Journal of Engineering and Development, Vol. 14, No. 2, June (2010) **ISSN 1813-7822**

Site Control Mean To Predict Compressive Strength Of Low Cost Concrete Works

Zainab Tariq Hadad
MS.c Building and Construction Engineering
University of Technology Baghdad

Abstract:

Concrete works occupy considerable total cost portion of construction projects. There are several factors influencing its quality, strength, and performance. Lack of quality control has been pointed out in private sector projects in general, and specifically with low income owners. Technical skills and extra cost required to control the quality of concrete are the most important factors that discouraged owners in adopting control measures, therefore, research work is implemented to determine easy, quick, and low cost measures to evaluate fresh concrete and predict its (28 day) compressive strength, also help site engineers in adjusting fresh concrete according to required standard before casting and hardening. The research covered an experimental work that includes, casting of 144 concrete cylinders having 48 different mixes of cement content, water content, and maximum size of coarse aggregate. Laboratory tests of the concrete cylinders have been carried out to determine its compressive strength, and statistical analysis of the experimental data and results led to propose an empirical formula. The proposed formula can be used by site engineers to judge the quality of concrete after wet sieving of fresh concrete.nThe research recommended the adoption of the concluded results, and to carry out further related researches.

***Key words:** concrete works; fresh concrete; field inspection; private low income owners; compressive strength.*

الخلاصـــــــــة:

تحتل الاعمال الخرسانية جزءا مهما من الكلفة الكلية للمشاريع الأنشائية .هنالك عوامل عديدة تؤثر على كفاءة ومتانة ونوعية مثل هذه الاعمال الخرسانية . يوجد نقص وضعف في اجراءات السيطرة النوعية على تنفيذ هذه الاعمال في مشاريع القطاع الخاص بشكل عام وتحديدا لدى ارباب العمل ذوي الدخل المحدود . ان المهارة اللازمة وتكاليف اجراء عمليات السيطرة هي من اهم الاسباب التي لا تشجع ارباب العمل على تبني اجراءات السيطرة لذلك تم البحث عن وسيلة سريعة وسهلة ورخيصة الكلفة لاختبار وتقييم الخرسانة الطرية والتنبؤ بمقاومة الانضغاط لها بعمر 28 يوم. ان هذه الوسيلة يجب ان تمكن مهندس الموقع من معالجة الخلطة الطرية وفقا للمواصفة المطلوبة قبل صب وتصلب الخرسانة. شمل البحث في جانبه العملي اعداد (144) اسطوانة من الخرسانة تضم (48) نوع مختلف من الخلطات يختلف فيها محتوى كل من الماء والسمنت اضافة الى اختلاف المقاس الاقصى للركام الخشن . تم اجراء الفحص المختبري لايجاد مقاومة الانضغاط للنماذج كذلك اجراء التحليل الاحصائي للنتائج حيث تمخض ذلك على اقتراح معادلة تجريبية .ان هذه المعادلة يمكن استخدامها من قبل مهندس الموقع للحكم على نوعية وصلاحية الخرسانة الطرية بعد اجراء التحليل المنخلي الرطب لها في الموقع. تم التوصل الى عدد من الاستنتاجات ذات الصلة بموضوع البحث كذلك تم اقتراح توصيات لتبني نتائج البحث اضافة الى اقتراح بحوث لاحقة في هذا المجال .

1. INTRODUCTION

Concrete is generally produced in batches at work site with local available materials of variable characteristics. It is therefore, likely to be variable from one batch to another. The magnitude of such variation depends upon several factors, such as the quality of constituent materials, mix proportion due to batching process, mixing equipment, workmanship and supervision.

There are no unique attributes to define the quality of concrete in its entirety. Under such facts, concrete is generally referred to as being of good, fair or poor quality. Due to the large number of variables that influence the performance of concrete, quality control is an essential task.

The aim of quality control is to reduce variations and produce uniform material that provides the desired characteristics for the job.

2. PROPERTIES OF CONCRETE

The principal properties of concrete which are of practical importance are those concerning its strength.

The strength of concrete at given age and under given curing conditions is assumed to depend mainly on water-cement ratio and degree of compaction. of the various strengths of concrete, the determination of compressive strength has received large amount of attention because concrete is primarily meant to withstand compressive stresses.

