A Preliminary Assessment of Shrinkage and Creep Losses in Pretensioned Concrete used in Sri Lanka

S. R. De S. Chandrakeerthy, C. Vipulanandan and N. Gowripalan

1. Introduction

Pretensioned concrete is widely used in Sri Lanka for certain applications like bridge beams, floor slabs and floor beams, roof beams, purlins, telegraph posts, railway sleepers, etc. Evaluation of losses, accurately, is an important step in the design of pretensioned concrete structures. Of these, losses due to shrinkage and creep contribute largely to the total losses. At present, designers in Sri Lanka compute losses using CP 110.[1] The quality of constituent materials used in pretensioned concrete construction in Sri Lanka is very high. However, ambient conditions, high water content due to non-availability of special admixtures which function as workability aids, poor grading of aggregates, poor workmanship, inadequate curing may influence local concretes to attain creep and shrinkage strains different from those specified in CP 110. Hence it was thought opportune to conduct an investigation on concrete used in pretensioned prestressed concrete production in Sri Lanka.

This investigation was aimed to get some idea of the magnitudes of shrinkage and creep strains of local concrete and to assess the validity of using CP 110 values for local conditions.

2. Experimental Investigation

2.1 *General*

In Sri Lanka the main pretensioning pre-cast yards are the State Development and Construction Corporation yard at Ratmalana and the State Engineering Corporation yards at Narahenpita and Ekala. It was found that at these yards concrete mix used was the same, namely 1 : 1½ : 3 (¾"). Aggregates used were similar and any variation in quality of aggregates at the different pre-cast yards was not considered to be greater than the variation in quality of aggregates to be expected with time at any one pre-cast yard. However, water-cement ratio was different. At the Ratmalana yard it was 0.40 while at Ekala and Narahenpita it was 0.38. Due to higher water-cement ratio used at S. D. & C. C., it was thought that results derived using concrete of S.D. & C.C. can be used by both S.E.C. and S.D. & C.C. with confidence as any error introduced will be on the conservative side. This is so as losses for water-cement ratio of 0.38 will be less than for those for a water-cement ratio of 0.40.

2.2 *Experimental investigation on shrinkage losses*

Shrinkage (7, 9) is defined as the deformation of concrete which occurs without externally applied loads. Following factors affect shrinkage :

(*a*) Type and composition of cement
(*b*) Fineness of cement
(*c*) Presence of admixtures
(*d*) Cement and water content of the mix
(*e*) Agg regate properties and aggregate content
(*f*) Size and shape of specimen and
(*g*) Ambient temperature and humidity.

In Sri Lanka only ordinary portland cement complying to BS 12 is used and hence variable (*a*) above need not be considered. For the same reason fineness variation is within limits specified in BS 12 and this variable need not be considered. As admixtures are not used in pretensioned concretes in Sri Lanka, this variable is not relevant. By using concrete that is used at the concrete yard, the variables (*d*) and (*e*) are controlled at the required values so that results represent shrinkage for concretes locally used. Variable (*f*) can be controlled by testing for shrinkage as specified in BS 1881 (2). At the concrete yard, curing is done by wetting the concrete for at least three days after casting. By curing the test specimens in a similar manner, variable (*g*) can be controlled so that test specimens reasonably represent the site concrete in maturity in all stages.

Having controlled the many variables which affect concrete so that results indicate shrinkage strains of local pretensioned concrete, the next stage is to decide on specimen size, measuring instrument to be used, number of specimens to be tested and the main environment factors to be measured.

Previous researchers (3, 4) have used specimen sizes varying from 4" × 4" × 20" to 3" × 3" × 12". BS 1881; Part 5 (2) specifies specimen size to be of length 150 to 300 mm. and the cross section shall be as near as practical to 75 mm. × 75 mm. As our investigation dealt with both shrinkage and creep losses, specimen size of 4" × 4" × 20" was adopted which was the size of creep specimens. It should be emphasised that this size is within the range of sizes used by previous researchers. According to BS 1881 : Part 5 the measuring apparatus shall incorporate a micrometer gauge or a suitable dial gauge reading accurately to 0.0025 mm.

'Soil test Demec gauge' was used which satisfies the requirements for accuracy. According to CP 110 design clauses, the main factor on which shrinkage depends is the relative humidity.

Hence it was decided to measure relative humidity of the environment in which specimens were placed, by observing wet and dry bulb temperatures. As done by some previous researchers, three specimens were used to measure shrinkage.

