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Mechanical hindrance second order problems through novel approach

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Abstract

Bridge problems are complicated. Complex mathematical techniques like partial differential equations, functional analysis, and calculus of variations are often required for higher-order issues. These techniques may be used to develop numerical methods for estimating the solutions to these challenging issues or analytical solutions. Bridge-related matters may be resolved in a variety of ways. A new approach, the novel method, was created among the other existing ways. The bridge issues in this paper are solved using the Novel approach. Static, dynamic, and different types of problems may be solved using this method. The key benefit of this approach is that it solves issues more quickly and accurately than other approaches. This method considered and resolved second-order bridge issues in the current research. A fundamental supported continuous beam with n supports and various loading conditions is employed. Specifically, two groups of bridges with varied lengths were evaluated. The entire length of the beam was supposed to fluctuate between -1 and 1 in the first example and between 0 and 1 in the second example before being solved using different approaches. Boundary circumstances were taken into consideration to resolve every instance involving space. Based on the outcome of this methodology, it can be seen that, in terms of space, the unique method approaches results are accumulating quickly and approaching the precise answer. The outcome of this procedure is then compared to the exact answer, and observed that it is nearly the same. For academic reasons and in numerous technical sectors, the current research will help resolve any issues with this method.

Keywords: Non-homogeneous; Bridge problems; Displacement; Slope; Curvature; Sharpness

1. Introduction

The method involves decomposing the nonlinear equation into simpler linear equations, which can then be solved iteratively. Each term in the series is calculated using the Adomian polynomials, a set of recursive polynomials that can approximate the solution of a nonlinear differential equation [1]. The Novel method has the advantage of applying to a wide range of nonlinear problems, including those that cannot be solved using traditional methods. It also allows for the calculation of analytical solutions, which can provide greater insight into the behavior of the studied system [2,3]. The method has technique in a variety of fields, including physics, engineering, and finance, and is effective in solving complex problems with high accuracy. The novel method is a powerful tool for solving nonlinear ordinary differential equations (ODEs) and partial differential equations (PDEs) [4,5]. The method involves decomposing the unknown solution into a series of functions called Adomian polynomials, which are obtained by applying the nonlinear operator of the differential equation to the solution itself. The method has several advantages over other numerical techniques for solving ODEs, some of which are: (a) Nonlinear problems: The Novel method is beneficial for solving nonlinear ODEs because it does not require any linearization or simplification of the problem. This makes it suitable for various applications with nonlinear governing equations [6]. (b) Convergence: The method has been proven to converge to the exact solution of the ODE, provided that the solution is sufficiently smooth and the nonlinear operator satisfies certain conditions [7]. (c) Analytical expression: The method provides an analytical expression for the solution regarding Adomian polynomials, which can be easily evaluated using standard numerical techniques [8]. (d) Efficiency: The Novel

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method is computationally efficient and can be easily implemented on a computer using standard programming languages [9,10]. (e) Flexibility: The method can be easily adapted to handle various types of boundary conditions, initial conditions, and other constraints that are commonly encountered in practical applications. No need for linearization or perturbation: Novel approach can be used to directly solve nonlinear PDEs without needing any linearization or perturbation techniques [11,12]. This makes the method particularly useful for solving highly nonlinear problems that cannot be solved using other analytical methods. Easy implementation: Novel approach is a straightforward and easy-to-implement method that can be applied to various nonlinear PDEs. A novel approach is a non-iterative method, meaning the solution is obtained in a single step. This makes the method much faster than iterative methods such as finite element or finite difference methods [13,14]. A novel approach can produce highly accurate solutions to nonlinear PDEs, particularly when compared to numerical methods such as finite element or finite difference methods. The novel is a powerful analytical technique used to sfor solvingr differential equations [15,16]. The method involves breaking down a nonlinear differential equation into a series of simpler equations that can be solved iteratively. While the Novel approach has proven to be an effective method for solving many problems, it can encounter practical problems that require specific solutions. Here are some common practical problems with the Novel approach and their solutions. Convergence Issues: Novel approach may not converge for some nonlinear differential equations. The solution to this problem is to use other numerical methods, such as the finite element method or the finite difference method to obtain a numerical solution. Difficulty in choosing the decomposition operator. Choosing the right one can be challenging [17]. One possible solution to this problem is to use different decomposition operators and compare the results to find the best one. Nonlinearities in the boundary conditions: Novel approach may not handle boundary conditions involving nonlinear functions [18]. In this case, one solution is to use perturbation techniques to linearize the boundary conditions. Nonlinearities in the initial conditions: Novel approach may also have difficulty handling nonlinear initial conditions. One possible solution is to use a linearization technique to convert the initial conditions into a linear form that can be easily solved using a Novel approach [19]. High computational complexity: Novel approach may require many iterations, which can result in high computational complexity. One solution to this problem is to use parallel processing or other high-performance computing techniques to reduce the computational time [20]. Overall, the Novel approach is a useful analytical technique for solving nonlinear differential equations. However, it is important essential the potential practical problems that may arise and the specific solutions that can be used to overcome them. The goal is to use a revolutionary technology solution to statistically solve starting and boundary problems. It is crucial to comprehend how such responses differ from exact solutions [21]. Also included are rough guidelines and modifications for such accurate replies. The model using finite elements must be addressed for diverse problems, and its reliability in various circumstances must be investigated.

