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Hercule Poirot and supports settlement

Vlaho Akmadžić, Ph.D.
Faculty of Civil Engineering, Architecture and Geodesy, University of Mostar, vlaho.akmadzic@fgag.sum.ba
Matej Lozančić, M.Sc.
Faculty of Civil Engineering, Architecture and Geodesy, University of Mostar, matej.lozancic@fgag.sum.ba
Matea Primorac
Faculty of Civil Engineering, Architecture and Geodesy, University of Mostar, matea.primorac@fgag.sum.ba

Abstract: The inspiration for writing this paper lies in the character of Hercule Poirot, a fictional Belgian detective who appears in the Agatha Christie novel series. In the television series, the detective role was played by actor David Suchet. The paper, which builds on a series of works related to the phenomenon of support settlement, the occurrence of cracks and the determination of the soil reaction coefficient, shows the connection between the shape of the mustache of the actor mentioned in the series and the settlement of the middle support of a continuous girder over two spans. The sought answer was found by observing the area between the limit cases of the bending moment diagram following fractal logic.

Key words: Hercule Poirot, soil reaction coefficient, settlement of supports, fractal

Hercule Poirot i slijeganje oslonaca

Sažetak: Inspiracija za pisanje ovog rada leži u liku Hercule Poirota, fiktivnog belgijskog detektiva koji se pojavljuje u seriji romana Agathe Christie. Detektiva je u televizijskoj seriji utjelovio glumac David Suchet. Rad, koji se nadovezuje na niz radova vezanih za fenomen slijeganja oslonaca, pojavu pukotina i određivanja koeficijenta reakcije tla, pokazuje povezanost oblika brkova spomenutog glumca u seriji i slijeganja srednjeg oslonca kontinuiranog nosača preko dva polja. Traženi odgovor je pronađen kroz promatranje područja između graničnih slučajeva oblika dijagrama momenata slijedeći fraktalnu logiku.

Ključne riječi: Hercule Poirot, koeficijent reakcije tla, slijeganje oslonaca, fraktal

1. INTRODUCTION

According to Encyclopaedia Britannica [1], Hercule Poirot is a fictional Belgian detective who appears in a series of Agatha Christie novels. In his approach to solving problems, he relies predominantly on his "little grey cells," on meticulousness in his personal habits, and on a methodological approach to work. He appears in Agatha's first novel, The Mysterious Affair at Styles (1920), as well as in a series of later books. Among the many works, one can point out two of the best known and probably most popular by the public, and these are the works Murder on the Orient Express (1933) and Death on the Nile (1937). The series of books ends with the final appearance and death of Hercule Poirot, which occurs in the novel Curtain (1975). Christie was said to have based Poirot's mannerisms on her personal research into the behavior of Belgian refugees in Great Britain during World War I [1].

Also, the detective Hercule Poirot was featured in a number of film adaptations, and was memorably portrayed by such actors as Tony Randall in the 1965 film adaptation of The Alphabet Murders, Albert Finney in the 1974 film adaptation of Murder on the Orient Express, and Peter Ustinov in the film adaptation of Death on the Nile (1978), Evil Under the Sun (1982), and Appointment with Death (1988) and in several made-for-television films. The role was given an exquisite touch by actor David Suchet shown in Figure 1 in the television series Agatha Christie: Poirot (1989-2013). It is interesting that David Suchet is also featured as Poirot in video games [1]. His mustache from the character in the television series was the inspiration for writing this paper, in which we will connect fractal, mustache and settlement. Eventually, John Malkovich played Poirot in a 2018 television miniseries, and Kenneth Branagh starred as Poirot in several films that he also directed, including Murder on the Orient Express (2017) and Death on the Nile (2022) [1].

Figure 1. David Suchet as Hercule Poirot [2]

2. THE PHENOMENON OF SETTLEMENT OF SUPPORTS

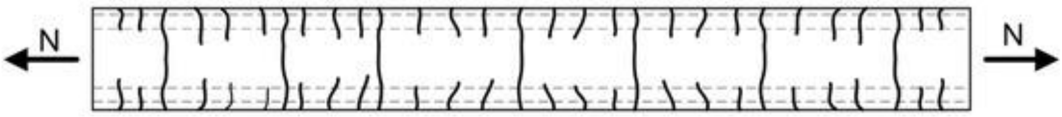
When discussing any structure, the discussion is about the necessity of its calculation, which is nowadays essentially reduced to the creation of appropriate computer models. In the first step, these are models based on CAD technology (Figure 2), which are then created for calculation purposes in one of the customized programs that should approximate the actual behavior of the structure in the best possible way.

