CHAPTER 8

Aesthetics in Engineering Design

INTRODUCTION

Many considerations go into any new design, including function, cost, material, how it will be fabricated, safety, environmental aspects, etc. The point of this chapter is that how a design looks is also an important consideration, one that can often mean the difference between a good design and a great one. From automobiles to airplanes to appliances, engineers create many of the physical forms that surround us. Therefore, it is their responsibility to make them as visually appealing as possible, so that these designs are pleasing now and in the future.

This chapter provides a broad overview of aesthetics and how it applies to engineering design. Some basic aesthetic concepts are discussed, and some aesthetic elements that can be used in engineering designs are presented. Finally, a tour of the University of Colorado at Boulder is presented to show how some of these aesthetic concepts are exemplified in campus architecture.

ASPECTS OF BEAUTY

One definition of aesthetic is; sensitive to the beautiful; artistic. But, what is considered beautiful is dependent on individual tastes. However, beauty can be broadly interpreted to have two different aspects: emotional and intellectual. An emotional appreciation of beauty depends on the personality of the perceiver and is therefore variable. In addition, it varies with time. The fashions shown in Figure 8.1, for example, were considered very stylish at the time, but today they look "old fashioned."

1. R. Buckminster Fuller (1895-1983) was one of the century’s most original minds, holder of more than 2,000 patents. His foremost invention is the geodesic dome.

2. American Heritage Dictionary

"When I am working on a problem, I never think about beauty. I only think about how to solve the problem. But when I have finished, if the solution is not beautiful, I know it is wrong.”

- Buckminster Fuller"
An engineering designer is more concerned with the intellectual aspect of beauty. From this aspect, the appearance of an object is strongly linked with its function, measuring the suitability of an object for its intended use.

**AESTHETIC CONCEPTS**

The following are broad overall concepts that may apply to any design.

**Less is More**

Mies van der Rohe\(^3\) was an architect who coined this apparent paradox. What he meant by this saying is that simple designs are the most pleasing and last longest over time. For example, the high-rise apartment buildings he designed for Lake Shore Drive in Chicago in 1952 still look modern and pleasing today (Figure 8.2).

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\(^3\) Ludwig Mies van der Rohe (1886-1969) was a German-born architect and designer. His buildings were characterized by accessible, simple designs devoid of applied ornament and were composed of spaces rather than masses.
Louis Sullivan was another architect who designed many buildings in Chicago. His dictum “form follows function” means that the first job of a designer is to make sure that the design functions as it is intended. Its form will then imply its function, suggesting what it is and how to use it.

An example of how this concept applies to design is shown in Figure 8.3. While the primary function of a chair is for sitting, the ability to stack chairs and move them around easily is another important function that is intimately linked with a chair’s form.

Figure 8.2. These high-rise apartment buildings on Lake Shore Drive in Chicago are as pleasing today as they were when they were built in 1952.

**Form Follows Function**

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4. Louis Henri Sullivan (1856-1924) was perhaps the foremost exponent of the Chicago school of architecture, producing 120 buildings, many of them landmarks. Frank Lloyd Wright was his student.
5. Lewis Mumford (1895-1990) was a social thinker and writer who was the architectural critic for the New Yorker.
If tools are designed well, it is obvious how to use them. No one is likely to need to read the owner’s manual to be able to pick up the tools shown in Figure 8.4 and use them.

Figure 8.4. The form of these tools tells how to use them.

**Unity**

The aesthetic concept of *unity* suggests that everything in a design looks like it belongs there. Nothing is missing, and nothing is extra. Manufacturers of a variety of different products use common colors, shapes, type fonts, etc., to create a “family” of products. For example, Figure 8.5 shows two different electronic instruments made by the same manufacturer. The basic shapes, color of the cases, etc. are similar between the two. The assumption is that if a user is familiar with one of these products, then they are more likely to purchase another product from the same vendor (assuming, of course, that the product works well).
However, care must be exercised. There is no exact formula for beauty, and too much of anything soon becomes repetitive and boring. The amateur decorator in Figure 8.6 has clearly gone too far!

Alberti⁶ put it this way:

"I shall define beauty to be harmony of all parts, fitted together with such proportions and connections that nothing could be added, diminished or altered but for the worst."

Roger Fry⁷ observed:

"The first quality that we demand in our sensations will be order, without which our sensations will be troubled and perplexed. The other quality will be variety, without which they will not be fully stimulated."

"Good grief, Marge! Not my pajamas, too!"

Figure 8.6. Anything can be overdone (The New Yorker, reproduced by permission).

