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# Prediction of Characteristic Compressive Strength of Masonry through Various Methods

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***Abstract:** In practice, the design of loadbearing walls and columns relies on the determination of the value of the characteristic compressive strength of the masonry ($f_k$) and the thickness of the unit required to support the design loads. This research paper attempts to congregate the obtainment of characteristic compressive strength of masonry determined through empirical and statistical approaches for a local data set of values obtained from experiments. It is seen that there is a delineation in finding the characteristic strength of specimen irrespective of the input value being unit or prism data. Two methods to determine the characteristic compressive strength values are discussed in this paper. Method-I adopts the masonry unit strength and mortar strength values to arrive at characteristic compressive strength of masonry. The present study attempted four approaches in this category wherein the four approaches have predicted consistent values for the four leading masonry materials. Method-II is adopted to evaluate the characteristic value of the same four leading masonry materials where the input variable can either be unit or prism strength value and two approaches were performed in this category. The values of characteristic compressive strength obtained through both methods show convergence respectively. The characteristic compressive strength of masonry plays an important role and is a significant parameter in limit state design philosophy of masonry.*

***Keywords:** characteristic compressive strength, masonry, prism strength, unit strength.*

## I. INTRODUCTION

The 12th five year plan has emphasized the need of housing for the ever-growing population in India. There is a great demand for mass housing required for both rural and urban sectors. The load bearing masonry construction is a step towards sustainability and an effective method for the construction industry which caters to the increasing issues associated with material prices, land prices, shortage of skilled workers, equipping low cost housing demands and maintaining the cost of the construction at an affordable price.

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The design criteria for load bearing masonry have some limitations in the present IS: 1905-1987 code. The permissible stress method has proved to be a simple and useful method but it does have some serious disadvantages as it is based on elastic stress, and it is not strictly applicable to plastic or semi-plastic materials such as masonry. Hence, there is a need to adopt more rational and flexible method of structural safety and serviceability which is sought as *'limit state'* and is probabilistically based. The work is aimed at achieving acceptable probabilities so that a structure or part of a structure would not reach a limit state when it would no longer fulfil the functions of its design. The limit state is regarded as structure which becomes unfit for its intended purpose when it reaches that particular condition. A limit state may be one of complete failure (ultimate limit state) or it may define a condition of excessive deflection or cracking (serviceability limit state). The advantage of this approach is that it permits the definition of direct criteria for strength and serviceability taking into account the uncertainties of loading, strength and structural analysis as well as questions such as the consequences of failure. Limit state design attempts to consider each item more closely so as to enable a more accurate factor of safety to be applied and depends upon the case being considered. This is achieved by breaking down the overall factor of safety used in the design into its various components, and then placing a specified factor called 'partial factor of safety' on that component for a given condition. The *characteristic strength of masonry* can be defined as the strength under which the test results fall within accepted probability.

A W Henry [1] defines the ultimate limit state of a particular structure, for failure to occur: $R^* - S^* \leq 0$, Where $R^* = (R_k/\gamma_m)$ is the design strength of the structure and $S^* = f\,(\gamma_t Q_k)$ is the design loading effects. Here $\gamma_m$ and $\gamma_t$ are the partial safety factors, $R_k$ and $Q_k$ are characteristic values of resistance and load actions, generally chosen such that 95% of samples representing $R_k$ will exceed this value and 95% of the applied forces will be less than $Q_k$.

The probability of failure is then: $P\,[R^* - S^* \leq 0] = p$. The *design strength of masonry* is obtained from the characteristic strength by dividing it by a material partial safety factor ($\gamma_m$).

This factor makes allowance for variation in quality of the materials employed and differences between the strengths of masonry constructed under site conditions and those built under laboratory conditions.

The leading international masonry codes relies on limit state design approach to masonry structures as against working stress method adopted by Indian masonry.

There is certainly adequate scope among researchers to employ limit state design approach to Indian masonry. In this pursuit, one has to consider the importance of the term characteristic strength which is coined based on statistical analysis and empirical relations.