Figure 2. 3D print model of the Hercule Poirot bust [3]

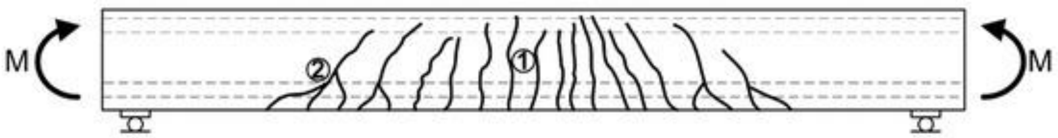
As every structure is supported on a base, and eventually on the ground, it is necessary to model how the structure is connected to the base. In many cases, this connection is not perfect, and causes a specific phenomenon known as the settlement of supports.

The best-known commonly discussed settlement prediction methods are those proposed by Terzaghi and Peck (1948), Schmertmann (1970), Schmertmann et al. (1978) and Burland and Burbidge (1985). The methods of Meyerhof (1956) and Peck and Bazaraa (1969) are similar to the one proposed by Terzaghi and Peck (1948). Two of the most recent methods are after Berardi and Lancellotta (1991) and Mayne and Poulos (1999). Sivakugan and Johnson (2004) proposed a probabilistic approach quantifying the uncertainties associated with the settlement prediction methods [4]. Computed and measured settlements of full-scale footings have been compared by Jeyapalan and Boehm (1986), Papadopoulos (1992) and Sivakugan et al. (1998). The message is loud and clear that the predictions are generally significantly greater than the measured values. Based on 79 case histories of shallow foundations, Sivakugan et al. (1998) showed that Terzaghi and Peck (1948) method overestimates the settlements by 218% and Schmertmann (1970) method overestimates the settlements by 339% [4].

When the uniform settlement of the entire structure within the allowable limits is concerned, the phenomenon does not threaten the other elements of the subject structure (Figure 7 a). On the other hand, if the settlement is nonuniform, problems increase with stiffness, which is manifested to the users of the structure through the occurrence of relevant cracks (Figure 7 c) on the structure.



(a)



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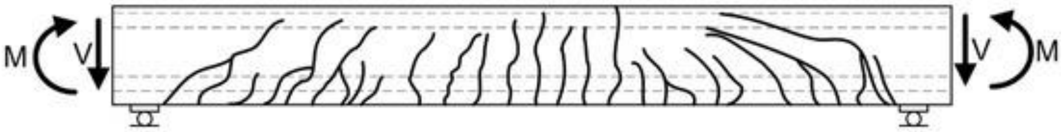

(c)

(d)

Figure 3. Types of cracks on the beam girder (a) due to tension, (b) due to pure bending, single cracks (1) or collective cracks (2), (c) due to moment M and shear force V, (d) due to torsional moment T [5]

The cracks specified on the static system of a simple beam (Figure 3) are classic cracks that occur when testing beam girders under external load. They help classify actual cracks identified on real structures.

Of interest for writing this paper were cracks that occur due to: incorrect foundation dimensions (cracking), changes in moisture content in clayey soils (expansion), poorly compacted soil (nonuniformity), too low bearing capacity, inhomogeneous soil characteristics across profiles, and the occurrence of uplift pressure, vibrations, and vegetation.

Figure 4. Cracks in a floor slab [5]

Figure 5. Cracks in walls [6]

Figure 6. Cracks due to vegetation [6]

When talking about the term settlement of supports, allowable limits are prescribed for its occurrence, which can be grouped into three categories. The first category refers to the total allowable settlement, which for example for masonry structures, depending on the method of foundation, is 2.5 - 5.0 cm [7]. The second refers to leaning, which is related to the concept of overturning, and for example for chimneys it is 0.004 L. The last third category is related to the most dangerous type of settlement known as differential settlement, for which the limit values are strict due to the consequences it entails. The most common examples are given below.

