Analyzing Parameters Affecting Strength of Concrete (A study on the high strength concrete mix)

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Abstract

Development in concrete technology has resulted in concrete strength as high as 120Mpa being used in civil engineering structures. Concrete is one of the most widely used construction material in Bhutan ever since the 1970's. However, there is no precedence on the production and the use of such high grade concrete in our construction industry. The most common grade used is M20 (20Mpa -28day strength) with the occasional higher grade concrete used in few projects.

This project aims to study the various factors that affect the strength of concrete and identify the key parameters required for the production of high grade concrete. The focus of the project is on improving the strength without compromising on the workability of concrete. The relationship between the various parameters and its bearing on the strength of concrete is analyzed. A maximum compressive strength of 40Mpa (28day) was achieved during the study. A comparative study on the properties and stress strain behavior is made. The moment resisting capacity of a RC member with M20 and M40 grade is analyzed.

Keywords : *high strength concrete, compressive strength, workability, stress strain behavior, moment capacity.*

1. INTRODUCTION

The history of high strength concrete dates Contradictory conclusions have been back to 35 years and now the use of high discovered from our literature study on the strength concrete is a very common practice impact of aggregate size on the strength of worldwide. The Burj Khalifa (828m) in Dubai concrete. According to the test conducted by is the epitome of not only the strength but also Okonkwo & Arinze (2015), 20mm size of the height and the architectural grandeur aggregate produce higher strength compared to possible with concrete. 25mm, 12mm and 6mm aggregate. However,

Day, Aldred, & Hudson(2013) state that Recent development in concrete technology smaller size aggregate gives higher strength to has resulted in production of concrete with concrete. compressive strength as high as 120Mpa (Neville 2009). In Bhutan, however, there is Thus, tests were conducted to assess the not much precedence on the use of such impact of aggregate size grading on the concrete. strength. The mix ratio that yielded the best result is then used to study the impact of other There are various factors that influence the parameters. quality and grade of concrete. The strength of concrete depends on factors such as water 2. LITERATURE REVIEW cement ratio, aggregate size and shape, fine and coarse aggregate ratio, curing method and The definition of high strength concrete defers duration, temperature etc. (Gambhir M. L., from country to country. The IS 456 (2000) 2013). Aggregate is one of the important classifies concrete into ordinary, standard and constituents which affect the strength of high strength as follows. concrete.

Ordinary : M10-M20 (N/mm2)
Standard : M25-M55 (N/mm2)
High strength : M60-M80 (N/mm2)

The strength of the concrete is highly affected by the type and size of aggregate. Various effects of aggregate were studied and among them Okonkwo & Arinze (2015),concluded that flaky or elongated aggregates are not desirable since they create larger percentage of voids which in turn requires larger amount of fine materials.

The use of crusher dust as fine aggregate improves the workability of the concrete. Nagabhushana& Bai (2011), concluded that concrete produced using crusher dust as a complete replacement of sand showed an increase in compressive strength of concrete by 5.08%, 4.56% and 3.78% respectively for M20, M30 and M40 grade of concrete.

3. MATERIALS AND METHODS

The materials used for the study include Ordinary Portland Cement (OPC 43) manufactured by Dragon cement, coarse aggregate (CA), fine aggregate (FA) and water. The aggregates used were of sizes 20mm and 10mm. The fine aggregate used was crusher dust from Lhapel Crusher Ltd. The crusher dust was classified under Zone II as per IS 383: 1970.

Tests to determine the specific gravity, water absorption, shape, particle size distribution and crushing strength as per the Indian Standard for coarse aggregate are conducted. Likewise test are also conducted for fine aggregate.

To determine the best coarse aggregate (CA) size gradation, initial trial samples of mix proportion of ratio 1:1:2 and water cement ratio 0.45 are prepared. The entire tests were conducted for 7day strength due to time limitation. The mix ratio and the water cement ratio were kept constant throughout the test. A total of three samples were made each for a ratio (CA-20mm:10mm) of 0:100, 20:80, 30:70, 40:60, 50:50, 60:40, 70:30, 75:25, 80:20 and 100:0.

