ISSN: 1805-6784.*

[1] Ilze Rozentale, M.xc.ing., Riga Technical University, Institute of Transport Infrastructure Engineering, Kalku Street 1, Riga, Latvia, LV 1658, ilze.rozentale@rtu.lv
[2] Ainars Paeglitis, Professor, Dr.sc.ing.degree, Riga Technical University, Institute of Transport Infrastructure Engineering, Kalku Street 1, Riga, Latvia, LV 1658, ainars.paeglitis@rtu.lv

1 INTRODUCTION

Bridge piers are important bridge design elements. They do not only provide the transferring loads caused by transport and structure self-weight to the foundation, but they are also important landscape elements. Bridge piers can take different forms, configuration and size.

The main objective of this paper is to develop the basic aesthetic requirements for bridge piers in order to give a visually light, slender, horizontally continuous structure with a transparent space beneath the bridge. Aesthetic requirements are based on the basic visual design aspects – line, shape, form and additional visual characteristics that can significantly affect piers influence on the bridge as a whole system– unity, order and proportion. According to the requirements output piers are conditionally divided into short and tall piers. The great attention is focused on the short piers, which have great aesthetic problems because of their proportions. The paper examines solutions of bridge piers in Latvia.

2 PRINCIPLES OF BRIDGE PIER AESTHETIC ASSESSMENT

Aesthetic requirements are discussed in the book written by Frederick Gottemoeller "BRIDGESCAPE: The Art of Design Bridge" [1] who is giving recommendations for creation of pier forms and paying attention to cap problems and pier placement. The author has developed guidelines based on the relative division into short and tall piers. The study of Burke M.P., Montoney J. [2] identifies some outstanding design manuals on bridge aesthetics and lists a number of primary design guidelines, but Hunt I. [3] discuss the current practice regarding aesthetic bridge design. The article of Sie-Young Moon "Aesthetic Approach on Bridge Pier Design" [4] published in 2009 is devoted to the aesthetic aspects of pier design. In the article the author gives visual aspects (Fig.1) and visual characteristics (Fig.2) of pier design. The schemes developed by Sie-Young Moon are more directly related to the solution of piers, but less emphasize total visual quality of pier and whole construction. However, the attention should be paid to the given classification of vertical pier shapes. Also Sarah Longstreth Billington has touched the questions of pier aesthetic in his study "Improving Standard Bridges Through Aesthetic Guidelines and Attractive, Efficient, Concrete Substructures" 5]. Objectives of this research was to develop visual guidelines for improvement of the aesthetics and efficiency of widely used moderate - span bridges in Texas and provide useful guidelines and examples for improvement of the aesthetics and efficiency of substructures for standard bridge systems. This study was devoted to the application of precast and cast-in-place concrete piers. Summarizing the existing aesthetic guidelines for bridge design, S.L.Billington has noted that most of them could be educational and can provide ideas for bridge designers. Inspecting the objects the mentioned author concluded that there is a tendency to utilize a successful solution which is not always economically and aesthetically successful according to other conditions. The authors of the present paper have an opinion that the draft of aesthetic guidelines included in the paper is useful. There the three blocks: form, composition, entity have been outlined. It should be noted that the authors of all studies based on the opinions and given determinants of aesthetic bridge appearance developed by Fritz Leonhardt „Bridges: Aesthetics and Design" [6]. There are not deep studies about aesthetic and visual aspects of bridge piers design in Latvia.

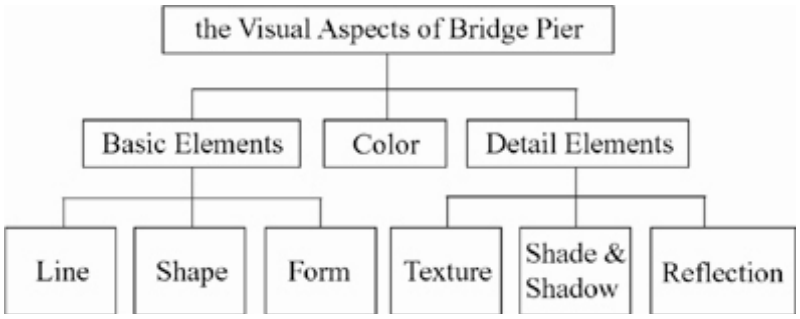


Fig. 1) A classification of the visual aspects of bridge pier design [4]

