Evaluation of Foundation Materials on Expansive Soil for English Aire Apartments' Tennis Court

Prepared for
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This report compares concrete and asphalt as materials for reconstruction of the tennis court at English Aire apartments according to the criteria of cost, safety, durability, and maintenance.

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Executive Summary

The tennis courts at English Aire apartments are deteriorating and need to be reconstructed. The Urban land and Ferris soil beneath the courts has a high potential for expansion and creates a heave force on the court surface.

The initial cost of asphalt is $46,300, but because of low tensile strength and low resistance to graveling, asphalt is more likely than concrete to crack and create an unsafe surface. It requires weekly maintenance to remove debris and repainting every 3 years. Its life expectancy is about 18 years; its annual cost is $2,572.

Post-tensioned concrete costs $70,500 to install, but its superior tensile strength makes it less likely to crack on swelling soil. Maintenance includes bi-weekly cleaning and repainting every 5 years. Its life expectancy is 30 years; the annual cost is $2,350.

In spite of higher initial cost, concrete provides superior safety, durability, and maintenance features and a lower annual cost.
Introduction and Problem Statement

The tennis court at the English Aire Apartment complex is deteriorating rapidly. The surface has many severe structural cracks, and the northern edge has foundation erosion problems (see Appendix figures A1 through A3). Ruddy's Consulting Group (RCG) has concluded that the current court problems are directly related to the properties of the soil and the soil environment.

The structural cracks indicate that major changes have taken place in the soil beneath the tennis court. A soil survey map (Figure 1) indicates that the court is built on Urban land and Ferris soil (UvE). UvE is 36% Ferris soil, a clay with a high potential for expansion. Ferris clay expands when water infiltrates the existing clay structure and causes the dry compacted clay particles to move in relation to one another. The movement of the particles to their new equilibrium positions increases the overall volume of the clay.

When the clay below the tennis court at English Aire gets wet and expands, the volume change creates a heave force on the tennis court surface. This force exceeds the shear strength of the asphalt surface and creates structural cracks.

The environment of the soil beneath the tennis court at English Aire also contributes to the cracks and to the foundation erosion along the northern edge. The soil survey map confirmed our results from an initial site inspection concerning the slope of the tennis court. The court was constructed on an excavated portion of a hill with a slope of 10% to 15%. The north side of the tennis court has soil shifting and erosion problems beneath the court's edge due to its relative location.
on the hill. The soil at the northern edge has tendencies to erode and slide because the soil was not compacted as well here. When the soil slides it creates a void spot below the court's northern side (Figure 2). These problems have caused long parallel cracks along the entire northern edge and have destroyed the structural integrity of this side.

**Purpose, Scope, and Methodology**

The purpose of this project was to recommend the best foundation reconstruction alternative for English Aire Apartments’ tennis court while considering the soil shifting problems. The foundation alternatives considered for reconstruction of the court are asphalt and concrete.

The alternative solutions were evaluated according to a set criteria provided by English Aire Apartments management: overall project cost, safety, material properties, and maintenance.

In order to evaluate asphalt and concrete as suitable foundation material, RCG acquired information using textbook materials, site research, phone interviews with sport court companies, Internet searches, and library research. RCG determined the problem of expansive soils and foundation erosion through site inspection and soil survey maps. Cost estimates were obtained from Dobb’s Sport Court and Sport Court of Austin. Please note that the cost figures given are to be considered estimates and should not be considered actual prices. Safety was determined through phone interviews with Dobb’s Sport Court, Austin Sport Court, and by direct connection with the material properties. According to Vick Sanchez of Austin Sport Court, “A safe court is one with no cracking and graveling problems.” The material properties of asphalt and concrete were collected from textbooks, library research, and Internet searches. Maintenance requirements were acquired from Internet searches and interviews.
Organization of Report

This report is divided into five sections. The first section, Alternative Solutions, explains in detail the two options considered by RCG. The second section, Solution Criteria, explicates the criteria used to evaluate concrete and asphalt. The third section, Evaluating Foundation Alternatives, assesses each option according to the criteria. The fourth section, Conclusions, shows how concrete best meets the criteria. The report concludes with recommendations for implementing the conclusions.