The mix which gave the best result was then used to study the impact of water cement ratio on the strength of the concrete. The idea was to find the maximum strength that can be achieved without the use of any admixture. A numerical analysis of sectional capacity with members of normal and higher grade concrete was also carried out as per IS 456:2000.

Finally, equations of the ascending and descending zone for various grades of concrete were generated using the stress-strain curve which can be used to determine the strain level in various grades of concrete.

4. RESULTS AND DISCUSSIONS

4.1. Specific gravity and water absorption test result

The results obtained for coarse and fine aggregate is given in Table 1.

Table 1: Specific gravity and water absorption test result.

Particulars	Specific Gravity	Water absorption (%)
Coarse aggregate (20mm)	2.97	0.28
Coarse aggregate (10mm)	2.66	0.38
Crusher Dust	2.72	1.83

The results show that the specific gravity of the coarse aggregate and fine aggregate both falls within the range of acceptable value for specific gravity which is 2.6 -2.9.

4.2. Compressive Strength Test Result

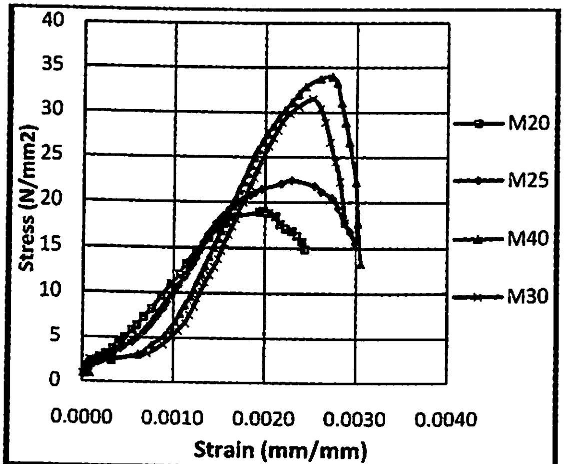

Figure 1: Stress strain curve for M20, M25, M30 and M40 using crusher dust

The ascending slope of the normal gradeconcrete is gentler than that of the higher grade concrete. The higher grade of concrete has a steeper descending slope compared to normalgrade. The maximum 7 day stress obtained for different curves were 34MPa, 31.51MPa, 22.4MPa and 18.89MPa which is expected togive strength of 52.31MPa, 48.47MPa, 34.46MPa and 29.06MPa in 28 days.

4.3. Result for different proportion of aggregate

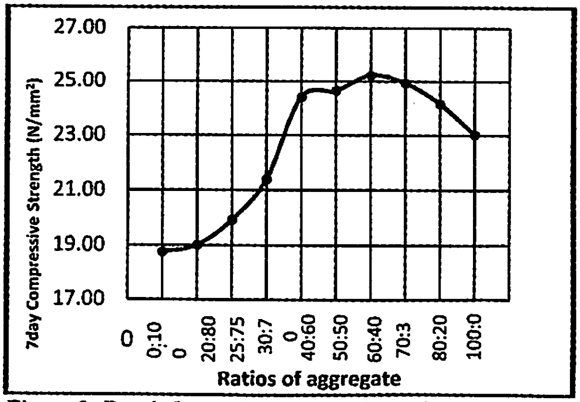

Figure 2: Result for various proportions of aggregate

Sample having aggregate ratio of 60% of 10mm aggregate and 40% of 20 mm aggregate gave the highest strength of 25.23MPa. It can be concluded that there is an optimum ratio of smaller and bigger size aggregate to produce the best strength for a given mix and w/c ratio. Smaller size aggregate in the mix provide more surface area for bonding with the mortar.

4.4. Result of different water-cement ratio

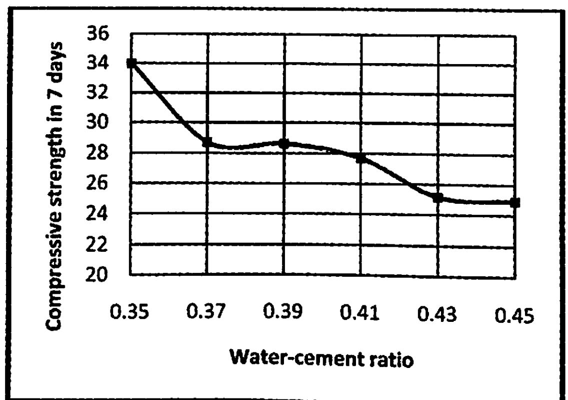

Figure 3: Compressive strength for different w/c ratio

The above graph indicates that the compressive strength of fully compacted concrete is inversely proportional to the watercement ratio i.e., higher the w/c ratio, lower is the strength of concrete. The highest 7 day strength obtained was 34MPa with a w/c ratio of 0.35 while the lowest was 24.92MPa for water-cement ratio of 0.45.

