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Recycling Practices of Ready Mix Concrete, Inc.

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RECYCLING PRACTICES OF READY MIX CONCRETE, INC.

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This report is the product of an education program, and is intended to serve as partial documentation for the evaluation of academic achievement. The report should not be construed as a working document by the reader.

ABSTRACT

This report was prepared for Ready Mix Concrete, Inc. of Puerto Rico in order to examine the environmental and economic consequences of current methods used to deal with returned plastic concrete and truck washout water. Several options for the reuse of concrete include chemical admixture stabilization, production of pre-cast blocks, and the use of reclaiming units. The implementation of a recycling program that utilizes such methods can yield substantial environmental and financial benefits for both the company and the community.

Authorship Page

Each member of the project team contributed equally to the contents of this paper. All research, writing, and thoughts presented are the work of the team. All sections were written, revised, and edited as a group.

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Executive Summary

Introduction

With 1998 production in excess of 1,250,000 yards of concrete, Ready Mix Concrete, Inc. is the largest producer of concrete in Puerto Rico. It commissioned Worcester Polytechnic Institute to conduct a study to determine the best methods for managing returned plastic concrete and truck washout water.

Project Goal

The goal of this project is to determine how environmentally sound and economically efficient Ready Mix's recycling methods are and to recommend methods as appropriate.

Background

Ready Mix has several options available to it when faced with the problem of returned plastic concrete. The project examines each of these options to determine which methods of recycling best suit Ready Mix.

One method used to deal with returned plastic concrete is the use of an admixture called DELVO. This admixture delays the hydration of the concrete by forming a barrier around the cement particles. This barrier prevents the concrete from hydrating for a certain length of time. The treated concrete can then be added to a new batch and used at another location.

DELVO can also be used to treat truck washout water. When rinsing the truck drum out at the end of the day, DELVO can be added to the water. This allows the water to stay in the truck over night and be used as batch water the following day.

In addition to using DELVO, Ready Mix also has other methods of dealing with returned plastic concrete. If molds are available, the plant manager can choose to make pre-cast blocks to be used at the plant. Plants two, eight, and twenty also have the option of using a reclaimer to salvage the material for use in subsequent batches. If none of these options are possible, the returned concrete is added to the stockpile and later hauled away for use as fill material.

Methodology

The first step in beginning these analyses was to collect necessary data. Information about DELVO, its usage and costs, and amounts of returned concrete was collected from the DELVO Forms provided by Ing. William Ramos. The Operations Department provided information regarding material and maintenance costs of associated machinery. This information was used to perform analyses on the amount of DELVO used.

Ready Mix uses the DELVO Forms to monitor usage of DELVO for washout water and returned concrete, and also to keep track of the number of blocks made. Although these forms provided much of the necessary information for analyses of the aforementioned topics, more thorough analyses could be possible if additional information were requested from the Form. For this reason a new version of the form was designed (See Appendix C). This new form will provide information such as the total amount of concrete returned to the plant, the amount dumped onto stockpiles, and the amount treated in reclaimers. With this information, a summary of current recycling practices, associated costs, and recommendations for future recycling procedures can be provided. Use of the new form began on April 5, 1999.

Analysis

After reviewing industry and company procedures, the WPI project team developed recommendations to improve Ready Mix's recycling program. Analysis was performed in each of the following categories:

- **Washwater -** *Normally, each truck mixer is rinsed with approximately 225 gallons of water at the end of each working day to wash away any residual concrete. To reduce washwater waste, Ready Mix uses DELVO in combination with fifty to eighty gallons of water to rinse each mixer drum. Since DELVO delays hydration of the concrete, the water is left in the drum overnight and used as batch water the next day. The amount of water saved by using DELVO and the cost of using DELVO were examined.*

- **Reusable Returned Concrete** – *Returned concrete that has not passed a certain stage of hydration may be treated with DELVO to prolong its setting time. The cost and savings associated with recovering returned concrete were compared to those associated with its disposal.*

- **Waste Concrete** – *Concrete that can not be reused must be disposed of in some manner. Two methods of disposal were examined: manufacturing of pre-cast blocks and disposal to the stockpile .*

- **Settling Basin Digging Machine** – *Ready Mix recently purchased a $300,000 'Digger' to service the settling basins of all twenty plants. This machine is used in place of a front-end loader to dig out material that has accumulated in the settling basins. The main problem with using front-end loaders to clean out the basins is that they must be driven into the pits, which leads to equipment failure due to concrete buildup on the axles. Since front-end loaders are also used for daily operations, their failure would make production nearly impossible. The bucket of the new digger is attached to a telescopic boom, which allows the pit to be cleaned without driving into the basin. Reduced front-end loader rental and maintenance fees were weighed against the cost of the 'Digger'.*

- **DELVO Puck Usage** – *DELVO is available in two forms: liquid and solid. The solid form is referred to as 'pucks'. These pucks are portable and can be used to treat the concrete of damaged or delayed trucks. At the time of writing, Ready Mix did not use this product, but its need for it was evaluated.*

Results

The following information was gathered from the DELVO Forms between March 1998 and February 1999.

Amount of Material Hauled by Hauling Service = 13,399 yd^3
Hauling and Disposal Cost for Hauling Service = $20,785.00
Estimated Amount of Material Hauled by Ready Mix = 49,368 yd^3
Estimated Hauling and Disposal Cost for Ready Mix = $58,080 to $71,280

Amount of Concrete Recovered By Using DELVO = 4,174.5 yd^3
Net Profit on Resold Concrete = $254,734.01
Net Profit per Yard of Resold Concrete = $61.04

Amount of Water Saved By Using DELVO for Washwater = 3,390,750 gallons
Expense to Treat Washwater With DELVO = $39,518.05

Blocks Made = 1,216
Block Production Cost = $5,472.00

Recommendations

Recommendations resulting from this study are as follows:

1. Ready Mix should purchase one new dump truck to haul waste material that is collected in stockpiles because it is less expensive than hiring a hauling service and could save, at best, nearly $30,000 per year.
2. Ready Mix should continue to create blocks as long as there is a need.
3. The average profit on a single yard of treated concrete is $61, over six times greater than the profit gained on the sale of a single yard of fresh concrete. Concrete that is returned should be treated and resold.
4. DELVO truck washout treatment should be continued. During the period between March 1998 and February 1999, using DELVO saved over 3.3 million gallons of water. In addition to daily treatment, this procedure should also be extended to Friday (weekend treatment) as well. By including DELVO in washwater treatment on Friday, there is a potential for an additional 20% in water savings.

5. The use of DELVO ESC pucks for stabilization of concrete in damaged or delayed trucks should be standard practice. Use of DELVO ESC for treatment of returned concrete and washwater, however, is not recommended.
6. Appropriate measures should be taken to repair the two Schwing RA-10 reclaimers and ensure that they are properly maintained.
7. Further analyses should be performed on the costs and benefits of reclaimers.
8. The use of reclaimers for water management should be investigated. In particular, the ENVIRO-PORT appears to be a good candidate for both storm and process water management.
9. For accurate future analyses, emphasis should be placed on the importance of completing the DELVO Forms on a daily basis. Plant managers should be informed of the importance of these forms and should be fully aware of that which is required of them. Also, procedures for data collection should be established to ensure plants are in compliance.
10. It appears that the DELVOmatic system can integrate Ready Mix's entire waste management program. This fully computerized system can ease data entry by recording all concrete returns, generating tables of monthly costs and savings, and linking all the plants to a central computer.
11. Methods, such as the use of scales, should be explored to better estimate the amount of concrete in a mixer to reduce error in DELVO dosage for stabilization of returned plastic concrete.

Closing Remarks

Ready Mix Concrete is determined to continue its mission of being first in service and quality. It strives to not only keep the environment clean, but to also produce the best possible product. By determining which methods of recycling washout water and plastic concrete are most efficient, this project helps Ready Mix to continue achieving its corporate goals.

1.0 Introduction

This report was prepared by members of a Worcester Polytechnic Institute Puerto Rico Project Team. The relationship of the team to Ready Mix Concrete, Inc. and the relevance of the topic to Ready Mix Concrete, Inc. are presented in Appendix A.

With over 1,250,000 cubic yards of concrete sold in 1998, Ready Mix Concrete, Inc. is the largest producer of ready mix concrete in Puerto Rico. On March 28, 1999, Ready Mix set the record for the fastest pre-mix concrete pour rate in the history of Puerto Rico. Over 125 ready mix trucks delivered a total of 4,400 cubic yards of pre-mix concrete to the foundation of the Torre Chardón office building in Hato Rey at an astonishing rate of 750 cubic yards per hour! The previous record (also established by Ready Mix) was 500 cubic yards per hour.

Concrete is used extensively in the construction industry, both in large and small construction projects for foundations, floors, walls, ceilings, highways, beams, posts, barriers, and numerous other structures. It has become a preferred building material because it offers the benefits of portability, workability, durability and high strength. In its plastic state, concrete can easily be transported and molded to a specific application. In its hardened state, concrete provides some of the highest strengths and durability of any building material.

This versatile material, however, is not without limitations. There are basic environmental and economic problems associated with the production of concrete. One major drawback of ready mix concrete is its limited usable life of roughly ninety minutes (after addition of water) or 300 mixer revolutions. Concrete that is not used within this time period becomes waste material. On an island such as Puerto Rico, this waste material is difficult to dispose of due to size limitations and lack of adequate storage and landfill space. Also, hauling and disposal costs associated with the removal of waste concrete can turn a profit into a net loss.

In addition to waste problems imposed by the limited life of concrete, a producer must also be aware of water waste at their facility. Seventy-three percent of water usage at a ready mix facility is the result of equipment cleanup around the plant [6]. For a large producer, this could amount to millions of gallons of wasted water each year. The associated environmental strain should be reason enough to seek better water management practices that reduce the amount of waste water generated at ready mix plants.

Reusing the aggregate of returned concrete minimizes not only the amount of raw material that is taken from the surrounding land, but also the amount of waste material that must return to it. This reduces the burden on the land and at the same time reduces supply and disposal costs to the concrete company.

In addition to environmental benefit, it is also important to recognize that the proper management and reuse of ready mix concrete and its primary byproduct, water, can generate substantial revenue. Since salvaged concrete is concrete that does not have to be generated to meet production demands, recycling returned concrete provides financial benefits by reducing production costs. Limiting water waste has the potential to increase revenue through elimination of heavy fines due to non-compliance discharges.

Although recycling concrete can be an attractive option for many ready mix companies, it may also be a necessary practice for some. Diminishing supplies of virgin aggregates, rising waste disposal costs, and stringent environmental policies make the recycling option the only option for some companies.

Ready Mix Concrete of Puerto Rico has commissioned Worcester Polytechnic Institute to conduct a study examining the environmental and economic issues associated with returned concrete and truck washwater management. Methods examined to manage returned concrete include treatment with admixtures to delay setting time, use of reclaimers to recover the raw materials in concrete, pre-cast block production, and disposal as fill material. The use of DELVO, a hydration-slowing admixture, to reduce truck washwater waste is also examined.

The goal of this project is to devise and implement a plan that will aid in the management of waste materials at ready mix facilities in a manner that is environmentally safe and economically efficient. To remain in business, a company must produce revenue, but it is important that a ready mix producer have an equal commitment to the environment and his community.

A 'green' business upholds a respectable environmental management program, thus providing the cleanest possible environment for a community and its inhabitants. By maintaining an environmentally conscientious policy, a company will be looked upon favorably and supported by its community. Such a business would have greater ease expanding into other communities, than would a company that ignores the needs of the environment.

The findings presented here, although intended for Ready Mix Concrete, could be valuable in constructing waste management procedures for other producers or suppliers of concrete products. In this report, water management practices and methods for recycling and reusing concrete are discussed which can used as the basis for a customized recycling program that is best suited for a particular concrete producer.

As an IQP, this project explores many technological solutions to the problem of waste concrete and washwater management while addressing specific social problems concerning economics and environmental regulations. The intent of the Ready Mix Project is to devise a conscientious waste management program that uses technology to achieve societal acceptance by means of sound environmental management practices.

2.0 Literature Review

The following literature review is intended to familiarize the reader with basic concrete recycling practices. To appreciate the complexity of the environmental and economical problems facing ready mix companies, it is necessary to first understand what concrete is and how it is produced. In this literature review, the properties of concrete are reviewed along with the relevant tests used to evaluate these properties. Only after comprehension of this material is it possible to develop solutions to recycling problems in the ready mix industry.

2.1 The History of Concrete

Concrete was discovered as a building material three millennia ago. In pre-modern times, concrete consisted mainly of broken clay bricks held together with a cement mortar. This is most likely the mixture the Romans used to create the Pantheon and was used in various forms until the dawn of the industrial revolution. In the early 1800s, John Smeaton was the first to use a mortar made of hydraulic lime mixed with ground tiles in order to rebuild the Eddystone Lighthouse in England. John Aspdin acquired the patent for Portland cement, one of the major components in concrete mixtures, in 1824. He called his mixture Portland Cement because he felt it closely resembled the stone found on the Isle of Portland in England [3].

The use of cement in the United States began in 1818. Cement was used in the construction of such projects as the Erie Canal. Deposits of cement were soon found all over the United States. New York, Pennsylvania, and Kentucky are a few of the locations containing cement deposits [3]. In 1870, David O. Saylor introduced the first plant in the U.S. that produced Portland Cement. The plant was located in Coplay, Pennsylvania. Before this, only naturally occurring deposits had been able to supply the materials that were used in construction [1].

Today, many types of Portland cement are used to make concrete mixtures. Each type has different properties and components [2]. Their specific uses and properties will be discussed in the following sections regarding the components of concrete mixtures.

2.2 The Making of Concrete

The following sections present an overview of different types of concrete, their components, and the different methods used to test their properties. An understanding of the basic structure of concrete is essential in determining proper methods of reuse and disposal.

2.2.1 Concrete Composition

A basic concrete mixture contains three components: aggregates, Portland Cement, and water. Portland Cement and water make up a mixture referred to as paste (see Glossary). When this paste is combined with aggregates, a material known as concrete is made that is widely used in the construction of buildings, roads, retaining walls, bridges, and other structures [2].

To ensure a homogenous mix, the components of the concrete mixture must be blended. Concrete producers use large mixer drums (see Glossary) attached to trucks to mix and transport concrete. When the cement comes into contact with water, a chemical process called hydration begins. During hydration, cement particles bond to one another forming a paste that joins the aggregates in the mix. It is through the hydration process that concrete gains its strength. If concrete completely hydrates (see Glossary), it stops gaining strength. Although most of the final strength of concrete is achieved within thirty days, with proper hydration it continues to gain strength for years after initial setting [2].

After the concrete is placed, it undergoes a curing stage (see Glossary) in which the material transforms from a plastic to a solid state. Once in the curing stage of hydration, the material is no longer workable. It is thus necessary for the concrete to be fully in place before the curing stage. This makes the pouring and placing of concrete a time sensitive process [2].

2.2.2 Aggregates in Concrete

Aggregates make up sixty to seventy-five percent of the weight of concrete. There are two types of aggregates used in concrete mixtures: coarse aggregates and fine aggregates. Coarse aggregates are a mixture of gravel and crushed stones. The diameter of coarse aggregates ranges from 0.375" to 1.5". Aggregates with a diameter less than 0.375" are referred to as fine aggregates. Fine aggregates are composed of a mixture of sand and crushed stone particles [2].

The surfaces of aggregates have varying textures. A rough-surface aggregate will have more surface area than an equivalent smooth-surface aggregate. Aggregates with smooth surfaces will tend to slide against each other and not form a strong bond with the paste, whereas rough-surface aggregates tend to interlock with each other, forming a strong bond. The use of coarse aggregate with a rough surface texture is preferred over aggregate with a smooth surface, because they produce a stronger and more durable concrete mixture than smooth aggregate [1].