(a) (b) (c)

Figure 7. Settlement of a building: as a rigid body (a), leaning (b) and differential settlement (c) [6]

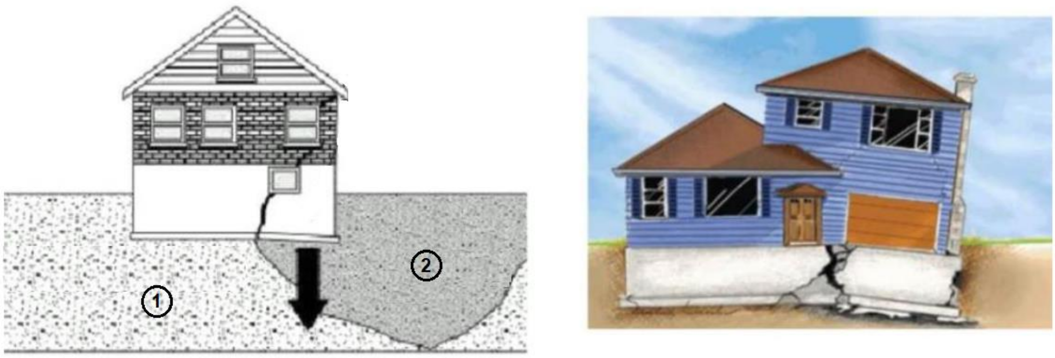

Figure 8. Differential settlement due to the difference in soil of good (1) and poor (2) bearing capacity [6]

In everyday practice, a large number of residential and industrial buildings are mostly constructed using a shallow foundation system. In order to adequately calculate the foundations and the system above, the engineer is faced with the challenge of how to describe the soil-structure connection. The answer is usually sought in modeling the soil-foundation connection using the Winkler spring model [8,9]. The numerical approach requires a numerical value for the stiffness of the Winkler spring through the so-called modulus of subgrade reaction [10,11], which simulates the elasticity of the base under that support. In fact, it is a relationship between the stress under the foundation and its displacement, which can be programmed depending on the approach of different authors [12].

3. ELASTIC SUPPORT

This paper considers a statically indeterminate structure in a plane over two spans in which the middle support is elastically deformable. This support is not absolutely rigid nor has it settled to a finite value [13,14,15] as shown in Figure 9. The goal is to show the behavior of the structure, or rather, to see what the response of the structure is with respect to the change in the elasticity coefficient k [m/N] of a particular support.

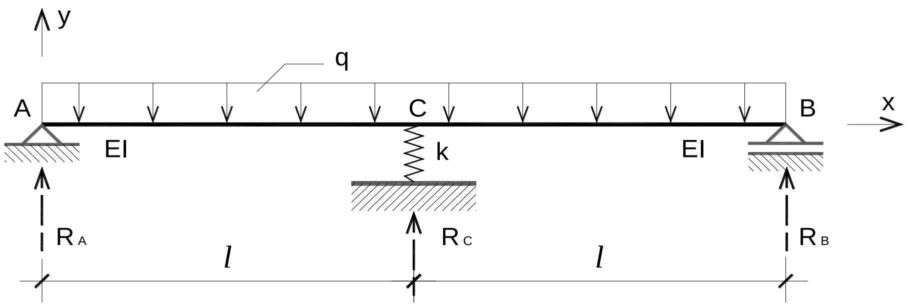

Figure 9. Continuous girder over two spans [13]

The static system shown in Figure 9 is once statically indeterminate. Since the middle support settles, it will be eliminated as a redundant quantity. The relationship between displacement, stiffness and force is known from the theory of structures, and it is expressed through the relationship:

$$F = K \cdot u \tag{1}$$

Where:

F = is force
K = stiffness
u = displacement

If the displacement in the direction of the spring is marked as λ, the equation in this example becomes:

$$R_c = K \cdot \lambda \ \rightarrow \ \lambda = K^{-1} \cdot R_c = k \cdot R_c \tag{2}$$

Where:

R_C = is the reaction at support C
K = stiffness
λ = displacement in the direction of the spring

