Contents lists available AInCEJ

Angolan Industry and Chemical Engineering Journal

Journal visit: aincej.com

Proposal for Monolithic Coefficients for Reinforced Concrete Columns Strengthened by Partial Reinforced Concrete Jacketing

[1]Tomás Fernando, [2]Mário Arruda, [3]João Pacheco and [4]Eduardo Júlio,

[1]Eng, FEUAN/IST, Av. Ho Chi Minh 56, Luanda, Angola
[2]PhD, Instituto Superior Técnico (IST), Avenida Rovisco Pais 1049-001, Lisbon, Portugal,
[3]PhD, c5Lab – Sustainable Construction Materials Association, R. do Central Park, 64ºC Linda a Velha 2795-242.
[4]PhD, Instituto Superior Técnico (IST), Avenida Rovisco Pais 1049-001, Lisbon, Portugal.

ARTICLE INFO

Keywords:
Columns;
Interface; K - Monolithic coefficient;
Partial Jacketing;
Strengthening

Reinforced concrete (RC) jacketing is one of the most widely adopted methods for strengthening RC structures. Full jacketing is adopted in the case of interior columns and monolithic behaviour is easily ensured. However, in the case of corner and edge columns, partial reinforced concrete jacketing should be considered. Partial jacketing also leads to a significant increase in stiffness and resistance, but monolithic behaviour is not achieved. For this reason, and in order to provide guidance for design, it is necessary to consider monolithic coefficients. The monolithic coefficient (K) is the relationship between the behaviour of the jacketed reinforced concrete element and the behaviour of an equivalent monolithic element, i.e. with the same geometry and materials. The value of K is unity for monolithic behaviour and less than 1 otherwise. To obtain a K value close to 1, it is necessary to ensure good adhesion between the jacketing and the original column. The main aim of the PhD thesis presented here is to propose K values for different design cases. The proposals will be based on numerical studies, validated with experimental tests and sensitivity analyses. The proposals will be compared with the K values proposed by EC 2 & 8-3, fib MC 2010 & 103, and ACI 318. Numerical models and experimental tests on columns strengthened by partial jacketing will analyse multiple parameters such as cracking, deformation and resistance.

1. Introduction

1.1. General Framework

Over the course of time, the need to rehabilitate RC structures became evident, leading to the adoption of diverse approaches. One such technique involved strengthening columns by jacketing them with reinforced concrete. In general, structural strengthening is employed to address anomalies resulting from construction shortcomings; usage-related issues; design inadequacies; new regulations, structurally more demanding; the need for functional modifications, or the necessity to enhance a structure's safety levels, especially in relation to seismic forces. The knowledge regarding seismic risk has evolved in most earthquake-prone areas. It is now recognized that buildings constructed either before the implementation of seismic risk Codes or under outdated seismic Codes, are subject to a much higher seismic risk than new buildings, as well as buildings that were inadequately designed or constructed.

Figure 0.Strengthening of RC columns by full RC jacketing [1].

In this context, the strengthening of RC columns by RC jacketing is generally carried out when the intention is to significantly increase the stiffness and strength of the structural element, or particularly relevant for seismic retrofitting. Due to the unfortunate earthquake events in Turkey and Syria, 230,000 buildings in Turkey spanning across 11 provinces were damaged or destroyed. Similarly, in northwest Syria, the impact led to a minimum of 10,600 buildings being partially or completely demolished. In Aleppo alone, the consequences are evident, with 3,500 buildings now in need of structural repair as a result of the damage, while an additional 700 buildings have been deemed unsafe.

1.2. Columns' Strengthening Methods

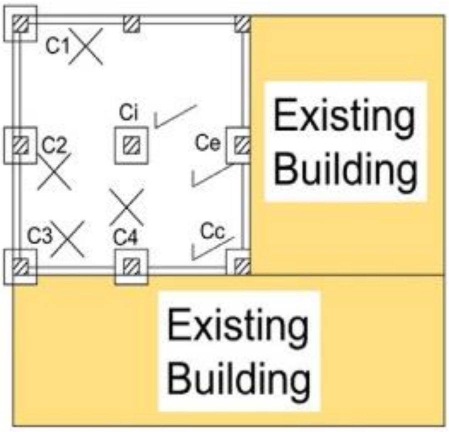
The conventional methods used for strengthening of columns involve the application of concrete and steel jackets, while the modern method employs fibre reinforced polymers (FRP) jackets. Despite being classified as a classical method, using concrete jackets remains the most well-known and prevalent approach. Jacketing with reinforced concrete brings several advantages, including cost-effectiveness, compatibility with the original concrete substrate, and the ability to enhance durability and fire protection. However, it is important to consider the drawbacks, such as the loss of floor space due to the enlargement of the column cross-section and potential difficulties during casting and compacting.

