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Parameters Driving Concrete Carbonation at its End-of-Life for Direct Air Capture in Transportation Projects

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16. Abstract

Recent California regulatory efforts, United States goals, and industry roadmaps all target net-zero greenhouse gas (GHG) emissions from the cement and concrete industries within a few decades. While changes in production of cement and concrete, including varying constituents, can greatly reduce GHG emissions, carbon dioxide removal (CDR) will be needed to meet this net-zero goal. Hydrated cement in concrete can carbonate (i.e., form carbon-based minerals with atmospheric CO_2) and thus act as a CDR mechanism. This process occurs faster with a large surface area, such as crushed concrete at its end-of-life (EoL), which can be uniquely leveraged by transportation infrastructure projects. In this work, a literature review of key parameters that can facilitate desired CO_2 uptake for transportation projects at their end of life is conducted and an initial meta-analyses of data from the literature to inform CO_2 uptake for individual projects is performed. Initial considerations for what concomitant impacts may arise from this process are presented. Finally, experiments to fill a key gap in understanding how thin crushed concrete must be spread to maximize uptake reactions are conducted. Cumulatively, findings will inform whether carbonation can be implemented in a way that would support policies that include carbonation as a route for reducing emissions from cement-based materials in transportation applications.

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Parameters Driving Concrete Carbonation at its End-of-Life for Direct Air Capture in Transportation Projects

A National Center for Sustainable Transportation Research Report

September 2024

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TABLE OF CONTENTS

List of Tables

List of Figures

Parameters Driving Concrete Carbonation at its End-of-Life for Direct Air Capture in Transportation Projects

EXECUTIVE SUMMARY

Recent California regulatory efforts, United States goals, and industry roadmaps all target net-zero greenhouse gas (GHG) emissions from the cement and concrete industries within a few decades. While changes in production of cement and concrete, including varying constituents, can greatly reduce GHG emissions, carbon dioxide removal (CDR) will be needed to meet this net-zero goal. Hydrated cement in concrete can carbonate (i.e., form carbon minerals with atmospheric CO_2) and thus act as a CDR mechanism. This process occurs faster with a large surface area, such as crushed concrete at its end-of-life (EoL), which can be uniquely leveraged by transportation infrastructure projects. In this work, a literature review of key parameters that can facilitate desired CO_2 uptake for transportation projects at their end of life is conducted and an initial meta-analyses of data from the literature to inform CO_2 uptake for individual projects is performed. Initial considerations for what concomitant impacts may arise from this process are presented. Finally, experiments to fill a key gap in understanding how thin crushed concrete must be spread to maximize uptake reactions are conducted. Cumulatively, findings will inform whether carbonation can be implemented in a way that would support policies that include carbonation as a route for reducing emissions from cement-based materials in transportation applications.

1. Introduction

The production of concrete is responsible for ~8% of the world's anthropogenic CO_2 emissions, and concrete is the most consumed construction material worldwide [1]. Life cycle assessment (LCA) is widely used to determine the impacts produced by the concrete industry. These LCAs are commonly only cradle-to-gate, focused on reducing greenhouse gas GHG emissions [2]. And findings from these studies often conclude that more than 50% of the CO_2 emissions from concrete production comes from the cement production, with values of over 80% reported in some studies (based on constituents and modeling inputs) [64], driven by the calcination of limestone [3] and the requisite heat and energy for manufacturing clinker (a precursor to Portland cement) [4–6]. In order to reduce the concrete industry's carbon footprint, several decarbonization tactics are often discussed, such as improving the kiln energy mix and using supplementary cementitious materials (SCMs) or other alternative materials to reduce the amount of clinker in concrete mixtures [7]. Yet more technology and research is needed to reach net zero emissions by 2050 [7]. Carbon capture utilization or storage (CCUS) in cement production are becoming more popular in research, but these technologies are currently being scaled and are not broadly implemented, in part due to costs [1].

Unlike many materials, hydrated cement can interact with atmospheric CO_2 under appropriate exposure conditions to mineralize that carbon in a process referred to as carbonation. Carbonation is heavily modelled in research, but there are parameters with limited data, gaps in applicability, and uncertain parameters that remain to be addressed [8]. Gursel *et al.* [9] discusses the importance of expanding the LCA to include the use and end-of-life (EoL) phases, such as the management of concrete at its EoL to support carbonation. Expanding LCA to include EoL, will also account for the different methods used in concrete EoL management such as crushing, stockpiling, and energy associated with reuse or recycling [3]. The applicability of the EoL methods also requires analyzing current supply and demand needs for recycled concrete. In order to reach net zero concrete emissions, not only are more sustainable technologies needed, but further research should be done to better carbonation models and modelling parameters and study of the impact of concrete use and EoL phases [1,8,10,11].

Despite the potential for crushed concrete to act as a CDR mechanism, pathways to capitalize on this EoL concrete have not been established. This work will identify the parameters that can drive CDR mechanisms in concrete at its EoL through two primary objectives. First, a systematic review of the literature to compile parameters to drive carbonation of concrete is assembled. This set of data are used to inform initial meta-analyses of parameters that are key to carbonation of crushed concrete. This review is also paired with preliminary consideration of potential co-benefits or unintended consequences of using crushed concrete from transportation infrastructure as a Direct Air Capture (DAC) mechanism. Next, an experimental investigation is performed to understand key drivers in facilitating CO_2 uptake in crushed concrete that has been stockpiled, focusing on the effects of: crushed concrete pile depth, mixed constituents with other demolition waste, and crushed concrete size.

2. Reactions Supporting Carbonation

Conventional concrete is formed by leveraging the hydration of Portland cement to bind together aggregates (e.g., crushed rocks). To manufacturing this hydraulic Portland cement, limestone is calcined and combined with silica at high temperatures to create calcium silicates. This process, along with other mineral phases, forms the Portland clinker, which is interground with gypsum (acting as a setting control) and other mineral additives, as appropriate, to form the cement. Hydration products are the result of this hydraulic cement combining with water. The hydration products are predominantly calcium silicate hydrate (CSH) and calcium hydrate (CH), along with some additional hydration products. Strength and durability of the concrete mixture is dependent on the amount and proportion of hydration products [12]. The carbonation reaction is a result of CO_2 reacting with both the hydrated and unhydrated constituents [13,14]. There are four main carbonation reactions [14]:

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O \qquad \text{Eq. 1}$$

$$(3CaO \cdot 2SiO_2 \cdot 3H_2O) + 3CO_2 \rightarrow (3CaCO_3 \cdot 2SiO_2 + 3H_2O) \qquad \text{Eq. 2}$$

$$(2CaO \cdot SiO_2) + nH_2O + 2CO_2 \rightarrow 2CaCO_3 + (SiO_2 \cdot nH_2O) \qquad \text{Eq. 3}$$

$$(3CaO \cdot SiO_2) + nH_2O + 3CO_2 \rightarrow 3CaCO_3 + (SiO_2 \cdot nH_2O) \qquad \text{Eq. 4}$$

These reactions happen when CO_2 from mostly open air diffuses into the concrete. Carbonation ultimately lowers the pH of the cement system to about 9-10 pH. In steel reinforced concrete, this reduced pH is an issue because the typically high pH acts as passive protection layer around reinforcing bars, and as such, the lowering of the pH can facilitate corrosion [8]. This carbonation process has been studied heavily in the past to understand effects on durability, and more recently, attempts to extend such frameworks have been approached to account for the uptake of the atmospheric CO_2 and its climate benefits [10,14].

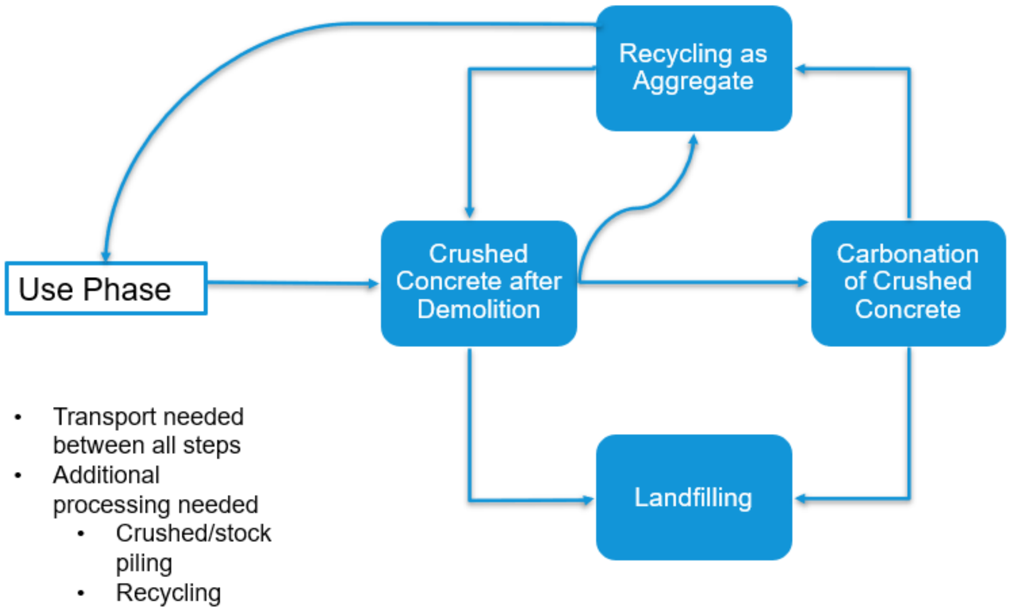
3. Considerations for End-of-Life Carbonation of Concrete

3.1 Methods to use concrete at EoL

The scope for concrete LCAs is most commonly cradle-to-gate, but this system boundary neglects the use and EoL phases. The use phase normally entails maintenance, rehabilitation, preservation, and some carbonation. For the purpose of this work, we recognize concrete has a wide range of uses, but we focus on EoL management, such as strategies including sending to a landfill, crushing and stockpiling, or recycling or reuse [2]. Recycled concrete aggregate (RCA) is heavily used in construction, but when looking at a cradle-to-gate system, the processes between EoL and its secondary use may be neglected [15]. It could be argued that crushing and stockpiling is also a step before recycling and reusing as part of the processing of RCA [15,16]. Making RCA may entail more transport to further site, crushing, screening, and additional processes that should be addressed when studying at concrete at EoL.

3.2 Preliminary consideration of co-benefits and unintended consequences

In order to estimate the feasibility of different EoL methods, an initial quantification of impacts was conducted followed by a questionnaire suggested by Harvey et al. [17]. This questionnaire is aimed at analyzing other impacts and costs of implementing “sustainability” efforts, and we adapt it here to provide initial consideration for the effects of concrete EoL management on other environmental impacts. To provide initial context into a larger system of impacts that could occur as a function of EoL management strategies such as use of crushed concrete for DAC, we conduct a simplified assessment following key steps of the method outlined by Harvey et al. [17]. For this assessment, we created mock scenarios to understand concomitant impacts. we use a system boundary that begins with demolition of the concrete and ends with installation in secondary application, which could include landfill, stockpile, or reuse. The functional unit is 22 tons of concrete, which is representative of the capacity of an end dump tractor trailer that is capable of transporting demolished and recycled concrete. The scenarios will begin in Santa Rosa, California, representing road construction off of route 101. The landfill used will be Petaluma, California, which is approximately 20 miles from the demolition site. We consider that recycled concrete will go to the recycling center in Windsor about 20 miles from the demolition site before going to the concrete recycling center to be made into base rock about 10 miles away [18]. The California electricity mix is used for all processes requiring electricity (e.g., sieving). It is also assumed that recycled materials will be transported another 20 miles to be reused in new construction. Figure 1 displays the EoL of concrete and current representations or energy needed at each step.



- Transport needed between all steps
- Additional processing needed
  - Crushed/stock piling
  - Recycling

Figure 1. EoL of concrete and processes.

Using California electricity mix, data from Miller et al. [19], and the emissions quantification available in OpenConcrete [20], initial estimates for key air emissions were calculated for the different EoL processes. Appendix 2 shows the data and calculations used to calculate the values found in Table 1. Jaw crusher energy calculations were made using data from Richardson's book on the Blake jaw crusher assuming generic reduction of particle size [21]. We note ¾ inch is the average base rock size for recycled aggregate [22].

Table 1. Environmental impacts associated with EoL processes (using models based on [20-22]).

	Recycling	**Landfill**	**Stockpile**
Emission	**per 22 tons & 50 mi (80.5km) roundtrip transport**	**per 22 tons & 20 mi (32.2km) transport**	**per 22 tons & 30 mi (48.3km) transport**
kg CO_2	9.76E+01	1.20E-01	1.79E-01
kg CH_4	9.89E-04	0.00E+00	0.00E+00
kg N_2O	1.44E-03	0.00E+00	0.00E+00
kg NO_X	1.13E-01	8.42E-04	1.26E-03
kg SO_X	3.06E-01	5.77E-05	8.66E-05
kg PM_{10}	1.12E-02	1.60E-05	2.40E-05
kg $PM_{2.5}$	4.71E-03	1.84E-05	2.76E-05
kg VOC	1.32E-03	6.80E-05	1.02E-04
kg CO	1.29E-02	9.23E-04	1.38E-03
kg Pb	2.57E-08	6.49E-10	9.73E-10

Findings from this preliminary assessment show other factors, beyond the quantity of CO_2 that can be taken up in concrete could occur. Table 1 shows only the additional impacts associated with using different EoL methods. It highlights the need to recognize the impacts associated with different processes and transportation impacts that are not associated with cradle-to-gate LCA. It is also worth noting that the additional screening and heavy equipment operation also associated with moving and crushing the concrete may not be properly captured here. Further, air pollutant emissions do not reflect dust particles being blown away; rather, they reflect emissions from energy resources. In practice, dust suppression activities may require water to reduce air pollutants. And studies have shown that high pH leachate can potentially form from RCA, which may impact local soil, surface water, and ground water [23].

3.3 Supply and demand feasibility

EoL management processes are often implemented to reduce the demand of virgin products, such as aggregate [3]. A California geological survey conducted in 2018 documenting 'Aggregate Sustainability in California' identified current reserves relative to 50 year aggregate supply demand [24]. Currently, northern California barely has the reserves (492 million tons) to support the 50 year demand (263 million tons), and southern California does not have the supply to meet demand (506 million tons reserves/1,320 million tons demand) [24]. This supply and demand issue highlights the potential need to transport greater quantities of aggregate from further distances.

With the combined effort of increasing aggregate supply and reducing environmental impacts, there may be increased need and demand for RCA. As such, the landfill and recycling rates for construction materials must be considered. According to a recent CalRecycle study, 19.9% of California's waste is composed of inert and other materials; this includes 1.2% of concrete, an estimated 373,185 tons [25]. According to California Construction and Industrial Materials Association (CALCIMA), 3,152,610 tons of concrete were recycled in 2010. A recent assembly bill (AB 2953) taking effect in 2024 will require increased recycled material use in California [26]. While the current recycling rate outweighs the landfill rate by 8.44 times, even if the landfilled concrete was all recycled, it still would not supplement the demand in several areas of the state to meet the 50-year demand for aggregate.

4. Key parameters affecting carbonation

Carbonation is highly dependent on chemical composition, physical qualities, and surface area, all of which are dependent on the concrete mixture proportions [3,27]. Crushing concrete after demolition can increase surface area, facilitating carbonation [3]. This can increase carbonation about 2.4 times more than when concrete is not crushed [3]. During concrete service life, 16% of emitted CO_2 from calcination is reabsorbed [3]. The chemical makeup and hydration products present in concrete during its service life will influence carbonation [3]. EoL characteristics of concrete will also be impacted by environment and use of the concrete [3]. Lagerblad [27] provided an inclusive report presenting background, data, and analysis on the process of carbonation in regard to the uptake of carbon. Fick's 1st and 2nd Laws of Diffusion are described by Lagerblad to further explain and justify concrete carbonation [27]. Water saturation and the porosity of the transport media will heavily impact the speed and amount of carbonation that occurs due to the diffusion process [27]. Table 2 further describes different key factors discussed by Lagerblad and other researchers and their effect on the carbonation of concrete [27–29]. While several key parameters of concrete carbonation and drivers that influence the kinetics of these reactions are known, authors such as Pade and Guimaraes [3] highlight the lack of knowledge in regard to demolished concrete carbonation.

Table 2. Various scenarios and their impact on concrete carbonation (based on reviews of [27-29]).

Factor/Scenario	Carbonation
Increased time	↑
Larger surface area	↑
More exposed cement paste	↑
Coarser capillary system	↑
Wet environment	↓
Humid environment	↑
Increased porosity	↑
Increased temperature	↑
Cracks	↑
Partial pressure of CO_2 in local atmosphere	↑
Decreased rate of diffusion	↓
Low w/c or w/b & high degree of hydration	↓
SCM content	↕

↓ Decrease
↑ Increase
↕ Varied Results
↔ No Change

In order to expand upon the carbonation factors described in Table 2, researchers have also incorporated the Steinour formula [30] to determine the capacity for the cement products to bind to CO_2 [28,31]. Steinour formula uses the chemistry of the mixture constituents and expresses it as a mass gain [30,31].

$$CO_2(wt\%) = 0.785(\%CaO - 0.7\%SO_3) + 1.09\%MgO + 0.71\%Na_2O + 0.468\%K_2O \qquad \text{Eq. 5}$$

This stoichiometric formula determines the theoretical max CO_2 sequestration that can be obtained by the concrete, and also considers the impact of the chemical makeup of the concrete mixture with SCMs [27,28,30,31]. Carbonation will be heavily influenced by the key factors in Table 2 as well as Eq. 5.

Researchers have investigated the idea of a ‘carbon sink’. With this idea in mind, models have been developed that account for existing roadway systems and structures to estimate current carbonation. Table 3 shows some of the models that have been developed for these purposes including those used to quantify the effect of crushing and stockpiling concrete. All sources of emissions, uptake, and time-dependencies of these fluxes should be considered to develop a full understanding of carbonation [32]. Further, while notable research efforts have been performed on carbonation modeling, there are many gaps identified by multiple researchers surrounding a few key parameters, such as porosity, exposure conditions, curing methods, location and atmospheric CO_2 concentration, and coatings. We provide a review of the literature on these subjects in this section (for summaries of individual studies, see Appendix 1).

Table 3. Carbonation models for LCA.

Author	Model	Parameters Studied
AzariJafari et al. [33]	$Uptake = \sum_{n=1}^{T} K_{DOC} A(\sqrt{t_{m+n}} - \sqrt{t_n})/(1000C_{U_{max}})$ $Uptake = mass\ of\ carbon\ sequestered\ by\ 1\ cubic\ meter\ of\ concrete$ $t_n = analysis\ year, t_{m+n} = next\ treatement\ action, K_{DOC} = carbon\ penetration\ factor$ $K_{DOC} = \sum_{i=1}^{2} (Day_i \times K_i \times DOC_i)$ $Day_i = fraction\ of\ rainy\ and\ non-rainy\ days$ $K_i = rate\ of\ carbonatio\ on\ surface\ \left(\frac{mm}{\sqrt{year}}\right)$ $DOC_i = degree\ of\ caarbonation\ for\ rainy\ and\ non-rainy\ days$ $C_{U_{max}} = \sum_{j=1}^{n} (B_j \times U_j) \prod_{j=1}^{n} cf_j$ $j = type\ of\ binder,$ $B_j = quantity\ of\ binder\ for\ 1\ cubic\ meter$ $U_j = \max^{theoretical\ uptake} \left(kg \frac{CO_2}{kg}\right)$ $cf_i = the\ correction\ factor$ $COST_{eol}(t) = \left(\sum_{m=1}^{t} q_m + \sum_{n=1}^{T} (q_{x+t} - q_n)\right) C_{land}$ $COST_{eol}(t) = total\ cost\ of\ stockpiling$ $t = years$	- Cost - Stockpiling - Rainy vs Non-rainy - Time

Author	Model	Parameters Studied
	$q = \text{quantity of concrete stockpiled,}$ $T = \text{anaysis period (years)}$ $C = \text{cost } (\frac{\$}{ton})$	
Ruschi Mendes Saade, Yahia, and Amor [34]	$C_{CO2}(t) = a_0 + \sum_{i=1}^{3} a_i \times e^{\frac{-t}{\tau_i}}$ $C_{CO2}(t) = \text{decay pattern of a } CO2 \text{ pulse emission}$ $a_i = \text{coefficients for the calcualtion of } CO2 \text{ fractions remaining in atmosphere; } a_0 = 0.217, a_1 = 0.259, a_2 = 0.338, a_3 = 0.186$ $\tau_i = \text{perturbation time; } \tau_1 = 172.9 \text{ years}, \tau_2 = 18.5 \text{ years}, \tau_3 = 1.186 \text{ years}$ $DCF_{inst,CO2}(t - t_j) = \int_{t_j}^{t} A_{CO2} \times C_{CO2}(t)dt$ $A_{GHG} = \text{specific radiative forcing per unit mass}$ $t_j = \text{time of occurrence of pulse emissions or uptake}$ $t = \text{time of the effect}$	• Crushed Concrete • Carbon Uptake: over time, increased SCM use, alternative fuels
Kikuchi and Kuroda [35]	$x = a \times (1 - b) \times c \times d(kg)$ $x = \text{amount of } CO2 \text{ uptake by 1 ton of recycled crushed} - \text{run stone } (kg)$ $a = \text{ratio of particle less than or equal to 5mm}$ $b = \text{ratio of insoluble residue}$ $c = CaCO3 \text{ content}$ $d = \text{ratio of molecule wts of } CO2 \text{ and } CaCO3$	• Crushed Concrete • Exposure Period: 0, 28, 91 days • Exposure conditions: dried vs alternatively wetted and dried

4.1 Porosity

Carbonation depth is affected by compressive strength and porosity and both need to be considered when modelling concrete carbonation [36]. The porosity of concrete provides internal surface area that can support carbonation. Several authors have leveraged concrete compressive strength as a partial proxy to reflect the porosity of concrete in carbonation models (e.g., [14]). While extension of models to reflect porosity directly is not always done, the porosity of concrete can be related to the strength as shown by:

$$S = S_o \exp\,(-kp) \qquad \text{Eq. 6}$$

where S is compressive strength, S_o is strength at zero porosity, k is a constant, and p is porosity [37]. Porosity directly impacts the diffusion of CO_2 in concrete, and it will also change over time. When carbonation happens, the porosity will decrease as the formation of carbonate minerals increases [38]. In general, higher porosity will support increased carbonation depth and rates of carbonation. The total porosity is greater with higher water to cement ratios (w/c), which can drive greater capillary voids in the paste [39]. Lower water to binder ratios tend to result in lower carbonation coefficients because of pore structure densification [40]. CO_2 diffusion is highly influenced by pores with a diameter larger than 200nm [39].

Atis [36] studied the relation of carbonation depth to porosity and proposed these factors have a linear relationship; carbonation depth and compressive strength have an inverse relationship. In this work, these parameters were combined and represented using Equation 7:

$$C = 5.32 - 0.112 \times S + 0.822 \times P \qquad \text{Eq 7}$$

where C is carbonation depth, S is compressive strength, and P is porosity. When the relationship of carbonation depth, porosity, and compressive strength are utilized together Atis was found that the correlation coefficient of R^2 increased from 0.85-0.90 to 0.96 [36]. Table 4 shows additional models and equations used to measure carbonation.

Table 4. Effect of porosity on carbonation.

Author	Model	Parameters Studied
Papadakis, Fardis, and Vayenas [41]	$x_c \approx 1650(\frac{w}{c} - 0.38)(1 - \frac{RH}{100})(y_{CO_2} t)^{1/2}$ $For \frac{w}{c} > 0.6, \frac{\left(\frac{w}{c}\right) - 0.25}{[1 + 2.6\left(\frac{w}{c}\right)]^{1/2}}$ $x_c = carbonation\ depth$ $y_{CO_2} = ambient\ CO2\ content\ by\ volume$ $RH = relative\ humidity$ $\frac{w}{c} = water\ to\ cment\ ratio$	- Porosity - Relative Humidity

4.2 Location and CO$_2$ concentration

Atmospheric CO$_2$ has exceeded 400ppm since 2015 and has been increasing for the last two centuries. CO$_2$ concentration will vary on location. Ekolu found that atmospheric CO$_2$ lacks research, but some researchers have documented concentrations based on location as shown in Figure 2 [8]. As diffusion-based models are commonly used to assess carbonation, the concentration of the CO$_2$ to which the concrete is exposed is a key modeling parameter. Authors such as Xi et al. [14] present relationships of location and the atmospheric CO$_2$ concentration in that area. Yet there are gaps in research as CO$_2$ concentration is not properly identified in many studies, e.g., [14,42], which limits the ability to replicate and expand upon these existing modeling efforts.