In order to apply the force method, the equation X_1=R_C will be introduced. Now the basic system looks like in Figure 10. The compatibility equation system is:

$$\delta_{11} \cdot X_1 + (\Delta_{1p} - \Delta_{1s}) = 0 \tag{3}$$

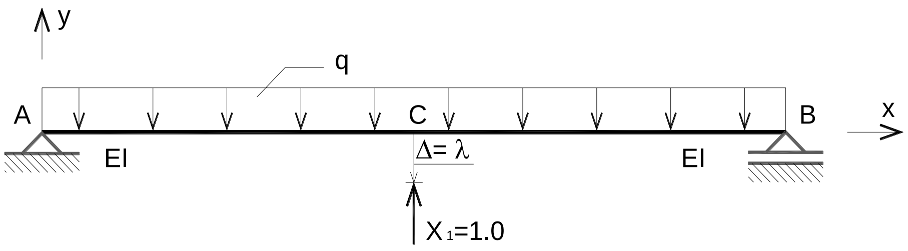

Figure 10. Basic system according to the force method [13]

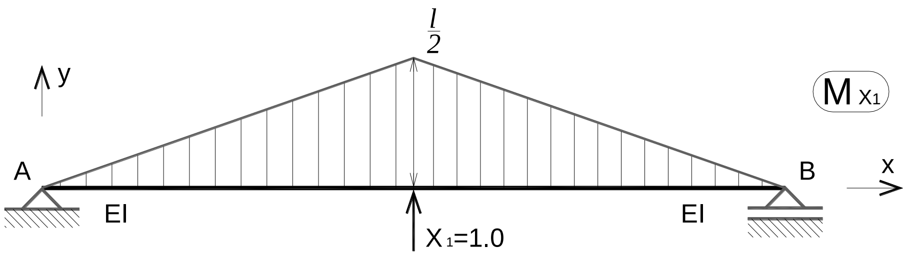

Figure 11. Moment diagram on the basic system from X_1=1.0 [13]

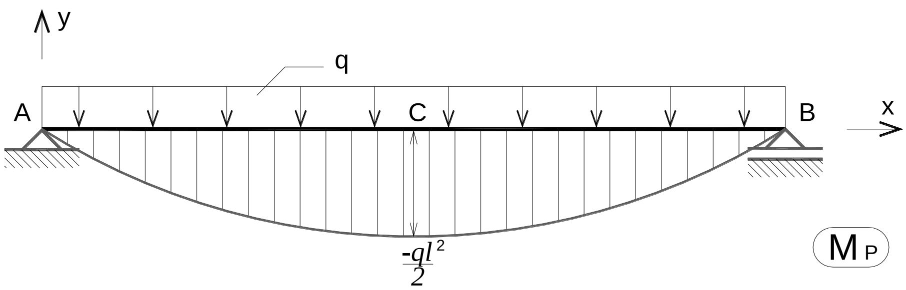

Figure 12. Bending moment diagram on the basic system from external load [13]

The values of the displacement coefficients are:

$$EI \cdot \delta_{11} = 2 \cdot \frac{1}{2} \cdot l \cdot \frac{l}{2} \cdot \frac{2}{3} \cdot \frac{l}{2} = \frac{l^3}{6} \tag{4}$$

$$EI \cdot \Delta_{1p} = -2 \cdot \frac{5}{12} \cdot \frac{l}{2} \cdot \frac{q \cdot l^2}{2} \cdot l = -\frac{5 \cdot q \cdot l^4}{24} \tag{5}$$

$$EI \cdot \Delta_{1s} = -1 \cdot \Delta \cdot EI = -\lambda \cdot EI = -k \cdot X_1 \cdot EI \tag{6}$$

Substituting the values obtained in expressions (4), (5) and (6) into equation (3) and solving it, the value of force X_1 specified in expression (7) is obtained. In order to construct moment diagrams, it is necessary to calculate the moment values at individual points of a continuous girder over two spans.