2. Methodology

The governing differential equation is of the form

$$\alpha \frac{\partial^{n} x}{\partial t^{n}} + \beta \frac{\partial^{n-1} x}{\partial x^{n-1}} + \gamma \frac{\partial^{n-2} x}{\partial y^{n-2}} + \delta \frac{\partial^{n-m} x}{\partial t^{n-m}} + \varepsilon \frac{\partial^{m} x}{\partial z^{m}} + \cdots + u^{2} + u^{3} + \left(\frac{\partial x}{\partial z}\right)^{n} + \cdots = f(x,y,z)$$

$$M_t = \frac{\partial^{n}}{\partial t^{n}},\, M_x = \frac{\partial^{n-1}}{\partial x^{n-1}},\, M_y = \frac{\partial^{n-2}}{\partial y^{n-2}},\, M_z = \frac{\partial^{m}}{\partial z^{m}}.$$

Separate the linear, non-linear, remainder, and forcing terms.

$$M_t x + M_x x + M_y x + M_z x + \cdots + H(x) = K(x,y,z)$$

Linear = $M_t x$, The remainder $(Px) = M_x x + M_y x + M_z x$

Linear term= M(x)+ P(x), Non-linear term = H(x)

$$M_t x + M_x x + M_y x + M_z x + \cdots + H(x) = K(x,y,z)$$

$$M_t x + P(x) + H(x) = K(x,y,z)$$

$$M_t x = K(x,y,z) - \big(P(x) + H(x)\big)$$

Apply $M_t^{-1}$the inverse on both sides

$$M_t^{-1}M_t x = M_t^{-1}\big(K(x,y,z) - P(x) - H(x)\big)$$

$$x = \text{‘n’ constants} + M_t^{-1}\big(K(x,y,z) - P(x) - H(x)\big)$$

$$= b_0 + tb_1 + \ldots + t^{n-1}b_{n-1} + M_t^{-1}K(x) - M_t^{-1}\big(P(x) + H(x)\big)$$

x is the function of both dependent and independent terms.

$$x_0 = b_0 + tb_1 + t^2b_2 + \cdots + t^{n-1}b_{n-1} + K(x,y,z)\ ;\ u_0 \text{ is an independent variable function}$$

$$x_1 = -M_t^{-1}\big(P(x_0) + H(x_0)\big)$$

$$x_2 = M_t^{-1}\big(P(x_1) + H(x_1)\big)$$

$$\vdots$$

$$x_n = -M_t^{-1}\big(P(x_{n-1}) + H(x_{n-1})\big)\ ;$$

$$x = x_0 + x_1 + x_2 + \cdots + x_\infty \text{ [11,15,16].}$$

3. Results and Discussion

A reinforced concrete bridge with six supports A, C, D, E, F, and B is shown in Fig. 1. The supports C,E, and F are roller supports, whereas A, D, and F are hinge supports. Each beam's orientation is tested under a range of loading conditions, from [0≤ ξ ≤1].For both AC and BF beams, with the h(x) forcing function. Beam forcing for DE is g(x)p(x)+k(x)+n. Figure 3 shows the beam alignment under different stress conditions starting at $[-\frac{1}{2} \le \xi \le \frac{1}{2}]$. The constraints for support AC and DB with the forcing function h(x). The forcing function for beam CD is g(x)p(x)+k(x)+n.

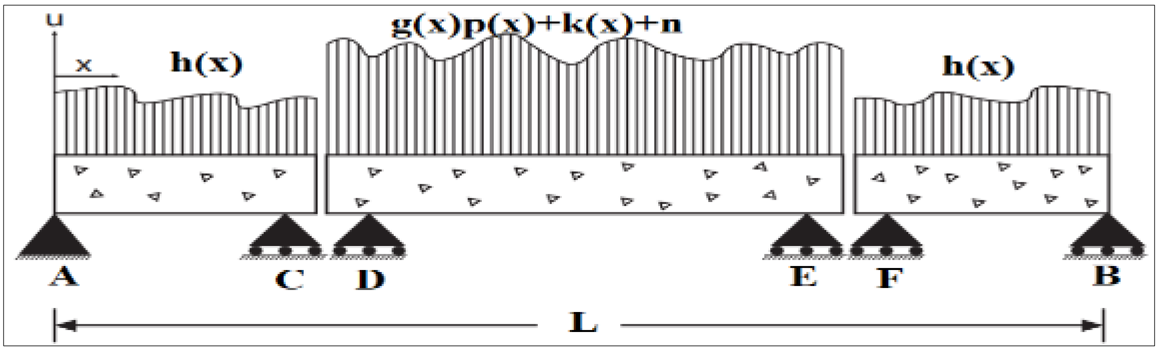

Figure 1 Beam with disparate loading varies from [$\mathbf{0 \le \xi \le 1}$]

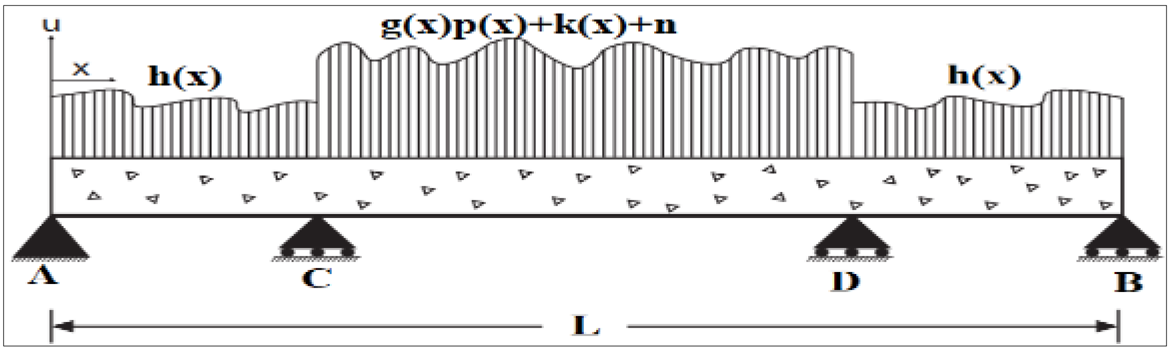

Figure 2 Beam with distinct loading conditions varies from [$\mathbf{-1 \le \xi \le 1}$]

The assumed leading differential equation (1)

$$EI\frac{d^n u}{dx^n} = u^{(n1)} = \begin{cases} h(x), & A \le \xi \le C, \\ g(x)p(x) + k(x) + n, & C \le \xi \le D, \\ h(x), & D \le \xi \le B, \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Boundary circumstances

$$\begin{Bmatrix} u(A) = u(B) & = a_{11}, u''(A) = u''(B) = b_{22} \\ u(C) = u(D) & = a_{11}, U''(C) = u''(D) = b_{22} \end{Bmatrix}$$

In reckoning (1) implicit EI = 1, n1 =2 , h(x) = k(x) = 1+u, p(x) = (π^2+1) sin(πx), n = -1, g(x) = -1.