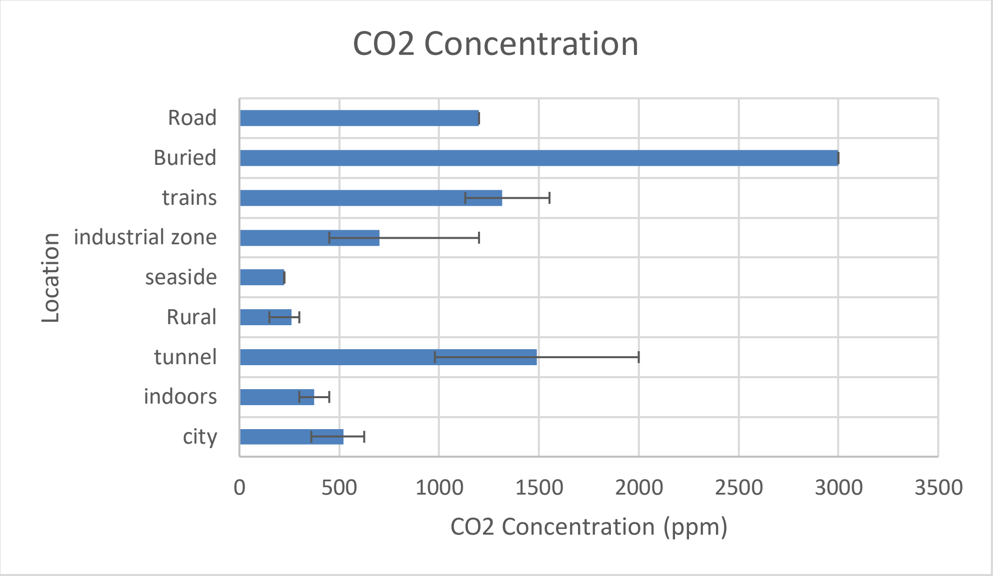


Figure 2. CO_2 concentration at various locations (based on data from [8,14,40,43,44]).

Figure 2 identifies a range of CO_2 concentrations for different exposures. The values reported for these locations vary from 150ppm to 16,690ppm, which is noteworthy as this range shows that the placement and application of the concrete can drive substantial variation in CO_2 exposure conditions [8]. CO_2 concentration is measured in open country, city, and industrial, and in several stables; findings indicate that carbonation depth increases at a faster rate of service years in low-aired stables than in open country [45]. The model produced by Saetta et al. predicted carbonation depth in low-aired stable as 11mm over 16 years of service and in the open country as 7mm over 23 service years [43,45]. The influence of CO_2 concentration was not found to be significant for structural concrete of over 60 MPa [8]. Different researchers have created models that evaluate CO_2 concentrations, but not many evaluate different locations, meaning results will vary based on location. Table 5 shows the models developed that take into account CO_2 concentration.

Table 5. Models showing effect of CO_2 concentration on carbonation.

Author	Model	Parameters Studied
Xi et al. [14]	$Carbonation\ depth = \sqrt{CO_2 concentration}$	• CO2 concentration
Lui, Yu, and Chen [46]	$d_c = K_x\left(\frac{w}{c} - 0.106\right)\left(C_e{}^2 - 508.351 \times C_e - 1195.624\right)(F + 112.460)(T - 277.662)\left(C_d{}^{0.538}\right)(RH^2 - 125.410RH + 2351.806)\sqrt{t}$ $d_c = carbonation\ depth\ (mm)$ $C_e and\ F = content\ of\ cement\ and\ admixture\ \left(\frac{kg}{m^3}\right)$ $T = testing\ temperture\ fo\ carbonation\ (K)$ $C_d = concentration\ of\ CO2\ (\%) in\ simulated\ test$ $RH = relative\ humidity\ (\%)\ in\ simualted\ test$ $t = carbonation\ time\ of\ concrete$ $\frac{w}{c} = water\ to\ cement\ ratio$ $K_x = comprehensive\ influencing\ factor\ of\ carbonation, fitted\ value\ for\ simulated\ test = 2.982 \times 10^{-12}$	• Relative Humidity • Temperature • CO2 concentration • SCM: Fly Ash
Khunthongkeaw, Tangtermsirikul, and Leelawat [40]	$D_{n,t} = A \times D_a \times \sqrt{t}$ $D_{n,t} = carbonation\ depth\ of\ concrete\ normal\ exposed\ in\ natural\ environment\ for\ t\ months$ $A = slope\ of\ the\ relationship$ $D_a = carbonation\ depth\ of\ same\ concrete\ tested\ in\ accelerated\ chamber\ for\ 1\ month\ (mm)$ $t = exposure\ time\ in\ real\ environment\ (months)$ $A = 0.22\frac{C^{0.56}}{RH}$ $C = CO2\ concentration\ (ppm)$ $RH = relative\ humidity\ (\%)$	• CO2 concentration • Time • Relative Humidity

Author	Model	Parameters Studied
Von Greve-Dierfeld et al.[47]	$X_c(t) = \sqrt{\frac{2 \times D_c \times c_s \times t}{a_c}} = \sqrt{\frac{2 \times c_s \times t}{R_{carb}}} = k\sqrt{t}$ $k(t) = k_0 \times t^n$ $x_c(t) = carbonation\ rate$ $D_c = diffusion\ coefficient\ of\ CO2\ \left(\frac{m^2}{s}\right)$ $c_s = CO2\ concentration\ at\ surface\ \left(\frac{kg}{m^3}\right)$ $a_c = amount\ of\ carbonatable\ material\ per\ unit\ volume\ \left(\frac{kg}{m^3}\right)$ $R_{carb} = carbonation\ resistance\ \left(\frac{a_c}{D_c}\right)$ $k = carbonation\ coefficient\ (\sqrt{\frac{2 \times c_s}{R_{carb}}})$	• CO2 concentration • SCMs

4.3 Exposure conditions

The exposure condition of concrete will also impact carbonation, and as such, analyzing the exposure condition of the concrete and its influence on carbonation and the LCA of the concrete is essential [48]. Exposure conditions, as frequently defined in the literature and as used here, refers to whether or not the concrete is sheltered or unsheltered. Exposure condition will also encompass the relative humidity of the area. Huy Vu et al. concluded in their study of sheltered vs unsheltered that blocked pores caused by precipitation prevent/reduce carbonation in unsheltered environments [49]. Other researchers confirm that the carbonation coefficient is larger when the area is sheltered with little/no exposure to rain than non-sheltered with exposure to rain [40]. Often times, carbonation is modeled using parameters that do not realistically represent the natural outdoor exposure environment [8]. Humidity transport will also impact potential failure of reinforced concrete when it reaches and breaks down the passive protection steel surface and causes corrosion of the rebar [3,43]. The literature suggests that depth of carbonation is up to 3-4 times less than 50% RH laboratory setting when outdoors [48]. Depth of carbonation is reduced 28%-51% when the specimen is inclined outdoors [48]. Ekolu [8] used a ratio model to study the effect of CO_2 concentrations, strength, and sheltering conditions using the following equations:

$$e_s = {f_c}^{-0.2} \qquad \text{Eq. 8}$$

$$e_s = sheltering \left(\frac{unshl}{shl}\right) ratio \qquad \text{Eq. 9}$$

$$e_c = \left\{\frac{\alpha {f_c}^{r} for\ 20 < f_c < 60\ MPa}{1.0\ for\ f_c \geq 60\ MPa}\right\} \qquad \text{Eq. 10}$$

where f_c is the 28 day compressive strength, e_c is a correction factor, α and r are variable based on CO_2 concentrations [8]. Pade and Guimaraes conducted a comparative study identifying flaws and gaps in study of demolished and crushed concrete carbonation [3], with results indicating that 40-80% relative humidity maximizes carbonation rate. These authors also indicated that indoor carbonation will be greater than outdoor exposed concrete [3], which could be supported by these relative humidities being common for indoor environments. Equation 11, a rewrite of Fickian diffusion, is a wildly accepted approximation for measuring carbonation:

$$d = k \times t^{0.5} \qquad \text{Eq. 11}$$

where d is the depth of carbonation, k is the rate constant, and t is time, but with higher strength concretes or outdoor conditions carbonation is found to be much slower than the square root of time. Therefore rate constant should be chosen based on strength and exposure condition [27]. Huy Vu et al. [49] looked at several locations and sheltered vs unsheltered carbonation depth vs strength are shown from Figure 3-Figure 7.

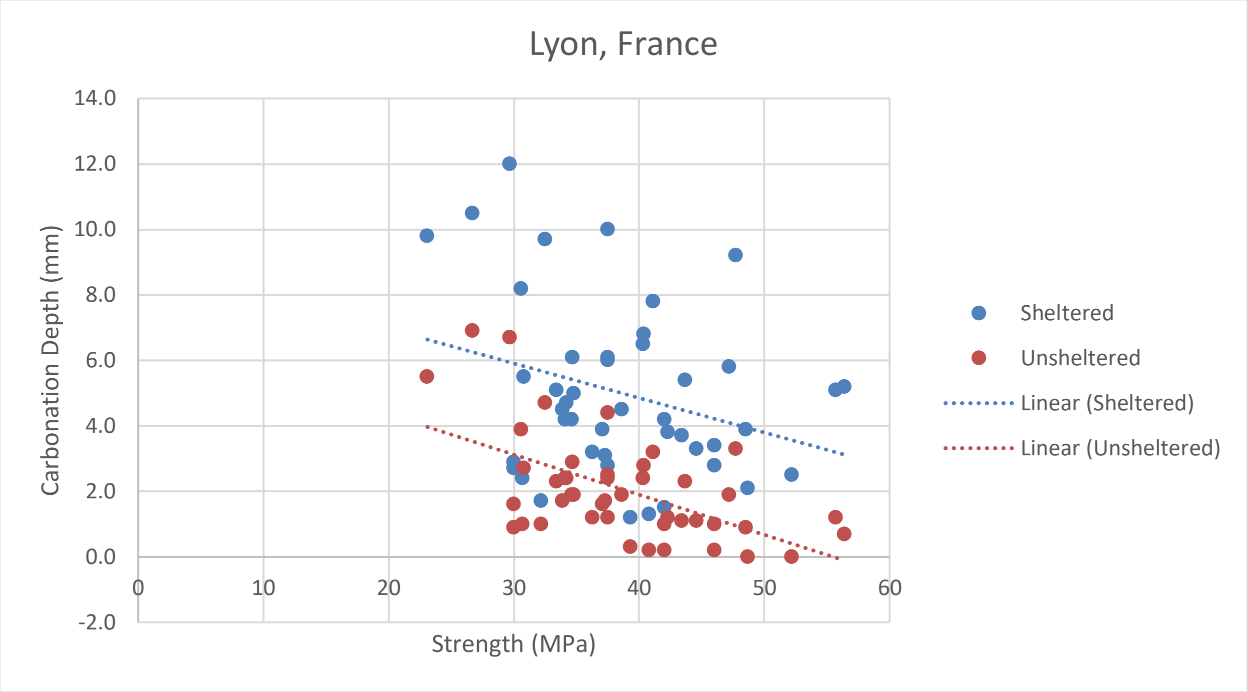


Figure 3. Carbonation depth (mm) vs. strength (MPa) for Lyon, France (note: figure made using data reported in [49]).

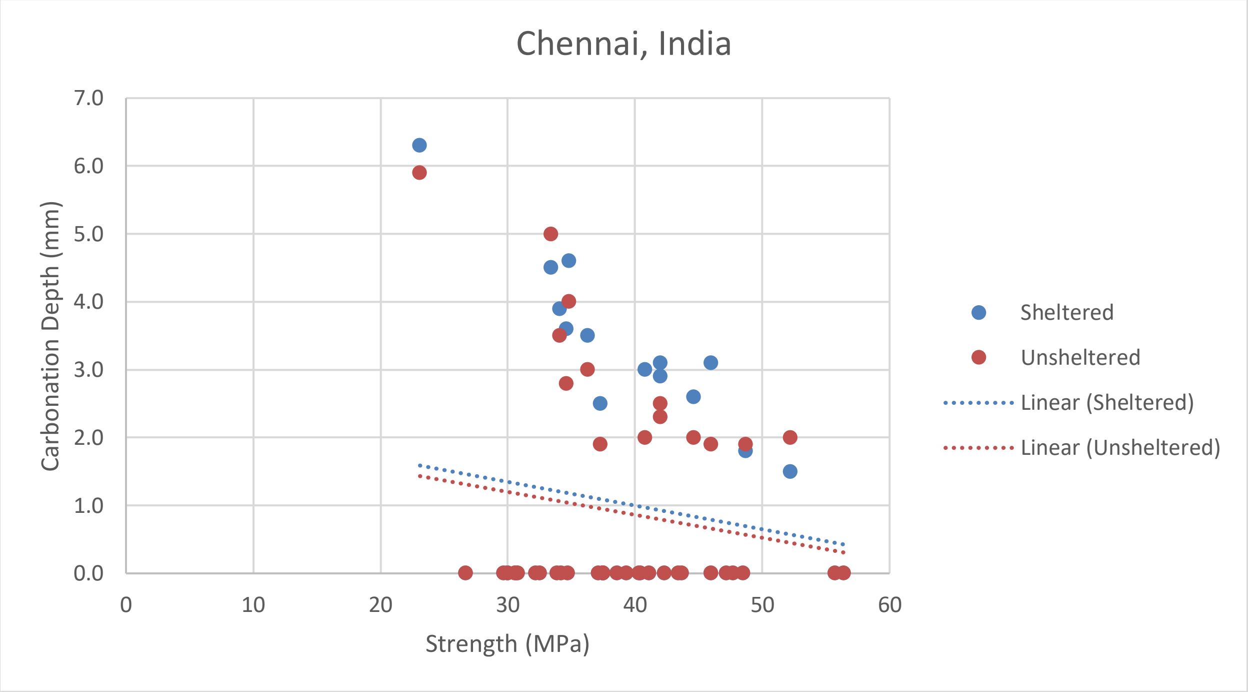


Figure 4. Carbonation depth (mm) vs. strength (MPa) for Chennai, India (note: figure made using data reported in [49]).

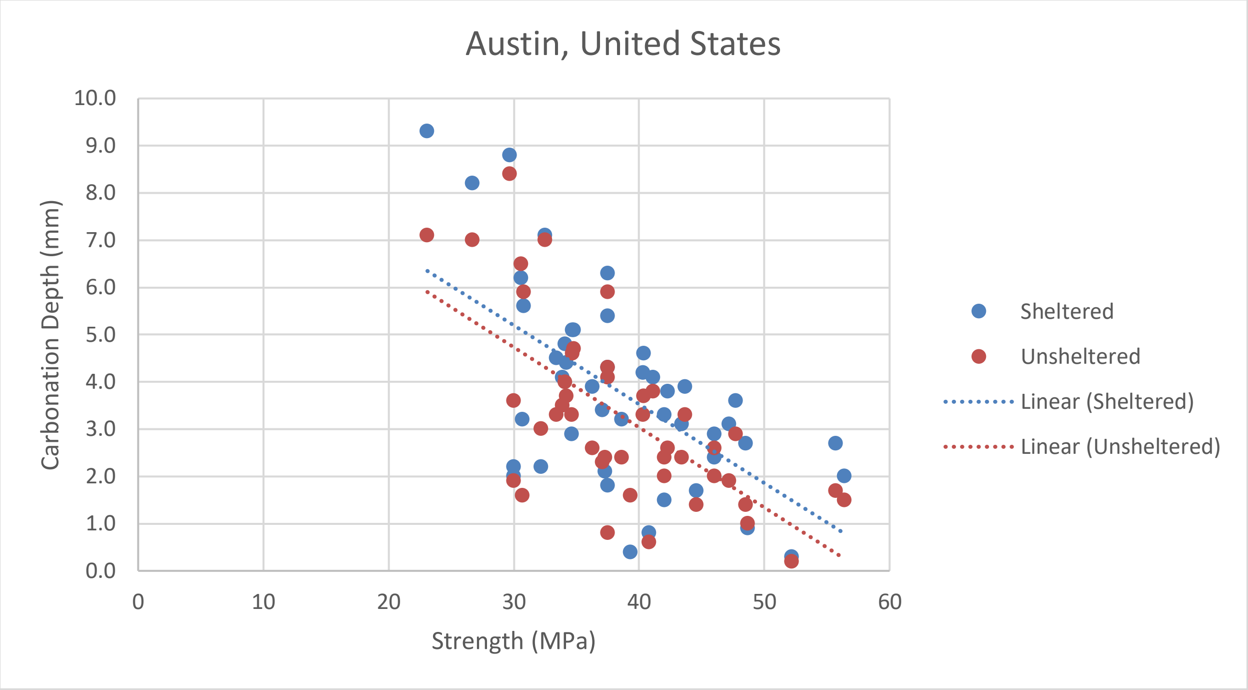


Figure 5. Carbonation depth (mm) vs. strength (MPa) for Austin, United States (note: figure made using data reported in [49]).

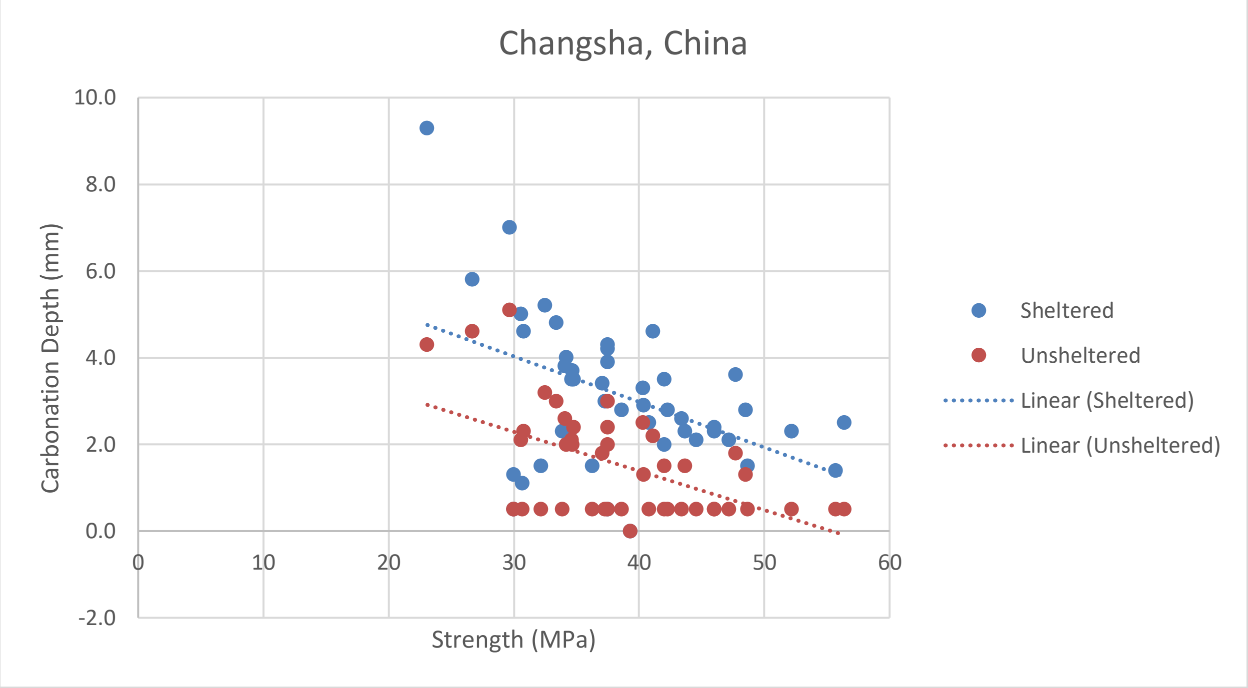


Figure 6. Carbonation depth (mm) vs. strength (MPa) for Changsha, China (note: figure made using data reported in [49]).

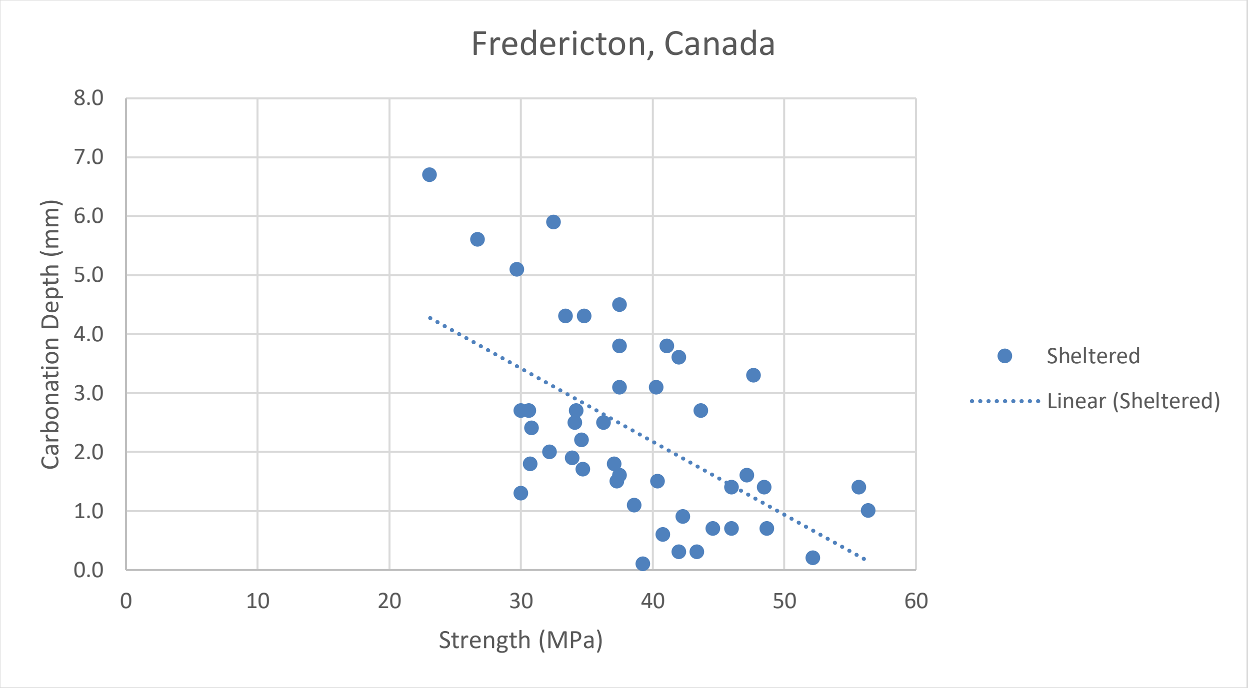


Figure 7. Carbonation depth (mm) vs. strength (MPa) for Fredericton, Canada (note: figure made using data reported in [49]).

Huy Vu et al found sheltered carbonation rates of various areas will be similar, which they attributed to sheltered concretes not being exposed to precipitation that blocked the pores in the concrete preventing the process of carbonation [49]. Table 6 shows additional models used to analyze exposure conditions and their effect on carbonation.

Table 6. Exposure condition models for carbonation.

Author	Model	Parameters Studied
Garcia-Segura, Yepes, and Alcala [50]	$t = (\frac{d}{k})^2 + \frac{80d}{\emptyset v_c}$ $t = \text{years of service life}$ $d = \text{concrete cover (mm)}$ $k = \text{carbonation rate coefficient}$ $\emptyset = \text{bar diameter (mm)}$ $v_c = \text{corrosion speed } (\frac{\mu m}{yr})$	• SCM content: Fly Ash and Blast furnace Slag • Carbon Capture/Carbonation Rate • Exposure condition: rain or covered • Various life cycle stages: production, construction, use, and demolition
Younsi, Turcry, and Ait-Mokhtr[51]	$Uptake(t) = CBC.X_c(t)$ $CBC = \text{CO2 binding capacity } (kg_{CO_2} \text{ per } m^3), X_c(t) = \text{carbonation depth (m) at expoure time } (t) \text{ in years}$ $X_c(t) = k\sqrt{t}$ $k = \text{carbonation rate defined by compressive strength class, the exposure conditions (sheltered or unsheltered), and the type and dosage of mineral additives}$ $CBC = K.U_K DoC, K = \text{clinker content } \left(\frac{kg}{m^3}\right),$ $U_K = \max \text{bound CO2 by carbonation of CaO from clinker } \left(\frac{kg}{kg}\right)$ $DoC = \text{degree of carbonation}; 0.4 = \text{indoor}, 0.75 = \text{outdoor sheltered}, 0.85 = \text{outdoor unsheltered}$ $Uptake = \frac{1}{R}\int_{X_c}^{R} CBC \times rdr = CBC\left[\frac{R^r - (R - X_c)^2}{R}\right]$ $R = \text{radius of cyclindrical specimen } (m)$	• Sheltered vs unsheltered

Author	Model	Parameters Studied
Pade and Guimaraes [3]	$d = k \times t^{0.5}$ $d = depth\ of\ carbonation$ $k = rate\ constant$ $t = time$ $Carbonated\ concrete\ (m^3) = \sum (A_{slabs} \times d) + (A_{walls} \times d) + \left(A_{foundations} \times d\right) + \cdots$ $A = surface\ area$ $d = depth\ of\ carbonation$ $CO_2 uptake\ \left(kg \frac{CO_2}{m^3} concrete\right) = 0.75 \times C \times CaO \times \frac{M_{CO_2}}{M_{Cao}} \left(\frac{kg}{m^3}\right)$ $C = mass\ of\ Portla\ cement\ clinker\ per\ m^3\ concrete$ $CaO = mass\ fraction\ of\ CaO\ in\ the\ cement\ clinker,$ $M = molar\ mass$	• Duration of Exposure • Compressive Strength • Surface Area • Exposure conditions

4.4 Curing Methods

Curing methods can affect the concrete microstructure, which in turn can influence carbonation and thus should be considered in modeling efforts. Ekolu [8] and Wang et al. [39] both emphasize the importance of curing methods being considered when evaluating concrete carbonation. Heat curing, air curing, moist curing, and any additional use of curing compounds are considered in many carbonation models, but their application is often not ideal in common construction sites. Site curing may look much different than experimental/lab created curing environments [8]. Research has found that the carbonation coefficient will increase as a result of curing temperature between 60-80 degrees [47]. Researchers have investigated different models utilizing different curing methods, such as that listed in Table 7.

