International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 07 | July 2020 www.irjet.net p-ISSN: 2395-0072

# 3D-Modelling of Stratified Reinforced Concrete Slabs

**Tarek Aly[1], Sameh Yehia[2], Ahmed M. Ahmed [3], Osama Hassaan[4]**

*[1]Professor, Faculty of Engineering, Helwan University, Egypt*
*[2]Associate Professor, Faculty of Engineering, Suez University, Egypt*
*[3]Assistant Professor, Faculty of Engineering and Applied Sciences, Nile University, Egypt.*
*[3]Assistant Professor, Faculty of Engineering, Helwan University, Egypt*
*[4]PhD. Student, Dept. of civil Engineering, The higher institute of engineering at el shorouk city, Egypt.*

---------------------------------------------------------------------***---------------------------------------------------------------------

**Abstract -** *This study aims to present a suitable model for analyzing reinforced concrete slabs fabricated by stratified concrete using finite element method. Stratified Concrete consist of two or more types of concrete; in particular, of composite materials consisting of High Strength Concrete (HSC) (60MPa) and Normal Strength Concrete (NSC) (25MPa). A nonlinear three-dimensional finite element analysis has been used to conduct an analytical investigation on the overall behavior of reinforced concrete stratified slabs. ANSYS computer program version 15 is utilized in the analysis. The two layers of concrete were idealized by using the 8-node iso parametric brick elements in ANSYS assuming good bond between them, while the reinforcement was modeled as link element by assuming perfect bond between the concrete and steel reinforcement. The numerical analysis includes material nonlinearity due to concrete cracking in tension, nonlinear stress strain relations of concrete in compression, crushing of concrete and yielding of steel reinforcement. The validity of the adopted models was verified through comparison with the one experimental slab, and the agreement has proven to be in acceptance range.*

***Key Words***: Composite Slab, Multi-Layers Concrete, High Strength Concrete, Nonlinear finite element analysis.

## 1. INTRODUCTION

Structural engineer should focus towards the structural analysis as well as functional design of the structure, but a major aspect that has a significant effect on the design process is the economy of the project. As a result of that, the concept of "Composite structures or partial elements" has been created to keep in mind economy and safety of the structure. The Finite element method is a relatively recent process of analysis; it is now known as a general method of wide applicability for solving engineering and physical science problems. It is a numerical method of analysis that can deal with problems of various boundary conditions and cases of loading. The finite element solution can be found in many text books (Willam and Warnke), (Zienkiewicz and Taylor) and (AN-SYS structural guide), [1]–[3]. As the HSC have exceptional material properties, however, their material costs are significantly higher than those of NSC. It is important to highlight the basic for using the composite elements that is implemented by combining the NSC and HSC or any recent advanced cementitious material in composite structures in order to achievement the advantages of the two materials in an optimal way. This concept of composite structures can be applied to new structures and to conservation projects.

The main part of the theoretical program can be indicated as a comparison between experimental and theoretical specimen to specify the actual coefficient of ANSYS (15.0). The experimental program consists of one reinforced concrete slab with a thickness of 150 mm with a length of 3200 mm and a width of the slab as a 500 mm strip. The bottom main steel reinforcement, 8 bars with a diameter of 16 mm per meter and secondary steel reinforcement 5 bars with a diameter of 12 mm per meter.

## 2. FINITE ELEMENT MODEL

Structural components encountered throughout the current study, corresponding finite element representation and elements designation in ANSYS program will be represent below.

### 2.1. Element types:

### 2.1. 1 Concrete Element:

Solid65, an eight-node solid element is used to model the concrete, which is special for 3-D modelling for solid concrete elements with or without reinforcing rebar. This element allows the presence of three different reinforcing materials. The solid element has eight nodes with three degrees of freedom at each node translations in the nodal x, y, and z directions. The element is capable of plastic deformation, cracking in three orthogonal directions, and crushing. The geometry and node locations for this element type are shown in **Fig -1**.

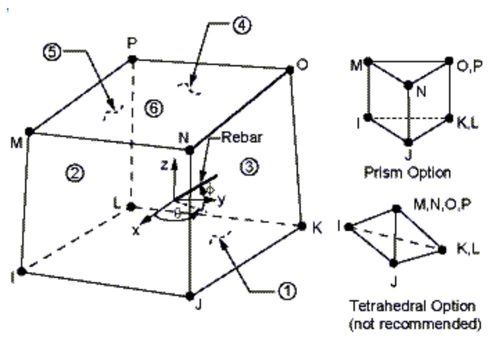


**Fig -1**: Solid 65 Element

### 2.1.2. Steel Reinforcement Element:

Link8, For the discrete model, Link8 is an element used to model the reinforcement. Two nodes are required for this element. Each node has three degrees of freedom, translations in the nodal x, y, and z directions. The element is also capable of plastic deformation. The geometry and node locations for this element type is shown in **Fig -2.**