All specimens were demoulded 24 hours after casting. Brass De Mec points were fixed on three sides of each specimen with Araldite. Initially the De Mec points were fixed at a distance of 10.1994". Curing was done for 3 days by sprinkling water on the specimens and for the first few weeks, readings were taken daily. As shrinkage reduces with time, later measurements were taken at longer intervals of time.

As the main aim of the study was to investigate the shrinkage-time behavior and the magnitude of shrinkage to be expected in concrete used for pretensioned concrete in Sri Lanka, a continuous record of shrinkage with time was observed. This paper reports the results of 180 days duration and the test is continuing.

2.3 *Experimental investigation on creep losses*

Creep (7,8,9) is a time dependent property of concrete. When the concrete is subjected to sustained stress it undergoes a gradual change in strain. This increase in strain is a function of time and is generally termed as creep. Creep includes deformation which occurs as a result of application of load only.

Factors affecting creep of concrete are :

(*a*) Type and composition of cement
(*b*) Fineness of cement
(*c*) Presence of admixtures
(*d*) Cement and water content of the mix
(*e*) Aggregate properties and aggregate content
(*f*) Size and minimum dimensions of the specimen
(*g*) Ambient temperature and humidity conditions
(*h*) Intensity of loading
(*i*) Age at the time of loading and
(*j*) Amount of compaction and air content.

Since same concrete mix used at a concrete yard is used, similar curing conditions were maintained, and because smaller sections were used, it can be considered that variables are effectively controlled so that values of creep obtained will realistically represent creep to be expected in pretensioned concrete made in Sri Lanka.

C · 110 specifies maximum compressive stress for serviceability of 0.33f cu which is about 16.5N/mm. for grade 50 concrete and 13.2N/mm.^{2} for grade 40 concrete. But actual stresses will be lower than this maximum permissible value. 8 to 13N/mm.^{2} was considered to be the order of stress to be expected in Sri Lanka. Crushing strength of concrete cubes at 28 days gave a mean strength of 52.1N/mm.^{2} and a characteristic strength of 40.8N/mm.^{2}. Cube strength at transfer of 7 days was measured to be 27.81N/mm.^{2}. Hence a stress of 10.16N/mm.^{2} was applied to the creep specimen using a spring loaded test rig (Fig. 1). The applied stress was within $\frac{1}{3}$ cube strength at transfer and $\frac{1}{2}$ cube strength at transfer.

Earlier studies on the creep of concrete were done on 6" cylindrical specimens and rectangular or square prisms which varied in size from 6" to 3". In this investigation 4"×4" square prism was adopted.

The height of the specimen was finalised by considering the following factors :

(*a*) Specimen height should satisfy the conditions of CP 110 for short columns;
(*b*) Height of the specimen should be such that it could be placed in the creep test rig;
(*c*) The maximum length that could be measured by the measuring gauge.

Based on the above considerations specimen length adopted was 20".

Previous researchers have used number of specimens varying from 2 to 5. The more the number of specimens tested, better and accurate will be the results. As one test rig was available, number of specimens tested was one. However, this was considered adequate to make a preliminary assessment of creep losses.

Measuring gauge used was a Soil test Demec gauge which can read accurately to 0.0025 mm.

At S. D. & C. C. yard the local transfer normally takes place on the 7th day after casting. But in some instances it is done on 8th or 9th day after casting. but of these most critical case will be the 7th day transfer, hence specimens were loaded on 7th day after casting.