Fig.2. The bounds occupied for extent AC, CD, and DB is [-$\frac{1}{2}$ ≤ ξ ≤ 1].

$$u^{(2)} = \begin{pmatrix} 1 + u, & -1 \le \xi \le -\frac{1}{2} \text{ and } \frac{1}{2} \le \xi \le 1, \\ -(\pi^2 + 1)\sin(\pi x) + u, & -\frac{1}{2} \le \xi \le \frac{1}{2}. \end{pmatrix}$$

Fig.1. The confines reserved for extent AC, CD, and DB is 0 ≤ ξ ≤ 1.

$$u^{(2)} = \begin{pmatrix} 1 + u, & 0 \le \xi \le 1 \\ -(\pi^2 + 1)\sin(\pi x) + u, & 0 \le \xi \le 1. \end{pmatrix}$$

3.1. CASE 1

The prevailing differential equivalence of the 2nd order equation is $u^{(2)}$ = 1+u, and the Boundary restrictions are [u (-1) = 0, u $\left(-\frac{1}{2}\right)$ = 0], and contrasts from [-1 ≤ ξ ≤ $-\frac{1}{2}$].

3.1.1. Novel technique solution:

Displacement, u = p exp(x) +q exp(-x) + r = 1.0263 exp(x) + 0.2290 exp(-x) – 1 …………….(2)

Slope, $\frac{du}{dx}$ = p exp(x) - q exp(-x) = 1.0263 exp(x) - 0.2290 exp(-x) .... (3)

3.1.2. Exact solution

The exact solution, u_e = p exp(x) + q exp(-x) + r = 1.0262 exp(x) + 0.2289 exp(-x)-1 ....(4)

3.1.3. Discussion of results for case 1

Fig.3. Depicts the displacement, slope, and error plot for both novel and computational methods. The novel and computational solutions precisely coincide for a beam length varying from [-1 ≤ ξ ≤ $-\frac{1}{2}$]. Displacement begins at -1,-0.5 unit and varies parabolically in both ways. At -1 units, the displacement error is -0.05, decreasing exponentially to -0.03 at -0.5 units. Both approaches have a slope, sharpness, 5th & 7th order of -200 at -1 unit, which grows linearly to 200 at -0.5 unit and zeroes at -0.75 unit. At -1 unit, the slope, sharpness, 5th & 7th order error is 0.05 and falls exponentially up to 0.03. Curvature, impendent, 6th order is 10000 at -1 unit and constant up to -0.5 unit. Curvature, impendent, 6th order is -0.05, decreasing exponentially to -0.03 at -0.5 units. Maximum displacement, slope, Curvature, sharpness, impendent, 5th, 6th, and 7th order values, observed being -30, 200, 1000, 200,1000, 200,1000, and 200 units, respectively.

