

SPECIAL PROJECT REPORT

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**REPORT ON
STRENGTH COMPARISON
OF 100 MM AND 150 MM CUBES**

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FOREWORD

At the request of the Standing Committee on Concrete Technology, the Public Works Central Laboratory (PWCL) of the Materials Division carried out a study to examine the suitability of using 100 mm cubes instead of 150 mm cubes for concrete quality control purposes. The main objective of the study is to investigate the suitability of specifying 100 mm cubes in construction works and to propose suitable compliance criteria for assessing the quality of concrete using the 100 mm cubes.

Mr W.C. LEUNG was responsible for the overall planning and supervision of the study. Mr K.S. HO assisted in the analysis of the test results, and the technical staff of the PWL assisted in carrying out the tests. Their contribution to the study is gratefully acknowledged.



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ABSTRACT

Although the use of 150 mm concrete cubes for compliance testing is specified in the General Specification for Civil Engineering Works (Hong Kong Government, 1992), the use of 100 mm cubes has its advantages. It is easier to handle and can result in saving of storage space, testing time, materials and labour. Moreover, the 2000 kN compression testing machines, which are used by most of the laboratories in Hong Kong, can be used to test high strength concrete if 100 mm cubes are used.

At the request of the Standing Committee on Concrete Technology, the Public Works Central Laboratory has conducted a study to examine the suitability of using 100 mm cubes in place of 150 mm cubes for concrete quality control purpose. A total of 1484 cubes of various grades of concrete were collected from six different projects and tested in accordance with the Construction Standard - Testing Concrete (CS1) (Hong Kong Government, 1990). This report summarises the findings of the investigation.

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1. INTRODUCTION

Concrete is a construction material comprises of several constituents. Its quality depends on its mix composition, the properties and consistency of its constituents as well as its workmanship on site. All these can be quite variable and therefore the quality of concrete needs stringent monitoring to ensure that it meets the required standard. Over the years, engineers have developed many tests to assess concrete quality. The tests commonly used are the compression test, tensile test, bending test, slump test, flow test, compaction factor test, permeability test, water absorption test, sorptivity test and chloride diffusion test.

The compression test on concrete cubes and cylinders is the most commonly used test. In Hong Kong and in the United Kingdom, cubes are commonly used, whilst in North America concrete cylinders are used.

The General Specification for Civil Engineering (Hong Kong Government, 1992) (G.S.) specifies the use of 150mm cubes for compliance testing whereas the Mass Transit Railway Corporation (MTRC) and the local concrete producers specify the use of 100mm cubes for internal quality control.

Most of the testing laboratories in Hong Kong are equipped with compression testing machines with a maximum loading capacity of about 2000kN. These machines are capable of testing 150mm cubes up to a strength of 90 MPa. With the development of high strength concrete, it is not uncommon that concrete of strength exceeding 140 MPa is specified for use in construction works. Such a high concrete strength is beyond the capacity of these machines. The wear and tear of the machine platens due to such a high loading is also very high.

The use of 100mm cubes for compliance testing will alleviate such problems. The 100mm cubes are easier to handle and will result in saving of materials and labour. It will save storage and curing space as well as testing time. The overall savings can be significant in financial terms. However, engineers and architects are reluctant to specify the use of 100mm cubes because of the perceived greater variability in their compressive strength over that of the 150mm cubes. Also, there is a lack of compliance criteria for the 100mm cubes as the General Specification provides acceptance criteria based on 150mm cube strengths only.

In view of this, the Public Works Central Laboratories (PWCL) proposed in 1993 to carry out an investigation to examine the suitability of using 100mm cubes for concrete quality control purposes. This proposal was accepted by the Standing Committee on Concrete Technology (SCCT) in mid-1993, and six construction projects were identified to be suitable for this investigation. The SCCT requested the PWCL to undertake the testing, analyse the data and report the findings. As some of the project sites were in the New Territories, the cubes for such contracts were cured and tested by the Regional Laboratories of the Materials Division.

2. LITERATURE REVIEW

It has been well known that given the same mix, the strength of a concrete specimen is mainly influenced by the following factors:

- (a) the ratio of the size of the specimens to the maximum size of the aggregates;

- (b) the rate of application of the load;
- (c) the moisture condition of the specimen;
- (d) the end restraint due to the platens of the compression machine;
- (e) the slenderness ratio of the specimens (i.e. the length to diameter ratio); and
- (f) the specimen size.

For concrete cubes cast, cured and tested in accordance with the Construction Standard - Testing Concrete (CS1) (Hong Kong Government, 1990), the equipment calibration and test procedures will ensure that the influence of the factors mentioned in items (a) to (d) above on the concrete strength is kept to a minimum. As the slenderness ratios of 100mm and 150 mm concrete cubes are both equal to unity, the only factor that can significantly affect the concrete strength is the specimen size.

Since concrete is composed of elements of variable strength, it is reasonable to assume that the larger the volume of the concrete, the more likely it is to contain an element of weaker strength. As a result, for a concrete specimen of the same batch, it is reasonable to expect that its strength and its variability will decrease as the specimen size increases. Since the size effect is a result of the inhomogeneity of the concrete, it follows that the more homogeneous the concrete the smaller will be the size effect.

There are few publications available on the strength comparison of 100mm and 150mm cubes. The published data were mostly on the comparison of the strength of concrete cylinders of different sizes. Lessard (1990) found that the compressive strength of cylinders of 150mm dia. by 300mm was about 94% that of cylinders of 100mm dia. by 200mm. Baalbaki et al (1992) repeated the experiment on a total of 126 cylinders and found that the strength of the cylinders of 150mm dia. was 93% that of cylinders of 100mm dia.. Neville (1977) suggested that the strength of the 100mm cubes was about 104% that of the 150mm cubes.

Apart from the small difference in strength between the 100mm and 150mm cubes, a slightly higher standard deviation in strength is also reported for the smaller specimens. Neville (1977) reported that the standard deviation in strength of the 70mm cubes was between 50% to 100% higher than that of the 150mm cubes. From the results of Baalbaki et al (1992), it can be stipulated that the standard deviation in strength of the 100mm cylinders was on average 73% higher than that of the 150mm cylinders.

3. METHODOLOGY

A total of six projects were nominated for this investigation. These comprise five public works projects and one MTRC project. The details of the projects together with the grades of concrete proposed for this investigation are listed below:

- (a) Grades 20 and 35 concrete from WSD Contract No. 25/WSD/92 -Sheung Shui Treatment Works Stage II;
- (b) Grade 35 concrete from DSD Contract No. CV/89/28 - Stanley Area Sewerage and Sewage Disposal;
- (c) Grade 30 concrete from Arch. SD Contract No. SSA389 - Special School at Area 14, Tin Shui Wai;
- (d) Grade 50 concrete from HyD Contract No. HY/89/04 - West Kowloon Corridor -

Yau Ma Tei Section, Stage IV, Phase I;

- (e) Grade 40 concrete from MTRC Contract No. UA 11/91 - Central Reclamation, Phase I; and
- (f) Grades 20, 30 and 40 concrete from HyD Contract No. HY/93/01 - Access Road to Wong Chuk Hang Estate.

It is intended that each project would cast at least 50 pairs of 100mm and 150 mm cubes for each grade of concrete selected. Two pairs of 100mm and 150mm cubes would be cast from the same batch of concrete in order to minimise strength variability. The cubes were cast, cured and tested in accordance with Construction Standard CS1 (Hong Kong Government, 1990).

Casting of the cubes commenced on 20.5.1993 and ended on 12.6.1995. All the cubes were cured and tested at 28 days of maturity by the PWL. A total of 1484 cubes were cast and tested.

4. RESULTS

The compressive strengths of the 100mm and 150mm cubes were examined for extreme results in accordance with the criterion specified in Clause 16.61(3) of the General specification for Civil Engineering Works (Hong Kong Government, 1992). The test results are discarded if the difference between the compressive strengths of a pair of test cubes made from the same batch of concrete exceeds 15% of their mean strength. A total of 1484 cubes were found to be acceptable and are included in the analysis. The strengths of the 100mm and 150mm cubes from the six projects and their means and standard deviations are given in Tables 1 to 9. A summary of the means and standard deviations of the strengths for all the nine concrete mixes is given in Table 10.

5. DISCUSSION

5.1 Mean Strength

As can be seen in Table 10, the 28-day strength of 100mm cubes is on the average about 5% higher than that of the 150mm cubes. This is close to the 4% reported by Neville (1977). Higher strengths were obtained for the 100mm cubes in all projects. The ratio of the mean strength of the 100mm cubes to that of the 150mm cubes varies from 1.03 to 1.09 with a mean value of 1.05.