Aggregate size is another important aspect when choosing aggregates for a mix design (see Glossary). Aggregates are an inexpensive component of a concrete mixture. By choosing aggregates of appropriate size, use of more expensive materials such as cement can be minimized [2]. In order to minimize the amount of cement needed in a mix, it is necessary to have as little void space as possible between aggregate. The void space is directly proportional to the aggregate size [1].

Aggregate size can be determined by gradation: a process by which the aggregates pass through a series of sieves to filter aggregates of a particular size. These sieves are placed in a column with the sieve containing the largest openings at the top. Aggregates of mixed size are poured into the top of the column. Aggregates retained on any given sieve are determined to have passed through all preceding sieves [2].

2.2.3 Production of Portland Cement

Portland Cement is the primary component in concrete mixtures. It is manufactured from limestone and clay. The two materials are ground together and heated in a kiln to produce what is referred to as clinker (see Glossary). Clinker is removed from the kiln and allowed to cool. After cooling, gypsum is usually added to control the rate of hydration of the finished concrete. This mixture of gypsum and clinker is thoroughly blended into a fine powder known as Portland Cement [1].

2.2.4 Types of Portland Cement

According to the American Society of Testing and Materials (ASTM), there are eight types of Portland Cement [2]. Type I is considered a general-purpose cement. It can be used for most construction purposes for which the concrete is not subjected to severe conditions, such as exposure to extreme climates. Type IA is similar to type I but contains an air-entraining chemical admixture (see Section 2.2.6) that gives the concrete more durability when subjected to climate changes. Type II is used when concrete may be exposed to sulfate, which is often the case when the structure is near groundwater. Adding an air-entraining admixture to Type II results in another cement referred to as Type IIA. Type III provides additional strength early in the curing process, which is useful for structures that must carry weight early in the construction stage. Type IIIA is similar to Type III but it contains an air-entraining admixture. Type IV is used in large-scale concrete structures because it allows for a slower hydration process, thus providing more uniformity. Type V is used in situations for which the concrete is exposed to large amounts of sulfate, such as near the ocean [2].

There are still other types of concrete in addition to those mentioned previously. Certain mixtures allow for concrete of different colors or different material properties. However, these mixes are modifications of the basic eight concrete mixtures.

2.2.5 Testing of Concrete

Before concrete can be placed, it is necessary to test certain properties of the batch to determine its specific qualities. Some of these properties include consistency, temperature, air content, strength, and unit weight. By testing these properties one can be sure of the quality of concrete being used. Testing ensures that all measures have been taken to produce a batch of concrete suitable for its intended building purpose [2].

Testing the consistency and workability of concrete requires a slump test (See Figure 1-1). Tools needed for this test are a slump cone and a steel rod. To perform the slump test, the larger end of the slump cone is placed firmly on the ground and filled to the one-third level with the concrete mixture to be tested. The mixture inside the cone is rodded (tamped firmly) twenty-five times with the steel rod to eliminate any voids in the material. The cone is then filled to the two-thirds level and rodded again. Finally, the cone is completely filled, rodded, and leveled. Immediately after leveling, the cone is removed and placed upside down next to the pile of wet concrete. Without the support of the cone, the concrete pile settles and the difference in height (measured to the nearest quarter inch) between the concrete and the cone is called the slump [2].

Figure 1-1: Slump Test

Concrete with high water content has a high slump and thus greater workability, while concrete with low water content has a low slump resulting in much firmer and less workable concrete. The slump value is used to indicate workability and maintain consistency between multiple loads being used at the same site. Slump is important when placing structures. A more firm concrete (lower slump value) would be useful when placing a wall while a floor could be made with a more fluid concrete mixture (higher slump value) [2].

The temperature and unit weight of concrete are two other important characteristics. These properties are helpful in determining the air content of concrete. One common device, the air meter, determines the air content of concrete by applying a specified pressure to the sample. Another method is the volumetric method, which removes all of the air in a sample by agitating it in water. By doing this, it is possible to find the new weight of the sample without the air and thus find the air content [2].

The strength of concrete is measured using the cylinder test (See Figure 1-2). This test requires several concrete molds to be made and cured. These cylinders are usually 12" in height with a 6" diameter. They are filled and rodded in the same way as the slump cone. After being filled, the molds are allowed to cure. Usually, these samples are tested at seven, fourteen, twenty-one, and twenty-eight days. Concrete strength is rated by the pressure (in PSI) it can withstand after a specified time period.

Figure 1-2: Stress Test

To test the compressive strength of concrete, a cylinder is placed in a large pressurized vice. The pressure is increased until the cylinder cracks, with the highest pressure attained being used to determine the strength of the concrete (e.g. 2500 PSI at seven days). Normally, the pressure on the cylinder is increased only until a minor crack develops but the cylinder in Figure 1-2 has been partially destroyed for demonstrative purposes.

Although it is possible to determine the compressive, flexural, and tensile strengths of concrete by applying pressure to the cylinder in various ways, the compressive strength is usually sufficient to specify general strength [2]. One instance where flexural strength would need to be specified is in the case of long load-bearing beams.

2.2.6 Admixtures

Admixtures, or additives, are added to concrete batches to alter the properties of the mix. Admixtures are materials other than the basic concrete components, which are added during the mixing process and used to intensify different properties of the concrete.

Some common types of admixtures are characterized as being air-entraining, retarding, accelerating, or water-reducing [14].

Almost every aspect of concrete can be adjusted or changed with the use of admixtures including the strength, water content, cement content, and curing time. The results gained by using admixtures can also be obtained by adjusting the basic components used in the concrete mixture. This could mean adding more water or using a different type of cement. However, adjusting the basic components is a difficult process because it requires extensive testing. Admixtures provide a simpler method of altering the properties of concrete [14].

2.2.6.1 Air-Entraining Admixtures

Air-entraining admixtures are chemicals added during the batching process to help the concrete resist changes in climate. These admixtures distribute pockets of air throughout the concrete mixture, referred to as voids. Severe winter freezing and thawing can cause concrete used outdoors to deteriorate because of the expansion and subsequent contraction of water that may have been in the voids. By using concrete with air-entrainment, it is possible to counter the freeze-thaw situation encountered in climates prone to wide temperature ranges [2].

2.2.6.2 Retarding Admixtures

Retarding admixtures are used to slow the rate of hydration in concrete. Retarders can ensure uniformity when pouring large structures. They can also be used if the concrete must travel a long distance (greater than one hour) from the plant to the site.

Retarding admixtures help counter the fast hydration brought on by extremely hot climates as shown in Figure 1-3 [2].

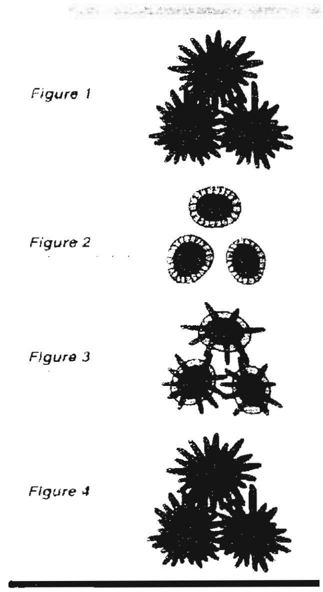

Figure 1-3: DELVO: Hydration Control Admixtures
Master Builder Technologies, 1997
MasterBuilders Inc. From DV-20 SAP#112480

The retarding admixture temporarily prevents hydration of the concrete by coating the cement particles. This delays the setting time of the mixture. The concrete is reactivated either over time, by addition of an activator, or by addition of fresh concrete to the mix [2].

Ready mix producers in warm climates may choose to add a small dosage of retarding admixtures as part of each batch to counter the effects of high ambient temperatures. In this case, the retarding admixture is actually an integral part of the mix design that is developed by the quality control lab.

2.2.6.3 Accelerating Admixtures

Accelerating admixtures are used to rapidly bring about higher strengths in concrete mixtures. This is opposite to what retarding admixtures accomplish. The effects of accelerating admixtures could also be achieved by using Type III Portland Cement [2]. Accelerating admixtures are often used to produce a shorter curing time when placing concrete in colder weather [14].

2.2.6.4 Water-Reducing Admixtures

Water-reducing admixtures reduce the amount of water needed in a batch of concrete while maintaining a particular slump. The use of this type of admixture can increase the strength and durability of concrete. In practice, the addition of water-reducing admixtures reduces the amount of water needed in the mixture by five to ten percent. Water-reducers can also reduce the amount of cement needed, which can lower the cost of the concrete mixture [14].

2.3 Recycling/Reusing Concrete

In recent years, recycling has become increasingly popular in the ready mix concrete industry due to the growing environmental concerns of truck wash out water and hardened waste concrete. For those incorporating recycling into production and management, there are three benefits: economic savings, reduced waste, and a cleaner environment.

2.3.1 Wash Water Dilemma

Water is an essential element in the ready mix concrete industry. It is used for batch water when mixing concrete, cleaning the mixer trucks before and after deliveries, controlling cement dust emissions, and watering aggregate stockpiles. A 1993 update of the Ready Mix Concrete Industry Environmental Code of Practice by Envirochem Special Projects Inc., found that twenty-seven percent of daily water at a ready mix plant could be attributed to concrete production. The remaining seventy-three percent of water usage was attributed to the clean up of concrete [6].

If the average water content of one cubic yard of concrete is thirty gallons, the production of one million yards would use thirty million gallons of water, resulting in 22.5 million gallons of waste water. Although the sticker price for water seems inexpensive, there are serious environmental issues in wasting this much water. Ready mix producers must find ways to use this water to their benefit, such as reusing it as batch water. By reusing this water ready mix producers not only avoid the associated costs of purchasing fresh water and for clean up of wastewater, but also are helping to preserve the environment.

Water usage for concrete clean up can be divided into two categories: rinsing of mixer truck exteriors before and after deliveries and rinsing of the interior of mixer drums after deliveries.

Often concrete will spill onto the exterior of the mixer trucks during loading which can harden and lead to equipment wear and failure. To reduce concrete buildup, mixer trucks are usually rinsed immediately after loading in a designated wash area. The exterior of the mixer is thoroughly rinsed by overhead sprayers or manually by the truck driver with a hose, depending on the facility. Another reason for rinsing the exteriors of the trucks after loading is to prevent spillage of concrete materials while the truck is in transit to the job site. Spilled concrete can contaminate storm water, resulting in environmental contamination and possible fines and penalties. Many facilities also rinse the mixers once a week with a water and muriatic acid solution to limit concrete buildup [6].

At the end of the day, an average mixer truck retains 600 pounds of material even after all the concrete has been emptied from the drum. It is industry standard to rinse the interior of the truck mixers with 150 to 300 gallons of water to clean the drum. Water that has been used to rinse concrete materials out of mixing drums is referred to as 'washwater'.

Washwater is usually drained into wastewater collection basins. According to a study performed by Envirochem Special Projects Inc., waste water that is collected in the basins from wash-out and concrete dumping is often recycled and reused for rinsing mixer drums. Fresh water is usually reserved for exterior truck washing and batching [6]. A summary of wastewater collection and treatment procedures common in the ready mix industry is given in Table 1-1.

Table 1-1: Waste Water Collection and Treatment

WASTE WATER COLLECTION	OBJECTIVE: EFFICIENTLY SEGREGATE AND COLLECT ALL CONTAMINATED WATERS
Collect all waste waters and contaminated suerface runoff for treatment	Pave all site surfaces which are subject to contamination by concrete and ingredients, including truck loading, slump racks, washout racks, sludge storage areas. Aggregate storage areas should not normally require paving. However, surface runoff which is discharged to waterbodies from aggregate storage areas must meet regulatory suspended solids limitations. Curb and grade paved surfaces to collect all waste waters and contaminated runoff. Direct all contaminated waters to a waste water collection basin/treatment system. Prevent uncontaminated water from entering water treatment system catchment through the use of curbing, sloping or drainage channels. Segregate paved process areas from plant areas not subject to surface contamination. Minimize traffic through contaminated waters by providing segregated drainage channels or by careful layout of traffic areas and collection basin location.
Provide adequate waste water holding basins	Provide sufficient collection volume for contaminated waters to manage effluent in high precipitation periods. Design and construct basins to minimize subsurface leakage (except where exfiltration is intended).
Waste Water Treatment	Objective: Treat contaminated waters to effluent standards
Treat uncontaminated effluents	Provide effective solids removal for collected waste waters. This may include a sloped concrete settling basin overflowing into a second basin, or a solids suspension system and water reuse in the batch. Neutralize discharges to surface waters to meet regulatory requirements for pH. Provide equipment and training for effective routine pH monitoring. Discharge effluents to sewer rather than directly to the environment, where allowed.
Optimize treatment effectiveness	Properly design and operate treatment systems within effective operating limits for hydraulic and solids loading. Regularly clean treatment systems to ensure efficient operation. Monitor the performance of treatment systems to ensure effectiveness and compliance with regulatory requirements.
Contain and control stormwater	Control drainage (slopes, curbs) to collect contaminated stormwater in a separate, properly sized settling basin to provide settling for a maximum 10 year return, 30 minute duration precipitation event. Obtain actual data from IDF curve for the nearest weather station. Contain clarified stromwater and recycle. An engineered infiltration basin is an alternative to unavoidable discharge of contaminated stormwater off-site.

Source: Envirochem Special Projects Inc. [6]

As can be seen from Table 1-1, one of the most important and difficult tasks is to keep the process water and storm water separate. Since storm water can usually be discharged directly into the environment while process water must first be treated, it is wise to limit the amount of water that must be treated by keeping the two types of water separate.

Process water is any water that has come into contact with cement, concrete, or machinery. Wash water is a form of process water, as is water used to rinse down the mixer trucks. The major concern with process water is its high pH level and suspended solids content, resulting mostly from the cement in the concrete.

Storm water is water resulting from rainfall or runoff. If proper water management practices are in place, storm water does not have to be treated prior to discharge. At many facilities however, storm water passes through the plant and at the very least collects oil and grease. Since the National Pollutant Discharge Elimination System (NPDES) strictly regulates discharge of these pollutants, storm water containing oil or grease can't be discharged. By using scrubbers, the amount of oil and grease can usually be decreased to the permissible discharge level.

In worse cases, the storm water comes into contact with cement or cement machinery and becomes process water. Figure 1-4 shows a ready mix plant with mixed storm water and process water. In an area such as Puerto Rico, heavy rainfall can push the water management resources of a ready mix plant beyond capacity. Since the storm water has come into contact with cement products and process water, it can no longer be discharged without treatment. What was once a manageable level of process water has now exceeded containment capacity due to an inability to keep the storm water separate from process water.