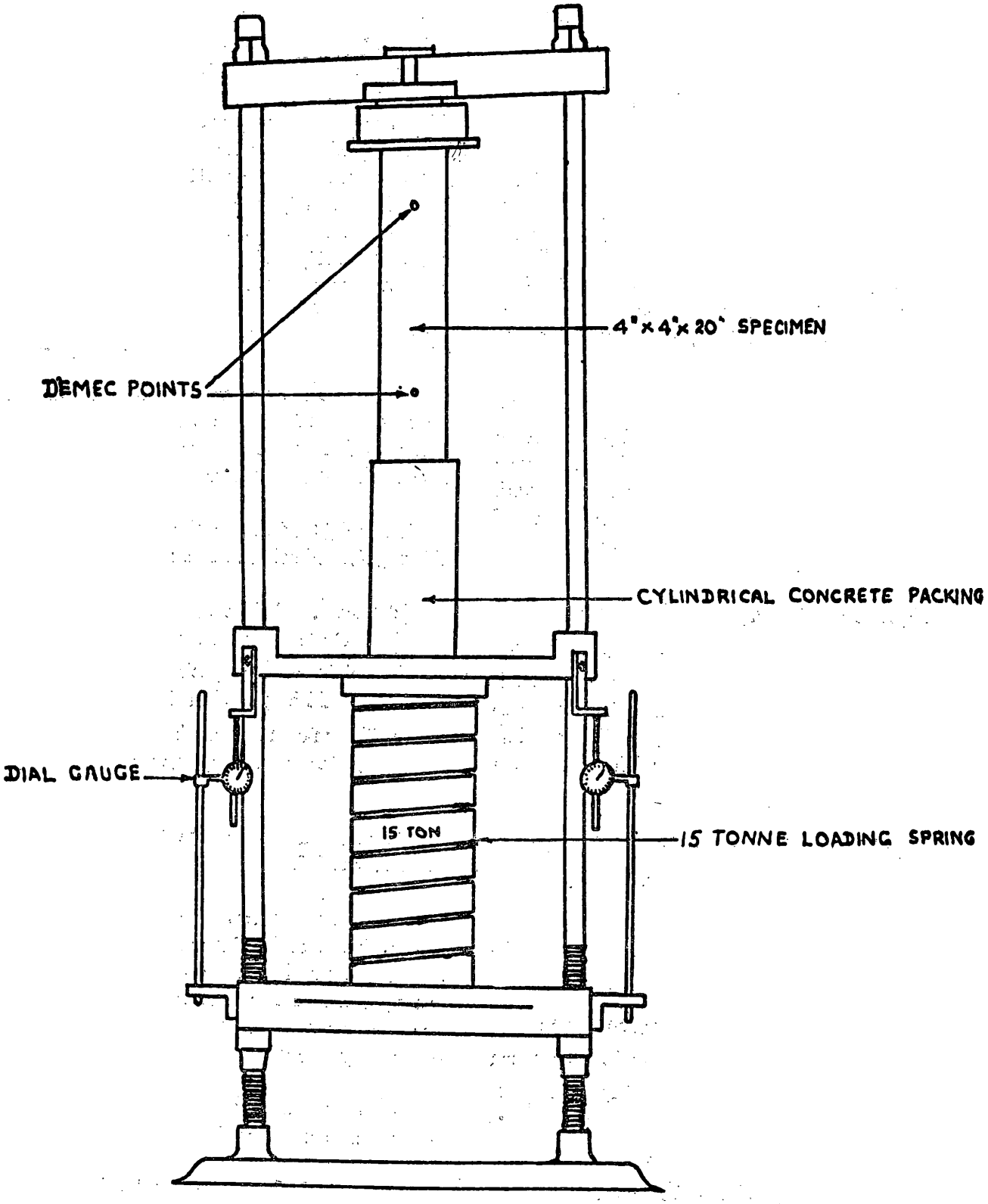


FIG 1. DIAGRAM SHOWING A SKETCH OF THE CREEP TEST RIG.

