Ingeniería y Agrimensura

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Improving Concrete Pavement Affordability

The Changing Role for Surveying in Modern Land Tenure Systems

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Mensaje del Presidente

Estimados lectores:

Es un placer dirigirme a ustedes en esta la que será la última edición de la revista Dimensión durante nuestra presidencia.

Nos enorgullece haber sido testigo de la calidad del contenido de esta publicación, que tiene un rol tan importante en el continuo proceso educativo de nuestros profesionales de la Ingeniería y la Agrimensura.

En esta edición compartimos dos interesantes artículos que amplían nuestra perspectiva sobre los temas del rol del agrimensor en los sistemas modernos de tenencias de tierras y sobre la tecnología de pavimentos en hormigón para las carreteras de nuestra Isla, un tema de gran actualidad.

Agradezco, a los colaboradores que comparten su conocimiento y experiencia con nosotros, así como al equipo editorial a cargo de la Revista Dimensión, liderado por el Dr. Benjamín Colucci.

Les invitamos a que disfruten de la lectura y compartan con sus allegados, para continuar educando sobre nuestras profesiones.

Cordialmente,

Ing. Ralph A. Kreil Rivera
Presidente

MENSAJE DEL PRESIDENTE DE LA JUNTA EDITORA

Un cordial saludo a todos los ingenieros y agrimensores del CIAPR. En esta segunda edición electrónica e impresa del año 2017 contiene dos artículos de sumo interés a nuestra matrícula, el "Diccionario zurdo" y el mensaje del Ing. Ralph A. Kreil Rivera, que culmina su presidencia del CIAPR durante el periodo del 2015-2017.

En el primer artículo técnico, "Mejorando la asequibilidad de pavimentos de hormigón", los ingenieros Jim Mack y Arturo Rosario de la empresa Cemex presentan su perspectiva de como los jefes de agencias e instrumentalidades del gobierno que tienen la responsabilidad de la construcción y mantenimiento de las carreteras de Puerto Rico pueden mejorar su eficiencia para obtener una mejor inversión con los fondos asignados para dichos fines. En primera instancia recomiendan que dichas agencias aumenten la competencia de la industria en el proceso de licitación de proyectos de pavimentos y que mejoren las prácticas de diseño y gerencia de pavimentos. Además, sugieren que se utilice la Metodología Mecanística-Empírica de Diseño (Pavement ME Design Procedure) publicadas por la American Association of State Highway and Transportation Officials (AASHTO) en combinación con otras herramientas como el Análisis del Costo del Ciclo de Vida (LCCA por sus siglas en inglés) para el desarrollo de diseños para proyectos específicos.

Enfatizan que dicho análisis integrado debe proveer un balance razonable entre los estimados de costos iniciales de construcción y de rehabilitación versus el rendimiento de dichos pavimentos durante su vida útil para las cargas de tráfico y clima que va a estar sometido, y que a su vez debe satisfacer los requerimientos presupuestarios de la agencia. Concluyen que este nuevo enfoque a largo plazo debe redundar en menos costos asociados a la congestión y mejorar la eficiencia de la inversión en pavimentos a nivel de toda la red de carreteras de Puerto Rico.

En el segundo artículo, titulado "El rol cambiante para la agrimensura de los sistemas modernos de tenencia de la tierra", el Dr. George M. Cole, profesor adjunto del Departamento de Ingeniería Civil y Agrimensura de la Universidad de Puerto Rico, Recinto de Mayagüez (UPRM) presenta la importancia de los sistemas catastrales para la protección del derecho a la tierra y de la distribución equitativa de las contribuciones sobre impuestos prediales en sistemas económicos de países desarrollados. El artículo está basado en su reciente libro publicado en conjunto con Don Wilson en la imprenta CRC titulado *Land Tenure, Boundary Surveys and Cadastral Systems* del 2016 que surge de los hallazgos de su investigación en carácter de profesor visitante en UPRM.

El artículo resalta como los Sistemas de Información Geográfica (GIS por sus siglas en inglés) y contribuye como plataforma de base para dichos sistemas económicos, convirtiéndose en materia esencial para el uso eficiente y ordenado del terreno. Además, el artículo hace referencia a las implicaciones específicas de estos sistemas a Puerto Rico, específicamente al Registro de la Propiedad, y al Centro de Recaudación de Ingresos Municipales (CRIM). Por último, el Dr. Cole sintetiza el rol evolutivo de la educación en la agrimensura utilizando estas herramientas y presenta recomendaciones en cómo debe ser el futuro de la educación en la agrimensura que incluya además de CAD: el manejo integrado de datos, GIS, conocimiento de los reglamentos, los procesos judiciales y administrativos asociados al uso de terrenos e integración de esta información en los sistemas de catastros de usos múltiples.

Espero que estos artículos le sean de utilidad y beneficio para los lectores y profesionales de la ingeniería y agrimensura de Puerto Rico. Les exhorto a que acudan a la página electrónica del CIAPR, **www.ciapr.org** para que también tengan acceso a las demás ediciones electrónicas de la *Revista Dimensión*.

No puedo cerrar este mensaje sin agradecer a los compañeros de la Junta Editora, a la familia Chevako de PRI, al personal del Centro de Transferencia de Tecnología y Transportación, igual que la aportación de los profesionales ingenieros y agrimensores que colaboraron en someter artículos durante los últimos dos años para las diferentes ediciones de la *Revista Dimensión*. Unidos logramos publicar artículos relevantes y diversos para toda nuestra matrícula.

Por último, un especial agradecimiento al Ing. Ralph A. Kreil Rivera por la confianza prestada en este servidor para servir como presidente de esta Junta Editora, eternamente agradecido Ralph.

Benjamín Colucci, PhD, PE
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Presidente, Junta Editora

IMPROVING CONCRETE PAVEMENT AFFORDABILITY

Jim Mack, PE and **Arturo Rosario, PE**

The United States spends an estimated $91 billion on its highways every year, with most of those pavement expenditures going to maintenance of the existing system. Despite this enormous outlay in roads and highways, traffic congestion due to poor conditions persists. According to the 2017 ASCE Infrastructure Report Card, US drivers waste 6.9 billion hours in traffic a year, equivalent to 42 hours per driver[1], which earns the US road system a D grade. Obviously, the system needs to be expanded, but current funding streams are not even able to keep up with maintenance needs.