Factors independent of the type of test that influence the strength of concrete are: type of cement, type of aggregate and admixtures, mix proportions, cement content, aggregate cement ratio, water cement ratio, and other factors like, age, degree of compaction, type and temperature of curing.[1]

3. INSPECTION AND TESTING

Inspection and testing play vital role in the overall quality control plan. Inspection could be of two types: quality control and acceptance inspection.

Concrete materials can be tested and inspected both in the fresh and hardened stages. Fresh concrete tests offer some opportunity for necessary corrective actions to be taken before it is too late. These actions include tests on workability, unit weight, or air content.

Accelerated strength tests by which reliable idea about the potential 28-day strength can be obtained within few hours. In contrast, the usual 28-day

Strength test is post mortem of concrete which has become history by then. It is, therefore, only acceptance tests which help designer or site engineer decide whether to accept or reject the concrete.[2]

4. REVIEW OF PREVIOUS RESEARCHES

Due to the importance of adjusting concrete mix before casting and hardening , researchers studied and suggested different methods for accelerated strength testing to predict 28-day strength of concrete whether it is from saving ,cost, time and assure quality point of view.

- Malhotra [3] implemented a study in 1994 and found that there is a significant relation between accelerated cured samples and 28-day standard cured strength. The predicted values vary plus or minus 15.2 to 23.6% from 28 day standard cured strength. The relations were independent of the aggregate used but depend at low strength level on w/c ratio of the concrete mix
- Meyer [4] conducted a research in 1997 using statistical comparison of accelerated concrete test method .His research depend on ACI (1987) Manual of Concrete Practice that suggests tow procedures which can be used to provide an indication of the 28-day strength of concrete after 24 hours. The first procedures is to cure concrete specimens in warm water, 23-24 hours at 35c° ± 3c°, the second is to cure the specimens in boiling water for 23 hours at 21c° ± 5c° and 3.5 hours at 100c°.Research results indicated that warm water curing is preferable to the hot water and suggested that dynamic model which permits changes in the regression parameters over time is more appropriate .
- Resheidat and Ghanma [5] carried out a research in 1998 using boiling water for accelerated test in to predict 28-day strength of concrete. The test procedure followed procedure of ASTM C(684).The outcome of this research in the form of prediction models confirm that accelerated strength testing could be accepted in lieu of the standard 28-day testing
- ASTM C(684-99) [6] covers four procedures for accelerated curing which are: A- Warm Water Method B- Boiling Water Method C- Autogenous Curing Method D- High Temperature and Pressure Method. Curing period ranging from 5-49 hours depending upon the procedure that is used. The variability of the test methods is the same or less than that from traditional methods. The results can be used in rapid assessment of the concrete quality and signalling the need for indicated adjustments. The magnitude of the strength values is influenced by the specific combination of materials of concrete mix.
- Resheidat and Madanat [7]carried out are search in 2006 using boiling water to cure cylinders of concrete and tested at 28.5h,and other cylinders were normally cured

and tested at 28days.The outcome of his statistical analysis confirm that accelerated strength testing con do everything the 28-day test can do but 27 days sooner.

- Tantawi and Gharaibeh [8] indicated in their research titled "Early Estimate Of Hardened Concrete Strength" carried out in 2006 that the importance of time and its direct impact on project cost inessential need is required to estimate the hardened concrete strength with in the first few hours. Accelerated test for early determination of concrete strength were used to generate expressions for prediction of hardened concrete strength as composite function of cement content and w/c ratio. The outcome suggested theoretical model shows a good agreement with experimental results.

5. INSPECTING FRESH CONCRETE

In order to reduce the time required between mixing and placement of concrete, and the determination of its quality and strength, it is necessary to carry out two types of tests on concrete. The first type of the mentioned tests is inspecting and testing fresh concrete, and the second is the acceptance testing of hardened concrete.

The inspection testing of fresh concrete includes workability tests, analysis of fresh concrete, accelerated and non destructive testing of fresh concrete. The field variations in the actual mix proportion of concrete can be determined by analyzing the composition of fresh concrete. The quality of concrete could be controlled if rapid analysis of fresh concrete is possible allowing the site engineer to take the necessary remedial measures if required before placing the concrete.

Cement and water contents of concrete could be determined by separating the constituents of fresh concrete by wet sieving according to ASTM C172-99 , and its proportions by weighing in water. There are many other rapid methods for determining the cement and other contents of fresh concrete sample.[9]

6. RSEARCH SIGNIFICANCE

There is lack and ignorance in quality control measures for concrete works that carried out by unprofessional private contractors or unskilled labor employed by private owners.