Figure 2. Strengthening of columns by steel jacketing (left) and by CFRP (right) [2][3].

Weak structures need to be strengthened. Reinforced concrete is the material of choice used to build structures in many earthquake-prone regions. In such regions, adding a reinforced concrete jacket to the columns of structures is a traditional and popular strengthening technique. Old concrete structures must be strengthened and maintained to meet their functions today and in the future. Choose to repair or strengthen the concrete structures instead of replacing them completely! This choice is not only better for the environment and the economy but also achievable with the availability of simple, rapid, and effective strengthening methods [4].

1.3. RC Jacketing (full and partial)

Reinforced concrete jacketing is a method used to enhance the stiffness/strength of structural elements like columns or beams. It involves adding an additional layer or jacket of reinforced concrete to increase the cross-sectional area, either by traditional methods of concrete or shotcrete, involving (totally or partially) the sides of existing RC columns. Generally, strengthening of columns by partial RC jacketing (2 and 3 sides), are applied to corner or edge columns, when it is not applicable to strengthen fully due to neighbouring buildings or to reserve the building's façade from distortion (irregularity between columns and the faces of the outer walls of the building).



Correct strengthening for columns

ci	Full jacketed internal column
ce	Jacketed edge column from three sides of the perimeter
Cc	Jacketed corner column from two sides of the perimeter
Incorrect strengthening for columns	
C1, c2	Not acceptable full jacket to reserve the façade of the building
C3	Not acceptable full jacket according to existing building and reserve the façade of the building
C4	Not acceptable full jacket according to existing building

Figure 3. The strengthening sides' number of column's perimeter due to column's location in the building [5].

Other relevant factors for the use of RC jacketing as a strengthening technique is that during (past) periods of uncontrolled construction, a non-negligible number of structures has design and execution defects that must be corrected. Since most of construction is made with RC, partial RC jacketing is a very suitable option for the rehabilitation/strengthening of a significant portion of the building stock. The several phases of strengthening of column by RC jacketing are presented below.

Given the significant role of the concrete industry in greenhouse gas emissions, it is essential to adopt measures that address this environmental concern. The foremost strategy entails reducing new construction and placing greater emphasis on the rehabilitation of existing buildings. By pursuing this path, we can foster infrastructures that embody safety, resilience, and sustainability. For that, it is necessary to improve increasingly the structural design projects of strengthening of RC elements, considering that most buildings are built with reinforced concrete.

1.4. Monolithic Coefficient

The monolithic coefficient (K) is the relationship between the behaviour of the jacketed reinforced concrete element and the behaviour of an equivalent monolithic element, i.e. with the same geometry and materials. The value of K is unity for monolithic behaviour and less than 1 otherwise. To obtain a K value close to 1, it is necessary to ensure good adhesion between the jacketing and the original column. K has its importance in the design of RC elements strengthened by partial RC jacketing and, above all, by taking it into account as a monolithic element in safety verification on column´s strengthening projects, by facilitating design in practice. The monolithic coefficients are defined by Equation 1.

$$K = \frac{\text{Response (M, V, K, q...) of the composite member}}{\text{Response of the equivalent monolithic member}} \quad (1)$$

Where K is the monolithic coefficients.

