Shrinkage in Concrete Made from Recycled Aggregate

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ABSTRACT— ***Drying shrinkage is one of the type of shrinkage occurs at the very beginning due to the loss of moisture added to the concrete mix after the cement ingredients react with water. A comprehensive study has been conducted on thirty samples of different concrete mixes. The study focusses on the effect of relative humidity and recycled aggregate. Different ratio of recycled coarse aggregated (RCA) were used (0, 25, 50, 75, 100%) and compare with natural aggregates. The dimensions of the specimen used in this study were 7.5, 7.5, 28.5 cm .The results of drying shrinkage for samples cured under dry environment were 8 times than samples cured under full humidity. Also, the results indicated that specimens with recycled aggregate produce more drying shrinkage than Natural aggregate.***

Keywords— Drying shrinkage; Shrinkage; Recycled concrete; Humidity

1. INTRODUCTION

Concrete shrinkage is a physical response that concrete displays due to many different parameters. These include water-to-cement ratio, coarse and fine aggregate proportions, cement type, curing temperature and humidity. An experimental study focused on the measurement of shrinkage when natural coarse aggregate replaced with recycled concrete aggregate (RCA).

Concrete samples with different percentage of recycled aggregate (RCA) (0.0 %, 25%, 50 %, 75% and 100 %) were exposed to several humidity conditions from zero to 100% to examine their shrinkage behavior. Also, the study focused on two locally used cement in concrete mixes.
The study also focuses on different curing conditions from 0.0 to 100% relative humidity.
The results of the study should clarify that RCA is appropriate to take the natural aggregate role in any project in terms of shrinkage under different curing conditions.

Other studies in this field presented similar results.
Jacob [1] made a study on RCA ratios of P0, P20, P50 and P100 with w/c ratios of 0.58. A specimen with dimension of 100x100×400 mm was used. The results are presented in table 1

Table 1: Drying shrinkage of various replacement percentages of recycled aggregates for 120 day Jacob (2011)

Percentage of recycled aggregate (%)	Strains (10^-6)			
	Time in days			
	30	60	90	120
0	350	430	495	510
20	390	500	520	600
50	410	510	590	640
100	430	550	660	670

Kou [2] used 0, 20, 50, 100 percentage of recycled aggregate with several w/c ratios of 0.4, 0.45, 0.50 and 0.55 and with temperature 55C and relative humidity of 95%. The dimensions of the prism were 70×70×285mm. The period for measurements taken throughout the study was 112 days.
Table 2 shows the Results for drying shrinkage at 112 days

Table 2: Drying shrinkage of the concrete mixtures for various percentages of recycled aggregates at 112 days Kou (2006)

Percentage of recycled aggregate (%)	Strain (10^-6)			
	Water cement Ratio			
	0.55	0.50	0.45	0.4
R0	405	396	379	325
R20	447	429	412	354
R50	476	462	435	387
R100	540	503	470	416

Park and Sim [3] conducted similar study to measure drying shrinkage for concrete specimen with the RCA ratios 0, 20, 40 ,60 ,80 and 100 with w/c ratio of 0.38 at 23+2 C and relative humidity of 50% and dimension 10×10×40cm. The results for range between 250 and 370 micro strain at 50 days and between 500 and 610 micro strain at 100 day.

Soberón [4] made cylinders of 0.15m in diameter and 0.45m in height. He stored the cylinders in chamber for 28 days (T = 20°C ± 2 and RH = 90% ± 5) after which they were moved to a climate chamber (T = 20°C and RH = 50%) until the end of the test period (270 days). The ratios of RCA were as follow; 0, 15, 30, 60 and 100 and w/c ratio of 0.52. The
results for range between 200 and 240 micro strain at 28 day and between 350 and 440 micro strain at 90 day.

CASTAÑO et al. [5] used prisms of 100×100×350mm in dimensions at constant conditions (T=20ºC, RH=50%) measured after 28 days curing. The result for w/c ratios 0.5 at 28-day range between 200 and 300 micro strains and 56 day between 280 and 490 micros strain. And for w/c ratio 0.65 at 28 day 200 and 310 micro strain and 56 day between 280 and 400 micro strain.