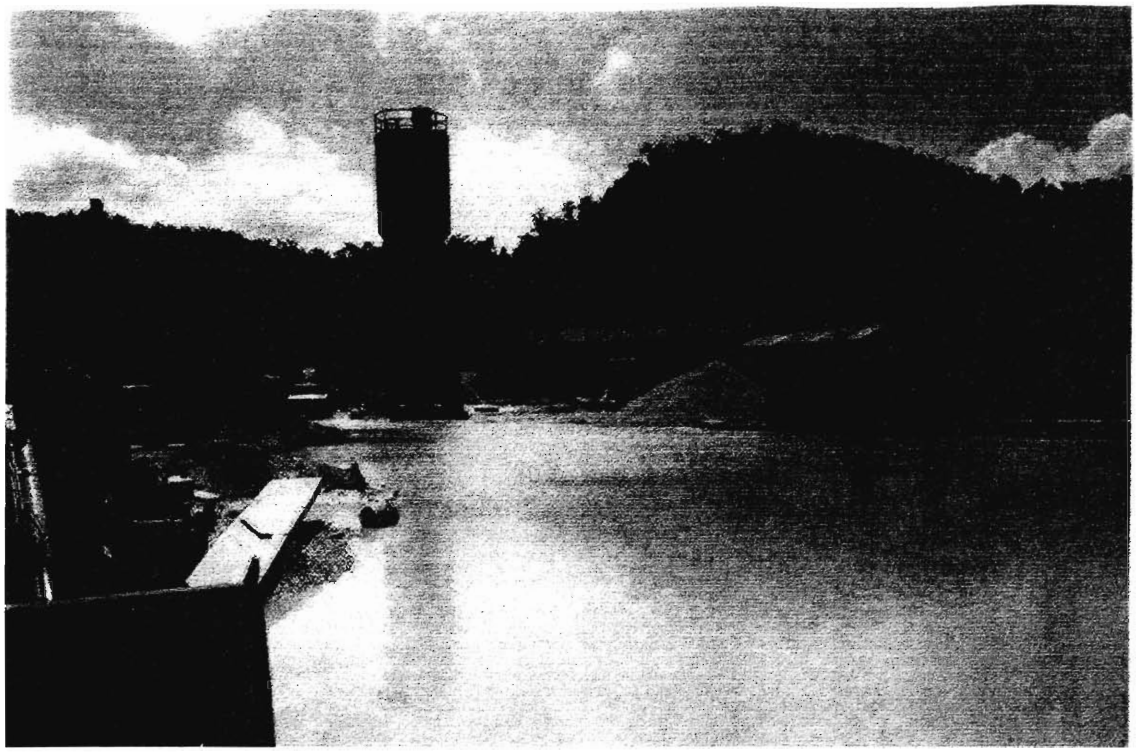

Figure 1-4: Storm Water Induced Flooding

The water shown in Figure 1-4 is covering nearly fifty percent of the plants surface area. When water overflows beyond the settling basins, it becomes difficult to collect and treat. Without treatment, however, the water can't be discharged into the surrounding environment. Additional rainfall could result in a discharge. According to NPDES, all discharges must be reported. If these discharges are in violation, not only is the surrounding community harmed, but large fines could also result.

2.3.2 Recycling of Hardened Concrete

Due to environmental concerns, recycling hardened concrete has become more and more of a necessity and obligation for many companies. The need to recycle hardened concrete arises from the fact that simply disposing of concrete can be very expensive and is usually in violation of some environmental regulation. Robert Davenport, in "Recycling Hardened Concrete," gives some scenarios dealing with the economic and environmental necessities for recycling concrete [14].

When concrete companies choose to simply dispose of hardened concrete at a site, there are consequences 'that can take several directions'. In one scenario, the dumping of hardened concrete at a site usually violates some environmental or federal regulation(s). Another scenario is that the producer may have a use for the space other than for dumping concrete. The author also states that hauling, dumping, and associated equipment expenses are often too costly for many producers [14]. Cases such as these can force companies to look into other methods for dealing with hardened concrete. A positive scenario presented by Davenport is that there could be an economic benefit to recycling the concrete, such as selling it as road base or landfill material [14].

Probably the most effective method of dealing with large quantities of hardened concrete is to crush it; making aggregate for new concrete. A crusher is a machine that grinds large slabs of concrete into pebble sized pieces, which are then used for fill material or aggregate for new concrete. Rudy Busse, in "Tips for Recycling Concrete," describes crushers as efficient machines for the disposal of hardened concrete. Crushers are available in either stationary or portable models. The author recommends using stationary machines in cases where the company would be doing numerous, small to medium sized jobs. For large jobs, Busse recommends portable machines because they offer reduced hauling costs and therefore have a greater profit potential. For companies that do not have a steady supply of waste concrete, the author recommends the company subcontract the service [14].

Yet another way to deal with hardened concrete is to use it as fill material without crushing it. Fill material should not be confused with *landfill*. By disposing of hardened concrete as fill material, a material that might otherwise clog a landfill is put to good use. Many regions allow hardened concrete to be used as fill material provided it does not contaminate runoff. This use is strictly governed by local environmental authorities.

2.3.3 Returned Concrete Management

Concrete returned from a job site has usually been paid for by the contractor who ordered the material. If the returned concrete then has to be disposed of, the associated costs can represent both a material and an economic loss. Therefore, it is advantageous for concrete companies to seek ways of utilizing returned concrete before it hardens.

Companies have the option to either dispose of returned concrete or reuse it in some way. Most ready mix producers do not prefer disposal of the returned concrete in a landfill. Certainly this alternative offers little benefit to the environment, but in some cases, it may be economically efficient for companies with small production and return amounts. A more environmentally friendly method of disposal is to use the material as fill. For most companies, however, disposal and its associated costs are often too expensive and inconvenient, so programs that reuse returned concrete are implemented [8].

Returned concrete that is not disposed of is usually dealt with in one of the following ways: incorporation into subsequent loads, production of secondary products, reclamation, or reuse at a later time [6].

On average, one to three percent of concrete production is returned to the manufacturing plant for disposal [6]. This can have significant consequences for a large ready mix producer. For a ready mix company producing one million cubic yards of concrete on an annual basis, the associated returns would be 10,000 to 30,000 cubic yards. If the material is not reused, hauling and disposal costs will result. In addition, valuable plant space must be designated for the storage of this waste material. One of the major incentives for reusing returned concrete is avoidance of the hassle involved in dealing with concrete after it has hardened. Figure 1-5 hints at the problem introduced by waste material collecting at a ready mix plant.

Figure 1-5: Waste Material at a Ready Mix Plant

By selling treated returned concrete, companies only need to invest in treating the concrete. This increases profit margins because the cost involved in treating the concrete is usually much less than making the same amount of new concrete. It is also environmentally beneficial to resell returned concrete because it eliminates the production of waste material.

In many locations, including Puerto Rico, virgin supplies of aggregate are in great demand. With such a scarcity of raw material, it is senseless to waste salvageable concrete. A plant with an average return of thirteen cubic yards per day is losing 3296 cubic yards in potential aggregate each year [8]. The aggregates in returned concrete could be recovered by using a reclaimer.

2.3.3.1 Immediate Reuse or Secondary Products

Some companies, in addition to supplying ready mix concrete, also manufacture concrete products. Returned concrete can be sent to these smaller projects to create revenue, rather than waste [9]. Examples of pre-cast products manufactured at ready mix facilities are retaining wall blocks, cinder blocks, and parking lot curbs. The production of concrete blocks (See Figure 1-6) is a major method used to deal with returned concrete. To make concrete blocks, returned concrete is poured into steel molds and allowed to harden. A front-end loader uses large pliers to pick up the blocks and move them around the plant for management of material such as aggregate.

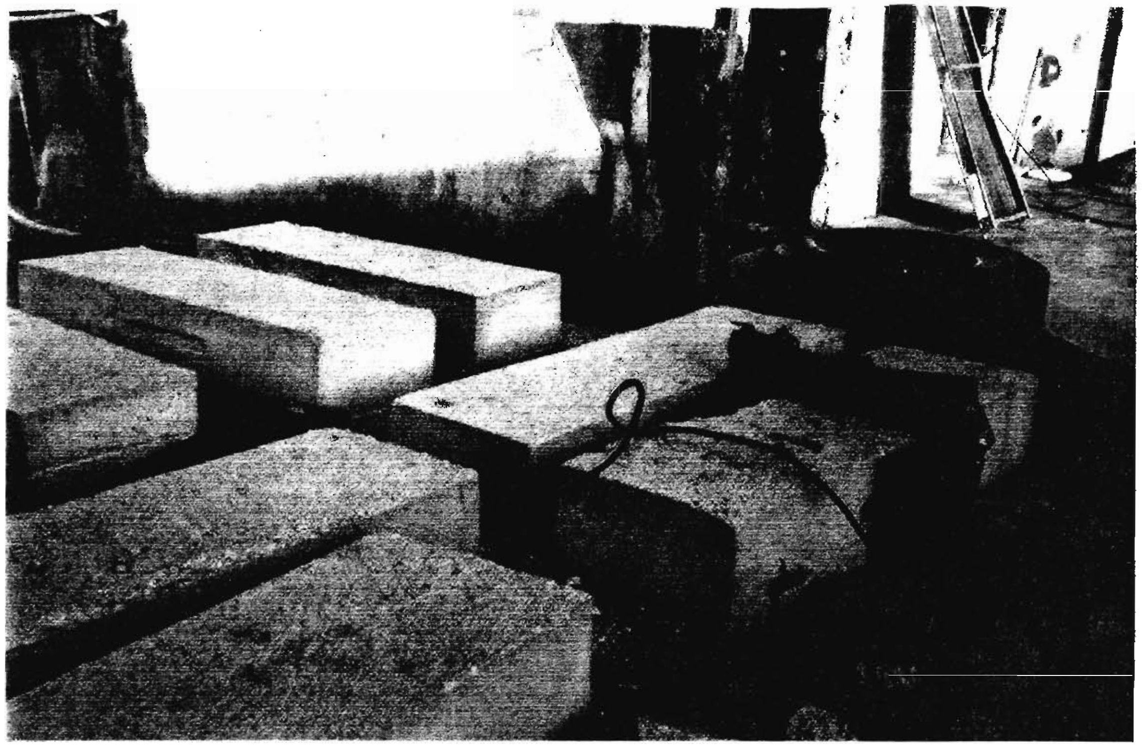

Figure 1-6: Concrete Blocks Manufactured at a Ready Mix Plant

2.3.3.2 Settling Basins

Envirochem Special Projects, Inc. reports the use of settling basins, also referred to as settling ponds, as the most common method of effluent treatment. A settling basin is a small pond, usually lined with concrete, which collects wastewater and returned concrete (See Figure 1-7).

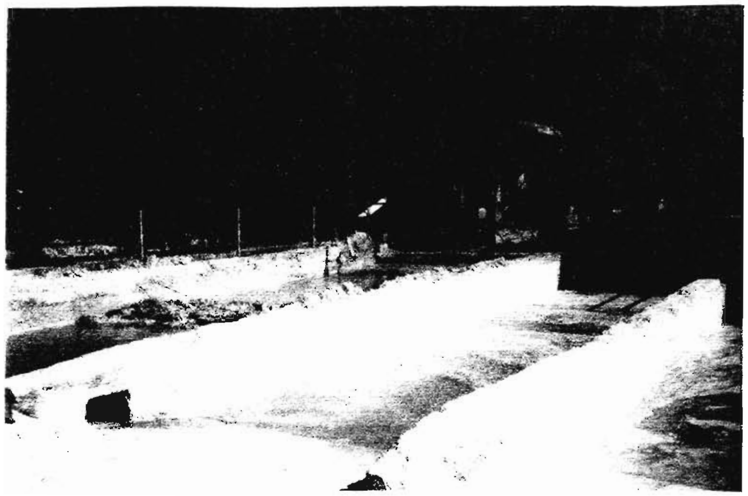

Figure 1-7: Settling Basins

The purpose of a settling basin is to separate the solid material from the water. The cement and water paste that settles to the bottom of the pond is referred to as slurry, or sludge. This material is removed from the pond (more on this later) and is often used as fill material. There is significant environmental importance in allowing the slurry to fully dry before it is used as fill or disposed of due to the high pH of the material when it is in a liquid state. By allowing the material to dry before disposal, a high pH runoff can be avoided [6].

The time it takes for the solids to settle out of solution in a settling basin depends on several factors such as the size of the basin and ambient temperature. Envirochem Special Projects, Inc. reported that eighty to ninety percent of the solids that were capable of settling fell out of solution within an hour [6].

The most effective application of the settling basin is the use of multiple ponds to separate water and solid material. This arrangement is illustrated in Figure 1-7. The highest level basin (left-most basin in this picture) collects all of the process and wash water, from which most of the solids are settled out of solution. Runoff from this basin flows to a second basin where more solids settle. The last basin (farthest right), the lowest level, contains water that is either suitable for reuse as batch water or, with minor pH treatment, discharge into the environment. Although this system requires more space than a single settling basin, it allows for better reuse of process water [15].

Proper maintenance of the settling basins requires that waste material that collects in the first and second basin be periodically dug out with a front-end loader. This waste material is added to the stockpile where it is allowed to dry, and eventually hauled to a fill site. If the material is not dug out on a regular basis, the basins become unusable (See Figure 1-8).

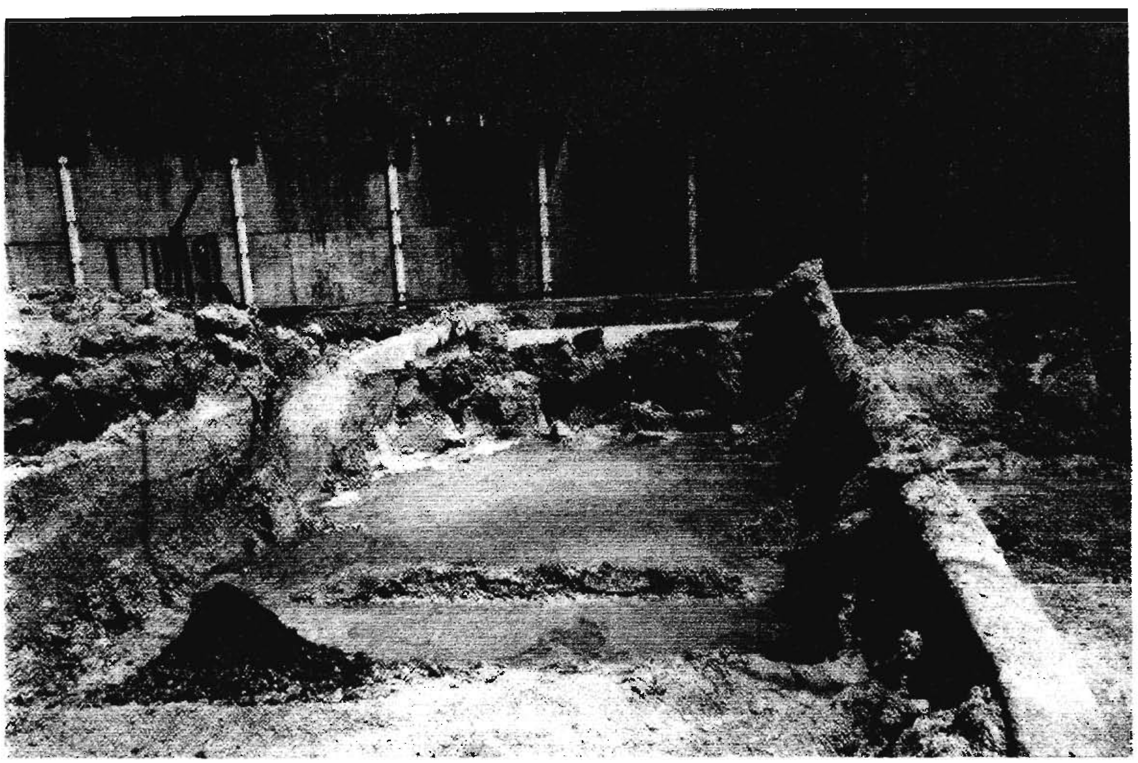

Figure 1-8: Unusable Settling Basin

2.3.3.3 Reclaiming Units

Many large facilities incorporate reclaiming units into their recycling process. In "Concrete and the Environment," Doug Ruhlin examines how reclaiming units, or reclaimers, work to recycle concrete (See Figure 1-9). He explains that a reclaimer offers the opportunity for complete, or near complete, use of returned concrete [15]. Reclaimers are generally characterized as aggregate recovery-only systems or one hundred percent systems. The main difference between the two systems is the reclamation of the slurry water.