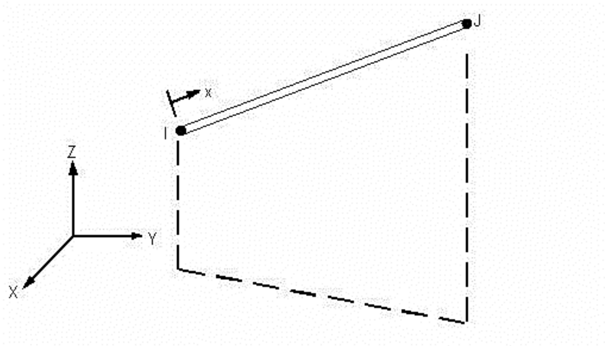


**Fig -2**: Link 180 Geometry

### 2.1.3. Lead Plates and Supports:

SOLID185 is used for 3-D modelling of solid structures. It was used to model Steel plates were added at support and point of loading locations. The geometry and node location for this element type are shown in Fig -3.

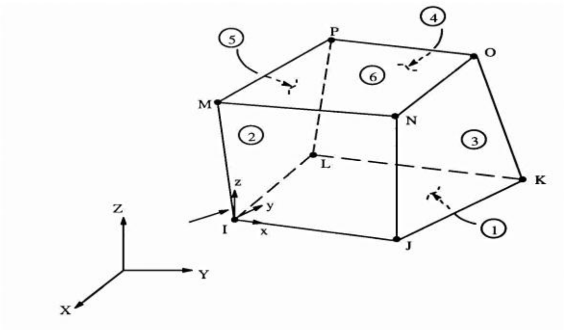


**Fig -3:** SOLID 185 Geometry, [4].

### 2.2. Real Constants:

The real constants for this model are shown in Tables from Table 1 to Table 3. Note that individual elements contain different real constant set exists for the solid185 element.

**Table -1:** Real Constants for Concrete Element

| Real Constant | Element Type | Constants | | | |
|---|---|---|---|---|---|
| 1 | Solid65 | Input Data | Real Constants for Rebar1 | Real Constants for Rebar2 | Real Constants for Rebar3 |
| | | Material Number | 0 | 0 | 0 |
| | | Volume Ratio | 0 | 0 | 0 |
| | | Orientation Angle | 0 | 0 | 0 |
| | | Orientation Angle | 0 | 0 | 0 |

**Table -2**. Real Constants for Main Steel Reinforcement Element (Φ 16)

| Real Constant | Element Type | Constants | |
|---|---|---|---|
| 2 | Link8 | Cross-Sectional Area ($mm^2$) | 201 |
| | | Initial Strain | 0 |

**Table -3**: Real Constants for Secondary Steel Reinforcement Element, (Φ 12)

| Real Constant | Element Type | Constants | |
|---|---|---|---|
| 3 | Link8 | Cross-Sectional Area ($mm^2$) | 113 |
| | | Initial Strain | 0 |

### 2.3. Material Modeling for Elements:
### 2.3.1. Concrete Elements:

The Solid65 element requires linear isotropic and multilinear isotropic material properties to properly model concrete. In this paper two type concrete are used (NSC and HSC). The multilinear iso-tropic material uses the von Mises failure criterion along with the Willam and Warnke ( 1974 ) [1] model to define the failure of the concrete. (EX) is the modulus of elasticity of the concrete (Ec), and PRXY is the Poisson's ratio (ν). The modulus was based on the Equation (1) for NSC based was mentioned by the Egyptian Code of Practice, [5], but for HSC is not applicable, where mechanical properties of concrete intrinsically depend on some other parameters, i.e., the water-to-cementitious materials ratio, the silica fume percentage used, the type of aggregates, etc. [6]. Nevertheless, still most existing expressions for the prediction of the modulus of elasticity of HSC and advanced concrete are based on its compressive strength; some of them are shown in Equation (2) to Equation (4), [7], [8], [9].

$$E_c = 4400\sqrt{F_{cu}} \quad MPa \qquad (1)$$

$$E_c = \left(3320\sqrt{f'_c} + 6900\right)\left(\frac{w}{2346}\right)^{1.5} \quad \text{for } 21 \le f'_c \le 83MPa, \text{ (ACI 363r), [7]} \qquad (2)$$

$$E_c = 10000(f'_c + 8)^{0.33} \quad \text{( CEB ), [8]} \qquad (3)$$

$$E_c = \left(3300\sqrt{f'_c} + 6900\right)\left(\frac{w}{2300}\right)^{0.5} \quad \text{, ( CSA ), [9]} \qquad (4)$$