Alternative Solutions

Ruddy's Consulting Group decided to evaluate asphalt and concrete because asphalt and concrete are the most commonly used foundation types for tennis courts. Other options were not considered based on English Aire Apartments management's desire for relatively low maintenance and overall cost.

Asphalt

Asphalt is a mixture of hydrocarbons that is used in various foundation applications. It is a durable material that is often used for tennis and sport courts. Proper construction using asphalt as the foundation can lead to a long lasting tennis court.

The basic construction of a properly designed asphalt court involves four components (see Figure 3 for a detailed cross section of an asphalt foundation):
1. A stable, compacted, and well-drained soil sub base,
2. A 6-to-8-inch compacted crushed stone base course,
3. A 3-to-4-inch-thick compacted hot asphalt pavement usually laid in two courses of a minimum thickness of 1 1/4" each and sloped from side to side of the court (not diagonally or end to end) at a slope of 0.8% to 1.0%, and
4. A liquid applied acrylic playing surface system squeegeed on top of the cured asphalt pavement (usually between 3 and 10 layers of surfacing)

If constructed properly, an asphalt tennis court has an expected life of 18 to 20 years, requiring repainting every 3 years, depending upon seasonal usage.

Figure 3: Typical Asphalt Cross Section
Concrete

Concrete is used in construction when strength is a main concern. Post-tensioned concrete is commonly used for the reconstruction of tennis courts on expansive soils. Post-tensioned concrete is cured concrete that has been reinforced with steel rods (Figure 4). Also embedded in the cured concrete are tubes and channels where cables or rods are inserted and stressed. The concrete bonds to the stressed rods, which then places the concrete in compression generating built-in resistance to tensile forces caused by ground movement.

Post-tensioned concrete is used in the majority of new tennis court construction. It is also the reconstruction method of choice for badly heaved or cracked courts. This method involves the following:
1. A pad of 4-inch thick concrete with 3/8" sheathed tension cables are centered in the concrete and anchored in a perimeter beam.
2. The fence and net posts are integrated into the slab when the concrete is poured. While the concrete is curing the cables are tensioned in both directions to pull the concrete together.
3. The surfacing system and lines are applied to create the playing boundaries.

![Figure 4: Typical Concrete Cross Section](image)

Solution Criteria

English Aire Apartments management provided RCG with set criteria in order to evaluate and recommend a suitable foundation material for the tennis court. The criteria are listed in order of importance.

Overall Project Cost

The overall project cost of the court includes the reconstruction cost and year-round maintenance costs over the life span of the court. The cost per year ratio is the overall project cost divided by the suspected life span of the court.

Safety

Unsafe conditions can result in increased liability concerns and costly lawsuits. Safety is defined as the ability of the foundation
material to resist cracking and graveling. Graveling occurs when pieces of aggregate loosen from the surface. Increased numbers of cracks and loosened gravel could cause players to trip or slip and injure themselves.

**Material Properties**

Material properties include durability, resistance to cracking and graveling, and reactions to soil swelling and ground shifting. Durability of the material is determined using the court’s life span. Resistance to cracking, graveling, and reactions of the materials under soil swelling and expansion conditions are determined by the strength of the material. These material properties will help gauge how well the foundation material will perform at the site’s location.

**Maintenance**

The condition of the court will be determined by the original construction of the court and regular maintenance. Poorly constructed courts will need more maintenance over the life span, which increases the overall cost. Repainting and cleaning are the requirements for general maintenance. Maintenance is calculated on a per year basis. Other repairs are not included in the maintenance section due to the inability to forecast possible problems.

**Evaluation of Foundation Alternatives**

This section evaluates asphalt and concrete according to the criteria defined by English Aire Apartments management.

**Asphalt**

**Overall Project Cost**

The cost of reconstructing English Aire’s tennis court can be broken into three parts: reconstruction, maintenance per year, and repainting. The cost of the reconstruction is one lump sum at the time of construction. Cleaning will be done weekly and repainting will occur every 3 years. Repairs made to the court vary in cost and are not included in the overall project cost.