2. State of the Art

2.1. Partial RC Jacketing

A column is fully jacketed when all its faces are jacketed, unlike partial jacketing, not all faces are jacketed, situations that occur most often in corner or edge columns. Although significant advancements have been made in the field of partial RC jacketing on a global scale, there is still a significant need for further research and study. Therefore, many parameters involved must be analysed. Ferreira et al. [6] conducted experimental tests aiming at studying the behaviour of reinforced concrete columns strengthened by partial jacketing. Result show that perfect ductility was not obtained in RC columns (implies that the columns didn´t exhibit substantial deformation capacity before reaching its ultimate failure point), since the concrete detachment occurred immediately before the failure. It was found that a jacketing layer of much higher strength and a better treatment of the original concrete surface is required, such as increasing the roughness. Mahmoud et al. [5] conducted experimental research on the behaviour of partially strengthened RC columns from two or three sides of the perimeter. In this study was used welding between core and jacket links on strengthening from two and three sides have. Therefore, by employing welding techniques to connect the original and strengthened concrete links, the load-bearing capacity of the structure can be enhanced. This welding acts as a dowel or connector, increasing the connection. However, caution should be exercised when using gravel in concrete columns, as the connectors in such columns can weaken the structure due to the holes created for their placement [5]. Ibrahim et al. [7] performed experimental research on experimental and theoretical behaviours of edge and corner jacketed RC. For partial jacketed columns, there is increased shear strength when the strengthening is done on the tensioned and compressed side simultaneously, the lateral load capacity of the column increased significantly. Shear strength is higher when the column is strengthened on the bending tensioned side in relation to the column is strengthened on the compressed side [7].

When considering the adoption of full jacketing for columns, notable advantages can be obtained, specifically the potential elimination of the requirement for interface surface treatment and steel dowels[8]. Conversely, in the case of partial jacketing, the strength of the interface assumes a significant role in ensuring the monolithic behaviour of the strengthened member and subsequently, the achievement of the desired design strength. Hence, meticulous focus must be placed on the design, detailing, and execution processes to ensure successful outcomes in this regard.

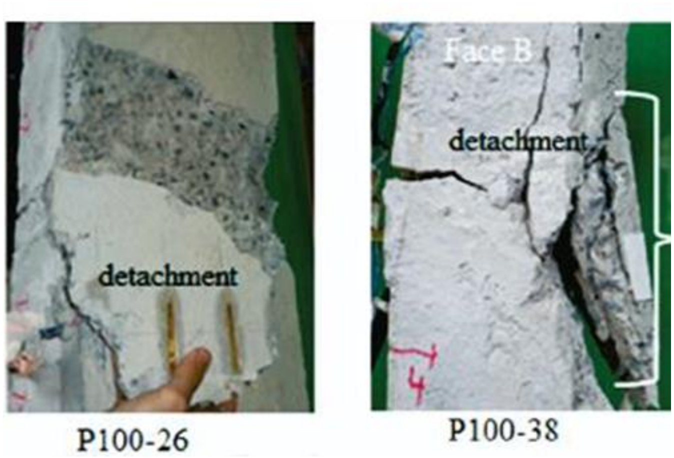


Figure 4. Interface between concretes of different ages [5].

2.2. Interface between concretes of different ages

The efficiency of jacketing depends on the proper stress transfer at the new concrete/old concrete occurs to increase compressive strength, increase the size of the cross section or to add more steel reinforcement to the concrete cross section. Concerning to adhesion between concretes of different ages, there interface.

According to Gomes & Appleton [1], this technique is usually more adequate when the need are several studies addressing the behaviour of both influence of interface. Júlio [9], for full jacketed columns, monolithic behaviour was observed, irrespective of the type of interface preparation (smooth/rough surface; with or without connectors); tests with M/V=1 and a jacket thickness = 17,5% width original column (under these considered conditions). However, Talbot et al. obtained good results with a combination of the latter technique followed by sandblasting. Júlio & et al. [8] studied the interface influence on monotonic loading response, the results had shown that there is no significant influence on strengthened column with axial load or without. In the reinforced models, the transverse reinforcement strain of the original model was lower in the strengthened model than in the no strengthened model [8].

Figure 1. Concrete crushing at column mid-height [6].

Rodriguez & Park [10] assessed RC columns strengthened by jacketing and subjected to simulated seismic loading. Chipping was performed to lightly roughen the surface of the as-built columns before the jackets were positioned to improve the concrete-concrete bond [10]. Júlio et al. [11] studied the influence of added concrete compressive strength on adhesion to an existing concrete substrate. Several specimens were subjected to the slant shear test, there were an increase in the compressive stress in the added concrete when subjected to the slant shear tests. These results were verified by finite element analysis, showing that, increasing the difference between the compressive strengths of the concrete layers of the slant shear specimens, higher values of normal stress are present in the interface, for the same level of shear stress [11]. Júlio et al. [8], [11], [12] researched concrete-to-concrete bond strength (influence of the roughness of the substrate surface), the results show that adopted bonding agent (epoxy resin) for smooth surfaces, using Icosit K 101 on the substrate surface, improves the bond strength of the interface concrete-concrete cast at different times. Surface roughening by sand blasting provides a better method [12]. In their research on interfaces between reinforced concrete jackets and columns, Oikonomopoulou et al. [13] illustrated that it is important to pay special attention to this aspect in upcoming experimental studies, because the mentioned disagreement can be explained by the application of axial load on the original column after the jacket has been built. This application leads to the development of favourable normal compressive stress on the interfaces, causing a significant enhancement in their shear resistance, which is not imminent in real applications [13].