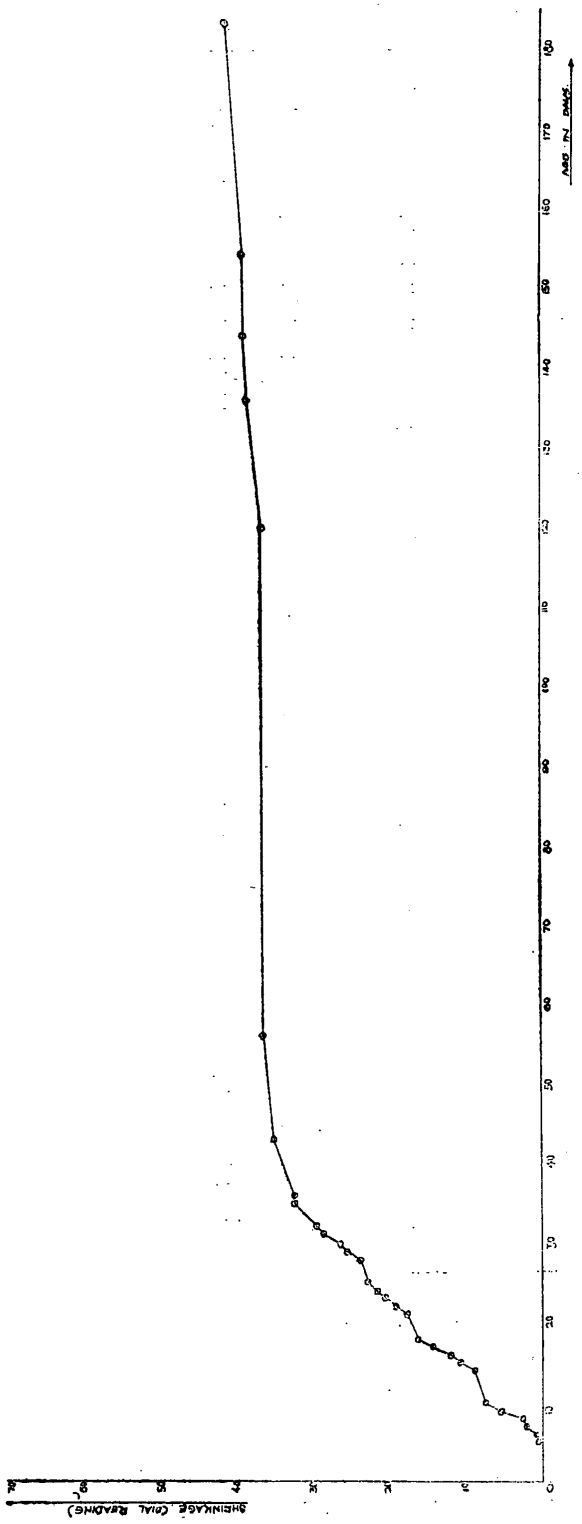


Fig. 2. Variation of Shrinkage with time.

TABLE 1.

Appendix 1 (C)

Age (*in days*)	*Temperatures* (*in F*) Dry	Wet	*Relative Humidity* (%)	*Shrinkage Specimens* (*in* 0.0001') A^1	A^2	A^3	B^1	B^2	B^3	C^1	C^2	C^3	*Average Shrinkage* × .0001"
1 ..	79	78	95	00	00	00	00	00	00	00	07	00	00
2 ..	80	78	92	00	00	00	00	00	00	00	00	00	00
3 ..	79	77	92	00	00	00	00	00	00	00	00	00	00
4 ..	80	79	96	00	00	00	00	00	00	00	00	00	00
5 ..	80	78	92	00	02	00	00	00	00	00	00	00	0.2
6 ..	80	78	92	00	03	00	00	00	00	03	00	00	0.7
7 ..	82	79	87	00	07	00	00	02	00	07	00	00	1.8
8 ..	82	79	87	00	08	00	00	04	00	10	00	00	2.4
9 ..	82	79	87	00	20	00	00	12	00	14	00	00	5.1
10 ..	82	80	92	00	31	00	00	18	00	16	00	00	7.2
14 ..	84	81	87	00	38	00	00	23	00	18	00	00	8.8
15 ..	83	81	91	00	43	00	00	31	00	20	00	00	10.4
16 ..	82	80	92	00	48	00	00	36	00	24	00	00	11.6
17 ..	82	80	92	00	54	00	00	41	00	29	03	00	14.1
18 ..	83	80	87	00	40	00	00	45	00	33	07	00	16.1
21 ..	82	79	87	00	62	00	00	47	00	38	10	00	17.4
22 ..	83	79	83	00	64	00	00	49	00	42	15	00	18.9
23 ..	82	79	87	00	65	00	00	50	00	48	18	00	20.1
24 ..	83	79	83	00	66	00	00	52	00	53	20	00	21.2
25 ..	83	80	87	00	69	00	00	56	00	58	22	00	22.8
28 ..	83	80	87	00	71	00	00	59	00	60	23	00	23.7
29 ..	82	80	92	00	75	00	00	62	00	64	29	00	25.6
30 ..	82	79	87	00	77	00	03	66	00	67	31	00	27.1
31 ..	82	80	92	00	79	00	00	68	00	70	33	00	28 4
32 ..	82	80	92	00	80	00	07	68	00	72	36	00	29.2
35 ..	82	80	92	00	85	00	08	74	00	75	41	08	32.3
36 ..	82	80	92	00	85	00	0	74	00	76	41	08	32.4
43 ..	82	79	87	00	88	00	13	74	00	76	41	24	35.1
56 ..	82	79	87	00	90	00	13	75	00	74	40	36	36 4
120 ..	83	78	81	00	92	03	13	75	00	74	40	40	36.7
136 ..	83	78	81	00	91	03	14	75	00	80	44	43	38.9
154 ..	84	77	79	00	91	04	16	77	00	80	44	43	39.4
183 ..	85	81	82	00	91	10	17	78	00	84	48	45	41.4

Test procedure consisted of : (*a*) casting specimens using concrete from yard and compacting under yard conditions; (*b*) demoulding specimens after 24 hours; (*c*) fixing De Mec points on surface of the specimen immediately after demoulding, (d) curing for three days as done at the yard by sprinkling water; (*e*) loading the specimen to the desired stress on 7th day after casting; (*f*) taking readings daily for the initial period and after a month of loading the readings were taken weekly; (*g*) adjustment of spring to maintain the desired load after specimen has undergone creep.