According to Austin Sport Court, the reconstruction of the tennis court using asphalt costs $25,000. The maintenance cost is $350 per year for cleaning and $2,500 every 3 years for resurfacing. This brings the total cost to $46,500 over an 18-year life expectancy period (Table 1). The cost is $2,572 per year.

**Safety**

If the court is not constructed properly, the soil shifting could create cracks, bumps, and uneven surfaces and make the court unusable in as little as a few months. According to Avi Mor, asphalt can withstand heavy loads, like a car, due to its bending properties, but the forces caused by soil shifting tear the asphalt, or place it in tension, and crack it from the bottom to the top due to its low tensile
<table>
<thead>
<tr>
<th>Description</th>
<th>Individual Costs</th>
<th>18-year Cost</th>
</tr>
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<tr>
<td>Reconstruction</td>
<td>$25,000</td>
<td>$25,000</td>
</tr>
<tr>
<td>Maintenance Per Year</td>
<td>@$350 x 18 years</td>
<td>$6,300</td>
</tr>
<tr>
<td>Repainting</td>
<td>@$2,500 x 6 times</td>
<td>$15,000</td>
</tr>
<tr>
<td>Total Cost (18 years)</td>
<td></td>
<td>$46,300</td>
</tr>
<tr>
<td>Cost per year</td>
<td>$46,300/18</td>
<td>$2,572</td>
</tr>
</tbody>
</table>

strength. The tensile strength of asphalt cannot be compared in a quantitative analysis to that of concrete due to different testing methods, but asphalt has a low tensile strength in a qualitative analysis compared to that of concrete. Asphalt has a very high tendency to bend and become very brittle causing asphalt to have a low resistance to graveling. The surface of the court becomes shifted with these forces and the aggregates break apart and become loose on the surface. Overall, asphalt generates a low safety rating because of its high ability to crack and gravel.

**Material Properties**

The properties that are relevant to constructing a long lasting court on expansive soils are durability, resistance to cracking and graveling, and reactions to soil swelling. The life expectancy for an asphalt tennis court, according to Xsports and S and S Developers, can be as much as 15 to 18 years. The life expectancy depends solely on proper construction and maintenance of the court. Asphalt has a low tolerance to cracking and graveling due to its low tensile strength; therefore, asphalt will fail and crack when placed under the soil swelling forces present at the proposed site, as stated by all of our sources.

**Maintenance**

Court maintenance can extend the life of the tennis court. Maintenance of an asphalt court necessitates regular cleaning and periodic repainting. The court must be blown and swept of debris regularly. If debris remains on the court it can act as an abrasive. When a player steps on the debris, the court surface may be scratched. RGC anticipates that an asphalt court will require cleaning and sweeping very frequently because of the surface's propensity to gravel. According to Xsports, weekly court cleaning and sweeping will be required in order to preserve the life of the court's surface. An asphalt tennis court must also be repainted. Xsports estimates that for a safe playable asphalt court to be maintained, it must be repainted every three years. An asphalt court must be repainted more often than concrete due to the inevitable debris abrasion.
Table 2: Overall Project Cost Items for Concrete

<table>
<thead>
<tr>
<th>Description</th>
<th>Individual Costs</th>
<th>18-year Cost</th>
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<tr>
<td>Reconstruction</td>
<td>$50,250</td>
<td>$50,250</td>
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<tr>
<td>Maintenance per year</td>
<td>@ $175 x 30 years</td>
<td>$5,250</td>
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<tr>
<td>Repainting</td>
<td>@ $2,500 x 6 times</td>
<td>$15,000</td>
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<tr>
<td>Total cost (30 years)</td>
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<td>$70,500</td>
</tr>
<tr>
<td>Cost per year</td>
<td>$70,500/30</td>
<td>$2,350</td>
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</tbody>
</table>

Concrete

**Overall Project Cost**

The cost of reconstructing the English Aire Apartments' tennis court with concrete can be broken into three parts: construction, cleaning, and repainting. The cost of the reconstruction will be one lump sum at the time of construction. Cleaning will be done once a year and repainting will occur every five years.