Figure 6. Slant shear test [10].

Randl studied design recommendations for interface shear transfer in fib Model Code 2010. In which this article summarizes the crucial findings of past and ongoing research, it provides an exposition of the theoretical foundation that forms the basis for the design principles articulated in the fib Model Code 2010 [14]. The results show that in the context of the fib Model Code 2010, design recommendations pertaining to interface shear transfer vary depending on whether a rigid or non-rigid bond exists along a concrete-to-concrete interface. This distinction reflects the acknowledgment of the two crucial limit situations frequently encountered in practice [14].

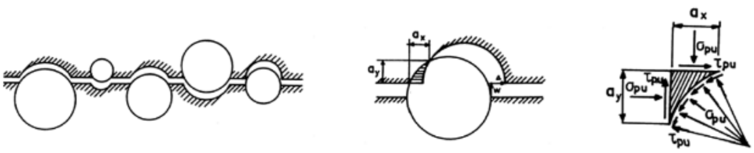


Figure 2. Modelling of aggregate interlock by Walraven [14].

2.3. Literature Background on Monolithic Coefficient

To achieve high monolithic coefficients (K) in reinforced concrete jacketing, several factors need to be considered, such as the quality of the concrete used, the size and spacing of the reinforcement, mechanical connectors or the bonding agents used to attach the jacket layer to the substrate, and the quality of the interface between the new and existing concrete surfaces. On this account, the K of the strengthened column is an important consideration In RC jacketing [15].

Lampropoulos et al. [16] studied the K values for design when strengthening RC columns with jackets in order to improve their seismic behaviour. The results showed that performance of the strengthened columns, and thus the corresponding K, depend on several factors the conditions at the interface between the new and the old concrete, as the main factor, and the value of the axial load. Monolithic coefficients for strength and stiffness are higher than those proposed in codes [EC 8, 2004; GRECO, 2010][16]. According to Thermou et al. [15] studied background to the K for the assessment of jacketed RC columns. There was a wide dispersion in the estimated K based on test results. Although the analytical values are more consistent, they do not always align with the conservative nature of the test-derived values. Analytical slip at failure reaches much higher values than the ones measured experimentally [15].

Table 1. Monolithic coefficient proposed in fib bullet 103 by Lampropoulos [12].

Jacket´s Type	t/b ratio	Monolithic Coefficients			
	(%)	K_F	K_K	K_{δ_y/θ_y}	K_{δ_u/θ_u}
Full	10	0.90	0.70	1.30	0.95
	30	0.85	0.55	1.50	1.00
	60	0.75	0.75	1.05	2.85
Partial	10	0.85	0.55	1.70	1.15
	30	0.80	0.55	1.40	1.10
	60	0.75	0.25	3.00	1.00

The dispersion of the results of the monolithic coefficients presented by some authors and, above all, the presentation of values above the unit presented by Thermou e Kappos 2022, showed that an equivalent monolithic column with the same dimensions, same reinforcement arrangements and same mechanical characteristics was not taken into account when calculating the monolithic coefficients.

Table 2. Experimental value of monolithic coefficients/monolithicity factors of differents authors [15].

Reference	$K_{\theta y}$	$K_{\theta u}$	K_{My}	K_v	K_k
Gomes and Appleton [11]	0.84	0.73, 1.07	0.99, 1.00	0.99, 1.00	1.18, 1.20
Ilki et al. [12]	0.77, 1.00	0.72, 0.92	0.57, 0.79	0.62, 0.70	0.74, 0.79
Vandoros and Dritsos [2,13,14]	1.49–4.54	0.75–1.26	0.78–0.99	0.82–0.98	0.22–0.64
Júlio et al. [15]	-	-	0.96–1.32	-	-
Bousias et al. [3,16,17]	0.26–1.41	0.88–1.21	0.79–1.06	0.76–1.02	0.64–3.65
Júlio & Branco [18]	0.71–1.53	0.97–1.41	0.98–1.13	0.98–1.17	0.72–1.56
min/max	0.26/4.54	0.72/1.40	0.57/1.32	0.62/1.17	0.22/3.65
Mean *	1.09	1.03	0.96	0.93	1.06

* Specimens with $K_{\theta y} > 2.5$ were excluded from the estimation of the mean.