**Where:**

$f_c'$ (MPa) is 28-day cylindrical compressive strength,
$E_c$ (MPa) is modulus of elasticity of concrete, and w (Kg/m$^3$) is the unit weight of concrete.
For NSC, Poisson's ratio was assumed to be 0.2 and for HSC was assumed 0.18. The compressive uniaxial stress-strain relationship for the NSC model was obtained using the following equations to compute the multilinear isotropic stress-strain curve for the NSC.

$$f = \frac{E_C . \varepsilon}{1+\left(\frac{\varepsilon}{\varepsilon_O}\right)^2} \qquad (5)$$

Where:
f = stress at any strain ε
ε = strain at stress f
$\varepsilon_o$ = strain at the ultimate compressive strength
($\varepsilon_o = 2 F_c'/ E_c$)
$F_c'$ = ultimate compressive strength for concrete and according to Egyptian Code of Practice [5]. It can be taken as 0.8 $F_{cu}$ but for the HSC, the compressive uniaxial stress-strain relationship was obtained using the following equations:

$$f_c = \frac{n\beta(\varepsilon_C/\varepsilon`_c)f`_c}{n\beta-1+(\varepsilon_C/\varepsilon`_c)^{n\beta}} \qquad (6)$$

***Where,***

$\beta=(f`_c/65.23)^3+2.59$, and n=3

Implementation of the Willam and Warnke (1974), [1] material model in ANSYS version 15 requires that different constants be defined. These 9 constants are:

1. Shear transfer coefficients for an open crack;
2. Shear transfer coefficients for a closed crack;
3. Uniaxial tensile cracking stress;
4. Uniaxial crushing stress (positive);
5. Biaxial crushing stress (positive);
6. Ambient hydrostatic stress state for use with constants 7 and 8;
7. Biaxial crushing stress (positive) under the ambient hydrostatic stress state
8. Uniaxial crushing stress (positive) under the ambient hydrostatic stress state
9. Stiffness multiplier for cracked tensile condition.

Typical shear transfer coefficients range from 0.0 to 1.0, with 0.0 representing a smooth crack (complete loss of shear transfer) and 1.0 representing a rough crack (no loss of shear transfer). The shear transfer coefficients for open and closed cracks were determined using the work of Kachlakev, et al. (2001) [10] as a basis. Convergence problems occurred when the shear transfer coefficient for the open crack dropped below 0.2. No deviation of the response occurs with the change of the coefficient. Therefore, the coefficient for the open crack was set to 0.2 for all grades of concrete. The uniaxial cracking stress was based upon the compressive strength of concrete after 28 days. This value is determined approximately using equation (7) for all grades of concrete,

$$F_{ctr} = 0.6 \sqrt{(F_{cu})} \qquad (7)$$

The uniaxial crushing stress in this model was based compressive strength of concrete after 28 days. It was entered as the same value of compressive strength of concrete after 28 days.

The biaxial crushing stress, Ambient hydrostatic stress, Biaxial crushing stress (positive) under the ambient hydrostatic stress state, Uniaxial crushing stress under the ambient hydrostatic stress state and Stiffness multiplier for cracked tensile condition set to default value.

### 2.3.2. Steel Reinforcement Elements:

The Link8 element is being used for all the steel reinforcement in the slab. Most of researches were assumed to be bilinear isotropic. This study describes how to use both of bi-linear isotropic and multi-linear isotropic to represent the stress strain curve for the reinforcement. Bilinear and multi-linear isotropic material is based on the von Mises failure criteria. The bilinear model requires the yield stress ($F_y$), as well as the hardening modulus of the steel to be defined. The yield stress was defined gradually from 400 MPa up to approach to the yielding point, and the hardening modulus was used from 2000 up to approach to experimentally curve dissenting most researches that take it with fixed value or left by default value. Also, the modulus of elasticity was defined as 2.1x10$^5$ MPa, and Poisson's ratio was defined as 0.3 for both bilinear or multilinear isotropic. For multilinear curve is used to help with convergence of the nonlinear solution algorithm for steel stress strain curve to approach to the experimental solution. The first point at the stress strain curve was taken at stress equal to the yield stress (from 430MPa to 480MPa) near to experimental curve.

### 2.3.3. Steel Plates:

The Solid185 element is being used for the steel plates at loading points and supports on the slab. Therefore, this element is modeled as a linear isotropic element with a modulus of elasticity for the steel (Es) equal to 3x10$^5$ MPa, and Poisson's ratio (ν) equal to 0.3. Parameters needed to define the material models can be found in the following Tables, there are multiple parts of the material model for each element. See Tables from Table -4 to Table -8.