## II. LITERATURE REVIEW

The approaches adopted by leading International masonry codes and researchers to arrive at characteristic strength value are discussed in this section.

The DR **AS 3700:2017**[2] defines characteristic value as the value of the material property that is exceeded by 95% of the material for strength properties. The clause 3.3.2 of the code states the characteristic compressive strength of masonry $f'_m$ shall be taken as $f'_m = k_h f'_{mb}$, where $f'_{mb} = k_m \sqrt{f'_{uc}}$, $f'_m$ is the characteristic compressive strength of masonry, $f'_{mb}$ is the characteristic compressive strength of masonry specimens for masonry units whose ratio of height to mortar bed joint thickness is 7.6, $k_m$ is the compressive strength factor (Table 3.1 of DR AS 3700:2017), $k_h$ is the joint thickness = 1.3 $(h_u/19t_j)^{0.29}$ but not to exceed 1.3, $f'_{uc}$ is the characteristic compressive strength of masonry units in mega pascals.The Appendix B of DR AS 3700:2017 covers a procedure for determining the characteristic value of a group of test results. If $n \geq 10, f' = k_k f_{ksp}$, where *n is* the number of test results in the set used to evaluate $f'$, $f'$ *is* a characteristic strength value for the type of masonry represented by the set of specimens, $k_k$ = a characteristic value factor used to assess a characteristic strength value of a population from a set of representative test results derived from Table B1of DR AS 3700:201, in which the coefficient of variation (*V*) is determined in accordance with paragraph B3, $f_{spl}$ = the least of the individual results in the set, $f_{ksp}$ = the (lower) 5th percentile value for the set of test results, measured or assessed from a relative cumulative frequency distribution of that test data.

The **NZS 4230:2004**[3] defines the characteristic or specified compressive strength, $f'_m$, as a singular value of strength normally at age of 28 days, which classifies masonry as to its strength class for purpose of design and consideration. The Appendix B of NZS 4230:2004 encompasses the details of determination of concrete masonry compressive strengths, $f'_m$, can be calculated from the strengths of grout and the masonry unit using the following equations, where $f_{cb}$ is the mean strength of concrete masonry unit, MPa, $f_g$ is the mean grout strength, MPa, $f_m$ is the mean masonry compressive strength , MPa, $f'_{cb}$ is the characteristic strength of masonry unit, MPa, $f'_g$ is the characteristic grout strength, MPa, $f'_m$ is the characteristic masonry compressive strength , MPa, $X_{cb}$ is the standard deviation of strength of concrete masonry unit, MPa, $X_g$ is the standard deviation of strength of grout, MPa, $X_m$ is the standard deviation of masonry strength, MPa, $\alpha$ is the maximum ratio of net area to gross area of masonry unit. The above equations presented were developed in correlation to predicting masonry compression strength as brought out by **Priestley and Chan** [4]. They proposed a simplified conservative relationship using compression strength of only masonry units and grout for design purpose. It was stated that the approach taken was followed based on the contributions of **Hilsdorf** [4,5] for brick/mortar prisms. The equilibrium of a stack-bonded prism of masonry units (clay bricks or concrete blocks) bonded with mortar beds were considered.