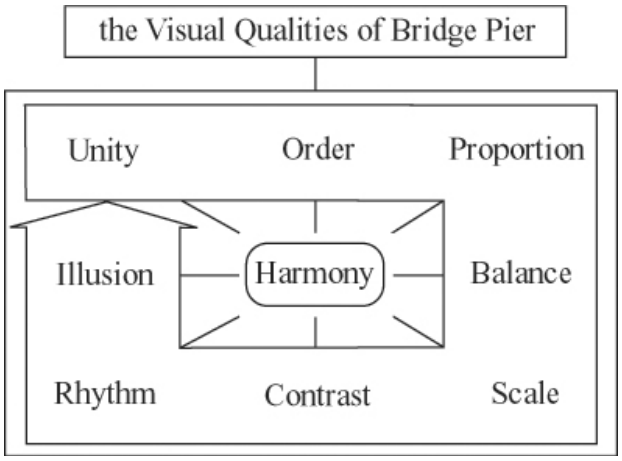
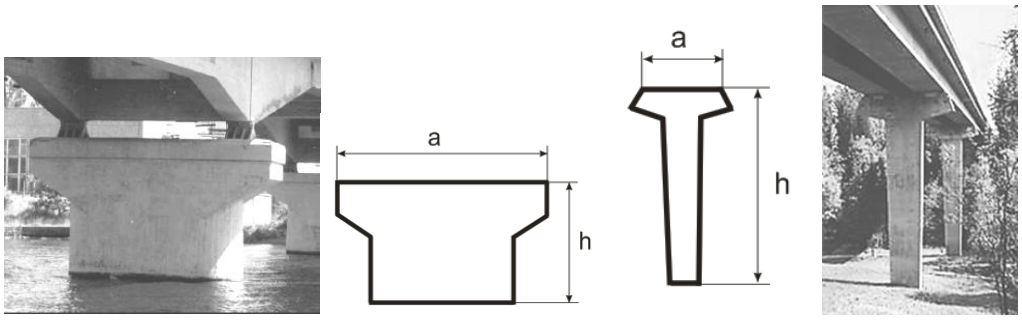


Fig. 2) A classification of the visual qualities of bridge pier design [4]

The following pier classifications for the aesthetic assessment of pier are possible:

1. According to the height the piers could be divided into small and high piers (fig. 3)) [1].



a) Small pier a>h b) Tall piers a<h

Key:
a – length of the pier at the top
b – exposed height of the pier

Fig. 3) Definition of short and tall piers. a) Pier of the bridge in Kundzinsala; b) Pier of the river Lorupe bridge [7]

2. According to the shape/form piers could be divided:
    a. By Frederick Gottemoeller classification – solid piers, hammerhead (T-type), multi – columns with or without pier caps and pile piers, [1];
    b. By Sie-Young Moon classification (fig. 4)).
3. According to the material the piers could be classified as concrete, stone, steel, wood.
4. According to the structural solution the piers could be divided as cast-in-place piers and precast piers.

3 TYPICAL PIER STRUCTURES OF BRIDGES IN LATVIA

There are three periods in bridge construction in Latvia:

1. The period up to 1941 including the Russian Empire and the period of the independent Republic of Latvia,
2. The period from 1941 to 1991 including the period of the USSR;
3. The period from 1991 including the period of independent Republic of Latvia regained its independence in 1991