**Table -4:** Material Models for NSC Element

| Material Model Number | Element Type | Material Properties | | |
|---|---|---|---|---|
| 1 | Solid65 | | | |
| | | **Linear Isotropic** | | |
| | | Ex | | 22000 MPa |
| | | PRXY | | 0.2 |
| | | **Multilinear Elastic** | | |
| | | Points | Strain | Stress (MPa) |
| | | Point 1 | 0.00027273 | 6 |
| | | Point 2 | 0.0006 | 11.9 |
| | | Point 3 | 0.00075 | 14.1 |
| | | Point 4 | 0.0009 | 15.9 |
| | | Point 5 | 0.00105 | 17.32 |
| | | Point 6 | 0.0012 | 18.39 |
| | | Point 7 | 0.00135 | 19.15 |
| | | Point 8 | 0.00153 | 19.71 |
| | | Point 9 | 0.001818 | 20 |
| | | Point 10 | 0.003 | 20 |
| | | **Concrete** | | |
| | | ShrCf-Op | 0.2 | |
| | | ShrCf-Cl | 0.9 | |
| | | UnTensSt | 3 | |
| | | UnCompSt | 25 | |
| | | BiCompSt | - | |
| | | HydroPrs | - | |
| | | BiCompSt | - | |
| | | UnTensSt | - | |

**Table -5:** Material Models for 60MPa HSC Element

| Material Model Number | Element Type | Material Properties | | |
|---|---|---|---|---|
| 1 | Solid 65 | | | |
| | | **Linear Isotropic** | | |
| | | Ex | | 31200 MPa |
| | | PRXY | | 0.18 |
| | | **Multilinear Elastic** | | |
| | | Points | Strain | Stress (MPa) |
| | | Point 1 | 0.000500 | 15.6 |
| | | Point 2 | 0.000900 | 28.07 |
| | | Point 3 | 0.001050 | 32.73 |
| | | Point 4 | 0.001300 | 40.3 |
| | | Point 5 | 0.001600 | 47.9 |
| | | Point 6 | 0.001800 | 50 |
| | | **Concrete** | | |
| | | ShrCf-Op | 0.2 | |
| | | ShrCf-Cl | 0.9 | |
| | | UnTensSt | 4.6 | |
| | | UnCompSt | 60 | |
| | | BiCompSt | - | |
| | | HydroPrs | - | |
| | | BiCompSt | - | |
| | | UnTensSt | - | |

**Table -6**: Material Models for Steel Reinforcements Element for Slabs Modeled by Bilinear Elastic.

| Material Model Number | Element Type | Material Properties | | |
|---|---|---|---|---|
| 2 | Link 8 | **Linear Isotropic** | | |
| | | Ex | | 210000 MPa |
| | | PRXY | | 0.3 |
| | | **Bilinear Elastic** | | |
| | | Trial 1 | Yield Stress | 400 |
| | | | Tangent Modulus | 2000 |
| | | Trial 2 | Yield Stress | 430 |
| | | | Tangent Modulus | 3000 |
| | | Trial 3 | Yield Stress | 480 |
| | | | Tangent Modulus | 2000 |
| | | Trial 4 | Yield Stress | 480 |
| | | | Tangent Modulus | 5000 |
| | | Trial 5 | Yield Stress | 480 |
| | | | Tangent Modulus | 6000 |
| | | Trial 6 | Yield Stress | 490 |
| | | | Tangent Modulus | 6000 |

**Table -7**: Material Models for Steel Reinforcements Element for Slabs Modeled by Multilinear Elastic

| Material Model Number | Element Type | Material Properties | | | |
|---|---|---|---|---|---|
| 2 | Link 8 | **Linear Isotropic** | | | |
| | | Ex | | 210000 MPa | |
| | | PRXY | | 0.3 | |
| | | **Multilinear Elastic** | | | |
| | | Trial No. | Point | Strain | Stress (MPa) |
| | | 7 | 1 | 0.0020952 | 440 |
| | | | 2 | 0.004 | 520 |
| | | 8 | 1 | 0.002 | 420 |
| | | | 2 | 0.004 | 520 |
| | | | 3 | 0.005 | 520 |
| | | 9 | 1 | 0.00215 | 430 |
| | | | 2 | 0.005 | 500 |
| | | | 3 | 0.03 | 550 |
| | | 10 | 1 | 0.002286 | 480 |
| | | | 2 | 0.004 | 480 |

| | | | | | |
|---|---|---|---|---|---|
| | | | 3 | 0.01 | 550 |
| | | | 4 | 0.02 | 600 |
| | | 11 | 1 | 0.002333 | 490 |
| | | | 2 | 0.003 | 500 |
| | | | 3 | 0.01 | 580 |
| | | | 4 | 0.02 | 600 |

**Table -8**: Material Models for Steel Plate Element.

| Material Model Number | Element Type | Material Properties | |
|---|---|---|---|
| 3 | Solid185 | Linear Isotropic | |
| | | Ex | 300000 (MPa) |
| | | PRXY | 0.3 |

### 2.4. Model Meshing:

Using Solid65 element of a rectangular mesh is recommended. The necessary element divisions are noted. The meshing of the reinforcement is a special case compared to the volumes. The mesh of the reinforcement is needed because individual elements were created in the modeling through free nodes created by the specimen volume. However, the necessary mesh attributes as described above need to be after each section of the reinforcement is created. The overall FE mesh of the specimen, steel loading plates, and steel supports volumes is shown in Fig -4.

