Evaluation the effect of lime on the plastic and hardened properties of cement mortar and quantified using Vipulanandan model

Abstract: In this study, the effect of lime content (L %) on the plastic properties such as water-cement ratio (w/c), setting times, flowability, compressive, flexural and bond strengths of cement mortar were investigated. Based on the information in the literature the amount of lime varied between 0 to 45% (by weight of cement). The experimental results were compared with the data collected from different research studies and quantified using two different models. The plastic and hardened properties of the cement mortar modified with different percentage of lime were conducted according to the ASTM and BS standards. Based on the literature data the water to cement ratio (w/c) ranged between 0.3-0.74 percent, the w/c of 0.5 was selected in this study. The compressive and flexural strengths of cement mortar modified with lime up to 28 days of curing were ranged between 3 MPa to 65 MPa and 2 MPa to 12 MPa respectively. The compressive, flexural and bond strengths of the cement mortar decreased with increasing lime content. Vipulanandan correlation model was used to correlate the relationship between lime with consistency, setting times, flowability and compressive strength of cement mortar. Compressive and flexural strengths of cement mortar modified with lime were quantified very well as a function of w/c, lime content and curing time using nonlinear relationship.

Keywords: Lime content, Curing time, Strengths, Tensile bonding, Statistical analysis, Modeling

1 Introduction

The mortar is a composite material consisting of a mixture of cementitious material (cement), fine aggregates (sand), an amount of water required for hydration reactions. Mineral admixtures, such as fly ash, lime, and silica fume have been widely used for the manufacture of cement mortar. The addition of mineral additive improved the performance, mechanical properties and durability of cement mortar also, the addition of mineral additives decrease CO₂ emission and may also reduce the adverse environmental effect caused by cement production [1–8].

The Limestone is calcareous sedimentary rock mainly consisting of calcium carbonate (CaCO₃), commonly called calcite. Limestone is used in cement and mortar for various purposes, as a raw material for clinker production and as coarse or fine aggregate. Lime is produced by finely grinding limestone in quarrying operations and has been suggested for use as an additive in Ordinary Portland Cement. Replacing of limestone into Ordinary Portland Cement has been studied [4, 9, 10]. Lime has been considering as an inert filler material that improves the hydration rate of cement compounds and consequently increases the strength at early ages. The incorporation of limestone powder with Portland cement has many advantages on initial compressive strength, durability, and workability. Workability, strength, and durability are three basics properties of cement mortar [11–16]. The increase in w/c reduced the value of mechanical properties and increased the workability. Several research studies have been performed to understand the effect of lime on the physical and mechanical properties of cement mortar (Table 1). Compressive and bonding strengths are the most critical property of cement mortar that describes its quality and performance for construction works. In addition, most of the other features such as flexural strength was improved in parallel with the increase in the compressive strength. In terms of compressive strength, the addition of hydrated lime to cement based mortars shows that lime-rich mortars are able to withstand a higher degree of deformation before fail-
The observations made, indicate that the lime additions allow for some accommodation of movement either under compressive loads or shear loading, and unlike the brittle failure of cement rich mortars, those with high lime content (where volume of lime is twice that of cement, e.g. 1:2:9 mortar) some elastic-plastic deformation is observed prior to brittle failure with increased lime content.

Although a reduction in compressive strength may be viewed as a negative result of hydrated lime addition to a mortar, the resulting performance does provide some accommodation from minor movement of the masonry, thus reducing the associated cracking, as typically seen with high strength (cement rich) mortars which although strong are more "brittle" [17–24].

In this study, the effect of lime on the workability, setting times and mechanical strength of cement mortar were performed based on experimental and collected data from the literature. The influence of water to cement ratio, curing time and lime content on the compressive, flexural strengths of cement mortar were quantified using a non-linear model.

### 1.1 Objectives

The primary objective of this study is to investigate and quantify the effect of lime on the properties of plastic and hardened properties of cement mortar using experimental and collected data from the literature. The specific objectives are as follows:

1. Statistical variations of the compressive and flexural strengths, water to cement ratio and lime content of cement mortar.
2. Investigate the effect of lime on the consistency, setting times, flowability and strength properties of cement mortar.
3. Develop a non-linear relationship to predict the compressive and flexural strengths of cement mortar as a function of w/c, lime content and curing time using the experimental data and data collected from the literature.
4. Develop the relationship between compressive and flexural strengths of the cement mortar modified with lime up to 28 days of curing.
5. To evaluate the relationship between the tensile bonding strength of cement mortar with lime content at seven days of curing.