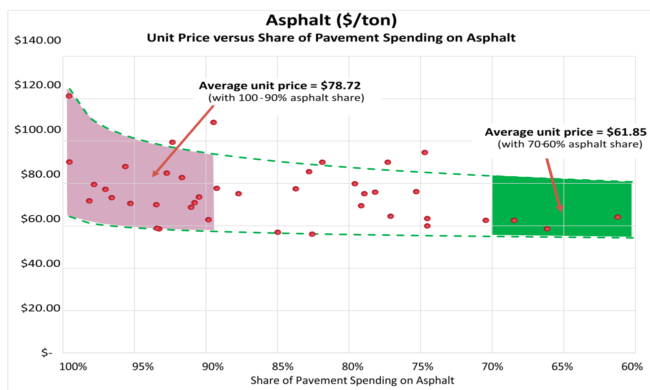
The primary approach to address this challenge has been to increase funding. While this is needed, agencies also need to improve the efficiency of their roadway investments to get more out of their pavements. This can be accomplished in two ways. First, agencies can and should increase competition in the pavement bidding process. Basic economics confirms that when there is competition among many contractors and across paving industries, the average unit prices for pavements lower significantly. Second, agencies must improve the design and management of their pavement assets. New tools such as the American Association of State Highway and Transportation Officials (AASHTO) Mechanistic-Empirical Pavement Design Procedure can be combined with other tools such as Life Cycle Cost Analysis (LCCA) to develop project-specific designs that balance initial costs, rehabilitation costs, and pavement performance to meet an agency's budget constraints. When used correctly, these tools will in the long term lower expenditures, reduce congestion, and improve the pavement network investment efficiency.

The Role of Competition

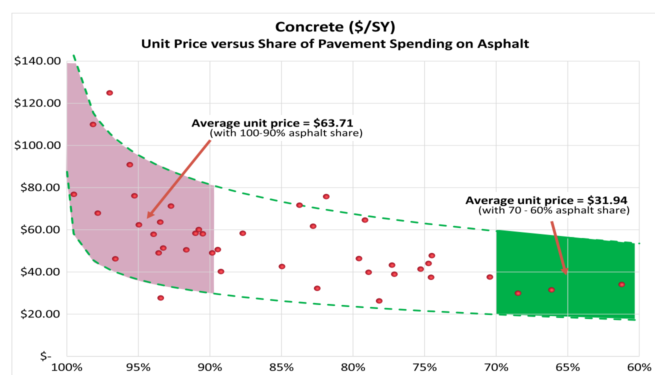
Now more than ever, given the significant economic restraints, growing infrastructure needs and increased public scrutiny, roadway agencies cannot afford to forgo any opportunity to make infrastructure dollars go farther. However, an analysis of bid data from 2009-2014 shows that well over 85% to 90% of all paving projects are currently bid with one material only – asphalt.[2]

Increasing competition between industries in the transportation construction marketplace can help ensure the highest return on investment of taxpayer dollars by driving down costs and fostering innovation because it brings additional contractors and suppliers to the market. That is, while competition among contractors that construct a single pavement type does provide some of these benefits, competition between pavement industries also makes material suppliers compete. This adds an additional level of competition to the supply chain that does not occur where only one pavement material is used regularly or exclusively.

To illustrate this, Figure 1 shows the average five-year state unit cost price for asphalt and concrete pavements versus asphalt's share of market spending, which is used as a proxy for competition.[2] The dotted lines are the 5th and 95th confidence interval of the unit cost for the various competition levels. The primary item to note is that when competition increases (as indicated by a decreasing share of asphalt spending from 100% to 60%), there is a clear trend to lower unit prices for both asphalt and concrete pavements. Second, the variability in the unit prices for both materials decreases with increasing levels of competition. Finally, it is also important to note that the states with higher levels of competition tend to be those with a stable and predictable paving program, which implies that sustained programs (for both concrete and asphalt) are important in maintaining predictable and low unit prices.



(a)



(b)

Figure 1. 2013 weighted unit costs vs. five-year average balance of DOT pavement type usage for asphalt (a) and concrete (b) pavements respectively. (Oman)

1 American Society of Civil Engineers (ASCE) 2017 Infrastructure Report Card

2 Oman. (n.d.). Oman Systems, Inc Bid Tabulation Data. Retrieved from http://www.omansystems.com

These results represent a tremendous opportunity for highway agencies looking to extend the purchasing power of their highway dollars. Table 1 is a break-even analysis that shows how a different allocation of pavement spending can impact the total amounts of pavement constructed for a $50 million/year investment. In this example, if a state spends 95 percent of the $50 million/year on asphalt (1st line) with virtually no industry competition, the asphalt bid price would be roughly $78.72/ton and the concrete bid price would be roughly $63.71/square yard (from Figure 1). At these prices, the state can purchase a little over 600,000 tons of asphalt (or 158 lane miles, assuming an 8-inch pavement) and a little over 39,000 square yards of concrete (6 miles) for their $50 million budget. Now suppose the state instills more competition by introducing a larger portion of concrete pavement into its program (via alternate bidding, programmatic selection or some other means) and in this scenario the state allocates 65% of its budget to asphalt pavement and the rest to concrete. In this case, with industry competition, the asphalt bid price is $61.85/ton and the concrete bid price is $31.94/square yard. While the state gets slightly less asphalt for the same $50 million budget, it gets an additional 508,000 square yards of concrete, which totals an additional 51 lane miles of pavement.

Table 1: Break-even analysis for $50 million per year budget for pavements

Budget ($M)	Asphalt. Market Share	Asphalt Expend. ($ M)	Asphalt Unit Price	Tons of Asphalt	Conc. Expend. ($M)	Concrete Unit Price	Square Yards Concrete
$50	95%	$47.5	$78.72	603,404 158 lane miles	$2.5 Total = 164 lanes miles	$63.71	39,240 6 lane miles
$50	65%	$32.5	$61.85	525,465 137 lane miles	$17.5 Total = 214 lanes miles	$31.94	547,902 78 lane miles

Improving Pavement Designs:

While the above is good information and provides the impetus for the introduction of more competition, implementing such a change can meet resistance because concrete is often perceived as too expensive and only applicable to new construction. However, over the last 15 to 20 years, the concrete pavement industry has worked with groups such as AASHTO to improve design practices and develop concrete solutions for all applications, not just new construction.

Using Pavement ME and Life Cycle Cost Analysis to Optimize Designs

In 2011, AASHTO adopted the Mechanistic Empirical Pavement Design Guide (MEPDG) as its official pavement design procedure. Unlike other pavement design procedures that determine only thickness, MEPDG and its companion software package, Pavement ME, predicts performance for key design distresses such as cracking, faulting and roughness. This ability to predict pavement performance for specific, individual designs over the analysis period allows the design engineers to perform trade-off analyses of features, such as extra thickness, widened lanes, stronger concrete, or others to determine which features offer the most benefit for improving performance. For example, the engineer can analyze a 12-inch jointed plain concrete pavement (JPCP) design with 15 foot joint spacing and an asphalt shoulder and compare its predicted performance to that of a 10-inch JPCP design with widened lanes and shorter joint spacing to see which will perform the best. (Based on this author's experience, the second design will be better and will cost less).