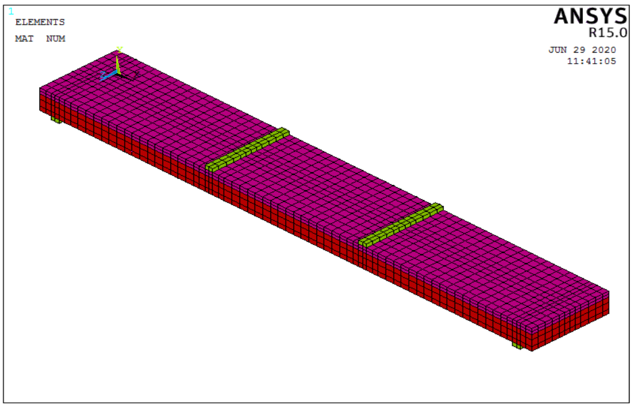


**Fig -4:** Slab Specimen After Meshing.

### 2.5. Supports Types and Loads:

The supports were modeled in such a way that a roller was created by a single line of nodes on the steel support which is given constraint in the UY direction, by doing this, the slab will be allowed to rotate at the support. The hinged support was created by a single line of nodes on the steel support which is given constraint in the UX and UY directions. Both of the roller support and hinged support has one point constrain in the UZ direction for stability. The supports condition is shown in Fig -5 and Fig -6.

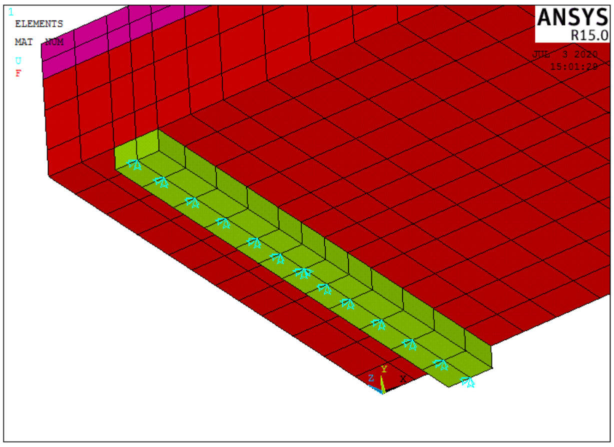


**Fig -5:** Hinged Support.

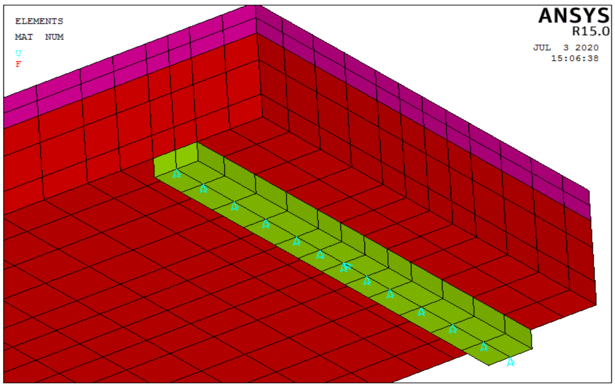


**Fig -6:** Roller Support.

The concentrated Load, P, applied at the steel loading plate. The force applied at each node on the plate calculated with respect to mesh area. The following Fig -7 shows the application of load on loading plates.

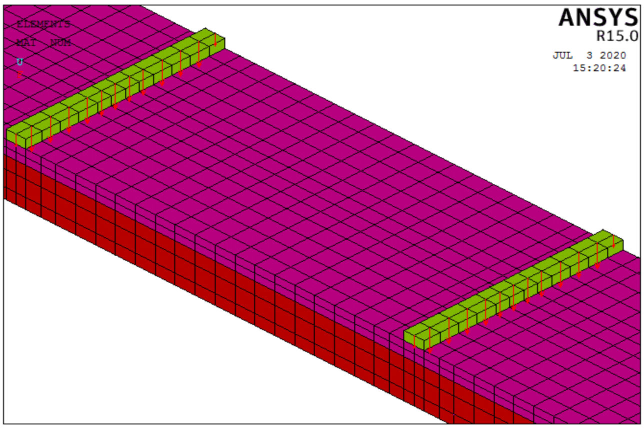


**Fig -7:** Application of Load.

### 2.6. Analysis Type:

The finite element model for this analysis is a simple slab under static loading. For the purposes of this model, the static analysis type is utilized to simulate the static load. The

Sol'n Controls command dictates the use of a linear or non-linear solution for the finite element model. Typical commands utilized in a nonlinear static analysis are shown in the Table -9 to Table -11.