### 2 Materials and methods

#### 2.1 Materials

The type of cement used in this study was Gasin Portland Cement from the Gasin Cement Company (Iraq, Kurdistan-Region, Sulaymaniyah City, and 35° 33′26″N 45° 26′08″E). Lime is typically used in the form of quicklime (CaO) or hydrated lime (Ca(OH)₂). Quicklime (CaO) is manufactured by chemical processes that transform calcium carbonate (limestone – CaCO₃) into calcium oxide (CaO). When quicklime reacts with water, it turns into hydrated lime.

Tap water was used in this study.

The sand used in the study was CEN standard sand which is well graded rounded particles having a silica content of 98% as specified in EN 196-1 standard requirements [8, 25].

#### 2.2 Methodology

The plastic and hardened properties of cement mortar modified with lime were tested according to ASTM and BS standard. At least three samples were tested for each condition.

X-ray diffraction (XRD) analyses were performed to determine the chemical composition of cement and lime at 25°C. The powder (2 g) was placed in an acrylic sample holder (3 mm) depth. The samples were analyzed by using parallel beam optics with CuKα radiation at 40 kV and 30 mA. The samples were scanned for reflections (2θ) from 0° to 90° in steps of 0.02° and a 2 sec count time per step. A similar procedure was conducted by [26]. The chemical composition of the cement and lime are illustrated in Table 2 and Table 3.

**Standard consistency test (BS EN 196-3:2016)**

This test aims to determine the minimum quantity of mixing water to initiate a chemical reaction between water and cement. Cement is one of the materials which the right amount of water leads to attaining required cement strength. The standard consistency was carried out according to the EN 196-3 standard using the Vicat apparatus. The cement paste was prepared by putting 500 g of cement into the bowl of the mixer. The amount of water was added to the cement. Firstly, the mixing was left for 10 seconds for absorption. Then the mixing apparatus was put at a low
Table 1: Summary properties of cement mortar modified with lime

| Reference  | Country       | Lime, L (%) | w/c | Curing time, t (Day) | Compressive strength, $\sigma_c$ (MPa) | Flexural strength, $\sigma_f$ (MPa) | Test(s)                        |
|------------|---------------|-------------|-----|----------------------|----------------------------------------|-----------------------------------|---------------------------------|
| [3]        | Canada        | 0-10        | 0.33| 1,3,7 and 28         | 29-64                                  | -                                 | Compressive strength            |
| [5]        | Turkey        | 0 and 30    | 0.5 | 2, 7 and 28          | 16-60                                  | 4-11                              | Compressive and flexural strengths |
| [6]        | China         | 0 and 30    | 0.5 | 3 and 28             | 17-60                                  | -                                 | Compressive strength            |
| [11]       | Ethiopia      | 0-35        | 0.5 | 2 and 28             | 6-7-62                                 | -                                 | Compressive strength            |
| [12]       | Italy         | 0-20        | 0.6 | 3, 7 and 28          | 3-33                                   | 2-12                              | Compressive and flexural strengths |
| [24]       | China         | 0 and 30    | 0.43| 3, 7 and 28          | 46-65                                  | -                                 | Compressive strength            |
| [56]       | China         | 0-45        | 0.3-0.5| 7 and 28         | 18-65                                  | 4-12                              | Compressive and flexural strengths |
| [57]       | Croatia       | 0-15        | 0.5 | 3, 7 and 28          | 15-40                                  | -                                 | Compressive strength            |
| [58]       | China         | 0-30        | 0.74| 7 and 28             | 5-32                                   | -                                 | Compressive strength            |
| [59]       | Norway        | 0-35        | 0.5 | 1 and 28             | 14-47.5                                | 3.4-7.9                           | Compressive and flexural strengths |
| [60]       | China         | 0-30        | 0.5 | 3, 7 and 28          | 18-54                                  | 4-11                              | Compressive and flexural strengths |
| Current study | Iraq        | 0-20        | 0.5 | 1,3,7 and 28         | 13.6-45                                | 3.4-9.2                           | Compressive and flexural strengths |
| Remarks    | 8 countries   | Up to 45% of lime was used | Varied between 0.3 to 0.74 | Tested up to 28 days of curing | Varied between 3 to 65 MPa | Varied between 2 to 12 MPa | Compressive and flexural strengths are mainly used |
Evaluation the effect of lime on the plastic and hardened properties