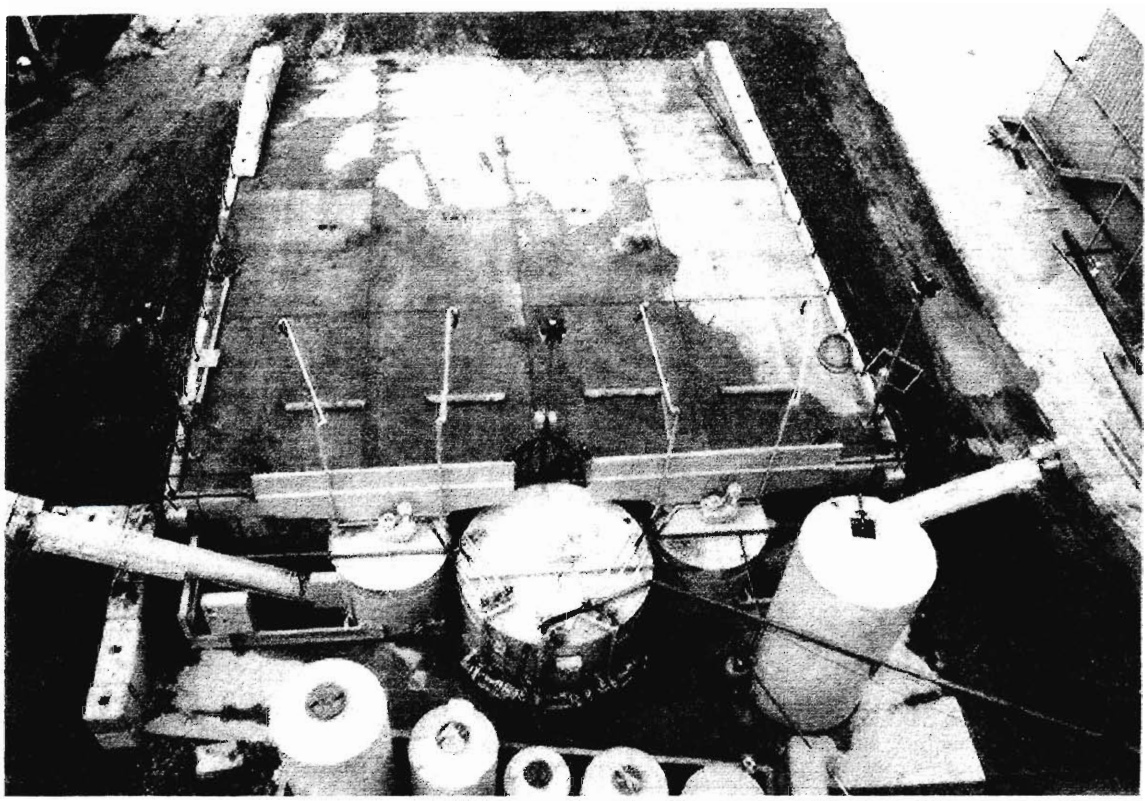

Figure 1-9: Enviro-Port Reclaimer

The reclaiming unit in Figure 1-9 is manufactured by Enviro-Port. Trucks pull up to one of the four stations to discharge returned plastic concrete or rinse the interior of the mixer drum. In both cases, all of the material is collected by the central holding tank that separates the sand and stone from the mix. Cleaned sand and stone are discharged by the two 'arms' on either side of the reclaimer. The remaining slurry is metered back through the long gray pipe in the lower right, to the batch plant for use in future mixes.

As was mentioned above, reclaimers can be used for the recycling of returned plastic concrete, truck washout water, or general water management. To recover aggregate, mechanical and hydraulic processes are used in combination with various screens to separate and clean the material. Figure 1-10 shows coarse aggregate that has been recovered from a Schwing RA-10 Reclaimer. This aggregate becomes valuable material in future batches rather than waste.

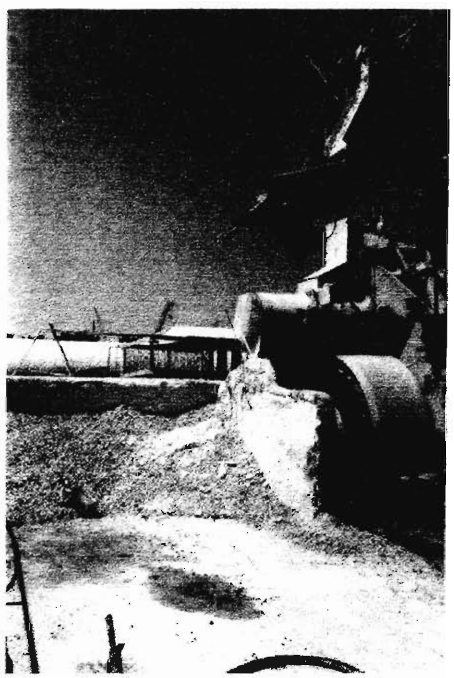

Figure 1-10: Reclaimed Aggregates

Once the aggregate are removed from the concrete, the remaining slurry can then be discharged into a settling basin. In a one hundred percent system, the slurry is reused as batching water, thus producing zero discharge [15]. The major concern for using slurry in place of batch water is the increased level of suspended solids. The exact level of suspended solids can vary greatly from day to day depending on the level of water and amount of concrete that is processed. For proper batching, it is important to know the exact level of suspended solids in the slurry. Depending on the manufacturer, flow meters are available to gauge the level of suspended solids. Schwing, for example, offers a density monitoring system that displays the temperature of the slurry, gallons delivered, and specific gravity of the slurry. Also, some restrictions require the use of 'clear' water for all batching purposes. For these applications, the slurry water can not be used because it is not clear.

Slurry water is usually kept in an agitation tank, where it is constantly stirred by large paddles. If the slurry water is not kept in agitation, the solids will settle out of solution and become waste material (which would defeat the whole purpose of reusing the slurry). Figure 1-11 shows an agitator stirring slurry in a large holding tank.

Figure 1-11: Slurry Tank Agitator

In 'A Study on the Reuse of Plastic Concrete Using Extended Set-Retarding Admixtures', Colin Lobo states that with the increasing cost of solid waste disposal and the large expense of settling basin treatment, reclaiming units can be a cost effective alternative for even mid-sized ready mix operations. He also states that the initial cost of a reclaiming unit is usually more than paid for by the savings in solids disposal and the need for settling basins [9].

2.3.3.4 Admixtures as an Alternative

Another option in returned concrete management is the use of chemical additives. There are mixed opinions on the use of chemical additives when treating returned concrete. Some are of the opinion that additives require too much attention and do not produce the desired results, while others feel that the benefits outweigh the difficulties in using additives. Various chemical additives were introduced in Section 2.2.6 that could be added to a batch to change certain properties of the concrete. For stabilization of returned plastic concrete, the admixture used is the retarding (or stabilizing) admixture.

To extend the life of a returned batch of concrete, a stabilizer must be added to the unused concrete. The stabilizer will temporarily suspend hydration by preventing the water from contacting the cement particles, thus retarding the setting time of the concrete. Some stabilizers allow the mix to remain idle for several days before setting begins. Since the rate of hydration increases with temperature, the amount of stabilizer needed to retard setting in warm climates can be substantially more than that needed in a colder climate [9]. Temperature can also govern whether or not an activator must be used to reactivate the concrete. Activators are usually needed when the temperature is not warm enough to allow natural hydration of the concrete [9].

The use of additives is particular to the type of cement, the batching conditions, the local climate, and even the time at which the additives are added. These considerations usually require in-depth research, experimentation, and consultation with local manufactures or distributors of admixtures [12]. This can be an intimidating process for any producer.

The admixture alternative offers increased flexibility of delivery schedules, reduced environmental strain, and lower waste disposal costs, but it is not the perfect solution. Determining proper dosage, usage of additives, and proper dispensing of the additives are also issues. Since most dosages are calculated for specific conditions, misapplication can have detrimental effects on concrete characteristics. If too much additive is added to a mix, the concrete may not harden as planned and could sag after the formwork is removed. If too little is used, the concrete may harden in the mixer causing not only a loss of product, but also added expenses for the cleanup of the drum [9]. For these reasons, many producers choose not to use chemical admixtures for the stabilization of returned plastic concrete.

Envirochem Special Projects, Inc. reported limited hope for the use of chemical additives for stabilization of returned plastic concrete in the ready mix industry. In their 1993 update for the Environmental Code of Practice, the authors cited several reasons why "…it is unlikely that the [ready mix] industry will adopt this practice on a large scale." (1993, p. 25) The authors state that additives may introduce quality problems with treated batches. They also noted that a great deal of care and supervision was required to ensure that the product was used correctly [6].

Jack Barfoot, in "Ready Mix Plants," identifies two methods for dispensing chemical additives: manual and automated distribution systems. For manual distribution, either the truck driver or a supervisor at the plant is responsible for treating the concrete. This method involves little additional expense beyond the cost of the additive, but it is risky since it is entirely dependent upon the responsibility and competence of the personnel. A more sophisticated method of dispensing additives is through the use of automated equipment (See Figure 1-12).

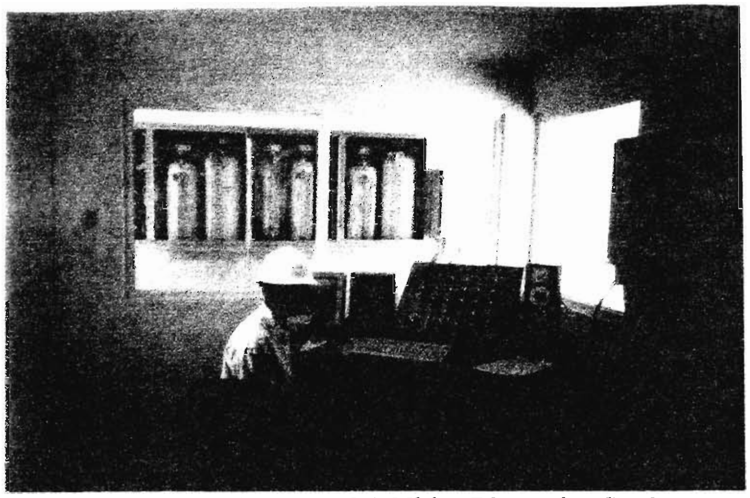

Figure 1-12: Automated Additive Dispensing Station

The automated additive dispenser is integrated with the batching equipment in the batching station. The control panel in the foreground controls the distribution of all materials into a mix, including cement, water, aggregate, and additives. What can not be seen in this picture are the large holding tanks for the additives. When an additive is called for in a mix design, or for stabilization of returned concrete, the required dosage is pumped into the silver tanks in the background. The yellow markers on the front of the tanks provide visual verification of dispensed additive amounts.

This automated system can dispense a pre-calibrated dosage of additive, which almost guarantees proper dosage. Barfoot cites that lower additive and concrete losses are two factors that will yield greater financial benefit for an automated dispensing system when compared to using manual distribution [11].

2.3.4 Environmental Regulations Governing Recycling Practices

A report prepared for Environment Canada on the Ready Mix Environmental Code of Practice stated that "...ready mix concrete plants do not generally pose significant problems in terms of environmental impact." (1993, p. 2) A summary of environmental concerns in the ready mix industry, developed by Envirochem Services, is reproduced in Table 1-2.

The major concern is for those facilities that discharge large volumes of effluent (see Glossary) into sensitive environmental areas [6]. The National Pollutant Discharge Elimination System (NPDES) regulates the discharge of pollutants into US waters. Companies must obtain relevant NPDES permits for any discharge of industrial process water, including water from exterior washing, drum and chute washing, and mixing water. NPDES also regulates the discharge of storm water that comes into contact with unhardened concrete or slurry [15].

Depending on the location, there may also be groundwater regulations that govern the discharge of pollutants possibly affecting the groundwater. This may apply to concrete that is disposed of in unlined settling basins, or concrete that is dumped directly on the ground. These regulations vary significantly from region to region [15]. Regulations may also exist that classify various concrete waste products as special wastes or hazardous materials due to their corrosive nature. The author also warns of possible regulations that could effect erosion, soil conservation, wetland preservation, and sedimentary-control programs [15].

There are many ways in which a ready mix producer can save water use around the plant. Some of those are provided in Table 1-3. Most of these suggestions are simply good housekeeping practices, but may not be readily apparent to many producers. These guidelines should be used as the basis for an environmentally conscious water management program. The best way to implement these guidelines will be particular to the individual ready mix plant.

Table 1-2: Summary of Potential Environmental Concerns from Ready Mix Concrete Facilities

ISSUE	CAUSE	CONCERN	LEVEL OF CONCERN
PH	Soluble cement constituents will raise pH in effluent and/or stormwater runoff	• High pH is toxic to fish • High pH is corrosive to metal • High pH is undesirable in drinking water	• PH > 10 will kill salmonid fish in minutes[1] • PH 6.5 to 8.5 recommended for drinking water supplies
Total Suspended Solids	Cement, sand and fines in effluent and/or stormwater runoff	• Can kill fish/shellfish through abrasive injury or clogging of gills and respiratory passages • May contain leachable toxic substances • Visible Plume in Receiving Waters • Screens light, contributes to oxygen depletion • Destroys fish habitat	• Ambient suspended solids highly variable in fish bearing waters, 50 to 125 mg/l desirable
Admixture Chemicals	Spills carried off-site in effluent or stormwater runoff	• High concentrations may injure or kill aquatic organisms by causing high chemical oxygen demand (C.O.D.), high pH, and/or aquatic toxicity	• Specific to active ingredients • MSDS's may indicate aquatic toxicity
Mineral Oil & Grease	Drips off mechanical equipment contaminate stormwater runoff	• Toxic to aquatic organisms[2] • "Oil/Grease" can include fuel, lubricants and hydraulic oil	• Highly variable with species • E.g., crude oil is extremely toxic at 0.3 mg/L[2]

References:

1. D.Mcleay and Associates Ltd., Toxicity of Portland Cement to Salmonid Fish, Vancouver, 1983.
2. Guidance Documents for Effluent Limitations and New Source Performance Standards for the Condrete Products Point Source Category, Effluent Guidelines Div., USEPA, Wash., D.C., Feg., 1978.

Source: Envirochem Special Projects Inc. [6]

Table 1-3: Minimizing Water Use at Ready Mix Facilities

WATER USE	OBJECTIVE: MINIMIZE CONTAMINATED EFFLUENT BY MINIMIZING NET WATER USE
Minimize the need for wash waters	Minimize truck exterior contamination by controlling dust losses during loading by continuous metered water spray on loading chute opening. Minimize contamination ot surfaces by controlling dust release and sludge storage pile drainage.
Minimize net water use	Restrict Fresh water uses to: • Truck exterior washoff • Hot water production • Batch water Use recycled process water and stormwater from paved process areas for: • Truck drum washout • Miscellaneous washdown operations If possible, use recycled water for batch water, subject to operational and product quality constraints. Reduce truck exterior wash volumes by using a spray instead of hose wash Install flow controls on freshwater sources • Install flow restricting nozzles/spring-loaded triggers at wash stations • Eliminate uncontrolled and unattended discharge of water spray • Consider mechanical control systems Employee training will minimize water use: • Ensure workers understand proper water reduction techniques available at the site • Monitor/supervise water use to reinforce the importance of controls and verify effectiveness
Minimize contaminant loadings	Minimize contamination of surface runoff by controlling dust release and sludge storage pile drainage. Control contaminant dispersal through good housekeeping and by minimizing vehicle traffic on contaminated site surface.
Maximize water reuse	Minimize drum washout water volume: • Use reclaimed water • Use multiple small-volume rinses rather than single large-volume rinses; series rinses are more effective and reduce total rinse volume • Consider the use of stabilizers to minimize washes

Source: Envirochem Special Projects Inc. [6]

3.0 Methodology

Upon our arrival at Ready Mix Concrete, Inc. we were introduced to several company executives including President Eng. René Di Cristina, Production Vice President Eng. William Ramos, and Auxiliary Production Vice President Eng. Pedro Franceschi. We also met our liaisons: Environmental Manager, Eng. Moises Rivera, Eng. José 'Kiko' Bisbál of the operations department, and Eng. Fernando Buxó of the quality control division, who would all be assisting us on a daily basis.