**Mohammad H Malek** [6] has brought out a method for calculating characteristic compressive strength of brick work masonry from small number of test results. In practice, only a small number of samples would be tested experimentally and assuming a normal distribution based on a small sample size would lead to unacceptable values for characteristic strength as the variation in strength of masonry is high. This tends to give rise to a high standard deviation of the sample. Also, the calculated mean based on a small sample would not represent the true mean. However, assuming lognormal distribution, provided when the number of test results is small, say a minimum of ten, it would be possible to calculate the characteristic value would be the closest that could be calculated compared to the actual true characteristic value if it was determined using normal distribution based on a much larger number of test samples. If the strengths obtained on *n* number of test specimens is $x_i$, for $i = 1$ *to* $n$, then , $X_k = X_m - K$. $where\ K = t_\alpha \left\{\frac{n+1}{n}\right\}^{0.5}$ , $X_k$ = characteristic strength of the sample, $S_d$ = standard deviation of the sample, $t_\alpha$ = Student's t with unilateral probability α % and (n-1) degrees of freedom. Using lognormal distribution, if, $y_i = \log(x_i)$, for i= *1 to n*, then calculating $Y_m$ and $S_y$ are computed using these equations, $Y_m = \left(\frac{1}{n}\right)\Sigma(Y_i)$ , $S_y = \left[\left(\frac{1}{n-1}\right)\left\{\Sigma y_i^2 - \frac{1}{n}(\Sigma y_i)^2\right\}\right]$ ^ 0.5, $Y_k = Y_m - K.S_y$, where *K* is a function of *n* and is obtained from student's t-distribution at 95% confidence level and $X_k = antilog(Y_k)$.

## III. CHARACTERISTIC COMPRESSIVE STRENGTH OF MASONRY

In this research paper, an attempt has been made to predict the characteristic compressive strength of masonry through the above discussed approaches.

The four leading masonry materials chosen are Table moulded bricks (TMB), Wire cut bricks (WCB), Solid Concrete blocks (SCB) and Hollow Concrete blocks (HCB). The results of these materials chosen are obtained from experiments. Also, the letter P attached with these acronyms stands for prism test data results.

The obtainment of characteristic compressive strength of masonry are categorized under two methods. Method-I adopts the masonry unit strength and mortar strength values to arrive at characteristic compressive strength of masonry. The present study attempted four approaches in this category. The details of the test results along with the equations adopted for each type of masonry material is presented as tables below. Method-II is adopted to evaluate the characteristic value of the same four leading masonry materials where the input variable is either unit or prism strength value and two approaches were performed in this category. The approaches that are considered for the present study are from the leading International masonry codes which advocates the limit state design philosophy and are discussed in the following sections.

**APPROACH - 1**

The equations of characteristic compressive strength of masonry as defined by clause 3.3.2 of DR AS 3700:2017[2] have been utilized to obtain $f'_m$ from the literature data of several research scholars. It is to be noted that the available test results are of M2 type mortar strength (CS 1:0:6) and in order to carry out the empirical computations and to induct the compressive strength factor, $K_m$, which is dependent on mortar type, an approximation is considered as M2 type of mortar being equalized to M3 type of mortar (CLS 1:1:6) of Table 11.1 of DR AS 3700:2017. Further, for calculating joint thickness factor, $K_h$, the height of masonry unit ($h_b$) has been taken as 75mm for TMB and WCB; 200mm for SCB and HCB and mortar joint thickness ($t_j$) is considered as 12mm**.** The computations are shown from table 1 to table 4.

**APPROACH – 2**

Attempts were made to evaluate the characteristic value of the property when a group of test results are available as listed in Appendix B of DR AS 3700:2017[2]. The results are tabulated in table 5**.**

**APPROACH – 3**

The equations developed by Priestley and Chai [4] which are inducted and modified in NZS 4230 – 2004, have been re-derived to suit the Indian masonry conditions which comprises the use of bricks, blocks and mortar. The mathematical derivation of these equations are presented as Appendix. The results obtained are presented in table 6.

**APPROACH – 4**

The calculations on obtaining characteristic compressive strength of brick work masonry from small number of test results as suggested M H Malek[6] were carried out using current available Student's t-distribution table to obtain K-value. The results are as shown in table 7.