Schoppe [6] studied multi RCA types (R, RS, RD, RLD, RHD) and w/c 0.45. The test prism dimensions 3 in x 3 in x 10 in and chamber has maintained a temperature and relative humidity of 23 and 50 % respectively using lime water for curing to 14 days after that he moved prisms to chamber for various percentage of R.C.A (25%,50%,75%,100%). Figure 1 shows the results of drying shrinkage for the specimens at different time.

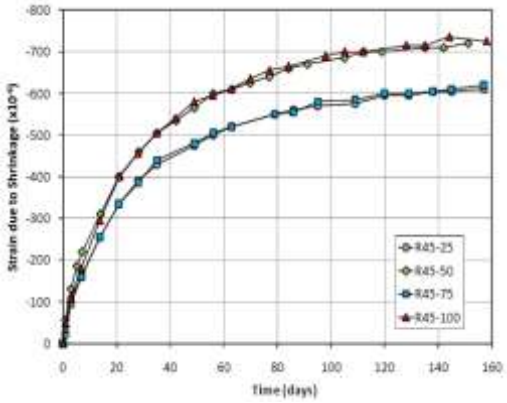

Figure 1: Drying shrinkage curves (25, 50, 75 and 100% RCA type R) Schoppe (2011)

2. MATERIAL USED AND ITS PROPERTIES IN THIS STUDY

In this study two types of cements were used CEM II 42.5 N Type A. and CEM I 52.5 N Type B. The grain size distribution for the natural and recycled aggregate is shown in Figure 2 Below and table 3 shows properties of recycled and natural aggregate

Table 3: Properties of recycled and natural aggregate

properties	Water absorption (%)	Unit weight (kg/m3)	Specific Gravity	Resistance to degradation (%)
Natural aggregate	2.88	1434	2.52	27.6
Recycled aggregate	4.31	1350	2.33	38.4

2.1 Mix design:

All samples used a mix proportion of 1:2:4 in this study with w/c equal to 0.4. The ratio of RCA in all specimens ranging from zero to 100%. The total number of specimens used in this study were 120 specimens as shown in Table 4.

A schematic diagram of the testing mold used in this study is shown in Figure 3.
Determination of the change in length of concrete specimens under controlled environment of moisture under temperature that have not been produced by any external forces.

In preparing the specimen, a mold made from non-absorbent material which does not react with cement paste with internal size of 286mm x 75mm x 75mm used in preparing concrete specimens as shown in Figure 4.

The size of specimens used in compression test were 100 × 100 × 100 mm concrete block

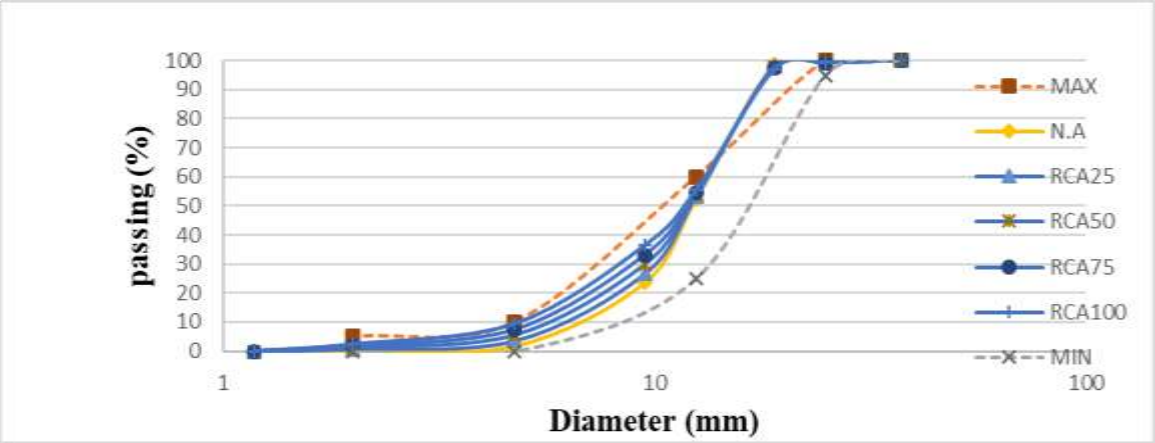

Figure 2: Gradation for used recycled and natural aggregate

Table.4: Number of specimens for shrinkage and compressive strength tests.

