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INTERAGENCY RESOURCES DIVISION
NATIONAL PARK SERVICE

United States Department of the Interior
National Park Service

National Register of Historic Places
Multiple Property Documentation Form

X New Submission ____ Amended Submission

A. Name of Multiple Property Listing

Historic Bridges of Puerto Rico, c. 1840 - 1950

B. Associated Historic Contexts

Land Transportation in Puerto Rico, c.1508 - 1950

C. Form Prepared by

name/title **Luis F. Pumarada O'Neill Ph.D., Industrial Archeologist**

organization **Arqueología Industrial Caribeña** date **July 31, 1994**

street & number **3-D-37 Villa Interamericana** telephone **(809) 264-4024**

city or town **San Germán** state **Puerto Rico** zip code **00683**

D. Certification

As the designated authority under the National Historic Preservation Act of 1966, as amended, I hereby certify that this documentation form meets the National Register documentation standards and sets forth requirements for the listing of related properties consistent with the National Register criteria. This submission meets the procedural and professional requirements set forth in 36 CFR Part 60 and the Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation. (___ See continuation sheet for additional comments.)

Arleen Pabón PhD, PRSHPO
Signature and title of certifying official

May 25, 1995
Date

Puerto Rico State Historic Preservation Office
State or Federal agency and bureau

I hereby certify that this multiple property documentation form has been approved by the National Register as a basis for evaluating related properties for listing in the National Register.

for Edson H. Beall 7-19-95

Signature of the Keeper Date

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SECTION E: ASSOCIATED HISTORIC CONTEXT

LAND TRANSPORTATION IN PUERTO RICO c. 1508-1950

INTRODUCTION

Geography and climate

Puerto Rico measures approximately 100 X 35 miles, with an area of 3,345 square miles (8,897 sq. km), yet more than three fourths of this area is mountainous and of rugged terrain.

Most rivers run north-south. Some important rivers are: Loiza, Plata, Arecibo, Manatí, Añasco and Guanajibo. In the southern coastal plains, most of the river beds are dry during the year, but heavy rains may produce dangerous flash floods.

The western part of the northern coastal plain is a karst region with sinkholes and bands of tower karst. This area has solution canyons, called **quebradas**, which are often significant obstacles in terms of transportation. The largest ones are: La Mala, Bellaca, Toro, Cedros, and Guajataca. The latter is traversed by the rivers of the same name. The only relatively large valley is the one in Caguas, an eroded batholith nearly south of San Juan.

GENERAL CONSIDERATIONS

Bridges in Puerto Rico for the most part were part of its highway and road system. Because of this one must study the development of the transportation system in the island in order to better understand the historical, social and engineering context for our bridges.

Highway construction in Puerto Rico has undergone periods of varied intensity depending on the population growth, economic and commercial activity, and the availability of funds. The enormous population growth during this century, the increase in economic and commercial needs, the importation of hundreds of thousands of motor vehicles, the trend towards modernization, and the availability of resources and credit, greatly accelerated the highway construction process.

The primary base of this network was drawn during the second half of the 19th century; many highways and bridges existed prior to the change in sovereignty that occurred in 1898. Nevertheless, only one fourth of the total length of paved highways existing by 1918 had been built during the Spanish Regime.[1]

THE SPANISH COLONY

The First Three Centuries

The first formal Spanish settlement in Puerto Rico was established in early in the sixteenth century under Juan Ponce de León. He founded the capital of the island, Caparra, in a region bordered by wetlands about two kilometers south of San Juan Bay. By the first half of the 16th century there existed a trail called

"Camino de Puerto Rico".[2] It connected the original site of San Germán, located at that time near the mouth of the Añasco River, with Caparra. This beaten road followed the course of the aforementioned river east to the present site of San Sebastián, going northward to the Arecibo region, and reaching Caparra after going through the Royal plantation of Toa, near the present site of Toa Alta. Most of this route traversed the northern slopes of the main mountain range, avoiding the broader rivers of the coastal plains. Its bridges must have been pieces of timber laid across the mountain streams.

