Sonja Krasić
Associate Professor
University of Nis
Faculty of Civil Engineering and Architecture
Serbia

Naomi Ando
Full Professor
Hosei University of Tokyo
Faculty of Engineering and design
Japan

Petar Pejić
PhD student
University of Novi Sad
Faculty of Technical Science
Serbia

Zlata Tošić
PhD student
University of Nis
Faculty of Civil Engineering and Architecture
Serbia

Teaching of Geometric Surfaces for Architectural Students at the Faculty of Engineering and Design, of Hosei University in Tokyo, Japan

The free-form objects are in expansion in the architecture of the 21st century, especially in high developed countries as Japan. Design and performing of free-form objects prefers knowledge of parametric modeling in softwares such as Rhinoceros. Before designing free-form objects, it is necessary to obtain knowledge of geometric surfaces and their use in architectural practice. This was also noticed by the Faculty of Engineering and Design, Hosei University in Tokyo, Japan. Subject Geometric Surfaces was introduced to give students a high-quality knowledge in this field, that they can apply for more creative designing of their architectural objects, which will be shown in this paper.

Keywords: *Architectural objects, Modeling, Geometric Surfaces, Rhinoceros software, Japan*

1. INTRODUCTION

Descriptive geometry was neglected although it is the only discipline at the technical departments which teaches future engineers to communicate with one another by means of drawings and also the only discipline which trains visual spatial intelligence [1]. At the beginning of the studies it is necessary for students to develop visual skills and to adopt geometrical knowledge from the field of representation of three dimensional objects in a two dimensional medium [2].

Descriptive geometry is studied extensively at technical faculties in Europe, more than in Asian countries. The importance of clear and careful spatial reasoning and its graphic representation in the education of future engineers makes descriptive geometry a traditional mathematical course at technical faculties, particularly at those related to civil engineering [3]. All fundamental courses, especially the ones taught during the first year of academic studies, must equip students with theoretical and practical knowledge, general and special competences and various skills upon which succeeding courses are relying [4].

To design the architecture under its various forms, a student of architecture needs to know the geometry of these forms [5]. Whereas the variety of shapes that could be treated by traditional geometric methods has been rather limited, modern computing technologies have led to a real geometry revolution [6]. Traditional orthogonal system is no longer dominant, but on the contrary, free, curved forms or parametrically designed shapes are going through an expansion in architectural and urban design [7].

One of the reasons for the introduction of the subject Geometry Surface in the study plan at the Department of Architecture, Faculty of Engineering and Design, Hosei University (in further text FEDHU) in Tokyo, Japan was to provide students adequate knowledge of geometric surfaces, which they lack due to insufficient teaching of this discipline. Another reason for the introduction of this course in Japan is that the architectural students can gain knowledge that can be applied in the design of their own objects.

2. EDUCATION SYSTEM IN ASIA AND EUROPE

There are differences between the educational system of Asia and Europe. In Asia school year at the Universities starts in April and in Europe starts in October. In Asia school year has 4 semesters, lasting 2 months each (8 weeks), which is different from Europe where there are 2 semesters, lasting 3 months each (15 weeks). In Asia school class lasts 90 minutes, which is different from Europe where it lasts 45 minutes.

2.1 Program of the subject Geometric surfaces in Architecture in Japan

The subject Geometric Surfaces in Architecture was offered to Japanese students of the second year in their III semester, in the school year of 2017/18, as an elective, and it was divided in two courses. The first course is theoretical (GSA_A) and the second is practical (GSA_B).

Teaching in Japan is conducted in English. All teaching materials were made by the author of the paper. The material is divided into 10 units for theoretical (GSA_A) and 12 units for the practical (GSA_B) course, according to the number of weeks and classes in the III semester. The course GSA_A is scheduled for 8 weeks, and course GSA_B for 7 weeks. Every week, both courses were scheduled for 2 classes per 90 minutes each [8].