Dritsos & Moseley [4] conducted studies monolithic coefficient design values for seismically strengthening RC columns. The utilization of K has been recognized as a practical approach to circumvent the need for complex and computationally demanding finite element analyses. This allows engineers to easily apply them in practical situations using conventional concrete design procedures [4]. To correlate the behaviour of a strengthened specimen with that of a respective monolithic specimen, K is required for the factors, as shown in the following equations:

Equation	Number
$K_F = \frac{F_{max\,(STR)}}{F_{max\,(MON)}}$	(2)
$K_V = \frac{V_{(STR)}}{V_{(MON)}}$	(3)
$K_{\theta_y} = \frac{\theta_{y\,(STR)}}{\theta_{y\,(MON)}}$	(4)
$K_{\theta_u} = \frac{\theta_{u\,(STR)}}{\theta_{u\,(MON)}}$	(5)
$K_{M_y} = \frac{M_{y\,(STR)}}{M_{y\,(MON)}}$	(6)
$K_{M_u} = \frac{M_{u\,(STR)}}{M_{u\,(MON)}}$	(7)
$K_k = \frac{k_{(STR)}}{k_{(MON)}}$	(8)
$V_{Rd,i} = cf_{ctd} + \mu\sigma_n + \rho f_{yd}(\mu sin\alpha + cos\alpha) \leq 0{,}5\nu f_{cd}$	(9)

Where K_F, K_V, K_{θ_y}, K_{θ_y}, K_{M_y}, K_{M_u} and K_K are monolithic coefficients for the strength (F), shear strength (V), deflection or rotation (θ), bending moment (M) and stiffness (k). These factors can be determined at yield (y) and failure (u) according to the above formulations. Subscripts STR and MON indicate strengthened and monolithic specimens.

3. Approaches to Monolithic Coefficients (K) in the Main Codes and Methods of Determination

3.1 Main Approaches to K in the Main Codes

Published works have shown that K depends on several parameters. Knowing the norms of Civil Engineering is the first step towards promoting a quality construction work with safety for all, the most crucial codes or most commonly used (EC, fib, ACI), such as EC and ACI, provide limited information regarding the coefficient K, with the exception of fib. In its latest version, fib bulletin 103, released in 2022, fib already offers a range of coefficients proposed by Lampropoulos. Nevertheless, further studies are needed to obtain these coefficients. As seen, the K value proposed in EC-8 2004 varies from 0,9 to 1,05. The most important codes, such as EC and ACI, present little information regarding the K, with the exception of fib, which in its new version fib bulletin 103 released in 2022, already presents a variety of coefficients proposed by Lampropoulos. Despite this, there is a need for further studies to obtain the coefficients. K proposed in EC-8 2004, as can be seen, ranges from 0.9 to 1.05.

Equation	Number
$V_y^* = 0{,}9V_y$	(11)
$M_y^* = M_y$	(12)
$\theta_y^* = 1{,}05\theta_y$	(13)

The relevant factor influencing the determination of the K and also the response of the strenghened column is the interface connection between concretes of different ages, which is influenced by the following relevant parameters:

- Roughness of the surface;
- Connectors/reinforcement crossing the interface;
- Bonding agents (usually epoxy resins);
- Jacket type (full or partial);
- Geometry (jacket thickness & M/V ratio);
- Properties of both new and old concretes.

The applied axial load also has an influence on the determination of the monolithic coefficient, in the updated version of Eurocode 8 this factor will already be considered, according to Dritsos & Moseley [4]. Below are the formulas for determining the shear stress in the main codes.

