International Journal of
Advanced Structures and Geotechnical Engineering
ISSN 2319-5347, Vol. 04, No. 02, April 2015

Pre-saturated Sawdust as a source of Internal curing in high performance concrete

IFTIKHAR AZIM[1], BAZID KHAN[2], SHAMS-UL-ISLAM[2], SIKANDAR HAYAT SAJID[3]
[1]*Department of Public Health Engineering, Peshawar, Pakistan*
[2]*CECOS University of IT & Emerging Sciences, Peshawar, Pakistan*
[3]*University of Engineering & Technology, Peshawar, Pakistan*
Email: iftikhar.azim@live.com

Abstract: This research paper presents a parametric experimental study which investigates the use of pre-saturated sawdust for producing high performance concrete (low w/c ratio concrete mixtures). Pre-saturated sawdust is used as a source of internal curing by partially replacing sand. Pre-saturated sawdust is used to replace fine aggregate at three replacement levels of 5, 10 and 15% by mass respectively. The samples are subjected to different curing conditions. Compressive strength tests are conducted and comparison with control mix and unit weight analysis is also carried out. The compressive strengths of the samples without external curing for 5% replacement level are improved by 81.92%, 51.16%, 4.01% and 7.64% at 3,7,14 and 28 days respectively. While the compressive strengths of specimens with external curing for 5% replacement level are improved by 8.55%, 27.57%, 50.35 and 6.26% at 3,7,14 and 28 days respectively. The unit weight is decreased by 5.52%, 10.71% and 17.49% for 5, 10 and 15% replacement levels of sawdust, respectively. The controlling factors for sawdust compressive strength are discussed and experimental results are reported.

Keywords: *Internal Curing, High Performance Concrete, Sawdust, Compressive Strength*

1. Introduction:

Concrete is an amalgamation of carefully proportioned aggregates and a binding agent whose chemical reaction with water gives binding strength to hold the coarse and fine aggregates together. A number of dynamic ways are executed in recent times for preparing a better concrete. One of them is the identification that the stability in concrete results from the selection of materials and procedures. Another way is the concept of high performance concrete and the development of these concepts by the inspired concept of internal curing (IC) [1]. The most challenging task that is experienced nowadays is to increase the compressive strength of concrete while at the same time diminishing the self-weight of concrete. The use of High Performance Concrete (HPC) is increased recently. The reason for HPC is to get resistance to chemical attack and freeze thaw, increased strength, low permeability and early age strength. These are the properties of concrete that are improved in HPC but are not fulfilled completely. In order to enhance these properties, internal curing is used to achieve end-results, including durability [1]. The HPC applications are growing constantly such as in high rise buildings, airport pavements, marine construction etc. HPC with very low w/c proportion is prone to low workability and self-desiccation that results in autogenous contraction and cracking [2].

Internal curing is permitting the concrete for curing 'from inside to outside' through IC such as super absorbent polymers, pre-wetted lightweight fine aggregates, pre-wetted wood fibers etc [3].

The specific IC agent used in this research is sawdust. Sawdust is easily available in Pakistan. Sawdust can be achieved economically from sawmills in Pakistan. The sawdust used in this research is locally known as ‘Shawwa’. This study is intended to examine the value of Sawdust as a source of IC and to find the finest percentage of sawdust that can be used to replace the fine aggregates in concrete which will improve the compressive strength meanwhile causing reduction in unit weight. The

compressive strength that can be achieved by IC could be more than that possible under saturated curing conditions due to increased water availability [2]. Increase in the compressive strength of HPC using IC agents remains the subject of research interest.

Although the concept of IC is new, it has been observed since the 1950s that water provided by permeable lightweight aggregates is helpful to the concrete [4]. The IC has been recently used to improve the qualities of concrete. The basic method for IC is to place additional water in key areas all through the concrete [5]. In High Strength Concrete (HSC), IC is a conventional approach to give water other than mixing water for continued hydration since in HSC; a low w/c ratio is traditionally adopted [6]. IC also saves cement from being waster in HSC as when a low w/c ratio is adopted, there is insufficient water supplied by mixing water to maintain hydration and a high internal relative humidity [7]. IC agents are permeable materials with insubstantial mechanical properties and their use in a high dense HPC matrix can alter the properties of HPC [2]. If different IC agents are used, the one with the lower density may limit the concrete strength because of its poor mechanical properties [8].