Test name	Shrinkage							Compressive strength		
Cement type	Type A			Type B			TOTAL	Type A	Type B	TOTAL
Relative humidity (%)	Dry	Partial	Full	Dry	Partial	Full		Full	Full	
RCA (%)										
0	3	3	3	3	3	3	18	3	3	6
25	3	3	3	3	3	3	18	3	3	6
50	3	3	3	3	3	3	18	3	3	6
75	3	3	3	3	3	3	18	3	3	6
100	3	3	3	3	3	3	18	3	3	6
TOTAL	15	15	15	15	15	15	90	15	15	30

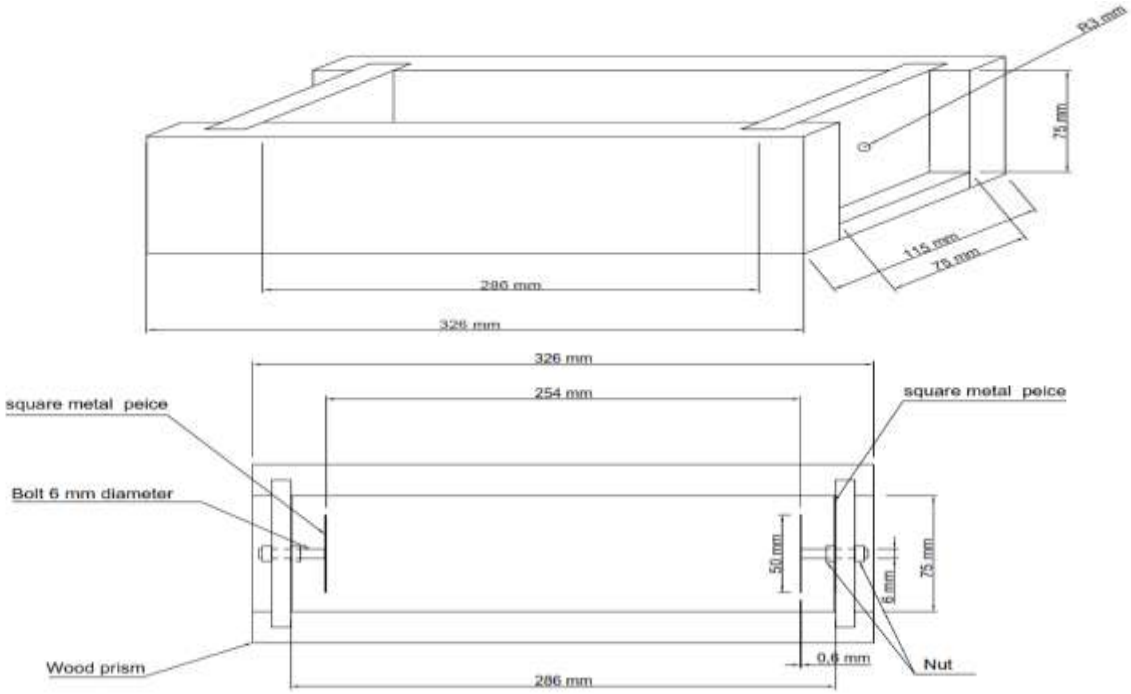

Figure 3: Schematic diagram of the testing mold with actual dimensions

Figure 4: Specimen in length comparator

3. RESULTS AND ANALYSIS

Results from figure 5 show compressive strength for 14 day and 28 day for two types of cement on different RCA ratio

Figure 6. show large differences in drying strain for samples cured at dry humidity and full humidity. It is very clear that samples left to dry in zero or partial humidity environment resulted in strain several times larger than samples cured at 100% humidity.

Figure 7 shows the results of samples with 25% RCA show similar results as samples with 0% recycled aggregate. So it is clear that strain increases as RH decreases even with RCA. The larger strain was at 60 days 0.2% for cured specimen at dry relative humidity while the stain was 0.025% for specimens cured at 100% humidity.

Figure 8 shows the results for samples with different RCA ratio and cured under full humidity environment. The results show similar trend. The strain for all specimens almost the same and did not exceed 0.025%.