Figure 1: Experimental program presentation of cement mortar modified lime (a) mixing, (b) setting time, (c) cube samples for strength tests (d) flexural test and (e) shape of failure

Cement mortar preparation (BS EN 196-1:2016)

After mixing the materials, the mortar filled cubic molds with a dimension of (4 x 4 x 16) cm. The mortar put into the mold in two layers and by applying to the mold 60 shocks each time using the shock device. After that, the mold was leveled and covered with a plastic bag and stored in the room temperature. After 24 h from the of the mixing procedure, the specimens removed from the mold and stored in water at 23°C ± 2°C and 95% of humidity until the time of the test. The samples were tested at 1, 3, 7 and 28 days for the compressive strength. Bending test machine is used to divide the specimen into two halves, and each part was subjected to the compressive strength using the compressive testing machine. The layout of the tested sample for flexural and compressive strengths are shown in Fig. 2.

Flowability (ASTM C1437)

The flowability of cement mortar was determined by using the flow table method as described in ASTM C1437. After mixing the cement mortar the mixing material was placed in the mold in two layers. Each layer was compacted 25 blows using the rod during the 15 sec. Additional lime content decreased the flowability of cement mortar.

Tensile Bonding strength (CIGMAT CT-3, modified ASTM C321)

Sandwiched samples were prepared to study the bonding strength according to CIGMAT CT-3 standard [29–31]. Different samples were prepared by using concrete brick. The bonding material was cement mortar and cement mortar modified with lime content up to 20%. The concrete brick was marked to ensure that the crossed concrete brick is placed in middle and at right the angle to each other. The second brick was placed on the mortar and the oriented correctly. The specimens were allowed to cure at room condition 25 ± 2 °C and 95% of humidity till the time of the test. Samples were tested by subjecting to tensile loading (Fig. 3). Stationary jaws held one brick while the other block was pushed by moving jaws creating a bond force on the bonding.

2.3 Data collection

In this study, more than 500 data were collected from the different research studies as summarized in Table 1 to characterize and evaluate the effect of lime content on the plastic properties such as consistency, flowability and setting times and hardened properties such as compressive, tensile bonding and flexural strengths of cement mortar.
Nonlinear relationships between the compressive strength, flowability, setting times and consistency with lime were performed using the Vipulanandan correlation model [32–54]. The model was proposed as follows:

\[ Y = Y_0 + \frac{X}{(A + B \cdot X)} \]  

where:

- \( Y \) = Cement mortar property (dependent variable, i.e. consistency, flowability and setting time, compressive strength)
- \( Y_0 \), A and B = model parameters (Table 6)
- X = cement mortar property (independent variables, i.e. lime content).

### Nonlinear model (NLM)

The compressive strength (\( \sigma_c \)) and flexural strength (\( \sigma_f \)) of cement mortar modified with lime (L) was influenced by the curing time (t) and water-to-cement ratio (w/c %) [35–38]. The effects L, t and w/c % of the cement mortar were separated as follows:

Compressive strength or flexural strength of cement mortar (L=0%):  

\[ \sigma_c \text{ or } \sigma_f = a(w/c)^b (t)^c \]  

Compressive strength or flexural strength of cement mortar modified with lime (L ≥ 0%):  

\[ \sigma_c \text{ or } \sigma_f = a(w/c)^b (t)^c + d(w/c)^e (t)^f (L)^g \]  

Based on experimental data and data collected from various research studied in the literature the model parameters (a, b, c, d, e, f, and g) were obtained from multiple regression analysis using the least square method (Table 7).
Table 6: Model parameters of plastic and hardened properties of cement mortar modified lime