5.2 Standard Deviation

As can be seen in Table 10, except with the cubes of Grade 50 concrete from the West Kowloon Corridor project, the standard deviations of the strength of the 100mm cubes are all higher than that of the 150mm cubes. The mean standard deviation of the strength of the 100mm and 150mm cubes are 6.15 MPa and 5.57 MPa respectively. Therefore, the standard deviation of the strength of the 100mm cubes is on average about 0.58 MPa higher than that of the 150mm cubes.

5.3 Effect on Compliance Requirement

The current compliance criteria adopted in Civil Engineering works is specified in Clause 16.61 of the G.S. (Hong Kong Government, 1992), which is reproduced in Table 11. The compliance is based on two criteria: the average strength and the individual strength. Take a Grade 30 concrete as an example. The G.S. requires that the average strength of any four consecutive test results shall exceed the grade strength by a margin of 5 MPa (3MPa if the standard deviation of at least 40 test results does not exceed 5MPa). Each individual test result shall be no more than 3 MPa below the grade strength. This is similar to that specified in the British Standard (BS5328: Part 4, 1990).

The CEB-CIB-FIP-RILEM Bulletin D'Information No. 110 (CEB-CIB-FIP-RILEM, 1975) gives a list of compliance criteria used in the European countries which is reproduced in Table 12. As can be seen, the criterion adopted in UK is that the average strength obtained from four consecutive test results shall be greater than the specified grade strength by a margin of 0.82 times the standard deviation.

From the results of this investigation, the mean standard deviation of the strength of 150mm cubes was 5.57 MPa. Based on the compliance criterion in Table 12 for the UK codes, the required strength margin is 4.6 MPa which is about the same as the 5MPa specified in the G.S.. If the same criterion is to be applied to the 100mm cubes, the required margin will become 5 MPa based on a mean standard deviation of 6.15 MPa. Therefore, the 100mm cubes should have a strength margin of 0.4 MPa higher than the 150mm cubes to allow for its higher standard deviation in strength.

5.3.1 Compliance Criteria on the Individual Strength

The results of this investigation indicate that for the same batch of concrete, the strength of the 100mm cubes is likely to be about 5% higher than the strength of the 150mm cubes. For the commonly used concrete grades such as Grades 20, 30 and 40, this represent a 1.0 MPa, 1.5 MPa and 2.0 MPa increase in strength values respectively for the 100mm cubes. The increase is likely to be more significant for concrete with a higher strength (e.g. 3 MPa for Grade 60 concrete).

The G.S. categorises all concrete grades into two main groups: namely those with a grade strength below 20 MPa and those with a grade strength of 20 MPa or above (see Table 11). For concrete with a grade strength below 20 MPa, the likely increase in strength of the 100mm cubes over the 150mm cubes is negligible. It is therefore proposed that the criterion in column A of Table 11 for this category of concrete remains unchanged, i.e. each individual test result should not be less than the grade strength by more than 2 MPa.

For concrete with a grade strength of 20 MPa or above, the G.S. specifies that the individual result of 150mm cubes should not be less than the grade strength by more than 3 MPa. The likely minimum increase in strength, if the 100mm cubes are used, is 1 MPa. It is therefore proposed that for this category of concrete, each individual test result of the 100mm cubes should not be less than the grade strength by more than 2 MPa.

A revised proposal of the strength criterion for the individual test result is detailed in column A of Table 13.

5.3.2 Compliance Criteria on the Running Mean of Four Consecutive Test Results

The G.S. uses three compliance criteria to assess the acceptance of consecutive test results: namely criteria C1, C2 and C3 as detailed in Table 11. Compliance criterion C3 applies to concrete with a grade strength below 20 MPa. Compliance Criteria C1 and C2 apply to concrete with a grade strength of 20 MPa or above. Compliance C2 applies if there is sufficient evidence that the standard of quality control using similar materials and plant is such that the standard deviation for at least 40 test results will not exceed 5 MPa.

As the standard deviation of the strength of 100mm cubes is about 0.58 MPa higher than that of 150mm cubes, it is proposed that the 5 MPa criterion be changed to 5.5 MPa as shown in Table 13.

The results of this investigation indicate that the 100mm cubes should have a margin of 0.4 MPa higher than the 150mm cubes to allow for its higher standard deviation in strength. Furthermore, the strength of the 100mm cubes is likely to be about 5% higher than the strength of the 150mm cubes. The combined effect of higher strength value and higher standard deviation for the 100mm cubes is that the margin as specified in the G.S. should be increased.

The likely increase in strength of 100mm cubes for concrete with a grade strength below 20 MPa is less than 1 MPa. It is proposed that the compliance criterion C3 be increased from 2 MPa to 3 MPa.

For the commonly used concrete grades such as Grade 30 concrete, the likely increase in strength is 1.5 MPa for the 100mm cubes. It is proposed that the compliance criteria for C1 and C2 be increased by 2 MPa (i.e. 7 MPa for compliance criteria C1 and 5 MPa for compliance criteria C2).

The proposed compliance criteria are detailed in column B of Table 13.

6. CONCLUSIONS AND RECOMMENDATIONS

In response to SCCT's request, the PWCL coordinated an investigation to examine the suitability of using 100mm cubes for concrete quality control purposes. Five public works projects and one MTRC project took part in this investigation. Altogether, a total of 1484 cubes were cast, cured and tested. Based on the 28-day strength, the following conclusions can be drawn:

- a) The 28-day strength of 100mm cubes is on average about 5% higher than that of the 150mm cubes made from the same batch of concrete.
- b) The standard deviation of the 100mm cubes is on average about 0.58 MPa higher than that of the 150mm cubes.
- c) Based on the compliance criterion adopted by the UK code, the 100mm cubes should have a strength margin of 0.4 MPa higher than the 150mm cubes to allow for its higher standard deviation in strength.

- d) The G.S. (Hong Kong Government, 1992) categorises all concrete grades into two main groups: those with a grade strength below 20 MPa and those with a grade strength of 20 MPa or above. The compliance criteria specified in the G.S. for the 150mm are based on the running mean of four consecutive test results as well as on individual test result. No compliance criterion was provided in the G.S. for the 100mm cubes.
- e) The combined effect of higher strength value and higher standard deviation for the 100mm cubes is that the strength margin as specified in the G.S. (for the 150mm cubes) should be increased. Proposed compliance criteria for the 100mm cubes are detailed in Table 13.

7. REFERENCES

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**Table 1 - Results of Tests on Grade 20 Cubes from Contract No. 25/WSD/92
- Sheung Shui Treatment Works - Stage II**

Sheet 1 of 2

Date Cast	Date Tested	Batch Number	150 mm Cubes		100mm Cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
21.09.93	19.10.93	515/108650	39.8		39.4		
			40.5	40.2	41.7	40.6	1.01
08.10.93	05.11.93	515/110013	26.5		27.0		
			25.9	26.2	28.6	27.8	1.06
01.11.93	29.11.93	515/112451	33.0		34.0		
			32.5	32.8	33.0	33.5	1.02
03.11.93	01.12.93	--	29.5		33.5		
			30.0	29.8	31.5	32.5	1.09
08.11.93	06.12.93	515/113176	37.0		38.5		
			35.5	36.3	39.0	38.8	1.07
15.11.93	13.12.93	515/114002	28.5		29.5		
			28.0	28.3	30.0	29.8	1.05
15.11.93	13.12.93	515/114018	26.0		26.5		
			25.5	25.8	26.5	26.5	1.03
17.11.93	15.12.93	515/114241	31.5		34.0		
			31.0	31.3	33.5	33.8	1.08
17.11.93	15.12.93	515/114252	35.0		36.5		
			36.0	35.5	36.5	36.5	1.03
23.11.93	21.12.93	515/114833	29.0		36.0		
			30.0	29.5	36.0	36.0	1.22
29.11.93	28.12.93	515/115516	32.5		34.5		
			32.0	32.3	33.5	34.0	1.05
03.12.93	31.12.93	515/115907	39.0		44.0		
			38.5	38.8	43.0	43.5	1.12
03.12.93	31.12.93	515/115962	28.5		31.5		
			29.0	28.8	29.5	30.5	1.06
03.12.93	31.12.93	515/115976	37.5		34.0		
			37.0	37.3	34.0	34.0	0.91
03.12.93	31.12.93	515/115988	31.5		38.0		
			33.5	32.5	41.5	39.8	1.22
03.12.93	31.12.93	515/115931	39.5		40.5		
			39.0	39.3	36.0	38.3	0.97
06.12.93	03.01.94	515/116317	31.5		36.5		
			33.0	32.3	33.5	35.0	1.09
06.12.93	03.01.94	515/116336	31.0		33.5		
			31.5	31.3	31.5	32.5	1.04
06.12.93	03.01.94	515/116359	40.0		44.0		
			38.5	39.3	40.0	42.0	1.07
06.12.93	03.01.94	515/116374	23.0		23.0		
			22.5	22.8	23.5	23.3	1.02
06.12.93	03.01.94	515/116388	32.0		33.0		
			32.0	32.0	34.0	33.5	1.05
08.12.93	05.01.94	515/116575	31.5		34.0		
			31.0	31.3	32.0	33.0	1.06
08.12.93	05.01.94	515/116602	31.0		34.0		
			31.5	31.3	34.5	34.3	1.10
08.12.93	05.01.94	515/116524	37.0		39.5		
			36.0	36.5	41.0	40.3	1.10
08.12.93	05.01.94	515/116536	32.5		37.0		
			31.0	31.8	35.5	36.3	1.14
09.12.93	06.01.94	515/116727	41.0		43.5		
			40.5	40.8	42.0	42.8	1.05