**Table 1 - $f'_m$ values for TMB with M2 type mortar [2]**
($K_m$ = 1.40, $K_h$ = 0.9309)

| $f'_{uc}$ | $f'_{mb} = k_m\sqrt{f'_{uc}}$ | $f'_m = k_h f'_{mb}$ |
|---|---|---|
| 5.70 | 3.34 | 3.11 |
| 5.70 | 3.34 | 3.11 |
| 5.97 | 3.42 | 3.18 |
| 3.80 | 2.73 | 2.54 |
| 5.33 | 3.23 | 3.01 |
| 5.33 | 3.23 | 3.01 |
| 4.96 | 3.12 | 2.90 |
| 7.13 | 3.74 | 3.48 |
| 13.65 | 5.17 | 4.82 |
| 13.65 | 5.17 | 4.82 |
| 6.20 | 3.49 | 3.25 |
| 10.75 | 4.59 | 4.27 |
| 9.14 | 4.23 | 3.94 |
| 10.75 | 4.59 | 4.27 |
| 7.03 | 3.71 | 3.45 |
| 8.27 | 4.03 | 3.75 |
| 8.60 | 4.11 | 3.82 |
| 4.13 | 2.85 | 2.65 |
| 5.17 | 3.18 | 2.96 |
| 5.58 | 3.31 | 3.08 |
| 7.52 | 3.84 | 3.57 |
| 6.82 | 3.66 | 3.40 |
| 6.08 | 3.45 | 3.21 |
| 5.79 | 3.37 | 3.14 |
| 9.51 | 4.32 | 4.02 |
| | **Mean** | **3.47** |

**Table 2 - $f'_m$ values for WCB with M2 type mortar**
($K_m$ = 1.40, $K_h$ = 0.9309) [2]

| $f'_{uc}$ | $f'_{mb} = k_m\sqrt{f'_{uc}}$ | $f'_m = k_h f'_{mb}$ |
|---|---|---|
| 23.00 | 6.71 | 6.25 |
| 12.95 | 5.04 | 4.69 |
| 9.01 | 4.20 | 3.91 |
| 10.90 | 4.62 | 4.30 |
| 14.25 | 5.28 | 4.92 |
| 6.37 | 3.53 | 3.29 |
| 11.06 | 4.66 | 4.33 |
| 13.83 | 5.21 | 4.85 |
| 12.95 | 5.04 | 4.69 |
| 10.31 | 4.50 | 4.18 |
| 7.80 | 3.91 | 3.64 |
| 14.75 | 5.38 | 5.01 |
| 11.02 | 4.65 | 4.33 |
| 14.25 | 5.28 | 4.92 |
| 8.42 | 4.06 | 3.78 |

| | | |
|---|---|---|
| 12.99 | 5.05 | 4.70 |
| | **Mean** | **4.49** |

**Table 3 - $f'_m$ values for SCB with M2 type mortar**[2] ($K_m$ = 1.40, $K_h$ = 1.25)

| $f'_{uc}$ | $f'_{mb} = k_m\sqrt{f'_{uc}}$ | $f'_m = k_h f'_{mb}$ |
|---|---|---|
| 5.69 | 3.34 | 4.17 |
| 4.73 | 3.04 | 3.81 |
| 4.56 | 2.99 | 3.74 |
| 3.75 | 2.71 | 3.39 |
| 3.26 | 2.53 | 3.16 |
| 5.70 | 3.34 | 4.18 |
| 2.44 | 2.19 | 2.73 |
| 7.00 | 3.70 | 4.63 |
| 4.72 | 3.04 | 3.80 |
| 5.54 | 3.30 | 4.12 |
| 4.72 | 3.04 | 3.80 |
| 5.13 | 3.17 | 3.96 |
| 3.25 | 2.52 | 3.15 |
| | **Mean** | **3.74** |

**Table 4 - $f'_m$ values for HCB with M2 type mortar**[2]

($K_m$ = 1.60, $K_h$ = 1.25)

| $f'_{uc}$ | $f'_{mb} = k_m\sqrt{f'_{uc}}$ | $f'_m = k_h f'_{mb}$ |
|---|---|---|
| 6.08 | 3.95 | 4.93 |
| 6.08 | 3.95 | 4.93 |
| 6.60 | 4.11 | 5.14 |
| 6.60 | 4.11 | 5.14 |
| 5.95 | 3.90 | 4.88 |
| 8.59 | 4.69 | 5.86 |
| 7.02 | 4.24 | 5.30 |
| 8.09 | 4.55 | 5.69 |
| 6.94 | 4.22 | 5.27 |
| 6.44 | 4.06 | 5.08 |
| 8.59 | 4.69 | 5.86 |
| 8.09 | 4.55 | 5.69 |
| 9.08 | 4.82 | 6.03 |
| 8.75 | 4.73 | 5.92 |
| 8.42 | 4.64 | 5.80 |
| 8.17 | 4.57 | 5.72 |
| | **Mean** | **5.54** |