| Depended Variable (Y-axis) | In depended Variable (X-axis) | Yo | A  | B  | RMSE | R²  | No. of Data | Fig. No. |
|----------------------------|-------------------------------|----|----|----|------|-----|-------------|----------|
| Consistency, C (%)        |                               | 24.4 | -3.51 | -0.545 | 0.07 % | 0.98   | 38          | 8(a)     |
| Initial setting time, t₁ (min) |                 | 165 | -0.33 | -0.005 | 2.44 min. | 0.97   | 43          | 8(b)     |
| Final setting time, t₂ (min) |                 | 209 | -0.70 | 0.000  | 1.23 min. | 0.98   | 38          | 8(c)     |
| Flow, F (%)                |                               | 108 | -0.96 | -0.05  | 0.24 % | 0.99   | 6           | 9        |
| Compressive strength (σc) for 1 day of curing | Lime, L (%) | 17.06 | -5.95 | 0.17 MPa | 0.99    | 17     | 10(a)       |
| Compressive strength (σc) for 3 days of curing | Lime, L (%) | 28.18 | -3.23 | 0.35 MPa | 0.97    | 15     | 10(b)       |
| Compressive strength (σc) for 7 days of curing | Lime, L (%) | 36.91 | -2.43 | 0.72 MPa | 0.92    | 12     | 10(c)       |
| Compressive strength (σc) for 28 days of curing | Lime, L (%) | 49.24 | -1.43 | 0.56 MPa | 0.98    | 15     | 10(d)       |
| Flexural strength (σf)     | Compressive strength (σc)    | 0.97 | 5.84  | 0.49 MPa | 0.93    | 24     | 13          |
| Bond strength (σb)         | Lime, L (%)                  | 1.2  | -8.95 | -1.05  | 0.01 MPa | 0.99   | 6           | 14       |

Table 7: Non-linear model (NLM) parameters for the compressive and flexural strengths of cement mortar modified with lime

| Effect of lime | w/c and t effect | a   | b   | c   | d   | e   | f   | g   | RMSE (MPa) | R²  | No. of data | Eq. No. | Fig. No |
|----------------|------------------|-----|-----|-----|-----|-----|-----|-----|-------------|-----|-------------|---------|---------|
| σc             |                  | 8.76| -1.22| 0.25| -0.27| -0.025| 0.15| 1.02| 2.68        | 0.88| 476         | 3       | 11      |
| σf             |                  | 3.47| -0.53| 0.20| -0.04| -0.250| 0.23| 0.86| 0.88        | 0.87| 69          | 4       | 12      |

3 Results and analyses

3.1 Statistical analysis

3.1.1 Water to cement ratio, (w/c)

Based on the total of 199 of water to cement (w/c) data for the cement mortar collected from the literature (Table 1), the w/c for the cement mortar varied between 0.3 to 0.74% with a mean of 0.47%, the standard deviation of 0.07% and the coefficient of variation (COV) of 17.63 % (Table 4). Almost 85 % of the total of w/c data was ranged between 0.44 and 0.52% (Fig. 4(b)).

3.1.2 Lime content, (L (%))

Based on the total 71 lime percent used to modify the cement mortar in the literature, the data varied from 3 % to 45% (by dry weight of cement) with the standard deviation of 11.5 % and the coefficient of variation (COV) of 58%. Almost 70 % of the total of lime content was ranged between 3 % and 20 % (Fig. 5).
474/ bar two
Warzer Qadir, Kawan Ghafor, and Ahmed Mohammed

Figure 4: Histogram of the water to cement ratio (w/c) for (a) cement mortar and (b) cement mortar modified with lime used in the literature

Figure 5: Histogram of percent of lime used in the literature

Figure 6: Statistical distribution of the compressive strength for (a) cement mortar and (b) cement mortar modified with lime up to 28 days of curing

3.2 Mechanical properties

Compressive strength
1. Cement mortar: A total of 318 compressive strengths ($\sigma_c$) data for the cement mortar collected from the literature (Table 1) the compressive strength ($\sigma_c$) of the cement mortar up to 28 days of curing ranged from 3 MPa to 65 MPa with a mean of 30 MPa, the standard deviation of 12 MPa and the coefficient of variation (COV) of 40% (Table 4). Different distribution tests for the compressive strength of cement mortar was performed. Based on the Anderson–Darling statistic (AD) and P value (hypothesis testing), Weibull frequency distribution for the compressive strength of cement mortar was observed as shown in Fig. 6(a).

2. Cement mortar modified with Lime: A total of 68 compressive strengths ($\sigma_c$) data for cement mortar modified with lime were collected from the literature (Table 1), the $\sigma_c$ ranged from 6.7 MPa to 65 MPa with a mean of 32.9 MPa, the standard deviation of 16.2 MPa and the coefficient of variation (COV) of 49.1% (Table 4). Based on the Anderson–Darling statistic (AD) and P value (hypothesis testing), the probability distribution was Weibull distribution as shown in Fig. 6(b).