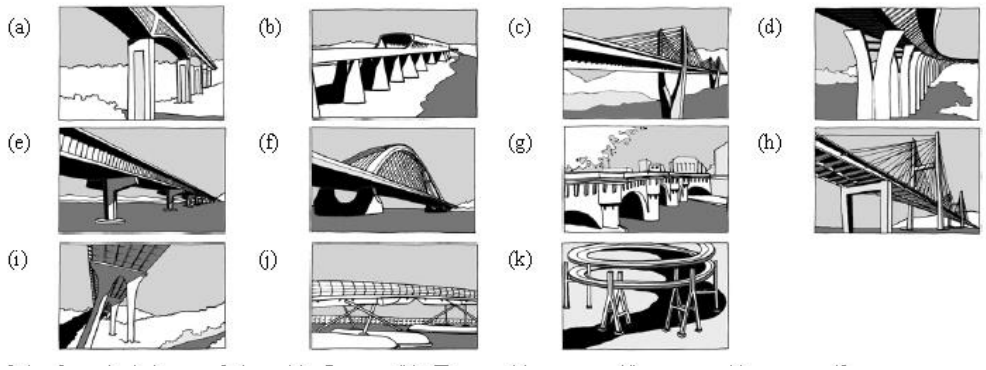
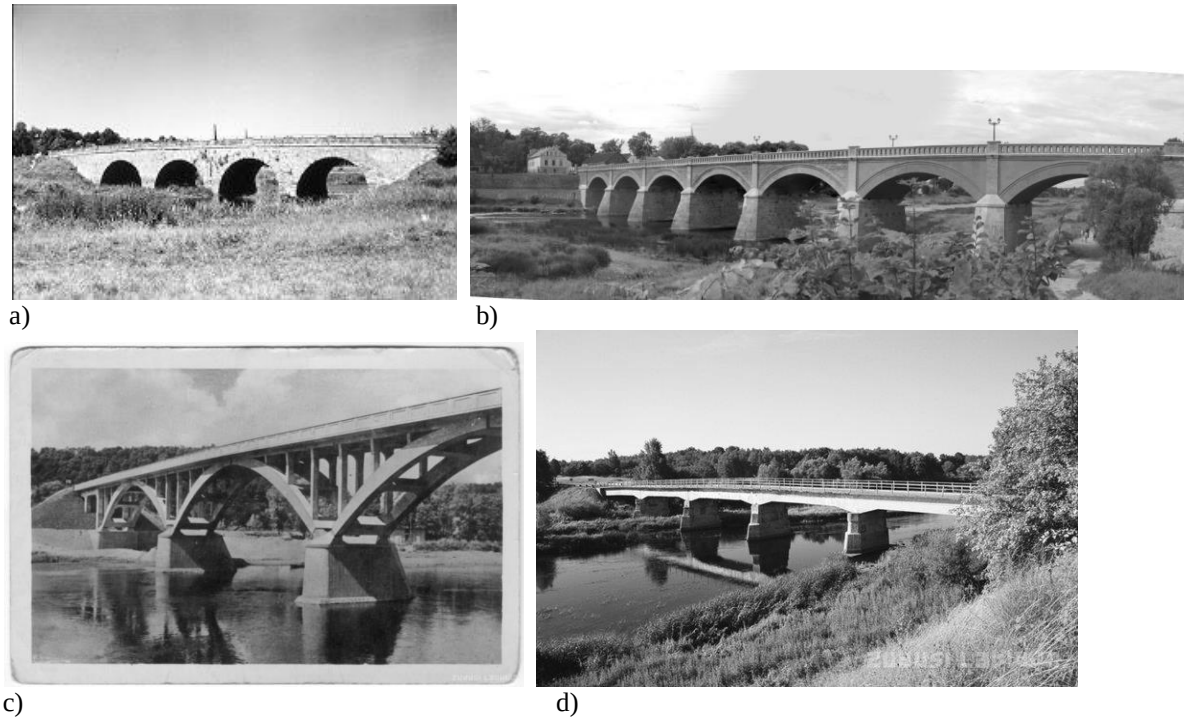


Fig. 4) Vertical shapes of piers: (a) Ⅰ-type, (b) Ⅱ-type, (c) V –type, (d) Y –type, (e) T –type, (f) U –type, (g) Arch –type, (h) Square –type, (i) PI(Ⅱ) –type, (j) X – type, (k) Mixed -type [4]

Each period is characterized by different structural solutions of bridge and its elements, the materials used and aesthetic quality.

Construction period until 1941

Construction period is characterized by stone masonry piers or solid concrete piers, that feature a rectangular shape with/without structure specially designed for pier protection – starling. Special weather conditions cause the necessity of starling – ice melting in the spring (see Figure 5)). Stone piers are characterized by the bridge over the river Abava in Kandava (1873), the bridge over the river Venta in Kuldiga (1874). At the beginning of the 20th century stone piers replaced the massive concrete piers keeping the characteristic stone pier shape with/without starling, such as the bridge over the river Gauja in Sigulda (1937), the bridge over the river Salaca (1909). The timber bridges with different piers forms are typical for the same construction period (see Figure 6)). Examples include the bridge over the river Gauja in Valmiera (1934), where piers retained massive stone pier form, but pier form, which can be considered as multi-column piers, are shown by the bridge over the river Pedele in Valka (see Figure 7)).