4.5. Compaction factor test result

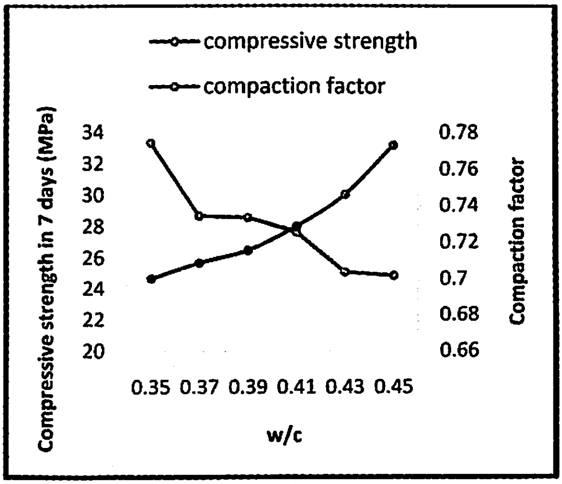

Figure 4: Compaction factor test result

Compaction factor test to investigate the workability of the mixes were conducted. It is observed that the increase in the compressive strength of concrete is marked by a huge drop in compaction factor value. The mix which resulted in the maximum strength has a compaction factor of 0.77, less than the generally accepted limit for concrete to be workable (BS 1881 Part-103).

4.6. Mathematical Model for Stress-Strain Curves

Empirical equations for the stress-strain response of different grade of concrete have been proposed in the form of Y =A ln(x) +B, where Y = load (F) / area (A) and x = change in length (□l) / original length (l). The empirical formula is valid for both ascending and descending portion of curve with different values of constants. The proposed empirical equations can be used to determine the corresponding value of strain for given stress (fck). The proposed equations have shown good correlation with experimental values.

Table 2: Constants used for the equation

Concrete grade	Constant for ascending curve	constant for descending curve
M40	A=26.27; B=189.03	A'=-129.8; B'=- 731.31
M30	A=33.285; B=231.67	A'=-103.2; B'=- 584.16
M25	A=17.149; B=128.93	A'=-19.64; B'=- 97.127
M20	A=11.247; B=89.587	A'=-18.95; B'=- 98.594

Table 3: Equation of the ascending and descending curves

Concrete grade	Equation for ascending curve	Equation for descending curve
M40	$y = 26.27\ln(x) + 189.03$	$y = -129.8\ln(x) - 731.31$
M30	$y = 33.285\ln(x) + 231.67$	$y = -103.2\ln(x) - 584.16$
M25	$y = 17.149\ln(x) + 128.93$	$y = -19.64\ln(x) - 97.127$
M20	$y = 11.247\ln(x) + 89.587$	$y = -18.95\ln(x) - 98.594$

4.7.Comparison of moment resisting capacity of normal and high grade concrete

Comparison of moment capacity for normal grade and higher grade of concrete was done according to IS 456:2000 and the result is as shown in Table 4.