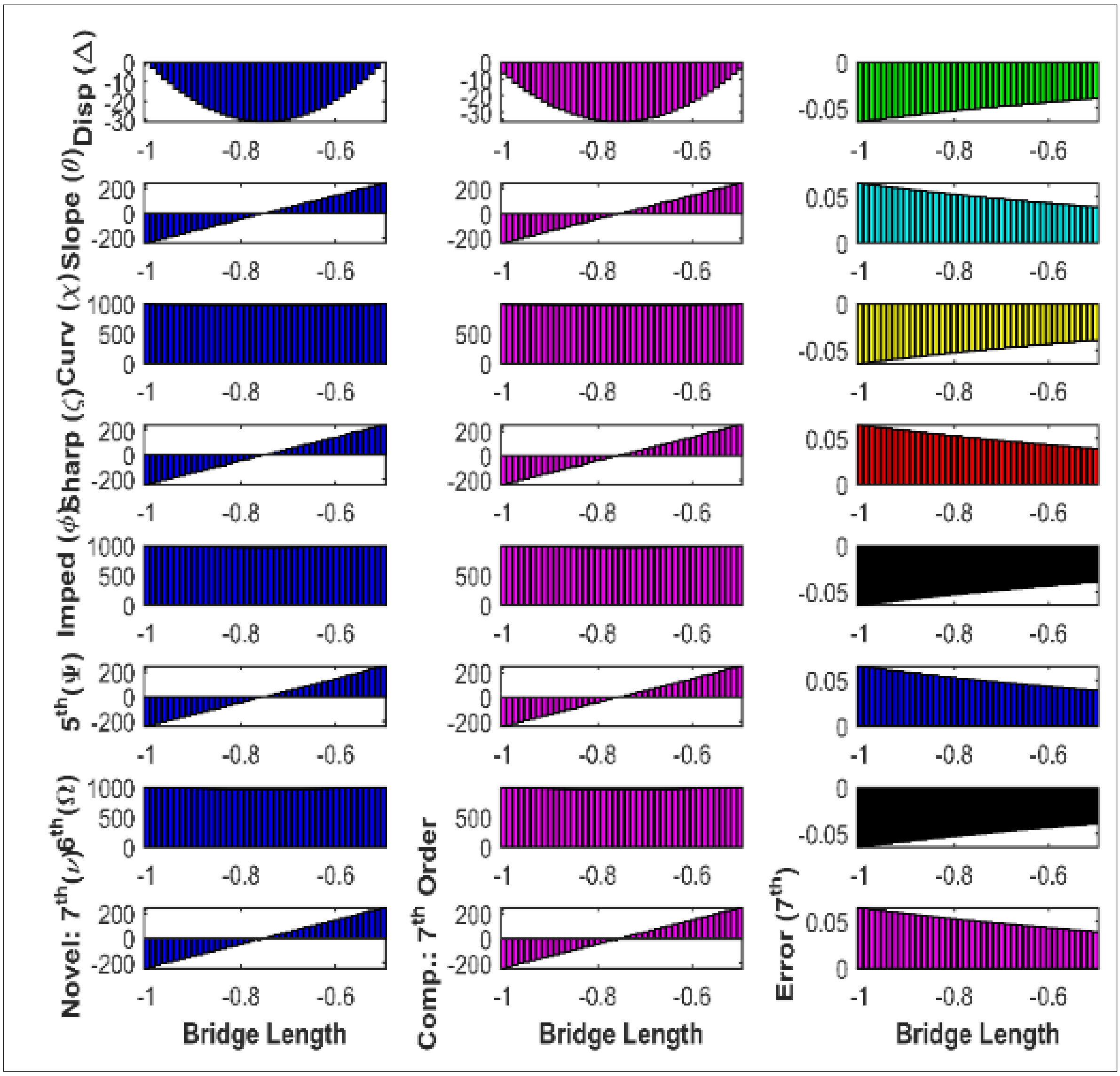

Figure 3 Different order solutions (Novel & Computational) for u $^{(2)}$ = 1+u varies from -1 ≤ **ξ** ≤ $-\frac{1}{2}$

3.2. CASE 2

The influential differential equality of the second order equation is u $^{(2)}$ = u - (π^2+1) sin(πx), and the Boundary preconditions are [u $\left(-\frac{1}{2}\right)$ = 0, u $\left(\frac{1}{2}\right)$ = 0], and varies from [$-\frac{1}{2} \leq \xi \leq \frac{1}{2}$].

3.2.1. Novel technique solution

Displacement, u = p sin(πx) + q exp(x) +r exp(-x) = sin(πx) - 0.9595 exp(x) + 0.9595 exp (- x) …………….(5)

Slope, $\frac{du}{dx}$ = p π cos(πx) + q exp(x) - r exp(-x) = π cos(πx) - 0.9595 exp(x) - 0.9595 exp (-x)……………. (6)

3.2.2. Exact solution:

The exact solution, u_e = p sin(πx) + q exp(x) + r exp (-x) = sin(πx) - 0.9595 exp(x) + 0.9499 exp(-x) ……………… (7)

3.2.3. Discussion of results for case 2

Fig.4. Illustrates the displacement, slope, and error plots for both new and computational approaches. For a beam length changing from [$-\frac{1}{2} \leq \xi \leq \frac{1}{2}$]. Displacement is 0 for both techniques at -0.5,0 and 0.5 units and varies parabolically. At -0.5 units, the displacement inaccuracy is -0.1 and drops exponentially to -0.06 at 0.5 units. Both approaches have a slope

of -200 at -0.5 unit, which grows parabolically to 1 at 0 unit. At -0.5 units, the slope error is 0.1 and reduces exponentially to 0.07 at 0.5 units. The highest measured displacement and slope values are 200 and 2000 units, respectively.