3. Experimental Results and Analysis

3.1 *Shrinkage measurements*

Table 1 and Fig. 2 show the shrinkage strains measured over a period of 180 days on concrete made from the mix used for pretensioned pre-stressed beams of S. D. and C. C. yard at Ratmalana. The strain is the average of nine readings measured on three sides of the three shrinkage specimens. Table 1 also shows the relative humidity values which fluctuate between 96% to 79%.

COMPARISON OF OBSERVED VALUES OF SPECIFIC SHRINKAGE WITH CP 110 VALUES. – FIG 3

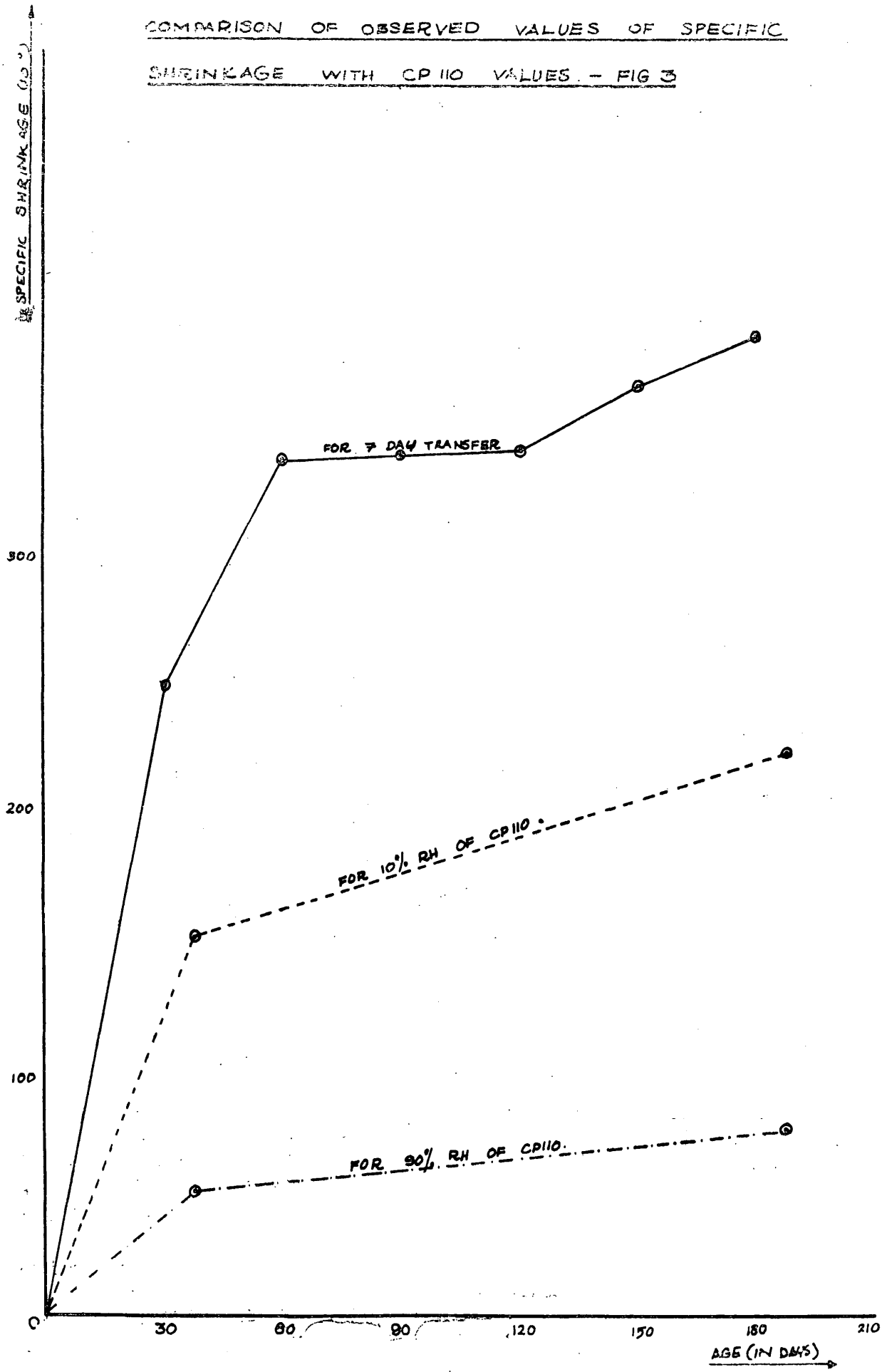


TABLE 2

Age (*in days*)	*Creep Specimen Reading* (0.0001″) *side* 1	*side* 2	*side* 3	*aver.*	*Average Shrinkage* (0.0001″)	*Total Creep* (0.0001″)
7 (1st Oct., 80)	00	02	04	2.0	1.8	0.2
8	00	02	06	2.7	2.4	0.3
9	00	07	09	5.3	5.1	0.2
10	02	10	11	7.7	7.2	0.5
14	02	13	13	9.3	8.8	0.5
15	02	15	16	11.0	10.4	0.6
16	03	16	18	12.3	11.6	0.7
17	05	20	20	15.0	14.1	0.9
18	06	21	24	17.0	16.1	0.9
21	06	22	26	18.0	17.4	0.6
22	07	23	28	19.3	18.9	0.4
23	07	25	30	20.7	20.1	0.6
24	07	26	32	21.7	21.2	0.5
25	09	27	34	23.3	22.8	0.5
28	12	29	34	24.7	28.7	1.0
29	15	29	34	26.7	25.6	1.1
30	16	30	39	28.3	27.1	1.2
31	17	31	42	30.0	28.4	1.6