**Table 5 Results of *f'*[2]**

| Type of Material | $n$ | $f_{ksp} = f_{sp}\left(\frac{n+10}{20}\right)$ | $f_{sp}(1)$ | $f_{sp}(2)$ | $f_{ksp}$ Interpolating | $K_k$ (Table B1) | $f' = k_k f_{k}$ |
|---|---|---|---|---|---|---|---|
| **TMB** | 15 | $f_{sp}(1.25)$ | 4.13 | 5.17 | 4.39 | 0.89 | **3.89** |
| **TMBP** | 25 | $f_{sp}(1.75)$ | 0.84 | 0.9 | 0.86 | 0.91 | **0.78** |
| **WCB** | 15 | $f_{sp}(1.25)$ | 6.37 | 7.8 | 6.73 | 0.89 | **5.96** |
| **WCBP** | 25 | $f_{sp}(1.75)$ | 2.94 | 3.07 | 3.04 | 0.91 | **2.77** |
| **SCB** | 12 | $f_{sp}(1.10)$ | 2.44 | 3.25 | 2.52 | 0.87 | **2.20** |
| **SCBP** | 15 | $f_{sp}(1.25)$ | 2.66 | 2.66 | 2.66 | 0.89 | **2.35** |
| **HCB** | 12 | $f_{sp}(1.10)$ | 5.95 | 6.44 | 5.99 | 0.87 | **5.23** |
| **HCBP** | 20 | $f_{sp}(1.25)$ | 2.97 | 2.97 | 2.97 | 0.91 | **2.69** |

**Table 6 Results of $f'_m$[3]**

| Type of Material | $f'_{cb}$ | $f'_j$ | $f'_j/f'_{cb}$ | $f_m$ | $f_m$ | α | $X_{cb}$ | $X_m = \sqrt{0.35\alpha^2 X_{cb}^2}$ | $f'_m = f_m - 1.65X_m$ |
|---|---|---|---|---|---|---|---|---|---|
| **TMB** | 7.42 | 10.30 | 1.50 | $4.8(0.1f'_{cb} + 0.039f'_j)$ | 5.49 | 1.00 | 2.02 | 1.20 | **3.52** |
| **WCB** | 11.39 | 10.30 | 0.96 | $4.8(0.1f'_{cb} + 0.039f'_j)$ | 7.40 | 1.00 | 2.61 | 1.54 | **4.85** |
| **SCB** | 4.57 | 7.12 | 1.68 | $5.82(0.1f'_{cb} + 0.0146\,f'_j)$ | 3.26 | 1.00 | 1.25 | 0.74 | **2.04** |
| **HCB** | 7.84 | 7.12 | 1.10 | $3.82(0.1f'_{cb} + 0.0146\,f'_j)$ | 5.17 | 0.55 | 1.00 | 0.31 | **4.66** |