**Table -9:** Commands Used to Solution Control – Basic

| Program Request | Inputted Data |
|---|---|
| **Analysis Options** | Small Displacement |
| **Calculate Prestress Effect** | No* |
| **Time at End of Load step** | Ranged From 120000 |
| **Automatic Time Stepping** | On |
| **Time Increment** | Chosen by User |
| **Time Step Size** | 2000 |
| **Minimum Time Step** | 400 |
| **Maximum Time Step** | 4000 |
| **Write Items to Results File** | All Solution Items |
| **Frequency** | Write Every Sub step |

**Table -10:** Commands Used to Solution Control (Non-Linear)

| Program Request | Inputted Data |
|---|---|
| **Line Search** | off |
| **DOF Solution Predictor** | Prog Chosen |
| **Maximum Number of Iteration** | 40 |
| **Cutback Control** | Cutback according to predicted number of iterations |
| **Equiv. Plastic Strain** | 0.15 |
| **Explicit Creep Ratio** | 0.1 |
| **Implicit Creep Ratio** | 0 |
| **Incremental Displacement** | 10000000 |
| **Point Per Cycle** | 13 |
| **Set Convergence Criteria** | |
| **Label** | U |
| **Ref.Value** | Calculated |
| **Tolerance** | Ranged From 0.05 to 0.25 |
| **Norm** | L2 |
| **Min. Ref.** | Not applicable |

**Table -11:** Commands Used to Solution Control - Non-Linear

| Program Request | Inputted Data |
|---|---|
| **Program Behavior Upon Nonconvergence** | Terminate but do not exit |
| **Nodal DOF Sol'n** | 0 |
| **Cumulative Iter.** | 0 |
| **Elapsed Time** | 0 |
| **CPU Time** | 0 |

## 3. EXPERIMENTAL PROGRAM:

The concrete mix for the test specimen was made from available materials, which were consists of cement content, natural sand, crushed dolomite, silica fume, super plasticizer, and tap drinking water. HSC mix proportion was done according to previous studies, [11], [12], [13]. Trial mix was placed and was tested to ensure required strength. The used concrete mix was designed to develop a cubic compressive strength of 60 MPa. The second concrete mix was NSC which was de-signed to develop a cubic compressive strength 25 MPa.

Concrete ingredients were tested according to the Egyptian Standard Specifications. Aggregate was tested according to ESS 1109/2002 [14], The cement used in this research was the CEMI 42.5N produced by the Suez Cement Company – Suez factory, Silica fume is commercially available through construction chemical company, (Visocrete-3425) high performance super plasticizer was used for the product HSC in order to achieve its required workability [15], The reinforcement steel was a high-grade steel B400B-R bars of diameters 12- and 16-mm. Table -12 to Table -16 show properties of used materials.

**Table -12:** Physical Properties of the Used Cement (CEM I 42.5N)

| Physical Properties | | Measured Values | Limits of the E.S.S 4756-1/2013, [16] |
|---|---|---|---|
| **Fineness ($cm^2/gm$)** | | 3628 | — |
| **Specific Gravity** | | 3.14 | — |
| **Expansion (mm)** | | 1.0 | Not more than 10 |
| **Initial Setting Time (minutes)** | | 110 | Not less than 60 |
| **Final Setting Time (minutes)** | | 200 | — |
| **Compressive Strength (MPa)** | **2 days** | 19 | Not less than 10 |
| | **28 days** | 53.5 | Not less than 42.5 and not more than 62.5 |

**Table -13:** Physical and Mechanical Properties of Natural Coarse Aggregate

| Property | Results | Limits |
|---|---|---|
| **Specific Weight** | 2.6 | — |
| **Bulk Density ($t/m^3$)** | 1.65 | — |
| **Water absorption%** | 1.58 | Not more than 2.5** |
| **Clay and Fine Dust Content%** | 1.4 | Not more than 2.5** |
| **Flakiness Index%** | 35.7 | Not more than 40%** |
| **Elongation Index%** | 10.55 | Not more than 25%** |
| **Abrasion Index%** | 17.8 | Not more than 30%** |
| **Impact Value %** | 12.60 | Not more than 45%** |

**Limits of ECCS203-2007

**Table -14**: Physical Properties of Fine Aggregate

| Properties | Results | Limits* |
|---|---|---|
| **Specific gravity** | 2.7 | - |
| **Bulk density (t/m³)** | 1.8 | - |
| **Materials finer than no 200 sieve%** | 1.8 | Less than 3 % |

*Limits of ECCS203-2007

**Table -15**: Physical Properties of the Silica Fume

| Properties | Test results* |
|---|---|
| **Specific surface area (cm²/gm)** | $17.8 \times 10^4$ |
| **Particle size (µm)** | 7.00 |
| **Bulk density (kg/m³)** | 345 |
| **Specific gravity** | 2.15 |
| **Color** | Light gray |