To improve the process even further, design engineers can combine the Pavement ME results with Life Cycle Cost Analysis to analyze the cost of the different design features to establish which features actually bring the most VALUE to the project. That is, there are many features that impact pavement performance (see Table 2), but each comes at a different cost. By developing and analyzing the cost impacts of the various features, and then combining them with a predicted performance impacts from Pavement ME, the designer can determine whether or not the extended performance is worth the additional costs. For example, if a feature adds five years to the performance, but it adds 20% additional cost, it is probably not cost effective. There are other design features that can be used to improve performance at a lower cost. Using Pavement ME and LCCA in this iterative manner helps ensure that the right features are used for a given project, without over-designing and raising costs.

Table 2: Optimizing Considerations for Concrete Pavements

Feature	Benefit or Options
Use appropriate sized dowels	Improves and ensures long-term load transfer. Use 1.25-in dowels for pavements less than 10 inches and 1.5-in dowels for pavements 10 inches or greater
Use 13-ft Widened Outside Lanes	Shifts loading to "interior loading" (reduces thickness)
Change Pavement Type	JPCP vs CRCP vs RCC vs various Asphalt
Shorten Joint Spacing	Reduces curling & warping stresses (reduces thickness but does increase joint sawing and dowel costs)
Change Shoulder Design	Concrete vs AC vs RCC; reduced /tapered thickness; no dowels; different mix, etc.
Optimized aggregate gradation	Reduces cement content and creates denser mix. Improves durability and reduces shrinkage
Use different concrete mixes	Mainline vs shoulder mixes, 2-layer construction, high early(2 to 6 hours) vs early opening (6 to 24 hours) vs normal strength.
Change base type	Granular vs asphalt treated vs cement treated ; reduce thickness,: Dense graded vs permeable; fabrics/geotextiles
Use narrow single saw cut & filled (not sealed)	Removes second sawing operation; reduces noise, minimizes intrusion of large incompressibles and water
Use longitudinal textures	Use longitudinal tining or diamond grinding. Reduces noise
Change Subgrade Stabilization	None vs lime vs lime/cement vs cement vs cement/FA, etc

Cement and Concrete based Pavement Solutions

A final way that an agency can increase competition is to recognize that there are viable cement- and concrete-based paving solutions that can be applied to all types of pavements – asphalt, concrete and composite – at any stage or condition. Table 3 lists viable concrete and asphalt treatment solutions, from simple preservation to overlays to reconstruction that can be used on any pavement application – highways, streets, local roads, airports, ports or parking lots – in any rural or urban setting. As agencies and owners develop their plans and programs for projects, they should apply a forward-looking approach and evaluate all viable options to determine the best options for the given situation. Sometimes it will be asphalt, but sometimes it will be a cement- or concrete-based solution. Only by actively looking for concrete and asphalt solutions can an agency signal to both industries that they are serious about spurring competition between industries. That is, by committing to a process that gets both industries involved in the program, they will incentivize both industries to innovate further due to the spirited competition within the agency's program.

Of all the treatment options in Table 3, the three that have the most potential to provide the biggest impact in improving a pavement network are: 1) Concrete Overlays of asphalt pavements, 2) Roller Compacted Concrete (RCC) and 3) Full Depth Reclamation (FDR) with Cement.

Concrete Overlays - Concrete overlays have been, and can be placed over both existing concrete and asphalt pavements as a rehabilitation technique in all applications such as residential streets and low-volume roads, intersections, general aviation pavements, and parking areas. Depending on the need and type used, concrete overlays can extend a pavement's life from as little as 10 to 15 years to as much as 40 years or more – it all depends on the project needs and requirements. In the US, concrete overlays have been in use since 1919, and over the last 8 to 10 years, they have come to account for about 15% of all concrete pavements placed.

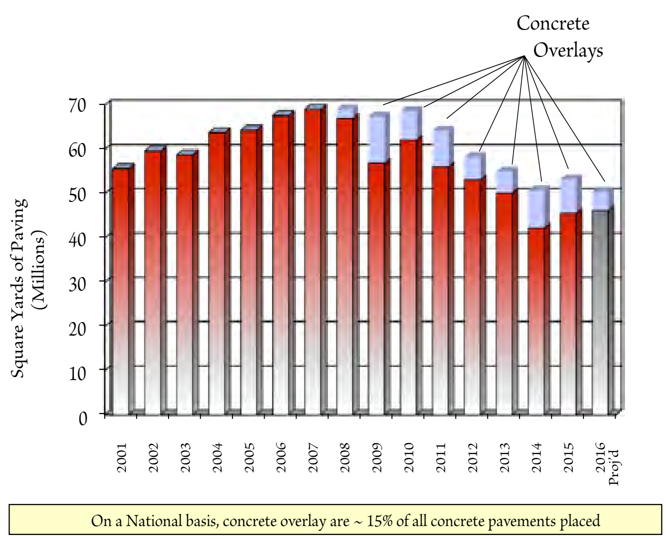


Figure 2. Concrete overlay use in the US. The increase in use shows that these are cost-effective and performing well

Table 3: Treatment Options for Concrete and Asphalt Pavements

Treatments applicable to Concrete Pavements

Category		Treatment Techniques	Materl. Used	Perform Period*
Preservation	Preventive maintenance	Crack/joint sealing	AC	5-10
		Partial / full-depth repair and Slab replacement	**PCC**	**5-15**
	Corrective maintenance	Concrete patch using asphalt	AC	1-3
		Joint LTE restoration	-	**5-15**
		Diamond grinding & grooving	-	**10-15**
	Minor Rehabilitation	Thin asphalt overlay (2-4")	AC	5-15
		Bonded concrete overlay (2-4")	**PCC**	**10-20**
		Thin concrete overlay (4-8")	**PCC**	**10-20+**
		RCC overlay (4-8")	**RCC**	**10-20+**
Major Rehabilitation		Asphalt overlay (4-8")	AC	5-20
		Asphalt overlay (>8")	AC	10-20
		Concrete overlay (8-12")	**PCC**	**20-35+**
		RCC overlay (>8")	**RCC**	**15-25+**
Reconstruction		New asphalt	AC	10-20
		New concrete	**PCC**	**25-35+**
		New Roller Compacted Concrete	**RCC**	**15-30+**

