Kurdistan Engineers Union

اتحاد مهندسي كوردستان

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Special Report about :

Comparing the accuracy and efficiency of software and hand calculations of shear and bending moment diagrams for indeterminate beams.

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Abstract

The world's flexible software is the program. A large number of researchers employed by various organizations effectively utilize these programs. The government body's proposal and approved method are also open to scrutiny using the Linpro, CSI-Etabs and Staadpro software. In the current situation, it is easier to obtain the result using software due to the time frame than it is by hand computation. A civil engineer's primary goal is to design buildings economically; hence many attempts have been made to use these software programs to the fullest degree possible in order to meet design requirements. The program employed for the study is called Lin-pro, and the current investigation focuses on computing shear and moment diagrams within indeterminate beams. The main objective is to determine the software's accuracy in conjunction with the goal.

Keywords: Software, shear and moment diagram Methods and statistically indeterminate beams .

Table of content :

1. Introduction:

Structural and material strength is one of the main courses given to students majoring in civil engineering. This course introduces techniques for calculating shear and moment diagrams inside beams. It goes without saying that structural engineers need this information in order to analyze and design structures. The engineer might have to perform a structural analysis on statically indeterminate beams in real-world situations. As a result, mechanical and civil engineering education may find the solution techniques for this particular issue to be interesting.

In engineering design, statistically indeterminate beams are useful because they can be utilized to support load-bearing structures (Hassan, 2016).

The shear and moment diagrams are constructed according to two basic equations that can be obtained using a free-body diagram and a continuous force applied along the length of the beam(Buchanan 1998).

Creating shear force and bending moment diagrams from repetitive beam sectioning can be an arduous and time-consuming procedure when a beam is subjected to a lot of external loads and moments, either in concentrated or scattered form. By requiring additional slope and displacement boundary conditions at single points on the beam where the functional form of the bending moment is not immediately integrable, the subsequent determination of beam deflection introduces even another layer of complication (Boedo, 2020).

Literature Review

For the study, a few current studies that touch on the basics of software mechanics from the structural point of view of civil engineering using staadpro and csi-etabs are taken into consideration. Among the best structural design programs is Staadpro. In this study, we employ Linpro analysis to determine the bending moments and shear forces in the unknown beam. Staadpro program more appropriate for some structural elements than Etabs software. In the etabs program, the regular and irregular structure's time period and base shift are twice as long as they are in the staadpro software (Vishwakarma and Balhar).

Methodology:

A structural is called statically if the number of unknown forces are exceed the number of equation. Usually, the statically indeterminate beams are analysis within two methods:

Hand calculation methods

All indeterminate analysis methods need that the solution achieve equilibrium and compatibility conditions, where compatibility is defined as the ability of the structure to fit together without gaps and the deflected shape to be consistent with the limits given by the supports(Buchanan 1998).

The analysis of statically indeterminate structures can be grouped into two groups:

the displacement (or stiffness) methods and the force (or flexibility) methods:

Consistent deformation method (force method)

The method of consistent deformations, also known as the superposition method or the flexibility method, is a process for examining linear elastic indeterminate structures. Beams, trusses, frames, shells, and other structural types can all be constructed using this method, but the computational work grows exponentially with the degree of indeterminacy. As a result, the method works best on structures that have a low level of indeterminacy.

The flexibility method is used to solve problems with finite elements. The finite element model is cut down into substructures using this method, which may ultimately lead to the reduction of the model to its component parts. The Direct Stiffness Method (DSM) preprocesses substructures to produce floating substructure free-free flexibility matrices (Felippa, 1997).

Castigliano's second Castigliano's second theorem (force method)

The Italian railroad engineer Alberto Castigliano wrote a book in 1879 that included a method for finding out the deflection or slope at a certain location in a structure, such as a truss, beam, or frame. This approach, also known as the method of last work or Castigliano's second theorem, is limited to constructions with linear flexible material response, rigid supports, and constant temperature. Theorem asserts that the displacement of a point, with regard to force acting at a point and in the direction of displacement, is equal to the first partial derivative of the strain energy in the structure (Ilkiu, 2023).