* By the provider data sheet

**Table -16:** Mechanical Properties of the Used High-Grade Steel

| Properties | Measured Values | | Minimum Specification Limits | |
|---|---|---|---|---|
| | High Grad Steel B400B-R Φ 12 | High Grad Steel B400B-R Φ 16 | Φ 12 | Φ 16 |
| **Yield stress (N/mm²)** | 430 | 463 | 400 | 400 |
| **Ultimate stress (N/mm²)** | 650 | 685 | 600 | 600 |
| **Weight per meter length (Kg)** | 0.879 | 1.606 | 0.888 | 1.58 |
| **Rm/ReH** | 1.25 | 1.26 | 1.08 | 1.08 |
| **Elongation %** | 12.0 | 13.0 | 5 | 5 |

*ES:262/2015, Egyptian Standards for Steel Reinforcement [17]

Two mixes were used to cast slabs (HSC 60MPa & NSC 25MPa) and they were designed for target 28 days' compressive strength of 60MPa and 25 MPa respectively. Table -17 show the mix proportions of the two used concrete mixes. The specimens were located under the cross head of the testing machine such that the centerline of the specimen was oriented perpendicular to the centerline of the cross head. The specimen was supported over two steel rods (hinge support). The slabs were tested using two concentrated loads. The locations of loading points were at distance 1025 mm from the support center line.

**Table -17**: Shows the Mix Ingredients for Concrete Mixes

| Constituents | Proportions | |
|---|---|---|
| | NSC | HSC |
| **Cement Kg/m³** | 360 | 550 |
| **S.F Kg/m³** | - | 55 |
| **Sand Kg/m³** | 627 | 480 |
| **Coarse agg. Kg/m³** | 1363 | 895 |
| **Water Kg/m³** | 180 | 170 |
| **Super Plasticizer % of cement** | - | 1 % |

## 4. Results, Analysis and Discussion:

A comparison study is conducted to verify the theoretical analysis with the experimental results and to demonstrate a theoretical sample matching with a laboratory sample. The comparison concentrated on the load-deflection relationship. This study focused on the effect of the stress-strain relationship for the steel reinforcement on flexural behavior. The stress-strain relationship for steel reinforcement is represented by two types which they are Bilinear Elastic and Multilinear Elastic.

The bilinear model requires the yield stress ($F_y$), as well as the hardening modulus of the steel or Tangent Modulus. The yield stress was defined gradually from 400MPa at Trial 1 up to 490MPa at Trial 6, and the hardening modulus was used from 2000 at Trial 1 up to 6000 at Trial 6 which its result approached to the Experimental results as shown at Chart-1.

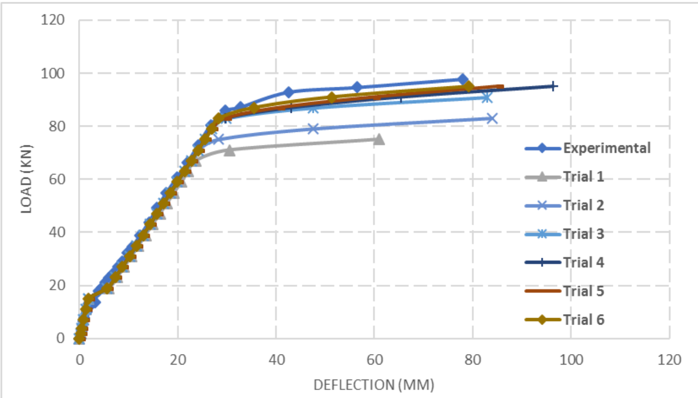


**Chart -1**: Comparison between Experimental and Theoretical Results (trials from 1 to 6) modeled by Bilinear Elastic.

As shown in the chart when using the $F_y$ by 400MPa in Trial 1, the yielding of the reinforcement was happened before the experimental specimen. In Trial 2, the yield stress was increased to 430MPa and the tangent modulus increased from 2000 to 3000 which led to obvious enhancement on the curve for both the load and the deflection. After that, the yield stress was increased to 480m MPa in Trial 3 which led to more enhancement on curve and the yield stress had become very close to the experimental curve. At Trial 4 and Trial 5 was still on increasing the tangent modulus by 5000 MPa and 6000 MPa, respectively which also led to more enhancement for the ultimate load and corresponding deflection. Finally, the yield stress was increased slightly to 490 MPa in Trial 6 performing closer to the experimental curve.

For the multilinear model not requires the yield stress and the hardening modulus of the reinforcement. Multilinear model requires the stress and the corresponding strain for some point that represent the stress strain for this material. So, the first point was taken at yielding stress and by dividing the yielding stress by the elastic modulus we get the corresponding strain. The yield stress was defined gradually from 420 MPa at Trial 8 up to 490MPa at Trial 11, and the other selected point was chosen to close the experimental curve which its result approached to the Experimental results as shown at Chart -2. As shown at this chart the multilinear was led to closer than the bilinear method. Also, it's obvious that, by many trials can closer to the experimental curve as shown at Trial 10 and Trial 11 which give the best result. For knowing the stress strain curve for the used steel reinforcement, the multilinear is the best choice to represent it because the bilinear give just two linear relationships first one before the yielding stress and the second after the yielding stress but, the multilinear give unlimited number for linear relationship to represent any curve.