Treatments applicable to Asphalt & Composite Pavements

Category		Treatment Techniques	Materl. Used	Perform Period*
Preservation	Preventive maintenance	Seals (chip/fog/slurry/micro-)	AC	1-5
		Asphalt Rejuvenation	AC	1-5
	Corrective maintenance	Asphalt Patching/Pothole filling	AC	1-5
	Minor Rehabilitation	Asphalt cold/hot in place recycling	AC	5-10
		Open gradation friction course	AC	5-10
		Full Depth Reclamation w/ cement	**AC**	**10-20**
		Mill / Thin Asphalt overlay (2-4")	AC	5-15
		Thin asphalt overlay (2-4")	AC	8-15
		Ultrathin concrete overlay (2-4")	**PCC**	**8-15**
		Thin concrete overlay (4-8")	**PCC**	**10-20+**
		RCC overlay (4-8")	**RCC**	**10-20+**
Major Rehabilitation		Asphalt overlay (4-8")	AC	5-20
		Asphalt overlay (>8")	AC	10-20
		Concrete overlay (8-12")	**PCC**	**20-35+**
		RCC overlay (>8")	**RCC**	**15-25+**
Reconstruction		New asphalt	AC	10-20
		New concrete	**PCC**	**25-35+**
		New Roller Compacted Concrete	**RCC**	**15-30+**

AC = Asphalt Concrete, PCC = Portland Cement Concrete, RCC = Roller Compacted Concrete

Concrete overlays can be classified according to whether they are bonded or unbonded to the underlying layer. Bonded overlays of asphalt (also known as thin whitetopping) are a 4 to 6 inch overlay placed on the prepared surface of an existing asphalt pavement. They are used when existing pavement is in good structural condition, but has some surface distress. Because bonded overlays of asphalt act as a composite pavement system where the concrete and asphalt share the load-carrying capacity of the pavement system, there needs to be enough asphalt (about 3 inches – more is better) for a good performance. These overlays also often contain fibers that hold tightly together the small cracks that develop. The overlays also use shorter joint spacing, typically between 3 or 6 feet, to minimize environmental stresses. The one caveat is that a four-foot joint spacing should not be used as this puts a joint in the vehicle wheel path.

Unbonded overlays of asphalt (also known as conventional whitetopping) are 6 inch or greater overlays on top of an existing asphalt pavement. They are used when an existing pavement is badly deteriorated, but the removal of existing pavement layers is not desirable or required, and where elevations in the pavement are not an issue (i.e. rural applications). In this case, the existing asphalt is treated as a stabilized base course and the new overlay is essentially a new concrete pavement on a strong base. While the typical thicknesses of unbonded overlays of asphalt for low-volume traffic applications are between 5 and 7 inches, they can get up to 11 inches for high-volume, heavy traffic applications.

Roller Compacted Concrete – RCC is a no-slump concrete that is placed by an asphalt paver and compacted with vibratory rollers similar to asphalt pavement construction. RCC pavements are strong, dense, and durable; and are often at parity or even lower in cost than other pavement solutions. These characteristics, combined with quick construction speed have made RCC pavements an excellent pavement for ports, intermodal, and military facilities, container yards, and manufacturing plants. Recently, RCC use has expanded to local roads, streets, parking lots, distribution lots and even highway shoulder applications.

With similar strength properties, RCC also has same basic ingredients as conventional concrete – well-graded aggregates, cementitious materials, and water – but with different mixture proportions. The biggest difference between RCC mixtures and conventional concrete mixtures is that RCC has a higher percentage of fine aggregates, which allows for tight packing and consolidation. RCC is typically placed with an asphalt-type paver equipped with a standard or high-density screed, followed by a combination of passes with rollers for compaction. Final compaction is generally achieved within one hour of mixing. Unlike conventional concrete pavements, RCC pavements are constructed without forms, dowels, or reinforcing steel. Joint sawing is still required, but transverse joints are typically spaced a bit farther apart than with conventional concrete pavements. RCC's chief advantage over other concrete pavement options is that gains strength faster and can be opened to traffic typically within 24 hours.

Figure 3: RCC Construction on Lamesa Drive, Midland, TX - 2014

Full Depth Reclamation (FDR) with Cement – FDR with cement is a rehabilitation method for an existing asphalt pavement that involves recycling the existing asphalt pavement and its underlying layer(s) into a new base layer. The FDR process begins with using a road reclaimer to pulverize an existing asphalt pavement and a portion of the underlying base, subbase, and/or subgrade. The pulverized material is then uniformly blended with cement to provide an upgraded, homogeneous material. Finally, the stabilized material is compacted in place with rollers. The result is a stiff, stabilized base that is ready for a new concrete or asphalt surface course.

Because FDR uses and recycles the in-place materials, the existing pavement does not need to be removed from the site (note: sometimes a small amount of material is removed to retain the existing elevation). Full-depth reclamation also reduces the amount of new material to be hauled to the site compared with methods that require granular material to be trucked to the site. By limiting the effort involved in removing and disposing of existing material and in hauling and placing new material, FDR saves time and money, minimizing hauling and labor costs compared with remove-and-replace construction methods.

The primary advantage of FDR with cement is that it increases the structural capacity of the new roadway by providing a stronger and more consistent base. The strong uniform support provided by FDR with cement results in reduced stresses on the subgrade, particularly when the surface course is asphalt, which in turn reduces potholes, and road roughness. The stiffer base also reduces deflections due to traffic loads, resulting in lower strains on an asphalt surface, which delays such surface distresses as fatigue cracking, and extends the pavement life.

Figure 4: Full Depth Reclamation with Cement on the Crowley Terminal Facilities in Puerto Rico

Summary

It is in the best interest of Puerto Rico to ensure that more than one industry participates in its paving program. Research and history has shown that sustained long-term competition among material industries adds more contractors and another level of competition to the bidding process, which lowers paving costs. However, to benefit from competition, agencies must make a conscience choice to implement policies that increase competition for individual projects. There are two ways to help agencies instill competition at the individual project level.

The first is for agencies to design concrete pavement using the AASHTO Pavement ME design procedure to predict the pavement's performance under different features and combine with the Life Cycle Cost Analysis in an iterative manner to produce a trade-off analysis of the features used to see which design features provide the best value at the lowest cost.

The second, is to open up the sets of treatment alternatives that they, the agencies, will accept. Although concrete is often only considered for new construction, over the last 15 to 20 years the concrete pavement industry has developed viable concrete- and cement-based treatments for both concrete and asphalt pavements that can be used on any pavement application in any condition. Three of the most promising and upcoming techniques that have the most potential to improve an agency's pavement network are 1) Concrete Overlays, 2) Roller Compacted Concrete (RCC) and 3) Full Depth Reclamation (FDR) with Cement.

By using these design process and opening up the options under evaluation, designers can remove the over-design that has characterized concrete pavement designs in the past, thus making them affordable. This then gives agencies and owners the opportunity to use market dynamics in a way that leverages the free market to the advantage of Puerto Rico and their taxpayers.