a) b) c) d)

Fig. 5) Examples of the stone and massive concrete piers in Latvia until 1941: a) Bridge over the river Gauja in Valmiera; b) Bridge over the river Venta in Kuldiga; c) Bridge over the river Gauja in Sigulda; d) bridge over the river Salaca near Vecsalaca [7]

a) b) c)

Fig. 6) Examples of the timber piers in Latvia until 1941: a) Bridge over the river Gauja in Valmiera; b) Timber bridge; c) Bridge over the river Pedele in Valka

Construction period from 1941 until 1991

Under the influence of political and economic situation in Latvia the precast concrete structures were mostly used. The main objective in designing was the economy of material, easy and quick construction, which could be achieved by using a standard construction. The period is characterized by multiple-columns or pile bents with pile caps. At this time the aesthetic issues were considered as secondary. During this period a number of bridges were constructed with sloping piers, which are a visually successful solution. The examples of bridge piers could be seen in Figure 7.

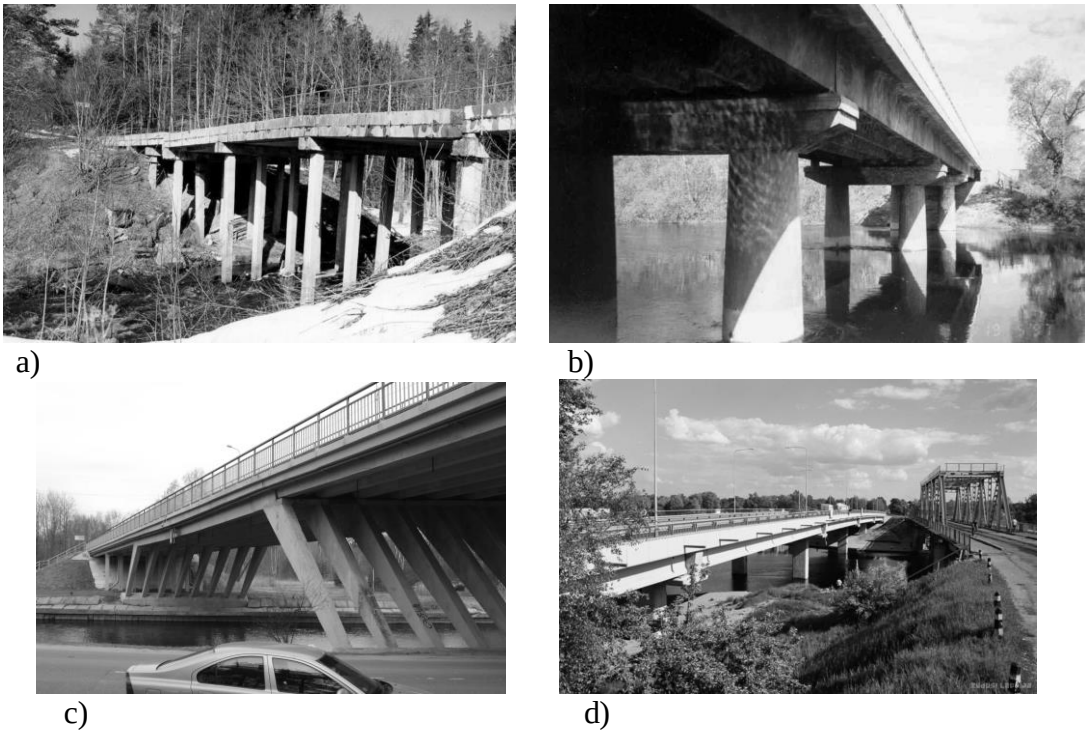


Fig. 7) Examples of the bridge piers in Latvia in the period from 1941 until 1991: a) Bridge over the river Riezupe in Kuldiga region; b) Bridge over the river Aiviekste; c) Bridge over the Channel Kisezers-Baltezers; d) Bridge over the river Bullupe [7]

Construction period starting from 1991

Construction period is characterized by the construction of monolithic concrete piers. In addition to the traditional pier types, the wall type piers appeared and new solutions of piers were searched to minimize caps or minimize their influence. A new approach to aesthetic was evolved and technologies were developed helping the designers to evaluate design solutions before the realization of the project. In Figure 8 the pier solutions in construction period from 1991 have been summarized.