**Table 7 Results of $X_k$[6]**

| Type of Material | Sample size n | $t_\alpha$@95% | $K = t_\alpha\left\{\frac{n+1}{n}\right\}^{0.5}$ | $Y_m$ | $S_y$ | $Y_k = Y_m - K.S_y$ | $X_k = antilog\,(Y_k)$ |
|---|---|---|---|---|---|---|---|
| **TMB** | 15 | 2.145 | 2.22 | 0.85 | 0.12 | 0.59 | **3.86** |
| **TMBP** | 25 | 2.064 | 2.10 | 0.17 | 0.15 | -0.14 | **0.73** |
| **WCB** | 15 | 2.145 | 2.22 | 1.04 | 0.11 | 0.80 | **6.35** |
| **WCBP** | 25 | 2.064 | 2.10 | 0.59 | 0.07 | 0.45 | **2.79** |
| **SCB** | 12 | 2.201 | 2.29 | 0.64 | 0.13 | 0.35 | **2.26** |
| **SCBP** | 15 | 2.145 | 2.22 | 0.52 | 0.07 | 0.36 | **2.29** |
| **HCB** | 12 | 2.201 | 2.29 | 0.89 | 0.06 | 0.76 | **5.71** |
| **HCBP** | 20 | 2.093 | 2.14 | 0.54 | 0.04 | 0.46 | **2.89** |

**Table 8 Summary of results**

| Method I - Masonry Units + Mortar strength | | | | |
|---|---|---|---|---|
| Type of Material | DR AS 3700:2017 *(Clause 3.3.2)* | DR AS 3700:2017 *(Appendix B)* | NZS 4230:2004 *(Appendix B)* | Malek |
| *Characteristic strength* | $f'_m$ | $f'$ | $f'_m$ | $X_k$ |
| TMB | 3.47 | 3.89 | 3.52 | 3.86 |
| WCB | 4.49 | 5.64 | 4.85 | 6.35 |
| SCB | 3.74 | 2.20 | 2.04 | 2.26 |
| HCB | 5.54 | 5.23 | 4.66 | 5.71 |

| Method II - Masonry prisms + Mortar strength | | |
|---|---|---|
| Type of Material | DR AS 3700:2017 *(Appendix B)* | Malek |
| | $f'$ | $X_k$ |
| TMBP | 0.78 | 0.73 |
| WCBP | 2.77 | 2.79 |
| SCBP | 2.35 | 2.29 |
| HCBP | 2.69 | 2.89 |

## IV. RESULTS AND DISCUSSIONS

The characteristic compressive strength of masonry obtained through various approaches are summarized in table 8. It is seen that under the combinations of Masonry Units + Mortar strength and Masonry prisms + Mortar strength, the characteristic strength values are almost equal to each other. Further, it is to note that when the characteristic strength value is obtained through statistical approach, the procedure is more stringent as the co-efficient of variation is well accommodated.

## V. CONCLUSIONS

The characteristic compressive strength of masonry can be obtained by two methods, viz, when the parameters are masonry units with mortar and prism strength with mortar. The approach involving the use of masonry unit compressive strength and mortar have been predominately advocated by the leading international masonry codes.

A similar attempt extended to the data set values of typical south Indian masonry has shown that the characteristic strength values obtained through the four approaches are almost in the same range as seen in table 8 of method I (masonry unit + mortar) where the methods are based on both empirical and statistical approaches. The four approaches under method – I for the four leading masonry materials have predicted the characteristic compressive strength values consistently. For TMB, it ranges between 3.47 – 3.86, for WCB it is between 4.49 – 6.35, for SCB it lies between 2.04 – 3.74 and for HCB it ranges from 4.66 to 5.71. It can be seen that the predicted characteristic compressive strength values are very close.

The comparison between the results found from two approaches as discussed in table 8 of method – II which do not account the geometry of the specimen (masonry prism + mortar) for evaluating the characteristic strength value (statistical based) shows convergence.

### *Appendix* – APPROACH – 3

**Deducing the characteristic strength equations for TMB and WCB**

The axial failure stress of a prism made of masonry unit and mortar yields the following equation (1), where the axial and transverse stresses are uniform across the section [4].

$$f_y = \frac{f'_{cb}}{U_u}\left[\frac{(f'_{tb} + \alpha f'_j)}{(f'_{tb} + \alpha f'_{cb})}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq(1)$$

The average prism stress can be estimated as $f'_m = X.f_y \ldots\ldots\ldots\ldots Eq(2)$