Inaccessibility and mosquitoes forced the settlers to move to the dry, rocky island of San Juan, which is separated from the main island by the narrow San Antonio Channel. The island's first formal highway linked Caparra with the capital's new location. Built between 1518 and 1521, it included the first bridges of any significance built on the island. After Caparra was abandoned, this road remained the only land link between San Juan and the main island.

One of its two bridges spanned the San Antonio Channel. The original San Antonio bridge, a stone causeway, was erected between 1519 and 1521. The causeway left an open segment for water passage; it was spanned by a small wooden bridge. Since 1558, when a water aqueduct was built over this structure to bring water from a spring in Miramar to San Juan, it has been known as the **Puente del Agua**, "the water's bridge".

The English Earl of Cumberland's efforts to conquer Puerto Rico in 1598 crashed against the forces defending this strategic access, commanded by Spanish militia officer Bernabé de Serralta. Upon its reconstruction, following the attack, the bridge was built of stone except for a small span made of wood to permit disassembly for defensive reasons. In 1660 this small wooden part was constructed of stone, but the end of the bridge located in the San Juan island was integrated into a fort, **Fortín San Antonio**. People, animals and vehicles entering the San Juan Island had to cross its large, strong door, defended by soldiers and artillery.

The second bridge in the area was part of the San Juan-Caparra road and spanned a natural estuary channel. It was constructed at the same time as the San Antonio Bridge. Its first version was a submersible causeway; its construction is associated to the St. Jerome Order, enslaved Indians, and a colonist called Martín Peña, after whom both the bridge and the channel were later named. A wooden bridge was later built upon this causeway; in 1784, after many reconstructions and repairs, the bridge was built of masonry, following the design of Juan Francisco Mestre.

During the unsucessful English invasion of 1797, by General Ralph Abercromby and Admiral Harvey, the english forces destroyed this bridge in order to prevent its recapture by Spanish regular and militia forces.

The growth of Puerto Rico's Caucasian population became stagnant during the second third of the century, as many settlers left the island to join the conquest of Mexico and Perú. Meanwhile, its aboriginal population decreased rapidly and very few slaves were imported.

River crossings relied on fords, ferries and patience. Most transportation took place by means of barges along navigable stretches of rivers and by sailboats which circumnavigated the island.

No other permanent bridges were erected during first three hundred years of Spanish jurisdiction in Puerto Rico, as no other roads were constructed. The gold resources of the island were already depleted by the 1520s, cane sugar export industry, begun in the same decade, did not flourish at this time. At its peak it consisted of approximately ten small **haciendas**, located mostly along navigable rivers near San Juan: such as Toa (Plata), Puerto Nuevo, Bayamón, and Loíza. The two **haciendas** located in the interior of the island produced only molasses for local sweetening and distilling.

Transportation by land was mostly carried out on bridle paths and wagon trails that connected the towns to rivers and coastal ports. Many paths and trails occupied parcels of land officially owned by the Spanish Crown and were, thus, for public use. They were called **"caminos reales"** (royal roads).

During the first three hundred years of Spanish rule, the role of Puerto Rico was a minor one, except in military terms. The port of San Juan, remained a critical defensive link for the Spanish Caribbean and a key port in the routes of the mainland treasure fleets. Spain had fortified the port and all access routes to the city, starting in the 16th century, and maintained a detachment of soldiers that defended them successfully on several occasions. Meanwhile, the rest of the island remained sparsely settled. A small, scattered population survived by farming and smuggling. The largest settlements outside San Juan in the 16th century were San Germán, Aguada, and Coamo.

By the mid-seventeenth century, while San Juan became a heavily fortified city, the island's economic activity was limited to a few cattle ranches and a handful of small cane sugar and tobacco plantations, plus disperse logging and small-scale ginger and hog production for smuggling. The majority of the island's relatively few civilians relied on farming, mostly maize, rice, and plantains plus raising hogs and chickens, and on the abundant natural resources. The main settlements were either near the coast, such as Aguada, Añasco, Manatí, Arecibo, Tuna (Isabela), or in large valleys, such as San Sebastián, Río Piedras, San Germán, Utuado, and Coamo.

Economic growth begins

In 1765, Alejandro O'Reilly, a royal envoy sent to evaluate the economic conditions and potential of the island, recommended the construction of more highways and the improvement of the existing roads in order to make agriculture economically feasible inland in the fertile valleys and slopes. According to O'Reilly, royal roads developed hereon should be wider and served by bridges.