2. Methodology:

Sawdust in this research is obtained from a wood sawing machine. The sawdust is passed through a 6 mm (0.25 in.) sieve as is the general recommendation for such sawdust [9]. Some species of sawdust contain extractable materials that can hinder with hardening properties, especially in lean concrete mixes. The setting of concrete is also affected by some species of Sawdust. Therefore, for these reasons, the sawdust is pre-treated before using it in concrete by soaking and washing it in water [9]. The degree of saturation of sawdust is found to be 397.25% of its oven dried mass and is calculated according to ASTM C1761 [10].

The fine and coarse aggregates are obtained from local quarries. The fineness modulus of fine and coarse aggregates is 2.73 and 3.52, respectively.

The physical properties such as specific gravity (SSD), moisture content and water absorption of fine and rough aggregates are presented in table 1.

Table 1: Physical properties of aggregates

Physical properties	Coarse aggregate	Fine aggregate
Specific gravity (SSD)	2.638	2.488
Moisture content	0.0%	0.88%
Water absorption	0.266%	6.38%

2.1 Control mix:

Two control mixes are prepared for comparison purposes. Mixes are acquired by integrating fine aggregate, coarse aggregate and cement in the ratio of 1:1.44:1.44 by weight based on actual data obtained from tests on fine and coarse aggregates. The difference between these two control mixes is the curing condition. One of the mixes is cured externally and the other mix is only covered with polyethylene bags. The w/c ratio by mass is kept as 0.35.

2.2 Sawdust Concrete:

Sawdust concrete is acquired by fractional substitution of fine aggregate of the control mix by pre-saturated sawdust. Four substitution levels 0%, 5%, 10% and 15% by mass are chosen. The mixes are designated as S0, S1, S2 and S3 for control mix, 5%, 10% and 15% sawdust replacement levels with no external curing. While in case of sawdust concrete with external curing, mixtures of the control mix, 5%, 10% and 15% sawdust replacement levels are designated as SD0, SD5, SD10 and SD15 respectively. The w/c ratio and material proportions are kept the same as that for control mix. A typical sawdust concrete mix is shown in fig. 1.

Fig. 1. A typical sawdust concrete mix with replacement level of 15%

2.3 Curing conditions*:*

The samples gathered from the different concretes are subjected to the subsequent curing situations:

- Control mix samples with no external curing. This is accomplished by wrapping the samples in polyethylene bags.
- Control mix samples with external curing. This is achieved by placing the specimens in water up to the day of testing.
- The specimens achieved from sawdust concrete are subjected to internal curing only. This is done by wrapping the samples in polyethylene bags.
- The specimens of sawdust concrete with external curing.

For each mix and curing condition, standard cylindrical specimens of 6 in. x 12 in. are tested.

2.4 Testing procedure:

Compressive strength tests and unit weight measurement are done in order to observe the effectiveness of sawdust as a source of IC. Compressive strength tests are conducted for the control mix and sawdust concrete along with the different curing conditions. Compressive strength tests are performed according to ASTM C-39 test procedure [11]. 6” x 12” standard cylindrical specimens are tested for compressive strength at 3, 7, 14 and 28 days respectively. The unit weight of the samples is found out by simply weighing the sample and dividing the sample weight by the volume of the standard cylindrical specimen mould.

3. Interfacial transition zone:

Cement paste and cement aggregate are the two different components of which concrete is composed. Both components affect the properties of each other. Cement paste can influence the aggregate by causing a chemical reaction between the reactive silica in the aggregate and highly alkaline pore solutions. The cement paste is also affected by presence of aggregate. In fresh concrete, when cement particles are floating in mixing water, they cannot gather smoothly when they are in the close surrounding area of specimens aggregate. This packing of particle phenomena is called the “wall effect”. The wall effect in the cement is magnified by the compressing pressure exerted on the cement mixture by the aggregate particles in the process of mixing. This segregates water from the cement particles. The outcome is a contracted region about the aggregate particles with a reduction of cement particles, and supplementary water. This phenomenon is termed the interfacial transition zone (ITZ) [12].