32	18	31	43	30.7	29.2	1.5
35	20	32	50	34	32.3	1.7
36	20	32	50	34	32.4	1.6
43	22	40	51	37.7	35.1	2.6
56	24	42	56	40.7	36.4	4.3
120	34	58	73	55.0	36.7	17.3
136	35	60	76	57.0	38.9	18.1
154 (25th Feb., 1980)	37	62	78	59.0	39.4	19.6
183 (25th March, 1980)	50	68	82	66.7	41.4	25.3

According to results following table gives shrinkage per unit length for 7th day load transfer.

Age (*in days*)	*Shrinkage per unit length*
30	248×10^{-6}
60	339.4×10^{-6}
90	340.8×10^{-6}
120	342.1×10^{-6}
150	367.5×10^{-6}
180	388.3×10^{-6}
(ultimate)*	(517.7×10^{-6})*

* Ultimate values were not measured yet. These figures were computed using Kong & Evans theory[6] for prediction of ultimate strains.

Figure 3 shows a comparison of shrinkage values obtained experimentally with that recommended by CP110. A large discrepancy exists and it can be attributed to high water-cement ratio, absence of workability aid admixtures, poor curing and poor grading of aggregates.

3.2 *Creep measurements*

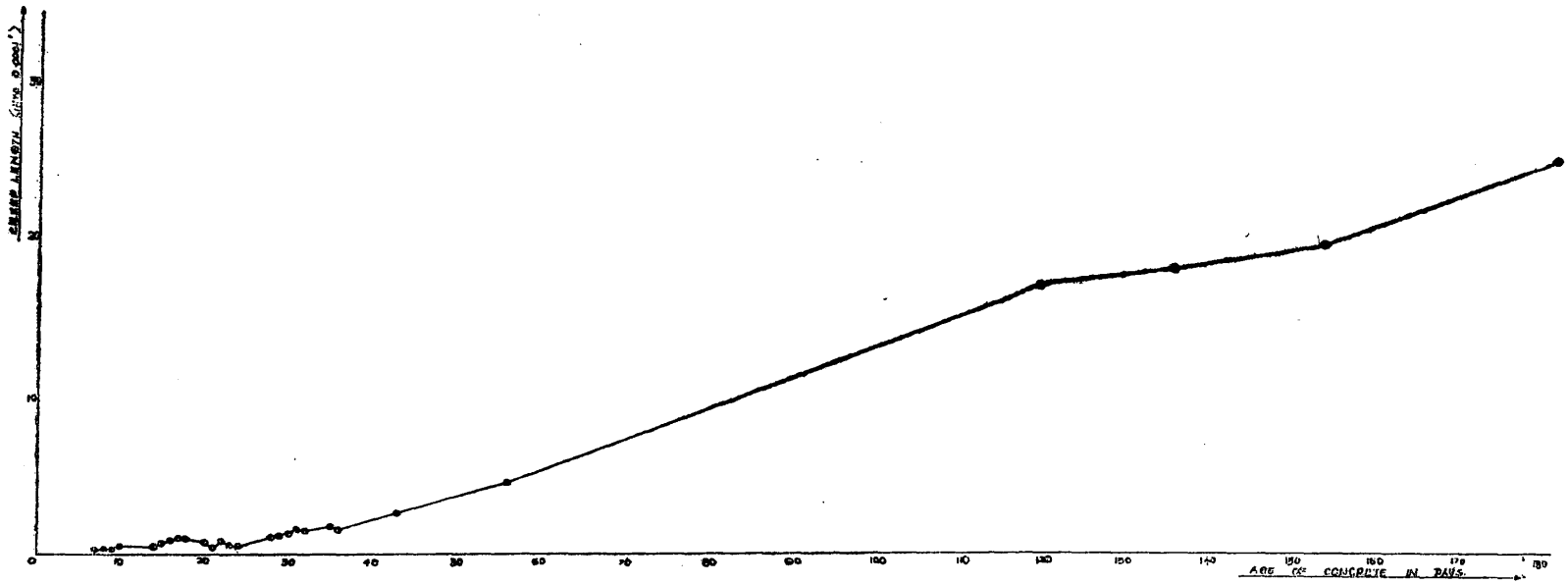
Table 2 and Fig. 4 show the creep strains measured. The creep obtained is the average of all readings taken on the surfaces of the specimen.