BIOGRAPHICAL NOTES

Jim Mack joined CEMEX in September 2007 as Director, Market Development. In this position, he works with state DOT's, cities, counties and other professionals to identify and develop cement and concrete opportunities and improved concrete pavement designs for highways, airports, streets, parking lots, and other applications. He has 27 years of pavement engineering experience with expertise is in concrete pavement design, rehabilitation and maintenance; construction; forensic evaluation; pavement management; materials specification and evaluation; and life cycle cost analysis and life cycle assessment (environmental impact).

Mr. Mack is currently the Technical Co-chair overseeing the pavement research on life cycle analysis at the Massachusetts Institute of Technology (MIT) Concrete Sustainability Hub. He is on the American Concrete Pavement Association (ACPA) board of directors and will be its chairman in 2019. He was recently awarded the Eldon J. Yoder Outstanding Paper Award for the 11th International Conference on Concrete Pavements held San Antonio, TX for his paper titled "Improving Network Investment Results by Implementing Competition and Asset Management in the Pavement Type Selection Process."

Mr. Mack holds a Master of Business Administration from the University of Chicago Graduate School of Business and a Master of Science in Civil / Pavement Engineering from the University of Illinois at Urbana-Champaign as well as a Bachelor of Science degree in Civil Engineering from the University of Illinois at Urbana-Champaign.

Arturo Rosario joined CEMEX in November 2010 as infrastructure and housing manager, promoting concrete applications in pavements for local municipalities, the Department of Transportation and Public Works (DTOP), and private industry. In 2012, Mr. Rosario led a team with the Puerto Rico Highway Authority to develop the PRHTA Special Provision 974 for Roller Compacted Concrete Pavements Applications and simultaneously constructed a pilot project in the dedicated bus lane of Ponce De Leon Avenue in San Juan. Over the last seven years, he has supervised the construction of more than 2,000,000 square feet of concrete pavements in commercial, residential, highway and airport applications. Currently, Mr. Rosario is finishing a full depth reclamation with cement project of roughly 600,000 square feet in the Crowley Terminal in San Juan, among other projects. Mr. Rosario has 17 years of construction experience in commercial, residential, high-rise buildings, and concrete pavements. Currently he is the president of the Youth Committee for the Associated General Contractors of America and president of the Concrete Pavement Committee for the *Asociación Puertorriqueña del Concreto* (Puerto Rico Ready Mix Association). Mr. Rosario holds a Bachelor of Science degree in Civil Engineering from University of Puerto Rico, Mayagüez (RUM).

THE CHANGING ROLE FOR SURVEYING IN MODERN LAND TENURE SYSTEMS

George M. Cole, PhD

Abstract

Cadastral systems for protection of land rights as well as for equitable assessment of land taxes are important components of the economic systems of today's advanced societies. With the adoption of geographic information systems as a base for such systems that have allowed the inclusion of additional land-based information, cadastral systems have become essential to orderly and efficient land use. This writing describes the systems and the evolving role of land surveying as well as surveying education created by their use.

Resumen

Los sistemas catastrales para la protección del derecho a la tierra, así como aquellos para la distribución equitativa de los impuestos prediales, son componentes importantes para un sistema económico de las sociedades avanzadas. Con la adopción de las Sistemas de Información Geográfica (GIS por sus siglas en inglés) como base para dichos sistemas económicos, el GIS se ha convertido en materia esencial para el uso eficiente y ordenado de la tierra. Este a su vez ha permitido la inclusión de información adicional relacionada a la tierra. Además de describir estos sistemas, este escrito detalla el rol evolutivo de la agrimensura, así como la educación en agrimensura que ha sido creada utilizando estas herramientas.

Background

"Mankind has always had a special relationship with the land, and with good reason since it is a primary key to existence. Land serves as the basic platform for life and source of nourishment, shelter and energy for mankind. It also serves as the basis of income for humans. Reflecting this, we often call land 'Mother Earth.' As a result of the special relationship with and dependence on land, humans have long had a tendency to claim exclusive rights over tracts of land that they occupy…" (Cole & Wilson 2016)

Presumably, early humans relied on physical force to defend their claimed territory as is the case with various other animal species. But very early in human history, a process of using the legal system to defend claimed territory was developed. In most advanced societies today, key elements of that legal defense are preparation of unique descriptions for parcels of land that form the bases for recording or registering land claims in a central database called a cadastral system. That public notice of a claim to a specific parcel of land allows utilization of the legal system for defense of the claim as opposed to physical defense and has allowed for the orderly possession and use of land.

In addition to protecting ownership claims, the process of representing land with a written description and the system for protecting claims to land described in this manner have allowed the trading of interests in land and of using such interests as collateral for loans. This has provided the basis for the advanced economy of most developed nations (De Soto 2000).

Modern Cadastral Systems

As described in Cole and Wilson (2016), a **cadastral system** is a comprehensive register of the real property of a country or any other designated area. It generally employs the use of a cadastral map, or cadastral survey. It also generally includes details of ownership, tenure, land use, area, and parcel values. Modern systems also include the precise location of parcels using geographical coordinates. Cadastres are traditionally classified as either juridical or fiscal cadastres. **Juridical cadastres** serve as repositories or registries of ownership and other land rights. These include **land records recordation systems** which serve as simple public repositories of various land records and more complex **land registration systems** which not only record but also warrant title. As opposed to juridical cadastres which are for the purpose of protection of land rights, **fiscal cadastres** serve as the basis for the comprehensive, equitable, and accurate taxation of land.

Internationally, **land registration systems** are the most common type of juridical cadastres. Such systems serve two functions. They allow interested parties to see who owns what and, in addition, they provide a registration of title or certification of ownership for each land parcel. Such cadastres are primarily for the purpose of security of title and not for apportionment of taxes. Since land registration systems involve certification of ownership for land parcels, it is important that such cadastres include ownership information for all land units in the covered area. As a result, land registration systems need a map element to insure complete coverage.

Within almost all of the mainland United States, rather than a land registration system, a more basic type of juridical cadastre, a **land records recordation system,** is utilized. Such a system is basically a public filing system for records dealing with title to land. Such records include deeds, easements, mortgages, liens, leases, and similar documents. Typically, formal subdivision plats (plans or cadastral maps) are also recorded in these systems as are probate records for wills and other judicial actions affecting land ownership. As with land registration systems, land records recording systems are primarily for the purpose of providing security of title rather than apportionment of taxes. Land records recordation systems provide public notice of ownership, leaving evaluation of the validity of that claim up to the individual land owner on a need basis. The function of such systems is to make available to the public all information concerning interests in real estate. Land records recordation systems, as typically structured in the United States, do not guarantee validity of title. Rather, by making deeds and other documents affecting land title publicly available, they provide constructive notice of ownership. By providing a database of land title records, such a system allows for searches to examine and determine the validity of any competing claims. Land records recordation systems typically do not have an associated cartographic element since they are basically a filing system. Within the mainland United States, juridical systems are located in each county, typically in the office of the County Clerk of Court.