3.1 DELVO and Data Collection

Without the use of DELVO, all concrete returned to the plant would have to be disposed of, which would be neither environmentally conscious nor economically efficient for Ready Mix. DELVO can be used for same-day, overnight, or weekend stabilization of returned concrete and also truck washout water stabilization. During our study, Ready Mix was only using DELVO same-day concrete and washout water stabilization. They are not confident that DELVO should be used for any longer time period due to possible quality problems that may arise in the concrete.

With the assistance of our liaisons, we were able to obtain company information regarding waste management practices. The first set of data that was collected by our team was from the 'DELVO Form,' which was used to record the management and distribution of DELVO at each plant. Information on these forms was supposed to be provided on a daily basis by each plant manager.

Information provided on these forms included the amount of DELVO that was added to washwater and used to recover returned concrete. This data was tallied to produce a yearly total for the time period beginning in March 1998 and ending February 1999, which can be found in the Results Section.

In order to determine what recycling methods would best suit Ready Mix, we needed that these forms contain additional information. For this reason, we decided it would be beneficial for Ready Mix to modify the existing form. To do this, we requested additional information such as, use of concrete after being recovered, total amount of DELVO used by each plant, total amount made into blocks, and total amount placed in reclaimers, be added to the existing form. With this additional information, a more accurate cost-benefit analysis could be produced that would offer Ready Mix better insight into the effectiveness of its recycling program.

3.2 Site Tours

To better appreciate the extensive labor and research that is involved in the production of concrete, we spent a morning in the quality control lab with Eng. Fernando Buxó observing techniques used to design and test concrete mixes. We were able to see first-hand how the slump, unit weight, air content, and compressive strength of concrete are determined. We also accompanied Eng. Bisbál on tours of the majority of Ready Mix's plants. We were able to observe the operation of Ready Mix plants, including the settling basins, control rooms, truck washout stations, and batching facilities. This provided us with a better understanding of the procedures used to produce and manage concrete at ready mix facilities.

3.3 Design of Analyses

To examine Ready Mix's waste management program, we were asked to perform analyses on the following subjects:

1. Hauling and Disposal Costs for Waste Material
2. Block Production
3. DELVO Usage for Stabilization of Returned Concrete
4. DELVO Usage for Treatment of Truck Washout Water
5. Possible DELVO Puck Usage
6. Return on Investment for Reclaimers
7. Return on Investment for New Gradall Digger

Due to time constraints, we were only able to provide thorough analyses of the first five topics. An explanation of these analyses is provided in the Analysis Section of this report. We only had time for a preliminary analysis of the digger and our reclaimer analysis produced inconclusive results.

Each of the above topics has certain benefits and costs that needed to be considered. The following issues and subsequent analyses were used to evaluate Ready Mix's current recycling processes and provide recommendations for future practices.

3.3.1 Hauling and Disposal Costs for Waste Material

Any concrete that can not be recovered or made into blocks is placed in a stockpile. Sludge that is removed from the settling basins is also collected in stockpiles.

Waste material that is collected in stockpiles is given away, free of charge, as fill to be used in various locations.

The major cost to the company in disposing of waste material is the hauling expense. Ready Mix owns three trucks that haul waste material from their plants. When these trucks can not haul all the material, an external hauling service is contracted. We were to estimate the total hauling expenses incurred by Ready Mix for disposal of waste material and provide recommendations as to which hauling method – independent, contracted, or combination of methods - would be most economical.

We were provided with receipts for all hauling done by contracted services for 1998, from which we determined the amount of material that was hauled and the subsequent costs. Records are not kept for hauling performed by Ready Mix, but it was estimated that they hauled approximately four times as much material as the contracted services did.

3.3.2 Block Production

Another method Ready Mix uses to deal with returned plastic concrete is to make pre-cast blocks. These blocks do not provide revenue for the company, but are produced for use as walls and barriers in the plants to separate aggregate stockpiles. The number of blocks produced at each plant is recorded in the DELVO Forms. Labor and material costs related to block production were provided from the operations department. With this information, we are able to create a cost analysis of block production.

The main objective of this analysis was to determine how much returned material was being used to produce blocks. If, however, the blocks are no longer needed, the economic feasibility of creating blocks with this volume of returned concrete would need to be re-evaluated.

3.3.3 DELVO Usage for Stabilization of Returned Concrete

Treating returned concrete with DELVO and then reselling the material provides a large profit for Ready Mix because the only investment needed to salvage the material is the expense of DELVO. Our analysis sought to compare the price for reclaiming concrete to the cost for other methods of reusing returned concrete, such as disposal, and block production. We also sought to determine the actual profit margin for selling treated concrete. Data on DELVO usage for returned concrete was collected from the DELVO Form, material costs and sale prices for concrete were collected from company records, and Master Builders provided the price for DELVO. With this information we could determine the level of profitability offered by DELVO treatment of same day concrete.

One of the issues we had to consider when deciding the cost effectiveness of stabilizing returned concrete was the quality of the treated material. Salvaging concrete is only worthwhile if the quality of the treated material can be ensured. Unfortunately, Ready Mix has had mixed results with the use of DELVO for stabilization of returned plastic concrete. Some of the problems sited were a lack of setting, accelerated setting, hardening in the drum, or undesirable slump. To address these issues, we consulted Ready Mix's Master Builders representative, Miguel Cabán.

Another issue for analysis was overnight and weekend stabilization of concrete. Master Builders states that DELVO can safely preserve concrete for up to 72 hours. Ready Mix, however, chooses not to treat concrete for any period longer than same-day because of the above mentioned problems. Since the potential for profit in reselling one yard of treated concrete is substantially large in comparison to producing one yard of fresh concrete, Ready Mix should seek ways to safely stabilize concrete for extended periods. Related topics are discussed in the Recommendations and Conclusions Sections of this report.

3.3.4 DELVO Usage for Treatment of Truck Washout Water

The procedures used to rinse mixer trucks at the end of the day are a major source of water waste. By treating truck washout water with DELVO, it is possible to save 225 gallons of water per truck, per day. Financially, our task was to compare the cost of using DELVO to the amount of water being saved. Environmentally, we needed to determine the impact of the amount of water saved by using DELVO. As mentioned earlier, DELVO usage for washwater was collected from the DELVO Forms and to estimate the price of water, we tallied the monthly water bills at each plant. With this information, we could determine how much money was being saved or lost by using DELVO to treat washwater.

3.3.5 Possible DELVO Puck Usage

DELVO pucks are similar to the DELVO Stabilizer, except they are produced in hockey-puck shaped tablets. These pucks offer the capability to extend the life of concrete that might otherwise become waste due to delays or damage to the truck and thus, have the potential for enormous savings because they can prevent a load of concrete from hardening in the drum. They also provide more flexibility in delivery schedule. The use of pucks was examined for use in washwater treatment as well. Our analysis of DELVO pucks compared the relative costs of the two products and provided recommendations as to which applications would be economically efficient for each product.

3.3.6 Return on Investment for Reclaimers

Ready Mix owns three concrete reclaimers (see Section 2.4.4.3, Reclaimers, for more information) located at Plants 2, 8, and 20. The reclaimers at Plant 2 and 20 are Schwing RA-10 models and are referred to as '100%' reclaimers because they completely recycle all components of the concrete mixture. The reclaimer at Plant 8 is twenty-five years old and is used only to separate aggregate from returned concrete. For this reclaimer, the remaining sludge is discharged into a settling basin, and disposed of in the stockpile.

Unfortunately, during our stay only the Reclaimer at Plant 8 was functioning properly and it is rarely used because the aggregate it recovers is of low quality. As for the two Schwing RA-10 units, Ready Mix has had problems keeping them in operation.

They have also complained that reusing the slurry (which makes the reclaimer 100%) has introduced substantial quality problems. Part of our study attempted to uncover causes of these problems. As part of our investigation, we have made arrangements for Schwing to perform on-site work to restore the two reclaimers to full operation.

No records were kept by Ready Mix on the amount of concrete that was processed by the reclaimers, and we were unable to obtain maintenance records for these units. By communicating with Schwing, however, we were able to develop an 'operations cost' estimate that is essentially the electrical cost to operate the reclaimer.

Our analysis of reclaimers focused on three manufacturers: Schwing, Henry Manufacturing, and ENVIRO-PORT. These companies provided us with technical information on new devices that could be aid in the integration of slurry water into the batching process. We were also provided estimates for purchase, options, and installation costs. Although we have researched this topic, we were unable to provide an estimate for return on investment or cost effectiveness of reclaiming units. A discussion of our findings is presented in the Recommendations Section.

3.3.7 Return of Investment for Gradall Digger

Ready Mix purchased a Gradall Digger to clean the settling basins at its plants. The new digger would hopefully reduce front-end loader maintenance costs associated with cleaning the basins. Available time only allowed for a very basic analysis of the Gradall. The majority of our analysis examined the problems associated with using front-end loaders to clean the settling basins. Some of the issues we considered were maintenance due to axle wear, lost production due to lack of a loader, and leasing costs to replace broken loaders during reparirs.

4.0 Results

This chapter presents findings based on the procedures used by Ready Mix Concrete, Inc. to deal with returned plastic concrete and truck washout water. A detailed discussion of the results and recommendations on how certain procedures could be changed or improved are given in the next chapter.

4.1 Data Sources

Data was collected from a variety of sources including DELVO forms (See Appendix C for a sample copy of the form) and annual records kept by the accounting and operations divisions. The DELVO Form has been in use by Ready Mix since the start of 1998. The data analyzed were for the time period of March 1998 to February 1999.

4.2 Waste Material Removal

Waste material in the form of returned concrete and sludge that is dug out of the settling basins is collected and placed in stockpiles at each of Ready Mix's plants. This waste material has to be removed from the plant when the stockpiles have reached their holding capacity. Either a hauling service is contracted or Ready Mix uses its trucks to haul the material to its destination. Some locations where this material can be disposed of are landfills or locations where fill is needed. However, instead of disposing of this waste in landfills, Ready Mix gives it away to be used as fill at various job sites. By doing this, Ready Mix avoids expensive landfill disposal charges and provides a community service to areas where fill material is needed but unaffordable.

To estimate Ready Mix's hauling and disposal costs, billing invoices from the hired hauling service for 1998 were tallied. Depending on the plant location, these costs ranged from \$25 to \$50 per trip, for an average of \$33.48. In addition to hauling services provided by outside companies, Ready Mix owns trucks that also haul waste material. Ready Mix's trucks haul approximately four times as much material as outside companies. The truck used by the hauling service has a 16.5 m^3 (21.6 yd^3) carrying capacity, while those used by Ready Mix can haul on average 14.27 m^3 (18.7 yd^3) per trip.

The numbers presented below are the totals for 1998 when using a hired hauling service and when Ready Mix hauls its material.

Table 4-1: Waste Material Removal Expense Summary - 1998

Hauling Service	Totals
Number of Trips Taken	627
Amount of Material Removed (yd^3)	13,399.00
Hauling and Disposal Cost (\$)	\$20,785.00
Average Disposal Cost/Yard (\$/yd^3)	\$1.55

Number of Trips Taken: Number of trips made by outside companies for removal of waste material. Provided directly by the receipts.

Amount of Material Removed (yd^3): Amount of waste material removed from plant. This is given as follows:

$$\text{Amount of Material Removed} = (\text{Number of Trips}) \cdot (\text{Carrying Capacity})$$

Hauling and Disposal Cost ($): Cost to haul and dispose of waste material as fill at job sites. *Total Hauling and Disposal Cost* is calculated by totaling all the invoices for 1998.

Average Hauling and Disposal Cost/Yard ($/yd^3): This is simply given as the following:

$$\text{Average Hauling and Disposal Cost} = (\text{Hauling and Disposal Cost}) \quad (\text{Material Removed})$$

Table 4-2: Waste Material Removal Expense Summary - 1998

Ready Mix	Totals
Number of Trips Taken	2,640
Amount of Material Removed (yd^3)	49,368.00
Hauling and Disposal Cost ($)	$58,080 - $71,280
Average Disposal Cost/Yard ($/yd^3)	$1.18 - $1.44

Number of Trips Taken: Number of trips made by Ready Mix trucks for removal of waste material. Of the three trucks, two have carrying capacities of twelve cubic meters and make on average three trips per day, while the third truck can haul seventeen cubic meters and makes five trips per day. At eleven trips per day, twenty days per month, for twelve months totals to 2,640 trips per year.

Amount of Material Removed (yd^3): Amount of waste material removed from plant. Carrying capacity is given as 157 cubic meters per day divided by eleven trips per day, or 14.27 cubic meters (19.27 cubic yards). This is given as follows:

$$\text{Amount of Material Removed} = (\text{Number of Trips}) \cdot (\text{Carrying Capacity})$$

Hauling and Disposal Cost ($): Cost to haul and dispose of waste material as fill at job sites, with an estimated range of $22 - $27 per trip. *Total Hauling and Disposal Cost* is calculated as follows:

$$\text{Hauling and Disposal Costs} = (\text{Number of Trips}) \cdot (\text{Cost per Trip})$$

Average Hauling and Disposal Cost/Yard ($/yd^3): This is simply given as the following:

(Hauling and Disposal Cost) (Amount of Material Removed)

4.3 Block Production

From March 1998 to February 1999, 1,216 blocks were produced from 495 yd^3 of returned concrete. This represents about one percent of the total concrete returned to the plants. The plants where blocks are produced are equipped with the molds and other equipment necessary for handling and moving the blocks. These blocks are not sold, but are used extensively by Ready Mix to build walls or barriers to separate various aggregate stockpiles. The blocks produced by Ready Mix are 72" x 22" x 12", or 0.407 yd^3.

Blocks can be manufactured at any plant that has molds and large clamps (to move the blocks). Since the molds were purchased prior to 1998 and the concrete has already been paid for upon returning to the plant, the only associated cost with block production is labor at $4.50 per block. It may, however, be necessary to purchase new supplies to replace old molds or to equip new plants. For this, an expense of $500 would have to be added.

The number of blocks produced at all the plants was tallied from the DELVO Forms. Below are the totals for the twelve-month period beginning March 1998 and ending February 1999.

Table 4-3: Block Production Summary - March 1998 to February 1999

	Totals
Blocks Made	1,216
Concrete Used (yd^3)	494.91
Production Cost ($)	$5,472.00

Blocks Made: Quantity of blocks produced, as indicated on DELVO Forms.