Explain by an example shown in figure1 the continuous in determinates beams carry two different load point load and continuous load solution by(Castigliano's second theorem)

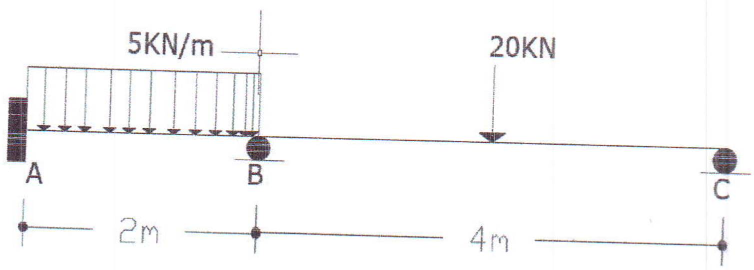

fig1

Solution:

Indeterminates beam

Assume:

i- moment at point (A) = X1

ii- vertical reaction at point (C)= X2

Finding all reaction force according to (X1,X2)

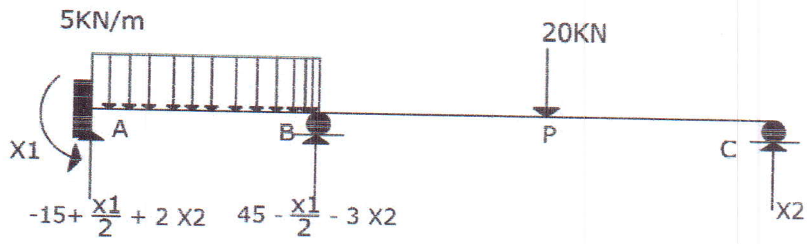

Fig2

Table 1: calculating the moment and derivation moment according to (X1, X2)

Portion	A-B	B-p	p-C
Origin	A	P	C
Limit (m)	0 – 2	0 – 2	0 – 2
Moment	$= (-15+\frac{x1}{2}+2*X2)*X-\frac{5x^2}{2}-X1$	X2 (2+X) – 20X	X2*X
$\frac{dM}{dx1}$	$\frac{X}{2}-1$	0	0
$\frac{dM}{dx2}$	2X	2+X	+ X

$$\left[sum \frac{1}{EI}\int_0^L M * \frac{dM}{dx1}\,dx \right] = 0$$

$0.67X1 - 1.33 \ X2 + 11.67 = 0$

(equ-1) 1

$\Delta C = [sum \frac{L}{EI} \frac{dM}{}$

$1.33 \ X1 + 32 \ X2 - 233.33 = 0$ (equ-2) »»