The basic literature for the courses were Presentations by units posted on the website of the Faculty of

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Correspondence to: Sonja Krasić, Associate Professor, University of Nis, Faculty of Civil Engineering and Architectur, Nis, Serbia
E-mail: krasic.sonja@gmail.com
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Engineering and Design, Hosei University http://hcms.hosei.ac.jp/portal/site/151501 [9], and the book "Geo–metric Surfaces in Architecture", which was published in a printed version in 2012 in Serbian, and available at the faculty library [10].

3. TEACHING AT GSA_A COURSE

Presentations for the GSA_A course are prepared gradually from simple surfaces to complex ones (fig. 1) [9]. Content of the GSA_A course was reduced from the Serbian one. Japanese students have learned about all rectilinear and sphere from the section double curved surfaces.

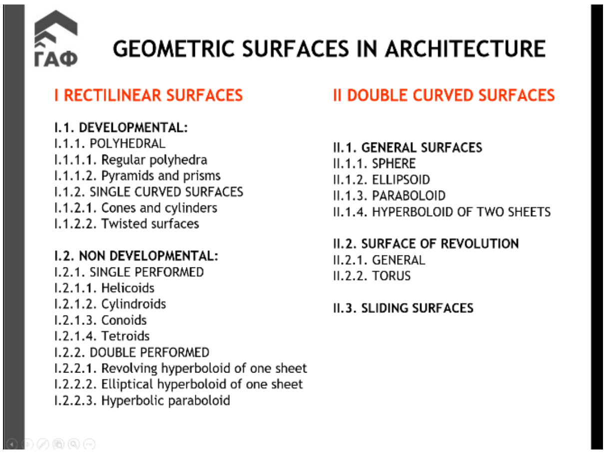


Figure 1. Main division of Geometric Surfaces

The concept of creating all presentations is the same (fig. 2-4). First, it begins with the basic characteristics of the surfaces (fig. 2a and 2b), the method of obtaining them, planar cross sections (fig. 3a) and breakthroughs. On the following slides, there are various examples of 3D models of surfaces. The next part contains examples of performed world objects of the mentioned surfaces (fig. 3b). This is followed by the slide with questions and answers to re-establish the knowledge gained during lecture.

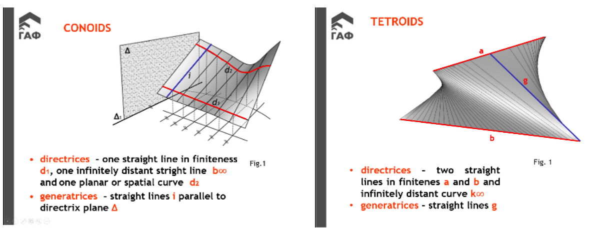


Figure 2. Main characteristics of a) Conoids and b) Tetroids

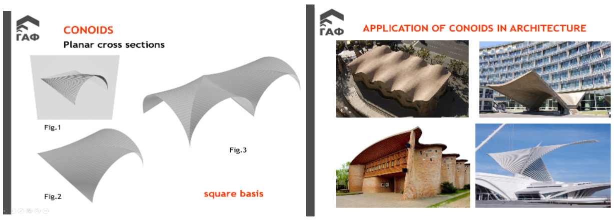


Figure 3. a) Planar cross sections of conoids and b) Exam–ples of conoidal performed objects

In the last part of the presentation there are examples of the best student's final works from the Faculty of Civil Engineering and Architecture (FCEA) in Niš (fig. 4).

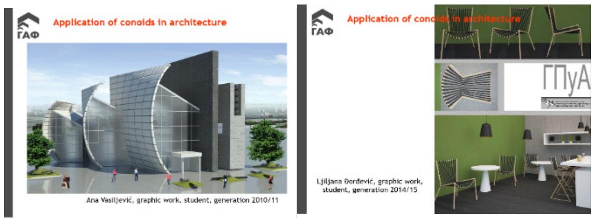


Figure 4. Examples of student final work from FCEA in Niš

3.1 Content at the GSA_A course

In the first week of the course GSA_A, students were introduced to the subject matter, the basic types of sur–faces (rectilinear and double curved). The content of this course is shown in Table 1.