$$\frac{l^3}{6} \cdot X_1 + \left(-\frac{5 \cdot q \cdot l^4}{24} + k \cdot X_1 \cdot EI\right) = 0 \;\rightarrow \left(\frac{l^3}{6} + k \cdot EI\right) \cdot X_1 = \frac{5 \cdot q \cdot l^4}{24}$$
$$\rightarrow \left(1 + k \cdot \frac{6 \cdot EI}{l^3}\right) \cdot X_1 = \frac{5 \cdot q \cdot l}{4} \tag{7}$$

$$X_1 = \frac{5}{4} \cdot \frac{q \cdot l}{1 + k \cdot \frac{6 \cdot EI}{l^3}}$$

The moment values at individual points are:

$$M_A = M_A = 0 \tag{8}$$

$$M_C = -\frac{q \cdot l^2}{2} + \frac{l}{2} \cdot \frac{5}{4} \cdot \frac{q \cdot l}{1 + k \cdot \frac{6 \cdot EI}{l^3}} \tag{9}$$

Since the previous expressions are given in general numbers, it is necessary to observe extreme cases in the first step. Then, the intermediate steps are solved, which lead to many interesting insights. For the beginning, let us assume that the support C is absolutely rigid, or that k=0, and then:

$$M_C^{rigid} = -\frac{q \cdot l^2}{2} + \frac{l}{2} \cdot \frac{5}{4} \cdot \frac{q \cdot l}{1 + 0} = \frac{q \cdot l^2}{8} = M_{max} \tag{10}$$

Also, the value of the reaction and the second extreme moment will be given as a result of the assumption:

$$R_C^{rigid} = X_1^{rigid} = \frac{5}{4} \cdot q \cdot l \qquad M_{min} = -\frac{9}{128} \cdot q \cdot l^2 \tag{11}$$

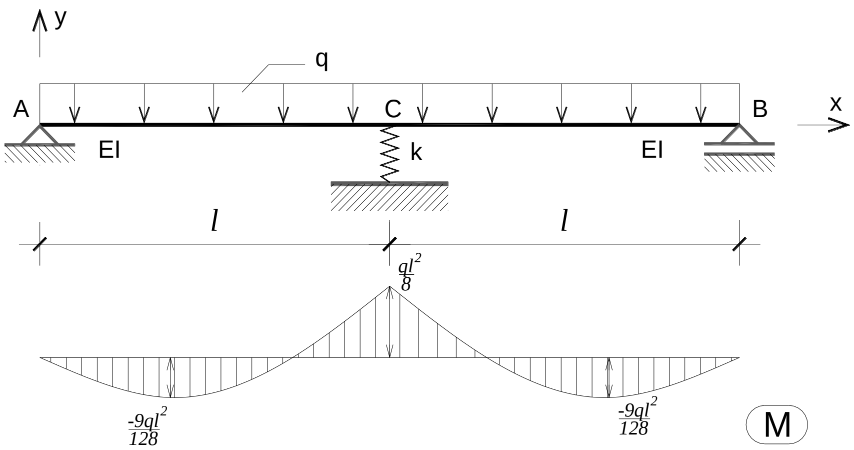

Figure 13. Diagram of bending moments for k=0 [13]

The second extreme case occurs when assuming that the support C is absolutely soft, or that $k = \infty$. So, as if there were no support. This conclusion is reached when the value of the moment in C is analyzed in more detail, which is:

$$M_C^{soft} = -\frac{q \cdot l^2}{2} + \frac{l}{2} \cdot \frac{5}{4} \cdot \frac{q \cdot l}{1 + \infty} = -\frac{q \cdot l^2}{2} = M_{min} \tag{12}$$