**Table 1 - Results of Tests on Grade 20 Cubes from Contract No. 25/WSD/92
- Sheung Shui Treatment Works - Stage II**

Sheet 2 of 2

Date Cast	Date Tested	Batch Number	150 mm Cubes		100mm Cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
15.12.93	12.01.94	515/117413	35.0		36.0		
			34.5	34.8	36.5	36.3	1.04
17.12.93	14.01.94	515/117588	34.0		34.0		
			37.0	35.5	36.0	35.0	0.99
18.12.93	15.01.94	515/117658	32.5		32.5		
			32.5	32.5	33.5	33.0	1.02
28.12.93	25.01.94	515/118433	29.0		31.0		
			29.0	29.0	27.5	29.3	1.01
05.01.94	02.02.94	515/119186	27.0		27.0		
			27.5	27.3	27.0	27.0	0.99
06.01.94	03.02.94	515/119300	40.5		42.0		
			40.0	40.3	42.0	42.0	1.04
11.01.94	08.02.94	515/119842	28.5		29.5		
			28.5	28.5	30.0	29.8	1.04
15.01.94	12.02.94	515/120234	42.5		45.0		
			42.5	42.5	45.0	45.0	1.06
15.01.94	12.02.94	515/120263	25.0		26.0		
			26.0	25.5	26.0	26.0	1.02
15.01.94	12.02.94	515/120290	36.0		38.5		
			37.0	36.5	36.5	37.5	1.03
17.01.94	14.02.94	515/120491	29.5		29.0		
			29.0	29.3	31.0	30.0	1.03
22.01.94	19.02.94	515/121034	31.5		33.5		
			30.5	31.0	31.5	32.5	1.05
22.01.94	19.02.94	515/121083	45.5		45.0		
			45.5	45.5	44.0	44.5	0.98
01.02.94	01.03.94	515/122350	29.0		28.5		
			27.0	28.0	29.0	28.8	1.03
23.02.94	03.03.94	515/132304	22.0		20.5		
			21.0	21.5	22.0	21.3	0.99
24.02.94	24.03.94	515/732352	31.5		28.5		
			33.0	32.3	31.5	30.0	0.93
24.02.94	24.03.94	515/732354	39.5		38.0		
			37.5	38.5	38.5	38.3	0.99
28.02.94	28.03.94	515/732789	40.0		39.5		
			42.5	41.3	40.0	39.8	0.96
28.02.94	28.03.94	515/732801	40.5		36.0		
			38.5	39.5	36.5	36.3	0.92
28.02.94	28.03.94	515/732763	36.0		37.0		
			38.5	37.3	33.0	35.0	0.94
28.02.94	28.03.94	515/732744	36.0		36.0		
			36.5	36.3	35.5	35.8	0.99
02.03.94	30.03.94	515/732977	29.5		33.0		
			29.0	29.3	32.5	32.8	1.12
02.03.94	30.03.94	515/732987	32.0		29.0		
			34.0	33.0	29.0	29.0	0.88
Legend:			Mean ₁₅₀ =	33.2	Mean ₁₀₀ =	34.3	
Average _x :			S.D. ₁₅₀ =	5.32	S.D. ₁₀₀ =	5.49	
			Mean ₁₀₀ / Mean ₁₅₀ =		1.03		
Mean _x :			S.D. ₁₀₀ / S.D. ₁₅₀ =		1.03		
S.D. _x :			standard deviation of the strength of the x mm cubes				

**Table 2 - Results of Tests on Grade 35 Cubes from Contract No. 25/WSD/92
- Sheung Shui Treatment Works - Stage II**

Sheet 1 of 2

Date Cast	Date Tested	Batch Number	150 mm Cubes		100mm Cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
12.09.93	11.10.93	515/107846	49.6		50.3		
			50.2	49.9	49.0	49.7	0.99
12.09.93	11.10.93	515/107862	55.0		53.5		
			52.4	53.7	49.0	51.3	0.95
12.09.93	11.10.93	515/107749	46.0		52.0		
			45.9	46.0	52.8	52.4	1.14
19.09.93	18.10.93	402/154023	55.6		55.2		
			55.4	55.5	55.6	55.4	1.00
19.09.93	18.10.93	402/154031	50.7		51.6		
			46.3	48.5	50.2	50.9	1.05
19.09.93	18.10.93	515/108320	49.1		54.7		
			42.6	45.9	54.5	54.6	1.19
19.09.93	10/18/93	515/108353	55.3		53.3		
			56.5	55.9	61.7	57.5	1.03
19.09.93	18.10.93	515/108385	53.6		50.6		
			53.2	53.4	51.7	51.2	0.96
05.10.93	02.11.93	515/109639	58.1		54.8		
			57.6	57.9	57.9	56.4	0.97
05.10.93	02.11.93	515/109659	53.7		65.6		
			55.4	54.6	68.7	67.2	1.23
05.10.93	02.11.93	515/109501	55.4		54.5		
			54.7	55.1	51.0	52.8	0.96
05.10.93	02.11.93	515/109518	55.7		51.8		
			57.5	56.6	52.4	52.1	0.92
05.10.93	02.11.93	515/109534	60.0		58.1		
			59.2	59.6	55.7	56.9	0.95
22.10.93	19.11.93	515/111380	54.3		60.3		
			54.9	54.6	58.7	59.5	1.09
22.10.93	19.11.93	515/111412	54.7		61.4		
			53.9	54.3	60.5	61.0	1.12
22.10.93	19.11.93	515/111426	49.1		52.8		
			51.5	50.3	54.6	53.7	1.07
24.10.93	22.11.93	515/111469	56.7		50.7		
			58.7	57.7	48.9	49.8	0.86
24.10.93	22.11.93	515/111503	51.9		53.8		
			52.6	52.3	53.9	53.9	1.03
24.10.93	22.11.93	515/111536	64.6		67.6		
			64.2	64.4	65.3	66.5	1.03
24.10.93	22.11.93	515/111586	54.5		54.0		
			52.9	53.7	53.9	54.0	1.00
27.10.93	24.11.93	515/111903	48.7		52.3		
			49.5	49.1	51.2	51.8	1.05
27.10.93	24.11.93	515/111842	47.2		51.3		
			49.0	48.1	52.0	51.7	1.07
27.10.93	24.11.93	515/111884	51.3		52.8		
			51.0	51.2	54.4	53.6	1.05
31.10.93	29.11.93	515/112394	54.0		60.5		
			57.5	55.8	59.5	60.0	1.08
31.10.93	29.11.93	515/112419	58.0		60.0		
			57.0	57.5	62.0	61.0	1.06
31.10.93	29.11.93	515/112288	55.0		55.5		
			59.0	57.0	64.5	60.0	1.05

**Table 2 - Results of Tests on Grade 35 Cubes from Contract No. 25/WSD/92
- Sheung Shui Treatment Works - Stage II**

Sheet 2 of 2

Date Cast	Date Tested	Batch Number	150 mm Cubes		100mm Cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
31.10.93	29.11.93	515/112277	53.5		55.5		
			59.5	56.5	57.0	56.3	1.00
31.10.93	29.11.93	515/112332	55.5		57.5		
			54.0	54.8	55.0	56.3	1.03
01.11.93	29.11.93	515/112542	51.5		54.0		
			50.5	51.0	55.0	54.5	1.07
01.11.93	29.11.93	515/112498	62.5		62.5		
			62.0	62.3	62.5	62.5	1.00
01.11.93	29.11.93	515/112511	64.0		66.0		
			67.5	65.8	71.0	68.5	1.04
01.11.93	29.11.93	515/112532	59.0		60.5		
			58.0	58.5	60.5	60.5	1.03
03.11.93	01.12.93	515/112718	56.5		59.5		
			53.0	54.8	60.0	59.8	1.09
03.11.93	01.12.93	515/112757	50.5		56.0		
			57.0	53.8	56.5	56.3	1.05
07.11.93	06.12.93	515/112946	54.0		51.5		
			59.5	56.8	50.5	51.0	0.90
07.11.93	06.12.93	515/112926	59.0		59.0		
			60.0	59.5	58.5	58.8	0.99
07.11.93	06.12.93	515/112936	62.0		62.0		
			61.5	61.8	60.5	61.3	0.99
20.11.93	18.12.93	515/114498	61.0		47.0		
			60.0	60.5	48.5	47.8	0.79
20.11.93	18.12.93	515/114514	57.5		55.5		
			58.0	57.8	58.5	57.0	0.99
20.11.93	18.12.93	515/114523	56.5		53.0		
			55.5	56.0	55.0	54.0	0.96
20.11.93	18.12.93	515/114529	49.5		52.5		
			51.5	50.5	53.5	53.0	1.05
20.11.93	18.12.93	515/114538	54.0		63.5		
			51.5	52.8	66.5	65.0	1.23
21.11.93	20.12.93	402/160519	56.0		63.0		
			53.0	54.5	62.5	62.8	1.15
21.11.93	20.12.93	515/114649	63.5		58.5		
			60.0	61.8	60.5	59.5	0.96
Legend:			Mean ₁₅₀ =	55.2	Mean ₁₀₀ =	56.6	
Average _x : average strength of the pair of x mm cubes			S.D. ₁₅₀ =	4.70	S.D. ₁₀₀ =	5.16	
			Mean ₁₀₀ / Mean ₁₅₀ =				1.03
Mean _x : overall mean strength of the x mm cubes			S.D. ₁₀₀ / S.D. ₁₅₀ =				1.10
S.D. _x : standard deviation of the strength of the x mm cubes							