Table 1. The content at the GSA_A course

Units	Title	Weeks
Unit 1	Surface characteristics and their development through historical periods	1st
Unit 2	Platonic and archemedian solids	2nd
Unit 3	Pyramids and prysms with folds structures	3rd
Unit 4	Cones and cylinders with folds structures	4th
Unit 5	Helicoids	5th
Unit 6	Conoids and tetroids	6th
Unit 7	Cylindroids	6th
Unit 8	Hyperbolic parabolids	7th
Unit 9	Hyperboloids of one sheet	7th
Unit 10	Spheres	8th

3.2 Teaching methods at the GSA_A course

The teaching method for GSA_A course was the oral presentation (fig. 5) for each Unit and additional expla–nations for clarifying basic terms, which was followed by drawings on the blackboard by the professor (fig. 6).

Figure 5. Oral presentation of professor

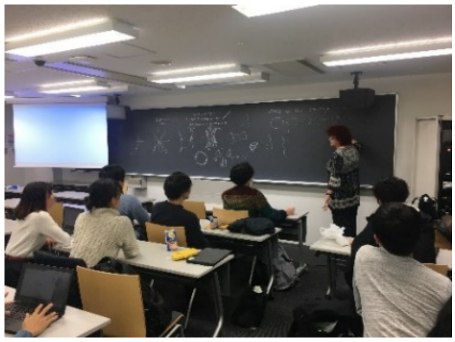
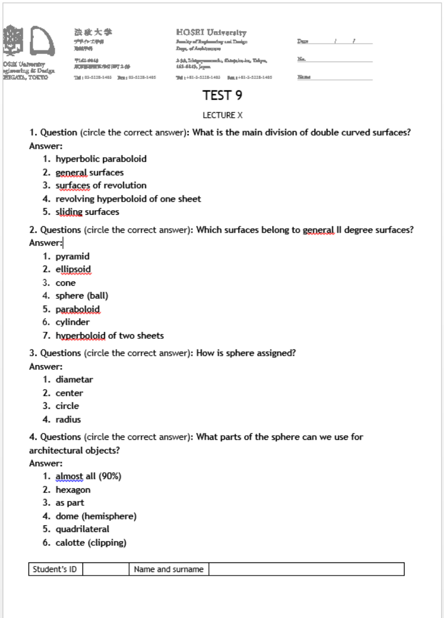


Figure 6. Additional explanations of professor

3.3 Evaluation at the course GSA_A

In the GSA_A course that was attended by 22 students, the pre-examination obligations were achieved on the tests (fig. 7), which were organized in the part of the lecture when the appropriate Unit was presented. There were a total of 9 tests from 9 units. The questions on the tests were about the basic characteristics of the surfaces and the students were solving them by picking the correct answer. The tests contained 4-6 questions. They make 70% of points. Tests were successfully solved by students. The average number of points for the 20 students is 54.55 out of 70.


TEST 9

LECTURE X

1. Question (circle the correct answer): What is the main division of double curved surfaces?
Answer:
   1. hyperbolic paraboloid
   2. general surfaces
   3. surfaces of revolution
   4. revolving hyperboloid of one sheet
   5. sliding surfaces
2. Questions (circle the correct answer): Which surfaces belong to general II degree surfaces?
Answer:
   1. pyramid
   2. ellipsoid
   3. cone
   4. sphere (ball)
   5. paraboloid
   6. cylinder
   7. hyperboloid of two sheets
3. Questions (circle the correct answer): How is sphere assigned?
Answer:
   1. diametar
   2. center
   3. circle
   4. radius
4. Questions (circle the correct answer): What parts of the sphere can we use for architectural objects?
Answer:
   1. almost all (90%)
   2. hexagon
   3. as part
   4. dome (hemisphere)
   5. quadrilateral
   6. calotte (clipping)

Student's ID		Name and surname	

Figure 7. Test for Unit 10

Examination of this course was the final work (fig. 8 and 9), which accounts for 30% of the points. The task for every student was to find one building as an example of applied geometric surface, that professor assigned them to. The object should be displayed on the PowerPoint presentation with as much data as possible. Students did their best and most of them did the final work with the maximum number of points.