Table 4: Comparison of normal and higher grade concrete according to IS 456:2000

M25	M40
fck = 25 N/mm^2 **fy = 415 N/mm^2**	**fck = 40 N/mm^2** **fy = 415 N/mm^2**
$\varepsilon u = \frac{0.876 X 415}{2 X 10^5} +$ $0.002 =$ **0.0038** $\frac{x_{ulim}}{d} = \frac{.0035}{.0035+\varepsilon_{su}} =$ **0.48** $\frac{x_u}{d} = \frac{0.87 f_y A_{st}}{0.36 f_{ck} bd} =$ **0.47<0.48** (ok)	$\varepsilon u = \frac{0.876 X 415}{2 X 10^5} +$ $0.002 =$ **0.0038** $\frac{x_{ulim}}{d} =$ **0.48** $\frac{x_u}{d} = \frac{0.87 f_y A_{st}}{0.36 f_{ck} bd} =$ **0.38<0.48** (ok)
$P_{t\ lim} = \frac{0.36 f_{ck}}{0.87 f_y} . \frac{x_u}{d} . 100$ $= \frac{0.36 X 25}{0.87 X 415} 0.48 X 100$ = **1.196%**	$P_{t\ lim} = \frac{0.36 f_{ck}}{0.87 f_y} . \frac{x_u}{d} . 100$ $= \frac{0.36 X 40}{0.87 X 415} 0.48 X 100$ = **1.91%**
Area of steel provided (25 mm dia) = 1472.6 mm^2	**Area of steel provided (25 mm dia) = 1472.6 mm^2**
$P_{t\ provided} = \frac{1472.6}{d\ 254 X 381} X$ $100 = 1.52 \% > P_{t\ lim}$ Therefore, provide P_t = **1.196%**	$P_{t\ provided} = \frac{1472.6}{d\ 254 X 381}$ $X\ 100 = 1.52 \% < P_{t\ lim}$ Therefore, provide P_t = **1.52%**
Ast = $\frac{1.196}{100}$ X254 X 381 = **1157.4mm^2** Using 3-20 mm dia and 1-16 mm dia **Provide Ast = 1143.5 mm^2** Therefore $P_{t\ provided}$ $= \frac{1143.5}{254 X 381} X 100 =$ **1.18%**	Ast = $\frac{1.52}{100}$ X254 X 381 = **1470.96mm^2** Using 3-20 mm dia and 1-25 mm dia **Ast provided = 1433.35 mm^2** Therefore $P_{t\ provided}$ $= \frac{1433.35}{254 X 381} X 100 =$ **1.48%**
Mu (concrete) = 0.36 $f_{ck} b\ d^2 (1-0.42 \frac{x_u}{d}) \frac{x_u}{d}$ =0.36 X 25 X 254 X 381^2 (1- 0.42 X 0.48)x0.48 **<u>=127.17KNm</u>**	**Mu (concrete) =** 0.36 $f_{ck} b\ d^2 (1-0.42 \frac{x_u}{d}) \frac{x_u}{d}$ =0.36 X 40 X 254 X 381^2 (1- 0.42 X 0.48)x0.48 **<u>=203.47KNm</u>**
M_u (steel) = 0.87 $f_y \frac{P_t}{100} bd^2 (1- \frac{P_t}{100} \frac{f_y}{f_{ck}})$ = 0.87 X 415 X 0.01196 X 254 X 381^2 (0.01196 X$\frac{415}{25}$) **<u>=126.3 KNm</u>**	M_u (steel) = 0.87 $f_y \frac{P_t}{100} bd^2 (1- \frac{P_t}{100} \frac{f_y}{f_{ck}})$ = 0.87 X 415 X 0.0148 X 254 X 381^2 (1-0.0148X$\frac{415}{40}$) **<u>=197.02 KNm</u>**

5. CONCLUSION

The test showed that the (40:60) ratio of 20mm and 10mm CA yields the best result for a mix of constant w/c ratio.

Grades of concrete higher than M40 (28day) were obtained in the lab environment without the use of admixture. However the compaction factor for such mixes was well below recommended workable range of 0.8-0.92. Water-cement ratio as low as 0.35 is used but this mix might not be able to be used at the site where the placing is done manually due to low workability. The use of sophisticated machines will also not be able to pump the dry mix because of possible segregation inside the pump hose.

The workability of the concrete is greatly compromised in the attempt to increase its compressive strength. Thus, the use of admixtures becomes indispensable for the production of concrete beyond certain grade.

The use of high grade concrete also increases the moment resisting capacity for the cross section of same geometrical dimension as that of a lower grade concrete section.

6. RECOMMENDATION

The relation between the w/c demand and the varying CA grading (ratio of smaller and bigger size) could not be studied and future studies could be conducted to investigate the relation and its bearing on concrete strength.

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