Table 3 - Results of Tests on Grade 35 Cubes (with PFA) from Contract No. CV/89/28
- Stanley Area Sewerage and Sewage Disposal

Sheet 1 of 1

DATE CAST	DATE TESTED	BATCH NUMBER	150 mm cubes		100mm cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
20.05.93	17.06.93	99606	47.5		52.5		
			46.5	52.2	53.0	52.8	1.01
21.05.93	18.06.93	100045	41.0		49.0		
			43.5	42.3	50.0	49.5	1.17
23.05.93	20.06.93	-	59.0		58.0		
			59.0	59.0	60.0	59.0	1.00
23.05.93	20.06.93	-	54.0		66.0		
			55.5	54.8	60.0	63.0	1.15
26.05.93	23.06.93	1871	52.5		55.0		
			54.0	53.3	56.5	55.8	1.05
26.05.93	23.06.93	1888	54.5		55.5		
			54.0	54.3	54.0	54.8	1.01
29.05.93	26.06.93	2925	56.0		60.0		
			52.5	54.3	60.0	60.0	1.11
29.05.93	26.06.93	3150	55.5		60.5		
			57.0	56.3	55.5	58.0	1.03
30.05.93	27.06.93	3388	49.0		46.0		
			50.0	49.5	43.0	44.5	0.90
03.06.93	01.07.93	5125	51.0		53.5		
			52.5	51.8	57.0	55.3	1.07
03.06.93	01.07.93	5279	52.0		57.0		
			53.5	52.8	53.5	55.3	1.05
04.06.93	02.07.93	5582	52.0		59.5		
			55.0	53.5	61.5	60.5	1.13
06.06.93	04.07.93	6456	49.0		58.0		
			51.0	50.0	51.0	54.5	1.09
09.06.93	07.07.93	8126	48.0		45.5		
			44.5	46.3	42.5	44.0	0.95
10.06.93	08.07.93	8767	50.5		52.0		
			46.5	48.5	51.5	51.8	1.07
10.06.93	08.07.93	8762	51.0		49.0		
			51.0	51.0	54.5	51.8	1.01
11.06.93	09.07.93	9126	48.5		49.5		
			49.0	48.8	48.5	49.0	1.01
12.06.93	10.07.93	9353	49.0		55.5		
			51.0	50.0	55.0	55.3	1.11
13.06.93	11.07.93	9452	56.5		59.0		
			54.5	55.5	61.5	60.3	1.09
15.06.93	13.07.93	10213	51.0		50.0		
			49.5	50.3	56.0	53.0	1.05
20.06.93	18.07.93	12334	50.5		51.5		
			48.5	49.5	53.5	52.5	1.06
21.06.93	19.07.93	13007	57.0		57.5		
			56.0	56.5	60.5	59.0	1.04
23.06.93	21.07.93	14372	59.0		59.0		
			58.0	58.5	61.0	60.0	1.03
23.06.93	21.07.93	14141	57.0		64.0		
			60.5	58.8	64.5	64.3	1.09
Legend:			Mean ₁₅₀ =	52.4	Mean ₁₀₀ =	55.1	
Average _x : average strength of the pair of x mm cubes			S.D. ₁₅₀ =	4.30	S.D. ₁₀₀ =	5.45	
Mean _x : overall mean strength of the x mm cubes			Mean ₁₀₀ / Mean ₁₅₀ =		1.05		
S.D. _x : standard deviation of the strength of the x mm cubes			S.D. ₁₀₀ / S.D. ₁₅₀ =		1.27		

**Table 4 - Results of Tests on Grade 30 Cubes from Contract No. SS A389
- Special School at Area 14, Tin Shui Wai**

Sheet 1 of 3

Date Cast	Date Tested	Batch Number	150 mm Cubes		100mm Cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
22.06.93	20.07.93	67257E	39.9		43.5		
			40.5	40.2	46.0	44.8	1.11
06.07.93	03.08.93	69296E	40.2		44.8		
			43.1	41.7	43.0	43.9	1.05
06.07.93	03.08.93	69310E	40.1		42.5		
			41.6	40.9	44.9	43.7	1.07
06.07.93	03.08.93	69264E	40.4		51.2		
			44.0	42.2	50.0	50.6	1.20
06.07.93	03.08.93	69307E	40.4		45.4		
			40.6	40.5	46.0	45.7	1.13
06.07.93	03.08.93	69282E	39.1		46.5		
			42.6	40.9	46.7	46.6	1.14
06.07.93	03.08.93	69257E	42.4		50.4		
			44.0	43.2	49.9	50.2	1.16
06.07.93	03.08.93	69273E	42.6		47.0		
			40.7	41.7	48.0	47.5	1.14
24.07.93	21.08.93	E080931	49.4		51.2		
			51.0	50.2	53.0	52.1	1.04
24.07.93	21.08.93	E080920	44.4		54.0		
			45.2	44.8	55.9	55.0	1.23
24.07.93	21.08.93	E080898	48.0		51.5		
			46.8	47.4	45.9	48.7	1.03
16.08.93	13.09.93	E091881	44.7		50.3		
			46.6	45.7	51.2	50.8	1.11
16.08.93	13.09.93	E091870	48.9		56.6		
			50.4	49.7	58.1	57.4	1.16
07.09.93	05.10.93	E099953	50.7		55.8		
			52.4	51.6	51.3	53.6	1.04
07.09.93	05.10.93	E099966	45.9		51.4		
			45.3	45.6	49.3	50.4	1.10
07.09.93	05.10.93	E099981	50.5		60.6		
			50.7	50.6	57.8	59.2	1.17
07.09.93	05.10.93	E099991	47.3		52.1		
			49.0	48.2	57.4	54.8	1.14
14.09.93	12.10.93	F011220	41.7		59.1		
			45.9	43.8	58.4	58.8	1.34
14.09.93	12.10.93	F011245	49.6		60.7		
			52.1	50.9	62.6	61.7	1.21
14.09.93	12.10.93	F011247	47.4		59.1		
			45.0	46.2	56.3	57.7	1.25
14.09.93	12.10.93	F011254	49.3		54.0		
			48.8	49.1	52.1	53.1	1.08
14.09.93	12.10.93	F011259	46.7		50.5		
			45.2	46.0	50.1	50.3	1.09
22.09.93	20.10.93	F011484	47.0		49.9		
			44.3	45.7	46.1	48.0	1.05
07.10.93	04.11.93	F003334	46.8		48.9		
			47.5	47.2	45.6	47.3	1.00
07.10.93	04.11.93	F003335	44.3		48.1		
			47.3	45.8	48.2	48.2	1.05
07.10.93	04.11.93	F003358	49.1		56.7		
			50.7	49.9	55.5	56.1	1.12
07.10.93	04.11.93	F003361	53.6		53.1		
			55.2	54.4	56.2	54.7	1.00