Owners and their supervisors have no means to ensure in advance that fresh concrete will provide the required strength for the type, life, and function of structures.

The existing production practices of fresh concrete for the mentioned works are:

a) No insurance or quality certificate that should be provided by concrete or material suppliers to users for their purchased quantities.

- **b)** Concrete material is usually mixed and handled by unskilled labor following non standard practices.
- **c)** Standard tests and other quality control measures at work sites require experienced staff, equipment, and extra cost. Owners do not accept spending extra cost because it is difficult for them to understand its importance and the amount of benefit which they can get from investing such extra cost.
- **d)** There are annual and continuous works constructed by private owners. Concrete works represent considerable portion of the constructed works cost, and significant portion of the overall construction sector activities in Iraq.

The significance of research dealing with such problems can be judged by the gain that will come out from introducing easy, and low cost means to encourage private owners in controlling the quality of their concrete works. The gain may be expressed by the increase of useful life, and the decrease in the depreciation cost of their investments.

7. RESEARCH OBJECTIVE

The objective is to develop easy, quick, and low cost means to control the quality of fresh concrete at work sites of private owners.

8. RESEARCH PLAN

The research plan is based on the following fields and steps which are:

- **a)** Theoretical review of subjects related to quality control, test, inspection, and major factors affecting the strength of concrete.
- **b)** Field work including the preparation of concrete test samples having different cement and water content. The aggregate is the normally type and size of aggregate used in construction works targeted by the aim of this research.
- **c)** Test samples should be cured and tested to get their 28-day compressive strength.
- **d)** Analysis of test results should be done to extract mathematical or empirical model for predicting(28-day)strength of fresh concrete.

The model should help site engineers in taking the right action to adjust fresh concrete to be in accordance with the required quality before casting and hardening.

9. SCOPE AND LIMITS

The scope and limits regarding types of materials used, mixing, and testing of concrete samples for this research is:

- **a)** Iraqi ordinary Portland cement according to the Iraqi standard specification No (5).
- **b)** Coarse and fine aggregate according to the Iraqi standard specification No (45). The maximum size of aggregate is (10 - 20) mm.
- **c)** Potable drinking water should be used in mixing and curing of concrete.

d) Curing of concrete samples should be under field conditions according to the method of casting and curing of concrete test specimens (ASTM C 31).[10]

e) The actual concrete casting and curing at site should be within normal accepted standard practices.

10. EXPERIMENTAL WORK

The experimental work and the analysis of test results include the following steps:

a) Producing 144 concrete cylinders (100 *200) mm. some of these cylinders are shown by fig.(1).Three cylinders for each 48 different mixes having different cement, and water content with different maximum size of aggregate. Table (1) gives details of the 48 different mixes.

b) Curing the concrete cylinders under field conditions, and tested to obtain the average compressive strength at age of (28-days). Table (2) illustrates the test results.

c) Carrying out statistical analysis to establish preliminary relationship between contents of fresh concrete, and the expected compressive strength after (28 days).The relationship has been adjusted and converted to an empirical formula through the analysis of error and the deviation between the field results and those predicted by the proposed empirical formula. Final adjustment has been carried out to refine the proposed formula to be useful tool that can be used by site engineers with the least possible error and deviation from actual field strength.

Fig. 1- Casted concrete cylinders (100*200) mm

Table1- Details of concrete cylinders

C.G	A.S	W.C	C.C	C.G	A.S	W.C	C.C
1	10	100	250	25	10	160	400
2	10	112.5	250	26	10	180	400
3	10	125	250	27	10	200	400
4	10	137.5	250	28	10	220	400
5	20	100	250	29	20	160	400
6	20	112.5	250	30	20	180	400
7	20	125	250	31	20	200	400
8	20	137.5	250	32	20	220	400
9	10	120	300	33	10	180	450
10	10	135	300	34	10	202.5	450
11	10	150	300	35	10	225	450
12	10	165	300	36	10	247.5	450
13	20	120	300	37	20	180	450
14	20	135	300	38	20	202.5	450
15	20	150	300	39	20	225	450
16	20	165	300	40	20	247.5	450
17	10	140	350	41	10	200	500
18	10	157.5	350	42	10	225	500
19	10	175	350	43	10	250	500
20	10	192.5	350	44	10	275	500
21	20	140	350	45	20	200	500
22	20	157.5	350	46	20	225	500
23	20	175	350	47	20	250	500
24	20	192.5	350	48	20	275	500