4. Test results and discussion:

Fig. 2 shows a standard cylindrical specimen being tested on the Universal Testing Machine (UTM) in laboratory.

Fig. 2. Testing of Standard Cylindrical Specimen on UTM

4.1 Compressive Strength results for sawdust without external curing of S0, S1, S2 & S3 mixes:

Fig. 3 shows compressive strength of the sawdust concrete at 3, 7, 14 and 28 days.

Table 2: Percentage decrease in unit weight of sawdust lightweight concrete

Type of concrete	w/c	Average Unit weight (pcf)	Percentage reduction in Unit weight (%)
Control mix	0.35	143.29	0
SD5	0.35	135.38	5.52
SD10	0.35	127.94	10.71
SD15	0.35	118.23	17.49

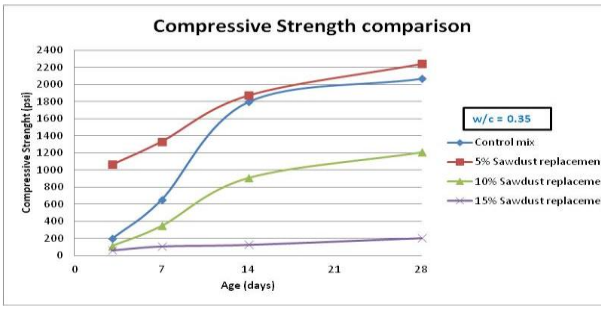

Fig. 3. Compressive Strength vs Sawdust Content

Fig. 3 shows that the early age strength of S1 is greater than control mix. The strength gain can be clearly observed in the course of 3 and 7 days. The compressive strength of 3 and 7 days of S1 is 81.92% and 51.16% more than the control mix. The 14 and 28 days compressive strength of S1 is 4.01% and 7.64% more than that of the control mix. The mix S1 early development of strength (3 and 7 days) along with 14 and 28 days is greater than control mix, S2 and S3. Higher early age strength observations are observed by other researchers using Liapor as an IC agent [8]. The higher early age strength gain of S5 than S0 and the final 28 days compressive strength can be best explained considering the moisture conditions of the concrete, the improved ITZ, the internal curing procedure and the decrease of eigenstresses due to lack of self-desiccation diminution.

1) Since internal curing provided by saturated lightweight aggregate is very effective in turning early age shrinkage into expansion [8]. Early age expansion of lightweight aggregate concrete is because of the expansion of the cement paste that is cured in almost saturated conditions, on account of water from the lightweight aggregate. The early age expansion depends more upon the degree of saturation of the lightweight aggregate and less upon their particle size. The sawdust particle size used in this research is smaller such that they can easily pass through 0.25 in. size sieve and the degree of saturation is calculated to be 397.25% as shown earlier. The early-age expansion is larger for smaller lightweight aggregate. As a result the strength is increased due to absence of shrinkage induced micro-cracking.

2) The increased strength can also be due to improved interfacial transition zone and enhanced hydration due to internal curing. The improvement in the quality of the ITZ could also have contributed to the strength because of the bond between the matrix and the lightweight aggregate [8].

3) Continued hydration at later stages because of the extra water absorbed by the sawdust can also contribute to the strength gain.

The compressive strength decreased evidently as the percentage of sawdust is increased even though the sample curing demand is fulfilled. The decrease in compressive strength for S10 for 3,7,14 and 28 days is 44.16%, 47.23%, 51.61% and 41.69% respectively. While for S15, the decrease in strength is found to be 67.97%, 83.54%, 93.29% and 90.30% for 3, 7, 14 and 28 days respectively. The following factors can be considered for the explanation of decrease in compressive strength.

1) The reduction in the compressive strength of the concrete as the sawdust percentage increase is due to the additional water immersed by pre-saturated sawdust is not entirely restrained. As internal curing requires complete absorption of the additional water, therefore, it affected the w/c ratio representing voids in the concrete and thus reduced the compressive strength. However for IC, it is obligatory that the absorbed water ought not to be free [13]. Therefore as a result, it affected the w/c ratio representing voids in the concrete and the compressive strength is decreased.