6. Leon Battista Alberti (1404-1472) was one of the most brilliant figures of the Renaissance. He was an architect, musician, painter, poet and philosopher.
7. Roger Fry (1866-1934) propounded an extreme formal theory of aesthetics in his role as an art critic, painter and aesthetic philosopher in England and New York City.
Styling

While the first three aesthetic concepts described above are concepts to emulate, styling is an aesthetic concept that should be avoided. Styling refers to ornamentation that is added to a product for sales appeal, but has no function rationale. Styling is the opposite of *form follows function*; it appeals to the emotional aspect of beauty and usually tarnishes with time. Clothing styles illustrate this concept well. The Porsche 911 (Figure 8.7), first produced in 1963, looks much better today than the “styled” Lincoln of the same vintage (Figure 8.8), because the Porsche’s clean, flowing lines are simple and aerodynamically functional.

![Figure 8.7. The Porsche 911 was first produced in 1963 and still looks good today.](image)

Another good example is the bicycle. The touring bicycle has evolved out of function into an aesthetically simple and pleasing shape (Figure 8.9), in contrast to a much heavier, styled bicycle (Figure 8.10).

![Figure 8.8. This heavily styled Lincoln from the 60’s looks very outdated.](image)
It is from basic aesthetic elements that one creates form. Some of these elements are listed below, although this chapter will not discuss color or contrast:

- **Lines**
- **Space**
- **Proportion**
- **Contrast**
- **Mass**
- **Balance**
- **Color**

## Lines

Both artists and engineers use lines as the basic building block to create shapes. However, there are many different styles of lines, and the style of line in a design can convey subtle messages about its function (Figure 8.11). For example, bold lines suggest strength and ruggedness and, therefore, would be good choices for depicting earthmoving equipment. Thin, fine lines, on the other hand, suggest precision and would be good to delineate parts of electronic instruments. Jagged lines convey danger and could be used in high voltage products.
One aspect of lines is that engineers have a tendency, acquired in engineering school, to think of the world in an X-Y-Z Cartesian co-ordinate system. While this system has mathematical advantages, it is important to realize that not all angles need to be $90^\circ$ and not all lines need to be straight. For example, consider the two light poles in Figure 8.12. The one on the left has parallel lines and right angles, whereas the one on the right uses tapered lines for the main column and radiused connections. In addition to being lighter, the pole on the right is also more aesthetically pleasing.

In physics, mass is the property that creates weight in a gravitational field such as on earth. From an aesthetics viewpoint, however, mass is the visual suggestion of weight. For example, consider the fork-lift truck shown in Figure 8.13, which is used to move heavy pallets of cartons around a warehouse. Under the covers, which define the overall shape, is probably a collection of individual components like a battery, hydraulic pumps, electronic circuits, wires, etc. By hiding these components with a monolithic covering, a single, massive shape is created that gives the appearance that it is powerful and rugged enough to do the job. In addition, the covering protects the inner workings

Figure 8.11. Different line types suggest different emotional qualities.

Figure 8.12. Two designs for a light pole: one using parallel lines and right angles, the other using a tapered form and radiused connections.

**Mass**

In physics, mass is the property that creates weight in a gravitational field such as on earth. From an aesthetics viewpoint, however, mass is the visual suggestion of weight. For example, consider the fork-lift truck shown in Figure 8.13, which is used to move heavy pallets of cartons around a warehouse. Under the covers, which define the overall shape, is probably a collection of individual components like a battery, hydraulic pumps, electronic circuits, wires, etc. By hiding these components with a monolithic covering, a single, massive shape is created that gives the appearance that it is powerful and rugged enough to do the job. In addition, the covering protects the inner workings

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8. René Descartes (1596-1650) was a French philosopher and mathematician. In addition to making major contributions to optics, he founded co-ordinate or analytic geometry.
from damage, dirt, moisture, etc. Of course, the truck must in fact be powerful enough to do the job, or it is of no use. This is a good example of *form follows function*.

![Fork-lift truck](image1.jpg)

Figure 8.13. A fork-lift truck appears to be massive enough for its task.

**Space**

When considering aesthetics, the opposite of mass is *space*, and designers can use space to their advantage to create light, airy designs that are visually interesting. One artist who understood the relationship between visual mass and space very well was Escher, who created wonderful optical illusions that played with these two concepts. His etching “Day and Night,” for example, changes seamlessly between mass and space in two dimensions (Figure 8.14). The fields in the lower portion of the drawing become flying geese as the eye moves up. In the daytime scene on the left, the dark geese fly in the lighter colored air, while on the mirrored nighttime scene on the right, the geese are white and the night sky dark.

![Day and Night](image2.jpg)

Figure 8.14. “Day and Night” by M.C. Escher.