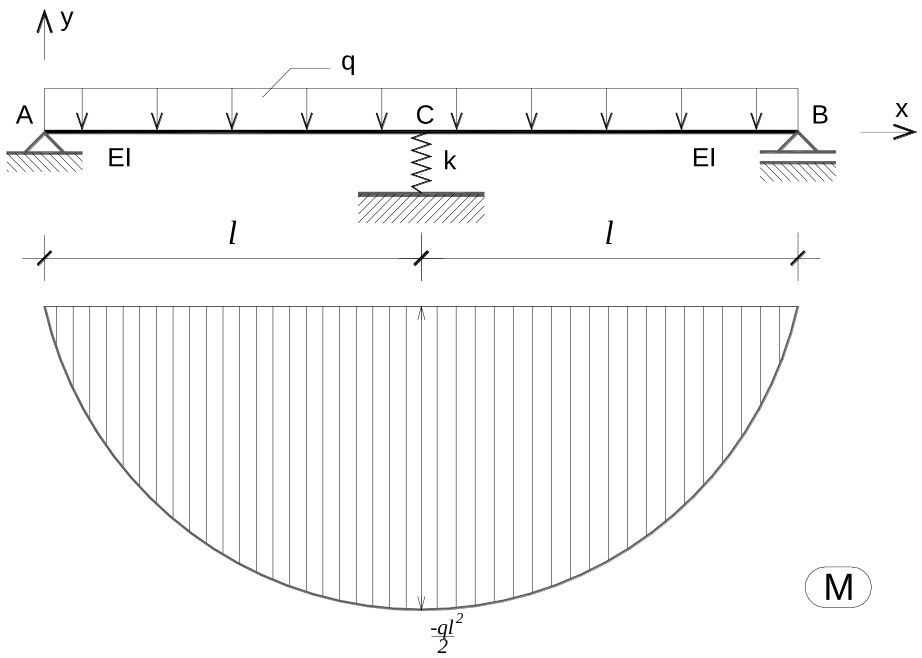

Figure 14. Diagram of bending moments for $k = \infty$ [13]

The value of the reaction confirms the fact that there is no second extreme moment, and it is:

$$R_C^{soft} = X_1^{soft} = 0 \tag{13}$$

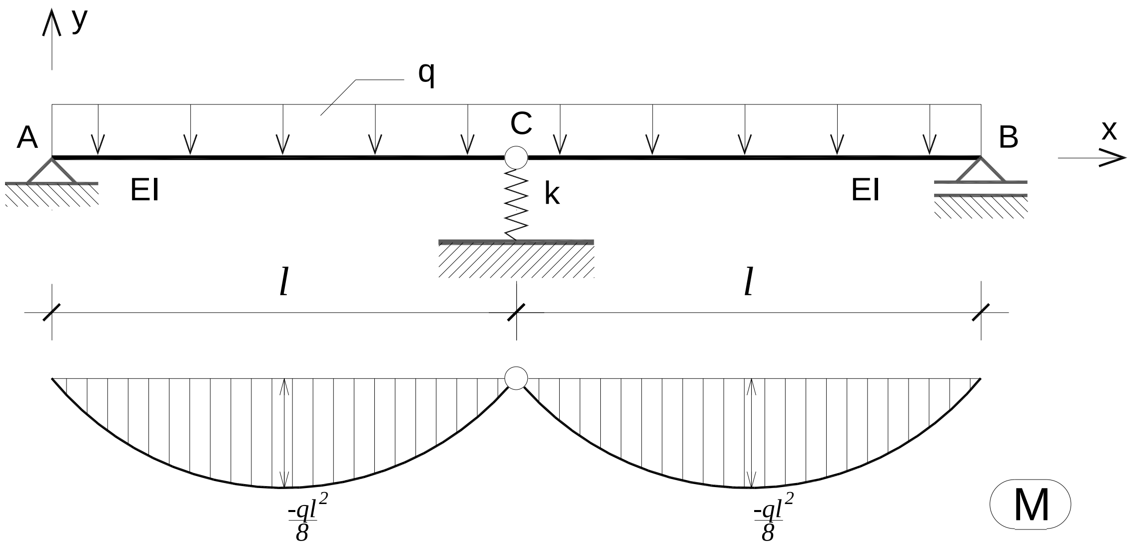

Figure 15. Diagram of bending moments for the case when there is a joint at point C [13]

Figures 13 and 14 in the bending moment diagrams show both these extremes (stiff and soft), as well as the case where there is a joint in support C at high support stiffness (Figure 15). In the latter case, the statically indeterminate girder is transformed into a statically determinate one, so the moment at point C is equal to zero.

4. CONNECTING SETTLEMENT, MUSTACHE AND FRACTALS

In order to have a better insight into the description of the intermediate states, it is necessary to present all three limit cases on a single diagram. As can be seen in Figure 16, varying the stiffness of the middle support will lead to different shapes of the moment diagrams within certain limit cases. Certainly, one of these shapes will be reminiscent of the unique shape of the mustache of the famous 'virtual' Belgian detective Hercule Poirot (Figure 17).