According to the results following table gives creep for 7th day load transfer.

Time (*days*)	*Creep* ($\times$ 0.0001″)	*Specific creep* (mm^2/N)
30	1.2	1.20×10^{-6}
60	5.1	4.90×10^{-6}
90	11.2	10.80×10^{-6}
120	17.3	16.6×10^{-6}
150	19.3	18.60×10^{-6}
180	24.7	23.80×10^{-6}
(Ultimate)*	—	(31.80×10^{-6})*

* Ultimate values were not measured yet. These figures were computed using Kong & Evans theory[6] for prediction of ultimate values.

VARIATION OF CREEP WITH TIME - FIG. 4.



SPECIFIC CREEP VS TIME - FIG 5

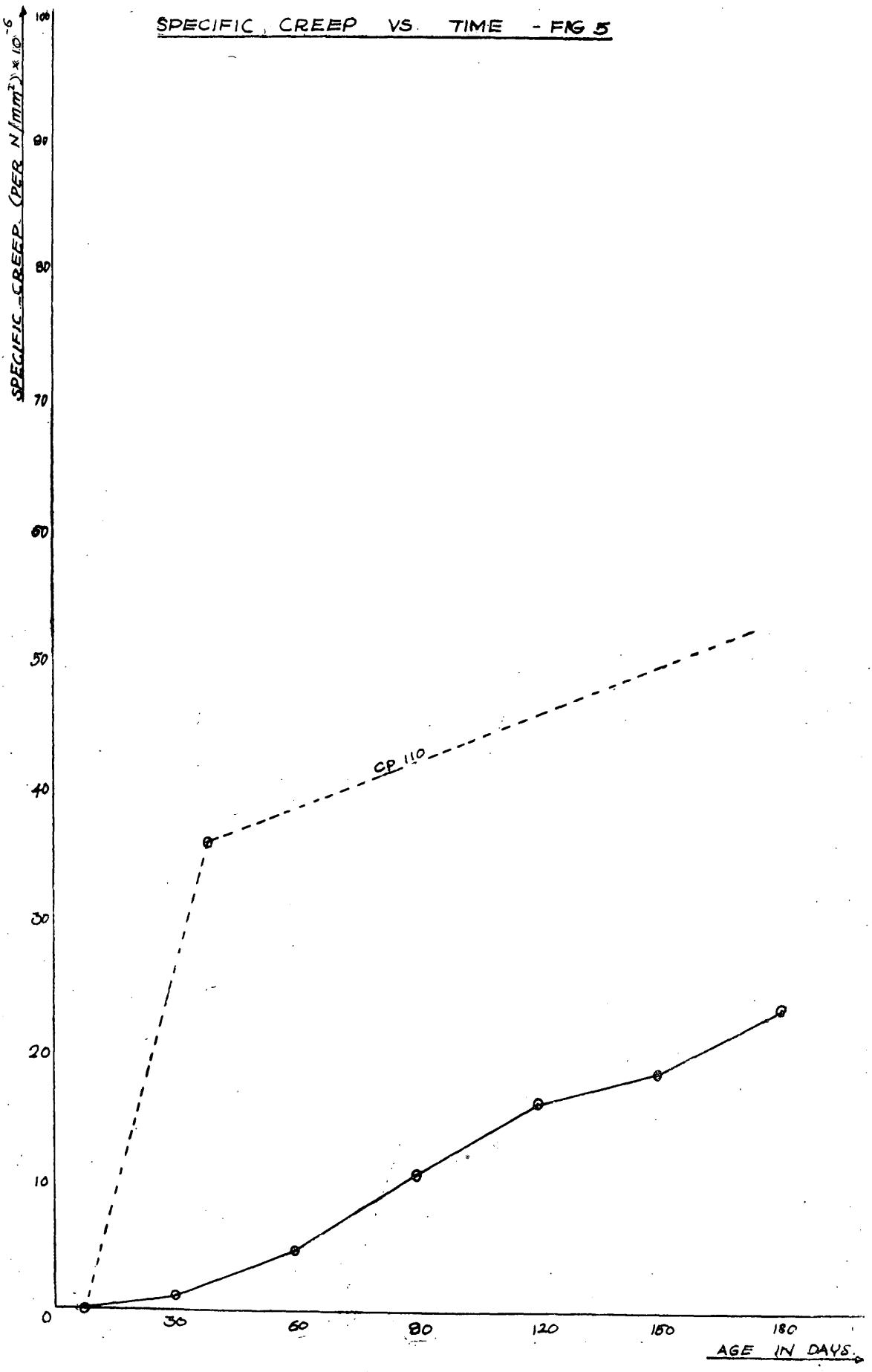


Fig. 5 shows a comparison of specific creep values obtained experimentally with that recommended by CP110. Actual measurements gave values very much less than those in CP110. This may be due to high quality of aggergates used in Sri Lanka.

4. Conclusions

Following conclusions can be drawn from this investigation :

(*a*) Experimental results of shrinkage are very much higher than those recommended by CP110;

(*b*) Experimental results of creep are very much lower than those recommended by CP110;

(*c*) Although accuracy of values used for shrinkage and creep losses in pre-stressed concrete design in Sri Lanka using CP 110 is doubtful, there is no cause for alarm as they tend to give total losses realistically;

(*d*) Further research is needed before we adopt our own values for shrinkage and creep losses. This will take some time as these are long term studies and also due to the fact that for creep testing large number of test rigs are needed.