Figure 9 shows the drying shrinkage of concrete specimens cured under different relative humidity with recycled aggregate ranging from 0% to 100%. It is very clear that most of the shrinkage occurs in the first two months. All samples cured under full humidity condition shows minimum strain of less than 0.03%. with natural and RCA. However, samples cured under dry and partially humid environment. with natural and RCA show strain of 0.2%. It is several times larger than the full humidity environment**.**

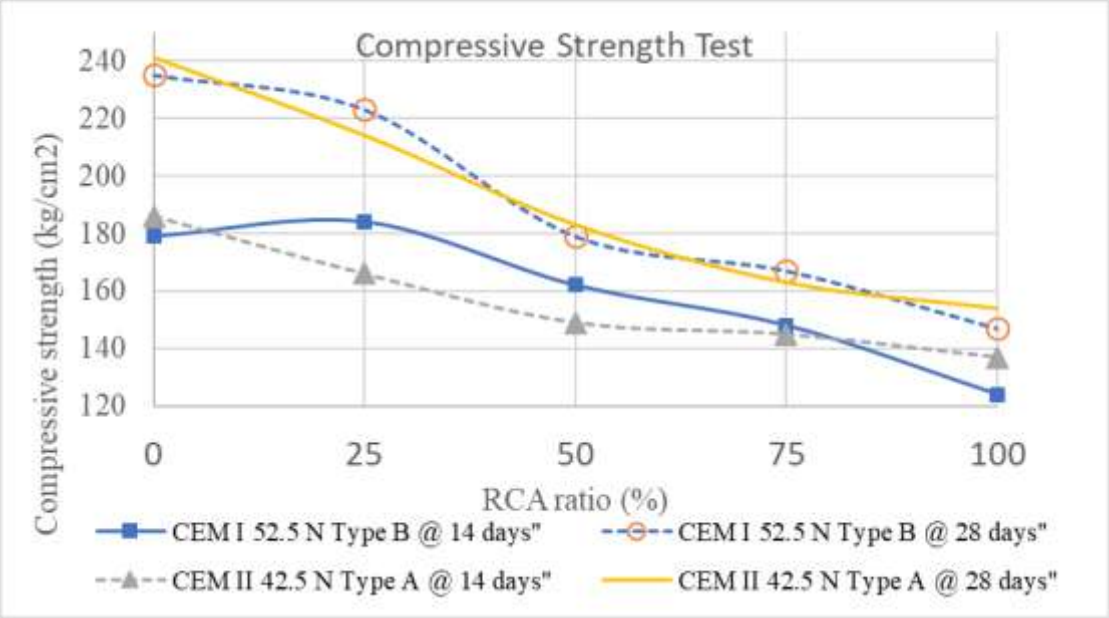

Figure 5: Compressive strength test on different RCA ratio for days 14th and 28th