Table 7. Model for curing methods on the effect of carbonation.

Author	Model	Parameters Studied
Silva et al [52]	$k_{ac} = \frac{c_d \times k_e}{\gamma_s \times \sqrt{t_{sl}}}$ $k_{ac} = coefficient\ of\ accelerated\ carbonation\ (mm\ yr^{-0.5})$ $c_d = reinforcement\ cover\ design\ (mm),$ $k_e = environmental\ parameter,$ $\gamma_s = safety\ factor\ (1\ for\ environmental\ class\ XC3\ and\ 1.25\ for\ environmental\ class\ XC4$ $t_{sl} = specified\ service\ life\ (year)$ *Reference EN 206-1 for description of environment classes	• Curing conditions • Replacement level of RCA in concrete carbonation • Size and origin of RCA in concrete • Chemical admixtures and additions

4.5 Coatings

Any coatings on existing concrete need to be analyzed as they can affect the diffusion of CO_2 into the concrete. Coatings often act as a barrier, but they degrade over time. Park [53] analyzes the degradation of coatings and its effect on carbonation depth over time by utilizing diffusion-permeability theory, and showed this method of approximation could be very accurate. Models found in Table 8 are a series of equations building from the depth of carbonation measured based on the exposure environment and quality of the concrete. These equations can help support analysis of the carbonation of concrete while considering both initial conditions and deterioration over time [48,53]. Table 8 shows different models used by researchers to study coatings.

Table 8. Model equations for review of coating influence on carbonation [48,53,54].

Author	Model	Parameters Studied
Ho and Harrison [48]	$\frac{dX}{dt} = \frac{D}{X + S"}$ $S" = S' - k(t - t')$ $X = depth\ of\ carbonation, k = rate\ of\ deteriation\ of\ coating$ $t' = age\ of\ concrete\ when\ coating\ applied$ $S' = resistance\ of\ the\ coating\ to\ carbon\ dioxide\ prior\ to\ deteriation\ or\ the\ intial\ equivalent\ thickness\ at\ time, t'$	• Coatings • Time • Deterioration of substrate
Park [53]	$C_{CO_2-Out} = 14.41\exp\ (0.00357t) + 1.99\sin(-1.99 + 0.54t) + 300.79$ $t = time\ (months)$ $F = [2 - \exp(\lambda \times t^N)]$ $F = measure\ of\ coating\ performance$ $t = time$ $\lambda\ and\ N\ are\ material\ constants$	• Coatings • Time • Permeability and Porosity
Merah [54]	$R = \mu \times S$ $R = coefficient\ of\ coating\ effectiveness$ $\mu = resistance\ coefficent\ of\ CO2\ diffusion$ $S = coating\ thickness$ $\gamma = 1 - \frac{x_t}{x_u}$ $x_t = carbonation\ depth\ of\ coated\ concrete$ $x_u = carbonation\ depth\ of\ uncoated\ concrete$ $\gamma = 1, completely\ effective\ anti - carbonation\ coating$ $\gamma = 0, completely\ ineffective\ anti - carbonation\ coating$	• Coatings

Author	Model	Parameters Studied
Monteiro et al. [55]	$K = 847{f_{cm}}^{-1.435}$ $K = carbonation\ coefficent\ (\frac{mm}{year^{0.5}})$ $f_{cm} = mean\ compressive\ strength\ (MPa)$	• Compressive strength • Coatings • Time

4.6 SCMs

SCM use has increased in the concrete industry and multiple studies have shown its influence on carbonation. Increasing SCM use can be used to lower the amount of clinker used in the mix, which alters the availability of CaO that can be carbonated. Increased clinker results in an increase in CaO; this results in increased potential for absorbed CO_2, which is predominantly driven by $CaCO_3$ formation, and reduced carbonation depth [56]. Several models in the literature have used the assumption that 75% of the original CaO in clinker has converted to $CaCO_3$ [3,27]. Fly ash has been found to potentially increase carbonation depth. Atis found that 70% replacement with fly ash concrete carbonated more than Portland cement concrete [36]. Further, the carbonation coefficient increases when fly ash content increases; at 50% fly ash, it is 2-3 times greater than mixtures with 0% fly ash [40]. Less than 15% SCM replacement has a negligible effect on carbonation rate [57]. Increased use of SCMs can positively impact carbonation rates; yet there are multiple factors acting concurrently in the paste system. It has been noted that incorporation of FA and reducing the water-to-cement ratio will drive variations in porosity that should be considered when studying their influence on carbonation depth [36]. Bucher et al. conducted a study looking at the effects of SCMs on compressive strength and carbonation depth [58], summarized in Figure 8.

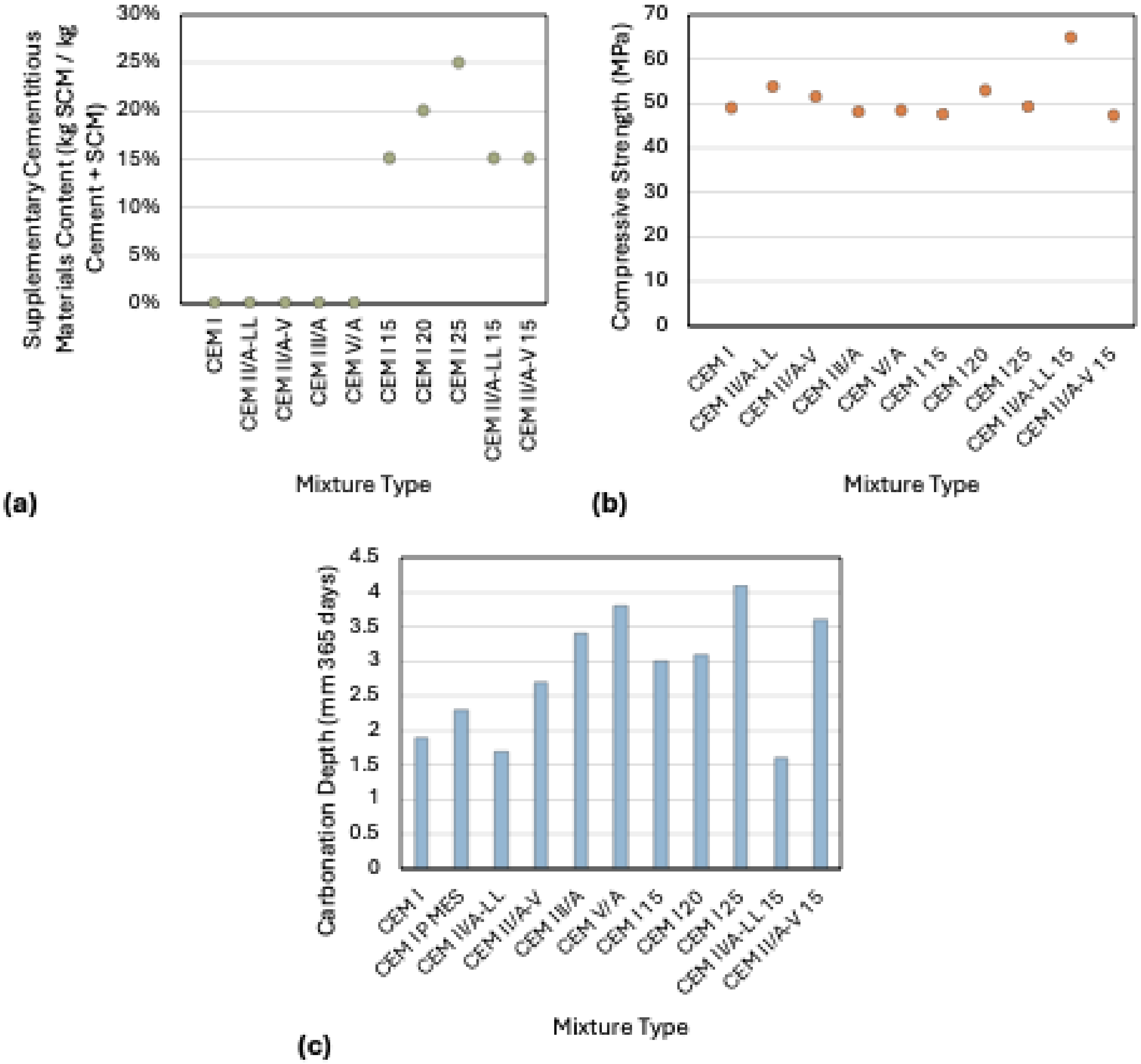


Figure 8. Carbonation depth and compressive strength vs. SCM [58].

5. Discussion

After analyzing the key factors that influence carbonation, there is evidence that more holistic analyses are needed to systematically address several parameters that would influence sustainable management of concrete at EoL. Ekolu [8] and Pade and Guimaraes [3] discuss the need for more research into demolished concrete, but these authors also make the point that demolished concrete will alter the properties of the concrete if it is reused to reduce the demand for natural aggregates.

As growing research and modelling strive to find sustainable methods for concrete EoL, it is imperative to ensure the LCA for these processes is complete. Carbonation is a growing topic of interest in environmental impact assessments, and certain parameters such as porosity, exposure conditions, location & CO_2 conditions, curing methods, coatings, and SCMs remain understudied for such modeling efforts.

Multiple models reference various parameters and use different variables. Without systematically addressing the role of each variable on carbonation (or their coupled effects), there will be inherent inaccuracies or uncertainty in using modeling efforts to predict carbonation for LCAs. Time is a variable that remains an influence across all parameters, that is attributed to two factors: (1) carbonation occurs over time; and (2) the microstructure of concrete changes over time [48]. Not only do these factors impact the models, but any spatiotemporal variation in exposures or time-driven alteration in exposures (e.g., coating deterioration) will also create shifts in carbonation. Time also plays a role in the climate impacts of CO_2 emissions and uptake (i.e., CO_2 fluxes). The total CO_2 fluxes from concrete can be over-estimated by 13-48% if carbonation is ignored; yet the rapid pulse of emissions from cement and concrete production relative to the decadal uptake of CO_2 through carbonation means that these uptake flows cannot simply be summed with the emissions flows [32]. While carbonation can result in notable uptake, the climate benefits of this uptake are not as great as the ~13-48% magnitude of uptake [32]. Further, any secondary use and emissions tied to that secondary implementation should be addressed in modeling efforts. For example, application of RCA and binder content need to be considered in determining carbonation [59].

This work highlights areas where future research can support technological advancements. We note cost is not assessed in this study as cost is ever changing for EoL management methods. Cost should be considered for transport, storage and crushing. Additional processing requires energy and labor which is associated with money. More research and data quality analysis should be done to complete holistic approach. Recycling and landfilling concrete could arguably be considered to be very high technology readiness, while stockpiling and storage should be further analyzed [17]. Stockpiling and storing crushed concrete are important to consider because is the middle step of recycling concrete at EoL, but it will have environmental implications. Carbonation increases over time and with increased surface area [14]. Further Pade and Guimaraes state that the effect of stockpiling on carbonation is negligible unless proper time is given, and 2 weeks to 4 months is the average stockpiling time in today's industry, which may not be sufficient [3].

The consideration that concrete should be stored for longer is unrealistic with the demand. Anecdotally, the supply of recycled concrete is much lower than the demand for concrete in the northern San Francisco area. Potential concerns are storage capacity in the state, but increasing storage sites may drive transportation impacts for the material. Further, crushing demolished concrete to ¾ inch base rock for use in the field could increase the surface area of the concrete thus increasing carbonation. But with demand for base rock higher than the supply in many areas and with the increased policy push to use recycled material, consumption drivers may not allow increased time for carbonation.

The responsibility of driving necessary change to increase concrete carbonation the alterations in demolished concrete exposure and storage may fall on the mining/construction industry and policy makers. The policy makers are involved because they required bill AB 2953 to increase recycling, but carbonation is also a sustainability and resiliency matter with interest of the government [26]. Both the industry and the government may need to create market drivers for this change. The largest cost would likely come from additional space for stockpiling, cost of stockpiling, and loss of materials. Based on current structures, it could be expected that federal and state governments would be involved in policy and allocating funds, but local county governments would be heavily impacted as they adjust their management schemes. State supported agencies, such as the California Department of Transportation (Caltrans) could instigate change because of their notable market for material resources, their control over demolished concrete, and the potential storage sites along highway systems. As indicated from this review, any EoL management method will contribute to other environmental impacts beyond carbon uptake. These impacts could be co-benefits, such as reduction in virgin material demand, or unintended consequences, such as dust from crushed concrete. Because of the multiple layers of the analysis, there are many modeling and policy aspects that require further analysis in future work.

6. Experimental

6.1 Introduction

There are several parameters that are known to influence carbonation of concrete. These include cement type, SCM use, and shape of the concrete element [14,60–62]. Carbonation of end-of-life (EoL) concrete is further dependent on particle size, exposed surface area, and the exposure time [60–62]. However, the CO_2 concentration at the surface of concrete is a key parameter in carbonation, where higher CO_2 concentration facilitates more rapid carbonate mineral formation. As a result, CO_2 availability at the surface of the concrete inherently becomes a limiting reactant in the carbon mineralization process. While it is known that the size of the crushed concrete can increase exposure area [61], this size distribution can also influence particle packing and affect the depth of CO_2 in a concrete pile, which can in turn influence amount of carbonation possible over a set time horizon [63]. Due to limitations in data availability, there are wide ranges of uncertainty associated with uptake potential tied to these parameters [29].

To determine the role of concrete gradation and depth of crushed concrete on CO_2 exposures, a series of experiments will be conducted using crushed concrete with 5 permutations to the gradations or constituents from demolition. Using diffusion-based models (e.g., [14,60]), data collected from these experiments can be used to understand the magnitude of carbonation possible based on crushed concrete gradation, thickness of carbonating material piles, and time of exposure.

6.2 Materials and methods

Crushed concrete was placed in containers sealed on 5 sides and with an open top exposed to ambient air conditions (see Figure 9) to measure CO_2 exposure over time for samples of different gradations and composition. Five samples were prepared using this crushed concrete: (i) the crushed concrete as received; (ii) the crushed concrete with 100% passing 3/8”; (iii) the crushed concrete with gradation of 3/8” and larger; (iv) a mixture of the crushed concrete as received (at 75% volume) and processed recycled asphalt pavement (RAP) millings passing 3/8” (at 25% volume); (v) a mixture of the crushed concrete as received (at 25% volume) and RAP millings (at 75% volume). Samples were held in 15-gallon plastic barrels. Recycled Class II Aggregate Base 3/4" Concrete Only Base Rock from Argent materials was used for the recycled concrete. Bulk specific gravity of the material was measured to be 2.426 in accordance with ASTM C127. Particle size was found to be 71% gravel, 16% coarse, 9% fine, and 4% silt. Table 9 shows the recorded sample from Consolidated Engineering Laboratories.

Table 9. Lab sieve results of recycled concrete sample.

Sieve size	Percent finer	Specification percent
1”	100	100
3/4”	99	87 - 100
1/2”	78	
3/8”	66	
#4	44	30 - 65
#8	32	
#16	22	
#30	16	5 - 35
#50	11	
#100	6	
#200	4.4	0.0 - 12

To determine changes in CO_2 concentration and relative humidity as a function of both gradation and distance from the exposed surface, experiments were run with continuous readings at controlled ambient temperature until CO_2 concentration recordings became negligible within the concrete piles. CO_2 sensors were used to measure CO_2 concentration within the containers and 1 set of sensors was used to measure ambient relative humidity (RH), temperature, and CO_2 concentration. Within the containers, 1 set of CO_2 and RH/temperature sensors was placed at the bottom and another was placed in the center of the sample, approximately 13 inches from the top. A probe 1% CO_2 USB Data Logger with Hydrophobic vent filter kit were used and connected to measure CO_2 concentration. The USB cords were used to record data, and these were protected with split wire tube conduit to ensure the cables were not damaged in the samples. HOBO Data Loggers: 0%to 95% Relative Humidity Measured, 32°F to 122°F, 0°C to 50°C, MX1102A, LCD were used to record the relative humidity and temperature inside the samples and ambient.

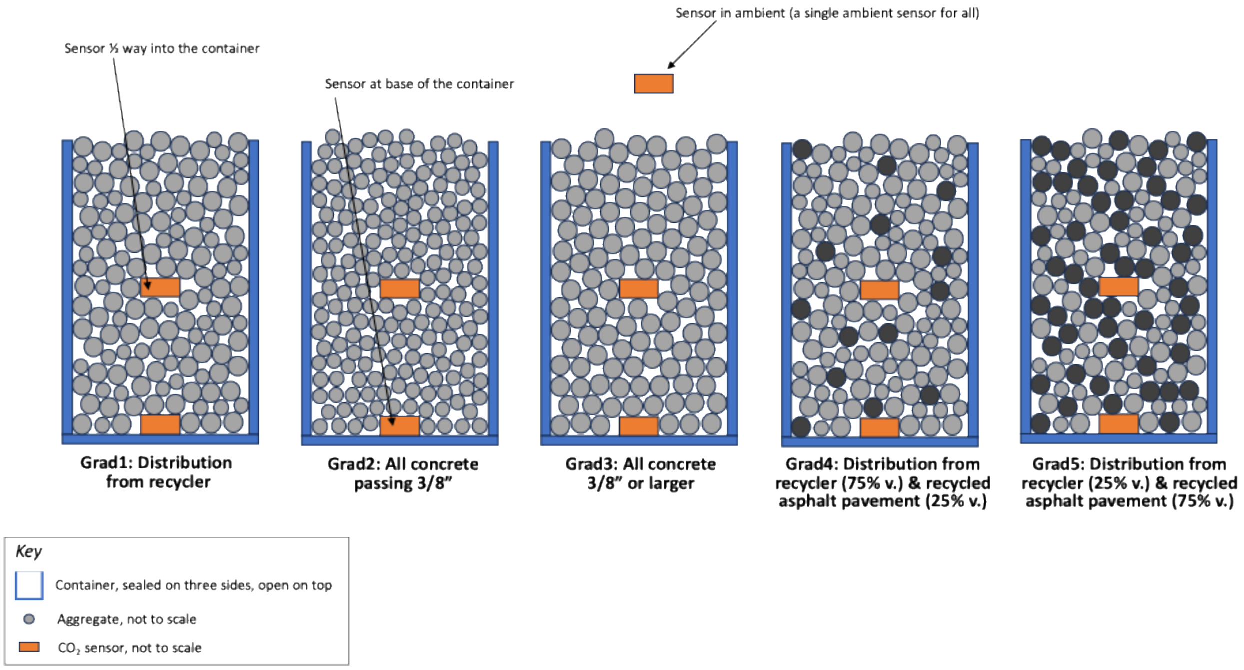


Figure 9. Experimental setup.

6.3 Results and discussion

Data from the sensors was recorded every minute for the first 24 hours and then every 6 hours for 7 days. Within 24 hours all sensors that were within the specimen containers showed a loss of CO_2. When removed from the sample the sensor returned to match ambient readings, confirming that the sensor was still reading. The readings within the crushed concrete containers have a 30-40ppm variation, but these concentrations are less than 10% of ambient conditions. These findings suggest gradation of the material, for each gradation and composition considered, was not enough to allow continuous CO_2 to flow to the sensor. The ambient reading continued to stay level. The sensors reached in a negligible CO_2 concentration in the following order: Grad 5, Grad 3, Grad 4, Grad 1, Grad 2. For each sample respectively, the bottom sensors reached a negligible CO_2 concentration before the sensor in the middle of the samples. Both sensors in the representative sample and both sensors in the passing 3/8" sample took approximately 30 more minutes to level out at negligible CO_2concentration. These low readings indicate that without adequate air flow, significant carbonation would not likely continue to occur in crushed concrete and recycled concrete/asphalt piles. Figure 10 shows the results in the first few hours of recording. The data from the experimental readings is available in Appendix 3.

This assessment provides a notable key finding: crushed concrete may not have proper access to atmospheric CO_2 to act as a DAC mechanism if not stored properly. Among all crushed concrete distribution sizes and in scenarios where asphalt was mixed in with crushed concrete, we find that there is not adequate continued exposure to CO_2 within less than an hour for concrete that is not near the surface of the pile. This work specifically focuses on ambient conditions and a one-dimensional flow of air (air can only enter from the top of this experimental setup). Based on these testing conditions and the parameters explored, these findings highlight areas for additional research. For example, the influence of even larger gradations (potentially supporting more air flow), understanding of air flow in a natural pile of crushed concrete, the effects in different localized environments (e.g., if more CO_2 is present, such as near an exhaust site), among other factors should be considered in future work.

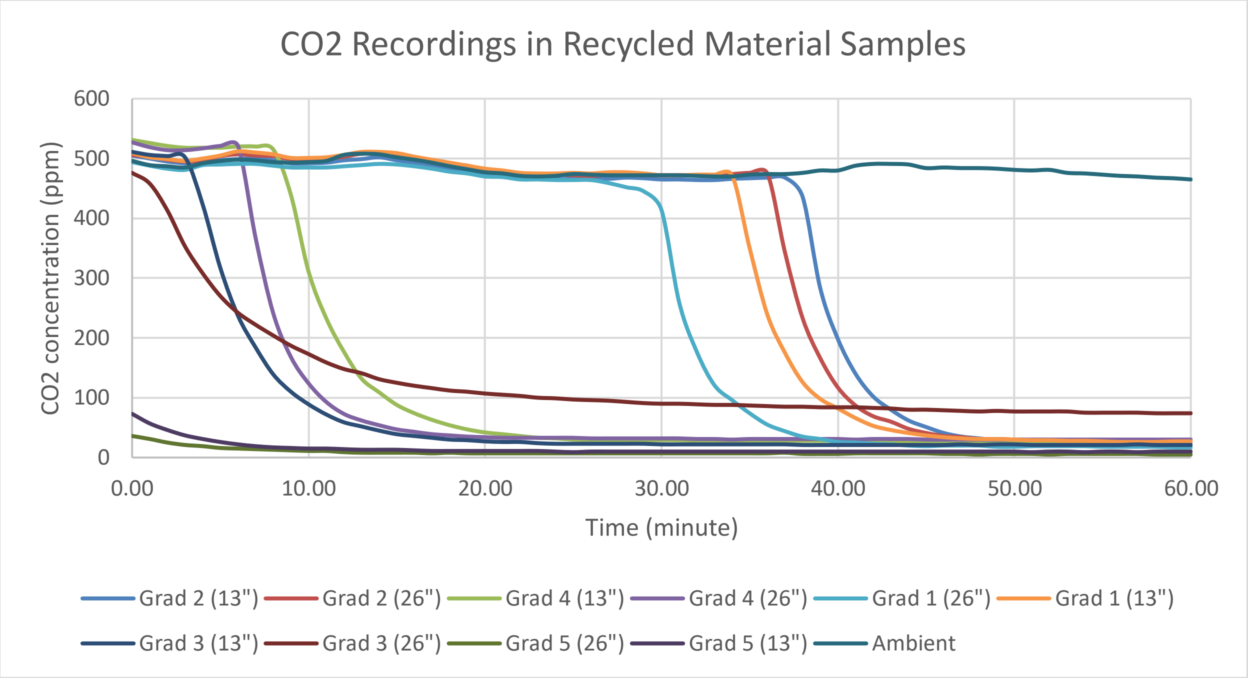


Figure 10. CO_2 recordings in Recycled Material Samples.

7. Conclusions

This work identifies key drivers for concrete carbonation as well as areas of uncertainty for concrete EoL management that require further research. Porosity, enclosure condition, curing method, location (which drives ambient CO_2 concentration, relative humidity, and temperature), and coatings are the key parameters that influence concrete carbonation. But the notable variability in the effects of these parameters on carbonation that are reported in the literature suggests further analysis to improve quantification for accounting for carbonation of concrete in LCA models should be performed. Landfilling, crushing and stockpiling, and reuse and recycling are the three methods currently used in the industry for concrete EoL management. Yet further research needs to be done in the holistic LCA and environmental impacts of the various EoL methods of crushed concrete to determine feasibility of each method. Additional processes involved in crushing and stockpiling concrete at EoL need to be included in future sensitivity analyses. The carbonation benefit should be quantified and applied as a credit in the LCA using each concrete EoL method. Further investigation needs to be done to associate the cost to stockpile, location for stockpiling, market allowance considering demand for aggregate, and realistic time of stockpiling to achieve quantifiable environmental benefits.

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Data Summary

Products of Research

The majority of this work was a review of the literature, summarized above. The only data collected were initial experimental readings, which are available in Appendix 3, and presented in Figure 10.