**Table 4 - Results of Tests on Grade 30 Cubes from Contract No. SS A389
- Special School at Area 14, Tin Shui Wai**

Sheet 2 of 3

Date Cast	Date Tested	Batch Number	150 mm Cubes		100mm Cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
13.10.93	10.11.93	F019147	40.7		43.3		
			42.2	41.5	44.2	43.8	1.06
13.10.93	10.11.93	F019149	40.5		48.5		
			39.8	40.2	48.4	48.5	1.21
13.10.93	10.11.93	F019104	44.9		44.9		
			44.4	44.7	47.9	46.4	1.04
13.10.93	10.11.93	F019105	48.5		53.7		
			50.1	49.3	52.4	53.1	1.08
25.10.93	11/22/93	F022094	57.9		62.0		
			56.9	57.4	62.5	62.3	1.08
30.10.93	27.11.93	F022365	47.5		51.1		
			49.4	48.5	47.2	49.2	1.01
01.11.93	29.11.93	F022454	46.4		52.5		
			48.3	47.4	54.3	53.4	1.13
01.11.93	29.11.93	F022457	46.4		49.1		
			47.6	47.0	51.9	50.5	1.07
01.11.93	29.11.93	F022444	51.6		53.6		
			51.1	51.4	48.4	51.0	0.99
03.11.93	01.12.93	F027530	46.4		50.7		
			45.5	46.0	46.2	48.5	1.05
10.11.93	08.12.93	F027717	43.1		46.6		
			44.8	44.0	47.0	46.8	1.06
10.11.93	08.12.93	F027722	41.3		44.8		
			41.4	41.4	40.7	42.8	1.03
10.11.93	08.12.93	F027727	48.4		51.1		
			48.4	48.4	53.9	52.5	1.08
10.11.93	08.12.93	F027734	47.5		52.9		
			50.2	48.9	52.0	52.5	1.07
10.11.93	08.12.93	F027735	43.3		47.4		
			43.9	43.6	49.4	48.4	1.11
10.11.93	08.12.93	F027759	45.4		47.8		
			46.2	45.8	52.1	50.0	1.09
20.11.93	18.12.93	F041039	55.0		47.0		
			54.0	54.5	46.4	46.7	0.86
20.11.93	18.12.93	F041057	38.3		40.9		
			35.5	36.9	40.4	40.7	1.10
30.11.93	28.12.93	F041346	41.9		43.3		
			40.8	41.4	43.9	43.6	1.05
30.11.93	28.12.93	F041354	42.8		47.5		
			44.3	43.6	47.5	47.5	1.09
30.11.93	28.12.93	F041357	43.6		46.7		
			44.8	44.2	49.3	48.0	1.09
29.12.93	26.01.94	F051896	56.3		57.5		
			55.6	56.0	60.0	58.8	1.05
29.12.93	26.01.94	F051931	26.3		29.3		
			25.7	26.0	25.6	27.5	1.06
04.01.94	01.02.94	F039783	41.0		42.0		
			40.0	40.5	43.5	42.8	1.06

**Table 4 - Results of Tests on Grade 30 Cubes from Contract No. SS A389
- Special School at Area 14, Tin Shui Wai**

Sheet 3 of 3

Date Cast	Date Tested	Batch Number	150 mm Cubes		100mm Cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
04.01.94	01.02.94	F039805	46.5	47.8	51.5	50.8	1.06
11.01.94	08.02.94	F051112	49.0		50.0		
13.01.94	10.02.94	F051218	42.5	43.0	47.5	48.0	1.12
			43.5		48.5		
21.01.94	18.02.94	F063143	49.5	49.8	51.5	52.3	1.05
			50.0		53.0		
			45.5		52.3		
			45.5	45.5	53.5	52.3	1.15
Legend:			Mean ₁₅₀ =	45.8	Mean ₁₀₀ =	50.0	
Average _x :			S.D. ₁₅₀ =	5.16	S.D. ₁₀₀ =	5.90	
					Mean ₁₀₀ / Mean ₁₅₀ =	1.09	
Mean _x :					S.D. ₁₀₀ / S.D. ₁₅₀ =	1.14	
S.D. _x :							

**Table 5 - Results of Tests on Grade 50 Cubes from Contract No. HY 89/04
- West Kowloon Corridor, Yau Ma Tei Section, Stage IV, Phase I**

Sheet 1 of 3

Date Cast	Date Tested	Batch Number	150 mm Cubes		100mm Cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
05.07.93	02.08.93	CA274075	45.3	45.6	50.7	51.3	1.12
			45.9		51.8		
		CA274111	48.3	49.7	52.4	53.5	1.08
			51.1		54.6		
21.07.93	18.08.93	CA274150	47.2	48.8	48.4	48.3	0.99
			50.4		48.2		
		CA277535	49.6	48.7	52.6	53.4	1.10
			47.8		54.2		
03.08.93	31.08.93	CA277571	45.6	47.5	48.9	46.7	0.98
			49.3		44.4		
		CA277618	51.2	51.3	57.0	56.7	1.11
			51.4		56.4		
10.08.93	07.09.93	CA279976	53.8	52.9	56.0	56.0	1.06
			52.0		55.9		
		CA280008	44.6	46.5	55.3	55.1	1.19
			48.3		54.8		
31.08.93	28.09.93	CA280055	52.6	52.8	54.4	54.0	1.02
			53.0		53.5		
		CA281485	58.1	58.1	59.7	60.1	1.03
			58.1		60.4		
10.08.93	07.09.93	CA281518	63.8	62.2	62.0	63.9	1.03
			60.6		65.8		
		CA281535	52.6	53.0	56.5	56.7	1.07
			53.3		56.9		
31.08.93	28.09.93	CA285619	60.3	60.0	65.7	65.9	1.10
			59.7		66.1		
		CA285657	62.9	63.7	64.2	65.9	1.04
			64.4		67.6		
31.08.93	28.09.93	CA285584	68.2	66.5	65.8	67.8	1.02
			64.8		69.7		
07.09.93	05.10.93	CA287228	61.5	60.5	69.1	66.7	1.10
			59.4		64.2		
		CA287305	58.0	59.2	67.5	65.3	1.10
			60.3		63.0		
09.09.93	07.10.93	CA287341	67.2	64.8	69.7	68.4	1.05
			62.4		67.0		
		CA287786	61.4	61.9	67.9	67.0	1.08
			62.3		66.0		
19.09.93	18.10.93	CA287824	60.7	60.2	69.4	66.8	1.11
			59.7		64.1		
		CA287862	61.2	59.8	66.3	65.3	1.09
			58.3		64.2		
20.09.93	18.10.93	CA289676	55.5	56.8	64.2	62.6	1.10
			58.1		60.9		
		CA289709	56.3	58.2	63.6	64.2	1.10
			60.0		64.8		
20.09.93	18.10.93	CA289741	55.9	58.8	65.7	66.0	1.12
			61.7		66.3		
		CA289975	60.9	63.0	67.1	67.4	1.07
			65.1		67.7		

**Table 5 - Results of Tests on Grade 50 Cubes from Contract No. HY 89/04
- West Kowloon Corridor, Yau Ma Tei Section, Stage IV, Phase I**

Sheet 2 of 3

Date Cast	Date Tested	Batch Number	150 mm Cubes		100mm Cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
20.09.93	18.10.93	CA289886	55.0		65.2		
			53.9	54.5	60.4	62.8	1.15
29.9.93	27.10.93	CA289933	55.6		63.3		
			55.3	55.5	61.9	62.6	1.13
		CA291093	61.5		67.1		
			65.8	63.7	68.1	67.6	1.06
		CA291150	58.8		60.5		
			53.9	56.4	69.1	64.8	1.15
05.10.93	02.11.93	CA291194	60.8		63.1		
			62.0	61.4	66.9	65.0	1.06
		CA292025	58.2		64.1		
			53.0	55.6	63.1	63.6	1.14
11.10.93	08.11.93	CA292043	56.7		64.1		
			56.3	56.5	64.6	64.4	1.14
		CA293324	67.4		72.2		
			66.6	67.0	70.1	71.2	1.06
		CA293370	77.7		82.6		
			71.6	74.7	76.7	79.7	1.07
18.10.93	15.11.93	CA293426	71.4		68.4		
			68.5	70.0	71.9	70.2	1.00
		CA294956	70.5		62.7		
			70.2	70.4	68.9	65.8	0.94
		CA294976	67.2		65.7		
			65.6	66.4	64.2	65.0	0.98
21.10.93	18.11.93	CA295014	73.7		76.7		
			65.1	69.4	70.2	73.5	1.06
		CA295675	66.5		71.4		
			75.4	71.0	72.3	71.9	1.01
27.10.93	24.11.93	CA295707	71.6		70.0		
			75.1	73.4	75.3	72.7	0.99
		CA296758	73.2		75.2		
			73.9	73.6	75.7	75.5	1.03
		CA296789	70.3		80.3		
			80.0	75.2	80.6	80.5	1.07
30.10.93	27.11.93	CA296811	76.7		81.8		
			79.6	78.2	82.1	82.0	1.05
		CA297480	70.2		64.3		
			73.5	71.9	64.6	64.5	0.90
		CA297507	77.8		72.8		
			71.0	74.4	69.9	71.4	0.96

**Table 5 - Results of Tests on Grade 50 Cubes from Contract No. HY 89/04
- West Kowloon Corridor, Yau Ma Tei Section, Stage IV, Phase I**