Concrete Used (yd^3): Total amount of concrete used to make blocks, calculated as follows:

$$\text{Concrete Used} = (\text{Blocks Made}) \cdot (\text{Concrete per Block})$$

Production Cost ($): Yearly cost to make blocks. The *Production Cost* is calculated as follows:

$$\text{Production Cost} = (\text{Labor Cost Per Block}) \cdot (\text{Blocks Made})$$

4.4 Recovered Material

DELVO is used by Ready Mix to reuse plastic concrete that would otherwise become waste material. When concrete is returned to the plant, the plant manager has the option of treating the concrete with DELVO to prolong its usable life. The dosage of DELVO required to treat plastic concrete varies greatly with mix design, amount of concrete, concrete temperature, elapsed time since batching, and hold-over time. The correct dosage is provided in a set of tables distributed by Master Builders Technology, the supplier of DELVO (See Appendix D).

The following results provide a summary of the recovered material data collected for all the plants during the twelve-month period beginning March 1998 and ending February 1999. Returned concrete is concrete that is brought back to the plant and has been paid for. Recovered concrete is considered as any concrete that is returned, treated with DELVO, and then resold.

Table 4-4: Recovered Material Summary - March 1998 to February 1999

	Totals
Recovered Concrete (yd^3)	4,173.50
DELVO Used for Hold-Over (oz.)	231,317.00
DELVO Hold-Over Cost ($)	$16,714.97

Recovered Concrete (yd^3): Amount of concrete recovered by using DELVO. Recovered concrete is any concrete that is returned, treated with DELVO, and then resold.

DELVO Used for Hold-Over (oz.): Amount of DELVO used to treat returned concrete for same day use.

DELVO Hold-Over Cost ($): Amount spent on DELVO to treat returned concrete. *DELVO Hold-Over Cost* is given as follows:

$$\text{DELVO Hold-Over Cost} = (\text{DELVO Used for Hold-over}) \bullet (\text{Cost of DELVO})$$

The cost of DELVO is $9.25 per gallon, or $0.07226 per ounce. This price includes the cost for the material, delivery, and maintenance of DELVO related equipment at the facilities.

Table 4-5: Recovered Material Summary - March 1998 to February 1999

	Totals
Average Cost to Recovered Concrete ($/yd³)	$4.01
Average Production Cost ($/yd³)	$55.82
Average Selling Price ($/yd³)	$65.04
Avoided Cost on Recovered Material ($)	$216,229.04
Sales on Resold Concrete ($)	$271,228.91
Net Profit on Resold Concrete ($)	$254,734.01

Average Cost for Recovered Concrete ($/yd³): When returned concrete is treated with DELVO, the only cost associated with recovering the concrete is the investment made in DELVO. This is calculated from the following formula:

$$\text{Average Cost for Recovered Concrete} = \text{DELVO Hold-Over Cost} / \text{Recovered Concrete}$$

Average Production Cost ($/yd³): This is how much it cost on average to produce one cubic yard of concrete.

Average Sale Price ($/yd³): This is the average price at which one cubic yard of concrete was sold, not including the cost for recovered concrete.

Avoided Cost on Recovered Material ($): Ready Mix has calculated, for each plant, the total cost of manufacturing one cubic yard of concrete which includes material, labor, and management costs. The following example gives a typical scenario of how DELVO provides a financial benefit when treating returned concrete: A contractor pays for ten yards of concrete to be used at a job site. However, only eight of the ten yards are used and the remaining two yards are returned to the plant. These two yards are treated with DELVO and used for another load instead of being disposed of. So, the next load has two yards that do not need to be freshly produced and the only cost associated with them is the cost for the amount of DELVO used ($4.01 per cubic yard). Thus, the avoided cost is considered to be the amount NOT spent in 're'-making the treated concrete

($51.81 per cubic yard) and is calculated for each plant on a monthly basis as follows:

Avoided Cost = (Recovered Concrete) • [(Average Production Cost) – (Average Cost to Recover Concrete)]

The *Avoided Cost on Recovered Material* (as given above in Table 4-5) is the sum of the monthly savings for all the plants for the said time period.

Sales on Resold Concrete ($): This is the sales on resold concrete. This is given as follows:

Sales on Resold Concrete = (Recovered Concrete) • (Average Selling Price)

Net Profit on Resold Concrete ($): This is the amount of money made by reselling treated concrete after the investment of DELVO ($61.03 per cubic yard). Implicitly stated in Table 8, the average profit per yard is given as the average sale price ($65.04) less the average cost for recovered concrete ($4.01). Since the contractor has already paid for concrete that is returned to the plant, treating and reselling this concrete increases the profit margin because no material investment other than DELVO is needed. Since the average selling price per yard varies from plant to plant, individual net profits were calculated for each plant. *Net Profit on Resold Concrete* is calculated as follows:

Net Profit on Resold Concrete = (Sales on Recovered Concrete) – (DELVO Hold-Over Cost)

The *Net Profit on Resold Concrete* (as given above in Table 4-5) is the sum of the net profits at each plant.

4.5 Washwater

When returning to the plants at the end of the day, each truck must go through a cleaning process so that no excess concrete is allowed to harden and build up on the trucks. This process involves rinsing both the inside and outside of each truck, which can result in waste of fresh water. To limit the amount of water wasted, it is possible to use DELVO to save the water used to rinse the inside of the truck's mixer drum. This water can then be left inside the drum over night and used as batch water the next day.

The following is a summary of the washwater data collected for all the plants for the twelve-month period starting March 1998 and ending March 1999.

Table 4-6: Washwater Summary - March 1998 to February 1999

	Totals
Number of Trucks Treated	15,070
Estimated Washwater Saved (gallons)	3,390,750
DELVO Used (oz.)	683,975
Cost for DELVO Used ($)	$49,424.03
Savings in Water Usage ($)	-$39,518.05

Number of Trucks Treated: Number of trucks that were treated with DELVO for washwater. This information was collected from the DELVO Forms.

Washwater Saved by Using DELVO (gallons): Amount of water, in gallons, saved by using DELVO to treat washwater at the end of the day. Washwater savings is calculated as follows:

Washwater Saved by Using DELVO = [(Number of Trucks Treated) • (Average Water Used for Washout)]

The *Average Water Used for Washout*, in gallons per truck, is estimated to be 225 gallons. At the end of the day, approximately 600 pounds of material remain in the mixer drum even after all concrete has been emptied. The interior of the mixer drums must be rinsed to prevent concrete buildup inside the drum and on the fins. Standard washout procedure requires the drum to be thoroughly rinsed with approximately 200 to 300 gallons of water. By adding DELVO to the washout water, however, a smaller amount of water (50-70 gallons) can be used. This water is left in the drum overnight and becomes part of the water needed for the first batch the following day. Thus, by using DELVO to treat washwater, Ready Mix saves an estimated 225 gallons of water per truck.

DELVO Used (oz.): Amount of DELVO that is used to treat washwater. Most plants treat each truck with 48 ounces of DELVO each night, but some use as little as 32 ounces. This information was tallied from the daily DELVO Forms for the given time period. Trucks are not treated on Friday nights because it may not be safe to hold the water in the drums over the weekend.

Cost for DELVO Used ($): Total cost of using DELVO to treat washwater. This figure is calculated as follows:

$$\text{DELVO Washwater Cost} = (\text{DELVO Used for Washwater}) \cdot (\text{Cost of DELVO})$$

Savings in Water Usage ($): Financial savings by using DELVO to treat washwater. To begin calculating *Savings in Water Usage* the following formula was used:

$$\textit{Savings in Water Usage} = [(\textit{Water Saved by using DELVO}) \cdot (\textit{Cost of Water})] - (\text{Cost of DELVO})$$

Since the price of water varied between $0.00237 to $0.01219 depending on the plant, *Savings in Water Usage* was calculated separately for each plant as given above. The overall *Savings in Water Usage* (as given above in Table 4-6) is the sum of the monthly *Savings in Water Usage* for all the plants.

5.0 Analysis

The analysis presented is primarily a discussion of the results provided in Chapter Four. The topics discussed in this chapter include waste material removal, block production, recovered material, washwater, and the possible use of DELVO pucks for stabilization of returned plastic concrete. Recommendations on how data collection and record keeping could be improved are also discussed.

5.1 *Waste Material Removal*

On average, 8 yd^3 of waste material is added to the stockpile each day at each plant and in 1998, an estimated 63,000 yd^3 of waste concrete were hauled from Ready Mix's plants. This includes the amount that was hauled by outside companies or by Ready Mix to be given away as fill material. In 1998, Ready Mix disposed of 13,399 yd^3 of waste by means of a hauling service, for an expenditure of $20,785, or an average of $1.55 per cubic yard of disposed waste material.

In 1998, Ready Mix owned three trucks with an average carrying capacity of approximately 14.27 m^3 (18.69 yd^3) per trip, and hauled approximately four times as much waste material (49,386 yd^3), using these trucks rather than the contracted hauling service. A purchase of one dump truck with a carrying capacity of 17 m^3 is needed in order for Ready Mix to haul and dispose of waste material by itself. Given a range of $22 - $27 per trip and an estimated 2,640 trips per year, the cost for hauling 49,386 yd^3 lies anywhere between $58,080 and $71,280, or $1.14 to $1.44 per yard. An estimate of potential savings for Ready Mix if it were to use its trucks to haul and dispose of material is given in Tables 5-1a and 5-1b.

Table 5-1a: Estimated Cost for Ready Mix to Do All its Own Hauling

Additional 17 m^3 Truck Purchase Price ($)	$107,000.00
Waste Material Hauled (yd^3/yr.)	62,785
Average Amount Hauled Per Trip (m^3/trip)	15.13
Average Amount Hauled Per Trip (yd^3/trip)	19.77
Estimated Number of Trips Made by All Trucks (trips/yr.)	3,177

17 m^3 Truck Purchase Price ($): Amount to purchase a dump truck with a carrying capacity of 17 m^3.

Waste Material Hauled (yd^3/yr.): Amount hauled for 1998. For the calculations presented in Table 5-1b, 62,785 yd^3/yr. is taken as a yearly average of waste material hauled.

Average Amount Hauled Per Trip (m^3/trip): If Ready Mix were to purchase another truck, then 15.13 (m^3/trip) is the average amount hauled per trip. The total number of trucks after the purchase would be four, two 17 m^3 and two 12 m^3. The 17 m^3 trucks make 5 trips per day, while the 12 m^3 trucks make 3 trips per day. The '*Average Amount Hauled Per Trip*' is calculated as follows:

[(Trips per Day • Number of Trucks • 17 m^3 per Truck) + (Trips per Day • Number of Trucks • 12 m^3 per Truck)] / Total Number of Trips =

$$[(5 \bullet 2 \bullet 17) + (2 \bullet 3 \bullet 12)] / (10 + 6)$$

Average Amount Hauled Per Trip (yd^3/trip): Same as above, except m^3 is converted to yd^3.

Estimated Number of Trips Made by All Trucks (trips/yr.): Estimated number of trips to be made. The calculation is given in the following formula:

# of Trips = (Waste Material Hauled) / (Average Amount Hauled Per Trip)

In Table 5-1b, the estimated cost per trip values of $22 and $27 are the upper and lower bounds that Ready Mix could have paid to haul waste material during 1998. These values are used as a range to give maximum and minimum expenses and savings when an additional dump truck is purchased.

Table 5-1b Estimated Return on Investment

Estimated Cost Per Trip by Ready Mix ($/trip)	$22.00	$27.00
Estimated Amount Spent Annually by Ready Mix ($/yr.)	$69,894.00	$85,779.00
Estimated Amount Spent by Ready Mix ($/yd^3 Hauled)	$1.11	$1.37
Average Cost per yd^3 for Hauling Service ($/yd^3)	$1.54	$1.54
Estimated Savings per yd^3 over Hauling Service ($/yd^3)	$0.43	$0.17
Estimated Annual Savings over Hauling Service ($/yr.)	$26,794.90	$10,909.90
Estimated Time to Payoff Truck Purchase Price (yrs.)	3.99	9.81

Estimated Cost Per Trip by Ready Mix ($/trip): Estimated average range from $22 to $27 per trip that Ready Mix pays to haul and dispose of waste material. This includes the driver labor cost, maintenance and operation costs of truck, and hauling and disposal costs of waste material.

Estimated Amount Spent Annually by Ready Mix ($/yr.): Amount Ready Mix would spend to haul 62,785 yd^3. Calculated by the following formula:

Estimated Amount Spent ($/yr.) = (# of Trips) • (Estimated Cost Per Trip)

Estimated Amount Spent by Ready Mix ($/yd³ Hauled): Amount Ready Mix would spend to haul one cubic yard. Calculated by the following formula:

Estimated Amount Spent ($/yd^3) = (Estimated Amount Spent Annually) / (Waste Material Hauled)

Average Cost per yd^3 for Hauling Service ($/yd^3): Amount the hauling service charged to haul one yard of concrete. Calculated from 1998 hauling data as total amount spent on hauling service divided by total yards hauled.

Estimated Savings per yd^3 Over Hauling Service ($/yd^3): Difference between '*Estimated Amount Spent by Ready ($/yd^3)*' and '*Average Cost per Trip for Hauling Service ($/yd^3)*'.

Estimated Annual Savings Over Hauling Service ($/yr.): Estimated amount saved annually over hauling service by purchasing truck. Given as follows:

Estimated Annual Savings ($/yr.) = Estimated Savings per yd^3 • Waste Material Hauled

Estimated Time to Payoff Truck Purchase Price (yrs.): Time it will take dump truck to pay for itself in savings. In order to realize savings after the purchase, this value must be less than the life-span of the dump truck, estimated at ten years. If the value is greater than or equal to ten years, purchasing the truck is not profitable.

Estimated Time (yrs.) = Purchase Price / Estimated Annual Savings

Table 5-1b shows that if Ready Mix were to purchase another dump truck to haul and dispose of waste material, it would take at least four years for the truck to pay for itself in savings. Assuming an estimated life-span of ten years for a dump truck, an average of nearly 63,000 yd^3 hauled per year, and an average of $22 per trip, the remaining six years would save nearly $161,000. With an average of $27 per trip, the truck will pay for itself in approximately ten years, for which the investment will break even. For the assumptions stated above, an additional dump truck will provide savings for Ready Mix. If average hauling and disposal costs are greater than $27 per trip then the purchase of a truck should not considered be because the time required for the truck to pay for itself in savings will exceed its longevity.

If an average of 50,000 yd^3 is hauled every year, the average cost per trip can be no greater than $26.50 for the investment to break even. For waste material less than 50,000 yd^3 per year, there is no need to purchase another dump truck or to use an external hauling service. If waste material to be hauled exceeds 63,000 yd^3 per year, the purchase of a dump truck should be considered.

The following assumptions are made for the comparisons shown in Table 5-2 of hauling and disposal methods: hauling and disposal cost range of $22 to $27 per trip for Ready Mix, $32.92 per trip for an outside hauling service, approximately 63,000 yd^3 hauled per year, and a life-span of ten years for dump trucks.

Table 5-2: Comparison of Hauling Methods

	Lower Bound	Upper Bound
Amount Spent for Hauling in 1998	$79,000	$92,000
Amount Spent if Ready Mix Hauls by Itself	$70,000	$86,000
Amount Spent if Hauling Service is Used	$97,000	$97,000

If Ready Mix continues its practice of contracting an outside hauling service to remove waste material and using its own trucks as well, it would cost approximately between $79,000 and $92,000 per year, or an average range between $1.25 and $1.47 per cubic yard. If Ready Mix chooses to haul all its waste material after the purchase of a dump truck, it would cost between $70,000 and $86,000 per year, as shown in Table 5-1b. If Ready Mix chooses to use a hauling service for removal of all waste material (i.e., does not use its trucks), it would cost approximately $97,000 per year.