4 ASSESSMENT OF BRIDGE PIERS

Only the assessments of small piers specific for the bridges in Latvia due to the flat topography have been given in the paper. The assessment is given only for the pier structure and its impact on overall structure and landscape regardless of the material and bridge type. The assessment criteria of aesthetic and visual quality have been developed on the basis of verities in the studies of Fritz Leonhardt, S.L.Billington and Sie-Young Moon:

1. Shape/form:
   vertical pier shape regardless of the pier material;
   proportions – balance and harmony between the elements;
   order – symmetry and lines, number of directions and edges.
2. Composition:
   character – impact on viewers;
   order in composition – view beneath the bridge (open view, restricted view, closed view). The principle also includes the effects on the landscape;
   proportions – impact on overall bridge appearance and landscape.

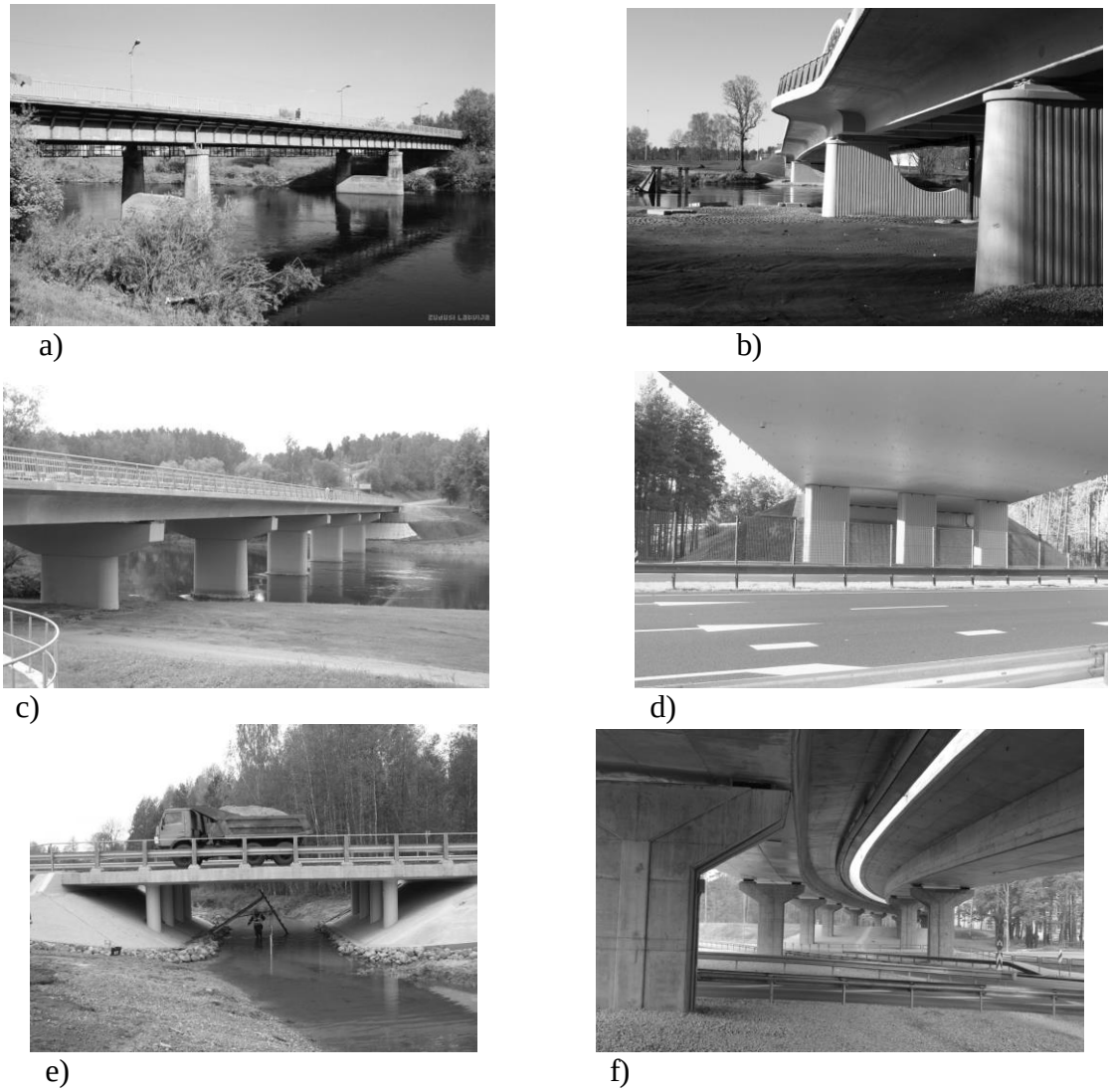


Fig. 8) Examples of the bridge piers period starting from 1991: a road) Bridge over the river Gauja in Valmiera; b) Bridge over the river Gauja in Adazi; c) Bridge over the river Gauja near Senite; d) Bridge over the A2; e) Bridge over the river Dzirla; f) Bridge over Meza street in Riga

The usage of established pier types remained in all periods of bridge construction in Latvia: solid piers, solid piers with two columns, multi – columns with or without pier caps, hammerhead (T-type) piers and pile piers with caps. In addition to above listed pier types the wall type piers are used in construction.

In Tab.1 the assessment of aesthetic qualities and visual impact for only some piers type bridges in Latvia have been summarized. Piers are analysed using visually previously accepted criteria. Sometimes evaluating the individual criteria the contradictory assessments result according to the assessor's feelings and the criterion of the assessment.

Fig. 9) Assessment of bridge piers in Latvia

Bridge	Assessment	
 Bridge over the river Venta in Kuldiga	Pier type and shape/form	Solid pier with starling Vertical form – arch-type [4]. The form is geometrically simple Proportions – the pier width and height in relation to the arch create a sense of stability and visual harmony Order – the pier symmetric to front edge of starling