Now, substituting for $f_y$ in Eq (2), $U_u = 1.5$ and also taking $X = 1.00$ (as there are no voids), we get

$$f'_m = \frac{f'_{cb}}{1.5}\left[\frac{(f'_{tb} + \alpha f'_j)}{(f'_{tb} + \alpha f'_{cb})}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . Eq(3)$$

Considering typical values for the parameters, as mortar bed thickness as 12 mm and height of the masonry unit as 75 mm for TMB and WCB,

$\alpha = \frac{j}{4.1\,h} = \frac{12}{4.1(75)} = 0.039$ and $f'_j = 1.5\, f'_{cb}$ *(from experimental data)*

Substituting these values in equation 3.3, we get

$$f'_m = \frac{f'_{cb}}{1.5}\left[\frac{(f'_{tb} + 0.0585 f'_{cb})}{(f'_{tb} + 0.039 f'_{cb})}\right]$$

Solving further mathematically, we get

$$f'_m = \frac{f'_{cb}}{1.5}\left[\frac{\left(\frac{f'_{tb}}{f'_{cb}} + 0.0585\right)}{\left(\frac{f'_{tb}}{f'_{cb}} + 0.039\right)}\right]$$

It has been stated that masonry tensile strength will be in the range of $0.05 \le \frac{f'_{tb}}{f'_{cb}} \le 0.2$. It is reasonable to adopt an average value of $\frac{f'_{tb}}{f'_{cb}} = 0.1$ and ignoring $f'_{tb}$ as a variable. Solving the above equation will yield as follows:

$$f'_m = \frac{f'_{cb}}{1.5}\left[\frac{(0.1+0.0585)}{(0.1+0.039)}\right] = 0.76\, f'_{cb}$$

Again considering equation 3 and solving it step-wise further, we get

$$f'_m = \frac{f'_{cb}}{1.5}\left[\frac{\left(\frac{f'_{tb}}{f'_{cb}} + \alpha\frac{f'_j}{f'_{cb}}\right)}{\left(\frac{f'_{tb}}{f'_{cb}} + \alpha\frac{f'_{cb}}{f'_{cb}}\right)}\right]$$

$$f'_m = \frac{f'_{cb}}{1.5}\left[\frac{\left(0.1 + \alpha\frac{f'_j}{f'_{cb}}\right)}{(0.1 + \alpha)}\right]$$

$$f'_m = \frac{1}{1.5}\left[\frac{(0.1 f'_{cb} + 0.039 f'_j)}{(0.139)}\right]$$

$$\boldsymbol{f'_m = 4.8(0.1 f'_{cb} + 0.039 f'_j)} \ldots\ldots\ldots\ldots\ldots . Eq(4)$$

**Deducing the characteristic strength equations for HCB and SCB**

Re-writing Eq(3), with X = 0.55 for HCB, Considering typical values for the parameters, as mortar bed thickness as 12 mm and height of the masonry unit as 200 mm for SCB and HCB,

$\alpha = \frac{j}{4.1\,h} = \frac{12}{4.1(200)} = 0.0146$, $f'_j = 1.7\, f'_{cb}$ (SCB), $f'_j = 1.1\, f'_{cb}$ (HCB)

Solving similarly, we get

$$\boldsymbol{f'_m = 5.8(0.1 f'_{cb} + 0.0146\, f'_j)} \ldots\ldots\ldots\ldots\ldots . Eq(5)$$ for SCB, and

$$\boldsymbol{f'_m = 3.2(0.1 f'_{cb} + 0.0146\, f'_j)} \ldots\ldots\ldots\ldots\ldots . Eq(6)$$ for HCB.

The equations 4, 5 and 6 are the obtained expressions for computing mean masonry compressive strength, $\boldsymbol{f_m}$. Although Priestley and Chai termed the expression as $\boldsymbol{f'_m}$ as the design strength value, the recent updated NZS 4230:2004[3] uses the expression as mean masonry compressive strength $\boldsymbol{f_m}$ and provides a statistical formula to compute $\boldsymbol{f'_m}$.

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## AUTHORS PROFILE

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