Table2-Test results of concrete cylinder

C.G	W/C	F.S	C.G	W/C	F.S
1	0.40	18.25	25	0.40	26.9
2	0.45	15.45	26	0.45	20.3
3	0.50	13.45	27	0.50	17.5
4	0.55	10.25	28	0.55	13.5
5	0.40	15.65	29	0.40	25.3
6	0.45	13.65	30	0.45	20.5
7	0.50	12.45	31	0.50	15.5
8	0.55	8.05	32	0.55	10.3
9	0.40	21.7	33	0.40	26.7
10	0.45	18.3	34	0.45	23.5
11	0.50	13.7	35	0.50	19.1
12	0.55	12.9	36	0.55	13.5
13	0.40	19.1	37	0.40	29.1
14	0.45	18.5	38	0.45	24.7
15	0.50	14.7	39	0.50	18.1
16	0.55	11.7	40	0.55	12.3
17	0.40	25.6	41	0.40	33
18	0.45	19.6	42	0.45	26.2
19	0.50	15.4	43	0.50	20.2
20	0.55	12	44	0.55	14
21	0.40	23	45	0.40	32.4
22	0.45	20.8	46	0.45	27.4
23	0.50	15.4	47	0.50	20.2
24	0.55	11.8	48	0.55	11.8

11. RESEARCH RESULTS

1- The statistical regression analysis of the experimental results have led to the following predicting formula:

P.S = 40 – 0.24W.C + X.C.C …… (1)

Where

P.S = Predicted compressive strength of concrete N/mm^2

W.C = Water content of concrete mix, kg/m^3

X = Variable factor of cement content as illustrated by table (3)

C.C = Cement content of concrete mix, kg/m^3

2- Table (4) show the deviation between field and predicted compressive strength of each cylinders group. The rang of deviation between compressive strength of concrete found through the field normally cured specimens tested at 28 day age and values obtained by the suggested predicting model is between -2.2 to +2.6 N/mm^2.

Table 3 - (X) Values

C.C	(X)	C.C	(X)
250	0.005	380	0.058
260	0.012	390	0.060
270	0.017	400	0.062
280	0.023	410	0.064
290	0.029	420	0.066
300	0.035	430	0.068
310	0.0384	440	0.070
320	0.0418	450	0.072
330	0.0452	460	0.0736
340	0.0486	470	0.0752
350	0.052	480	0.0768
360	0.054	490	0.0784
370	0.056	500	0.08

Table 4 - Deviation between results

F.S	P.S	D	F.S	P.S	D
18.25	17.25	-1.0	26.9	26.4	-0.5
15.45	14.25	-1.2	20.3	21.6	+1.3
13.45	11.25	-2.2	17.5	16.8	-0.7
10.25	8.25	-2.0	13.5	12	-1.5
15.65	17.25	+1.6	25.3	26.4	+1.1
13.65	14.25	+0.6	20.5	21.6	+1.1
12.45	11.25	-1.2	15.5	16.8	+1.3
8.05	8.25	+0.2	10.3	12	+1.7
21.7	21.7	0.0	26.7	29.2	+2.5
18.3	18.1	-0.2	23.5	23.8	+0.3
13.7	14.5	+0.8	19.1	18.4	-0.7
12.9	10.9	-2.0	13.5	13	-0.5
19.1	21.7	+2.6	29.1	29.2	+0.1
18.5	18.1	-0.4	24.7	23.8	-0.9
14.7	14.5	-0.2	18.1	18.4	+0.3
11.7	10.9	-0.8	12.3	13	+0.7
25.6	24.6	-1.0	33	32	-1.0
19.6	20.4	+0.8	26.2	26	-0.2
15.4	16.2	+1.8	20.2	20	-0.2
12	12	0.0	14	14	0.0
23	24.6	+1.6	32.4	32	-0.4
20.8	20.4	-0.4	27.4	26	-1.8
15.4	16.2	+0.8	20.2	20	-0.2
11.8	12	+0.2	11.8	14	+2.2

3- indicated that compressive strength increased by the increase of cement content and decreased by the increase of the (w/c) ratio.