The experimental data collected were CO_2 concentrations. These data were used to create an initial foundation for assessment of how much CO_2 could be available within crushed concrete piles to support carbonation.

Data Format and Content

The data are presented in Appendix 3 and in Figure 10 within this report.

Data Access and Sharing

The general public can access these data via this technical report.

Reuse and Redistribution

Use of information from this report should provide appropriate citation(s) of this work.

Appendix 1. Literature Review Table & Summaries

Table 10. Summary of key reviewed literature (not exhaustive of all literature read for the report).

Authors	Title	Parameters studied	Key findings
S.O. Ekolu	A review on effects of curing, sheltering, and CO2 concentration upon natural carbonation of concrete	• Curing: natural vs accelerated; steam and oven curing; alterations of temperature, RH, and CO2 concentration • Sheltering: sheltered/unsheltered; rain/no rain • CO2 concentration: based on location- 150ppm- 16,690ppm	• Relative humidity, cement type, curing, CO2 concentration, temperature, quality and types of concrete, shelter and rain are all factors that influence carbonation. The factors can be divided into material characteristics and environmental factors. • Permeability/diffusion and strength-based models are well developed through the characteristics of permeability and strength. • No generalized mathematical relationship has been developed between accelerated and natural carbonation. • The curing methods of heat curing, air curing, moist curing, and use of curing compounds are widely used in laboratories but not in construction. • Long term carbonation behavior is not affected much by site curing. • Carbonation depth and rate of unsheltered to sheltered ratios are strength dependent. The ratio of unsheltered to sheltered should be between 0.3 and 0.8 for structural concrete. • The effect of CO2 concentration on natural carbonation is not well studied. The influence of CO2 concentration is strength dependent but was not found to be significant for structural concrete of 60 MPa or greater.
Anna V. Saetta, Renato V. Vitaliani	Experimental investigation and numerical modeling of carbonation process in reinforced concrete structures. Part I: Theoretical Formulation	• Reinforced concrete deterioration • Mathematical modelling	• The coefficients of cement hydration, ideal carbonation rate, diffusivity of water and carbon dioxide, and the carbonation and humidity transport interaction were analyzed to develop a numerical model for carbonation of reinforced concrete. • Experimental results and numerical simulations are provided in Part II of this work. • CO2 concentration is measured in open country, city, and industrial, and in several stables as reported.

Authors	Title	Parameters studied	Key findings
Anna V. Saetta, Renato V. Vitaliani	Experimental investigation and numerical modeling of carbonation process in reinforced concrete structures Part II. Practical applications	• Diffusivity of relative humidity • Diffusivity of carbon dioxide • Cement hydration coefficient • Coefficient of interaction between carbonation and CO2 diffusivity • CO2 concentration • Temperature • Relative humidity	• Carbonation depth measured in the web of the beam was three times shallower than on the underside of the beam. • The mathematical model accurately predicted carbonation depth in low-aired stable as 11mm over 16 years of service and in the open country as 7mm over 23 service years. • Carbonation depth increases at a fester rate of service years in low-aired stables than in open country.
Jinbang Wang, Hongxin Xu, Dongyu Xu, Peng Dua, Zonghui Zhou, Lianwang Yuan, Xin Cheng	Accelerated carbonation of hardened cement pastes: Influence of porosity	• Accelerated Carbonation • w/c: 0.3, 0.35, 0.40, 0.45, 0.5, 0.55, 0.6 • Curing time: 1-7 days • Carbonation time: 0-4 hours	• The growth of w/c ratio increases total porosity. • Carbon dioxide diffusion is highly influenced by pores with a diameter larger than 200mm. • Reduction in porosity of hardened paste happens after accelerated carbonation of 4 hours and also results in improved compressive strength. • Carbonization reactions primarily occur in the first 6 hours in accelerated carbonation. Increased carbonation time, w/c ratios, and porosity increased carbonation depths and rates.
Cengiz Duran Atis	Carbonation-Porosity-Strength Model for Fly Ash Concrete	• Moist vs dry curing • Fly Ash Cement Replacement: 50% and 70% • Porosity: 5.8-12.5% • Compressive Strength: 15-85 MPa	• Carbonation depth of concrete deceases with increased compressive strength. Carbonation depth increases with increases in porosity. • Mixture proportioning could be evaluated and optimized using compressive strength and porosity models of carbonation aiding performance and durability. • 70% fly ash replaced concrete carbonated more than natural Portland cement concrete and 50% fly ash replaced concrete with moist and dry curing.
Claus Pade, Maria Guimaraes	The CO2 uptake of concrete in a 100 year perspective	• Demolished and Crushed concrete • Carbonation depth • Hydration products	• Crushing concrete after demolition increases carbonation. This can increase carbonation about 2.4 times more than not crushing. • During concrete service life, 16% of emitted CO2 from calcination is reabsorbed. • The chemical makeup and hydration products present in concrete during its service life will influence carbonation.

Authors	Title	Parameters studied	Key findings
David W. S. Ho and Rex S. Harrison	Influence of Surface Coatings on Carbonation of Concrete	• Reinforced concrete deterioration • Penetration of carbon dioxide, chloride ions, water, and oxygen • Permeability • Inclined vs vertical surfaces • Coated and treated surfaces	• Coefficient of Carbonation is a function of time because when the concrete is exposed to the elements the quality changes, such as permeability. • Depth of carbonation of treated concretes can be determined with the chalking coefficient • Depth or carbonation is up to 3-4x less then 50% RH laboratory setting when outdoors. • Depth of carbonation is reduced 28%-51% when the specimen is inclined outdoors. • Carbonation depth increases 21-30% when strength increases.
D.C. Park	Carbonation of concrete in relation to CO2 permeability and degradation of coatings	• CO2 permeability • Degradation of Coatings • Diffusion-reaction carbonation • Diffusion-permeation theory	• Diffusion coefficient of carbon dioxide increased in the order of polyvinyl chloride, polyurethane, epoxy and acrylic coatings. • As a result of carbonation, concrete densifies and the diffusion coefficient decreases. • More coatings help prevent calcium hydroxide concentrations from declining.
Ahmed Merah	Concrete anti-carbonation coatings: a review	• Coatings: organic, inorganic, mortars, and paints • Thickness of coating • Coefficient of resistance to CO2	• The estimate of resistance of carbonation and penetration of chloride ions can be determined by air permeability and water absorption of concrete substrate. • Temperature can influence the durability of anti-carbonation coatings. • Concentration of pigments has an no effect on the diffusion coefficient of water vapor and permeability to water.
Fengming Xi, Steven J. Davis, Philippe Ciais, Douglas Crawford-Brown, Dabo Guan, Claus Pade, Tiemao Shz, Mark Syddall, Jie Lv, Lanzhu Ji, Longfei Bing, JiaoyueWang,WeiWei, Keun-Hyeok Yang, Björn Lagerblad, Isabel Galan, Carmen Andrade, Ying Zhang and Zhu Liu	Substantial Global Carbon Uptake by Cement Carbonation	• CO2 uptake • Carbon sequestration	• CO2 net sink increased from 0.1 to 0.25 GtC yr-1 between 1998 and 2013; this is a 40% increase over 5 years. • 4.5GtC is estimated to be the cumulative amount of sequestered carbon emissions over 43 years. • Carbon sequestration can be determined by mortar utilization thickness and carbonation depth found using Fick’s diffusion law.

Authors	**Title**	**Parameters studied**	**Key findings**
Ronny Andersson,Katja Fridh,Hakan Stripple, and Martin Haglund	Calculating CO2 Uptake for Existing Concrete Structures during and after Service Life	• Surface Condition: crushed, total surface area • Exposure Condition: sheltered; exposed to rain • Stockpiling: stage of demolition	• Modeling overestimation of carbon uptake can be avoided by defining the maximum theoretical carbon uptake. • Thickness influences carbon uptake. Thicker concrete will carbonate less than thinner materials. • In Sweden, 17% of total emissions were sequestered by existing structures from the production of new cement.
Peng Wu, BoXia , Xianbo Zhao	The importance of use and end-of-life phases to the life cycle greenhouse gas (GHG) emissions of concrete - a review	• End of life: landfill vs recycled • Indirect emissions, maintenance, rehabilitation effect on carbonation	• Cradle-to-gate assessments limit creditability of the environmental information in the life cycle system because it sets boundaries. • ISO 14067 and the implementation of Building Information Modelling will help models and research promote true complete life cycle assessments. • Demolished and landfill end-of-life methods may not be quantified in the life cycle because many studies do not account for carbonation.
Senthil Kumar Kaliyavaradhan, Tung-Chai	Potential of CO2 sequestration through construction and demolition (C&D) waste – An overview	• Carbonated RCA • Crushed concrete • Construction and Demolition Waste • Porosity • Curing method • Particle size • Water absorption • Moisture content • Curing time • Relative humidity • Temperature • CO2 concentration	• 1 ton of waste cement can result in about 0.27t of CO2 sequestered. • 1 ton of crushed concrete aggregate can uptake 11 kg of CO2. • Construction and demolition waste is a feasible way to lower the impact of GHG emissions by sequestration.

Authors	**Title**	**Parameters studied**	**Key findings**
Liu, P., Yu, Z. & Chen, Y.	Carbonation depth model and carbonated acceleration rate of concrete under different environment	• Carbonation Depth • CO2 concentration: 1-90% • Fly ash • Temperature: 283-303K • Relative Humidity: 40-90%	• A pH value curve can be the basis to determine the partial carbonation zone when the pH is set 7-9. • There is a power function, exponential function, and polynomial function between CO2 concentration, temperature, and relative humidity respectively, and there effect on carbonation depth is significant. • The quantity of micro pore, cross sectional characteristic, and compactness of micro structure are changed by relative humidity.
C. Lian a, Y. Zhuge b, S. Beecham a	The relationship between porosity and strength for porous concrete	• Porosity • Strength • Gradation: 13.2–4.75 mm; 9.5–6.7 mm; 9.5–4.75 • SCM: 7% Silica Fume	• Aggregate shape and absorption should be considered in the proposed model. • There is acceptable correlation between strength and porosity. • Griffith's model of fracture I used to explain mechanical performance related to porosity.
Qiwen Qiu	A state-of-the-art review on the carbonation process in cementitious materials: Fundamentals and characterization techniques	• Porosity • Curing condition: moist vs heat curing; time for curing; water vs air curing • Exposure Condition: sheltered vs unsheltered • Carbonation Depth	• Moist or wet curing causes a more obvious positive effect of longer curing time on pore structure. • Phenolphthalein indicator, TGA, FTIR spectroscopy, Raman spectroscopy, NMR spectroscopy, XCT and EIS are all methods of testing carbonation characterization that will help assist exploring the mechanism of cementitious carbonation as they advance. • For fly ash concrete, chloride aerosol ingress plus carbonation can lead to a denser pore structure.
JI Yongsheng, YUAN Yingshu, SHEN Jianli, MA Yuqiang, LAI Shaoping	Comparison of concrete carbonation process under natural condition and high CO2 concentration	• Carbonation Depth • Natural vs accelerated carbonation • pH • CO2 Concentration: 5-20% • Relative Humidity: 60-80%	• 5-40% CO2 concentration has little effect on the length of the semi-carbonation zone. • Higher relative humidity slows the diffusion of CO2 but increases the carbonation rate. • High CO2 concentration accelerate climate environments shortens the length of the semi-carbonation zone compared to natural conditions.

Authors	**Title**	**Parameters studied**	**Key findings**
I. Monteiro a, F.A. Branco b, J. de Brito b, R. Neves	Statistical analysis of the carbonation coefficient in open air concrete structures	• Reinforced Concrete • Porosity • Age	• There is an initial delay in carbonation when reinforced structures are painted. • Carbonation depth increases with aging. • For open air structures, cover thickness can range from 30mm for high strength to 40mm for low strength concrete.
J. Khunthongkeaw a, S. Tangtermsirikul a, T. Leelawat	A study on carbonation depth prediction for fly ash concrete	• Exposure Condition: Sheltered vs non-sheltered; rural vs seaside • Fly Ash • w/b ratio: 0.4, 0.5, 0.6 • CO2 concentration: 225-625 ppm	• Carbonation coefficient increase when fly ash content increases; at 50% fly ash, it is 2-3x greater than 0%. • Lower water to binder ratio results in lower carbonation coefficient because of pore structure densification. • The carbonation coefficient is larger when the area is sheltered with little/no exposure to rain than non-sheltered with exposure to rain.
V.G. Papadakis, M.N. Fardis, C.G. Vayenas	Effect of composition, environmental factors and cement-lime mortar coating on concrete carbonation	• Coatings: various resins, thicknesses, applications • Chemical Composition • Porosity • Relative humidity	• Carbonation-induced corrosion can be postponed with high lime content coating and 5.8 low w/c ratio. • Applying a coating to concrete later in its service life to already carbonated concrete can help maintain it for longer with increased alkalinity. • The model described is accurate for OPC and pozzolanic cement concrete and mortar with constant relative humidities above 50%.
Hessam AzariJafari , Fengdi Guo, Jeremy Gregory, Randolph Kirchain	Carbon uptake of concrete in the US pavement network	• Life Cycle stages influence on carbonation: use phase vs end-of-life CO2 uptake • Carbon Uptake: Use vs stockpiling vs landfill • Stockpiling: time of stockpiling	• 5.8 million metric tons CO2 can be sequestered in the US pavement network, and 52% of the network will be sequestered when demolished and stockpiled. • 26% of the US roadway network with the highest use uptake is within Texas and California. • Stockpiling allows for carbonation but with a cost, where some countries choose to recycle and thus no sequestration at end of life.

Authors	Title	Parameters studied	Key findings
Daragh Fitzpatrick, Mark G. Richardson, Eanna Nolan	Sequestration of Carbon Dioxide by Concrete Infrastructure: a Preliminary Investigation in Ireland	• Permeability • Humidity • Diffusivity of cement paste • pH	• If Carbon uptake was account for globally, estimated net CO2 emissions from calcination could be reduced by 20%. • 60% more CO2/t of cement can be estimated to be sequestered over 100 years service life when incorporating the new model. • The role of open-textured concrete products at end-of-life need to be considered; they have a noteworthy impact in carbon uptake.
Stefanie von Greve-Dierfeld, Barbara Lothenbach, Anya Vollpracht, Bei Wu, Bruno Huet, Carmen Andrade, César Medina, Charlotte Thiel, Elke Gruyaert, Hanne Vanoutrive, Isabel F. Sáez del Bosque, Ivan Ignjatovic, Jan Elsen, John L. Provis, Karen Scrivener, Karl-Christian Thienel, Kosmas Sideris, Maciej Zajac, Natalia Alderete, Özlem Cizer, Philip Vanden Heede, Robert Douglas Hooton , Siham Kamali-Bernard, Susan A. Bernal, Zengfeng Zhao, Zhenguo Shi, Nele De Belie	Understanding the carbonation of concrete with supplementary cementitious materials: a critical review by RILEM TC 281-CCC	• Curing Conditions: air, moist, sealed, heat, steam • Time of curing • SCM: silica fume, fly ash, volcanic rocks, blast furnace slag, organic matter ashes	• Neutralization of concrete is a potential consequence of reducing clinker content and increasing SCM content. • Carbonation coefficient will increase as a result of curing temperature between 60-80 degrees. • w/b ratio between 0.4-0.65 will increase the carbonation coefficient.
Daniel Costa Reis, Marco Quattrone, Jhonathan F. T. Souza, Katia R. G. Punhagui, Sergio A. Pacca, Vanderley M. John	Potential CO2 reduction and uptake due to industrialization and efficient cement use in Brazil by 2050	• SCM: limestone filler, slag, pozzolan, fly ash, pozzolan • Cost	• Low carbon scenarios of alternative fuels an energy efficiency can reduce CO2 emissions by 10% and with use of filler an additional 23% reduction. • The cement dilution effect can be compensated in industrial applications with the use of high filler substitution. • An accumulative 590 Mt CO2 reduction, up to 56% CO2 emissions is possible utilizing the low carbon scenarios by 2050.

Authors	Title	Parameters studied	Key findings
Miguel Angel Sanjuán, Cristina Argiz, Pedro Mora, and Aniceto Zaragoza	Carbon Dioxide Uptake in the Roadmap 2050 of the Spanish Cement Industry	• Reported CO2 uptake in Life Cycle and service life in different decades 2000-2010 and 2011-2020 • Carbon uptake modelling • Carbon capture methods of measurement	• Direct emissions from cement in Spain decreased from 815 to 679 kg CO2/t between 1990 and 2018. • Direct emissions from cement in Europe decreased from 783 to 667 kg CO2/t between 1990 and 2018. • To reach 100% decarbonization by 2050, Spain would need to capture 272 kg CO2/t cement. • The model assumes that 20% of carbon is captured during use phase and 3% for the end-of-life and secondary phases. • From 1898 to 2018, globally it is estimated 0.14 of CO2 was carbonated.
Akli Younsi, Philippe Turcry, Abdelkarim Aït-Mokhtar	Quantification of CO2 uptake of concretes with mineral additions after 10-year natural carbonation	• SCM • Life Cycle • Carbon Uptake • Carbonation Depth • Exposure Condition • Sheltered/unsheltered	• 18-21% of CO2 emissions in concrete structure will bind after 100 years. • Carbonation is an important carbon sink but can be evaluated and measured differently r results inconclusive and it is not incorporated in life cycle inventories. • 30% fly ash replacement is more resistant to carbonation than cement only. • Unsheltered conditions results in lower carbonation depths than sheltered.
M. Collepardi, S. Collepardi, J.J. Ogoumah Olagot and F. Simonelli	The Influence of Slag and Fly Ash on the Carbonation of Concretes	• SCM • Carbonation rate	• At a given water-to-cement ratio, with SCM replacement, carbonation rate increases ,but less than 15% replacement it is negligible. • At a given w/c, concrete without SCMs is more resistant to CO2 penetration. • As long as strength is not reduced, there is not a risk of concrete with slag and fly ash to corrode faster than without SCMs.
Wajeeha Mahmood, Asad-ur-Rehman Khan and Tehmina Ayub	Carbonation Resistance in Ordinary Portland Cement Concrete with and without recycled coarse aggregate in natural and simulated environment	• W/c ratio: 0.43-0.4 • Recycled coarse aggregate • Compressive Strength • Tensile Strength	• w/c ratio and CO2 duration exposure results in CO2 carbonation depth incremental increases. • In a natural environment, with a consistent w/c, Carbonation depth increases earlier than in a simulated environment. • Compressive strength reduces with use of RCA and the reduction increases with increased amount of RCA.

Authors	Title	Parameters studied	Key findings
Lagerblad	Carbon dioxide uptake during concrete life cycle	• Diffusion of CO2 • Chemistry • Crushed Concrete • Wet concrete • Fick's Law • Exposure conditions	• Crushed concrete will carbonate more because the surface area is increased. • Carbonation is increased with cyclic wetting and drying and increased temperature. • Different calculations for various environmental conditions will have result in different k values for carbonation. • To calculate carbonation, time frame, use, end uses, amount, surface area, exposure environments and k-value must be known.
A. Younsi, Ph Turcry, E. Rozière, Abdelkarim Aît-Mokhtar, A. Loukili	Performance-based design and carbonation of concrete with high fly ash content	• Curing Conditions: air vs water • Exposure conditions: accelerated conditions • SCM: fly ash, limestone • Porosity	• Lower clinker content results in decreased carbonation. • Porosity decreases when water-cured than air cured and more resistant to carbonation. • Water-reducing methods can reduce viscosity and result in poor compaction.
Andreas Leeman, Josef Kaufmann, Peter Nygaard, Roman Loser	Relation between carbonation resistance, mix design and exposure of mortar and concrete	• Oxygen Diffusion • SCM: fly ash, limestone powder	• Limestone powder and portlandite increase oxygen diffusion while micro silica and GGBS decrease it. • In natural and accelerated conditions, decreasing the w/b in OPC mortars decreases the carbonation rate. • Carbonation rate increases with mineral additions. • Sheltered conditions have a higher carbonation coefficient than unsheltered. • Carbonation decreases porosity.
Isabel Galan, Carmen Andrade, Pedro Mora, & Miguel A. Sanjuan	Sequestration of CO2 by Concrete Carbonation	• Carbonation • SCM: fly ash, silica fume • Sheltered/unsheltered • Porosity • Humidity	• Humidity is the most influential to carbonation rate. Sheltered concretes had a higher carbonation rate than unsheltered. • Decrease in porosity is a result of increased cement content but results in decreased carbonation depth and absorbed CO2. • Increased clinker results in an increase in CaO. This results in increased absorbed CO2 and reduced carbonation depth.

Authors	**Title**	**Parameters studied**	**Key findings**
Håkan Stripple Christer Ljungkrantz Tomas Gustafsson Ronny Andersson	CO2 uptake in cement - containing products	• Humidity • End-of-life methods	• In Sweden, with about 1.5 million tonne of concrete produced annually, it is estimated 6.4 kg CO2/m3 would be carbonated. • In Norway, it is estimated that 90% of demolished concrete can increase carbon uptake. 10% of consumed concrete is demolished. • In the Netherlands, it is estimated that the carbon uptake at end-of-life is 4% of calcination emissions are.
Inamullah Inam, Mohammad Khalid Nasiry, Mirwais Sediqmal, Mohammad Nasir Wahdat, Ibadurrahman Momand	A Study on the Carbonation Rate of Concrete Exposed in Different Climatic Conditions	• Sheltered/unsheltered • Relative humidity • Temperature • SCM: fly ash	• Carbonation rate increases in relatively dry environments. • Relative humidity between 45-70% results in increased carbonation rates. • Reduced rainfall lowers carbonation rates.
Quoc Huy Vua, Gabriel Phama, Alain Chonier, Eric Brouard, Sundar Rathnarajan, Radhakrishna Pillai, Ravindra Gettu, Manu Santhanamb, Federico Aguayoc, Kevin J. Folliard, Michael D. Thomas, Ted Moffat, Caijun Shie, Anup Sarnot	Impact of different climates on the resistance of concrete to natural carbonation	• Exposure conditions • SCM: limestone, slag, fly ash, pozzolan • Curing Age: 5 years • Climate region	• Lower temperatures across countries result in lower carbonation rates. • Carbonation rate decreases with the number of increased rainy days. • Carbonation depth remains unchanged up to 5 years and with between 1-28 days of curing.
Zhi Cao T. Reed Miller, Rupert J. Myers, Richard C. Lupton,Huabo Duan, Romain Sacchi, Nan Zhou, Jonathan M. Cullen, Quansheng Ge	The sponge effect and carbon emission mitigation potentials of the global cement cycle	• Carbon capture and storage methods • Carbonation	• Mitigation measures of thermal efficiency, electric efficiency, clinker substitution, and carbon capture and storage need to be considered holistically as emission reducers. • Clinker replacement reduces CO2 uptake marginally. • Carbon uptake of buried demolition waste is modelled to 0.041 Gt.

Authors	**Title**	**Parameters studied**	**Key findings**
Marcella Ruschi Mendes Saade, Ammar Yahia and Ben Amor	Is crushed concrete carbonation significant enough to be considered as a carbon mitigation strategy?	• Crushed Concrete • Carbon Uptake: over time, increased SCM use, alternative fuels	• Service life carbonation of all concrete is measured to account for 1.6% of the global warming effect. This was measured between 2018-2050 estimated. • Carbon capture and storage is estimated to reach 25-29% of direct CO2 emissions generated in cement making at 2050, which accounts for starting at 0 in 2030. • The study evaluated the impact to SCM and alternative fuel to other environmental impact categories, human health, and the ecosystem. The study concluded they decrease impact until 2050.
Toshifumi Kikuchi and Yasuhiro Kuroda	Carbon Dioxide Uptake in Demolished and Crushed Concrete	• Crushed Concrete • Exposure Period: 0, 28, 91 days • Exposure conditions: dried vs alternatively wetted and dried	• Alternately wetted and dried exposure conditions significantly increase the amount of CO2 uptake of demolished concrete. • 11 kilograms of CO2 uptake are estimated from one ton of recycled crushed concrete. • Field surveys show that crushing facilities vary in their crushing production per day from 480-3520 tons/day. • Crushing methods include jaw crushers, impact, and gyratory depending on is they use primary, secondary, and/or tertiary methods. • Crushing method will crush 40mm, 20mm, 5mm, 2mm, 0.5mm.
Stefanie von Geree-Dierfeld, Christoph Gehlen	Performance-based durability design, carbonation part 2 – Classification of concrete	• Carbonation depth at 40 measuring points • Exposure time of 140 days and 2mm carbonation depth • Carbonation rate • SCM content: Fly Ash, Silica Fume, Granulated Blast Furnace slag, Limestone • w/b: 0.45-0.65	• Carbonation rate increases with clinker replacement. • Porosity is one of the factors that will influence the increase in carbonation rate as clinker replacement increases. • Carbonation rate is affected by the rate of hydration which is influenced by the cement strength class.