Dobb's Sport Court estimates the reconstruction of the tennis court using concrete will cost $70,500. The maintenance cost of a concrete court is $175 per year for cleaning and $2,500 every 5 years for resurfacing. This brings the total cost to $70,500 over a 30-year life expectancy period (Table 2). This gives a cost per year ratio of $2,350.

**Safety**

According to Prestressed Concrete Design, concrete normally has a high resistance to cracking due to its high compressive strength, 5,000 to 8,000 psi. The ground movement and poor soil conditions, however, will place tensile forces on the foundation. According to Avi Mor, concrete's tensile strength is one-tenth its compressive strength. Post-tensioned concrete increases its tensile strength to approximately 5,000 to 5,000 psi.

Post-tensioned concrete as the reconstruction method will reduce the chance of cracking under ground movement and soil swelling conditions according to all of our sources. In addition to cracking, Vick Sanchez states that graveling is not likely to occur with post-tensioned concrete. Overall, concrete has a superior safety rating compared to asphalt.

**Material Properties**

Constructing a long lasting court on expensive soils requires high durability, high resistance to cracking and graveling, and minimal reactions to soil swelling. A post-tensioned court on average lasts 30 years, according to S & S Developers and Xsports. Post-tensioned concrete also has a high resistance to cracking and graveling. According to Prestressed Concrete Design, concrete has a high resistance to cracking due to its high compressive strength. The post-tensioned
concrete is designed to resist the tensile forces present in conditions such as ground shifting, so cracking should not be a concern with this method. Overall, post-tensioned concrete performs well under ground shifting conditions, according to all of our sources.

**MAINTENANCE**

The maintenance required for a concrete court is similar to maintenance required for an asphalt surface, but the cleaning can be less frequent. According to Xsports, a concrete surface must be swept and cleaned once every two weeks to remove any dust, dirt, and eroded surface particles. Xsports also states that a concrete court must also be repainted every five years. Intervals between paintings are longer with concrete than with asphalt because a concrete surface is tougher and is less likely to have serious abrasion problems.

**Conclusions**

Based on the valuation of foundation alternatives using the criteria defined by English Aire Apartments management, RCG has reached the following conclusions concerning the reconstruction of the English Aire Apartments' tennis court.

1. Constructing an asphalt tennis court had the lower overall project cost of the two alternatives at $46,300. It has a life expectancy of approximately 18 years with regular maintenance. Asphalt, however, had a cost per year ratio of $2,573. Cracking and graveling will occur more quickly on an asphalt court due to the soil shifting properties causing unsafe conditions. The asphalt foundation requires weekly maintenance and repainting every 3 years.

2. Constructing a post-tensioned concrete court had the higher overall project cost at $70,500. The post-tensioned court has a life expectancy of 30 years giving a cost per year ratio of $2,350. On the post-tensioned court, cracking is rare and graveling is virtually nonexistent under the soil swelling conditions. Without cracking and graveling, the court will be safe for the players. Also, a post-tensioned concrete court requires cleaning every two weeks and repainting every 5 years.

In spite of the higher initial cost, concrete will provide a more satisfactory long-term choice. Choosing to construct a post-tensioned tennis court, English Aire Apartments management will benefit for several reasons. The advantages of post-tensioned concrete courts over conventional asphalt courts are as follows:

- Lower cost per ratio of $2,350
- Resistance to cracking and graveling
- Increased safety
- Greater durability and longer life span
- Less maintenance which leads to lower maintenance costs
Recommendations

In order to increase usage of the courts, attract new tenants, and decrease liability concerns, Ruddy’s Consulting Group recommends that English Aire Apartments management reconstruct the present tennis court with post-tensioned concrete. In order to implement this recommendation, RCG suggests the following:

1. Remove current asphalt foundation and sublayers.
2. Compact and level the soil starting from the bottom up with a roller to create a firm base for the next layers of construction.
3. Create a frame or form the size of the outside diameter of the finished court.
4. Pour a pad of 4” thick concrete with ½” sheathed tensioned cables centered in the concrete and anchored in a perimeter beam.
5. Apply the surfacing system (a ¼” of cold asphaltic emulsion, or cushion) and paint the lines after the concrete has cured.

References


Mor, Avi. Doctor Mor and Associates, Head Consultant. e-mail. November 5, 1997.