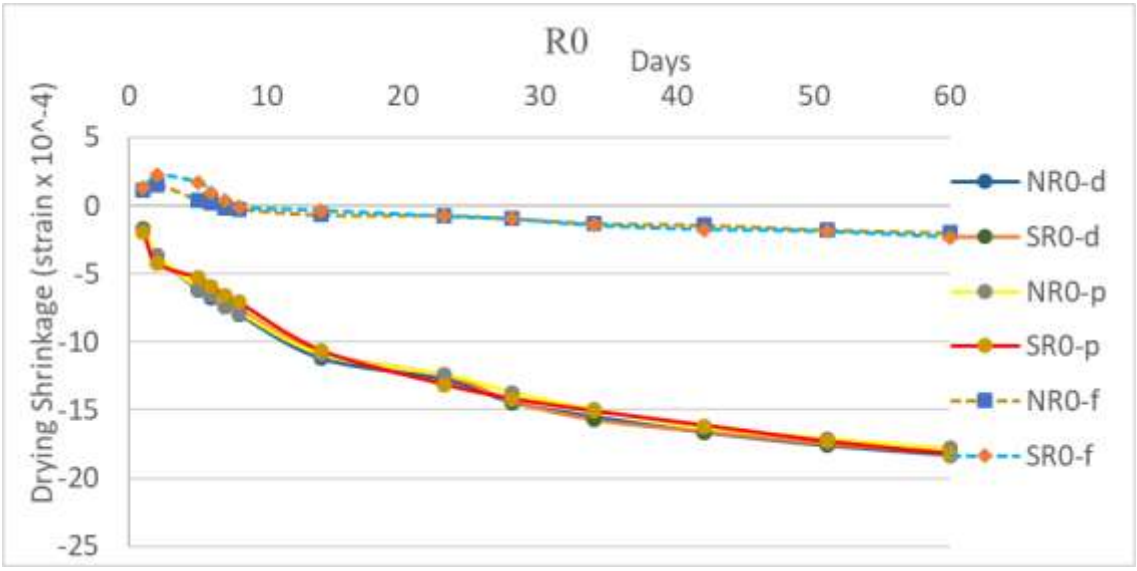

Figure 6: Samples with Natural aggregate, different cement and different RH

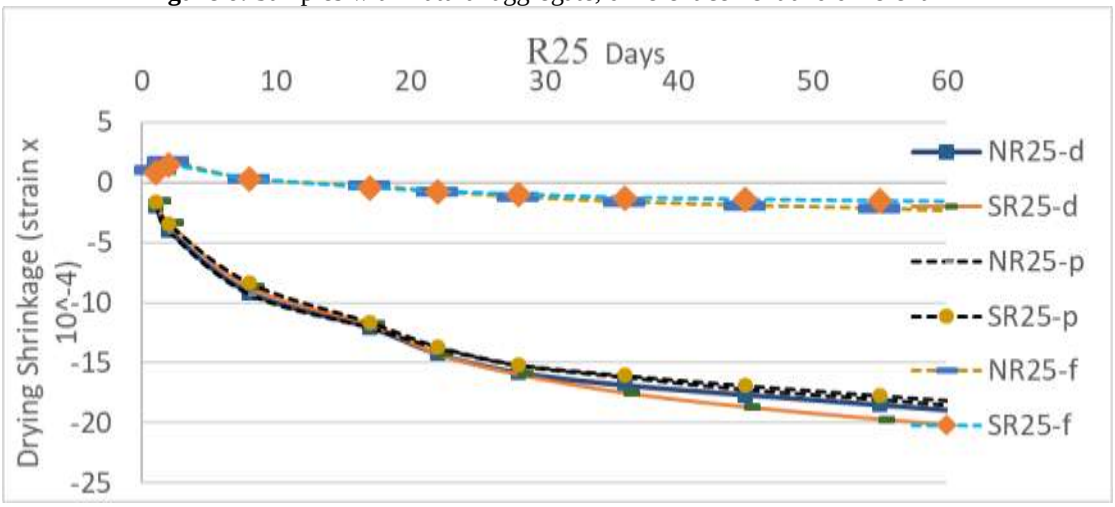

Figure 7: Samples with Natural aggregate, different cement and different RH

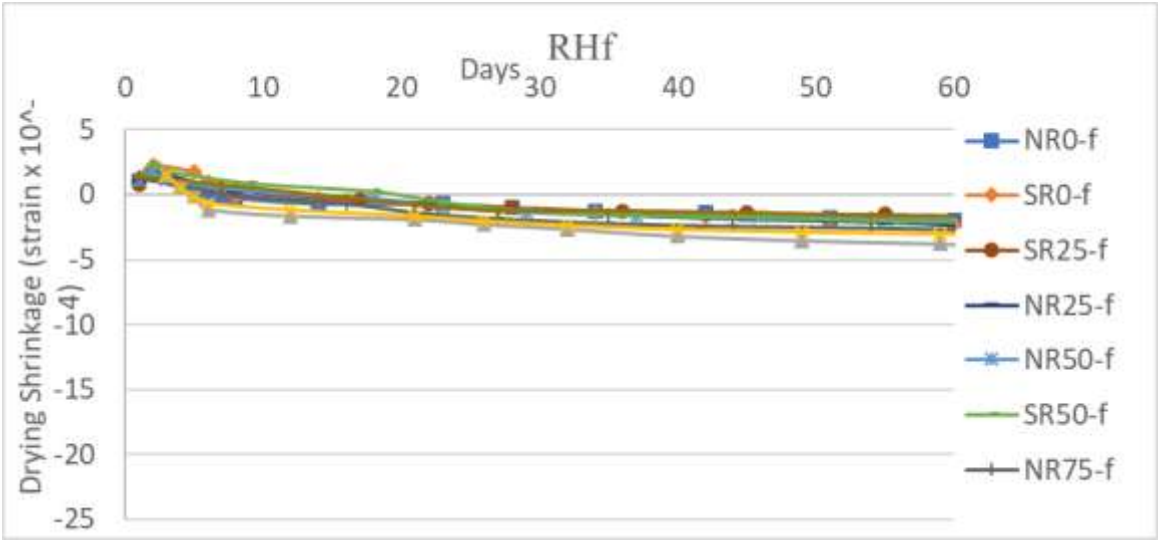

Figure 8: Samples with different RCA with different cement and full humidity

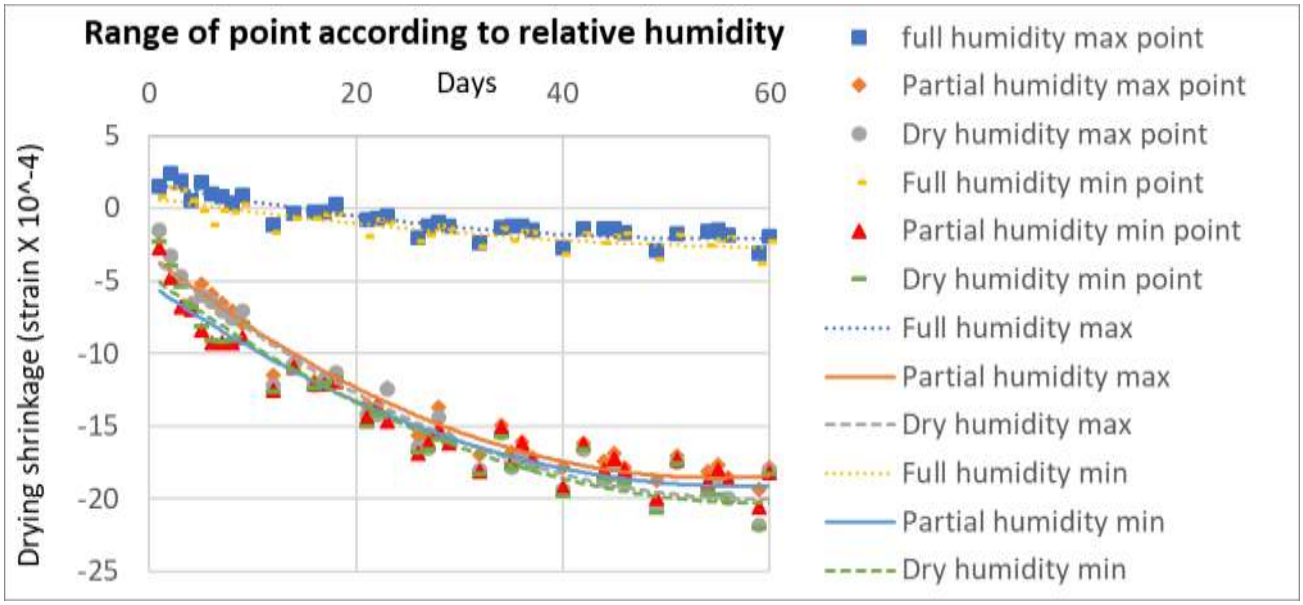

Figure 9: Samples cured under different relative humidity, cement and RCA ratio

All data points for strain measurement redrawn in Figure 10. The best fitting curve has been drawn through the results for the three cases of curing conditions Full, dry and a partially dry. The results indicated a strain of 0.014% at the end of 28 days while curing in dry environment gives 0.15% strain at the 28 days.
The results of more than 100 samples indicated the following equations;
Full humidity conditions

$$y = (0.11X^2 - 12.8X + 131.11)\times 10^{-6} \quad \text{Eq. (1)}$$

Partial humidity equation

$$y = (0.53X^2 - 57.45X - 344.52)\times 10^{-6} \quad \text{Eq. (2)}$$

Dry humidity equation

$$y = (0.53X^2 - 59.61X - 321.5)\times 10^{-6} \quad \text{Eq. (3)}$$

4. CONCLUSION

Samples cured at high relative humidity will give minimum strain compare to samples cured at dry relative humidity.
There is no difference in the strain of samples cured dry or partially dry environment.
There is small difference in strain values for samples cured at dry or partially dry. Samples cured under dry or partially dry environment give strain several times larger than samples cured under full humidity environment. It gives strain up to 0.2%