Spanish reform in 1778, allowed foreign immigrants to settle in Puerto Rico in return for their allegiance to Spain. Trade restrictions were also relaxed in an attempt to undercut contraband trading, and a 1765 cédula authorized seven ports, in addition to San Juan, to trade with the Spanish Caribbean. However, these were not provided with the necessary custom officials and were not able to export officially until 1804.

The last half of the 18th century saw the birth and eventual growth of successful export activities, centered on coffee, tobacco, and cane sugar. This contributed to, population growth, increased slave trade, and an expanded economy and trade. The growing population began to settle in the interior mountains, and generated the creation of towns such as Lares, Yauco, Las Piedras, Guaynabo, Caguas, Moca and Cayey. In the coast, new towns were founded close to navigable rivers or coves: Fajardo, Bayamón, Mayagüez, Rincón, Cabo Rojo, Guayama, Aguadilla, and La Vega.[3] In a period of only thirty-five years following O'Reilly's visit, in an economy boosted by changes in the monopolistic trade policies of Spain and in the development of coffee production and its exportation, more towns had been founded than in the preceding two and half centuries.

The new towns needed to communicate with the ports on the coast and with other communities. Thus, new paths were cut and roads were beaten, while others were widened to allow traversing by carriages and ox carts, and coastal shipping became more reliable.

Highway construction in the first half of the 19th century

The 19th century was a critical period in Puerto Rican history. It witnessed several conspiracies and revolts against Spanish rule, the development of a middle class, the rise of agrarian capitalism and large-scale export production, the rise of an immigrant commercial elite immersed in international trade, the settlement of the interior of the island and significant changes in terms of its population. As it came to an end, the island found itself under a new colonial sovereignty.

Stimulated by the 1804 opening of the ports and high market prices, sugar production extended from San Juan to the island. Coffee and tobacco plantations, as well as farms producing plantains, rice, and corn increased. Population growth accelerated, increasing the demand for production and trade. The Royal Decree of Favors of 1815 stimulated economic growth through a number of concessions regarding immigration, agriculture, trade, slavery, and industry. During the first decades of the 19th century, the Puerto Rican coastal plains became basically a sugar colony.

The structural changes occurring concurrently with economic and population growth required more and better transportation facilities. In the 1820s the colonial government improved San Juan's communications with the interior of the island. Governor Miguel de la Torre took the first steps toward the construction of a highway heading south from San Juan to Río Piedras; and opened a navigable channel to communicate the Cangrejos, San José and Piñones lagoons with the eastern part of the San Juan bay.[4]

By the 1830s, the island's economic, social, and political life had come to revolve around the production of sugar for export, with Ponce, Guayama, and Mayagüez leading in imports. Boosted by foreign capital investment, immigration of entrepreneurs, and the expanding sugar production, this decade was a time of accelerated population growth and economic, institutional and infrastructure development.

A wagon road was built during the decade linking Ponce, Juana Díaz and Coamo, the heartland of Puerto Rico's sugar production. But, on many occasions, while bridges and highways were being built and improved, torrential rains caused landslides and opened trenches and potholes in some points, trapping coaches and wagons and interrupting passage. Puerto Rico, due to its tropical climate and humidity required paving for all its highways. Up to the middle of the 19th century most bridges built in Puerto Rico were made of wood or lumber. Because of the climate and the quick deterioration of wood, wooden bridges were classified as "temporary" by the authorities.

Even though, since 1831, a paved road had existed from Ponce to its port, with a wooden bridge spanning the Portugués River[5], before the 1830s there were practically no paved highways in Puerto Rico. Labor shortage was one of the major difficulties faced by road construction. Under these circumstances, very few kilometers of paved highway could be built on the island annually. An 1838 decree forced all landless men to work on the construction of roads and highways in their respective municipalities. Until 1842 the building of roads and highways had been left up to the initiative of municipalities and plantation owners. On that year the Spanish government created the Commission of Roads and Channels and a fund for the construction of roads with a lottery game to finance it. In the same date, a suspension bridge with stone abutments was planned to substitute the wooden bridge across Ponce's Portugués River. However, it was never built.