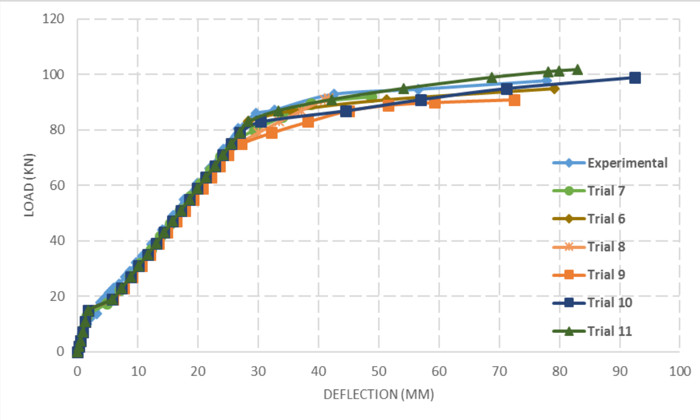


**Chart -2**: Comparison between Experimental and Theoretical Results (trials from 7 to 11) modeled by Bilinear Elastic.

## 5. SUMMARY AND CONCLUSION:

A comparison between experimental and theoretical specimen was carried out to specify the actual coefficient of finite element program, ANSYS version 15. This study was described how to use both of bi-linear isotropic and multi-linear isotropic to represent the stress strain curve for the reinforcement. The multilinear curve was showed with convergence of the nonlinear solution algorithm for steel stress strain curve the best fit to approach of the experimental solution.

## REFERENCES:

[1] E. P. William, K.J. / Warnke, "Constitutive model for the triaxial behaviour of concrete III-l," 2019.

[2] O. C. Zienkiewicz, CBE, FRS, R. L. Taylor, and J. Z. Zhu, "Method : Its Basis and Fundamentals," vol. Sixth edit, p. 802, 2005.

[3] T. D. Canonsburg, "ANSYS FLUENT Tutorial Guide," vol. 15317, no. October, pp. 724–746, 2012.

[4] M. B. Mahmood and V. C. Agarwal, "Non-Linear Finite Element Analysis of RC Slabs Strengthened with CFRP Laminates," vol. 5, no. 3, pp. 140–143, 2013.

[5] Egyptian Code of Practice for Design and Construction of Concrete Structures ECCS (203-2007).

[6] D. MOSTOFINEJAD and M. NOZHATI, "Prediction of the modulus of elasticity of high strength concrete," vol. 29, 2005.

[7] H. G. Russell et al., "State-of-the-Art Report on High-Strength Concrete Reported by ACI Committee 363," vol. 92, no. Reapproved, 1997.

[8] C.-F. Model, Structural Concrete Textbook on behaviour, design and performance. 2010.

[9] CAN/CSA-A23.3-04, "Design of concrete structures," 2007.

[10] D. Kachlakev and T. Miller, "FINITE ELEMENT MODELING OF REINFORCED CONCRETE STRUCTURES STRENGTHENED WITH FRP LAMINATES," 2001.

[11] S. R. Hunchate, S. Chandupalle, V. G. Ghorpode, and V. R. T. C, "Mix Design of High Performance Concrete Using Silica Fume and Superplasticizer," vol. 3, no. 3, pp. 10735–10742, 2014.

[12] V. D. Sabale, M. D. Borgave, and S. D. Shinde, "Study the Effect of Addition of Silica Fume on Properties of High Strength Concrete," vol. 3, no. 1, pp. 267–270, 2014.

[13] "ESS 1109/2002, Egyptian Standard Specification 'Aggregates for Concrete.'" .

[14] Sameh Yehia , Tarek Aly , Ahmed Mohamed Abd Elkhalek , Osama Hassaan, 2020, Effect of Cold Joint on Stratified Slabs, INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) Volume 09, Issue 07 (July 2020),

[15] H. Performance and S. Concrete, "Sika ViscoCrete ® - 3425," no. 12, pp. 4–5, 2015.

[16] "ES 4756-1 (2009) (Arabic): Cement Part:( 1) Composition, Specifications And Conformity Criteria For Common Cements," vol. 1, 2009.

[17] ES:262/2015, "Egyptian Standards for Steel Reinforcement."

## BIOGRAPHY:

**Dr. Sameh Yehia** is an Egyptian author for different publications and books in the field of structural civil engineering. He has work as a faculty member in many universities. You can visit him at: https://scholar.google.com/citations?user=dxZOr9wAAAAJ&hl