	Composition	Character - solid, create a sense of stability Order – a restricted view beneath the bridge. An oblique angles view can be completely obstructed. Significant impact on the surrounding landscape. Proportions – overall bridge appearance – harmonious, corresponding principles of Fritz Leonhardt [6], adapts in landscape
Pier assessment (bridge aesthetic assessment)	Solid pier with consistent proportions. The bridge fulfils aesthetic requirements for stone arch bridges. Visually adapts into the landscape.	
 Bridge over the river Uzava (before reconstruction)	Pier type and shape/form	Multi-column pier with caps Vertical form – adequate to I-type [4] Proportions – proportion of pier height is disarranged by the cap, which appears as an additional element Order – cap disarranges the principle forming an additional surface and creating eyesight problems
	Composition	Character - cap creates a visual complexity Order – columns restrict a view beneath the bridge. Significant impact on the surrounding landscape. Order defects the beneath of the bridge. Proportions – in the placement of multi-column the ratio between the column spacing and span length has not been considered - forming the "column forest".
Pier assessment (bridge aesthetic assessment)	Pier cap end interrupts the horizontal smooth of lines. Pier cap end is the brightest surface of the bridge which firstly attracts the attention. "Column forest" covers up the view beneath the bridge. The aesthetic issues have not been taken into the consideration in the constructive solution of the pier and bridge.	
 Bridge over the river Uzava (after reconstruction)	Pier type and shape/form	Multi-column pier without caps Vertical form – adequate to I-type [4] Proportions – well-proportioned Order – piers visually simple without additional edges and lines
	Composition	Character - simple piers with clearly perceived function Order – an open view beneath the bridge Proportions – the ratio between the columns spacing and span length have been taken into the consideration in the placement of multi-column piers