EC 2 – 1-1: 6.2.5 - Shear strength at the interface between concrete cast at different times:

$$\tau_{Rdi} = c_r f_{ck}^{1/3} + \mu.\sigma_n + k_1.\rho.f_{yd}.(\mu.sin\alpha + cos\alpha) + k_2.\rho.\sqrt{f_y.f_{cd}} \leq \beta_c.\nu.f_{cc} \quad (12)$$

$\tau_{Rd,j}$ → design value of shear strength at interface;
C & μ → are factors which depend on the roughness of the interface;
ρ → is ratio of reinforcement crossing the interface (A_s/A_i);
f_{ctd} → value of the design tensile strength;
σ_n → stress per unit area caused by the minimum external normal force across the interface that can act simultaneously with the shear force, positive for compression, $\sigma_n < 0{,}6.f_{cd}$;
α → is angle of connector $45^0 \leq \alpha \leq 90^0$;
ν → is a strength reduction factor ($0{,}6.[1 - f_{ck}/250]$).

fib MC 2010, Part II, chapter 7 – Design; 7.3.3.6 – Design limit value shear stress at the interface between concrete cast at different times:

ρ → is ratio of reinforcement crossing the interface ($\rho = A_s/A_2$);
c_r → is the coefficient for aggregate interlock effects at rough interfaces;
k_1 → is the interaction coefficient for tensile force activated in the reinforcement or the dowels;
k_2 → is the interaction coefficient for flexural resistance;
σ_n → is the (lowest expected) compressive stress resulting from an eventual normal force acting on the interface;
μ → is the friction coefficient;
ρ → is the reinforcement ratio of the reinforcing steel crossing the interface;
α → is the inclination of the reinforcement crossing the interface;
f_{cc} → compressive strength;
ν →is the effectiveness factor for the concrete, $\nu = 0{,}55(\frac{30}{f_{ck}})^{1/3} < 0{,}55$;
β_c → is the coefficient for the strength of the compression strut.

ACI 318 – 19: 16.4.4.2 - Nominal horizontal shear strength

$$\lambda\left(260 + 0{,}6\frac{A_v f_{yt}}{b_v s}\right) \; (14); \; b_v d \; 80 b_v d \quad (15)$$

d → distance from extreme compression fiber for the entire composite section;
λ → modification factor;
b_v → width of cross section at contact surface being investigated for horizontal shear, in;
A_v → area of shear reinforcement within spacing.

3.2. Methods of Determination of K

The monolithic coefficient (K) is the ratio between the behaviour of the jacketed reinforced concrete element and the behaviour of a monolithic element made with the same geometry and materials. The K can be determined from experimental test responses, analytical analysis, and numerical modelling. It should be noted that only the analytical and numerical formulations have been arrived at, as their results are increasingly closer to the responses of the experimental tests. With the research already done on experimental tests to determine the response of the reinforced columns, it is possible to determine the monolithic coefficients, through which, different authors (Lampropoulos, Dritsos, Thermou, etc.), have developed analytical formulation and numerical models for the calibration and validation of experimental tests.

4. Conclusions

The main objective of this Chapter is to propose of the monolithic coefficients in the strengthening of columns by partial RC jacketing. Well, it is also the main aim of the PhD programme whereby is to propose Monolithic Coefficients (K), using numerical modelling (ABAQUS). A parametric study will be conducted to calculate K, which will be compared with those proposed in EC 2 & 8-3 (2017), fib MC 2010 and ACI 318; modifications will be proposed if necessary; Additionally, experimental tests will be performed to validate the numerical study.

Based on the studies already done to K, it can be noted the existence of very few studies and, above all, the main EC and ACI codes present constant monolithic coefficient values, with the exception of fib code that launched in 2022 fib bulletins 103 which already presents several monolithic coefficients for total and partial reinforcement of reinforced concrete.

It has been observed that some authors have erroneously calculated the monolithic coefficient, without taking into account an equivalent monolithic column with the same dimensions, reinforcement arrangements and the same mechanical characteristics of the materials (concrete and steel).

Regarding studies of the K, complex finite element analyses are required to determine the behaviour of strengthened RC columns and the interface between the new and the old concrete needs to be simulated using specific contact elements. Although Numerical models and experimental tests on columns strengthened by partial jacketing will analyse multiple parameters such as cracking, deformation and resistance. Therefore, more experimental, and numerical studies must be proceeded for obtaining K of form to facilitate in the practice the strengthening of columns by RC jacketing design, therefore, there is an easiness in the conceptual design, as already approached, considering as monolithic the strengthened structural element in study for the design.