Authors	Title	Parameters studied	Key findings
Tatiana García-Segura & Víctor Yepes & Julián Alcalá	Life cycle greenhouse gas emissions of blended cement concrete including carbonation and durability	• SCM content: Fly Ash and Blast furnace Slag • Carbon Capture/Carbonation Rate • Exposure condition: rain or covered • Various life cycle stages: production, construction, use, and demolition	• 47, 41, and 20% of CO2 emissions are captured by Portland cement, 35% replaced fly ash, and 80% replaced blast furnace slag. • High amounts of cement replacement reduce the service life given the 10% shorter carbonation rate coefficient. • 35% fly ash replacement emitted 20% less CO2 per year compared to Portland cement and had a reduces service life and CO2 capture. • Concrete protected against rain has a higher carbonation rate because the pores are partially blocked by the rain.
Patricia Aparicio, Domingo Martína, Rocío Baya-Arenas, Vicente Flores-Alés	Behaviour of concrete and cement in carbon dioxide sequestration by mineral carbonation processes	• Crushed, sized fractions • 20% moistened • 24-720 hours at 10 bars of CO2 • Mineral vs physical carbonation	• Smaller grain size and higher reaction time increases carbonation performance. • Mineral carbonation and physical absorption of CO2 are both mechanisms found in C&D waste. • After 72 hours, maximum carbonation was reached, fixed at 6.5% of CO2.
O. Troconis de Rincón; J.C. Montenegro; R. Vera; A.M. Carvajal; R. Mejía de Gutierrez; S. Del Vasto; E. Saborio; A. Torres-Acosta; J. Pérez-Quiroz; M. Martínez-Madrid; W. Martinez-Molina; E. Alonso-Guzmán; P. Castro-Borges; E.I. Moreno; F. Almeraya-Calderón; C. Gaona-Tiburcio; T. Pérez-López; M. Salta; A.P. de Melo; I. Martínez; N. Rebolledo; G. Rodríguez; M. Pedrón; V. Millano; M. Sánchez; E. de Partidas	Concrete Carbonation in Ibero-American Countries DURACON Project: Six-Year Evaluation	• 9 test sites with different climates: Bolivia, Chile, Columbia, Costa Rica, Mexico, Spain, Uroguay, Portugal, and Venezuela • Six years of exposure • w/b ration: 0.45 and 0.65	• Carbonation-induced corrosion was more likely to occur in concrete prepared in Venezuela than in Cali Columbia. • Sites with the higher average temperature also had higher carbonation depth. Higher temperatures favor CO2 ingress because of the reduced moisture inside the concrete. • There is a decrease in carbonation depth with an increase in relative humidity.

Authors	**Title**	**Parameters studied**	**Key findings**
Aiyoub Abbaspour, S.M.ASCE; Burak F. Tanyu, M.ASCE, P.E.; Bora Cetin, A.M.ASCE; and Michael C. Brown, M.ASCE, P.E.	Stockpiling Recycled Concrete Aggregate: Changes in Physical Properties and Leachate Characteristics Due to Carbonation and Aging	• Plastic limit of recycled concrete aggregate • pH levels • Leaching concentrations of Ca, Al, Mg, and Fe	• Over a year, leachate becomes less corrosive in recycled concrete aggregate; pH decreases from 11.5 to 10. • Stockpiling stabilizes elements of Ca, Al, and Fe. • With gain, there is not noticeable change in mortar content.
Tahir Gonen, Salih Yazicioglu	The influence of compaction pores on sorptivity and carbonation of concrete	• Pore structure: air, capillary, gel pore and compaction • Exposure conditions • Sorptivity coefficient • Compressive strength	• Compaction decreases carbonation and sorptivity coefficient. • There is a proportional relationship between mass and carbonation depth of the specimen. • Compressive strength decreased an insignificant amount with increase in porosities of 9%, 12%, and 17%. Compressive strength decreased 34% with 20% porosity.
N Venkat Rao and T Meena	A review on carbonation study in concrete	• SCM: Ground Granulated Blast Furnace Slag and Silica Fume • w/c ratio • curing • depth of concrete • grade of concrete • admixtures • strength • porosity • permeability	• Higher w/c ration increases carbonation depth • Carbonation depth decreases with increased curing time. • Minimum 7 days of curing improve resisting power. • Admixtures reduce porosity and modify the pore structure. • A linear relationship exists between accelerate carbonation and porosity; carbonation depth increases with porosity. • GGBS and SF reduce the depth of carbonation and reduce porosity. • Service life can be enhanced, and carbonation rate reduced with surface coatings.
W.P.S. Dias	Reduction of concrete sorptivity with age through carbonation	• Aging: 4 years • Depth of carbonation • Porosity • Sorptivity • Curing: wet vs dry curing	• Carbonation of the surface zone increases weight and reduces sorptivity with age in air-dried OPC concrete specimens. • Bad curing can cause carbonation and reduce sorptivity. • There were increased depths of carbonation and decreased sorptivity shown in cores cut from structures 30-150 years in age.

Authors	**Title**	**Parameters studied**	**Key findings**
Anna V. Saetta, Bernhard A. Schrefler and Renato V. Vitaliani	The carbonation of concrete and the mechanism of moisture, heat and carbon dioxide flow through porous materials	• Relative humidity: 40, 60, 80% • Temperature: 1 degree, 20 degrees, and 90 degrees Celsius	• Carbonation depth increases over time, and is higher with reduced temperature. • Increased relative humidity causes a slight decrease in carbonation depth respective to relative carbonate content. • Increased relative humidity causes a slight decrease in carbonation depth respective to relative carbon dioxide content.
Frank Collins	Inclusion of carbonation during the life cycle of built and recycled concrete influence on their carbon footprint	• Stage of life cycle: primary and secondary • Emissions factor based on SCM, other constituents, activities	• Quality of recycle concrete aggregate (RCA) is likely less than quarried natural aggregate and should not be used for structures with an assumed service life longer than 30 years. • Primary life is assumed to be 100 years and secondary life is assumed to be 30 years following demolition and crushing. • RCA will carbonate more with air-exposed than is buried and in a moist environment. • Emission estimates can be over-estimated by 13-48% if carbonation is ignored. Application of RCA and binder content need to be considered in determining carbonation.
R.V. Silva, R. Neves, J. de Brito, R.K. Dhir	Carbonation behaviour of recycled aggregate concrete	• Curing conditions • Replacement level of RCA in concrete carbonation • Size and origin of RCA in concrete • Chemical admixtures and additions	• Increasing levels of RCA in concrete mix design increases carbonation depths. Max increase is 2x the carbonation depth with 100% replacement. • Permeability increases in recycled aggregate and causes greater carbonations depths. • Carbonation depth is insignificantly affected by the strength of the original material. • The age of when the concrete was crushed for RCA does not influence the carbonation depth of the new concrete. • Using water-reducing admixtures to reduce w/c ration can increase mechanical properties and reduce carbonation.
M. Thiery, P. Dangla, P. Belin, G. Habert, N. Roussel	Carbonation kinetics of a bed of recycled concrete aggregates a laboratory study on model materials	• Grain size • Paste quality • w/c ratio: 0.45	• Liquid-water saturation degree below 0.4 and grain size below 2mm improves the rate of CO2 absorption. • 50% CO2 concentration can result from absorption capacity of 65%. • Carbonation is affected by binding capacity which is determined by w/c ratio and CO2 concentration.

Authors	Title	Parameters studied	Key findings
Masrur Mahedi, Bora Cetin	Carbonation based leaching assessment of recycled concrete aggregates	• Particle size • Alkalinity and pH • Liquid-to-Solid (L/S) ratio	• High pH leachate can be produced from RCA. This can contaminate soil, surface water, and groundwater. • pH increases with decreases particle size which is reflected as smaller sieve size in this study. • Carbonation amounts of concrete can be determined by the amount of calcium carbonate. • Effect of leached concentrations: Alkalinity decreases with increased calcium carbonate. Calcium decreases linearly with increased calcium carbonate. Magnesium increases linearly with increased calcium carbonate. Barium decreases linearly with increased calcium carbonate. Chromium increases with increased calcium carbonate. Sulfate increases with increased calcium carbonate.

Appendix 2. Sensitivity Analysis Calculations

Table 11. Data and calculations used to calculate the values found in Table 1.

	Unit	kg GHG				kg NOX	kg SOX	kg PM10	kg PM2.5	kg VOC	kg CO	kg Pb	kg Water	Ckg Water Withdrawal	MJ Energy Demand
transport of material	per tkm	1.67E-04				1.19E-06	8.15E-08	2.26E-08	2.60E-08	9.60E-08	1.30E-06	9.16E-13	0.25419	0.254185	0.8
Jaw crusher			**kg CO2**	**kg CH4**	**kg N2O**	**kg NOX**	**kg SOX**	**kg PM10**	**kg PM2.5**	**kg VOC**	**kg CO**	**kg Pb**	**kg Water**	**Ckg Water Withdrawal**	
11783.405	MJ/ton		4.42386177	4.49E-05	6.54E-05	0.005028	0.01392	0.00051	0.000212	5.21E-05	0.00048	1.10E-09	9.91451	182.426	
			per MJ												
	CA mix %		**kg CO2**	**kg CH4**	**kg N2O**	**kg NOX**	**kg SOX**	**kg PM10**	**kg PM2.5**	**kg VOC**	**kg CO**	**kg Pb**	**kg Water Ckg**	**Water Withdrawal**	
	0.14% Coal		0.26029006	2.64E-06	3.85E-06	0.000296	0.000819	2.98E-05	1.25E-05	3.07E-06	2.84E-05	6.44E-11	0.583347	10.73353	
	0.03% Oil		0.211613424	7.32E-06	1.39E-06	0.000361	0.000701	0.000202	1.83E-05	1.63E-07	5.87E-07	4.25E-12	0.249632	10.73353	
	45.89% Natural Gas		0.161726076	2.86E-06	6.44E-07	7.89E-05	8.41E-06	7.54E-06	6.72E-06	4.64E-06	0.000112	1.99E-12	0.298608	6.284182	
	3.12% Biomass		0	0.000128	1.7E-05	0.001035	0.003731	0.000594	1.3E-05	3.12E-05	0.001275	4.26E-12	0.299599	15.40724	
	9.33% Nuclear*		0	0	0	0	0	0	0	0	0	0	0.80833	23.08005	
	13.41% Hydroelectric*		0	0	0	0	0	0	0	0	0	0	3.929329	3.942068	
	5.98% Geothermal*		0	0	0	0	0	0	0	0	0	0	0.397272	0.399867	
	13.82% Solar*		0	0	0	0	0	0	0	0	0	0	0.482324	0.46629	
	7.18% Wind*		0	0	0	0	0	0	0	0	0	0	0.00062	0.03282	
Recycling	**per 22 tons & 50 mi (80.5km) roundtrip transport**		97.62410497	0.000989	0.001439	0.112711	0.306385	0.011201	0.004706	0.001317	0.012934	2.57E-08	668.281	4463.534	
Landfill	**per 22 tons & 20 mi (32.2) transport**		0.11965841	0	0	0.000842	5.77E-05	1.6E-05	1.84E-05	6.8E-05	0.000923	6.49E-10	180.0648	180.0648	
Stockpile	**per 22 tons & 30 mi (48.3km) transport**		0.179487615	0	0	0.001263	8.66E-05	2.4E-05	2.76E-05	0.000102	0.001384	9.73E-10	270.0971	270.0971	

	Carbonation		
	Recycling	**Landfill**	**Stockpile**
kg CO2	9.76E+01	1.20E-01	1.79E-01
kg CH4	9.89E-04	0.00E+00	0.00E+00
kg N2O	1.44E-03	0.00E+00	0.00E+00
kg NOX	1.13E-01	8.42E-04	1.26E-03
kg SOX	3.06E-01	5.77E-05	8.66E-05
kg PM10	1.12E-02	1.60E-05	2.40E-05
kg PM2.5	4.71E-03	1.84E-05	2.76E-05
kg VOC	1.32E-03	6.80E-05	1.02E-04
kg CO	1.29E-02	9.23E-04	1.38E-03
kg Pb	2.57E-08	6.49E-10	9.73E-10
kg Water C	6.68E+02	1.80E+02	2.70E+02
kg Water	4.46E+03	1.80E+02	2.70E+02

Appendix 3. CO₂ Concentrations Recordings

Table 12. CO₂ concentrations data from experimental readings.

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
16:22.5	00:00.0		510									
17:59.4	01:36.9			499								
18:45.7	00:46.3				498							
20:59.8	02:14.1					462						
21:51.2	00:51.4						492					
23:47.8	01:56.6							485				
24:21.5	00:33.7								483			
25:33.5	01:12.0									471		
26:14.7	00:41.2										484	
27:49.6	01:34.9											469
46:16.5	18:26.9									151		
46:21.3	00:04.8										378	
46:32.2	00:10.9									138		
46:38.8	00:06.6										342	
47:45.3	01:06.5									100		
52:28.5	0.00	505	506	531	527	494	509	511	476	36	73	496
53:28.5	1.00	500	503	526	519	488	502	506	458	31	57	489
54:28.5	2.00	495	498	521	514	483	499	504	413	25	46	487
55:28.5	3.00	492	495	518	514	481	496	502	353	21	37	485
56:28.5	4.00	493	497	518	517	489	500	423	308	19	31	492
57:28.5	5.00	497	504	518	521	490	505	317	270	16	26	496
58:28.5	6.00	499	507	520	521	491	512	237	242	15	22	498
59:28.5	7.00	500	505	520	367	491	510	184	222	14	19	497
00:28.5	8.00	497	504	515	241	488	507	139	204	13	17	494
01:28.5	9.00	492	499	439	168	485	501	110	187	12	16	493
02:28.5	10.00	492	500	311	124	485	501	89	173	11	15	494
03:28.5	11.00	493	500	233	93	485	502	72	159	11	15	496
04:28.5	12.00	497	503	177	73	487	506	59	148	9	14	506
05:28.5	13.00	499	508	132	62	489	511	52	141	8	13	508
06:28.5	14.00	502	508	109	54	491	511	45	131	8	13	507
07:28.5	15.00	497	505	88	47	490	509	39	125	8	13	502
08:28.5	16.00	493	501	74	43	487	503	36	120	8	12	498
09:28.5	17.00	488	495	63	39	483	498	33	116	7	11	493

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
10:28.5	18.00	484	491	54	37	478	493	30	112	8	11	487
11:28.5	19.00	478	488	47	35	475	488	29	110	7	11	482
12:28.5	20.00	474	481	42	34	470	483	27	107	7	11	477
13:28.5	21.00	471	478	39	33	469	480	26	105	7	11	475
14:28.5	22.00	466	474	36	33	465	476	26	103	7	11	471
15:28.5	23.00	466	473	33	33	465	475	24	100	7	11	470
16:28.5	24.00	465	473	32	33	464	475	23	99	7	10	471
17:28.5	25.00	466	472	30	33	464	476	23	97	7	9	474
18:28.5	26.00	466	471	29	32	464	475	23	96	7	10	473
19:28.5	27.00	466	473	29	32	459	477	23	95	7	10	472
20:28.5	28.00	468	473	28	32	452	477	23	93	7	10	472
21:28.5	29.00	467	472	29	32	445	475	23	91	7	10	472
22:28.5	30.00	465	472	29	32	414	472	22	90	7	10	472
23:28.5	31.00	465	472	29	32	260	472	22	90	7	10	472
24:28.5	32.00	464	472	28	31	177	473	22	89	7	10	471
25:28.5	33.00	464	472	28	31	121	473	22	88	7	10	470
26:28.5	34.00	466	474	28	30	96	472	22	88	7	10	470
27:28.5	35.00	467	476	28	31	74	350	22	87	7	10	473
28:28.5	36.00	468	475	28	31	55	239	22	86	7	10	474
29:28.5	37.00	468	343	28	31	44	175	22	85	8	10	474
30:28.5	38.00	436	233	28	31	35	126	21	85	6	10	476
31:28.5	39.00	283	166	28	31	31	98	21	84	6	10	480
32:28.5	40.00	198	117	28	31	26	82	21	84	6	10	480
33:28.5	41.00	140	87	28	30	25	66	21	84	7	10	488
34:28.5	42.00	102	69	27	31	23	53	21	83	7	10	491
35:28.5	43.00	80	60	27	31	22	46	21	82	7	10	491
36:28.5	44.00	62	48	27	31	20	41	21	80	7	10	490
37:28.5	45.00	51	41	27	30	19	37	21	80	7	10	484
38:28.5	46.00	41	36	27	30	20	34	21	79	6	10	485
39:28.5	47.00	35	34	27	30	20	32	22	78	6	10	484
40:28.5	48.00	32	31	27	30	20	31	21	77	5	10	484
41:28.5	49.00	29	31	27	30	18	31	22	78	6	10	483
42:28.5	50.00	27	30	27	30	18	30	22	77	6	10	481
43:28.5	51.00	25	29	27	30	19	29	21	77	6	9	480
44:28.5	52.00	24	28	27	30	19	29	21	77	5	10	481
45:28.5	53.00	23	27	27	30	19	28	21	77	6	10	476
46:28.5	54.00	23	27	27	30	19	28	21	75	6	9	475

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
47:28.5	55.00	22	27	27	30	18	27	21	75	6	10	473
48:28.5	56.00	23	28	27	30	18	26	21	75	6	10	471
49:28.5	57.00	23	28	27	30	18	26	22	75	6	9	470
50:28.5	58.00	22	27	27	30	18	26	21	74	5	10	468
51:28.5	59.00	22	27	27	30	17	27	21	74	5	10	467
52:28.5	60.00	22	27	27	30	17	27	21	74	5	10	465
53:28.5	61.00	22	27	27	30	18	28	21	74	5	10	462
54:28.5	62.00	22	27	27	30	18	28	21	73	5	10	461
55:28.5	63.00	22	27	28	29	17	28	21	73	5	10	461
56:28.5	01:00.0	22	27	27	29	17	28	22	72	5	9	459
57:28.5	02:00.0	22	27	27	30	18	28	21	72	5	9	459
58:28.5	03:00.0	22	27	27	30	18	28	21	72	5	10	460
59:28.5	04:00.0	22	27	27	30	18	28	21	71	5	10	459
00:28.5	05:00.0	21	27	27	30	18	28	21	71	5	10	459
01:28.5	06:00.0	21	27	27	30	18	27	21	71	5	10	459
02:28.5	07:00.0	21	27	27	30	18	27	21	71	5	9	458
03:28.5	08:00.0	21	27	27	29	18	27	22	71	6	9	458
04:28.5	09:00.0	21	27	27	29	18	27	22	70	5	9	458
05:28.5	10:00.0	21	27	27	29	18	28	22	70	5	9	456
06:28.5	11:00.0	21	27	28	29	18	27	22	70	4	9	455
07:28.5	12:00.0	21	28	28	29	18	27	22	69	5	9	454
08:28.5	13:00.0	21	27	28	30	18	27	21	69	5	9	455
09:28.5	14:00.0	22	27	28	30	18	28	21	69	4	9	455
10:28.5	15:00.0	21	27	27	30	18	28	22	69	5	9	454
11:28.5	16:00.0	21	27	27	29	18	27	22	69	5	9	453
12:28.5	17:00.0	21	27	27	29	18	27	22	68	5	10	454
13:28.5	18:00.0	21	27	27	29	17	27	22	68	5	9	453
14:28.5	19:00.0	21	27	27	29	17	27	21	68	5	9	453
15:28.5	20:00.0	21	27	27	29	17	27	21	67	5	9	452
16:28.5	21:00.0	21	27	27	29	18	27	21	67	5	9	452
17:28.5	22:00.0	22	28	27	29	18	27	21	67	5	10	452
18:28.5	23:00.0	22	28	28	30	17	27	21	67	5	9	452
19:28.5	24:00.0	22	28	28	30	17	27	21	66	5	9	452
20:28.5	25:00.0	21	28	28	29	17	27	21	66	5	9	450
21:28.5	26:00.0	22	28	27	29	17	27	21	66	5	9	450
22:28.5	27:00.0	21	28	27	29	17	27	21	65	5	9	450
23:28.5	28:00.0	21	28	27	29	17	27	20	65	5	9	449

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
24:28.5	29:00.0	21	28	27	28	17	27	20	65	5	9	449
25:28.5	30:00.0	21	28	27	29	17	27	20	65	5	9	449
26:28.5	31:00.0	21	28	27	29	17	27	20	65	5	9	449
27:28.5	32:00.0	22	28	27	29	17	27	20	64	5	9	448
28:28.5	33:00.0	21	28	28	29	17	27	20	65	5	9	448
29:28.5	34:00.0	21	27	28	29	17	27	20	64	5	9	449
30:28.5	35:00.0	21	28	28	29	18	27	20	65	5	9	449
31:28.5	36:00.0	21	27	27	29	18	27	20	64	5	9	449
32:28.5	37:00.0	21	27	27	29	18	27	20	64	5	9	448
33:28.5	38:00.0	20	28	27	29	18	27	20	64	4	9	448
34:28.5	39:00.0	21	28	27	29	17	27	20	64	5	9	447
35:28.5	40:00.0	21	28	27	29	18	27	20	64	5	9	448
36:28.5	41:00.0	21	28	27	29	18	26	20	64	4	9	448
37:28.5	42:00.0	21	28	27	29	18	26	20	63	4	9	448
38:28.5	43:00.0	21	28	27	29	18	27	20	63	5	9	448
39:28.5	44:00.0	21	28	28	29	18	27	20	63	4	9	447
40:28.5	45:00.0	21	28	27	29	18	27	20	63	4	10	447
41:28.5	46:00.0	22	28	28	29	18	27	20	62	5	9	447
42:28.5	47:00.0	22	28	28	29	18	26	21	61	5	9	446
43:28.5	48:00.0	21	28	27	29	18	27	20	62	4	9	446
44:28.5	49:00.0	21	28	28	28	18	27	20	61	4	9	447
45:28.5	50:00.0	21	28	28	29	17	27	20	61	4	9	446
46:28.5	51:00.0	21	28	28	29	18	27	20	61	4	9	446
47:28.5	52:00.0	21	28	28	29	18	27	20	61	4	9	446
48:28.5	53:00.0	21	28	28	29	17	27	20	61	4	9	445
49:28.5	54:00.0	21	28	28	29	17	27	20	61	4	9	445
50:28.5	55:00.0	21	28	28	29	18	27	21	60	4	9	445
51:28.5	56:00.0	21	28	28	28	18	27	20	60	4	9	445
52:28.5	57:00.0	21	28	28	29	18	27	21	61	4	9	446
53:28.5	58:00.0	21	28	28	29	18	27	21	60	4	9	445
54:28.5	59:00.0	21	28	28	29	18	27	21	61	4	9	445
55:28.5	00:00.0	21	28	28	29	18	27	20	59	4	9	445
56:28.5	01:00.0	21	28	28	30	18	27	21	60	3	9	445
57:28.5	02:00.0	21	28	28	29	18	27	21	60	3	8	445
58:28.5	03:00.0	21	28	28	29	17	27	21	60	4	8	445
59:28.5	04:00.0	21	28	28	29	17	27	21	60	4	9	445
00:28.5	05:00.0	21	28	28	29	17	27	21	60	4	8	445

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
01:28.5	06:00.0	21	28	28	29	17	26	21	59	4	9	444
02:28.5	07:00.0	21	29	28	29	17	26	21	59	4	8	444
03:28.5	08:00.0	21	29	28	29	17	25	21	59	5	8	444
04:28.5	09:00.0	22	28	28	29	18	25	21	59	4	8	443
05:28.5	10:00.0	21	28	28	29	18	25	21	59	4	8	443
06:28.5	11:00.0	21	28	28	29	18	25	21	59	3	8	443
07:28.5	12:00.0	21	28	28	29	18	25	21	58	3	8	444
08:28.5	13:00.0	21	28	28	29	17	25	21	59	4	8	444
09:28.5	14:00.0	21	28	28	29	18	25	21	58	3	8	444
10:28.5	15:00.0	21	28	28	29	17	25	21	58	3	8	444
11:28.5	16:00.0	21	28	28	29	18	25	20	58	3	8	444
12:28.5	17:00.0	21	29	28	28	18	25	22	58	3	8	444
13:28.5	18:00.0	21	29	28	29	18	25	21	58	3	8	444
14:28.5	19:00.0	21	28	28	29	18	25	21	58	4	8	444
15:28.5	20:00.0	21	29	28	29	17	25	21	58	4	8	444
16:28.5	21:00.0	21	29	27	29	17	26	21	57	4	8	444
17:28.5	22:00.0	22	29	27	29	17	25	21	57	4	8	443
18:28.5	23:00.0	22	29	27	29	17	25	21	57	4	8	443
19:28.5	24:00.0	22	29	27	29	17	25	21	57	4	8	443
20:28.5	25:00.0	22	29	27	29	17	25	21	57	4	8	443
21:28.5	26:00.0	22	29	26	29	17	26	21	57	3	8	443
22:28.5	27:00.0	22	29	26	29	17	26	21	56	4	8	443
23:28.5	28:00.0	21	29	26	29	17	25	21	56	4	8	442
24:28.5	29:00.0	21	29	26	29	17	25	21	56	3	8	443
25:28.5	30:00.0	21	29	26	28	17	25	21	56	3	8	442
26:28.5	31:00.0	21	29	26	29	17	25	21	56	4	8	443
27:28.5	32:00.0	22	29	26	29	17	25	21	56	3	9	442
28:28.5	33:00.0	22	29	26	29	17	25	21	56	3	8	442
29:28.5	34:00.0	21	29	26	28	17	26	21	56	3	8	443
30:28.5	35:00.0	22	29	26	29	17	26	21	56	3	8	443
31:28.5	36:00.0	21	29	26	29	17	26	21	56	3	8	442
32:28.5	37:00.0	21	29	26	28	17	25	21	56	3	8	442
33:28.5	38:00.0	22	29	26	28	17	26	21	55	3	8	442
34:28.5	39:00.0	21	29	26	29	17	26	20	55	3	8	443
35:28.5	40:00.0	21	29	26	30	17	26	20	55	3	8	442
36:28.5	41:00.0	21	29	26	29	17	26	20	55	3	8	442
37:28.5	42:00.0	22	29	26	29	17	25	21	55	3	8	442