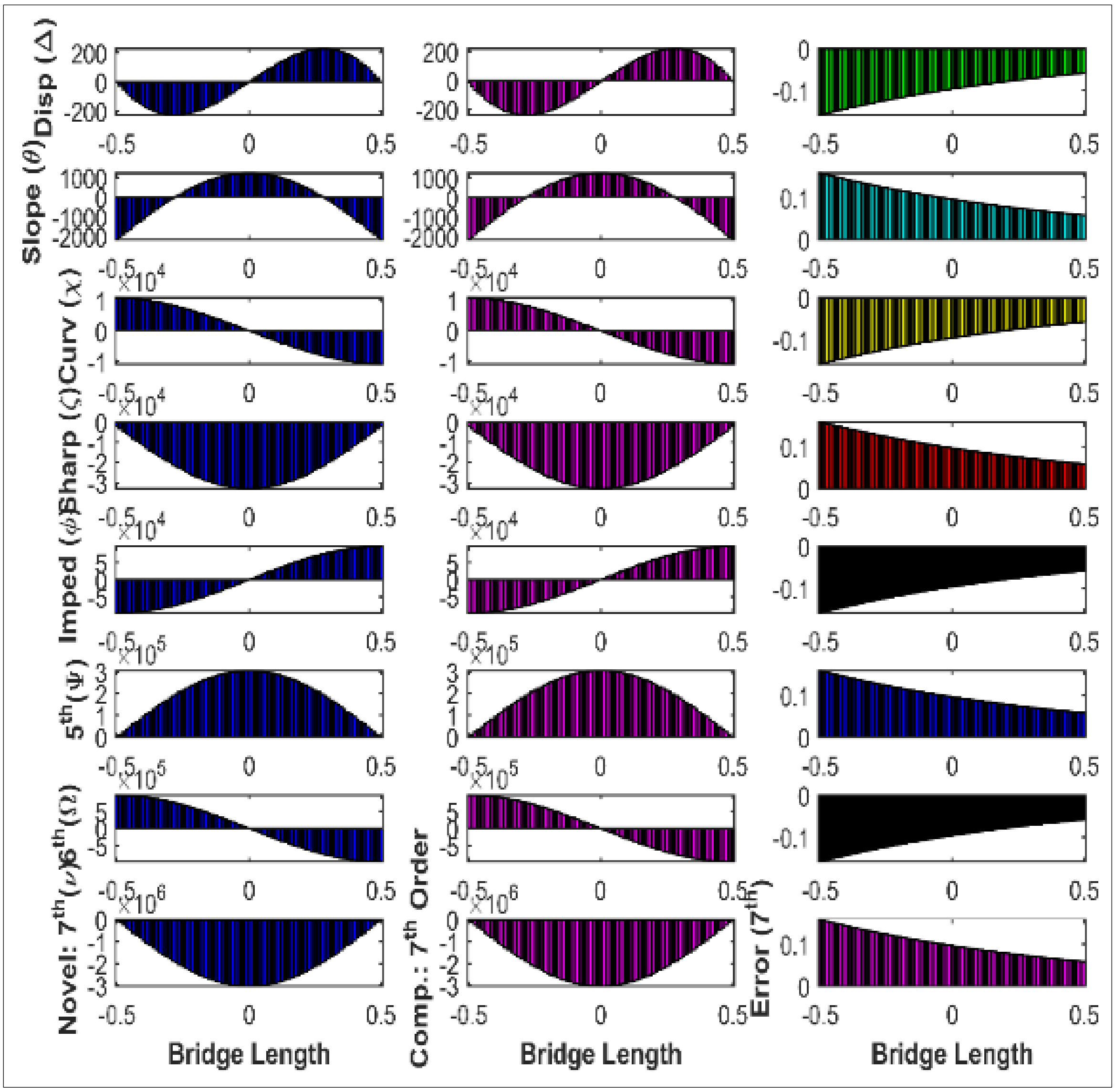

Figure 4 Different order solutions (Novel & Computational) for $u^{(2)} = -(\pi^2+1)\sin(\pi x) + u$ differs from $-\frac{1}{2} \leq \xi \leq \frac{1}{2}$

3.3. CASE 3

The presiding differential equivalence of the 2nd order equation is $u^{(2)} = 1+u$, and the Boundary provisions are [u (1) = 0, $u\left(\frac{1}{2}\right) = 0$], and differs from [$\frac{1}{2} \leq \xi \leq 1$].

3.3.1. Novel technique solution

Displacement, u =p exp(x) + q exp(-x) + r = 0.2290 exp(x) + 1.0263 exp(-x) – 1 .... (8)

Slope, $\frac{du}{dx}$ = p exp(x) - q exp(-x) = 0.2290 exp(x) - 1.0263 exp(-x) .... (9)

3.3.2. Exact solution

The exact solution, u_e = p exp(x) + q exp(-x) + r = 1.0262 exp(x) + 1.0160 exp(-x)– 1 .... (10)

3.3.3. Discussion of results for case 3:

Fig.5. Illustrates the displacement, slope, and error plots for both innovative and computational approaches. The creative and computational solutions meticulously correspond to a beam length change from [$\frac{1}{2} \le \xi \le 1$]. Displacement is initially 0 at 0.5 units and zeroes at 1 unit for both procedures, varying parabolically. At 0.5 units, the displacement error is –0.05, decreasing exponentially to -0.03 at 1 unit. Both techniques have a slope, sharpness, 5th & 7th order of -200 at 0.5 units, which reduces to 200 at 1 unit. The slope, sharpness, 5th & 7th order error is 0.05 at 0.5 units and decreases exponentially to 0.03 at 1 unit, curvature, impendent, 6th order is 10000 at 0.5 unit and constant up to 1 unit. Curvature, impendent, 6th order is -0.05, decreasing exponentially to -0.03 at 1 unit. With maximum displacement, slope, curvature, sharpness, impendent, 5th, 6th, and 7th order values observed being -30, 200, 1000, 200,1000, 200,1000, and 200 units, respectively.

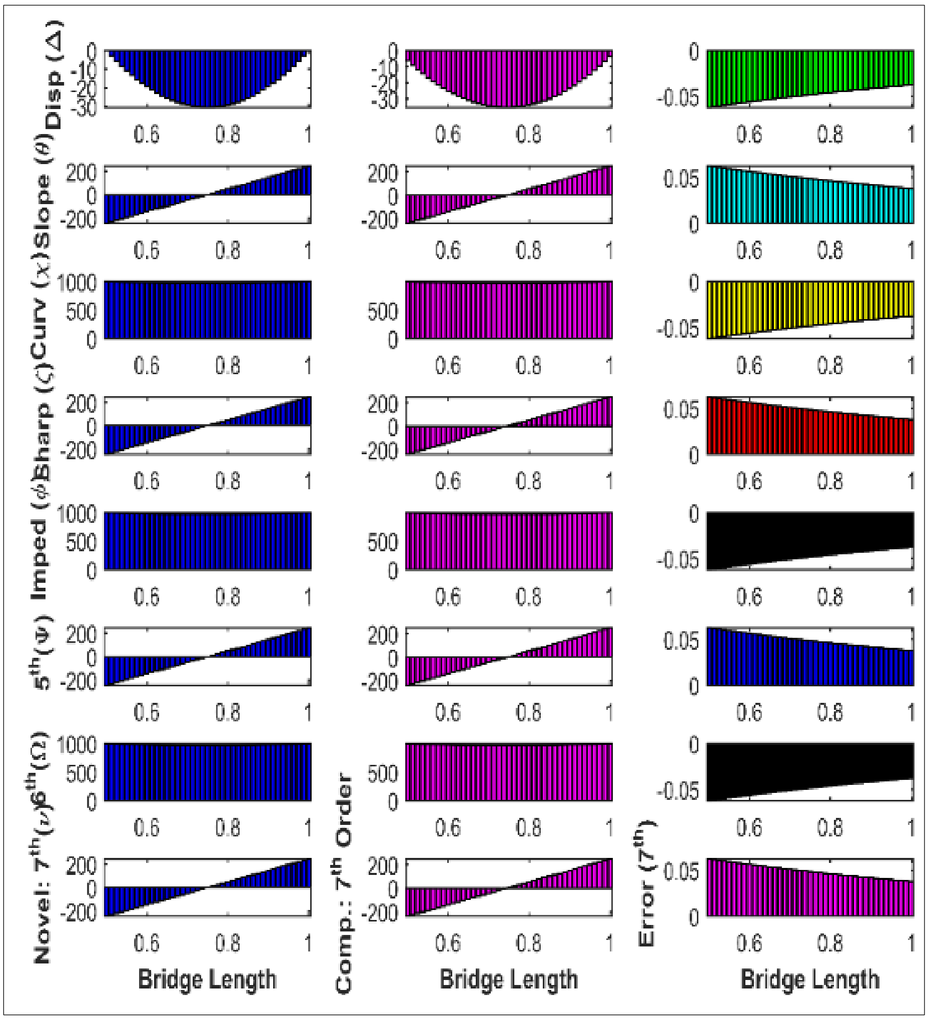

Figure 5 Different order solutions (Novel & Computational) for $u^{(2)} = 1+u$ varies from $\frac{1}{2} \le \xi \le 1$