Figure 8. Final work GSA_A Conference tower, Tokyo

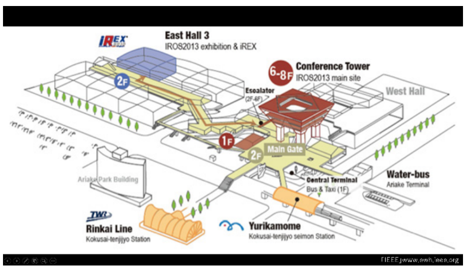


Figure 9. Pyramid and Prism presentation, Park Yaehyun

The average number of points for 17 students who have submitted final work was 24.20 out of 30 points. In this way, they have shown that they learned to recognize geometric surfaces and find inspiration in already performed famous buildings.

Table 2. The final grades from the GSA_A course

Grades	A+	A	B	C	D	E
%	32,0	27,3	9,0	9,0	0,0	22,7

The final grades from the GSA_A course, which was attended by 22 students are shown in table 2, where 17 students passed the exam, while 5 have dropped out of the course. In this course, students showed that they mastered the program. In the GSA_A course 77.3% of students passed.

4. TEACHING AT GSA_B COURSE

The GSA_B course was prepared for computer work in the software Rhinoceros 5. For all 12 units, text expla–nations and sketches in the steps are prepared as templates (fig.10) [11]. The authors tried to make the tasks attractive and simple with as less options as possible. The templates are prepared so the students can repeat the exercise at home and master the program Rhinoceros better.

The main traditional approach to the problem is the presentation of three-dimensional space on two-dimen–sional paper. This is possible only by using a photo realistic render of building 3D model and presentation as a perspective image [12].

Sketches (fig. 11) were made in the software Rhino–ceros and were usually given in the perspective view. For some units, other views were used, if the modelling procedures were explained better in those. Sketches contain mostly basic dimensions. On each template, there is a top and front view for a final object with all dimensions. Since drawing is a basic medium of com-munication in the technical practice, this method was easier for the students to do in class or at home.

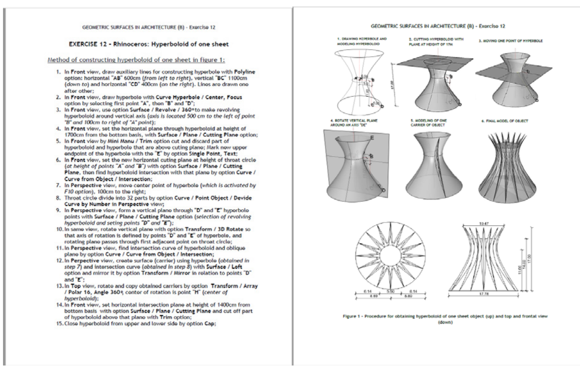


Figure 10. Exercise template for Unit 12

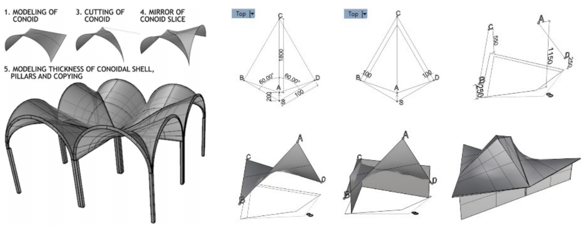


Figure 11. Sketches for Unit 10 and 11

4.1 Content at the GSA_B course

In the first week of GSA_B course, students learned about the basic options for working in the Rhinoceros software. The content of the GSA_B course is shown in Table 3.