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9. The works of the Dutch graphic artist, Maurits Cornelis Escher (1898-1972) have intrigued and delighted for generations. His distortions of space and time have created a dedicated following around the world.
Balance

From the study of physics, we know that there are several ways to balance a weight on a lever. In the top of Figure 8.15, equal weights will be balanced if they are equal distance from a fulcrum. This may be termed “symmetric balance.” A lighter weight may also balance a heavy one, however, if the lighter one is further from the fulcrum, as seen in the bottom of Figure 8.15. This principle is equally well understood by children on a teeter-totter on a playground!

![Symmetric and asymmetric balance](image)

Figure 8.15. Symmetric and asymmetric balance.

From an aesthetics viewpoint, objects may also be either symmetrically or asymmetrically in balance (Figure 8.16). In general, designs that are symmetrically balanced suggest stability, precision, and simplicity; they can also be boring. Designs that exhibit asymmetric balance are more dynamic and interesting to the eye.

![Symmetric and asymmetric shapes](image)

Figure 8.16. Three simple shapes can be symmetrically (L) or asymmetrically (R) balanced. Symmetric balance connotes stability, while asymmetric balance is more eye-catching.

Early space capsules were symmetric for aerodynamic reasons (Figure 8.17), while the Space Shuttle exhibits asymmetric balance (Figure 8.18). Its shape suggests that it really can fly, as opposed to the Apollo capsule, which is more of a ballistic particle.
The symmetric balance of the calculators in Figure 8.19 suggests the precision they display. The oscilloscope in Figure 8.20 is also a precision instrument, but the asymmetric balance created by the extreme left screen placement makes it more visually interesting.

Figure 8.17. The Apollo space capsule’s symmetric aesthetic balance is driven by its aerodynamic function.

Figure 8.18. The Space Shuttle exhibits asymmetric balance and is more visually intriguing.

The symmetric balance of the calculators in Figure 8.19 suggests the precision they display. The oscilloscope in Figure 8.20 is also a precision instrument, but the asymmetric balance created by the extreme left screen placement makes it more visually interesting.

Figure 8.19. These calculators are symmetrically balanced.
Lines can be combined to create geometric shapes. Proportion refers to the relationship between the lengths of lines in a geometric shape. Using the same proportioned shapes throughout a design is one way to create aesthetic unity. While many systems of proportion are possible, we will consider a classic system of proportion for rectangles that was discovered and utilized by the ancient Greeks.

Consider the three rectangles in Figure 8.21. To most observers, the top rectangle is “too skinny,” the bottom one “too fat,” but the one in the middle appears “just right.” While the other two rectangles are arbitrary, the middle one is known as a golden rectangle, which has a unique proportion that is precisely defined and has interesting properties.

One of a golden rectangles properties is that if a square is subtracted from (or added to) a golden rectangle, the resulting shape will also be a golden rectangle (Figure 8.22). This allowed the ancient Greeks to scale this proportion up or down geometrically (without using calculators!) to relate different aspects of buildings to each other in a visually pleasing way (Figure 8.23).
A simple mathematical derivation shows that this “divine ratio,” as it is also called, is numerically equal to an irrational number:

\[ \Phi = 1.618034 \ldots \]

The intriguing fact about this ratio is that it appears repeatedly throughout nature. For example, the ratios of the successive lengths of the finger bones in the human being follow this proportion. The ratio \( \Phi \) can also be found throughout the natural world of plants, fish, etc. (Figure 8.24).
One may speculate why this proportion appears so pleasing to the human eye. Perhaps its prevalence in nature is significant. Another possibility is that the field of vision of the human eye is elliptical and fits neatly into a golden rectangle. In any case, the use of a consistent proportion, such as the golden rectangle, throughout a design can contribute to a sense of aesthetic completeness, or unity. It should not be overdone, however. The world would be a boring place if every building and every human-made artifact were based on golden rectangles.

**A CAMPUS TOUR**

The University of Colorado at Boulder campus is renowned for its aesthetic beauty. One architectural critic calls it the most beautiful public college campus in the US, and fourth among all institutions [1]. Although the emphasis of this chapter is on aesthetics in engineering design, many of the concepts apply to the campus architecture as well.

In 1876, what is now known as Old Main became the first building on a new campus, which was then a treeless bluff (Figure 8.25). Since then, a succession of campus architects, working in cooperation with a strong Design Review Board, have maintained a consistency of style to uphold the integrity and harmonious look of the campus.

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10. Top-ranked campuses are Stanford and Princeton Universities, and Wellesley College.
The aesthetic concept of unity is evident, particularly in the native Colorado sandstone façades and red tile roofs that characterize almost all buildings on campus. For example, Ketchum Hall, which was the original engineering building, was built in 1937 (Figure 8.26).
Forty years later, an addition to Norlin Library (Figure 8.27) was built adjacent to Ketchum. Although building techniques changed much during forty years, the use of common architectural elements tie the two buildings together well (Figure 8.28). In addition, a large circular plaza unites these buildings.

Figure 8.27. This addition to Norlin Library was built in 1977.