3.4. CASE 4

The reigning differential reckoning of the second order equation is $u^{(2)} = 1+u$, and the Boundary requirements are [u (0) = 0, u (1) = 0], and contrasts from [$0 \le \xi \le 1$].

3.4.1. Novel technique solution:

Displacement, u = p exp(x) + q exp(-x) + r = 0.2689 exp(x) + 0.7311 exp(-x)– 1 ………………(11)

Slope, $\frac{du}{dx}$ = p exp(x) - q exp(-x) = 0.2689 exp(x) - 0.7311 exp(-x) ……………… (12)

3.4.2. Exact solution

The exact solution, $u_e = p \exp(x) + q \exp(-x) + r = 0.2689 \exp(x) + 0.7238 \exp(-x) - 1$ ...... (13)

3.4.3. Discussion of results for case 4:

Fig.6. Depicts the displacement, slope, and error plots for both novel and computational methods. The novel and computational solutions attentively correspond for a beam length changing from [$0 \leq \xi \leq 1$]. For both ways, displacement is initially 0 at 0,1 unit and varies parabolically. The displacement inaccuracy is -0.05 at 0 units and decreases exponentially to -0.03 at 1 unit. The slope for both techniques is -400 at 0 unit; then, it increases to 400 at 1 unit and zeroes at 0.5 unit. The slope error is 0.05 at 0 unit and decreases exponentially up to 0.03. The maximum displacement and slope values measured are 100 and 400 units, respectively.

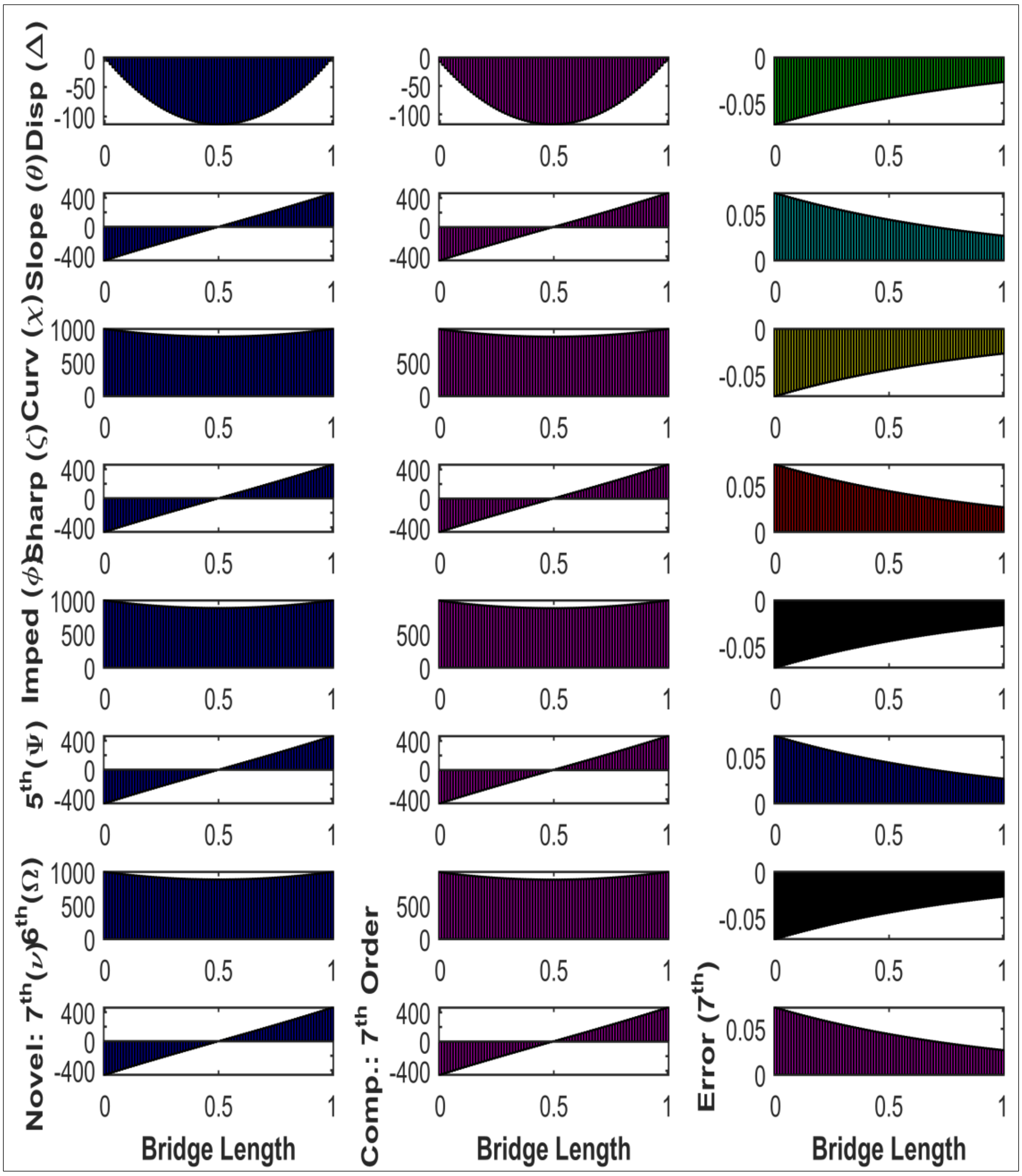

Figure 6 Displacement, slope, and error (Novel & Computational) for $u^{(2)} = 1+u$ varies from $\mathbf{0 \leq \xi \leq 1}$

3.5. CASE 5

The influential differential evaluation of the 2nd order equation is $u^{(2)} = u - (\pi^2+1)\sin(\pi x)$, and the Boundary prerequisites are [u (0) = 0, u (1) = 0], and differs from [$0 \leq \xi \leq 1$].