The actual matching goes into the domain of form finding. Namely, if one wants to find a real moment diagram that would describe the upper and lower curves of the subject mustache with great precision, the supports, load and stiffness of the spring would have to be varied. In this case, this would probably involve placing fixed or elastically fixed supports at the ends and setting some form of trapezoidal load.

On the other hand, from the aspect of architecture, it is known that the form itself is not arbitrary but is the result of a parameter change, which in this specific case, in simple terms, would be the parameter of change in the middle support stiffness that results in a transformation of the visual pattern of the moment diagram.

The architectural form itself often comes into being as a response to various effects such as gravity, light, function, context, material and the like. The link can be based on fractals, where complexity is built by applying a simple rule through different scales in the architectural design of space. In practical application, this is carried out through digital tools and scripted processes that result in architectural solutions possessing fractal characteristics.

Using the metaphor of Poirot's moustache, form goes beyond mere visual recognition and is an example of how patterns that acquire meaning through interpretation often appear in culture. In architecture, the same principle is used to understand formal patterns as carriers of identity, symbolism, and relationships, and not just as geometric concepts.

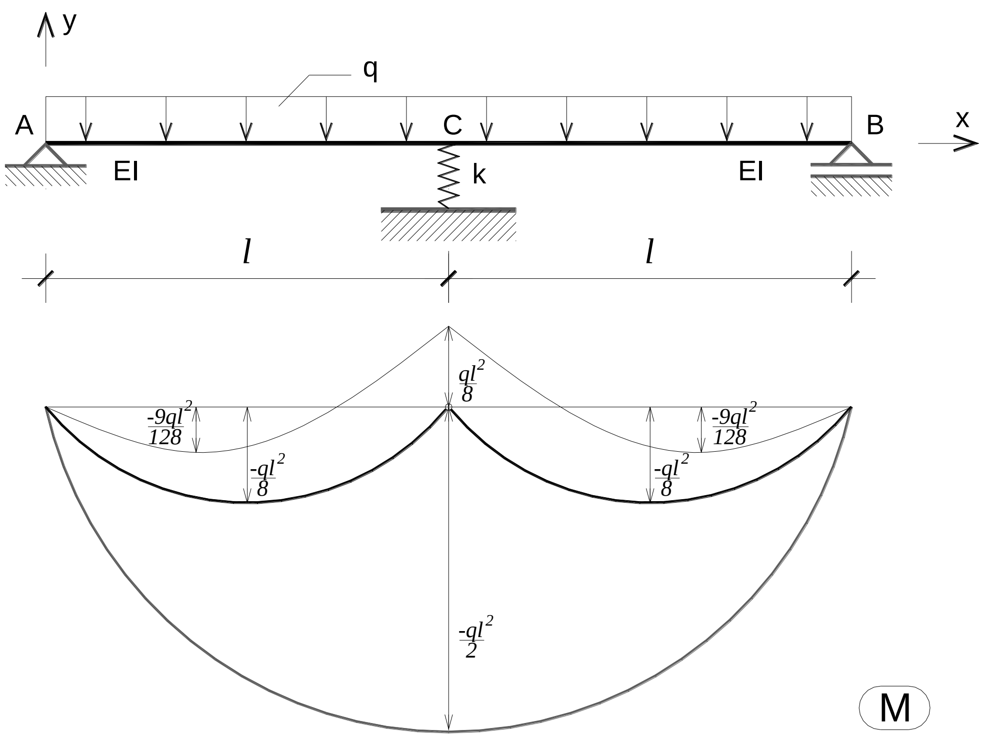

Figure 16. Integral diagram of bending moments [13]

Figure 17. The shape of Hercule Poirot's moustache [2]

Just as Poirot arrives at a solution through a series of clues, so too does the engineer read space, connect seemingly invisible effects, and shape a structure that either already exists or will exist in the potential of the environment in which the engineer is modeling. Namely, fractals connect different mathematical concepts (settlement) with things in the environment that can be identified (in this case, the mentioned mustache) and help the engineer to design different structures and to connect seemingly invisible things in the environment, which is precisely what the previously mentioned potential of the environment represents.