Table 3. The content at the GSA_B course

Units	Title	Weeks
Unit 1	Drawing points, straight lines, free and regular curves	2nd
Unit 2	Drawing surfaces and geometric solids	2nd
Unit 3	Platonic solids - pentagonal dodecahedron	3rd
Unit 4	Platonic solids - icosahedron	3rd
Unit 5	Pyramidal folds	4th
Unit 6	Prysms folds	4th
Unit 7	Conical folds	5th
Unit 8	Breakthrough of cylinders	5th
Unit 9	Helical staircase	6th
Unit 10	Conoidal and cylindroidal canopy	6th
Unit 11	Hyperbolic paraboloid building	7th
Unit 12	Hyperboloid of one sheet building	7th

Last week, students were modeling two famous buildings. The first is hyperbolic paraboloid (fig. 12) - the building above the triangular basis, San Vicente de Paul Chapel, in Mexico, architect Felix Candela (Unit 11). Another building is hyperboloid of one sheet (fig.13) - the object above circular basis, Cathedral Brasilia, in Brazil, architect Oscar Niemeyer (Unit 12).

At the end of class, students had time to try to make their designs, obtained from the given surface. They were very creative, which was the goal of this course. The students played with the surfaces and they were very satisfied that their creativity came to the approval of the professor. There were some very interesting solutions and one example will be presented in this paper (fig.14).

Figure 12. Modeling of hyperbolic paraboloid - Unit 11

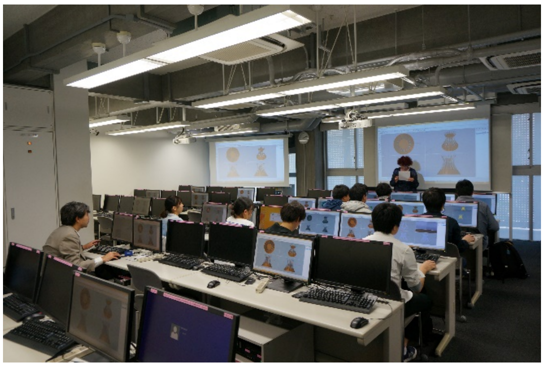


Figure 13. Modeling of hyperboloid of one sheet - Unit 12

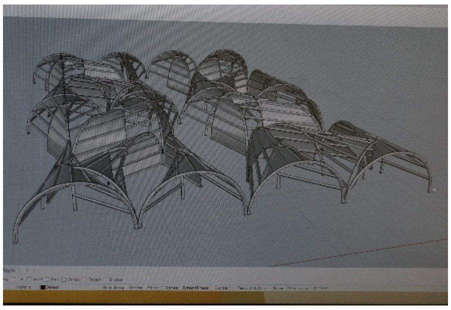


Figure 14. Example of student's original solution

4.2 Teaching methods in the GSA_B course

The teaching method on the GSA_B course, was modeling the given surface in the software Rhinoceros by the professor, with the presentation via video bim (fig. 15). Each student repeated the process of modeling gradually. Units in the GSA_B course were performed after theoretical preparation in the GSA_A course.

Figure 15. Modeling of pyramidal folds Unit 5

4.3 Evaluation at the course GSA_B

In the GSA_B course, which was attended by 24 students, pre-examination obligations were achieved through their work on classes with the total of 60%. Students were able to complete all the tasks of the exercises. The average number of pre-assessment points achieved was 56.57 out of 60 of the total of 19 students who regularly attended the exercises. They successfully mastered the course program.

Examination of this course was the final work, which accounts for 40% of the points. The task for the final work of this course was to use the surface assigned by the professor for the architectural object in the original way. There are examples in which the surface was used for an industrial product, which could have been accepted as an original idea. 3D model of the object and materialization are made in software Rhinoceros, and the environment in the software Lumion. The final work is submitted in the form of a digital poster size 50x70cm (fig. 16, 17 and 18). The top and front views must be displayed on the poster, and also the steps to get the final object and perspective images from the basic surface, which would show their idea the best. Besides posters, students also submitted rhinoceros files of their objects (fig. 19).

Students completed this task excellently. Average points for 18 students who have submitted the final work is 28.5 out of 40 points.