Instead of giving away waste concrete as fill material, another option is to dispose of the waste material in landfills. Ready Mix does not use this option for several reasons. The hauling and disposal costs for disposal into landfills greatly exceed the costs associated with simply hauling the material and giving it away. According to an estimate require the following costs: pickup fee (hauling cost), rental fee for the container, and a per yard disposal fee. The pickup fee ranges from $75 to $230 per trip, depending on the proximity of the landfill to the plant, the rental fee for the container is $150 per plant, and the disposal charge is $38 per ton (approximately $57 per cubic yard).

To dispose of 62,785 yd^3 of material using USA Waste De Puerto Rico this would cost anywhere between $3,848,445 and $4,335,145. If there is one waste container per plant, the annual rental fee for nineteen plants is $34,200. Since each container holds 20 yd^3 of material, disposing of 62,785 yd^3 of material would require 3140 trips. Since, the price ranges between $75 and $230 per trip, then at a minimum, 3140 trips would cost $235,500 and at most, $722,200. Assuming 1.5 tons of material per cubic yard, 62,785 yd^3 would weigh 94,177.5 tons. At $38 per ton, the annual disposal cost would be $3,578,745. Finally, the total cost to dispose of this material in a landfill would be anywhere between $3,848,445 and $4,335,145. The $92,000 that Ready Mix spends, at maximum for 1998, to haul waste material to be given away as filler material is much cheaper – by more than forty times – than hauling and disposing of it in a landfill.

Aside from being too expensive, the bigger problems are the environmental issues concerning the disposal of concrete in landfills. On an island such as Puerto Rico, occupying limited space with waste material that can be better used would be neither economically beneficial for the company nor environmentally beneficial for the community. By giving away this waste material for use in rebuilding and construction, Ready Mix provides a valuable service to the community, both from an environmental and social standpoint.

5.2 *Block Production*

Although some companies use returned concrete to produce pre-cast blocks for sale, Ready Mix chooses not to because there is sufficient need for them within the company's plants. The blocks produced are 72" x 22" x 12", or 0.407 yd^3. Ready Mix would have to purchase additional molds and related equipment to produce blocks for a suitable size to be purchased. Also, workers would have to be hired specifically for the construction and sale of these pre-cast blocks. Eventually, though, the need for more pre-cast blocks to be used within the plants will not exist. When this circumstance arises, the sale of pre-cast blocks should definitely be considered. Otherwise, the returned concrete normally used for block production would become waste material and consequently an added expense. Until then, blocks should be produced as needed.

5.3 Recovered Material

Financially and environmentally, recovering concrete is the best method for dealing with returned material. A contractor pays for all the concrete that was ordered, whether or not it was fully used at the job site. So when concrete is returned to the plant, there is no financial loss associated with it. Treating and reselling returned concrete is the most environmentally conscious way to deal with returned concrete because it is reused and there is no waste material.

By using DELVO to recover returned concrete, Ready Mix can resell it for an additional profit, rather than selling an equivalent amount of newly made concrete. As given in Table 4.5, one cubic yard of fresh concrete costs, on average, $55.82 to produce and is sold at $65.04 for a profit margin of $9.22. If the returned concrete were not recovered, then it would either have to be disposed of in the plant's stockpile or made into a block. If dumped, the hauling and disposal cost for one yard of concrete is, on average, $1.48. This reduces the profit margin to $7.74 per cubic yard. If made into a blocks, the production cost would be $11.05 for one cubic yard of concrete. This costs more than the initial sale and nets a loss of $1.83. However, if returned concrete is recovered, at an average cost of $4.01 per yard, and resold, the profit margin would be $61.03, because the only 'production' cost is the amount spent to recover the concrete. Ready Mix should continue its use of DELVO for recovering concrete because it allows for the reuse of potential waste concrete, eliminates unnecessary disposal in landfills, and helps preserve the environment by not wasting additional new materials to produce fresh concrete. This method, when compared to disposal or block production, creates the fewest financial and environmental losses to the company.

However, recovering concrete with DELVO does have certain limitations. If concrete has been in a truck for too long or is at too high a temperature it cannot be recovered. Severe quality problems could occur at this point, which in turn would affect the quality of the structure being poured and the reputation of the ready mix supplier. When concrete is unrecoverable, then the demand for blocks should first be considered before disposing of the returned material.

"DELVO Forms" are used to keep track of how much DELVO is used to treat returned concrete. These forms are a good way of determining how much of the admixture was used at each plant and how much concrete was actually treated and reused. However, the data collected from these forms has been incomplete and inadequate. An estimated ten to fifteen percent of the forms were missing and for the data collected, there was no way of knowing whether returned concrete was treated but not recovered. The new DELVO forms will provide the additional information necessary to thoroughly analyze the situation. Although the new DELVO forms will provide the information needed, forms still must be collected on a daily basis to ensure accurate record keeping and to allow more complete analyses in the future.

Aside from proper data collection and record keeping, a problem when treating returned concrete with DELVO is determining the quantity of yards in the mixer drum. At Ready Mix Concrete the truck driver estimates the amount of concrete by simply looking in the mixer drum. Even though this method is rather accurate, a better method of estimating the amount of material to be treated should be investigated to prevent loss of potentially reusable concrete. A greater problem with treating returned concrete is the misreading of DELVO tables (Appendix D). In some cases, the batchman will refer to the incorrect table resulting in improper DELVO dosage, which leads to quality problems with the treated concrete. To remedy this problem, batchmen should be instructed on the proper use of the tables, for which a review training session is recommended.

Also, when concrete is returned to the plant at the end of the day, it is either disposed of in the stockpile at the plant or made into blocks. If end-of-the-day returned concrete could be treated overnight, this can result in additional profit for Ready Mix and reduced waste material. The major problem with overnight treatment of returned concrete is improper dosage of DELVO resulting in hardened concrete in the mixer drum. Treatment of end-of-the-day returned concrete should be researched in conjunction with developing a method to accurately measure the amount of material inside a mixer drum.

5.4 Washwater

Water management is a difficulty at ready mix plants and the less water added to settling basins, the better. A major problem with adding washout water to the settling basins is that they can overflow and inadvertently discharge into the environment in cases of heavy rainfall. Water that escapes from the basin has a high pH and a large concentration of suspended solids, two environmental factors that are monitored in discharges from a ready mix facility.

There are numerous environmental laws regulating the usage of water, for which there are consequent fines for noncompliance. Treating and reusing washwater is a great way to preserve the environment and to avoid fines for noncompliance to water discharge regulations. By taking nearly a $40,000 expense to use DELVO to treat washwater, Ready Mix was able to prevent the loss and accumulation in settling basins of over three million gallons of fresh water. By treating washwater with DELVO, the level in the settling basins can be kept to a minimum. This makes it easier to prevent runoff in case of heavy rainfall. The $40,000 spent to save over three million gallons of water is fully justified because of direct benefits to community and environment. This method for washwater treatment and management should be continued.

Five trucks, on average, are treated for washwater at each plant every day from Monday to Thursday. Ready Mix does not treat trucks for washwater on Fridays because the following day plants do no operate. If Ready Mix were to employ a weekend treatment plan for truck washwater, approximately one million gallons of water that are being wasted can be saved. Table 5-3 shows the investment needed for weekend washwater treatment to save an additional one million gallons of fresh water.

Table 5-3 Weekend Treatment

	Totals
Number of Trucks Treated	4,500
Estimated Washwater Saved (gallons)	1,012,500
DELVO Used (oz.)	432,000
Cost for DELVO Used ($)	$31,216.32
Savings in Water Usage ($)	-$28,482.57

Weekend treatment requires the usage of 96 ounces of DELVO, instead of 48 ounces used for overnight treatment. To stabilize for more than two days (weekend), 48 ounces have to be added for each additional day. The additional cost to treat weekend washwater would be approximately $31,500 dollars per year. The savings of over one million gallons of water justifies a net expense of $28,500 (Cost of DELVO less Cost of 'Saved' Water).

5.5 DELVO Pucks

As mentioned earlier, DELVO comes in two forms: liquid (DELVO Stabilizer) and dry (DELVO ESC). DELVO ESC comes in the form of pucks with sixteen ounces of the chemical admixture in each. Since the pucks are easy to manage and transport, they may be easier to use than the DELVO Stabilizer. Pucks are used in the same way as DELVO in its liquid form, but because they are in solid form, they are more portable.

When using DELVO for same-day treatment of returned concrete, a five to ten percent error in dosage can be tolerated. Since there already is an error in treating returned concrete for same-day use because of inaccuracies when estimating the amount of concrete in the mixer drum and DELVO needed to treat it, there is no need to be exact in the dosages. For this reason, the use of pucks instead of DELVO Stabilizer for same-day treatment of returned concrete could prove to be much easier and just as effective. Table 5-4 shows the minimum dosage of DELVO ESC that can be used to remain within the specified tolerance.

Table 5-4 Minimum Dosage Amounts for Pucks

Margin of Error	Minimum Dosage of DELVO (oz.)	# of Pucks	Ounces
5%	152	10	160
6%	121	8	128
7%	104	7	112
8%	89	6	96
9%	88	6	96
10%	72	5	80

Margin of Error: Percentage of allowable mis-dosage of DELVO for recovering returned concrete. Ten percent is the maximum tolerable error in dosage.

Minimum Dosage of DELVO (oz.): Minimum dosage required to remain within the acceptable margin of error when treating returned concrete. Using the pucks below the minimum dosage will exceed the acceptable tolerance.

If, however, the dosage amount is less than the specified minimum dosage, DELVO ESC should not be used because the allowable margin of error will have been exceeded, in which case DELVO Stabilizer should be used. Often the dosage of DELVO used for same-day treatment of concrete is below fifty ounces, for which DELVO ESC can be used in 16, 32, or 48 ounces. If, for example, returned concrete had to be treated with 38 ounces of DELVO, neither the 32 or 48 ounce dosages could be used, as they would exceed the maximum 10% margin of error. In fact, there would be nearly a 20% error in dosage, in which case the treated concrete will not set in time for delivery. Also, DELVO ESC costs $.0496 more per ounce than DELVO Stabilizer which can amount to approximately $11,500 extra spent for same-day treatment of 4,173 yd^3 of returned concrete, for the twelve month period from March 1998 to February 1999. So for practical and financial ease, DELVO Stabilizer should be used for same-day treatment of returned concrete.

Another possible application of DELVO ESC is for overnight washwater treatment. Since the amount of DELVO used for overnight washwater treatment is either 32 oz. or 48 oz., DELVO ESC may be more efficient, in management and use, than DELVO Stabilizer. For the twelve-month period from March 1998 to February 1999, 683,975 oz. of DELVO were used for washwater treatment. At 16 oz. per puck, this equates to 42,749 pucks at $1.95 per puck, it would cost nearly $84,000 for overnight washwater treatment. This is much more expensive in comparison to the $50,000 spent when using DELVO Stabilizer for the same time period.

Although the pucks are more expensive than the liquid form of DELVO, being able to use them in cases of emergency helps to avoid other costs such as chipping hardened concrete out of a truck after a major delay. DELVO pucks can be stored inside trucks and used when delays are encountered. This can save time and money for both the company and the contractor. The concrete neither has to be returned to the plant for hold-over treatment nor does the contractor have to wait longer than necessary. Also, it is possible that the concrete could be unrecoverable if the truck cannot return to the plant in time for the concrete to be treated. This can be avoided with the use of DELVO ESC. Pucks could also be used to stop concrete from getting too old to treat with DELVO Stabilizer. Before returning to the plant, a driver could add pucks to the load in order to bring the concrete back to the plant to be treated and resold. For these purpose, DELVO ESC has a viable use.

Even though DELVO ESC may be much easier to use and manage than DELVO Stabilizer, the major drawback is that it costs much more than DELVO Stabilizer. The best use for DELVO ESC is for treating concrete at a job site when delays or problems are encountered or for preventing concrete from getting too old to treat.

6.0 Conclusions

The results and analysis presented in this study are centered on the practices and methods used at Ready Mix Concrete, Inc. With eighteen plants located throughout Puerto Rico, Ready Mix is the largest producer of ready mix concrete on the island. In addition, many of the production and recycling procedures of Ready Mix are unique to Puerto Rico's tropical climate. The reader should be aware that recommendations made for Ready Mix might not be appropriate for all ready mix producers. In general, these recommendations could be extended to companies of comparable size and location.

The waste management program currently in use by Ready Mix is unique because it achieves environmental excellence while providing the highest possible quality product. Ready Mix has also been exceptional in its concern for the environment. Ready Mix is intent on establishing practices above and beyond what is necessary to avoid doing damage to the environment.

As the largest producer of ready mix concrete in Puerto Rico, other companies are influenced by the actions of Ready Mix. Being a role model for other companies helps Ready Mix to continue to strive for excellence in their waste management program.

The following are recommendations based on our analyses.

6.1 Waste Material Disposal

We commend Ready Mix for not using landfills to dispose of its waste concrete. It should continue to avoid using landfills as a method of disposal. Landfills are not only costly but also a major hazard to the environment. Other methods of disposing of waste concrete are more economically efficient and environmentally sound.

Ready Mix disposes of material that collects in its stockpiles by giving it away as fill to those whom otherwise may not have been able to afford it. By doing this, Ready Mix avoids the environmental and economic burden of landfills and is also able to provide a valuable service to the community. This service should be continued not only for its social value but also for environmental reasons. Regardless of how the material is disposed, the amount of waste material placed in the stockpiles should be minimized.

Also, the option of purchasing additional trucks for Ready Mix to increase its capacity for hauling waste material should be considered. The initial investment of nearly $115,000 may seem excessive, but a return on investment could be seen in as little as four years and as much as $30,000 per year can be saved.

6.2 Block Production

The production of pre-cast blocks to be used at Ready Mix plants should be continued. When the need for blocks is exhausted, the production of pre-cast blocks for sale should be considered. Market research would have to be performed to determine which pre-cast products are in demand and in which markets, but there is the potential for additional revenue.

6.3 Recovered Material

Ready Mix should strive to recover as much returned material as possible. Of all the current methods available for dealing with returned concrete, reuse of the material offers the most benefit to both Ready Mix and the environment. A yard of treated concrete generates $61 more profit than a yard of freshly batched concrete. The environment also benefits because there is no need for disposal of any waste material.

Ready Mix should also consider the possibility of using DELVO for overnight and weekend treatment of returned concrete. Although quality problems are a concern, with additional testing Ready Mix could find a way to use the admixture to its benefit. This would require joint research between Ready Mix and Master Builders to determine safe and efficient procedures for the stabilization of overnight and weekend concrete.

6.4 Washwater

The practice of treating truck washout water with DELVO should be continued at all Ready Mix plants. During the twelve-month period studied, an estimated 3.4 million gallons of water were saved by the use of DELVO for an expense of nearly $40,000. This is advantageous not only for Ready Mix but also for the environment.

Ready Mix does not treat on Friday afternoons because of difficulties with material hardening over the weekend. We have discussed this situation with Mr. Cabán of Master Builders, and believe it would be feasible for Ready Mix to treat washwater during the weekends. In order for weekend treatment to be successful, trucks **must** be treated with the correct amount of DELVO and **must** not be allowed to retain the washwater beyond Monday morning without additional treatment.

DELVO washwater treatment on Fridays can potentially increase the amount of water saved by 20%. This will not only be beneficial to the environment but also reduce water levels in settling basins, simplify water management, and possibly avoid discharge fines for non-compliance. For these reasons, we feel that the necessary steps should be taken to establish weekend washwater treatment at all Ready Mix plants.

6.5 DELVO Stabilizer vs. DELVO Pucks

DELVO pucks are portable and easy to handle but nearly seventy percent more expensive than DELVO Stabilizer. When treating returned concrete or truck washwater, DELVO Stabilizer should be used. When delays are encountered, having DELVO Pucks with trucks could save mixer trucks and entire loads of concrete. For this reason, Ready Mix should consider equipping all trucks with DELVO pucks.