References

[1] V. V. Rodrigues, "Reforço Sísmico de Pilares de Betão Armado - Análise e Avaliação Experimental," Mestre em Estruturas de Engenharia Civil, a Universidade do Porto, Porto, 2005.

[2] H. Kaplan and S. Ylmaz, "Seismic Strengthening of Reinforced Concrete Buildings," in Earthquake-Resistant Structures - Design, Assessment and Rehabilitation, InTech, 2012. doi: 10.5772/28854.

[3] W. M. Souza, "Behaviour of reinforced concrete columns with GFRP bars under different loading conditions," Strcture, University of Lisbon - Instituto Superior Técnico, Lisboa, 2021.

[4] S. Dritsos and J. Moseley, "Monolithic coefficient design values for seismically strengthening RC columns with jackets," ce/papers, vol. 3, no. 2, pp. 172–176, Apr. 2019, doi: 10.1002/cepa.971.

[5] K. M. Mahmoud, E. A. Sallam, and H. M. H. Ibrahim, "Behavior of partially strengthened reinforced concrete columns from two or three sides of the perimeter," Case Studies in Construction Materials, vol. 17, p. e01180, Dec. 2022, doi: 10.1016/j.cscm.2022.e01180.

[6] D. B. FERREIRA, R. B. GOMES, A. L. CARVALHO, and G. N. GUIMARÃES, "Behavior of reinforced concrete columns strenghtened by partial jacketing," Revista IBRACON de Estruturas e Materiais, vol. 9, no. 1, pp. 1–21, Feb. 2016, doi: 10.1590/S1983-41952016000100002.

[7] H. Ghatass, khaled mahmoud, and E. Sallam, "Experimental and Theoretical Behaviors of Edge and Corner Jacketed R.C. Columns Subjected to Combined Axial and Lateral Loads," Port-Said Engineering Research Journal, vol. 0, no. 0, pp. 0–0, Feb. 2023, doi: 10.21608/pserj.2023.186945.1214.

[8] E. Júlio, F. Branco, and V. Silva, "Reinforced Concrete Jacketing – Interface Influence on Monotonic Loading Response," ACI Struct J, vol. 102, pp. 252–257, Mar. 2005.

[9] E. N. B. S. Júlio, "The influence of Interface on the Behaviour of RC Columns Strengthened by Reinforced Concrete Jacketing," Especialidade de Mecânica das Estruturas e dos Materiais, Universidade de Coimbra, Coimbra, 2001.

[10] M. Rodriguez and R. Park, "Seismic Load Tests on Reinforced Concrete Columns Strengthened by Jacketing," Nov. 1992.

[11] E. N. B. S. Júlio, F. A. B. Branco, V. D. Silva, and J. F. Lourenço, "Influence of added concrete compressive strength on adhesion to an existing concrete substrate," Build Environ, vol. 41, no. 12, pp. 1934–1939, Dec. 2005, doi: 10.1016/j.buildenv.2005.06.023.

[12] E. N. B. S. Júlio, F. A. B. Branco, and V. D. Silva, "Concrete-to-concrete bond strength. Influence of the roughness of the substrate surface," Constr Build Mater, vol. 18, no. 9, pp. 675–681, Nov. 2004, doi: 10.1016/j.conbuildmat.2004.04.023.

[13] E. Oikonomopoulou, V. Palieraki, E. Vintzileou, and G. Genesio, "Interfaces Between Reinforced Concrete Jackets and Columns," 2023, pp. 1315–1324. doi: 10.1007/978-3-031-32519-9_133.

[14] N. Randl, "Design Recommendations for Interface Shear Transfer in fib Model Code 2010," Structural Concrete, vol. 14, no. 3, pp. 230–241, Sep. 2013, doi: 10.1002/suco.201300003.

[15] G. E. Thermou and A. J. Kappos, "Background to the Monolithicity Factors for the Assessment of Jacketed Reinforced Concrete Columns," Buildings, vol. 12, no. 1, p. 55, Jan. 2022, doi: 10.3390/buildings12010055.

[16] A. P. Lampropoulos, O. T. Tsioulou, and S. E. Dritsos, "Monolithic Coefficient Values for Design when Seismically Strengthening RC Columns with Jackets," Journal of Earthquake Engineering, vol. 16, no. 7, pp. 1023–1042, Oct. 2012, doi: 10.1080/13632469.2012.689120.