As opposed to the land registration or land records recordation systems which exist primarily for the purpose of providing security of title, a **fiscal cadastre** is one with the primary purpose of apportioning taxes. Such a system is basically a file of all land parcels within the system's jurisdiction with information on ownership and various factors regarding the land that would affect its value. An essential component of most fiscal cadastres is a map of all of the land parcels in the jurisdiction. Thus, unlike the land records recordation system, a fiscal cadastre typically has a cartographic component. As with juridical cadastres, fiscal cadastres in the United States are typically decentralized and located in the office of the county tax assessor/property appraiser. The fiscal cadastre and land records recordation systems are typically very closely coordinated and traditionally co-located in the county court house.

The typical fiscal cadastre has two major components: a property map depicting the location and configuration of each parcel in the jurisdiction and an appraisal file for each parcel. The main purpose of the property map is to depict the boundaries of parcels. In addition to parcel boundaries, such maps may or may not also depict structures on the parcels. Usually this map is photo-based. Such a map is designed to insure that all land is accounted for in the taxation system and also to allow detection of overlapping parcels to prevent double taxation.

For jurisdictions such as Puerto Rico that use a land registration system as opposed to a land records recordation system, conflicts between that system and the fiscal cadastre (maintained for tax purposes) may occur. Both systems have a cartographic element and it is obviously critical that maps used for both purposes agree. Ideally, the same map should be used for both purposes. Yet, since the land registration and tax assessment processes typically involve different government entities, coordination can sometimes be a difficult task.

Modern technology has made significant changes in cadastral systems. Possibly the most significant change is the almost universal use of geographic information systems (GIS). Such systems allow for far easier development and maintenance, and also allow systematic referencing of information associated with each parcel in the map. As an example, use of a GIS as a basis of a fiscal cadastral map allows connections to land value information for each parcel. In addition, it allows overlaying of aerial photography, topography, soil maps, wetland maps, and other data pertinent to determining the value of the property.

In addition, use of a GIS as a basis allows for widespread use of the parcel map for purposes other than taxation since it allows the display and analysis of multiple layers of data. Since the cadastral parcel is the basic spatial unit of most human activity, a cadastral map can serve as an ideal base map for many other aspects of society. Therefore a parcel-based land information system may serve a wide range of users. These may include serving as a basis for planning and zoning, for disaster impact assessment, for emergency response, as well as use for elections, school districting, agriculture, insurance, retail sales and many other land-based activities. Such GIS-based cadastral systems also have the advantage of being able to depict interests in land other than ownership by incorporating various administrative and judicial records associated with land use regulation and restrictions. Among others, these include FEMA flood zones which may restrict development, wetlands which may restrict land use, land use classifications, subdivision regulations, and many others. Information regarding such interests allows determination of what can be done with a parcel of land as well as who has the power to regulate.

One result of GIS-based cadastral systems is that the value of the systems to areas of society other than property registry and tax assessment can actually far outweigh the original purpose. As a result, many governmental organizational changes have resulted from this trend. Another result is a trend towards open access to the information contained in these systems through the internet.

Implications for Puerto Rico

Because of the importance of multipurpose GIS-based cadastral systems to an advanced economy, such systems have significant implications for Puerto Rico today. As this is written, the island is in the throes of a severe financial crisis. Yet, the island is rich in unused land resources as well as having many other advantages associated with a beautiful tropical island. Having well-functioning GIS-based cadastral systems is therefore central to the efficient use of the island's land resources for economic development.

In Puerto Rico today, a juridical cadastre for voluntary property registry, the *Registro de la Propiedad*, exists in the Justice Department. In addition, a fiscal cadastre for tax assessment purposes, is administered by the *Centro de Recaudacion de Ingresos Municipales (CRIM)*. The latter entity is directed by a Board of Directors that includes seven municipal mayors, the President of the Government Development Bank and the Commissioner for the Office of Municipal Affairs. Unfortunately, the two entities are generally seen as unrelated entities today with numerous discrepancies reportedly existing between the two systems (Bryan ca. 2000). Further, there is currently not a connection of related land-use information between the two systems.

Yet, in 2014, the creation of a multipurpose geographic information system, El Sistema de Información Geospacial del Estado Libre Asociado de Puerto Rico (SIGELA) was authorized by Law 184 of November 10, 2014 to be created in the Office of the Land Surveyor within the Office of Permits Management (Oficina de Gerencia de Permisos). That system is intended to incorporate all geospatial information produced by government agencies and municipalities, including cadastral information. The new system will be linked to the CRIM fiscal cadastral system and also will contain all of the juridical cadastral information in the Registro de la Propiedad. Therefore, if the system is developed as planned, it will serve as a basis for a multi-purpose GIS-based cadastral system. As a result, if the SIGELA is implemented as planned, it offers significant promise as an aid to the economic recovery of Puerto Rico. It is noted that since February of 2017, the position of Director of the Office of Land Surveyor has been vacant, and the SIGELA program was transferred to the IT Office of the Puerto Rican Planning Board.

Traditional Roles of Surveying in Land Tenure Systems

Land Surveying has always played a major role in such land tenure systems. The most basic surveying function is the **subdivision of raw land** into parcels with unique identifiers. An example of this is the United States Public Land Survey System where a large percentage of the North American continent was subdivided into sellable lots to encourage settlement and generate revenue for the nation. Associated with the subdivision process, another traditional role of land surveying has been the **preparation of land descriptions** that are sufficient to represent the land in various legal transactions such as buying and selling, serving as collateral for loans, and appropriate taxation. Such descriptions must also allow for the precise location of the limits of a parcel of land for many years after it is written. The **demarcation or monumentation of boundaries** for land management purposes has always been another traditional role for surveying. And perhaps the most common traditional role of land surveyors is the field location of land that has been previously surveyed and for which either a graphic or written description exists based on the original survey, otherwise known as **retracement surveys**.

The Changing Role of Surveying for Cadastral Systems

The widespread use of cadastral systems as the basis for multi-purpose geographic information systems (GIS) has had significant effect on the role of land surveying. Land surveying practice has always been at the very heart of land tenure and cadastral systems with the previously discussed functions such as subdivision of land, preparation of land descriptions, interpretation of land descriptions, and the plotting of those descriptions. Yet, with the advent of multipurpose GIS based cadastral systems, the role for surveying has expanded considerably.