4- Figures (3,4) show that the predicted compressive strength have more closely values to the field values when (w/c) ratios are 0.45 and 0.50 than those values of (w/c) 0.40 and 0.55 as indicated by fig.(2,5)

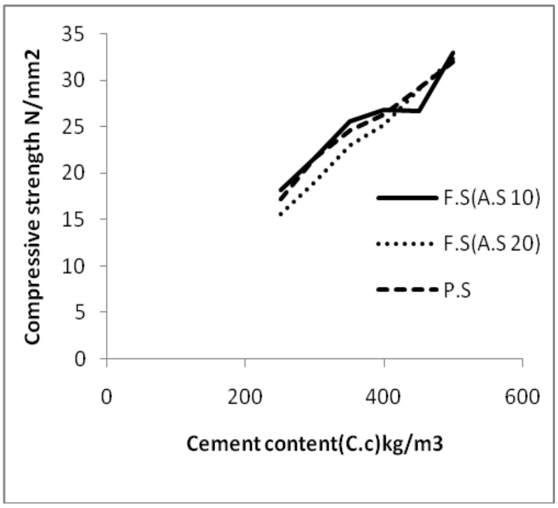

Fig. 2 Compressive strength at (W/C)=0.40

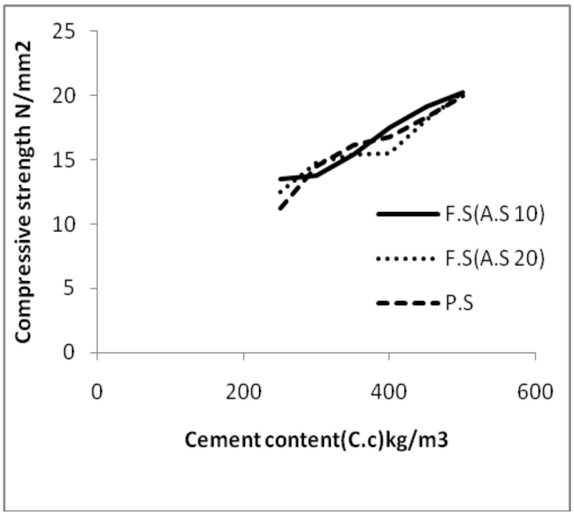

Fig. 3 Compressive strength at (w/c)=0.50

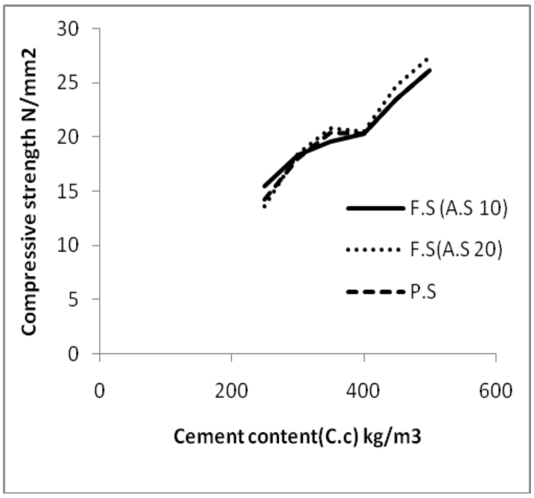

Fig.4 Compressive strength at(W/C)=0.55

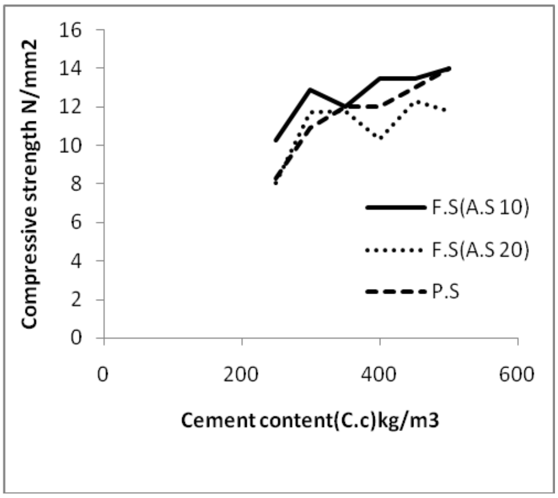

Fig. 5 Compressive strength at(W/C)=0.45

5- The statistical analysis of results variances of the proposed predicting formula (No.1) indicated that the reliability of the formula is considered as 92% with an error of (□) 2 N/mm^2.

6- Compressive strength can be increased up to 21.7 N/mm^2 by increasing the cement content up to 300 kg/m^3 in the condition that (w/c) should be as minimum as possible and should not exceed 0.4.

7- It is possible to have further and considerable strength up to 25.6 N/mm^2 by increasing the cement content in the mix up to 350 kg/m^3 if concrete mixes having (w/c) not more than 0.4 can be casted without any additive materials.