3.3 Flexural strength

3. Cement mortar: Based on a total of 43 flexural strengths ($\sigma_f$) data for cement mortar up to 28 days
of curing were collected from the literature (Table 1), the flexural strength $\sigma_f$ varied from 2 MPa to 12 MPa with a mean of 7.2 MPa, the standard deviation of 2.58 MPa and the COV of 35% as summarized in Table 4. In this study, the statistical details and the histograms were performed for each flexural strength data set to identify the distribution. Different distribution tests for the $\sigma_f$ of cement mortar were performed. Based on the Anderson–Darling statistic (AD) and P value (hypothesis testing), Gamma frequency distribution for the flexural strength of cement mortar was selected (Fig. 7(a)).

4. **Cement mortar modified with Lime:** A total of 25 flexural strengths ($\sigma_f$) data for cement mortar modified with lime were collected from the literature (Table 1), the flexural strength varied from 4 MPa to 11 MPa with a mean of 7.1 MPa while the standard deviation was 1.78 MPa and the coefficient of variation (COV) of 25.3% as summarized in Table 4. Based on the Anderson–Darling statistic (AD) and P value (hypothesis testing), 3-parameter lognormal Distribution for the flexural strength of cement mortar modified with lime was selected (Fig. 7(b)).

### 3.4 Property correlation

#### Consistency

The consistency of cement decreased as the lime increased. Adding of lime content decreased consistency of cement. The consistency of cement with lime was predicted using Vipulanandan correlation model (Eq. 1). The model parameters, $R^2$ and RMSE are summarized in Table 6. Adding 20% of lime decreased the consistency of cement by 6% as shown in Fig. 8(a).

#### Setting times

Additional of lime accelerate the initial setting time and final setting time of cement. The variation of initial and final setting times of cement modified with lime was predicted using Vipulanandan correlation model (Eq. 1). The model parameters, the coefficient of determination ($R^2$) and root mean square error (RMSE) are summarized in Table 6. Additional of 20% of lime decreased the initial and final setting times by 27% and 16% respectively as shown in Fig. 8(b and c). The reduction could be because of that the lime acts as a nucleation matrix of C-S-H, and accelerates the hydration of cement. Due to the crystal core effect of lime, the hydration of Tricalcium silicates $C_3S$ accelerated at an early age [39].

#### Flowability

The flow table test was conducted to evaluate the effect of lime on the fluidity of cement mortar. The fluidity of cement decreased as the lime content increased. The variation of flow of cement mortar with lime was predicted using Vipulanandan correlation model (Eq. 1). The model parameters $Y_0$, $A$, $B$, $R^2$, and RMSE were $108$, $-0.96$, $-0.05$, $0.99$ and $0.24$ % respectively (Table 6). Additional of 20% of lime decreased the fluidity of cement mortar by 4% (Fig. 9). A reduction in the flow of cement mortar could be because of the lime disperses the cement particles more efficiently. The ability of lime is thus probably caused by lower reactivity than cement and less gel formation [40, 41].

#### Compressive strength

The lime decreased the compressive strength ($\sigma_c$) of cement mortar up to 28 days of curing. With the increase in the lime content, the $\sigma_c$ of cement mortar is nonlinearly decreased (Fig. 10). The variation of $\sigma_c$ versus dL was represented using Vipulanandan correlation model (Eq. 1). The model parameters, $R^2$, and RMSE are summarized in Table 6. Additional of 20% of lime decreased the compressive strength of cement mortar by 20% at 1 day of curing.
Additional of 16% of lime decreased the $\sigma_c$ of cement mortar by 20% at 3 days of curing. Additional of 12% of lime decreased the $\sigma_c$ of cement mortar by 19% at 28 days of curing (Fig. 10). Addition of lime decreased the compressive strength of cement mortar because of the fineness of the lime, the lime with large particle has a lower fineness than a small particle which cannot fill the void (filling effect) as a result the strength reduced. The reason lies in the reduction of hydraulically active clinker fraction of cement upon the lime replacement [15]. A multiple linear regression analysis was used to investigate the effect of lime on the compressive strength of cement mortar, the compressive strength ($\sigma_c$) was correlated to the independent variables such as w/c, curing time and lime using a non-linear relationship (Eq. 2(b)) as shown in Fig. 11. The model parameters were obtained from multiple regression analyses using the least square method (Table 7). Based on the non-linear model parameter ($d = -0.27$) in Eq. 3 the lime has the highest effect in decreasing the compressive strength of cement mortar compared to water to cement ratio and curing time.