Sheet 3 of 3

Date Cast	Date Tested	Batch Number	150 mm Cubes		100mm Cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
07.11.93	06.12.93	CA298919	72.3	72.9	72.9	73.5	1.01
			73.4		74.0		
		CA298946	67.8	68.9	79.5	77.4	1.12
			69.9		75.3		
			74.8		75.1		
		CA298991	72.9	73.9	71.2	73.2	0.99
Legend:			Mean ₁₅₀ =	61.8	Mean ₁₀₀ =	65.3	
Average _x : average strength of the			S.D. ₁₅₀ =	8.94	S.D. ₁₀₀ =	8.14	
			Mean ₁₀₀ / Mean ₁₅₀ =				1.06
Mean _x : overall mean strength of the x mm cubes			S.D. ₁₀₀ / S.D. ₁₅₀ =				0.91
S.D. _x : standard deviation of the strength of the x mm cubes							

**Table 6 - Results of Tests on Grade 40 Cubes from Contract No. UA 11/91
- Central Reclamation, Phase I**

Sheet 1 of 4

DATE CAST	Date Tested	Batch Number	150 mm Cubes		100mm Cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
27.02.94	28.03.94	A063244	61.0		63.0		
			60.0	60.5	63.0	63.0	1.04
27.02.94	28.03.94	A063328	66.0		65.0		
			63.5	64.8	63.0	64.0	0.99
27.02.94	28.03.94	A063374	64.0		64.0		
			65.0	64.5	67.0	65.5	1.02
03.03.94	31.03.94	A064744	57.0		61.0		
			59.0	58.0	60.5	60.8	1.05
08.03.94	05.04.94	A066696	46.0		49.5		
			48.5	47.3	49.5	49.5	1.05
08.03.94	05.04.94	A066763	48.0		50.5		
			47.5	47.8	49.5	50.0	1.05
10.03.94	07.04.94	A067163	65.5		61.5		
			66.0	65.8	62.5	62.0	0.94
10.03.94	07.04.94	A067351	63.5		62.5		
			62.5	63.0	66.0	64.3	1.02
10.03.94	07.04.94	A067488	63.0		61.5		
			62.0	62.5	62.5	62.0	0.99
14.03.94	11.04.94	A068759	70.0		70.0		
			66.0	68.0	66.5	68.3	1.00
14.03.94	11.04.94	A068780	68.0		73.5		
			65.0	66.5	72.5	73.0	1.10
20.03.94	17.04.94	A070602	57.0		60.0		
			57.5	57.3	63.5	61.8	1.08
20.03.94	17.04.94	A070619	55.5		65.0		
			57.0	56.3	63.5	64.3	1.14
20.03.94	17.04.94	A070636	56.5		66.0		
			56.5	56.5	61.5	63.8	1.13
20.03.94	17.04.94	A070649	57.0		60.0		
			56.5	56.8	62.5	61.3	1.08
20.03.94	17.04.94	A070615	68.0		73.0		
			69.0	68.5	70.5	71.8	1.05
20.03.94	17.04.94	A070710	61.0		58.0		
			58.5	59.8	60.0	59.0	0.99
20.03.94	17.04.94	A070669	61.5		64.5		
			62.5	62.0	65.0	64.8	1.04
23.03.94	20.04.94	A071782	53.5		56.0		
			56.5	55.0	57.0	56.5	1.03
25.03.94	22.04.94	A072633	56.0		58.0		
			57.5	56.8	57.0	57.5	1.01
25.03.94	22.04.94	A072507	55.0		58.5		
			55.0	55.0	60.0	59.3	1.08
25.03.94	22.04.94	A072693	56.5		58.5		
			58.0	57.3	57.0	57.8	1.01
04.04.94	02.05.94	A076428	55.5		53.0		
			56.0	55.8	56.5	54.8	0.98
04.04.94	02.05.94	A076373	56.0		58.0		
			58.0	57.0	56.5	57.3	1.00
04.04.94	02.05.94	A076280	66.5		67.5		
			66.0	66.3	69.0	68.3	1.03
09.04.94	07.05.94	A077830	53.5		53.0		
			52.0	52.8	52.0	52.5	1.00

**Table 6 - Results of Tests on Grade 40 Cubes from Contract No. UA 11/91
- Central Reclamation, Phase I**

Sheet 2 of 4

DATE CAST	Date Tested	Batch Number	150 mm Cubes		100mm Cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
09.04.94	07.05.94	A077671	52.5		50.0		
			52.5	52.5	50.5	50.3	0.96
09.04.94	07.05.94	A077754	56.5		58.5		
			57.5	57.0	59.0	58.8	1.03
10.04.94	08.05.94	A077954	54.0		58.5		
			52.5	53.3	60.0	59.3	1.11
10.04.94	08.05.94	A077959	59.0		59.0		
			59.0	59.0	57.0	58.0	0.98
12.04.94	10.05.94	A078600	51.0		52.5		
			48.5	49.8	50.5	51.5	1.04
12.04.94	10.05.94	A078667	54.5		54.0		
			54.0	54.3	52.0	53.0	0.98
12.04.94	10.05.94	A078730	57.0		58.0		
			56.5	56.8	58.0	58.0	1.02
13.04.94	11.05.94	A078855	47.0		44.0		
			45.5	46.3	50.0	47.0	1.02
13.04.94	11.05.94	A078967	49.5		46.5		
			48.5	49.0	50.5	48.5	0.99
13.04.94	11.05.94	A079204	53.0		51.0		
			52.0	52.5	50.0	50.5	0.96
15.04.94	13.05.94	A080049	50.0		47.5		
			50.0	50.0	52.0	49.8	1.00
16.04.94	14.05.94	A080364	52.0		53.0		
			50.5	51.3	54.5	53.8	1.05
19.04.94	17.05.94	A081291	49.0		54.5		
			48.5	48.8	53.5	54.0	1.11
19.04.94	17.05.94	A081225	50.0		55.0		
			51.5	50.8	56.5	55.8	1.10
20.04.94	18.05.96	A081626	57.5		55.0		
			57.5	57.5	54.5	54.8	0.95
20.04.94	18.05.94	A081726	47.5		53.5		
			51.0	49.3	54.0	53.8	1.09
20.04.94	18.05.94	A081679	53.5		61.0		
			53.0	53.3	60.0	60.5	1.14
21.04.94	19.05.94	A081925	42.0		43.5		
			42.0	42.0	45.0	44.3	1.05
21.04.94	19.05.94	A082004	45.5		48.5		
			46.5	46.0	47.5	48.0	1.04
22.04.94	20.05.94	A082366	46.0		46.5		
			46.0	46.0	45.0	45.8	0.99
25.04.94	23.05.94	A083186	59.5		61.5		
			59.0	59.3	60.0	60.8	1.03
25.04.94	23.05.94	A083251	58.5		62.0		
			59.0	58.8	60.5	61.3	1.04
25.04.94	23.05.94	A083148	62.5		65.0		
			63.0	62.8	66.0	65.5	1.04
27.04.94	25.05.94	A083975	47.5		49.5		
			47.0	47.3	46.5	48.0	1.02
27.04.94	25.05.94	A084034	45.0		48.5		
			45.0	45.0	49.5	49.0	1.09
29.04.94	27.05.94	A085088	47.5		47.5		
			48.0	47.8	47.5	47.5	0.99

**Table 6 - Results of Tests on Grade 40 Cubes from Contract No. UA 11/91
- Central Reclamation, Phase I**

Sheet 3 of 4

DATE CAST	Date Tested	Batch Number	150 mm Cubes		100mm Cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
29.04.94	27.05.94	A084999	53.5		56.5		
			52.0	52.8	53.5	55.0	1.04
29.04.94	27.05.94	A084874	52.0		48.5		
			51.0	51.5	52.0	50.3	0.98
30.04.94	28.05.94	A085226	47.5		55.0		
			47.5	47.5	55.0	55.0	1.16
30.04.94	28.05.94	A085263	48.5		56.0		
			48.0	48.3	59.5	57.8	1.20
30.04.94	28.05.94	A085296	56.5		56.5		
			57.0	56.8	57.5	57.0	1.00
09.05.94	06.06.94	A087984	49.0		58.5		
			48.5	48.8	47.5	53.0	1.09
09.05.94	06.06.94	A088049	55.5		54.5		
			52.5	54.0	52.0	53.3	0.99
10.05.94	07.06.94	A088480	54.5		57.0		
			57.0	55.8	55.0	56.0	1.00
10.05.94	07.06.94	A088549	62.0		66.0		
			62.0	62.0	62.5	64.3	1.04
10.05.94	07.06.94	A088616	59.0		59.0		
			59.5	59.3	57.0	58.0	0.98
13.05.94	10.06.94	A089775	49.5		52.5		
			51.0	50.3	48.0	50.3	1.00
17.05.94	14.06.94	A091330	47.0		50.0		
			46.0	46.5	49.5	49.8	1.07
17.05.94	14.06.94	A091365	50.0		48.5		
			48.5	49.3	46.5	47.5	0.96
17.05.94	14.06.94	A091270	52.0		51.5		
			52.0	52.0	52.0	51.8	1.00
17.05.94	14.06.94	A091211	57.5		56.0		
			56.0	56.8	52.5	54.3	0.96
17.05.94	14.06.94	A091155	50.5		50.0		
			49.0	49.8	55.0	52.5	1.06
22.05.94	19.06.94	A093328	56.5		58.5		
			57.5	57.0	58.5	58.5	1.03
22.05.94	19.06.94	A093334	55.5		58.0		
			54.5	55.0	58.5	58.3	1.06
28.05.94	25.06.94	A095216	55.0		53.0		
			55.5	55.3	54.5	53.8	0.97
28.05.94	25.06.94	A095245	56.0		53.5		
			51.0	53.5	55.0	54.3	1.01
04.06.94	02.07.94	A097298	55.5		58.0		
			55.0	55.3	60.0	59.0	1.07
10.06.94	08.07.94	A099200	51.0		50.0		
			51.0	51.0	49.5	49.8	0.98
10.06.94	08.07.94	A099220	49.0		47.5		
			50.5	49.8	47.5	47.5	0.95
15.06.94	13.07.94	A100039	51.5		53.5		
			52.5	52.0	53.0	53.3	1.02
15.06.94	13.07.94	A100073	54.0		52.5		
			51.0	52.5	52.5	52.5	1.00
22.06.94	20.07.94	A102246	53.0		56.5		
			53.0	53.0	58.5	57.5	1.08