To function correctly, all of the layers of data with such a system must be based on a common geographic coordinate system based on the same spheroid and datum. Further, since modern geodetic science has recognized that the land masses of the earth are in a state of continual flux due to tectonic motion, this adds additional complexity. As a result, for a precise GIS, all coordinates entered must be based on a specific epoch as well as the same spheroid and datum. Standards must therefore be developed for data as well as for informing users of the level of precision associated with various layers of information. This means that surveyors must insure that their work products meet those standards. Further, the initial development of a multi-purpose GIS based cadastral system, including the manipulation of large data sets, as well as the interpretation and plotting of land descriptions required for continuing maintenance of the system all require contemporary surveying and mapping skills.

Changes for Surveying Education

Surveying education has traditionally and must continue to include coverage of measurement technology. Nevertheless, it should be understood that of all the knowledge used by the surveying profession, use of technology is the least durable. Due to constantly changing technology, that knowledge must be constantly updated throughout a surveyor's career. Therefore, both academic-based education prior to registration as well as continuing education throughout a surveyor's career is important to keep abreast of the latest measurement technology.

Yet, more important than measurement technology is the need of a solid grounding in boundary surveying, land tenure and the overall land tenure system in our modern society. Those activities were the very origin of land surveying and play an even more critical role now with the value of land and the sophistication of modern cadastral systems. Further, with the increasingly broad and important role that multipurpose cadastral systems are playing in modern society, surveyors need an understanding of the relationship between surveying, land tenure and cadastral systems in modern capitalistic society. Very often, those processes are considered separately. Nevertheless, they are very much inter-related, and none of these processes may be completely understood without an understanding of the others. This is especially true considering the advent of georeferenced cadastral maps reflecting the location of land parcels relative to many other components of the physical and legal infrastructure.

With the advent of georeferenced GIS, the role for surveying has expanded to include the provision of geographical coordinates in addition to the traditional products of boundary surveying. This requires knowledge of modern geodetic science as well as that of traditional cadastral surveying. While geodesy has always been a basic element of survey education, greater emphasis needs to be placed on this topic since it will be increasingly used for almost all surveying products. Further, since modern geodesy recognizes the dynamic nature of the earth's land masses, it is important that surveyors understand that all positions have a forth dimension – time. That understanding will help to ensure that all elements in a georeferenced cadastral GIS are based on coordinates for the same epoch.

Surveyors also need to be well-versed in data management techniques. Modern surveying systems produce huge sets of data. It is critical that surveyors have the knowledge and ability to manage those data for optimum use of modern survey technology. Related to data management is the graphic portrayal of surveys. Portrayal of survey data has evolved considerably with time – from hand drawn sketches to computer assisted drafting (CAD) and more recently to geographic information systems (GIS). If the surveying profession is to continue to have the ability to not only have the responsibility for determining boundaries but also to portray the results of those boundaries, the education process must include a solid grounding in all aspects of handing the data resulting from field surveys as well as in portraying those data in various evolving systems such as GIS.

In addition, surveying education needs to include training in the best use of the various administrative and judicial records associated with land use regulation and restrictions that may now be depicted in multi-use cadastral systems. Proper use of such data will allow surveyors to provide far more useful surveys for land owners.

The original role of land surveying was boundary surveying. Today, that function is sometimes overlooked with the exciting new measurement technologies. Nevertheless, that function continues to be the most critical function of surveying to our modern economy. Thus it is important that surveyors have a good understanding of that process as well as the systems in which boundary surveying information is used to protect ownership and to serve as the basis for our society today. It is therefore important that surveying education continue to prepare surveyors to fulfill their role in these systems. We most closely examine the survey education process to insure that it serves all of the needs of society today.

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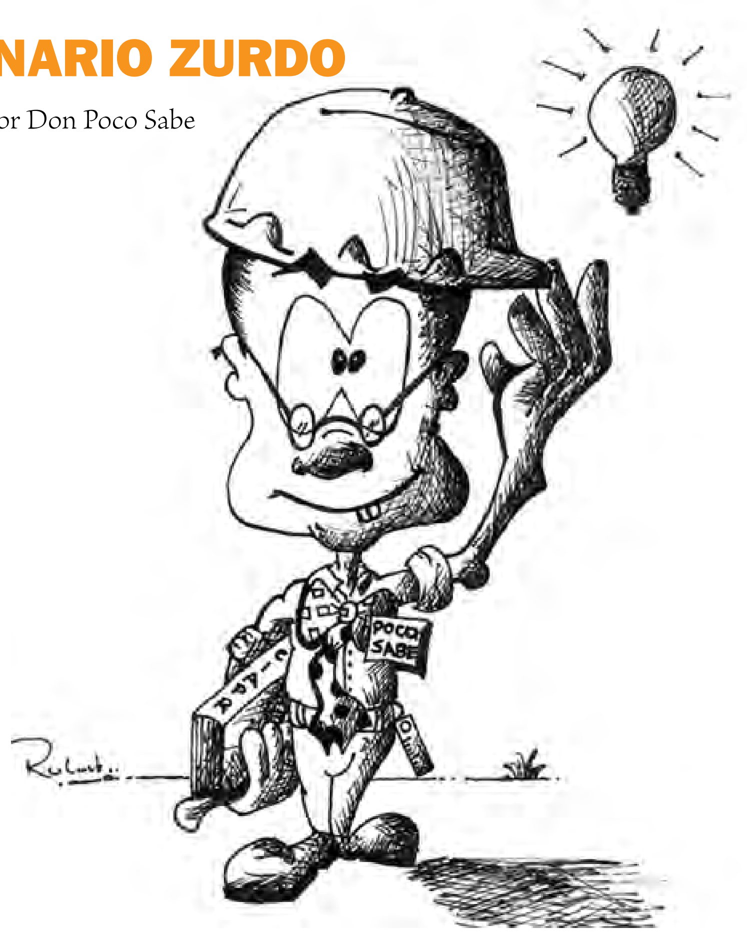
BIOGRAPHICAL NOTES

George M. Cole is a professional surveyor, engineer, and geographer. His background includes service as a commissioned officer (final rank Lt. Commander) of the U.S. Coast & Geodetic Survey (now NOAA); as the State Cadastral Surveyor for Florida; as a private consultant directing private surveying and mapping operations in both the United States and Latin America; and as a visiting professor at the University of Puerto Rico. Currently he serves as an adjunct professor at Florida State University and the University of Puerto Rico.