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
38:28.5	43:00.0	22	29	27	28	17	26	21	55	4	8	442
39:28.5	44:00.0	22	29	27	28	17	25	21	55	3	8	442
40:28.5	45:00.0	21	29	26	28	16	26	21	55	3	8	442
41:28.5	46:00.0	22	29	26	28	17	25	21	55	3	8	442
42:28.5	47:00.0	22	29	26	28	17	25	21	55	3	8	443
43:28.5	48:00.0	21	29	26	28	17	25	21	55	3	8	441
44:28.5	49:00.0	22	29	26	28	17	25	21	53	3	8	441
45:28.5	50:00.0	22	30	26	28	17	25	21	53	3	8	441
46:28.5	51:00.0	21	30	27	28	17	25	21	54	3	8	442
47:28.5	52:00.0	21	30	27	28	17	25	21	54	3	8	442
48:28.5	53:00.0	21	30	27	28	17	25	21	54	3	8	442
49:28.5	54:00.0	21	29	27	28	17	25	21	54	3	8	442
50:28.5	55:00.0	22	30	27	28	17	25	21	54	3	9	442
51:28.5	56:00.0	22	29	27	28	17	25	21	53	3	9	442
52:28.5	57:00.0	22	29	27	28	16	25	21	54	3	8	444
53:28.5	58:00.0	22	29	27	28	16	25	21	54	3	8	444
54:28.5	59:00.0	22	29	27	29	16	25	21	53	3	8	444
55:28.5	00:00.0	21	29	26	29	16	25	21	53	3	8	444
56:28.5	01:00.0	22	30	26	29	16	25	21	53	3	8	444
57:28.5	02:00.0	21	30	27	30	16	26	21	53	3	8	444
58:28.5	03:00.0	21	30	27	29	16	26	21	53	3	8	444
59:28.5	04:00.0	21	30	27	29	16	26	21	53	3	8	444
00:28.5	05:00.0	22	30	26	29	16	26	21	53	4	8	443
01:28.5	06:00.0	22	30	26	28	16	26	22	53	3	8	443
02:28.5	07:00.0	22	30	27	28	17	26	22	53	3	8	443
03:28.5	08:00.0	22	29	27	28	17	26	22	53	3	8	443
04:28.5	09:00.0	21	30	26	28	16	26	22	51	3	8	443
05:28.5	10:00.0	21	30	26	28	17	25	22	52	3	9	444
06:28.5	11:00.0	21	30	26	28	16	25	21	52	2	8	443
07:28.5	12:00.0	21	30	26	28	16	25	21	53	3	8	443
08:28.5	13:00.0	21	30	26	29	16	25	21	52	2	9	443
09:28.5	14:00.0	21	30	26	28	16	26	21	52	3	9	443
10:28.5	15:00.0	22	30	26	28	17	26	22	51	3	9	443
11:28.5	16:00.0	22	30	26	28	16	26	22	51	2	9	444
12:28.5	17:00.0	21	30	26	29	16	26	22	51	3	8	445
13:28.5	18:00.0	22	30	27	29	16	25	22	52	3	9	444
14:28.5	19:00.0	22	30	27	28	16	25	21	52	3	8	444

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
15:28.5	20:00.0	22	30	27	29	17	26	21	52	3	8	445
16:28.5	21:00.0	22	30	27	29	16	26	21	51	3	8	445
17:28.5	22:00.0	22	29	27	28	16	25	22	50	3	8	445
18:28.5	23:00.0	22	29	27	28	16	25	21	51	3	9	445
19:28.5	24:00.0	22	29	27	28	16	25	21	51	3	9	445
20:28.5	25:00.0	22	30	26	28	16	25	21	51	3	9	446
21:28.5	26:00.0	22	29	26	28	16	26	21	50	3	9	446
22:28.5	27:00.0	22	30	26	28	16	25	21	50	3	9	446
23:28.5	28:00.0	22	30	26	28	16	25	21	50	2	8	445
24:28.5	29:00.0	21	30	27	27	16	26	21	50	2	8	444
25:28.5	30:00.0	22	30	27	28	16	26	20	50	3	8	446
26:28.5	31:00.0	22	30	27	27	16	25	20	50	2	8	446
27:28.5	32:00.0	22	30	27	27	16	26	20	50	2	8	446
28:28.5	33:00.0	22	30	27	27	16	26	20	50	2	8	446
29:28.5	34:00.0	21	30	27	27	16	26	20	50	2	8	447
30:28.5	35:00.0	21	29	27	28	16	26	20	50	3	8	447
31:28.5	36:00.0	22	29	27	27	16	26	20	50	2	8	446
32:28.5	37:00.0	22	30	27	27	16	25	21	51	2	8	446
33:28.5	38:00.0	22	30	26	27	16	26	20	50	2	8	446
34:28.5	39:00.0	22	30	27	28	16	26	20	50	2	8	446
35:28.5	40:00.0	22	30	27	28	16	25	20	50	1	8	446
36:28.5	41:00.0	22	30	27	28	16	26	21	50	1	9	447
37:28.5	42:00.0	22	30	27	28	16	25	21	50	2	9	446
38:28.5	43:00.0	21	30	27	27	17	26	20	49	2	9	446
39:28.5	44:00.0	21	30	27	27	17	25	20	49	2	8	446
40:28.5	45:00.0	21	30	27	27	17	25	20	49	2	9	446
41:28.5	46:00.0	21	30	27	27	17	26	20	49	2	8	446
42:28.5	47:00.0	21	30	27	27	16	26	20	48	2	9	446
43:28.5	48:00.0	21	30	27	27	17	26	21	49	2	9	446
44:28.5	49:00.0	21	29	27	27	17	26	21	49	2	9	446
45:28.5	50:00.0	22	30	27	27	17	25	21	49	2	8	446
46:28.5	51:00.0	22	29	27	27	17	26	21	49	2	9	447
47:28.5	52:00.0	22	29	27	28	17	25	21	49	2	9	447
48:28.5	53:00.0	22	30	27	28	17	25	21	49	2	9	447
49:28.5	54:00.0	23	30	28	28	17	25	21	49	2	9	445
50:28.5	55:00.0	22	30	27	28	17	25	21	48	2	9	445
51:28.5	56:00.0	21	29	27	28	17	25	21	48	2	8	447

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
52:28.5	57:00.0	21	29	27	28	17	25	21	48	2	8	447
53:28.5	58:00.0	22	30	27	28	17	25	21	48	3	8	448
54:28.5	59:00.0	21	29	27	28	17	25	21	48	3	9	447
55:28.5	00:00.0	22	30	27	28	17	26	21	48	2	9	447
56:28.5	01:00.0	22	30	27	27	17	26	21	48	2	9	446
57:28.5	02:00.0	22	30	27	28	17	26	21	49	2	8	446
58:28.5	03:00.0	22	30	27	28	17	26	21	49	2	8	447
59:28.5	04:00.0	22	29	27	27	16	26	21	48	1	8	446
00:28.5	05:00.0	22	29	27	27	16	26	21	48	2	8	446
01:28.5	06:00.0	22	29	27	27	17	26	21	48	2	8	446
02:28.5	07:00.0	22	29	27	27	17	26	21	48	2	9	447
03:28.5	08:00.0	22	30	27	27	17	26	21	48	2	9	447
04:28.5	09:00.0	22	30	27	27	17	26	21	47	2	9	447
05:28.5	10:00.0	22	29	27	27	17	26	21	48	2	9	446
06:28.5	11:00.0	21	30	27	27	17	26	21	47	2	9	446
07:28.5	12:00.0	22	30	27	27	16	26	22	47	2	9	446
08:28.5	13:00.0	21	30	27	27	16	26	22	47	2	8	446
09:28.5	14:00.0	21	30	27	27	16	26	21	47	2	8	447
10:28.5	15:00.0	21	30	27	27	17	26	21	48	2	8	447
11:28.5	16:00.0	21	30	27	27	17	26	21	47	2	9	447
12:28.5	17:00.0	21	29	27	27	17	26	20	47	2	8	447
13:28.5	18:00.0	21	30	27	27	16	25	20	47	2	9	448
14:28.5	19:00.0	20	30	27	27	16	25	21	47	2	9	447
15:28.5	20:00.0	20	30	27	27	17	26	21	47	2	9	448
16:28.5	21:00.0	20	30	27	27	17	26	21	47	2	8	447
17:28.5	22:00.0	20	29	27	27	16	26	21	46	1	8	448
18:28.5	23:00.0	20	30	27	27	16	26	21	46	1	9	449
19:28.5	24:00.0	20	30	27	27	17	26	21	46	1	9	449
20:28.5	25:00.0	20	30	27	26	16	25	21	46	1	8	448
21:28.5	26:00.0	21	30	27	27	17	25	21	46	2	8	448
22:28.5	27:00.0	21	30	27	27	17	26	21	46	1	8	448
23:28.5	28:00.0	20	30	27	27	17	26	21	46	1	8	449
24:28.5	29:00.0	21	30	27	27	16	26	21	46	1	8	449
25:28.5	30:00.0	20	30	27	27	17	26	21	46	1	9	449
26:28.5	31:00.0	20	30	27	27	17	26	21	46	0	9	449
27:28.5	32:00.0	21	30	27	26	17	26	21	46	1	9	449
28:28.5	33:00.0	21	30	27	27	17	26	21	46	2	9	449

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
29:28.5	34:00.0	21	30	27	27	17	26	21	45	1	9	449
30:28.5	35:00.0	21	29	27	27	17	25	21	46	1	9	449
31:28.5	36:00.0	21	30	28	27	16	25	21	46	1	9	450
32:28.5	37:00.0	21	30	27	27	16	25	21	46	0	9	449
33:28.5	38:00.0	20	30	27	26	16	25	21	45	0	9	449
34:28.5	39:00.0	21	30	27	27	16	25	21	46	1	9	449
35:28.5	40:00.0	21	30	28	27	16	26	21	45	1	8	449
36:28.5	41:00.0	21	30	27	27	16	26	21	45	1	9	449
37:28.5	42:00.0	21	30	27	26	16	26	21	46	1	9	449
38:28.5	43:00.0	21	30	27	26	16	26	21	45	1	9	450
39:28.5	44:00.0	21	30	28	28	16	26	21	45	1	9	450
40:28.5	45:00.0	21	30	28	27	16	26	21	46	1	9	450
41:28.5	46:00.0	21	29	27	27	16	26	21	46	1	9	449
42:28.5	47:00.0	21	29	27	27	16	26	21	45	1	9	449
43:28.5	48:00.0	20	29	27	27	16	26	21	46	1	9	450
44:28.5	49:00.0	20	29	27	27	16	26	21	45	1	9	449
45:28.5	50:00.0	21	29	27	27	17	26	21	46	1	9	449
46:28.5	51:00.0	21	30	28	27	17	26	21	45	1	9	450
47:28.5	52:00.0	21	29	28	27	17	26	21	45	1	9	449
48:28.5	53:00.0	21	31	28	26	16	26	21	44	1	9	450
49:28.5	54:00.0	21	29	27	27	17	26	21	46	1	9	450
50:28.5	55:00.0	21	30	27	26	17	25	21	46	0	9	450
51:28.5	56:00.0	21	30	27	26	17	25	21	45	0	8	450
52:28.5	57:00.0	20	30	27	26	17	26	21	45	0	8	450
53:28.5	58:00.0	20	30	27	26	17	25	21	44	1	9	450
54:28.5	59:00.0	21	30	27	26	16	25	21	44	1	8	450
55:28.5	00:00.0	21	30	27	27	16	26	21	44	1	8	450
56:28.5	01:00.0	21	30	27	26	16	26	21	44	1	8	449
57:28.5	02:00.0	20	30	27	27	16	26	21	44	1	8	449
58:28.5	03:00.0	21	30	27	27	16	26	21	44	1	9	450
59:28.5	04:00.0	21	30	27	27	16	26	21	44	1	8	449
00:28.5	05:00.0	20	31	28	26	17	26	21	44	0	8	449
01:28.5	06:00.0	20	30	28	26	16	25	21	44	1	8	449
02:28.5	07:00.0	20	31	28	27	17	25	21	44	0	8	449
03:28.5	08:00.0	20	30	28	27	16	25	21	44	0	8	449
04:28.5	09:00.0	20	30	27	27	16	26	21	44	0	8	450
05:28.5	10:00.0	20	30	27	27	16	26	21	44	0	8	450

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
06:28.5	11:00.0	20	30	28	26	17	26	21	44	1	8	450
07:28.5	12:00.0	21	30	27	26	16	26	21	44	1	8	451
08:28.5	13:00.0	21	30	27	27	16	26	21	44	1	8	451
09:28.5	14:00.0	21	30	27	27	17	26	22	44	1	8	451
10:28.5	15:00.0	21	31	28	27	16	26	21	44	1	8	451
11:28.5	16:00.0	21	30	28	27	16	25	22	44	1	8	451
12:28.5	17:00.0	21	30	27	26	16	25	22	44	0	8	450
13:28.5	18:00.0	21	30	28	26	16	25	22	43	0	8	450
14:28.5	19:00.0	20	30	28	27	16	25	22	44	0	8	450
15:28.5	20:00.0	21	30	28	26	16	25	22	43	0	8	450
16:28.5	21:00.0	20	31	27	26	16	25	21	44	0	8	450
17:28.5	22:00.0	21	30	27	26	16	25	21	44	1	8	450
18:28.5	23:00.0	21	30	27	27	16	25	21	44	0	8	450
19:28.5	24:00.0	22	30	27	27	16	26	21	44	1	8	450
20:28.5	25:00.0	21	30	27	26	16	26	21	44	1	8	450
21:28.5	26:00.0	21	30	27	26	16	25	21	44	1	8	451
22:28.5	27:00.0	21	30	27	26	16	25	21	44	1	8	451
23:28.5	28:00.0	20	30	28	26	16	25	21	44	1	8	451
24:28.5	29:00.0	21	30	27	26	16	26	21	44	1	8	451
25:28.5	30:00.0	20	30	28	26	16	26	21	44	1	8	451
26:28.5	31:00.0	20	31	27	26	16	25	21	44	1	8	451
27:28.5	32:00.0	20	30	28	26	16	25	21	44	1	8	451
28:28.5	33:00.0	20	30	28	26	16	25	21	44	1	8	451
29:28.5	34:00.0	20	30	27	26	16	25	21	44	1	8	451
30:28.5	35:00.0	20	30	27	26	16	25	21	44	1	8	451
31:28.5	36:00.0	20	30	27	26	16	25	21	43	1	8	451
32:28.5	37:00.0	21	30	27	26	16	26	21	43	0	8	451
33:28.5	38:00.0	21	30	27	26	16	26	21	43	0	8	451
34:28.5	39:00.0	21	30	27	27	17	26	22	43	1	8	450
35:28.5	40:00.0	21	30	28	26	17	25	21	43	1	8	451
36:28.5	41:00.0	21	30	28	26	17	25	21	43	0	8	451
37:28.5	42:00.0	20	30	28	27	17	25	21	43	1	8	451
38:28.5	43:00.0	20	30	27	26	17	25	21	43	1	8	451
39:28.5	44:00.0	21	30	28	26	17	25	21	43	1	8	451
40:28.5	45:00.0	21	30	28	26	17	25	21	43	1	8	451
41:28.5	46:00.0	21	30	28	26	17	25	21	43	0	8	450
42:28.5	47:00.0	20	30	27	26	17	25	21	43	0	8	451

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
43:28.5	48:00.0	20	30	28	26	17	26	21	43	0	8	451
44:28.5	49:00.0	21	30	27	26	17	25	21	43	0	8	452
45:28.5	50:00.0	21	30	28	26	17	25	21	44	0	8	452
46:28.5	51:00.0	21	30	27	26	17	26	21	43	1	8	452
47:28.5	52:00.0	21	30	27	26	17	26	21	44	0	8	452
48:28.5	53:00.0	21	30	27	26	16	26	21	43	1	8	452
49:28.5	54:00.0	21	30	27	26	16	25	22	43	0	8	452
50:28.5	55:00.0	21	30	27	26	16	25	22	43	0	8	452
51:28.5	56:00.0	21	30	27	26	16	25	22	43	0	7	452
52:28.5	57:00.0	21	30	28	25	15	25	22	44	0	8	453
53:28.5	58:00.0	20	29	27	26	16	24	22	43	0	8	453
54:28.5	59:00.0	21	30	27	25	16	24	22	43	0	8	453
55:28.5	00:00.0	21	30	27	26	16	24	22	42	0	8	453
56:28.5	01:00.0	21	30	28	26	16	24	22	42	0	8	452
57:28.5	02:00.0	21	30	28	26	16	24	21	43	0	8	452
58:28.5	03:00.0	21	30	28	26	17	25	21	43	1	8	452
59:28.5	04:00.0	21	30	28	26	17	25	21	42	1	8	452
00:28.5	05:00.0	21	30	28	25	16	25	21	42	1	8	451
01:28.5	06:00.0	20	30	28	25	16	25	21	42	1	8	451
02:28.5	07:00.0	21	30	28	25	16	25	21	43	1	8	451
03:28.5	08:00.0	21	30	28	26	16	24	22	43	1	7	452
04:28.5	09:00.0	21	30	28	26	16	24	22	42	1	8	452
05:28.5	10:00.0	20	30	28	25	16	24	22	42	1	8	452
06:28.5	11:00.0	20	30	28	26	16	24	21	42	1	8	454
07:28.5	12:00.0	21	30	28	26	16	24	21	42	0	8	453
08:28.5	13:00.0	21	30	28	25	15	24	22	42	0	8	453
09:28.5	14:00.0	21	30	28	26	16	24	22	41	1	8	452
10:28.5	15:00.0	20	30	27	26	16	24	22	41	0	8	452
11:28.5	16:00.0	20	30	27	26	16	24	22	42	0	8	452
12:28.5	17:00.0	20	30	27	26	16	24	22	42	0	8	452
13:28.5	18:00.0	20	30	27	26	16	24	22	42	0	8	452
14:28.5	19:00.0	20	30	26	26	16	24	22	42	1	8	452
15:28.5	20:00.0	21	30	27	26	16	24	22	42	0	8	451
16:28.5	21:00.0	20	31	27	26	16	24	22	42	1	8	451
17:28.5	22:00.0	21	30	26	26	16	24	22	42	0	8	452
18:28.5	23:00.0	20	30	26	26	16	24	22	42	0	8	452
19:28.5	24:00.0	21	30	27	26	16	24	21	42	0	8	452

		Grad 2 (13")	**Grad 2 (26")**	**Grad 4 (13")**	**Grad 4 (26")**	**Grad 1 (26")**	**Grad 1 (13")**	**Grad 3 (13")**	**Grad 3 (26")**	**Grad 5 (26")**	**Grad 5 (13")**	**Ambient**
		#4-	**#4-**	**25%AB**	**25%AB**	**representative**	**representative**	**3/8+**	**3/8+**	**75%AB**	**75%AB**	**Ambient**
		Top	**Bottom**	**Top**	**Bottom**	**Bottom**	**Top**	**Top**	**Bottom**	**Bottom**	**Top**	**Ambient**
	Time	**4T-CC7 [K-30 1%]**	**4B-D13 [K-30 1%]**	**25AB-D0C [K-30 1%]**	**25ABB-B33 [K-30 1%]**	**RepB-B42 [K-30 1%]**	**RepT-D0B [K-30 1%]**	**38T-C4C [K-30 1%]**	**38B-B3C [K-30 1%]**	**75ABB-B38 [K-30 1%]**	**75ABT-D0F [K-30 1%]**	**Amb-B3A [K-30 1%]**
20:28.5	25:00.0	21	30	27	25	17	24	21	42	0	8	452
21:28.5	26:00.0	21	30	27	25	15	24	21	42	0	8	453
22:28.5	27:00.0	21	30	26	26	15	24	21	41	0	8	452
23:28.5	28:00.0	21	30	26	26	15	24	21	42	0	8	452
24:28.5	29:00.0	21	30	26	26	15	24	21	41	0	8	453
25:28.5	30:00.0	21	30	26	26	16	24	21	41	0	8	453
26:28.5	31:00.0	21	30	26	26	15	24	21	41	0	8	453
27:28.5	32:00.0	21	30	26	26	15	24	21	41	0	8	452
28:28.5	33:00.0	20	30	26	26	15	24	21	41	1	8	452
29:28.5	34:00.0	21	30	26	26	15	24	21	41	0	8	452
30:28.5	35:00.0	21	30	26	25	16	24	21	41	0	8	452
31:28.5	36:00.0	21	30	26	25	16	24	21	41	0	8	452
32:28.5	37:00.0	21	30	27	25	15	24	21	42	0	9	452
33:28.5	38:00.0	21	30	26	26	15	24	21	41	0	8	452
34:28.5	39:00.0	21	30	26	25	15	24	20	41	0	8	451
35:28.5	40:00.0	21	30	26	25	16	24	20	41	0	8	452
36:28.5	41:00.0	21	30	26	26	16	24	20	41	0	8	452
37:28.5	42:00.0	21	30	27	26	16	24	20	41	0	8	452
38:28.5	43:00.0	21	30	26	26	16	23	20	41	0	8	451
39:28.5	44:00.0	21	30	26	26	15	23	20	41	0	8	451
40:28.5	45:00.0	21	30	26	26	15	23	20	41	0	8	452
41:28.5	46:00.0	21	30	26	25	16	24	20	41	0	8	451
42:28.5	47:00.0	21	30	26	25	15	24	20	41	0	8	452
43:28.5	48:00.0	21	30	26	25	16	24	20	41	0	9	452
44:28.5	49:00.0	21	30	27	25	15	24	20	41	0	8	452
45:28.5	50:00.0	21	30	27	26	16	24	20	41	0	9	452
46:28.5	51:00.0	21	30	27	26	15	24	20	41	0	8	451
47:28.5	52:00.0	22	30	26	25	16	24	20	41	0	9	451
48:28.5	53:00.0	22	30	26	25	16	24	20	41	0	8	452
49:28.5	54:00.0	22	30	26	26	16	24	20	41	0	8	452
50:28.5	55:00.0	21	30	26	25	16	24	20	40	0	8	452
51:28.5	56:00.0	21	31	26	25	15	24	20	40	1	8	452
52:28.5	57:00.0	21	31	26	25	15	24	20	40	1	8	452
53:28.5	58:00.0	21	31	26	25	15	24	21	40	0	8	452
54:28.5	59:00.0	21	31	26	25	15	24	21	40	0	8	452
55:28.5	00:00.0	21	31	27	25	15	23	20	40	1	8	452
56:28.5	01:00.0	21	31	26	25	15	23	20	40	1	8	452

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
57:28.5	02:00.0	21	31	26	25	15	23	21	40	0	8	453
58:28.5	03:00.0	21	31	26	26	15	24	21	40	0	8	453
59:28.5	04:00.0	21	30	26	26	16	24	21	40	0	8	452
00:28.5	05:00.0	21	30	26	26	15	24	21	40	0	8	452
01:28.5	06:00.0	21	30	27	25	16	23	20	40	1	8	452
02:28.5	07:00.0	21	30	26	25	16	24	20	40	1	9	452
03:28.5	08:00.0	21	30	26	25	15	23	20	40	0	9	452
04:28.5	09:00.0	21	30	26	25	15	24	20	40	0	9	452
05:28.5	10:00.0	21	31	27	24	15	24	20	40	0	8	452
06:28.5	11:00.0	21	31	26	24	15	24	20	40	0	8	453
07:28.5	12:00.0	21	31	26	25	15	23	20	40	0	8	453
08:28.5	13:00.0	21	31	26	25	15	23	20	40	0	8	453
09:28.5	14:00.0	21	31	26	25	16	23	20	40	0	8	452
10:28.5	15:00.0	21	31	26	25	16	23	20	40	0	8	451
11:28.5	16:00.0	21	30	26	25	15	23	20	40	0	8	451
12:28.5	17:00.0	21	30	27	25	16	23	21	40	0	8	452
13:28.5	18:00.0	21	30	26	26	16	23	20	40	0	8	451
14:28.5	19:00.0	20	31	26	25	15	23	20	40	0	8	451
15:28.5	20:00.0	21	31	27	25	15	23	20	40	0	8	451
16:28.5	21:00.0	21	30	27	25	15	23	20	40	0	8	452
17:28.5	22:00.0	21	30	26	24	15	23	21	40	0	8	451
18:28.5	23:00.0	22	30	26	25	15	23	21	39	0	8	451
19:28.5	24:00.0	22	31	27	25	15	23	21	40	0	8	452
20:28.5	25:00.0	22	31	27	25	15	23	21	40	0	8	451
21:28.5	26:00.0	22	31	27	25	15	23	21	40	0	8	452
22:28.5	27:00.0	21	31	26	25	15	23	20	40	0	8	452
23:28.5	28:00.0	21	31	26	25	16	23	20	40	0	8	451
24:28.5	29:00.0	21	31	27	25	16	23	20	39	0	8	452
25:28.5	30:00.0	21	31	27	25	16	23	21	39	0	8	452
26:28.5	31:00.0	21	31	26	25	16	23	20	39	0	8	452
27:28.5	32:00.0	21	31	26	25	16	23	20	39	0	8	451
28:28.5	33:00.0	21	31	26	24	16	23	20	39	0	8	451
29:28.5	34:00.0	21	30	26	25	16	23	20	39	0	8	452
30:28.5	35:00.0	21	30	26	25	16	23	20	39	0	8	451
31:28.5	36:00.0	21	30	26	25	16	23	20	39	0	8	451
32:28.5	37:00.0	21	31	26	25	16	23	20	39	0	8	450
33:28.5	38:00.0	21	31	26	25	16	23	20	39	0	8	450