Figure 16. Final work - GSA_B, Ryoga Wakabayashi

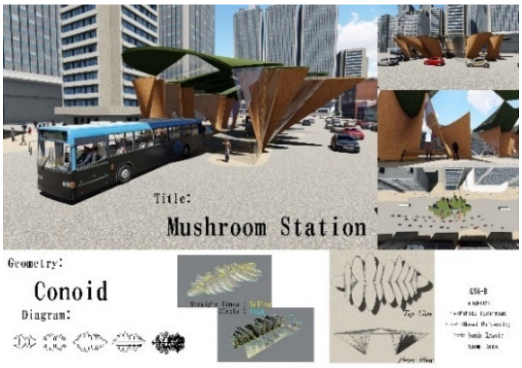


Figure 17. Final work - GSA_B, Fuhito Yoshizawa

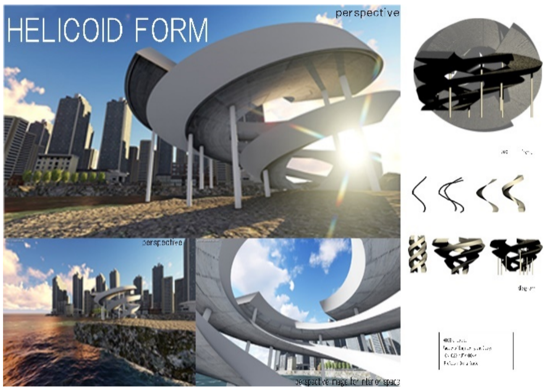


Figure 18. Final work - GSA_B, Yuta Ooka

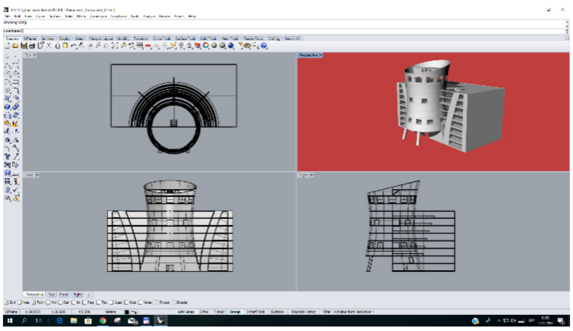


Figure 19. Rhinoceros file of final work - GSA_B

Table 4. The final grades from the GSA_B course

Grades	A+	A	B	C	D	E
%	29,2	20.8	16,6	8,4	4,0	21,0

The final grades from the GSA_B course, which were attended by 24 students are shown in table 4, where 18 students passed the exam, while 6 have dropped out of the course. In these courses, students showed that they mastered the program. In the GSA_B course 75,0% of students passed.

5. CONCLUSION

Teaching the subject Geometric Surface is of great importance for students of the Department of Architecture at the Faculty of Design and Engineering, Hosei University in Tokyo. Students have shown that they have learned not only to recognize geometric surfaces in performed architectural objects, but also, which is even more important, to apply them when designing their projects. Their works were original, they have shown exceptional creativity, which was the goal of this subject. For the evaluation of students for both courses, their independent work was taken into account. The students were very satisfied with the results and knowledge they gained, and they are using it today while designing their projects. It is going to be considered how to upgrade these subjects in the future and also introduce new ones, in which we will refer to the design of the free-form objects.

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НАСТАВА ИЗ ГЕОМЕТРИЈСКИХ ПОВРШИ ЗА СТУДЕНТЕ АРХИТЕКТУРЕ ФАКУЛТЕТА ЗА ИНЖЕЊЕРСТВО И ДИЗАЈН, ХОСЕИ УНИВЕРЗИТЕТА У ТОКИЈУ, ЈАПАН

С. Красић, Н. Андо, П. Пејић, З. Тошић

Објекти слободне форме су у експанзији у архитектури 21. века, нарочито у високо развијеним земљама као што је Јапан. Пројектовање и извођење објеката слободне форме захтева познавање параметријског моде–ловања у неком од софтвера, као што је Рхино–церос. Пре пројектовања објеката слободне форме потребно је добити знање о геометријским површима и њиховој употреби у архитектонској пракси. То је такође уочио Факултет за инжењерство и дизајн, Хосеи Универзитета у Токију, Јапан.

Предмет Геометријске површи је уведен да студенти добију квалитетно знање из ове области, које могу применити за креативније пројектовање њихових архитектонских објеката, што ће бити показано у овом раду.