2) Partially dried concrete shows higher strength than moist concrete [14]. The same is observed here

as the percentage of pre-saturated sawdust is increased, the amount of curing water also increased as a result, the compressive strength dramatically decreased.

4.2 Compressive Strength results for Sawdust with external curing at SD0, SD1, SD2 & SD3 replacement level:

Fig. 4 shows the trend line for 3, 7, 14 and 28 days. The trend of early strength gain of 5% sawdust is evident with external curing.

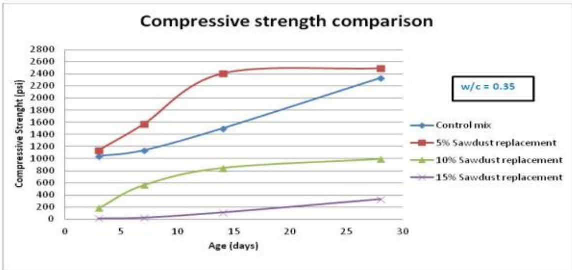

Fig. 4. Compressive Strength vs Sawdust Content

The 3 and 7 days strength of SD1 is 8.55% and 27.57% greater than that of control mix. The 14 days strength of SD1 is 50.35% greater than control mix. Also the 28 days compressive strength of SD1 is 6.26% more than control mix. Early age strength gain can also be seen here for 5% sawdust replacement level. The final age strength here is also greater than control mix, SD10 and SD15. Improved ITZ, absence of shrinkage induced micro-cracking and continued hydration are contributed in the gain of strength. The decrease in compressive strength for SD10 for 3,7,14 and 28 days is 82.34%, 50.56%, 29.32% and 57.55% respectively. While for SD15, the decrease in strength is found to be 98.60%, 97.59%, 90.38% and 85.80% for 3, 7, 14 and 28 days respectively. The trend of decrease in compressive strength with the increase in the sawdust concrete percentage can be observed also in the externally cured samples. The strength decreased as the percentage of pre-saturated sawdust is increased; spalling is associated with it, particularly in the specimens of 15% pre-saturated. After 24 hours of casting the cylinders, during the demolding operation; spalling is most often allied with the specimens which indicate failure. Also as sawdust amount is increased, amount of water increased and the water is not fully contained by sawdust, this can contributed to the decrease in strength. The specimens with higher sawdust content are moister than specimens with lower sawdust content which also decreased the compressive strength dramatically [14]

4.3 Comparative statements of Unit weight of Sawdust concrete and control mix:

In this study, sawdust is utilized as an internal curing agent. Table 4 demonstrates the reduction in the unit weights of SD5, SD10 and SD15 with control mix. The decrease in unit weight of sawdust lightweight concrete is shown in the graph in Fig. 5.

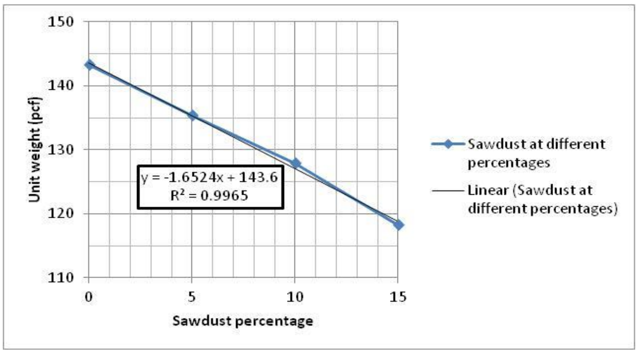

Fig. 5. Unit Weights comparison

5. Conclusions:

The accompanying conclusions are drawn from this exploratory work:

- 5% use of Sawdust as partial replacement of fine aggregates is found as an effective source of internal curing.
- The effects of sawdust on compressive strength with and without external curing are higher for early strength (up to 14 days) and lower for later strengths (28 days). The percentage increase for sawdust concrete’s strength with no external curing for 3, 7 and 14 days are 81.92%, 51.16 and 4.01% respectively. And with external curing for 3, 7 and 14 days are 8.55%, 27.57% and 50.35% respectively.
- The use of sawdust in the concrete reduced the unit weight of concrete. For instance, the diminution in the unit weight is found as 5.52% for SD5. Reduction in unit weight of the construction material is good to have lower dead loads and consequently lower strength demand. Also the risk of the damages in a seismic event is lower given the lesser inertial forces because of lower weight of the structure.