Figure 8.28. The two buildings flank a large circular plaza that integrates them well.
Charles Klauder was undoubtedly the architect who most influenced the CU campus. His firm completed a campus master plan in 1919, and he designed 15 buildings during the next 20 years [2]. Sewall Hall, built in 1934, is considered the best of his buildings, exemplifying the Tuscan Vernacular style that characterizes the CU campus (Figure 8.29).

Figure 8.29. Sewall Hall (1834) was originally known as Women’s Residence Hall.

The Student Recreation Center (1973) shows a strong influence of proportion (Figure 8.30). The prominent concrete columns on the façade define a series of rectangles (not Golden!) whose proportions are used throughout the facility to tie it together. Aesthetic beauty is not achieved by formula, and the human eye would quickly tire if all buildings used the same proportions.

Figure 8.30. The Student Recreation Center (1973) uses a rectangular form throughout, although it is not the Golden Rectangle.
Although the Engineering Center (1965) is certainly the most controversial building from an aesthetic standpoint, it has won awards for its bold, innovative architecture suggestive of the mining heritage of the state of Colorado (Figure 8.31). This 500,000-sq. ft. complex, while often confusing to navigate, has also proved to be very functional. Although it makes strong use of exposed concrete, the campus elements of Colorado sandstone and red tile roofs integrate it with the remainder of campus.

When the Integrated Teaching and Learning Laboratory (ITLL) was designed 30 years later, the architects faced a daunting challenge: to respect the external architecture of the Engineering Center, while at the same time creating a more open, visible architecture that would stimulate creative learning within (Figure 8.32).

Figure 8.31. The Engineering Center (1965) is both controversial and functional.

Figure 8.32. The Integrated Teaching and Learning Laboratory (1997) connects with the Engineering Center to the west. It was named the Grand Prize Winner for buildings built in Colorado by the Construction Management Report in 1997.
From the outside, large, sloping roof monitors that are identical in slope to those on the Engineering Center top the large, square building mass. However, whereas the roof monitors in the larger Engineering Center house mechanical equipment, those in the ITLL are open from below and contain large clerestory windows that bring in the wonderful indirect north light favored by artists. In both cases, these are good examples of *form follows function*. The ITLL architects chose the square as the geometric element to bring *unity* to the design. The goal is to create unity both within the laboratory, and to tie it to the Engineering Center. Close inspection finds this square shape prevalent in many places throughout the 35,000-sq. ft. building. For example, square acoustic panels are distributed throughout the large, open laboratory plazas to help control sound, another example of *form follows function* (Figure 8.33).

![Square acoustic panels attenuate noise and also integrate well aesthetically.](image)

**Figure 8.33.** Square acoustic panels attenuate noise and also integrate well aesthetically.

The square wire mesh panels in the balcony and stair railings are both functional and aesthetic (Figure 8.34). However, the overall framework that contains them is rectangular to avoid overuse of the square element (recall the cartoon of Figure 8.6). When using any aesthetic element, like the square, it is important to use it in moderation.

![Square wire mesh panels are both functional and aesthetic.](image)

**Figure 8.34.** Square wire mesh panels are both functional and aesthetic.
Square glass blocks allow natural light to silhouette the stairway to the lower laboratory plaza (Figure 8.35). Their solid 3-in. thick construction provides both fire protection required by building codes and better light transmission than the more common hollow glass block form. This is another excellent example of form follows function.

The square cutouts in the steel stair risers (Figure 8.36) allow a small amount of light to pass through, but their function is primarily aesthetic.

The overall floor plan of the ITLL, like the Engineering Center it adjoins, is based on a 20ft x 20ft square modular dimension that is accentuated by the pattern of floor tiles in the laboratory plazas. This is particularly noticeable when viewed from the overlook (Figure 8.37).
And, when outside looking up at the underside of the bridge that connects the ITLL with the Engineering Center, a square “waffle” pattern is evident (Figure 8.38). This pattern reduces weight in the structure and requires less concrete, saving cost. A square is the simplest pattern to implement, and this same feature is evident in the undersides of many exposed concrete structures in the Engineering Center. Using the same pattern in both locations makes them look like an integral structure, instead of structures that were built thirty years apart in time.
CONCLUSION

Engineers are responsible for most of the fabricated world around us and thus, have a responsibility to create products that are beautiful as well as functional. It should be the goal of any engineering designer to create designs that look as good twenty years from now as they do today. It is necessary to consider the aesthetics of a design during the design phase in order to create truly superb designs.

However, engineers must also exercise caution. Engineers love to use simple formulas to solve problems, but there is no simple formula that will guarantee aesthetic beauty. An awareness of some basic aesthetic concepts and recognition of them in the designs of others can help the designer create beautiful products.

REFERENCES