Dr. Cole has served as technical advisor to several states on boundary issues; and has provided expert testimony in a number of local, state and federal courts, including a special master of the US Supreme Court. He also has made significant contributions to professional literature and is the author of several surveying textbooks (with notable examples being *Water Boundaries*, John Wiley & Sons, *Surveyor Reference Manual*, Professional Publications, 2009, and *Land Tenure, Boundary Surveying and Cadastral Systems* (with Don Wilson), CRC Press, 2016). Cole holds a bachelor of science degree in mathematics from Tulane University as well as master of science and doctor of philosophy degrees in geography from Florida State University

DICCIONARIO ZURDO

por Don Poco Sabe



21 de julio de 2017

En estos tiempos algo difíciles para nuestra querida **Aguacatinia,** vemos a muchos autóctonos **aguacates** teniendo que salir a buscárselas fuera de los límites territoriales de nuestro archipiélago (como nos llama **Aguacatazo**, un estudioso de la historia que publica muchas curiosidades sobre la historia de nuestra jurisdicción territorial). La gran mayoría de los viajeros van a jurisdicciones de habla **shakespeariana,** donde es menester conocer suficiente de esa lengua. Aunque los estudios del **shakespeariano** son obligatorios en **Aguacatinia** desde los grados primarios, muchos **aguacates** no parecen dominarlo a cabalidad. **Don Poco**, quien luego de haberse retirado de la **alquimia dimensionaria** ha desarrollado una pequeña práctica de traducciones e interpretación entre los dos lenguajes, ha tenido muchas experiencias interesantes viviendo en el continente. Muchas de las destrezas que se necesitan para su nueva práctica las adquirió al tropezar con las diferencias entre lo que había aprendido y cómo se habla el **shakespeariano** en realidad. Aquí veremos unos cuantos consejos para atender situaciones frecuentes en las que los viajeros se pueden encontrar, a veces de sorpresa, estar inmersos en el habla **shakesperiana**.

Pronunciación de la vocal "i" y la combinación "ee": por alguna razón, en la época que don Poco estudió sus grados primarios, no pudo captar la diferencia en la pronunciación entre la "i" y la doble e, como en *ship* y *sheep*. La primera tiene un sonido corto, casi como la "e" de **Lares** cuando la pronuncia un **aguacate** originario de esa jurisdicción. La segunda se pronuncia como cualquier "i" del **cervantino**. No saber diferenciar entre esos dos sonidos nos puede hacer sonar como si estuviéramos diciendo oveja cuando estamos queriendo decir barco (una es *sheep*, la otra *ship*), o salchicha cuando queremos decir ganador (una es *wiener*, la otra *winner*), y aún peor, como si estuviéramos hablando de la sábana del toro cuando quisiéramos referirnos a algo como la caca de toro, expresión común en **shakespeariano** cuando consideramos una expresión o idea como falsa o inane. Don Poco lo ha exclamado muchas veces al ver escritos sobre los "horrorosos" daños a la naturaleza y a la salud de toda **Aguacatinia** que pueden causar los residuos de la quema del carbón, luego de ser puestos bajo tierra siguiendo las especificaciones que manda la ley, por muchos **ambientalistos** —que son más políticos que expertos en el ambiente— para causar desasosiego y ventaja política entre la gente común que confía en sus "conocimientos" pseudocientíficos.

Pronunciación de la combinación "oo": Esta es más complicada, y requiere de mucha atención, oído entrenado y buena memoria. Un ejemplo de confusión involuntaria frecuente es entre la pronunciación de los vocablos **shakespearianos** *kook* y *cook*. Si usted no tiene el cuidado, o el oído entrenado, puede que insulte al cocinero, diciéndole que es un gran tonto cuando en realidad lo que le quisiera decir es que es un gran cocinero. Hay muchos vocablos en los que la combinación "oo" se pronuncia parecido a la "u" en **cervantino** y aún más de ellos en los que los que pronuncia en una de las otras formas **shakespearianas.** Algunos vocablos de los que se pronuncian parecido a la "u" **cervantina** son: *toot*, *scoop, moot, spook, shoot…* Otras que suenan parecido entre ellas pero bien diferente a la u latina son: *book, cook, nook…* y si vas a hablar de sangre (*blood*), o inundación (*flood*), esas no se pronuncian ni como *kook* ni como *cook*, sino \'bləd\[1], en signos diacríticos.

1 Link: https://www.merriam-webster.com/dictionary/blood

DICCIONARIO ZURDO

Uso de las preposiciones *in, on* y *at*. Eso ha sido lo más difícil de aprender para don Poco. Quizás se debe a que en **cervantino** las preposición "en" es sumamente amplia, que denota en qué lugar, tiempo o modo se realiza lo expresado por el verbo a que se refiere (**mataburros** de la RAE[2]). En **shakespeariano** la cosa es diferente. Hace unos días don Poco vio en el **Libro-de-caras** a un **aguacate** publicando que estaba en la exhibición de perros de raza y escribió *"I'm in the dog show."* Pues en **shakespeariano** lo que se entendería es que está participando en la exhibición con su perro o ¡como perro! La expresión correcta debió ser *"I'm **at** the dog show"*. En **cervantino** no hay ninguna ambigüedad cuando decimos "estoy en la exhibición de perros de raza" o "estoy en la plaza en Juana Díaz" (en **shakespeariano** sería más correcto decir *"I am at the town square in Juana Díaz"* que *"I am in the town square in Juana Díaz"*). Para esta a don Poco no le parece haber una forma fácil de aprender su uso excepto leyendo y escuchando mucho.

Es difícil recordar todas estas tonalidades en las traducciones entre ambos lenguajes. El mejor consejo práctico que don Poco te puede ofrecer es que, en vez de tratar de aprender los signos diacríticos y tratar de descifrar pronunciaciones, que es difícil y confuso, debes escuchar atentamente cómo lo dicen los que hablan el **shakespeariano** como lengua materna, e imitarlo lo mejor que puedas, así te harás entender mejor, y estarás respetando la lengua **shakespeariana** tal como todos queremos que se respete nuestra lengua **cervantina.** Después de todo así es como aprendimos nuestra lengua materna.

Don Poco ha oído a muchos **aguacates** ofendidos porque un visitante, tratando de hablar **cervantino,** pronuncia o expresa sus ideas incorrectamente. Recuerda don Poco a un amigo que buscaba el Coliseo Gallístico en Isla Verde y le preguntó a un muchacho en la calle que "dónde era la guerra de los pollos". El muchacho, gracias a Dios, no se ofendió, y cuando se figuró lo que decía el visitante, le dio instrucciones para llegar al Coliseo. Apliquémonos el cuento cuando estemos hablando **shakespeariano**, especialmente fuera de **Aguacatinia**, para que nadie piense que no le respetamos su lengua, o tenga que figurarse qué diantres estamos diciendo.

Para oír pronunciaciones de vocablos en **shakespeariano** para los que no tengas la oportunidad de oír la pronunciación de parte de alguien que hable **shakespeariano** como lengua nativa**,** don Poco sugiere el diccionario Merriam-Webster[3] online.

2 Link: http://www.rae.es

3 Link: https://www.merriam-webster.com