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
34:28.5	39:00.0	21	30	26	25	15	23	20	39	0	8	450
35:28.5	40:00.0	21	30	26	26	15	23	20	39	0	8	450
36:28.5	41:00.0	21	30	26	26	15	23	20	39	0	8	451
37:28.5	42:00.0	21	31	26	25	15	23	20	39	0	8	451
38:28.5	43:00.0	21	31	26	25	16	24	20	39	0	8	451
39:28.5	44:00.0	21	31	26	25	16	23	20	39	0	8	451
40:28.5	45:00.0	21	31	26	25	16	23	20	39	0	8	450
41:28.5	46:00.0	21	31	26	25	16	24	20	38	0	8	451
42:28.5	47:00.0	21	31	26	25	15	23	20	39		8	450
43:28.5	48:00.0	21	31	26	26	15	23	20	39		8	450
44:28.5	49:00.0	21	31	26	25	15	23	20	39	0	8	450
45:28.5	50:00.0	21	31	27	25	15	23	21	39	0	8	450
46:28.5	51:00.0	21	31	27	25	15	23	20	39	0	8	450
47:28.5	52:00.0	21	31	26	25	15	23	20	39		8	450
48:28.5	53:00.0	21	31	27	24	15	23	20	38	0	8	450
49:28.5	54:00.0	21	31	26	25	15	23	20	39		8	450
50:28.5	55:00.0	21	31	26	26	15	23	20	39		8	451
51:28.5	56:00.0	22	31	27	25	15	23	21	39		8	449
52:28.5	57:00.0	21	31	26	25	15	23	21	38		8	450
53:28.5	58:00.0	21	31	26	25	16	23	21	39	0	9	451
54:28.5	59:00.0	22	31	26	24	16	23	21	38	0	9	451
55:28.5	00:00.0	21	31	26	25	15	24	21	38	0	8	451
56:28.5	01:00.0	21	31	26	25	15	23	20	38	0	8	450
57:28.5	02:00.0	21	31	26	24	15	23	20	38	0	8	450
58:28.5	03:00.0	21	31	26	24	16	23	21	38	0	8	451
59:28.5	04:00.0	21	31	26	24	15	23	20	38	0	8	451
00:28.5	05:00.0	21	31	27	24	15	23	20	38	0	8	451
01:28.5	06:00.0	21	31	27	24	15	24	20	38		8	451
02:28.5	07:00.0	21	31	27	24	15	24	21	38	0	8	451
03:28.5	08:00.0	21	31	27	25	15	23	21	38		8	451
04:28.5	09:00.0	21	31	27	25	15	24	21	37	0	8	451
05:28.5	10:00.0	21	31	27	25	15	23	20	38		8	451
06:28.5	11:00.0	21	31	27	25	15	23	21	38	0	8	452
07:28.5	12:00.0	21	31	26	24	15	23	21	38		8	452
08:28.5	13:00.0	21	30	26	25	15	24	21	37	0	8	451
09:28.5	14:00.0	21	30	26	25	15	24	21	38		8	451
10:28.5	15:00.0	21	30	26	25	15	24	20	38		8	452

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
11:28.5	16:00.0	21	31	26	24	15	24	20	38		8	452
12:28.5	17:00.0	21	31	26	24	15	23	21	38		8	452
13:28.5	18:00.0	21	31	26	24	15	24	20	37	0	8	452
14:28.5	19:00.0	21	31	26	24	15	23	21	37	0	8	452
15:28.5	20:00.0	21	31	26	24	15	23	20	37	0	8	452
16:28.5	21:00.0	22	31	27	24	15	23	20	37	0	8	452
17:28.5	22:00.0	22	31	27	24	15	23	20	37	0	8	452
18:28.5	23:00.0	22	31	27	24	15	23	20	37	0	8	452
19:28.5	24:00.0	21	31	26	24	16	23	20	37	0	8	452
20:28.5	25:00.0	21	31	27	24	15	23	20	38		8	452
21:28.5	26:00.0	22	31	26	24	15	23	20	38		8	452
22:28.5	27:00.0	22	31	26	24	15	24	21	37		8	451
23:28.5	28:00.0	21	31	27	24	15	23	21	37		8	451
24:28.5	29:00.0	21	31	27	24	15	24	21	37		8	451
25:28.5	30:00.0	21	31	27	24	15	24	21	37		9	451
26:28.5	31:00.0	21	31	26	25	16	23	21	37		8	452
27:28.5	32:00.0	21	31	27	24	15	23	21	37		8	452
28:28.5	33:00.0	21	31	26	24	15	23	21	37	0	8	453
29:28.5	34:00.0	21	31	26	24	15	23	20	37		9	453
30:28.5	35:00.0	21	30	27	24	15	23	20	37		9	453
31:28.5	36:00.0	21	31	26	24	16	23	20	37	0	9	453
32:28.5	37:00.0	21	31	26	24	16	23	21	37		9	452
33:28.5	38:00.0	21	31	26	24	15	23	21	37		8	452
34:28.5	39:00.0	21	31	26	24	15	23	21	37		8	452
35:28.5	40:00.0	21	31	26	24	15	24	21	37		8	452
36:28.5	41:00.0	21	31	27	24	15	23	21	37		8	452
37:28.5	42:00.0	21	30	26	25	15	23	20	37		8	451
38:28.5	43:00.0	21	31	27	24	15	23	20	37		9	452
39:28.5	44:00.0	21	31	27	24	15	23	20	37		8	453
40:28.5	45:00.0	21	31	26	24	15	23	21	37		8	453
41:28.5	46:00.0	21	31	26	24	15	23	21	37	0	8	454
42:28.5	47:00.0	21	31	26	24	15	23	21	37	0	9	453
43:28.5	48:00.0	20	31	26	24	15	23	21	37	0	8	453
44:28.5	49:00.0	21	31	27	24	15	23	21	37		8	451
45:28.5	50:00.0	21	31	26	24	14	23	20	37		8	450
46:28.5	51:00.0	21	31	26	24	15	23	20	37		8	451
47:28.5	52:00.0	21	31	27	24	14	23	21	37		8	451

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
48:28.5	53:00.0	21	31	27	24	15	23	21	37	0	8	451
49:28.5	54:00.0	21	31	27	25	14	23	21	37		8	451
50:28.5	55:00.0	21	31	27	25	15	23	21	37		8	451
51:28.5	56:00.0	21	31	27	24	15	23	21	37		8	451
52:28.5	57:00.0	22	31	27	25	15	23	21	37		7	452
53:28.5	58:00.0	21	31	27	25	15	23	21	36		8	452
54:28.5	59:00.0	21	31	27	25	15	23	20	37		8	452
55:28.5	00:00.0	21	31	27	25	14	23	20	37		8	452
56:28.5	01:00.0	21	31	26	26	15	23	20	37		8	452
57:28.5	02:00.0	21	31	26	25	15	23	20	36		8	451
58:28.5	03:00.0	21	31	26	25	15	23	20	37		8	451
59:28.5	04:00.0	21	31	26	26	14	23	21	36		8	450
00:28.5	05:00.0	21	31	26	26	15	23	21	37		8	450
01:28.5	06:00.0	21	31	26	26	14	23	21	37		8	450
02:28.5	07:00.0	21	31	26	25	14	23	21	36		8	450
03:28.5	08:00.0	21	31	27	25	14	23	21	36		8	450
04:28.5	09:00.0	21	31	27	26	14	23	21	37		8	451
05:28.5	10:00.0	21	31	26	25	15	23	20	37		8	451
06:28.5	11:00.0	21	31	27	25	15	23	20	37		8	451
07:28.5	12:00.0	21	31	27	25	15	23	20	36		8	450
08:28.5	13:00.0	21	31	26	25	14	23	20	36		8	450
09:28.5	14:00.0	21	30	26	25	15	23	20	36		7	451
10:28.5	15:00.0	21	30	26	25	14	23	20	37		8	451
11:28.5	16:00.0	21	30	26	25	14	23	21	36		8	450
12:28.5	17:00.0	21	30	26	25	14	23	21	36		8	450
13:28.5	18:00.0	21	31	26	25	14	22	21	36		8	450
14:28.5	19:00.0	21	31	26	25	14	23	21	36		8	451
15:28.5	20:00.0	21	31	26	25	14	22	21	36		8	450
16:28.5	21:00.0	21	31	26	25	14	23	21	36		8	449
17:28.5	22:00.0	21	31	26	25	14	23	21	36		8	449
18:28.5	23:00.0	21	31	26	25	14	22	21	36		8	450
19:28.5	24:00.0	21	31	26	25	14	23	20	36		8	450
20:28.5	25:00.0	21	31	27	25	14	23	20	36		7	450
21:28.5	26:00.0	21	30	27	25	15	23	20	36		7	450
22:28.5	27:00.0	21	31	26	25	15	23	20	36		7	450
23:28.5	28:00.0	21	31	26	25	15	23	21	36		7	450
24:28.5	29:00.0	22	31	26	25	15	23	21	36		7	450

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
25:28.5	30:00.0	21	30	26	25	15	23	21	36		7	450
26:28.5	31:00.0	21	30	26	25	14	23	21	35		7	450
27:28.5	32:00.0	22	30	27	25	14	23	21	35		7	450
28:28.5	33:00.0	21	31	27	25	14	23	21	36		7	451
29:28.5	34:00.0	21	31	27	25	14	23	21	35		7	451
30:28.5	35:00.0	21	31	27	25	14	23	21	36		7	451
31:28.5	36:00.0	21	31	26	25	15	23	21	36		7	450
32:28.5	37:00.0	21	31	26	25	15	23	21	36		7	450
33:28.5	38:00.0	20	31	26	25	15	23	21	35		7	450
34:28.5	39:00.0	21	31	26	24	15	23	21	36		8	450
35:28.5	40:00.0	21	31	27	25	15	23	21	35		8	450
36:28.5	41:00.0	21	31	27	25	15	23	21	36		7	450
37:28.5	42:00.0	21	31	26	25	15	23	21	36		7	449
38:28.5	43:00.0	21	31	26	24	14	23	20	35	0	7	449
39:28.5	44:00.0	21	30	26	24	15	23	21	35	0	7	449
40:28.5	45:00.0	21	30	27	24	14	23	21	35	0	7	449
41:28.5	46:00.0	21	31	26	25	14	23	20	35		7	450
42:28.5	47:00.0	21	31	26	25	14	23	20	35		8	449
43:28.5	48:00.0	21	30	26	25	15	23	20	35		7	449
44:28.5	49:00.0	21	30	26	25	15	23	20	35		7	450
45:28.5	50:00.0	20	30	26	25	14	23	20	35		7	450
46:28.5	51:00.0	21	30	26	25	14	23	21	35		7	449
47:28.5	52:00.0	21	30	26	25	15	23	20	35	0	7	449
48:28.5	53:00.0	21	30	26	25	15	23	20	35	0	7	450
49:28.5	54:00.0	21	31	26	25	14	23	21	34		7	450
50:28.5	55:00.0	21	30	26	25	15	23	21	34		7	450
51:28.5	56:00.0	21	30	26	25	15	23	21	34		7	450
52:28.5	57:00.0	21	30	26	25	15	23	21	34		8	450
53:28.5	58:00.0	21	30	26	25	14	23	20	35		8	450
54:28.5	59:00.0	21	30	26	25	14	23	20	35		8	451
55:28.5	00:00.0	21	30	26	25	14	23	20	35		8	451
56:28.5	01:00.0	21	30	27	25	14	23	20	35		8	451
57:28.5	02:00.0	20	30	27	25	14	23	21	35		8	451
58:28.5	03:00.0	20	30	26	25	14	23	21	35		8	451
59:28.5	04:00.0	20	30	27	25	14	23	21	34		7	452
00:28.5	05:00.0	21	31	27	25	14	23	21	34		7	451
01:28.5	06:00.0	21	31	27	25	14	23	21	35		7	451

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
02:28.5	07:00.0	20	31	27	24	14	23	20	35		7	451
03:28.5	08:00.0	20	31	26	25	14	22	20	35		7	451
04:28.5	09:00.0	21	31	26	25	14	22	21	35		7	450
05:28.5	10:00.0	21	31	26	25	14	23	21	35		7	450
06:28.5	11:00.0	21	31	26	25	14	23	21	35		7	451
07:28.5	12:00.0	21	31	26	25	14	23	20	35		7	450
08:28.5	13:00.0	21	31	26	25	14	23	20	35		8	450
09:28.5	14:00.0	21	31	26	25	14	23	21	34		7	450
10:28.5	15:00.0	21	31	27	25	14	22	21	34		7	450
11:28.5	16:00.0	21	31	27	25	14	23	21	34		8	450
12:28.5	17:00.0	21	31	27	25	14	23	21	34		8	450
13:28.5	18:00.0	21	31	27	25	14	23	21	34		8	450
14:28.5	19:00.0	21	31	26	25	14	23	21	34		8	451
15:28.5	20:00.0	21	31	26	24	14	23	21	35		8	451
16:28.5	21:00.0	20	31	27	24	15	23	21	34		8	451
17:28.5	22:00.0	21	31	27	25	15	23	20	34		8	450
18:28.5	23:00.0	21	31	26	25	15	23	21	34		8	450
19:28.5	24:00.0	21	31	26	25	15	23	21	34		8	451
20:28.5	25:00.0	21	30	26	24	15	23	21	34		8	450
21:28.5	26:00.0	21	30	27	25	14	22	21	34		8	451
22:28.5	27:00.0	21	30	27	24	14	22	21	34		8	450
23:28.5	28:00.0	21	31	27	24	14	23	21	34		8	450
24:28.5	29:00.0	21	31	26	24	14	22	21	34		8	451
25:28.5	30:00.0	21	31	26	24	14	23	20	34		8	451
26:28.5	31:00.0	21	30	26	25	14	23	21	35		7	451
27:28.5	32:00.0	20	30	26	24	14	23	21	35		8	451
28:28.5	33:00.0	21	30	26	25	14	23	20	35		7	451
29:28.5	34:00.0	21	31	26	25	14	23	21	34		8	451
30:28.5	35:00.0	21	30	26	25	15	23	21	34		8	451
31:28.5	36:00.0	21	30	26	25	14	23	21	34		8	451
32:28.5	37:00.0	21	30	26	25	14	22	20	34		7	451
33:28.5	38:00.0	21	30	26	24	14	22	21	34		7	451
34:28.5	39:00.0	21	30	27	24	14	22	21	34		7	451
35:28.5	40:00.0	21	30	26	24	14	23	21	35		8	451
36:28.5	41:00.0	21	30	26	24	14	23	21	34		8	451
37:28.5	42:00.0	21	30	26	24	14	23	21	34		8	452
38:28.5	43:00.0	21	31	27	24	14	23	20	34		8	452

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
39:28.5	44:00.0	20	31	27	24	14	23	20	34		8	451
40:28.5	45:00.0	20	31	26	24	14	23	20	34		8	451
41:28.5	46:00.0	20	30	27	24	14	23	20	34		8	451
42:28.5	47:00.0	20	30	27	24	14	22	20	34		8	451
43:28.5	48:00.0	20	30	27	24	14	23	21	34		7	451
44:28.5	49:00.0	21	31	27	24	14	23	21	34		8	451
45:28.5	50:00.0	21	31	27	25	14	23	21	33		7	450
46:28.5	51:00.0	21	31	27	24	13	22	21	33		7	451
47:28.5	52:00.0	21	31	27	24	13	22	21	33		8	451
48:28.5	53:00.0	20	31	27	24	13	23	21	33		7	451
49:28.5	54:00.0	21	32	27	24	14	23	21	33		8	451
50:28.5	55:00.0	21	32	26	24	13	22	21	34		7	451
51:28.5	56:00.0	21	32	27	23	14	22	21	34		7	452
52:28.5	57:00.0	21	31	27	24	14	23	21	33		7	451
53:28.5	58:00.0	21	32	27	24	14	23	21	34		7	451
54:28.5	59:00.0	22	32	27	25	14	23	21	34		8	452
55:28.5	00:00.0	21	32	27	24	14	23	21	33		8	451
56:28.5	01:00.0	21	31	27	24	14	23	20	33		8	451
57:28.5	02:00.0	21	31	27	24	14	23	20	33		8	451
58:28.5	03:00.0	21	32	27	24	14	23	20	33		7	451
59:28.5	04:00.0	21	31	26	25	14	22	20	34		7	450
00:28.5	05:00.0	21	32	26	24	14	23	20	34		7	451
01:28.5	06:00.0	20	32	27	24	14	22	20	34		7	451
02:28.5	07:00.0	21	32	27	25	14	22	20	34		7	451
03:28.5	08:00.0	21	32	27	24	15	22	21	33		8	450
04:28.5	09:00.0	21	32	26	24	14	22	21	33		8	451
05:28.5	10:00.0	21	32	26	24	15	22	20	33		8	452
06:28.5	11:00.0	21	32	27	24	15	23	19	32		7	451
07:28.5	12:00.0	21	32	26	24	15	22	20	33		8	450
08:28.5	13:00.0	21	32	26	24	15	22	20	33		8	451
09:28.5	14:00.0	21	32	26	25	15	22	21	33		7	452
10:28.5	15:00.0	21	32	26	24	15	22	20	34		7	452
11:28.5	16:00.0	21	32	26	24	15	22	21	34		7	452
12:28.5	17:00.0	21	32	26	24	15	22	21	34		7	451
13:28.5	18:00.0	21	32	26	24	15	22	20	34		7	451
14:28.5	19:00.0	21	33	26	23	15	22	20	34		7	452
15:28.5	20:00.0	21	33	27	24	15	22	20	34		7	451

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
16:28.5	21:00.0	21	33	27	24	15	23	21	34		7	451
17:28.5	22:00.0	21	32	26	24	15	22	20	35		7	451
18:28.5	23:00.0	21	32	26	24	15	22	20	34		7	451
19:28.5	24:00.0	21	32	26	24	15	23	20	34		7	451
20:28.5	25:00.0	21	32	26	24	15	23	20	34		7	452
21:28.5	26:00.0	21	32	26	24	15	23	20	34		7	452
22:28.5	27:00.0	20	31	26	24	15	23	20	34		7	452
23:28.5	28:00.0	20	32	26	24	15	23	20	34		7	451
24:28.5	29:00.0	21	32	26	24	15	23	21	34		7	451
25:28.5	30:00.0	21	32	26	24	14	23	21	34		7	452
26:28.5	31:00.0	21	32	26	24	14	23	20	34		7	452
27:28.5	32:00.0	21	32	26	23	14	22	20	34		7	452
28:28.5	33:00.0	21	32	26	23	14	22	20	34		7	452
29:28.5	34:00.0	21	32	26	23	14	22	21	34		7	453
30:28.5	35:00.0	21	32	26	23	14	22	20	33		7	453
31:28.5	36:00.0	21	31	26	23	14	22	21	33		8	453
32:28.5	37:00.0	21	32	26	24	14	22	21	33		8	454
33:28.5	38:00.0	21	32	26	24	14	22	21	33		8	454
34:28.5	39:00.0	21	32	26	24	14	22	20	33		8	453
35:28.5	40:00.0	20	32	26	24	14	22	20	34		8	453
36:28.5	41:00.0	21	31	27	24	14	22	20	34		8	453
37:28.5	42:00.0	20	31	26	24	15	23	20	33		8	453
38:28.5	43:00.0	20	31	26	23	15	22	20	34		8	453
39:28.5	44:00.0	21	32	26	23	15	22	20	33		8	453
40:28.5	45:00.0	21	32	26	23	15	22	20	34		8	453
41:28.5	46:00.0	20	32	26	23	15	23	20	34		8	453
42:28.5	47:00.0	20	32	26	24	15	22	20	34		7	453
43:28.5	48:00.0	21	32	26	24	15	22	20	34		7	454
44:28.5	49:00.0	21	32	26	24	15	22	20	34		7	453
45:28.5	50:00.0	21	32	26	23	15	22	20	34		7	453
46:28.5	51:00.0	21	32	26	23	14	22	20	34		8	453
47:28.5	52:00.0	21	32	26	24	14	22	20	34		8	453
48:28.5	53:00.0	21	32	27	23	14	22	20	34		8	453
49:28.5	54:00.0	21	32	26	24	14	22	20	34		8	453
50:28.5	55:00.0	21	32	26	23	14	23	20	34		8	454
51:28.5	56:00.0	21	33	26	23	14	22	20	34		8	454
52:28.5	57:00.0	21	32	26	23	14	23	20	33		8	454

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
53:28.5	58:00.0	21	32	26	23	14	22	21	33		7	454
54:28.5	59:00.0	21	32	26	23	14	22	20	33		7	454
55:28.5	00:00.0	21	32	26	23	14	22	20	33		7	453
56:28.5	01:00.0	21	32	26	23	14	22	20	33		7	454
57:28.5	02:00.0	21	32	26	24	14	22	20	33		7	454
58:28.5	03:00.0	21	32	26	24	14	22	20	33		7	454
59:28.5	04:00.0	21	32	26	24	14	22	20	33		7	454
00:28.5	05:00.0	21	32	26	23	14	22	20	33		7	453
01:28.5	06:00.0	21	32	26	23	14	22	20	33		7	454
02:28.5	07:00.0	21	32	26	24	15	22	20	33		7	454
03:28.5	08:00.0	20	32	26	23	15	22	20	33		8	453
04:28.5	09:00.0	21	32	26	23	14	22	20	33		8	455
05:28.5	10:00.0	21	32	27	24	15	22	20	33		8	454
06:28.5	11:00.0	21	32	27	24	14	22	20	32		8	454
07:28.5	12:00.0	21	32	27	24	14	22	20	32		8	454
08:28.5	13:00.0	21	32	26	24	14	22	20	32		8	454
09:28.5	14:00.0	21	32	26	24	14	23	20	33		8	454
10:28.5	15:00.0	22	31	26	23	15	23	20	32		8	454
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12:28.5	17:00.0	21	32	26	23	15	22	20	32		8	455
13:28.5	18:00.0	21	32	26	24	15	22	20	32		7	454
14:28.5	19:00.0	20	32	26	23	14	22	20	32		7	455
15:28.5	20:00.0	21	32	26	23	14	23	21	32		7	455
16:28.5	21:00.0	21	32	26	23	14	22	20	32		7	455
17:28.5	22:00.0	20	32	26	23	14	22	20	33		7	455
18:28.5	23:00.0	21	32	26	23	14	22	20	33		7	454
19:28.5	24:00.0	21	32	26	22	15	22	20	33		7	454
20:28.5	25:00.0	21	32	26	23	15	22	20	33		7	455
21:28.5	26:00.0	21	32	26	23	14	22	20	33		7	454
22:28.5	27:00.0	21	32	26	23	14	22	20	32		7	455
23:28.5	28:00.0	21	32	26	23	14	22	20	32		7	456
24:28.5	29:00.0	20	32	26	23	14	22	20	32		7	455
25:28.5	30:00.0	20	32	26	23	14	22	20	33		7	455
26:28.5	31:00.0	20	32	26	23	15	22	20	33		7	455
27:28.5	32:00.0	20	32	26	23	15	22	20	33		7	455
28:28.5	33:00.0	20	32	26	23	14	22	20	33		7	455
29:28.5	34:00.0	20	32	26	23	14	22	20	33		7	456