$$
\sigma_c = 8.7 \times \left( \frac{t^{0.25}}{w/c^{1.22}} \right) - 0.27 \times \left( \frac{L^{0.15}}{w/c^{0.025}} \right)
$$

No. of data = 476, $R^2 = 0.88$ (3)

### Flexural strength

Nonlinear Regression Analysis was used to study the effect of lime on the bending strength (modulus of rupture) of cement mortar, the flexural strength ($\sigma_f$) was correlated to the independent variables such as w/c, curing time and lime content using a non-linear relationship (Eq. 2(c)) as shown in Fig. 12. The equation parameters were obtained from multiple regression analyses using the least square method (Table 7). Based on the non-linear model parameter ($d = -0.04$) in Eq. 4 the lime has also the highest effect in decreasing the flexural strength of cement mortar compared to water to cement ratio and curing time.

$$
\sigma_f = 3.47 \times \left( \frac{t^{0.20}}{w/c^{0.57}} \right) - 0.04 \times \left( \frac{L^{0.232}}{w/c^{0.86}} \right)
$$

No. of data = 69, $R^2 = 0.88$ (4)
Evaluation the effect of lime on the plastic and hardened properties

The Relationship between compressive strength ($\sigma_c$) and flexural strength ($\sigma_f$) of cement mortar modified with lime

Based on the total of 24 experimental cement mortar data modified with lime content. The variation of $\sigma_f$ and $\sigma_c$ was represented using the Vipulanandan correlation model (Eq. 1). The model parameters $Y_0$, $A$, $B$, the coefficient of determination ($R^2$) and root mean square error (RMSE) were 0.969, 5.84, 0.93 and 0.49 MPa respectively (Table 6). The flexural strength of cement mortar increased from 4 to 9 MPa when the compressive strength increased from 15 to 45 MPa for cement mortar (Fig. 13).

$$\sigma_f = 0.97 + \frac{\sigma_c}{5.84} \quad \text{No. of data} = 24, R^2 = 0.93 \quad (5)$$

Tensile bonding strength

The addition of lime decreased the bond strength ($\sigma_b$) of cement mortar at 7 days of curing. The variation of $\sigma_b$ and $L$ was represented using the Vipulanandan correlation model (Eq. 1). The model parameters $Y_0$, $A$, $B$, the coefficient of determination ($R^2$) and root mean square error (RMSE) were 1.2, −8.95, −1.05, 0.99 and 0.01 MPa respectively (Table 6). The bond strength of cement mortar without lime content was 1.2 MPa at 7 days of curing. Addition of 20% of lime content decreased the bond strength by 131% (Fig. 14). Different type and shape of failure were proposed by CIGMAT CT-3 as summarized in Table 5. The type...
of failure between the mortar and concrete bricks were type 2 failure based on CIGMAT CT-3 standard [29, 31] as shown in Fig. 15.

\[
\sigma_b = 1.2 - \frac{L}{(-8.95 - 1.05 \times L)} \quad \text{No. of data} = 6, R^2 = 0.99
\]  

(6)

4 Conclusions

The focus of this study was to investigate and quantify the effect of lime on the setting times, consistency, flowability and strengths properties of cement mortar. Based on experimental and collected data the following conclusions are advanced:

1. Additional of lime to cement mortar decreased the consistency, initial and final setting times of cement mortar by 5%, 27%, and 16% respectively.
2. Additional of 20% of lime as a replacement of cement in cement mortar reduced the flowability by 4%.
3. Based on the experimental data additional of 20% of lime decreased the compressive strength of cement mortar at 1, 3, 7 and 28 days of curing. Based on NLM the lime content had the highest effect on reducing the compressive strength of cement mortar compared with w/c and curing time.
4. Additional of 20% of lime reduced the bond strength of cement mortar by 138% at 7 days of curing.
5. The Compressive strength (CS) of the cement mortar modified with different percentage of lime was predicted well as a function of w/c, curing time, lime content. From the NLM parameter effect of curing time on the CS of cement mortar was much higher than the effect of w/c and lime content.
6. The CS and workability of cement mortar modified with different percentage of lime (up to 20%) was less than unmodified cement mortar by 8% and 25% respectively.

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