12. CONCLUSIONS

1- Literatures and previous researches as this research achieved its objectives by adopting statistical methods especially regression analysis to introduce predicting model of 28 day age compressive strength of concrete.

2- Previous researches based on accelerated testing of specimens cured through different conditions such as boiling water, warm water and other accelerated curing method while this research adopted the normal curing method and the normal compressive strength test at 28 day age to build the suggested model.

3- Some of previous researches recommended dynamic quadratic model, other recommended non liner regression model, but this research adopted the linear regression to build the predicting model.

4- All previous researches as well as this research concluded that their model proved that it is efficient, reliable and can be used assuring high confidence level of results.

5- All previous researches adopted accelerated specimens test result to predict the 28 day strength except Tantawi and Gharaibeh despite of using accelerated curing and testing to build their model, but their outcomes agree with this research that generating prediction expression of hardened concrete will be as composite function of cement content and w/c ratio.

6- In general, figures (2,3,4,5) indicated that samples test results showed higher compressive strength when maximum aggregate

7- size is 10mm compared with 20mm except samples of 300 and 400Kg/ m^3 cement content and w/c ratio is 0.45 these results can be explained by the fact that smaller size aggregates provide larger surface area for bonding with the mortar matrix.

8- The minimum compressive strength as indicated by figure (2) is 18.25 N/mm^2 when cement content is 250 kg/m^3 , w/c is 0.4 and maximum aggregate size is 10mm while the maximum becomes 33 N/mm^2 by only increasing the cement content to 500 kg/m^3.The results agree with fact that cement content is a factor independently increases the compressive strength of concrete when other factors like type of cement type of aggregate, degree of compaction and concrete mix proportion are fixed.

9- The lowest compressive strength is 8 N/mm^2 as indicated by figure (5) when cement content is 250 kg/m^3, maximum aggregate size is 20mm, and w/c is 0.55. The results confirm the facts that decreasing cement content and increasing w/c ratio in concrete mix should decrease the compressive strength of concrete.

13. RECOMMENDATIONS

Based on the outcome and the discussion of the research results the following recommendations are required:

1- Low cost concrete having acceptable compressive strength of 21.7 N/mm^2 can be achieved by adopting cement content mix of 250 kg/m^3 , maximum aggregate size of 10mm and (w/c) should be as minimum as possible, but should not exceed 0.4.

2- The rapid analysis of fresh concrete on site will help site engineers in predicting the 28 days compressive strength using the proposed formula to control and adjust the quality before concrete casting.

3- Cement content should not exceed 350 kg/m^3 to produce low cost concrete and when designs require compressive strength greater than 25N/mm^2.design should be reviewed to keep down the cost.

4- Further researches are required to study other factors rather than cement content and water cement ratio that influencing the property of concrete for low cost concrete construction works.

REFERENCES

1.ACI 318-08, "Building code requirements for structural concrete and commentary".

2.Wills, M. H., "Accelerated strength tests", ASTM Standard Technical publication No. 169 B, 1978.

3.Malhotra, VM.," Analysis of accelerated 24-hour concrete strengths from field tests " Published by Transportation research board (TRB)of the national academies,1994.

4. Meyer,D.H, " A statistical comparison of accelerated concrete testing methods" journal of applied mathematics and decision sciences, 1997.

5. Resheidat Musa R. and Ghanma Mwafaq S" Accelerated strength and testing of concrete using blended cement "Published by Elseiver Ltd ,1998.

6.ASTM C684 - 99(2003) Standard Test Method for Making, Accelerated Curing, and Testing Concrete Compression Test Specimens.

7. Resheidat, M. R. and Madanat,O.N," Accelerated strength and testing of concrete in Jordan" springer Netherlands, 2006.

8.Tantawi ,Hasan M and Gharaibeh,Emhaidy S." Early estimation of hardened concrete strength" journal of applied sciences, 2006.

9.ASTM C172 – 99 Standard Practice for Sampling Freshly Mixed Concrete.

10. ASTM C31/C31M - 03a Standard Practice for Making and Curing Concrete Test Specimens in the Field.

NOTATION

A.S = Maximum. Size of coarse aggregate, mm

C .C = Cement content in concrete mix, kg/m^3.

C. G = Cylinders group number.

D = Deviation of predicted from field Compressive strength N/mm^2

F.S = Field compressive strength of Concrete, N/mm^2

P.S = Predicted compressive strength of Concrete N/mm^2

W.C = Water content in concrete mix, kg/m^3.

X = Variable factor of cement content