**Table 6 - Results of Tests on Grade 40 Cubes from Contract No. UA 11/91
- Central Reclamation, Phase I**

Sheet 4 of 4

DATE CAST	Date Tested	Batch Number	150 mm Cubes		100mm Cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
22.06.94	20.07.94	A102280	51.5		56.0		
			51.5	51.5	53.5	54.8	1.06
22.06.94	20.07.94	A102296	54.5		55.0		
			54.5	54.5	56.0	55.5	1.02
25.06.94	23.07.94	A103563	47.5		49.0		
			47.0	47.3	48.0	48.5	1.03
Legend:			Mean ₁₅₀ =	54.5	Mean ₁₀₀ =	56.1	
Average _x : average strength of the pair of x mm cubes			S.D. ₁₅₀ =	5.90	S.D. ₁₀₀ =	6.30	
					Mean ₁₀₀ /Mean ₁₅₀ =	1.03	
Mean _x : overall mean strength of the x mm cubes					S.D. ₁₀₀ /S.D. ₁₅₀ =	1.07	
S.D. _x : standard deviation of the strength of the x mm cubes							

**Table 7 - Results of Tests on Grade 20 Cubes from Contract No. HY/93/01
- Access Road to Wong Chuk Hang Estate**

Sheet 1 of 1

DATE CAST	DATE TESTED	BATCH NUMBER	150 mm cubes		100mm cubes		Average ₁₀₀
			Cube Strength _i	Average ₁₅₀	Cube Strength _i	Average ₁₀₀	Average ₁₅₀
14.09.94	12.10.94	A127267	38.5	39.0	39.0	39.3	1.01
			39.5		39.5		
14.09.94	12.10.94	A127297	38.5	37.5	37.0	37.0	0.99
			36.5		37.0		
30.09.94	28.10.94	A131843	34.5	33.0	35.5	35.0	1.06
			31.5		34.5		
30.09.94	28.10.94	A131860	33.0	32.8	35.5	35.5	1.08
			32.5		35.5		
18.10.94	15.11.94	A138400	29.0	28.8	30.5	30.8	1.07
			28.5		31.0		
30.10.94	27.11.94	A143035	51.0	50.0	51.5	48.8	0.98
			49.0		46.0		
30.10.94	27.11.94	A143039	48.0	48.3	54.0	53.0	1.10
			48.5		52.0		
22.11.94	20.12.94	A151868	42.0	42.8	43.5	44.3	1.04
			43.5		45.0		
22.11.94	20.12.94	A152217	42.5	43.0	47.5	47.3	1.10
			43.5		47.0		
Legend:			Mean ₁₅₀ =	39.4	Mean ₁₀₀ =	41.2	
Average _x : average strength of the pair of x mm cubes			S.D. ₁₅₀ =	7.05	S.D. ₁₀₀ =	7.30	
Mean _x : overall mean strength of the x mm cubes			Mean ₁₀₀ / Mean ₁₅₀ =		1.04		
S.D. _x : standard deviation of the strength of the x mm cubes			S.D. ₁₀₀ / S.D. ₁₅₀ =		1.04		

**Table 8 - Results of Tests on Grade 30 Cubes from Contract No. HY/93/01
- Access Road to Wong Chuk Hang Estate**

Sheet 1 of 2

Date Cast	Date Tested	Batch Number	150 mm Cubes		100mm Cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
17.05.94	14.06.94	A091396	45.5		42.0		
			45.0	45.3	48.5	45.3	1.00
17.05.94	14.06.94	A091453	45.0		46.5		
			45.5	45.3	45.5	46.0	1.02
03.10.94	31.10.94	A132781	50.5		52.5		
			49.0	49.8	50.5	51.5	1.04
03.10.94	31.10.94	A132845	55.0		52.0		
			50.5	52.8	52.5	52.3	0.99
19.10.94	16.11.94	A138915	48.5		52.5		
			52.0	50.3	54.0	53.3	1.06
19.11.94	16.11.94	A138972	41.5		52.5		
			47.0	44.3	51.0	51.8	1.17
20.10.94	17.11.94	A139175	46.0		50.0		
			45.5	45.8	49.5	49.8	1.09
20.10.94	17.11.94	A139231	46.5		51.5		
			46.0	46.3	51.0	51.3	1.11
20.10.94	17.11.94	A139268	45.0		52.0		
			48.0	46.5	51.0	51.5	1.11
20.10.94	17.11.94	A139390	46.0		50.5		
			45.0	45.5	49.5	50.0	1.10
22.10.94	19.11.94	A139976	47.5		52.5		
			49.5	48.5	50.0	51.3	1.06
22.10.94	19.11.94	A140020	50.0		56.0		
			50.5	50.3	51.5	53.8	1.07
22.10.94	19.11.94	A140035	49.0		53.5		
			50.5	49.8	53.5	53.5	1.08
23.10.94	20.11.94	A140356	41.5		45.5		
			42.5	42.0	44.0	44.8	1.07
23.10.94	20.11.94	A140393	43.5		44.5		
			44.0	43.8	44.0	44.3	1.01
27.10.94	24.11.94	A141980	41.0		44.0		
			37.5	39.3	40.5	42.3	1.08
27.10.94	24.11.94	A141993	42.0		42.0		
			42.0	42.0	39.5	40.8	0.97
29.10.94	26.11.94	A142572	46.5		46.0		
			48.0	47.3	50.0	48.0	1.02
29.10.94	26.11.94	A142502	47.5		49.0		
			46.5	47.0	51.0	50.0	1.06
29.10.94	26.11.94	A142621	45.0		53.0		
			45.5	45.3	48.5	50.8	1.12
01.11.94	29.11.94	A143995	52.0		54.0		
			52.0	52.0	53.5	53.8	1.03
01.11.94	29.11.94	A144009	52.0		52.0		
			51.5	51.8	51.0	51.5	1.00
05.11.94	03.12.94	A145211	45.5		46.5		
			45.5	45.5	53.0	49.8	1.09
05.11.94	03.12.94	A145401	47.0		45.5		
			45.0	46.0	42.5	44.0	0.96
27.11.94	25.12.94	A154000	58.5		53.0		
			52.5	55.5	61.0	57.0	1.03
03.12.94	31.12.94	A155948	53.0		54.5		
			57.5	55.3	57.5	56.0	1.01

Table 8 - Results of Tests on Grade 30 Cubes from Contract No. HY/93/01
- Access Road to Wong Chuk Hang Estate

Sheet 2 of 2

Date Cast	Date Tested	Batch Number	150 mm Cubes		100mm Cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
03.12.94	31.12.94	A156183	52.0	54.8	56.5	58.3	1.06
			57.5		60.0		
03.12.94	31.12.94	A156207	55.5	55.8	60.5	59.8	1.07
			56.0		59.0		
04.12.94	01.01.95	A156403	38.0	37.0	38.0	39.0	1.05
			36.0		40.0		
07.12.94	04.01.95	A157418	43.0	43.3	47.5	49.3	1.14
			43.5		51.0		
07.12.94	04.01.95	A157554	45.5	47.3	46.0	47.5	1.01
			49.0		49.0		
Legend:			Mean ₁₅₀ =	47.4	Mean ₁₀₀ =	50.1	
Average _x : average strength of the pair of x mm cubes			S.D. ₁₅₀ =	4.86	S.D. ₁₀₀ =	5.12	
			Mean ₁₀₀ / Mean ₁₅₀ =		1.06		
Mean _x : overall mean strength of the x mm cubes			S.D. ₁₀₀ / S.D. ₁₅₀ =		1.05		
S.D. _x : standard deviation of the strength of the x mm cubes							