5. Acknowledgements

Authors wish to thank Mr. E. J. S. Perera, Resident Engineer, S. D. & C. C. concrete yard, Ratmalana for his interest and continued assistance during this investigation. Thanks are also due to Professor D. S. Wijeyesekera for his encouragement.

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පෙරදි කොන්ක්‍රීට් සැලසුම් නිර්මාණයේ සැලකිය යුතු වැදගත් අවස්ථාවක් වනුයේ "හානි වල අගය සෙවීමයි" හැකිළීම සහ රූරාව යන ගතිගුණ ඉහත සඳහන් හානිවලට ප්‍රධාන හේතුව වන බැවින් එම ගතිගුණ වල නිවරදය තක්සේරුව නිර්මාණයේ ප්‍රධාන අවශ්‍යතාවයක් වනු ඇත. ඉහත තක්සේරුව සඳහා වර්තමානයේ භාවිතා වනුයේ සී පී 110 නැමැති ග්‍රන්ථයයි. නමුත් විදේශ රටවල අවශ්‍යතාවන් අනුව නිපැයුණු මෙම ග්‍රන්ථය ලංකික අවශ්‍යතාවයනට නොගැළපෙන බව පැහැදිලිය.

මෙම අන්වේෂණයේ පරමාර්ථය වනුයේ ලාංකික තත්වයන් යටතේ හැකිළීම සහ රූරාව යන ගතිගුණ මූලික වශයෙන් පරීක්ෂණයට භාජනය කොට ලැබෙන ප්‍රතිඵල සී. පී. 110 ග්‍රන්ථයේ සඳහන් අගයන් සමග සංසන්දනය කිරීමයි.

சுருக்கம்

முன்தகைத்த கொங்கிறிற்று விதானத்தில் நட்டங்களின் பெறுமானங்களைத் துணிதல் ஒரு முக்கியமான படியாகும். சுருக்கவும் படரும் முழுநட்டத்திற்கும் பெருமளவு பங்களிப்பதனால், ஒரு விதானத்தின் வெற்றிக்கு அவற்றின் செம்மையான மதிப்பீடு இன்றியமையாதது. எமது நாட்டின் நிலைமை பிரித்தானியாவிலிருந்து. வேறுபட்டிருக்கின்ற போதிலும், தரவு பற்றாக்குறையினால், தற்பொழுது இந்நட்டங்களின் மதிப்பீட்டிற்கு C. P. 110 ஏ பாவிக்கப்படுகின்றது.

மேற்படி ஆராய்வு, எம் நாட்டின் நிலைமைகளின் கீழ் சுருங்கல், படர் என்பவற்றால் ஏற்படக்கூடிய நட்டங்களின் ஆரம்பநிவ் மதிப்பீட்டைக் கொடுப்பதுடன், C. P. 110 பெறுமானங்களுடன் அவதானித்த பெறுமானங்களை ஒப்பிடுகின்றது.