5. CONCLUSION

Fractals are one of the interesting examples of reflecting mathematical concepts in the nature around us. The best-known example is certainly the snowflake. On the other hand, in architecture, fractals are not only an aid for creating visually interesting structures, but also a way to develop a functional space following natural patterns and rhythms. As this paper has shown, part of this also lies in other branches of engineering.

Based on all of the above, and primarily in order to bring the analysis of load-bearing structures and space closer and make it interesting to a wider audience, an attempt is made here to connect an important branch of the construction profession with the filming of literary works. No civil engineer is unfamiliar with the described problem, since the phenomenon known as settlement of supports causes significant defects in the structure, which sometimes result in its collapse. Involving constantly expanding knowledge in the subject area in order to achieve the goal, which is to provide an answer to the task set, a Hercule Poirot-like detective approach is required again and again when reconstructing, renewing or extending buildings, or when designing a new one.

REFERENCES

1. The Editors of Encyclopaedia Britannica. "Hercule Poirot." Encyclopedia Britannica, 13 December 2024. https://www.britannica.com/topic/Hercule-Poirot.
2. https://www.mediastorehouse.com.au/memory-lane-prints/mirror/0000to0099-00044/david-suchet-plays-agatha-christies-poirot-21322102.html
3. https://www.cgtrader.com/3d-print-models/art/sculptures/hercule-poirot-david-suchet-3d-printable-bust-portrait
4. Lukić, I.: Pregled metoda slijeganja plitkih temelja na zrnatim tlima, e-Zbornik: Electronic collection of papers of the Faculty of Civil Engineering University of Mostar, 2013.
5. Golewski, G. L.: The Phenomenon of Cracking in Cement Concretes and Reinforced Concrete Structures: The Mechanism of Cracks Formation, Causes of Their Initiation, Types and Places of Occurrence, and Methods of Detection—A Review. Buildings. 2023; 13(3):765. https://doi.org/10.3390/buildings13030765
6. Tomlinson, M. J.: Foundation design and construction, 5th edition, Longman Scientific & Research, London. 1986.
7. Skempton, A. W., MacDonald, D. H: Allowable settlement of buildings, Proc Inst Civ Engrs, Part III, 1956.
8. Prskalo, M., Akmadžić, V., Vrdoljak, A.: Influence of subgrade reaction coefficient modelling on simple 3D frame exposed to symmetric horizontal load, e-Zbornik, Electronic collection of papers of the Faculty of Civil Engineering, 9(18), pp. 35-43, 2019.
9. Mianji, P., Hosseininia, E. S.: A Modified Method for Modelling of Spread Footing Under Uniform Distributed Load Using Winkler's Model, Journal of Theoretical and Applied Mechanics, Vol. 49 (1), pp. 39-50, 2019.
10. Sandrekarimi, J., Akbarzad, M.: Comparative study of methods of determination of coefficient of subgrade reaction, Electronic Journal of Geotechnical Engineering, Vol. 14, pp. 1-14, 2009.
11. Prskalo, M., Vrdoljak, A.: Analysis of settlement of foundation plates by finite difference method, Proceedings of the 27th DAAAM International Symposium, Katalinic, B. (Ed.), pp. 0854-0859, 2016, https://doi.org/10.2507/27th.daaam.proceedings.123
12. Akmadžić, V., Vrdoljak, A.: Determination of the soil reaction coefficient value – software solution, e-Zbornik: Electronic collection of papers of the Faculty of Civil Engineering, 8 (15), pp. 22-29, 2018, https://hrcak.srce.hr/203800
13. Akmadžić, V., Trogrlić, B., Prusac, K.: Građevna statika II – Metoda sila kroz primjere, Sveučilište u Mostaru, Mostar, 2016.
14. Gidak, P., Šamec, E.: Statički neodređeni sistemi, Sveučilište u Zagrebu Građevinski fakultet, 2022., urn:nbn:hr:237:724696
15. Mihanović, A., Trogrlić, B., Akmadžić, V.: Građevna statika II., Fakultet građevinarstva, arhitekture i geodezije u Splitu, Split, Hrvatska, 2014., ISBN 978-953-6116-57-7
16. Vrdoljak, A., Miletić, K.: Principles of fractal geometry and applications in architecture and civil engineering. Electronic Collection of Papers of the Faculty of Civil Engineering, 10(17), pp. 40-52, 2019.