3.5.1. Novel technique solution:

Displacement, $u = p \sin(\pi x) = \sin(\pi x)$ .... (14)

Slope, $\frac{du}{dx} = p\pi \cos(\pi x) = \pi \cos(\pi x)$ .... (15)

3.5.2. Exact solution:

The exact solution, $u_e = p \sin(\pi x) = \sin(\pi x)$ .... (16)

3.5.3. Discussion of results for case 5

Fig.7 shows displacement, slope, and error plots for both novel and computational approaches. Length varies for a beam [0 ≤ ξ ≤ 1]. In both methods, displacement begins at zero and increases parabolically. At 0 units, the displacement inaccuracy is 0 and grows parabolically up to 0.3 at 1 unit. The slope for both approaches is 2000 at 0 unit, -2000 at 1 unit, and zeroes at 0.5 unit. At 0 unit, the slope error is -0.6 and climbs to 0.75. The maximum displacement and slope values observed are 1000 and 2000 units, respectively.

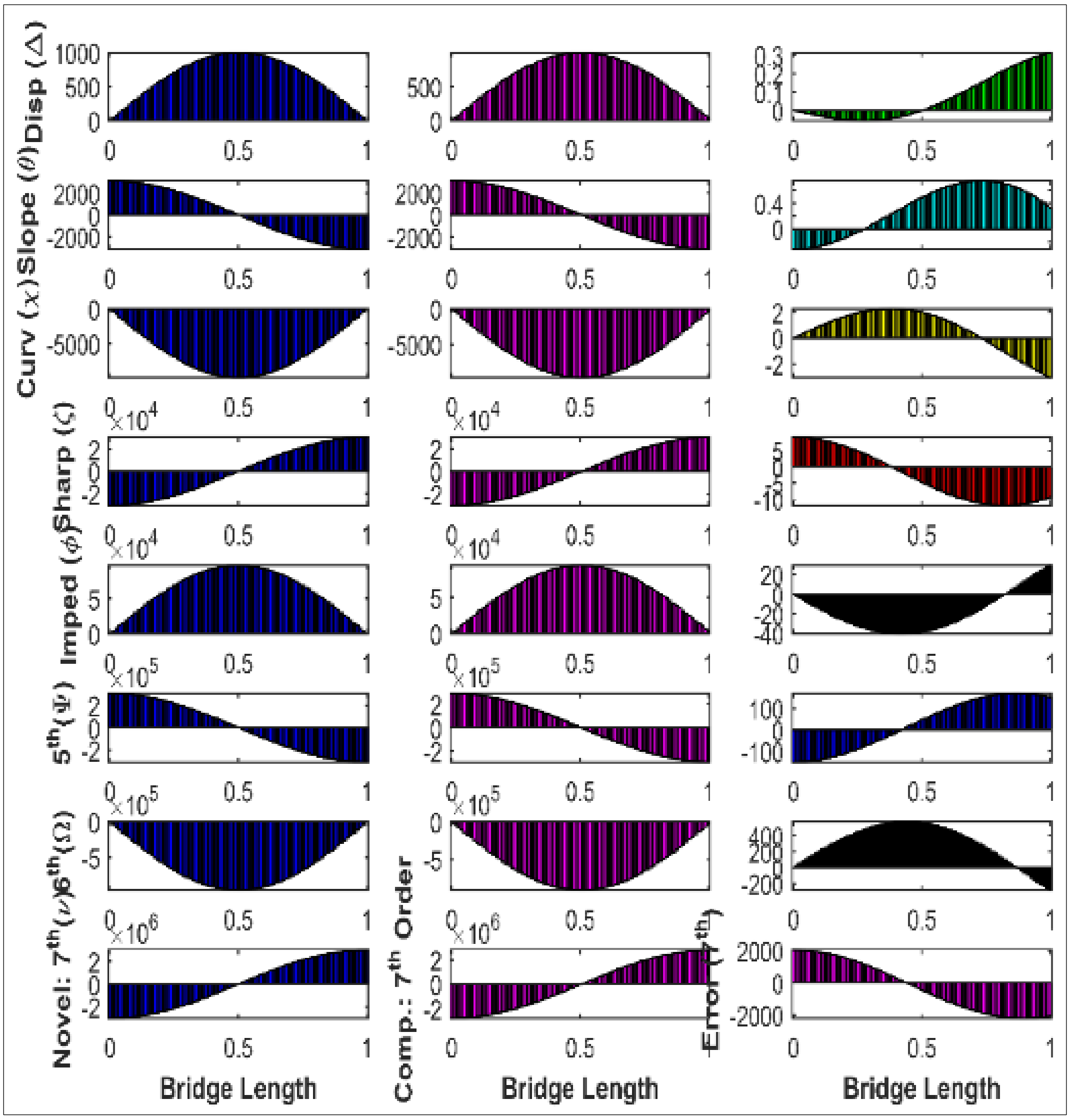

Figure 7 Different order solutions (Novel & Computational) for $u^{(2)} = u - (\pi^2+1) \sin(\pi x)$ varies from $0 \leq \xi \leq 1$

3.6. CASE 6

The governing differential reckoning of the second order equation is $u^{(2)} = 1+u$, and the Boundary specifications are [u (0) = 0, u (1) = 0], and varies from [$0 \leq \xi \leq 1$].