$(X1 = - 3.2 \ KN.M)(X2 = 7.16 \ KN)$

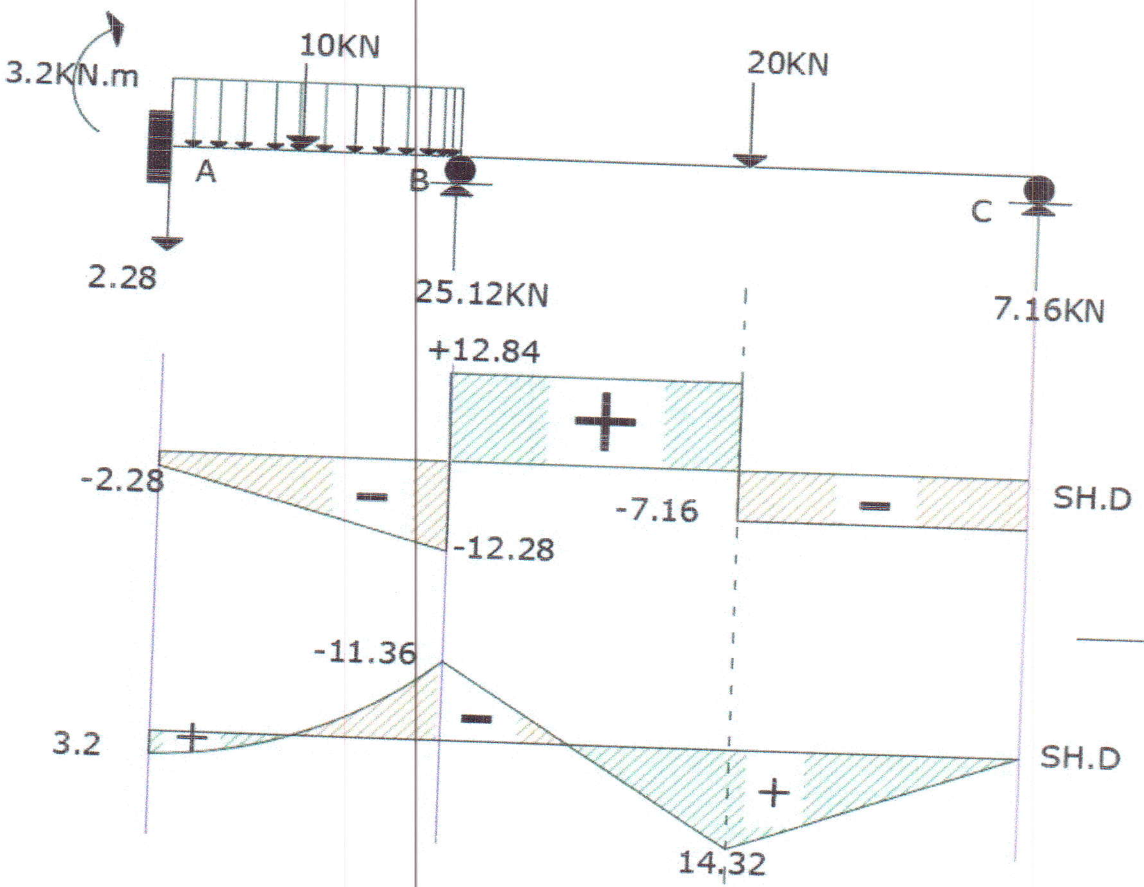

Fig3: shear moment diagram

Slope-deflection equation (Displacement method)

In the displacement methods is (the slope – deflection). George A. Maney first presented the slope-deflection method in 1915. This method, which is based on a specific formula that connects the member end moments to the displacements and rotations at the ends of the members, is used to evaluate statically indeterminate beams and frames. Basic slope-deflection equations are applied to each member at both the near and far ends. Equilibrium equations are also applied for specific structural joints. The system of simultaneous equations is then solved to analyze the structure. In particular circumstances (when the beam or frame's end span is supported by a pin or roller at its far end), one slope-deflection is sufficient for the span applied at the fixed end in order to minimize computations. This particular slope-deflection equation is referred to under these circumstances as the "modified slope-deflection equation." The slope-deflection method's key benefits are its broad applicability for indeterminate structures and its ease of programming (Husain, 2015).

$$M_N = 2Ek(2\theta_N + \theta_F - 3\psi) + (\text{FEM})_N$$

For Internal Span or End Span with Far End Fixed

Equation 1 (Hibbeler and Nolan 1997)

$$M_N = 3Ek(\theta_N - \psi) + (\text{FEM})_N$$

Only for End Span with Far End Pinned or Roller Supported

Equation 2 (Hibbeler and Nolan 1997) Where:

MN = internal moment in the near end of the span; this moment is positive clockwise when acting on the span.

E, k = modulus of elasticity of material and span stiffness k = I / L.

θ N, θ F = near- and far-end slopes or angular displacements of the span at the supports; the angles are measured in radians and are positive clockwise.

ψ = span rotation of its cord due to a linear displacement, that is, $\psi = \Delta/L$; this angle is measured in radians and is positive clockwise.

(FEM)N = fixed-end moment at the near-end support; the moment is positive clockwise when acting on the span; refer to the table on the inside back cover for various loading conditions (Hibbeler and Nolan 1997).

Solution the same beams that shown in figure1 by (Slope-deflection equation)

$$(FEM)AB = \frac{-WL^2}{12} \quad \frac{-5(2)^2}{12} \quad = \quad = -1.667\ KN.M$$

$$(FEM)BA = \frac{WL^2}{12} \quad \frac{5(2)^2}{12} = \quad = 1.667\ KN.M$$

$$(FEM)BC = \frac{-3PL}{12} = \frac{3*20*4}{16} = -15\ KN.M$$

Note: that (FEM)AB and (FEM)BC are negative since they act counterclockwise on the beam at A and B, respectively. Also, since the supports do not settle, ψ AB = ψ BC = 0. Applying Equation1for span AB and realizing that θ A = 0 (Husain, 2015). By using equation1

$$MAB = \frac{2EI}{2}(2\theta A + \theta B - 3(0) + (-1.667)$$

$$MAB = EI\ \theta B - 1.667$$

2E I

$MBA= \frac{}{2}(2\theta B + \theta A - 3(0) + (1.667)$

$MBA = 2EI\ \theta B + 1.667$

By using equation2

$MBC= \frac{3EI}{24}(\theta B - 0 + (-15)$

$MBC == \frac{3}{4}\ EI\theta B - 15$

Equations of Equilibrium:

$MBA+(M)BC=0$

$2EI\ \theta B + 1.667 + = \frac{3}{4}\ EI\theta B - 15 = 0$

»» $\theta B = \frac{4.848}{EI}$

MAB= 3.18 KN.M

MBA = 11.363 KN.M

MBC = -11.363 KN.M

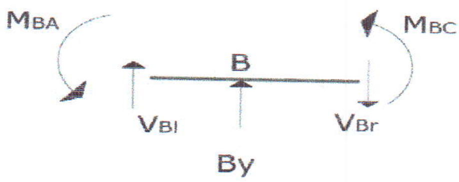

Fig 4

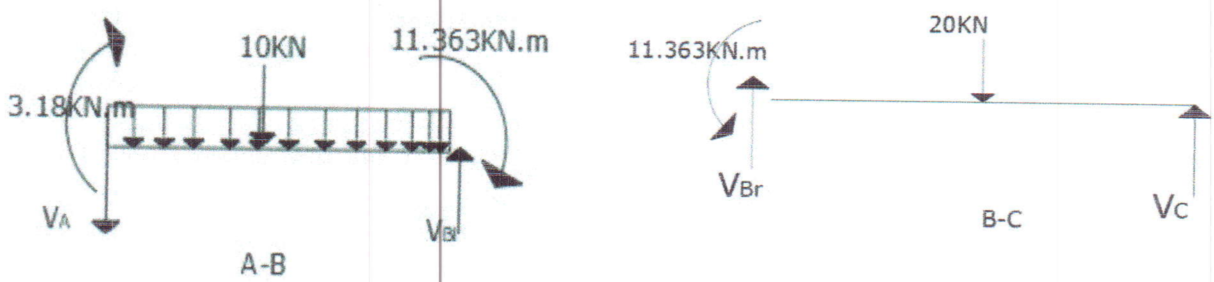

Fig 5

VA= 2.27 KN

VBl = 12.27, VBr =12.84 »» VB= 25.11 KN

Vc = 7.16KN

Moment distribution method (Displacement method):

Moment distribution is a method for determining the end moments in members of indeterminate beams band frames using a sequence of straightforward computations that was devised by Hardy Cross in the early 1930s. The moment distribution approach assumes that all of a structure's joints that are free to rotate or move are temporarily restrained. We will calculate the member end moments in each span of the continuous beam using the slope-deflection equation in order to build the moment distribution method (Rojas et al.,2011).

software methods:

1- Linpro

2- Staad pro

3- Sap 4- CSI-Etabs 5- Etc.....

By software program we runed the same example and getting the bellow shear and moment diagram:

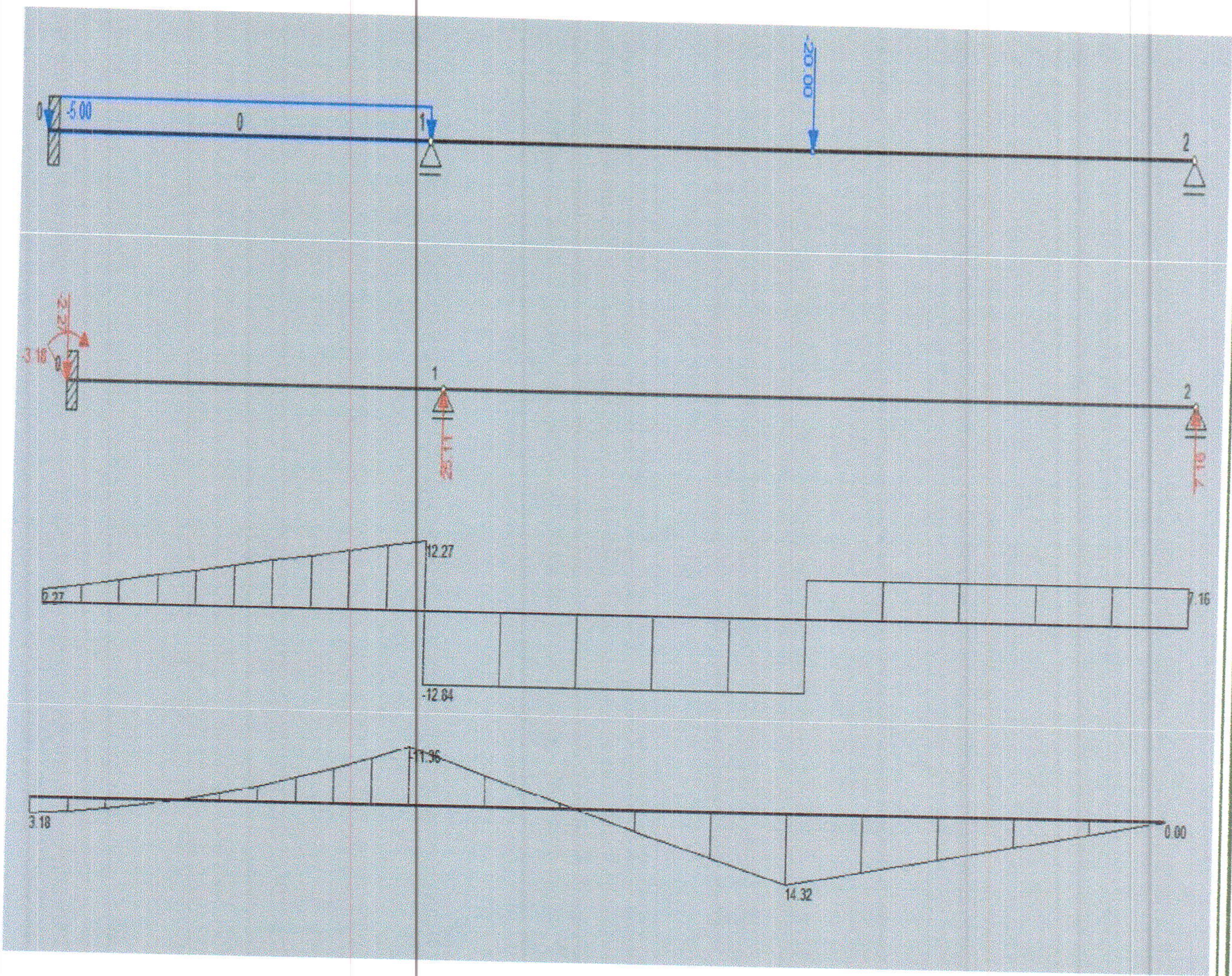

Figure 6: shear and moment diagram software result by Linpro

Results

After calculating the indeterminate beam carry two different load the continuous load (5KN/M) on span (A- B) and (20 KN) point load at mid span of (B-C) we used two hand calculate methods and one software program (Lin pro) getting the result of the bellow table2:

Table 2: Results of the different method of shear and moment

points	Castigliano's second theorem force method		Slope-deflection equation Displacement method		software program (Lin pro)		Castigliano's - (Lin pro)	
	Shear (KN)	Moment (KN.M)	Shear (KN)	Moment (KN.M)	Shear (KN)	Moment (KN.M)	Shear (KN)	Moment (KN.M)
A	-2.28	3.2	-2.27	3.2	-2.27	3.2	0.01	0.02
B	25.12	11.36	25.11	11.36	25.11	11.36	0.01	0.00
p	20	14.32	20	14.32	20	14.32	0.00	0.00
C	7.16	0.00	7.16	0.00	7.16	0.00	0.00	0.00

Discussion :

After reviewing additional literature and analyzing the shear moment diagram using both approaches to gather near findings, a comparison of the data showed that the difference in shear and kinked values at point (A) (0.01 kn) might have been caused by the software methods' use of closeness numbers. On the other hand, utilizing software produces dependable and speedy outcomes. However, manually verifying might help identify the mistake.

The complex structure of the beam and the techniques employed determine the accuracy of shear and bending moment diagrams. Since software techniques take into consideration a number of rules, they often give accurate findings for indeterminate beams. Hand calculations, however, can be prone to human error and need a thorough grasp of structural analysis techniques (Cain et al., 1990).

Software saves a great deal of time when it comes to comprehensive computations, particularly for complicated structures. Hand computations are labor-intensive for indeterminate beams because they need manual steps.

Conclusion :

In shear and bending analysis of indeterminate beams, computerized computations are typically more precise and effective than manual calculations, much like beam analysis. Complex loading and boundary conditions that would be challenging to solve by hand may be handled by software, which can also produce findings that are more precise and detailed. On the other hand, manual computations might be helpful for making fast estimates or validating software findings. It is crucial to remember that the quality of the input data and the modeling assumptions used affect how accurate the program produces results. Therefore, before employing software for analysis, it is important to have a solid grasp of the underlying theory and concepts of beam analysis. The decision between manual computations and software ultimately comes down to the user's particular requirements and available resources.

Recommendation :

Both software and manual computations should be used for the study of shear and moment diagrams for indeterminate beams.

- using Soft Wear Program in Complex Situation Like For structures that are complex and highly variable.
- Check Using Hand Calculations Perform computations by hand in simpler situations or as a check.
- Think About Sources and Time To choose the best realistic course of action, evaluate the project's scale, complexity, and available resources.

While programs may automate the procedure, doing the computations by hand increases your knowledge.

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