In 1844 a steady drop in market prices began, caused by the introduction of subsidized European beet sugar. Premium sugar lands were reorganized into fewer but larger plantations, which nevertheless remained barely profitable. The economy became stagnant and the sugar barons were demanding better transportation to lower their costs.

Probably as part of this, in 1846, a new masonry bridge was designed and built by the Engineer Santiago Cortijo over the stone foundations left by the frustrated British invaders of 1797 at the Martín Peña Channel. Funding for the 200-foot long structure, was attained by means of a toll collected since 1818 at the provisional wooden bridge erected after the invaders' destruction of the previous structure. The new bridge consisted of nine elliptical arches, 0.7 meters thick; its roadway was about 6 meters wide. As this bridge was being concluded, the construction of the 41 kilometers of macadam highway between San Juan and Caguas was also begun. Designed by Colonel Eng. Diego Gálvez, its construction was first assigned to Colonel Tulio O'Neill and later to Commander Santiago Cortijo. The San Juan-Río Piedras stretch was finished in 1853.

A decree imposing taxes on livestock, letters and local passports was enacted in 1847, in order to raise funds for highway construction. The extension of the San Juan-Caparra highway, westward to Cataño, and subsequently to Vega Baja, was ordered in that year. The following administration, however, decentralized planning and created ad hoc road commissions for each district.

As the construction of the Río Piedras-Caguas highway progressed, the bridge over the Piedras River was finished in 1853, followed by the viaduct over the Frailes Creek, completed in 1855, and the Concepción Bridge over Caguas' Cañas River in 1856. When the wooden bridge over the Cagüitas River just north of Caguas was destroyed by a flood in 1854, engineer Gustavo Steinacher designed a suspension bridge using cables to replace it. The project was finished in 1856 with a cost of 18,205 **pesos**. It had a wooden floor system and the cables were held up by cast iron columns resting on piers made of ashlar and bricks, 7 meters wide, with a suspension span of 25 meters. It became the main attraction of the San Juan-Caguas highway when it was completed in 1857.

However, the Cagüitas cable suspension bridge, the first of its type erected in the Antilles, never gained the trust of the Chief Engineer Manuel Sánchez-Nuñez. Although over one hundred cable suspension bridges had been successfully built in Europe by French engineers and they had become popular in the United States, the Chief Engineer worried about the durability of this type of construction in a tropical climate. After a flood in 1861 partially undermined one of the bridge's abutments, Sánchez-Nuñez replaced the 1857 structure with a standard iron through truss.

During the 1850's much activity was displayed in the construction of municipal roads and highways all over the island. The Mayagüez-Añasco highway was built following the route traced by Eng. Captain José Tejeda before 1857. By 1858 an improved road beyond this point finally permitted travel between Rincón and Mayagüez by coach instead of on horseback.[6] In 1862, the state took over the highways and extended the existing five kilometers of pavement up to the Añasco River's Duque de Tetuán Bridge, a total of 9 kilometers. This wooden through truss bridge was rebuilt in 1866 at a cost of 48,128.96 **escudos**.[7] In 1858, the town of Coamo had commmissioned Engineer Timoteo Luberza to design a paved highway between Juana Díaz and Coamo, a portion of which had been finished by 1861. This period also saw the construction of highways between Caguas and Guayama, Mayagüez and San Germán and Cataño and Bayamón. The first of these projects was carried out by military Engineer Manuel Soriano and Architect Juan Pablo Roselló.

Efforts to stimulate highway construction - 1859 General Highway Plan[8]

In the second half of the 19th century the social-economic, administrative and military considerations made the Spanish government take action to remedy the problems of land transportation in Puerto Rico. The Administration of Public Works (established in 1857) under its Chief Engineer, Manuel Sánchez-Nuñez created the General Highway Plan (1859) a complete highway plan for the coastal towns and the mountainous interior. The Plan, approved by the Spanish Crown in 1860, contemplated the development of first order and second order highways to improve transportation combining the use of funds from the Spanish Colonial treasury and of municipal personal tax for road work.