6.6 Reclaimers

Ready Mix owns three reclaimers which should be serviced and placed into operation. Reclaimer companies, such as Schwing America, offer services that include repair and maintenance of such units. The use of a reclaimer provides benefits such as the profit from reusing mixture components and protection of the environment. Ready Mix should implement and enforce proper record keeping concerning reclaimed material and the amount of water saved to analyze the effectiveness of the reclaimers and for future purchases.

6.7 General Recommendations

In order to accurately keep track of the recycling program in place at Ready Mix, better record keeping must be established. By having plant managers correctly fill out the DELVO Forms, precise analyses could be made if records were complete and exact. It would be beneficial for the company to teach plant managers how to fill out the DELVO Forms. This could be done on an individual basis or by having a seminar to explain the correct procedure to complete the forms.

Many treatment options are available using DELVO is which Ready Mix is not confident. These options have the potential of significantly increasing profit for Ready Mix. It would also be beneficial for Ready Mix to research the use of DELVOmatic. This system is a computerized version of the DELVO Forms, which would reduce the daily paperwork and possibly improve record keeping. However, because of the lack of communication between Ready Mix and Master Builders about the importance and usefulness of using DELVO for recycling returned concrete, Ready Mix is not able to take full advantage of the product and accompanying technologies. Better communication on this issue might be beneficial to both companies.

7.0 Appendices

7.1 Appendix A: Company Profile

Ready Mix Concrete, Inc. (RMC) has been a subsidiary of the Puerto Rican Cement Company (PRCC) since November of 1995. Ready Mix is the largest concrete producer in Puerto Rico. As of 1999 they have eighteen plants located throughout Puerto Rico, with two additional plants nearing completion. Ready Mix operates 217 trucks, employs over 430 people, and has a production rate of more than 1,250,000 cubic yards of concrete per year. Ready Mix Concrete has worked on projects with the United States Navy, U.S. Air Force and Army, and the Atomic Energy Commission.

In Puerto Rico, the WPI Ready Mix project group worked with Ing. Moises Rivera and Ing. José 'Kiko' E. Bisbal. Ing. Rivera is the Environmental Manager for Ready Mix. His job is to ensure that all of the company's facilities, including the production plants and maintenance shop, operate in full compliance with the environmental laws that are applicable to the ready mix industry.

As Operations Engineer, Ing. Bisbal is in charge of general operations of all eighteen plants. He was most recently involved with the installation of the newest Ready Mix Plant in Moca.

Both Ing. Rivera and Ing. Bisbal provided the project group with valuable company information and guidance.

Ready Mix's main objective is to continue providing excellent service along with strict quality control. Ready Mix strives to recycle 100% of the materials generated by their plants. Their motto is "First in Quality and Service".

Ready Mix Concrete, Inc.
Corporate Structure

- President
  Ing. René Di Cristina
  - Production VP
    Ing. William Ramos
    - Auxiliary Production VP
      Ing. Pedro Franceschi
    - Maintenance Manager
      Ing. Pedro Santana
      - Assistant Maintenance Manager
        Ing. José Rivera
  - VP & Controller
    Carmen Betancourt
  - Sales & Marketing VP
    José E. Bisbal
  - Sales & Quality Assurance VP
    Ing. Luis Juncos
    - Quality Assurance Engineer
      Ing. Fernando Buxó
    - Field Technician Engineer
      Ing. Iván Ruiz
  - Environmental Manager
    Ing. Moises Rivera
  - Safety & Security Director
    Iván Laracuente

7.2 *Appendix B: Glossary of Terms*

The following is a list of terms relevant to the concrete industry.

Additives- general term for a material that may be used either as an addition to cement or admixture in concrete [Definition provided by ACI Manual of Concrete Practice]

Admixtures – anything added to the basic components of a concrete mixture to enhance certain properties of the mixture

Aggregate Gradation – method of determining relative size of aggregates based on size of sieve.

Aggregates – one of the major components in a concrete mixture, a combination of rocks or varying sizes held together by paste

Cement Slurry – water and cement residue remaining when equipment or formwork is rinsed with water

Clinker – a mixture of ground limestone and clay

Concrete – a mixture of aggregates, Portland cement and water

Curing – the process by which a concrete mixture gains its strength and hardens after being set in place

Drum – A rotating/holding facility on a mixing truck for the storage of freshly mixed concrete

Effluent – Any concrete byproduct

Flexural Strength – also called the modulus of rupture, tested by using a beam with three point loading

Hydration – the chemical reaction occurring between cement and water

Mix Design – a description of the exact components in a batch of concrete

Mixer Drum – rotating container, referred to as a drum, which is used to maintain a homogenous mix.

Paste – the combination of Portland cement and water

Plastic concrete – concrete capable of being molded or formed

Ready Mix Concrete – a concrete mixture that had been mixed and transported to a site ready for placing

Rebar – metal rods place in concrete prior to hardening in order to provide reinforcement to the concrete structures

Slump – a measure of the consistency or workability of a concrete mixture

7.3 Appendix C: DELVO Forms

The following are two forms used to collect data on DELVO usage.

- The first form is the original DELVO Form that was used.
- The second is the revised version of the DELVO Form, which was first used on April 5,1999.

The following is the additional information added to the old DELVO form:

Total DELVO Used (Total DELVO Usado)

- Total DELVO used to treat truck washout water.

Air Admixture Used (Air Admixture Usado)

- When concrete is disposed of in a stockpile, five to six ounces of an air admixture are added so that the concrete can be broken apart easier.

Total DELVO Used to Treated Returned Concrete (Total DELVO Usado Para Hormigón Tratado)

Total Yards Recovered (Total Yardas Recuperadas)

Total Yards Deposited in Reclaimers (Total Yardas Depositadas en Reclaimer)

Blocks Made (Bloques Fabricados)

Total Yards Not Used (Total Yardas No Usado)

Total Air-Entrained Admixture Used (Total Air-Entrained Admixture Usado)

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Ready Mix Concrete, Inc.
Delvo en Washwater

OLD DELVO FORM

Planta # 7

Fecha 98 OCT 28 PM 8-58 8-98

Atención Ing. W. Ramos

Amount of DELVO used

Amount of water to be substracted from next batch

DELVO used in washwater

Numero	Camion #	Cantidad de agua a añadirle al camión	Dosis de Delvo a añadirle al camión	Galones de agua a restarle para la próxima carga
1	172	30 Gal	48 - OZ	80 - Gal
2	49	" "	" "	" "
3	138	" "	" "	" "
4	143	" "	" "	" "
5	39	" "	" "	" "
6	374	" "	" "	" "
7	69	" "	" "	" "
8	52	" "	" "	" "
9	57	" "	" "	" "
10	308	" "	" "	" "
			480	
			1477	
			1957	

DELVO used in Hold-over concrete treatment

Yards Treated

Delvo Usado Para Hormigón Tratado

Amount of DELVO used

Unidad	Liga Devueltas	Yardas Devueltas	Factor de Cemento	Tiempo de Cargado	Delvo Usado	Nueva Liga Cargada	Cantidad Yardas Cargadas	Estructura Depositada
348	72N	1	4.30	3 Hrs	96	44 V	10	PISO
348	144-V	2	4.20	2 Hrs	124	83 4-N	6	Paredes
116	72-N	3 1/2	4.30	2 1/2 Hr	3[illegible]	9-N	7	ACERAS
346	72 V	1	4.20	2 1/2 Hr	87	19-N	10	Zapatas
57	72N	1 1/2	4.30	1 1/2 Hr	[illegible]	19. N	10	Paredes.
69	66	6	4.10	1 1/2 Hr	264	72. V	10	Paredes.
116	66	6	4.10	2 Hr.	458	72-V	7	paredes.
					1477			

Total Yardas Recuperadas = 21

Bloques Fabricados = 0

Total Yards Recovered using DELVO

Total Blocks Made

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Ready Mix Concrete, Inc.

Planta # [ ] Atención [ ]

Fecha [ ] Gerente de Planta [ ]

DELVO en Washwater

Número	Camión #	Cantidad de agua a añadirle al camión	Dosis de DELVO a añadirle al camión	Galones de agua a restarle para la próxima carga
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
		Total DELVO Usado =		

Hormigón Devuelto

Camión #	Liga (Devueltas)	Yardas (Devueltas)	Factor de Cemento	Tiempo de Cargado	DELVO Usado	Nueva Liga Cargada	Cantidad Yardas Cargadas	Estructura o Proyecto/ Reclaimer/ Bloques/ No Usado	Air Admixture Usado

Total DELVO Usado Para Hormigón Tratado =
Total Yardas Recuperadas =
Total Yardas Depositadas en Reclaimer =
[illegible]ques Fabricados =
Total Yardas No Usadas =
Total Air-Entrained Admixture Usado =

Firma ______________________

7.4 *Appendix D: DELVO Charts*

The following DELVO charts are distributed by Master Builders to determine the correct dosage of DELVO for returned concrete and truck washout water. Batchmen sometimes used the wrong chart to treat the concrete. The differences between the charts are the concrete temperature (Temperatura de Concreto) and the cement factor (Factor de Cemento) which can easily be overlooked when quickly glancing at the charts. This is the main cause of error in dosages.

PARA USO EN READY MIX CONCRETE, INC.

Estabilizador DELVO requerido para estabilizar el mismo día

TEMPERATURA CONCRETO 85° - 94°F

FACTORES DE CEMENTO ENTRE 260 - 580 LBS. POR YARDA CÚBICA

DOSIS POR YARDA CÚBICA DE CONCRETO REGRESADO

TIEMPO TRANSCURRIDO DESDE QUE SE MEZCLÓ INICIALMENTE ESE CONCRETO

Factor de Cemento (lbs.)	Tiempo en Horas 0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0
580	29	46	64	81	110
560	28	45	62	78	106
540	27	43	59	76	103
520	26	42	57	73	99
500	25	40	55	70	95
480	24	38	53	67	91
460	23	37	51	64	87
440	22	35	48	62	84
420	21	34	46	59	80
400	20	32	44	56	76
380	19	30	42	53	72
360	18	29	40	50	68
340	17	27	37	48	65
320	16	26	35	45	61
300	15	24	33	42	57
280	14	22	31	39	53
260	13	21	29	36	49

PARA USO EN READY MIX CONCRETE, INC.

Estabilizador DELVO requerido para estabilizar el mismo día

TEMPERATURA CONCRETO 95° -104°F

FACTORES DE CEMENTO ENTRE 260 - 580 LBS. POR YARDA CÚBICA

DOSIS POR YARDA CÚBICA DE CONCRETO REGRESADO
TIEMPO TRANSCURRIDO DESDE QUE SE MEZCLÓ INICIALMENTE ESE CONCRETO

Factor de Cemento (lbs.)	Tiempo en Horas 0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0
580	41	58	87	104	No
560	39	56	84	101	
540	37	54	81	97	
520	36	52	78	94	Recomiendo
500	35	50	75	90	
480	34	48	72	86	
460	32	46	69	83	Estabilización
440	31	44	66	79	
420	29	42	63	76	
400	28	40	60	72	
380	27	38	57	68	
360	25	36	54	65	
340	24	34	51	61	
320	22	32	48	58	
300	21	30	45	54	
280	20	28	42	50	
260	18	26	39	47	

Temperatura del Concreto F° C°	Tiempo de trabajabilidad adicional sobre retardación normal. (1½ hr.) .5-1	>1-1.5	>1.5-2	>2-2.5	>2.5-3	>3-3.5
(Al momento de la pesada)	(Onzas por cada 100 lbs. de Cemento)					
100-109(38-43)	5	6	7	8	9	10
90-99(32-37)	4	5	6	7	8	9
80-89(27-32)	3	4	5	6	7	8
70-79(21-26)	2	3	4	5	6	7
60-69(16-21)	1	2	3	4	5	6

Note: Por cada ½ hora adicional de retardación luego de llegar al limite de la tabla añadir 1 onza/100 lbs de DELVO®

PARA USO EN READY MIX CONCRETE, INC.

Estabilizador DELVO requerido para estabilizar el mismo día

PARA CARGAS COMPLETAS, SIN LA NECESIDAD DE AÑADIR HORMIGóN FRESCO AL HORMIGóN REGRESADO.

TEMPERATURA DEL HORMIGóN 85°- 94°F

DOSIS POR YARDA CúBICA DE CONCRETO REGRESADO
TIEMPO TRANSCURRIDO DESDE QUE SE MEZCLó INICIALMENTE ESE CONCRETO

Factor de Cemento (lbs.)	Tiempo en Horas 0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0
640	16	31	50	71	106
620	16	30	49	69	104
600	15	29	47	67	102
580	15	28	45	65	99
560	14	27	44	63	95
540	14	26	41	61	93
520	13	25	40	58	89
500	13	24	39	56	86
480	12	23	37	54	82
460	12	22	36	51	78
440	11	21	34	50	76
420	11	20	32	47	72
400	10	19	31	45	68
380	10	18	30	43	65
360	9	17	28	40	61
340	9	16	26	38	59
320	8	16	25	36	55
300	8	15	23	34	51
280	7	14	22	31	48
260	7	13	20	29	44

PARA USO EN READY MIX CONCRETE, INC.

Estabilizador DELVO requerido para estabilizar el mismo día

PARA CARGAS COMPLETAS, SIN LA NECESIDAD DE AÑADIR HORMIGóN FRESCO AL HORMIGóN REGRESADO.

TEMPERATURA DEL HORMIGóN 95°- 104°F

DOSIS POR YARDA CúBICA DE CONCRETO REGRESADO

TIEMPO TRANSCURRIDO DESDE QUE SE MEZCLó INICIALMENTE ESE CONCRETO

Factor de Cemento (lbs.)	Tiempo en Horas 0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0
640	23	38	67	90	
620	23	37	65	88	
600	22	36	63	85	
580	21	35	61	83	
560	20	34	59	81	
540	19	32	57	78	
520	18	31	55	75	
500	18	30	53	72	
480	17	29	50	69	
460	16	28	48	66	
440	16	26	46	63	
420	15	25	44	61	
400	14	24	42	58	
380	14	23	40	54	
360	13	22	38	52	
340	12	20	36	49	
320	11	19	34	45	
300	11	18	32	43	
280	10	17	29	40	
260	9	16	27	38	

2.5-3.0: No Recomiendo Estabilización

Building Tomorrow Together® SKW·MBT

PARA USO EN **READY MIX CONCRETE, INC.**

Estabilizador **DELVO** requerido para estabilizar el mismo dia

TEMPERATURA CONCRETO 95° - 104°F

FACTORES DE CEMENTO ENTRE 260 - 680 LBS. POR YARDA CÚBICA

DOSIS POR YARDA CÚBICA DE CONCRETO REGRESADO

TIEMPO TRANSCURRIDO DESDE QUE SE MEZCLÓ INICIALMENTE ESE CONCRETO

Factor de Cemento	Tiempo en Horas				
Lbs.	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0
680	51	68	102	119	
660	49	66	99	116	
640	47	64	96	113	No
620	45	62	93	110	
600	43	60	90	107	
580	41	58	87	104	Recomiendo
560	39	56	84	101	
540	37	54	81	97	
520	36	52	78	94	Estabilización
500	35	50	75	90	
480	34	48	72	86	
460	32	46	69	83	
440	31	44	66	79	
420	29	42	63	76	
400	28	40	60	72	
380	27	38	57	68	
360	25	36	54	65	
340	24	34	51	61	
320	22	32	48	58	
300	21	30	45	54	
280	20	28	42	50	
260	18	26	39	47	

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