6. Recommendations:

Based on this experimental study, the following recommendations are formulated for further research work on sawdust as a source of internal curing:

1) For early gain of strength particularly in the initial 3 days, 5% sawdust replacement (in cases without external curing and with external curing) is greatly recommended. Firstly, it will gain strength at timely rate. Secondly, it will give higher 28 days strength as compared to the control mix at w/c ratios lower than 0.35.

2) Even though the 10% sawdust replacement level 28 days compressive strength is almost 41% smaller than the Control mix, however, this proportion can be further decreased if the replacement of sawdust concrete at a w/c proportion smaller than 0.35 is done. The use of pre-saturated sawdust prepared a workable mix due to which the lower w/c ratios will not create the problem of harsh mix.

3) For the selection of the best internal curing agent a comparison among various internal curing agents is desired to be drawn.
4) The increase in the percentage of sawdust resulted in the decrease of the compressive strength of pre-saturated sawdust specimens. But the 10% pre-saturated sawdust shows strength gain subsequently which may possibly show that the old age strength can be equivalent to the standard strength concrete. Therefore, evaluation of the compressive strength at age more than 28 days is required to be done.

7. References:

[1] Roberts, J., "High Performance Concrete: Enhancement Through Internal Curing" Concrete InFocus Vol. 2006: 55-59.

[2] Zhutovsky, S., and Kovler, K. "Effect of internal curing on durability- related properties of high performance concrete," Cement and Concrete Research, vol.42, Jan. 2012: 20-26.

[3] Ambily, P. S. and Rajamane, N. P. "Self curing concrete – an introduction", Proceed. of CSIR sponsored National Seminar Recent Trends in Concrete Technology (NSRTCT-2007), Kongu Engineering College. March. 2007: 88-89.

[4] Klieger, P., "Early High Strength Concrete for Prestressing" proceedings World Conference on Prestressed Concrete, San Francisco, CA, July 1957, A5-1 to A5-14.

[5] Cubit, E. "The Expanded Shale Clay and Slate Institute, Internal Curing: An unconventional idea within a conventional business." ESCSI. 2011.

[6] Bentz, D.P., Weiss, W. J., Henkensiefken, R., Castro, J., and Kim, H. "Concrete in focus." Vol 8, 2009: 22-30.

[7] Schlitter, J., R. Henkensiefken., Castro, J., K. Raoufi., Weiss, J., and Nantung, T. "Development of Internally Cured Concrete for Increased Service Life." Publication FHWA/IN/JTRP-2010/10. Joint Transportation Research Program, Indiana Department of Transportation and Purdue University, West Lafayette, Indiana. 2010.

[8] Lura, P. "Autogenous deformation and internal curing of concrete." Ph.D. thesis, Delft University of Technology, Delft. 2003.

[9] Paramasivam, P., and Loke, Y. O. "Study Of Sawdust Concrete." The international Journal of Lightweight Concrete. Volume-2, 1980: 57-61.

[10] ASTM C1761-13b, 2013, "Standard Specification for Lightwieght Aggregate for Internal Curing of Concrete." Annual Book of ASTM Standards, 4(2), ASTM International, West Conshohocken, PA. ASTM C1761-13b. 2013.

[11] ASTM C39, 2003, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens." Annual Book of ASTM International, West Conshohocken, PA. 2003. C 39.

[12] Jennings, H. and Thomas, J. "Materials of cement science primer." Infrastructure Technology Institute, TEA-21 funded projects, Northwestern University, Evanston. 2009. A474.

[13] Bashir A., Z. Ullah, F. U. Jan, K. Shahzada, S. Afzal. " Performance of Pre-Wetted Sawdust as a source of Internal Curing of Concrete" International Journal of Advanced Structures and Geotechnical Engineering, ISSN 2319-5347, Vol. 01, No. 02. 2012.

[14] Jensen, O.M. and Hansen, P.F. "Autogenous deformation and change of the relative humidity in silica fume- modified cement paste." ACI Materials Journal 1996: 539-543.