3.6.1. Novel technique solution

Displacement, $u = p \exp(x) + q \exp(-x) + r = 0.2689 \exp(x) + 0.7311 \exp(-x) - 1$ ....(17)

Slope, $\frac{du}{dx} = p \exp(x) - q \exp(-x) = 0.2689 \exp(x) - 0.7311 \exp(-x)$ .... (18)

3.6.2. Exact solution

The exact solution, $u_e = p \exp(x) + q \exp(-x) + r = 0.2689 \exp(x) + 0.7238 \exp(-x) - 1$ ……………..(19)

3.6.3. Discussion of results for case 6

Fig.8 shows displacement, slope, and error plots of both novel and computational approaches. The novel and computational solutions narrowly correspond for a beam length changing from $[0 \leq \xi \leq 1]$. For both methods, displacement begins at zero and increases parabolically. At 0 units, the displacement error is -0.05 and falls exponentially to -0.03 at 1 unit. Both systems have a slope of -400 at 0 unit, climbs to 400 at 1 unit, and zeroes at 0.5 unit. At 0 units, the slope error is 0.05 and falls exponentially up to 0.03. The maximum displacement and slope values measured are 100 and 400 units, respectively.

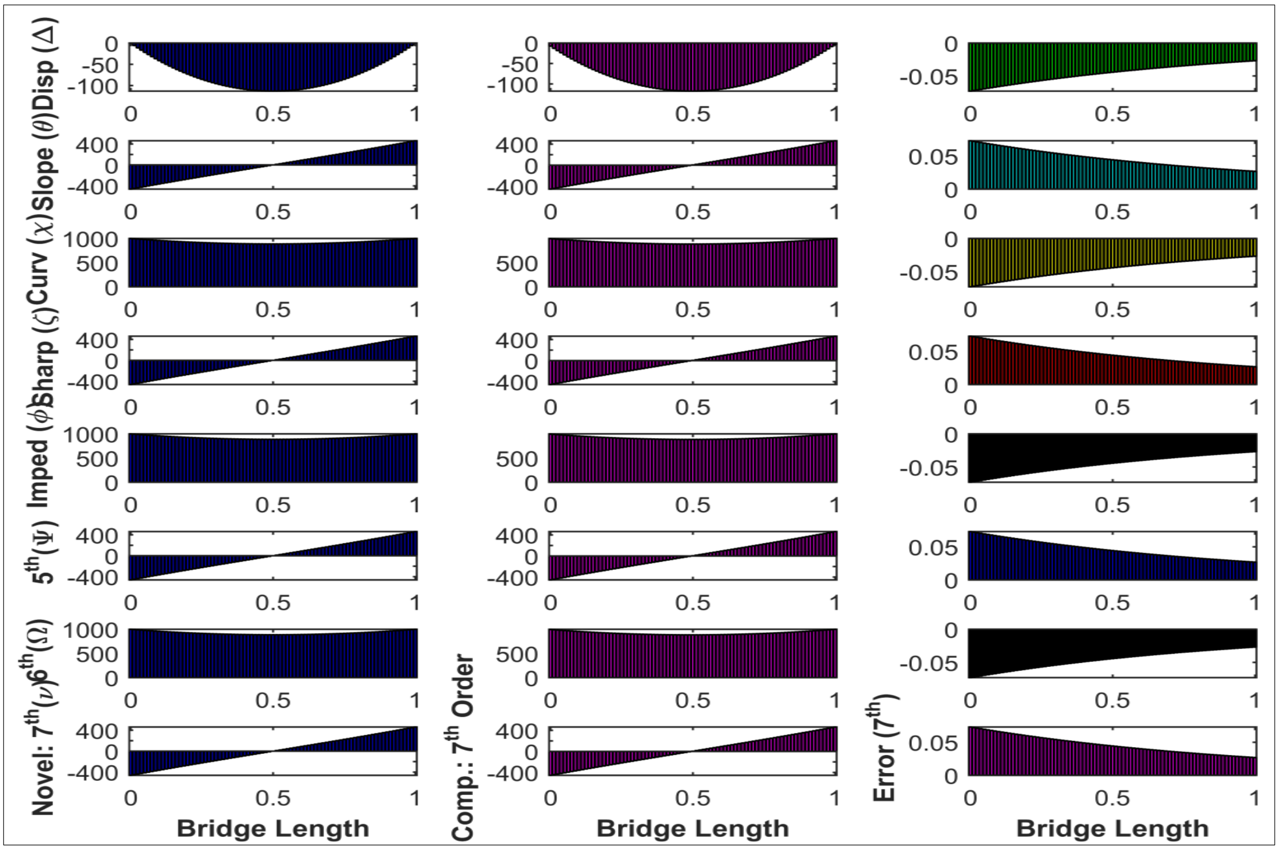

Figure 8 Different order solutions (Novel & Computational) for $u^{(2)} = 1+u$ varies from $\mathbf{0 \leq \xi \leq 1}$

4. Conclusion

A novel method is employed to manage various technical and continuing support bridge challenges. Consequently, the unique technique's results are contrasted with the precise solution. The novel approach is simple to utilize, even for multi-media tasks. The solution is supplied as rapidly converging progressions with easily computable components using the present unique method. In the second order, non-homogeneous Problem, from case 1 to case 6. For case 1, the maximum displacement and slope values recorded were 30 and 200 units, respectively. The most outstanding values for the displacement and slope measurements for case 2 are 200 and 2000 units, respectively. For scenario 3, the maximum displacement and slope values were 30 and 200 units, respectively. In cases 4 and 5, the maximum displacement and slope values were observed to be 100 and 400 units, respectively. In contrast, in cases 4 and 6, the maximum displacement and slope values were measured to be 100 and 400 units, respectively. The Novel approach technique's outcomes are assessed using precise responses. It has been proven that this strategy accurately predicts the precise answers to all problems. To show the robustness of various equations, several problems have been taken on. In the vast majority of cases, this tactic delivered excellent results.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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