**Table 9 - Results of Tests on Grade 40 Cubes (with PFA) from Contract No. HY/93/01
- Access Road to Wong Chuk Hang Estate**

Sheet 1 of 2

Date Cast	Date Tested	Batch Number	150 mm Cubes		100mm Cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
04.10.94	01.11.94	A133405	53.5		51.0		
			61.0	57.3	56.5	53.8	0.94
04.10.94	01.11.94	A133319	58.5		52.5		
			55.5	57.0	52.5	52.5	0.92
08.10.94	05.11.94	A134851	55.0		48.0		
			56.0	55.5	46.5	47.3	0.85
08.10.94	05.11.94	A135039	51.5		49.5		
			54.0	52.8	50.5	50.0	0.95
10.10.94	07.11.94	A135579	62.5		63.5		
			56.5	59.5	65.0	64.3	1.08
10.10.94	07.11.94	A135614	57.5		65.5		
			61.0	59.3	63.5	64.5	1.09
12.10.94	09.11.94	A136334	55.5		47.5		
			51.0	53.3	51.0	49.3	0.92
12.10.94	09.11.94	A136347	51.5		52.5		
			51.5	51.5	53.0	52.8	1.02
15.10.94	12.11.94	A137327	61.0		65.5		
			62.5	61.8	68.0	66.8	1.08
15.10.94	12.11.94	A137244	62.5		70.5		
			58.5	60.5	69.0	69.8	1.15
17.10.94	14.11.94	A137907	52.5		59.0		
			57.0	54.8	58.5	58.8	1.07
25.10.94	22.11.94	A141020	67.0		73.5		
			64.0	65.5	70.5	72.0	1.10
25.10.94	22.11.94	A141177	66.5		71.0		
			65.5	66.0	73.5	72.3	1.09
02.11.94	30.11.94	A144121	60.5		69.5		
			60.5	60.5	68.0	68.8	1.14
03.11.94	01.12.94	A144483	56.0		57.5		
			57.5	56.8	58.0	57.8	1.02
03.11.94	01.12.94	A144504	55.0		58.5		
			58.0	56.5	58.0	58.3	1.03
08.11.94	06.12.94	A146524	60.5		63.5		
			59.0	59.8	66.5	65.0	1.09
08.11.94	06.12.94	A146566	60.5		59.5		
			57.0	58.8	67.0	63.3	1.08
18.11.94	16.12.94	A150525	59.5		57.0		
			60.5	60.0	58.0	57.5	0.96
20.11.94	18.12.94	A151336	66.5		65.0		
			65.0	65.8	65.0	65.0	0.99
23.05.95	20.06.95	A209276	59.5		57.0		
			57.0	58.3	58.0	57.5	0.99
24.05.95	20.06.95	A209287	57.0		61.5		
			57.5	57.3	58.5	60.0	1.05
11.05.95	21.06.95	A209357	53.5		58.0		
			51.5	52.5	59.5	58.8	1.12
11.05.95	21.06.95	A209369	56.5		59.5		
			56.5	56.5	58.5	59.0	1.04
31.05.95	28.06.95	A212405	58.5		57.0		
			55.5	57.0	57.0	57.0	1.00
31.05.95	28.06.95	A212396	54.0		59.0		
			57.0	55.5	60.0	59.5	1.07

**Table 9 - Results of Tests on Grade 40 Cubes (with PFA) from Contract No. HY/93/01
- Access Road to Wong Chuk Hang Estate**

Sheet 2 of 2

Date Cast	Date Tested	Batch Number	150 mm Cubes		100mm Cubes		Average ₁₀₀
			Cube Strength	Average ₁₅₀	Cube Strength	Average ₁₀₀	Average ₁₅₀
31.05.95	28.06.95	A212417	54.0	55.8	52.5	55.8	1.00
			57.5		59.0		
12.06.95	10.07.95	A216460	54.0	55.3	59.5	60.3	1.09
			56.5		61.0		
12.06.95	10.07.95	A216502	58.5	58.3	57.5	58.3	1.00
			58.0		59.0		
12.06.95	10.07.95	A216538	54.5	56.3	58.5	59.3	1.05
			58.0		60.0		
Legend:			Mean ₁₅₀ =	57.8	Mean ₁₀₀ =	59.8	
Average _x : average strength of the pair of x mm cubes			S.D. ₁₅₀ =	3.94	S.D. ₁₀₀ =	6.49	
Mean _x : overall mean strength of the x mm cubes			Mean ₁₀₀ / Mean ₁₅₀ =		1.03		
S.D. _x : standard deviation of the strength of the x mm cubes			S.D. ₁₀₀ / S.D. ₁₅₀ =		1.65		

Table 10 - Summary of Cube Test Results

Project Name	Project Number	Cubes		Compression Strength (N/mm ²)				Mean ₁₀₀
				Mean		Standard Deviation		
		Grade	Pair	150mm (Mean ₁₅₀)	100mm (Mean ₁₀₀)	150mm (SD ₁₅₀)	100mm (SD ₁₀₀)	Mean ₁₅₀
Sheung Shui Treatment Works Stage II	25/WSD/92	D20/20	98	33.2	34.3	5.32	5.49	1.03
		D35/20	88	55.2	56.6	4.70	5.16	1.03
Stanley Area Sewerage and Sewage Disposal	CV/89/28	35/20 PFA	48	52.4	55.1	4.30	5.45	1.05
Special School at Area 14 Tin Shui Wai	SSA 389	30/20	110	45.8	50.0	5.16	5.90	1.09
West Kowloon Corridor, Yau Ma Tei Section	HY/89/04	50/20	96	61.8	65.3	8.94	8.14	1.06
Central Reclamation Phase I	UA 11/91	40/20	162	54.5	56.1	5.90	6.30	1.03
Access Road to Wong Chuk Hang Estate	HY/93/01	D20/20	18	39.4	41.2	7.05	7.30	1.04
		D30/20	62	47.4	50.1	4.86	5.12	1.06
		D40/20 PFA	60	57.8	59.8	3.94	6.49	1.03
		Mean value				5.57	6.15	1.05

Table 11 - Compliance Criteria for Compressive Strength of Designed Mix Concrete Given in the General Specification for Civil Engineering Works (Hong Kong Government, 1992)

Grade Strength (MPa)	Compliance Criteria	Column A	Column B
		Maximum amount by which each test result may be below the grade strength (MPa)	Minimum amount by which the average of any four consecutive test results shall be above the grade strength (MPa)
20 or greater	C1	3	5
	C2	3	3
below 20	C3	2	2
Note: Compliance criteria C2 shall apply if in the opinion of the Engineer there is sufficient evidence that the standard of quality control using similar materials and plant is such that the standard deviation for at least 40 test results will not exceed 5 MPa			

Type	National Code	Number of Tests	Standard Deviation	Constant λ	Compliance Criterion
A	German Federal Republic	35	Estimated by S_{35}	1.65	$\bar{x}_{35} - 1.65 S_{35} \geq f_c$
B		15	Known σ	1.65	$\bar{x}_{15} - 1.65 \sigma \geq f_c$
C		3	Unknown	--	$\bar{x}_3 - 5.0 \geq f_c$ and $x_1 \geq f_c$
D		9	Unknown	--	$\bar{x}_3 - 5.0 \geq f_c$ and $x_1 \geq 0.8 f_c$
E	Netherlands	12	Estimated by S_{35}	1.52	$\bar{x}_{12} - 1.52 S_{12} \geq f_c$
F		6	Known σ	1.52	$\bar{x}_6 - 1.52 \sigma \geq f_c$
G	United Kingdom	4	Known σ	0.82	$\bar{x}_4 - 0.82 \sigma \geq f_c$
H	Spain	12	Unknown	--	$2 \frac{x_1 + x_2 + \dots + x_5}{5} - x_6 \geq f_c$
I		6	Unknown	--	$x_1 + x_2 - x_3 \geq f_c$
J	U.S.A.	3	Unknown	--	$\bar{x}_3 - 5.0 \geq f_c$ and $x_1 \geq 0.8 f_c$
K	France	30	Estimated by S_{35}	1.69	$\bar{x}_{30} - 1.69 S_{30} \geq f_c$

Table 13 - Proposed Compliance Criteria for the Compressive Strength of the 100mm Cubes of Designed Mixed Concrete

Grade Strength (MPa)	Compliance Criteria	Column A	Column B
		Maximum amount by which each test result may be below the grade strength (MPa)	Minimum amount by which the average of any four consecutive test results shall be above the grade strength (MPa)
20 or greater	C1	2	7
	C2	2	5
below 20	C3	2	3

Note: Compliance criteria C2 shall apply if in the opinion of the Engineer there is sufficient evidence that the standard of quality control using similar materials and plant is such that the standard deviation for at least 40 test results will not exceed 5.5 MPa