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
30:28.5	35:00.0	20	31	26	23	14	22	20	32		7	456
31:28.5	36:00.0	20	31	26	23	14	22	20	33		7	457
32:28.5	37:00.0	21	31	26	23	15	22	20	33		7	456
33:28.5	38:00.0	20	32	26	23	14	22	20	32		7	456
34:28.5	39:00.0	20	32	27	22	15	22	20	33		8	456
35:28.5	40:00.0	20	32	26	23	14	22	21	32		7	457
36:28.5	41:00.0	21	32	26	23	14	22	21	32		7	457
37:28.5	42:00.0	21	31	26	23	14	22	21	32		7	457
38:28.5	43:00.0	21	32	26	23	15	22	20	32		7	458
39:28.5	44:00.0	21	32	26	23	15	22	20	32		7	458
40:28.5	45:00.0	20	32	26	23	15	22	20	32		8	458
41:28.5	46:00.0	21	32	26	23	14	22	20	32		7	457
42:28.5	47:00.0	21	32	26	23	15	22	20	32		7	457
43:28.5	48:00.0	21	32	26	23	14	22	20	32		7	457
44:28.5	49:00.0	21	33	26	23	14	22	20	31		7	457
45:28.5	50:00.0	21	32	26	23	14	22	20	32		7	459
46:28.5	51:00.0	20	32	26	23	14	22	20	32		7	460
47:28.5	52:00.0	20	31	26	23	14	22	20	32		7	459
48:28.5	53:00.0	20	32	26	23	14	22	20	32		7	458
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50:28.5	55:00.0	20	32	26	23	14	22	20	32		7	459
51:28.5	56:00.0	20	32	26	23	14	22	20	32		8	461
52:28.5	57:00.0	21	32	26	23	14	22	20	32		8	460
53:28.5	58:00.0	21	32	26	23	15	22	20	32		8	460
54:28.5	59:00.0	21	32	26	23	15	22	20	32		8	461
55:28.5	00:00.0	21	32	26	23	15	22	20	32		7	461
56:28.5	01:00.0	21	32	26	23	15	22	21	32		8	461
57:28.5	02:00.0	21	32	26	23	15	23	20	32		8	461
58:28.5	03:00.0	21	32	26	23	15	23	20	32		7	462
59:28.5	04:00.0	21	32	26	22	14	23	20	32		7	462
00:28.5	05:00.0	21	32	26	22	14	23	20	32		7	462
01:28.5	06:00.0	20	32	26	23	14	23	20	32		7	462
02:28.5	07:00.0	21	32	26	23	15	23	20	32		7	462
03:28.5	08:00.0	21	32	26	23	14	23	20	31		7	462
04:28.5	09:00.0	21	32	26	23	14	23	20	31		8	462
05:28.5	10:00.0	20	32	26	22	14	23	20	31		7	463
06:28.5	11:00.0	21	33	26	22	14	23	20	31		7	463

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
07:28.5	12:00.0	21	32	26	22	14	23	20	31		7	463
08:28.5	13:00.0	21	32	26	22	14	23	20	31		7	462
09:28.5	14:00.0	21	31	27	23	14	23	20	31		7	463
10:28.5	15:00.0	21	32	26	23	14	23	21	31		7	463
11:28.5	16:00.0	20	32	26	23	14	23	20	32		7	463
12:28.5	17:00.0	20	32	26	23	14	23	20	32		7	463
13:28.5	18:00.0	20	32	26	22	14	23	20	31		8	463
14:28.5	19:00.0	20	32	26	23	14	23	20	32		8	463
15:28.5	20:00.0	20	32	26	23	14	23	20	32		8	463
16:28.5	21:00.0	20	32	26	22	14	23	20	32		7	463
17:28.5	22:00.0	20	32	26	23	14	23	20	32		8	463
18:28.5	23:00.0	20	31	26	23	15	23	20	32		8	463
19:28.5	24:00.0	20	32	25	23	14	23	20	32		8	464
20:28.5	25:00.0	20	32	26	23	15	23	20	32		7	464
21:28.5	26:00.0	20	32	26	23	14	23	20	32		7	465
22:28.5	27:00.0	20	32	26	23	14	23	20	32		7	465
23:28.5	28:00.0	20	32	26	22	14	23	20	31		7	465
24:28.5	29:00.0	20	32	26	23	14	23	20	31		7	465
25:28.5	30:00.0	20	32	26	23	14	23	20	31		7	466
26:28.5	31:00.0	20	31	26	23	14	23	20	32		7	467
27:28.5	32:00.0	20	31	26	22	14	23	20	31		7	467
28:28.5	33:00.0	21	31	26	22	14	23	20	31		7	467
29:28.5	34:00.0	21	32	26	22	14	23	20	31		7	467
30:28.5	35:00.0	21	31	26	22	14	23	20	31		7	467
31:28.5	36:00.0	21	32	26	22	14	23	20	31		8	467
32:28.5	37:00.0	21	31	26	22	14	23	20	31		7	466
33:28.5	38:00.0	21	31	26	23	14	23	20	31		7	467
34:28.5	39:00.0	20	32	26	23	14	23	20	31		7	467
35:28.5	40:00.0	21	32	26	23	14	23	20	31		7	467
36:28.5	41:00.0	21	32	26	23	14	22	20	31		7	467
37:28.5	42:00.0	21	32	26	23	14	23	20	31		7	467
38:28.5	43:00.0	21	32	26	23	14	23	20	31		7	467
39:28.5	44:00.0	20	32	25	23	14	23	20	31		7	466
40:28.5	45:00.0	21	31	25	23	14	23	20	31		7	468
41:28.5	46:00.0	21	31	25	23	14	23	20	32		7	466
42:28.5	47:00.0	21	32	25	23	14	23	20	32		7	465
43:28.5	48:00.0	21	31	26	23	14	23	20	31		7	466

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
44:28.5	49:00.0	20	31	25	23	14	23	20	31		7	467
45:28.5	50:00.0	21	31	26	23	14	23	20	31		7	465
46:28.5	51:00.0	20	32	26	22	13	23	20	31		7	467
47:28.5	52:00.0	21	32	26	22	14	23	20	31		7	466
48:28.5	53:00.0	20	32	26	22	14	23	20	31		7	466
49:28.5	54:00.0	20	31	26	23	14	23	20	31		7	466
50:28.5	55:00.0	20	32	26	22	14	23	20	31		7	466
51:28.5	56:00.0	20	32	26	22	14	23	20	31		7	466
52:28.5	57:00.0	20	32	25	22	14	22	20	31		7	467
53:28.5	58:00.0	20	31	26	22	14	23	20	31		7	466
54:28.5	59:00.0	20	32	26	23	14	23	20	31		7	466
55:28.5	00:00.0	20	32	26	23	14	23	20	30		7	466
56:28.5	01:00.0	20	32	26	23	14	23	20	30		7	466
57:28.5	02:00.0	20	32	26	23	14	23	20	30		7	465
58:28.5	03:00.0	20	32	26	23	14	23	19	30		7	466
59:28.5	04:00.0	20	31	26	23	14	23	20	30		7	465
00:28.5	05:00.0	20	31	26	23	13	23	20	31		7	465
01:28.5	06:00.0	20	31	25	22	14	23	19	31		7	466
02:28.5	07:00.0	20	32	25	23	14	22	20	31		7	465
03:28.5	08:00.0	20	31	25	23	14	23	20	31		7	465
04:28.5	09:00.0	21	32	26	22	13	23	20	31		7	465
05:28.5	10:00.0	21	32	26	22	13	23	20	31		7	466
06:28.5	11:00.0	21	32	26	23	14	23	20	31		7	465
07:28.5	12:00.0	21	32	26	22	14	23	20	31		7	466
08:28.5	13:00.0	21	32	26	22	14	23	20	31		7	466
09:28.6	01:00.1	21	32	26	22	13	23	20	31		7	466
10:28.6	01:00.0	21	31	26	22	12	23	20	31		6	465
11:28.7	01:00.1	21	31	26	22	12	23	20	31		6	465
12:28.9	01:00.2	21	31	26	22	13	23	20	30		7	465
13:29.0	01:00.1	21	31	26	22	13	23	20	31		7	465
14:29.1	01:00.1	21	31	26	22	13	23	19	31		7	465
15:29.4	01:00.3	22	31	26	22	13	22	19	31		7	465
16:29.9	01:00.5	22	32	26	22	13	22	19	31		7	465
17:30.3	01:00.4	22	32	27	22	13	23	19	31		7	465
18:30.7	01:00.4	21	31	27	21	13	23	19	31		7	465
19:31.5	01:00.8	21	31	27	22	13	22	19	31		7	465
20:32.1	01:00.6	21	31	27	21	13	22	19	30		7	465

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
21:32.9	01:00.8	21	32	27	22	14	22	19	30		7	466
22:33.7	01:00.8	21	31	27	22	14	23	19	30		7	466
23:34.6	01:00.9	22	32	27	22	14	23	19	30		6	466
24:35.4	01:00.8	22	31	27	22	14	23	19	31		7	465
25:36.4	01:01.0	21	31	27	23	14	23	19	31		7	466
26:37.4	01:01.0	21	32	27	23	14	23	19	31		7	466
27:40.9	01:03.5	21	31	27	22	14	23	19	30		6	465
28:42.2	01:01.3	21	31	27	22	14	23	19	30		7	465
29:43.5	01:01.3	21	32	27	21	14	23	19	30		7	465
30:44.7	01:01.2	22	31	27	22	13	23	19	30		7	465
31:46.1	01:01.4	22	31	27	21	13	23	19	30		7	466
32:47.5	01:01.4	22	31	27	22	13	23	19	30		7	466
33:49.1	01:01.6	22	32	27	22	14	23	19	30		6	466
34:50.6	01:01.5	22	32	27	22	14	23	19	30		6	465
35:52.0	01:01.4	22	32	27	22	14	23	19	30		6	466
36:53.6	01:01.6	22	32	27	22	14	23	19	30		6	466
37:55.2	01:01.6	21	32	27	22	14	23	19	30		6	468
38:57.0	01:01.8	21	31	27	22	14	23	20	30		6	467
39:58.8	01:01.8	21	31	27	23	14	23	20	30		7	467
41:00.6	01:01.8	22	31	27	23	14	23	20	30		7	466
42:02.6	01:02.0	22	31	27	23	13	23	19	30		7	466
43:04.5	01:01.9	21	31	27	23	13	22	19	29		7	467
44:06.5	01:02.0	21	31	27	23	13	23	19	30		7	467
45:08.7	01:02.2	21	31	27	23	13	22	19	29		7	467
46:11.1	01:02.4	21	31	26	23	13	22	19	29		7	467
47:13.4	01:02.3	21	31	26	23	13	22	19	30		7	464
48:15.6	01:02.2	21	31	26	23	13	23	19	30		7	465
49:18.0	01:02.4	21	31	26	23	13	23	20	30		7	465
50:20.4	01:02.4	21	31	26	22	13	23	19	29		7	466
51:23.0	01:02.6	21	31	26	23	13	22	20	29		6	466
52:25.5	01:02.5	21	31	27	23	14	23	20	29		6	465
53:27.9	01:02.4	21	32	27	23	13	22	19	30		7	465
54:30.5	01:02.6	21	32	27	23	13	22	19	30		7	465
55:33.1	01:02.6	21	32	27	23	13	22	19	30		7	465
56:35.8	01:02.7	21	32	26	23	13	22	19	30		7	466
57:38.8	01:03.0	22	31	26	23	13	23	19	30		7	466
58:41.9	01:03.1	22	31	27	23	13	22	19	30		7	465

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
59:45.1	01:03.2	20	31	27	23	14	22	19	30		7	465
00:48.2	01:03.1	21	31	27	23	14	22	19	30		7	465
01:51.4	01:03.2	21	31	26	23	14	22	19	29		7	465
02:54.5	01:03.1	21	31	26	23	14	22	19	29		7	465
03:58.0	01:03.5	21	31	26	23	14	22	19	30		7	465
05:01.3	01:03.3	21	31	26	23	14	22	19	30		7	465
06:04.8	01:03.5	21	31	27	23	14	22	20	30		7	465
07:08.3	01:03.5	21	31	26	22	14	23	19	30		7	465
08:11.8	01:03.5	21	31	26	23	13	22	19	30		7	464
09:15.5	01:03.7	21	31	27	23	14	22	20	30		7	465
10:19.3	01:03.8	21	31	26	23	14	22	20	30		7	464
11:23.2	01:03.9	21	32	27	23	13	22	20	30		6	464
12:27.1	01:03.9	21	32	27	23	13	22	20	29		7	464
13:31.1	01:04.0	21	31	27	23	14	23	20	30		7	464
14:35.1	01:04.0	21	31	27	23	14	22	21	30		7	464
15:39.2	01:04.1	22	32	27	24	13	22	20	30		7	464
16:43.2	01:04.0	22	32	26	23	13	22	20	29		6	463
17:47.4	01:04.2	22	31	26	22	13	22	20	29		6	464
18:51.7	01:04.3	22	32	26	23	13	23	20	29		6	464
19:56.1	01:04.4	21	33	26	23	13	23	20	29		6	464
21:00.4	01:04.3	22	32	27	23	13	23	20	29		6	464
22:05.1	01:04.7	22	32	26	23	13	22	21	29		7	464
23:09.7	01:04.6	21	32	26	23	13	22	21	30		6	464
24:14.3	01:04.6	22	32	26	23	13	23	21	30		6	464
25:19.0	01:04.7	21	32	26	23	13	23	21	30		6	463
26:23.7	01:04.7	21	32	26	23	13	22	21	30		6	464
27:28.7	01:05.0	21	32	26	23	13	22	20	29		6	464
28:33.7	01:05.0	21	32	26	23	12	22	21	29		6	464
29:38.7	01:05.0	21	32	26	22	13	22	21	29		7	463
30:43.9	01:05.2	21	32	26	23	13	22	20	30		6	464
31:49.0	01:05.1	22	32	26	23	13	22	20	29		6	464
32:54.1	01:05.1	22	32	27	23	13	22	20	29		6	463
33:59.4	01:05.3	22	32	26	23	13	22	20	29		7	464
35:04.7	01:05.3	22	32	26	23	14	22	20	29		7	464
36:10.1	01:05.4	22	32	26	23	13	22	20	29		7	464
37:15.5	01:05.4	22	32	26	23	13	22	20	29		7	463
38:20.9	01:05.4	22	32	26	23	13	22	20	28		7	462

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
39:26.4	01:05.5	21	31	27	23	13	22	20	29		7	462
40:32.1	01:05.7	21	32	27	23	13	22	20	29		7	461
41:37.7	01:05.6	21	32	26	23	13	22	20	29		6	462
42:44.6	01:06.9	21	32	26	23	13	22	21	28		6	475
43:53.5	01:08.9	21	32	26	23	13	22	21	29		7	474
45:02.8	01:09.3	21	32	26	23	13	22	21	29		7	474
46:12.3	01:09.5	21	32	26	22	13	22	21	29		7	474
47:19.7	01:07.4	21	31	26	22	13	22	20	29		6	470
48:27.6	01:07.9	21	32	26	22	13	22	20	29		6	469
49:34.3	01:06.7	21	32	26	23	14	22	20	29		6	469
50:40.6	01:06.3	21	32	27	23	14	22	20	29		6	469
51:46.9	01:06.3	21	31	27	23	14	23	21	29		7	469
52:53.3	01:06.4	21	31	26	23	14	22	20	29		7	469
53:59.8	01:06.5	20	32	26	23	14	22	20	29		6	468
55:06.4	01:06.6	21	32	26	23	14	22	20	29		7	468
56:13.1	01:06.7	21	32	26	23	14	22	21	29		7	467
57:19.7	01:06.6	21	32	26	23	13	22	21	29		7	466
58:26.4	01:06.7	21	32	27	23	13	22	20	29		8	466
59:33.2	01:06.8	21	32	27	23	14	22	20	29		7	466
00:40.1	01:06.8	21	32	27	23	13	22	20	29		7	466
01:47.0	01:06.9	21	32	27	23	13	22	21	29		7	465
02:54.0	01:07.0	21	32	26	23	13	22	21	28		7	465
04:01.0	01:07.0	21	31	26	23	13	22	20	29		7	464
05:08.2	01:07.2	21	32	26	23	13	23	20	29		7	465
06:15.3	01:07.1	21	32	26	23	13	22	20	29		7	463
07:22.7	01:07.4	21	32	27	23	13	22	20	29		7	463
08:30.0	01:07.3	21	31	27	23	13	22	20	28		7	465
09:37.4	01:07.4	21	32	26	23	13	22	21	28		7	464
10:44.8	01:07.4	21	32	26	23	14	22	20	29		6	465
11:52.3	01:07.5	21	31	26	23	13	22	21	29		7	464
13:00.0	01:07.7	21	31	26	23	13	22	20	29		7	464
14:07.8	01:07.8	21	31	26	23	13	22	20	29		7	463
15:15.5	01:07.7	21	31	26	23	13	22	21	29		7	463
16:23.3	01:07.8	21	31	26	23	13	22	20	29		7	463
17:31.1	01:07.8	21	31	26	23	13	22	20	29		6	463
18:39.2	01:08.1	21	31	26	23	13	22	21	29		6	463
19:47.2	01:08.0	21	31	26	23	13	22	21	29		6	464

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
20:55.3	01:08.1	21	32	26	23	13	22	20	29		7	464
22:03.6	01:08.3	21	31	26	23	13	22	20	29		7	465
23:11.8	01:08.2	21	31	26	23	13	22	20	29		7	465
24:20.2	01:08.4	21	31	26	23	14	22	20	29		7	466
25:28.5	01:08.3	21	31	27	23	14	22	20	29		7	465
26:36.8	01:08.3	21	32	26	23	14	22	20	29		7	466
27:45.1	01:08.3	21	31	26	23	13	22	20	29		7	467
28:53.6	01:08.5	21	32	26	23	12	22	20	29		7	467
30:02.1	01:08.5	21	32	26	23	13	22	20	29		7	470
31:10.9	01:08.8	21	31	26	23	13	22	20	29		7	470
32:19.7	01:08.8	21	31	26	22	13	22	20	28		7	471
33:28.4	01:08.7	21	32	27	22	13	22	20	28		7	471
34:37.2	01:08.8	21	31	26	22	13	22	20	28		7	471
35:46.0	01:08.8	21	32	27	22	13	22	20	29		6	471
36:54.9	01:08.9	21	31	27	22	13	21	20	29		6	469
38:03.8	01:08.9	21	32	27	22	13	22	20	29		7	469
39:12.8	01:09.0	20	32	26	23	13	22	20	29		7	468
40:21.9	01:09.1	20	32	26	23	13	22	20	28		7	468
41:31.0	01:09.1	21	32	27	23	13	21	20	28		7	468
42:40.3	01:09.3	21	32	27	23	14	22	20	29		7	468
43:49.5	01:09.2	21	32	26	23	14	22	20	29		7	467
44:58.7	01:09.2	21	32	26	23	13	22	20	29		7	467
46:08.2	01:09.5	21	32	26	23	13	22	20	28		6	467
47:17.8	01:09.6	21	32	26	22	13	22	20	29		6	467
48:27.4	01:09.6	21	32	26	22	13	22	20	29		6	466
49:37.1	01:09.7	21	31	26	22	14	22	21	29		7	466
50:46.6	01:09.5	21	31	26	22	13	22	20	28		7	468
51:56.3	01:09.7	21	32	27	22	13	22	20	28		6	468
53:06.0	01:09.7	21	32	26	22	14	22	20	29		6	467
54:15.9	01:09.9	21	32	26	23	13	22	20	28		6	466
55:25.7	01:09.8	21	31	26	23	13	22	20	28		6	466
56:35.7	01:10.0	21	32	26	23	13	22	20	28		6	466
57:45.7	01:10.0	21	32	26	23	13	22	20	28		7	466
58:55.8	01:10.1	21	32	26	22	13	22	20	28		7	466
00:05.9	01:10.1	21	32	26	23	13	22	20	28		7	466
01:16.0	01:10.1	21	31	26	23	13	22	20	28		6	467
02:26.3	01:10.3	21	31	26	23	13	22	20	28		6	471

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
03:36.7	01:10.4	22	31	26	23	13	22	20	28		7	472
04:47.0	01:10.3	22	32	27	23	13	22	20	28		7	471
05:57.3	01:10.3	21	32	26	23	13	22	20	28		7	471
07:08.5	01:11.2	21	32	27	23	13	22	20	28		7	472
08:19.0	01:10.5	21	32	26	23	13	22	20	28		6	472
09:29.6	01:10.6	21	32	26	23	13	22	20	28		7	472
10:40.3	01:10.7	21	32	26	23	13	22	20	28		7	472
11:51.1	01:10.8	21	32	27	23	13	22	20	28		7	472
13:01.9	01:10.8	21	32	26	23	13	22	20	27		6	473
14:12.8	01:10.9	20	31	27	23	13	22	20	28		7	473
15:24.3	01:11.5	21	32	26	23	13	22	20	28		7	473
16:35.8	01:11.5	20	32	26	23	14	21	20	28		7	473
17:46.9	01:11.1	20	32	26	23	13	22	20	28		8	473
18:58.0	01:11.1	21	32	26	22	14	22	20	28		8	472
20:09.0	01:11.0	20	32	26	22	14	21	20	28		8	472
21:20.3	01:11.3	21	32	26	22	13	22	20	27		8	472
22:31.4	01:11.1	21	32	26	23	14	21	20	28		8	472
23:42.9	01:11.5	21	32	26	23	13	22	20	28		8	473
24:54.4	01:11.5	20	32	26	23	13	22	20	28		8	472
26:05.9	01:11.5	20	31	26	23	13	22	21	28		7	470
27:17.5	01:11.6	21	31	26	23	14	21	20	28		7	469
28:29.3	01:11.8	21	32	26	23	14	21	20	28		8	468
29:41.1	01:11.8	20	32	26	23	14	22	20	27		8	467
30:52.8	01:11.7	21	32	26	23	14	22	20	28		8	466
32:04.7	01:11.9	20	32	26	22	14	21	20	28		7	465
33:16.7	01:12.0	20	32	26	22	13	22	20	28		7	464
34:28.7	01:12.0	20	32	26	23	15	22	20	28		8	463
35:40.7	01:12.0	20	32	26	22	14	22	20	27		7	461
36:52.8	01:12.1	20	31	27	22	14	21	20	27		7	461
38:05.2	01:12.4	21	32	26	22	14	22	20	27		7	461
39:17.5	01:12.3	21	31	26	22	14	21	19	27		7	462
40:32.3	01:14.8	20	32	26	22	14	22	20	27		7	462
41:44.6	01:12.3	20	32	26	22	14	22	20	27		7	462
42:57.1	01:12.5	20	31	26	22	14	22	20	27		7	463
44:09.7	01:12.6	21	32	26	22	15	22	20	28		7	463
45:22.1	01:12.4	20	32	26	22	15	22	20	28		8	464
46:34.7	01:12.6	20	32	26	22	14	22	20	28		7	463

		Grad 2 (13")	Grad 2 (26")	Grad 4 (13")	Grad 4 (26")	Grad 1 (26")	Grad 1 (13")	Grad 3 (13")	Grad 3 (26")	Grad 5 (26")	Grad 5 (13")	Ambient
		#4-	#4-	25%AB	25%AB	representative	representative	3/8+	3/8+	75%AB	75%AB	Ambient
		Top	Bottom	Top	Bottom	Bottom	Top	Top	Bottom	Bottom	Top	Ambient
	Time	4T-CC7 [K-30 1%]	4B-D13 [K-30 1%]	25AB-D0C [K-30 1%]	25ABB-B33 [K-30 1%]	RepB-B42 [K-30 1%]	RepT-D0B [K-30 1%]	38T-C4C [K-30 1%]	38B-B3C [K-30 1%]	75ABB-B38 [K-30 1%]	75ABT-D0F [K-30 1%]	Amb-B3A [K-30 1%]
47:47.4	01:12.7	20	32	26	22	15	22	20	28		7	463
49:00.2	01:12.8	20	32	26	22	14	21	20	28		7	465
50:13.1	01:12.9	20	32	26	22	15	21	21	27		7	464
51:26.1	01:13.0	20	31	26	22	14	21	20	27		7	465
52:39.1	01:13.0	21	32	26	22	13	21	20	27		7	465
53:52.1	01:13.0	20	32	26	22	14	21	20	27		7	466
55:05.2	01:13.1	20	32	25	22	14	22	20	27		7	467
56:18.3	01:13.1	20	31	25	21	14	22	20	27		8	466
57:31.5	01:13.2	20	32	26	22	14	22	20	27		7	467
58:44.8	01:13.3	20	32	26	22	13	21	20	27		8	466
59:58.1	01:13.3	21	31	26	22	14	21	20	27		7	467
01:11.5	01:13.4	20	31	26	22	14	21	20	27		8	471
02:24.9	01:13.4	21	31	26	22	13	21	20	27		7	475
03:38.4	01:13.5	20	31	26	22	13	21	20	27		7	479
04:52.1	01:13.7	21	32	26	22	14	21	20	27		7	485
06:05.7	01:13.6	21	32	26	22	14	21	20	27		7	486
07:20.7	01:15.0	21	31	26	22	14	21	20	27		7	517
08:36.7	01:16.0	21	32	26	22	13	21	20	27		7	520
09:52.5	01:15.8	21	32	26	22	13	21	20	27		7	522
11:07.4	01:14.9	21	32	26	22	14	21	20	28		7	520