Strains for RCA and natural aggregate are the same for all percentage of recycled aggregate.
Samples cured under full humidity environment gives maximum strain of less than 0.024%,

The results of more than 100 points can be used to predict the strain with any percentage of natural or recycled aggregate. The prediction can be used through equation 1,2 or 3.

In all cases, the majority of strain occur in the first 4 weeks for all samples

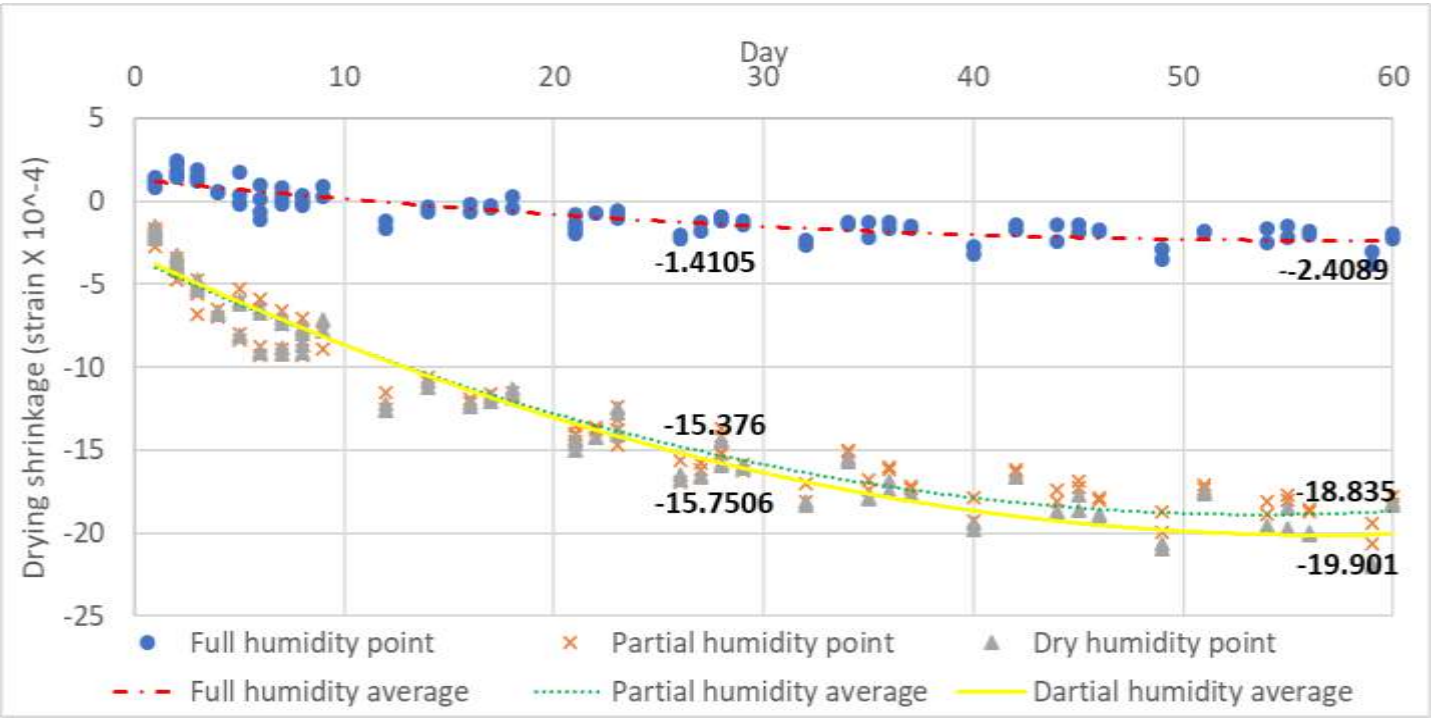

Figure 10: The average of humidity range of all points

5. REFERENCES

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