<table>
<tr><td>Pier assessment (bridge aesthetic assessment)</td><td colspan="2">Open view beneath the bridge. The bridge successfully adapts in the environment. The horizontal flow of structure lines has been maintained.</td></tr>
<tr><td rowspan="2"> 
Bridge over the river Gauja in Valmiera</td><td>Pier type and shape/form</td><td>Solid pier with two columns
Vertical form – adequate to U-type [4]
Proportions – successful ratio between the base of solid pier and column-type elements
Order – piers visually simple without additional edges and lines</td></tr>
<tr><td>Composition</td><td>Character - simple piers with clearly visible function
Order – an open view beneath the bridge
Proportions – piers visually adapt in overall structure</td></tr>
<tr><td>Pier assessment (bridge aesthetic assessment)</td><td colspan="2">Open view beneath the bridge. The bridge successfully adapts in the environment. The horizontal flow of structure lines has been maintained.</td></tr>
<tr><td rowspan="2"> 
Bridge over Meza Street in Riga</td><td>Pier type and shape/form</td><td>Pier of one element
Vertical form – adequate to T-type [4]
Proportions – the elements of piers symmetrically around the axis of symmetry, harmony between the elements of the piers
Order – piers visually simple without additional edges and lines</td></tr>
<tr><td>Composition</td><td>Character - simple piers with clearly perceived function
Order – a restricted view beneath the bridge
Proportions – piers visually adapt in overall structure</td></tr>
<tr><td>Pier assessment (bridge aesthetic assessment)</td><td colspan="2">Restricted view beneath the bridge. The bridge successfully adapts in the environment. The horizontal flow of structure lines has been maintained. Pier form is suitable for developing the families of piers</td></tr>
<tr><td rowspan="2"> 
Bridge over the river Gauja in Adaži</td><td>Pier type and shape/form</td><td>Solid pier with two columns
Vertical form – adequate to U-type [4]
Proportions – successful ratio between the base of solid pier and column-type elements
Order – piers visually simple without additional edges and lines</td></tr>
<tr><td>Composition</td><td>Character - simple elegant shape with clearly visible function
Order – a restricted view beneath the bridge
Proportions – piers visually adapt in overall structure</td></tr>
<tr><td>Pier assessment (bridge aesthetic assessment)</td><td colspan="2">Solid piers partly restrict the view beneath the bridge. The bridge successfully adapts in the environment. The horizontal flow of structure lines has been maintained.</td></tr>
</table>

5 CONCLUSION

Construction period from 1941 until 1991 is characterized by standard solutions of piers (multiple-columns/ pile piers with pile caps) leading to the unattractive appearance of bridge in many cases. The main problem is related to superstructure. It is important to consider the

ratio of pier width, spacing of separate columns/piles and span length. It is significant to search for new solutions minimizing or eliminating the cap end in order to obtain a harmonious landscape, aesthetically pleasing bridge solution (for example, bridge over the river Uzava before and after the reconstruction).

Reconstruction period from 1991 provides with many examples of a new approach to the bridge design. That results in construction of aesthetically qualitative bridges, which harmoniously adapt in the landscape. Usage of new technologies such as 3D modelling allows estimating the pier form/shape, its impact on the overall bridge solution and surrounding landscape before the project is fulfilled. 3D modelling can help to develop a new aesthetically and visually qualitative pier forms.

Taking into account previously collected results the following main recommendations for the design aesthetic pier can be formulated:

- Minimizing cap or visible surfaces of hammerhead (T-type) pier overhang end;
- Pier width should be proportional to the superstructure height, span lengths and exposed height of piers;
- Minimizing number of columns in multi-column piers;
- Piers and bridge as a whole should be in harmony with surrounding environment;
- Avoid the use of solid piers, if possible.

REFERENCES

[1] Gottemoeller, F. *Bridgescape. Second Edition. The Art of Designing Bridges.* New York: John Wiley&Sons, Inc., 2004.

[2] Burke, M.P., Montoney, J. *Science, technology, and aesthetics: three aspects of design excellence.* Transportation Research Record (1549). 1995, pp. 93-98. ISSN 03611981.

[3] Hunt, I. *Bridge aesthetics and the question of 'structural honesty'*. Structural engineer. Volume 88, issue 20, 2010, pp. 26-27. ISSN 14665123.

[4] Moon, Sie-Young. *Aesthetic Approach on Bridge Pier Design.* URL: http:// www.iasdr2009.org/ap/navigation/byappearance.html.

[5] Billington, S.L. *Improving Standard Bridges Through Aesthetic Guidelines and Atractive, Efficient, Concrete Substructures.* Ferguson Structural Engineering Laboratory. URL: http:// fsel.engr.utexas.edu/publications/detail.cfm?pubid=605153208.

[6] Leonhardt, F. *Bridges. Aesthetics and Design.* Stuttgart: Deutsche Verlags-Anstalt GmbH DVA, 1994.

[7] LNB. Zudusī Latvija. URL: http:// www.zudusilatvija.lv.

[8] *European Landscape Convention.* Council of Europe. ETS No.176. Explanatory report. Florence, 20 October 2000.