As conceived, the 1859 plan's four first order highways were: one paved highway that would link the coastal towns; a second highway, connecting the towns of San Juan and Ponce over the central mountain range; a third highway, also travelling over the central mountain range would link up the northern coastal town of Arecibo to Ponce; the fourth and last highway, would travel from east to west crisscrossing the other two north-south highways (San Juan/Ponce and Arecibo/Ponce). The plan contemplated the use of existing roadways funded by municipalities. Of these local roadways integrated into the Plan were those in the coastal areas, the San Juan/Caguas highway, and the Ponce/Juana Díaz highway.

In the second order highways, the pavement, if there was one, was not to be so rigorously built as that of the first order. These secondary highways would serve to connect towns with their administrative and judicial centers on the coast or with the first order highways.

Highway development at the end of the 19th century

By the end of the century the mainly rural population was at least as large in the mountains as in the coastal plains. Population growth would remain at a steady 90,000 inhabitants per decade until the end of the century, when it totaled almost one million persons. However, the success of coffee and sugar farming had set back the production of food crops. Coffee became equivalent to cash, and many farmers in the interior produced coffee for export and traded it for imported foodstuffs. On the other hand, sugar cane had about displaced all other crops from the plains.

Exports and imports fed the port cities and their commerce. The main ports served the regions of: Mayagüez-San Germán-Añasco, Arecibo-Utuado, Aguadilla-Moca-San Sebastián, Ponce-Yauco-Juana Díaz, Guayama-Arroyo-Patillas. San Juan, the colonial capital, was the major importer of goods, but its population and economy lagged behind main agro-industrial and export centers such as Ponce, Utuado, and Mayagüez. Together with the small size of the island, this structure made it possible to have significant economic growth in spite of poor land communication.

As an emergency measure, several routes slated to become first order highways had bridges erected on key river crossings, even though the highways served were not much more than beaten roads. Many of these were well-built permanent iron bridges, and were expected to eventually serve the planned paved highway.

In 1860, the island government commissioned engineer Niceto Blajot the design of a paved highway between the cities of Ponce and Juana Díaz. To improve the communication between northern coastal towns and San Juan a new bridge was constructed substituting a run-down 1853 wooden bridge built in 1853 over the Bayamón River on the Cataño-Bayamón highway. Finished in 1869, the De la Serna Bridge was Puerto

Rico's first metal bridge. It was imported from France and assembled by Isidoro Abarca from **Fundición Abarca.**

In 1868, a revision of the plan was needed because of the lack of progress in highway construction. Among the main causes for the failure of the 1859 plan were the simultaneous allocation of state funds to various highway construction projects, and the unreliability and unfair practices of the work taxation imposed by the municipalities on their residents. The new plan of 1868 still maintained the purpose of the original first order highways. It limited the island's treasury to investing on these routes and left to the municipalities the secondary highways.[9] Of the first order highways conceived in both plans, only the route from San Juan to Ponce had been constructed. This route, completed in 1898, was named **Carretera Central.**

In spite of all these road-building activities, only 48 kilometers of highway were paved by 1872.[10] These were mostly between San Juan and Caguas, with a few other short stretches serving Ponce and Mayagüez.

The Carretera Central

Between 1875 and 1880, the Delegation of Public Works took over the existing municipal highways connecting Ponce, Juana Díaz, and Coamo and made them, officially, part of the **Carretera Central.** At that time, some of the drainage work had not been constructed and some stretches were not yet paved.[11] The highway's bridges, crossing main rivers (Portugués, Bucaná, Inabón, Jacaguas, and Guayo), were temporary structures owing to the fact that plans existed to eventually change rivers' courses which were prone to flash flooding.[12] The Ponce port road, where an iron truss bridge had been erected in 1876, became a part of the **Carretera Central** in 1880.

The stretch from Caguas to Cayey, designed by engineer Manuel López-Bayo, was the first built under the Delegation of Public Works directly for the **Carretera Central.** The project engineers were Raimundo Camprubí and Enrique Gadea-Giráldez. It was begun in 1875 and finished in 1881, except for the magnificent bridge which still spans the Plata River, which was concluded in 1894. The stretch of highway between Aibonito and Coamo was also designed by engineer Timoteo Luberza in 1861; Ricardo Camprubí began its construction in 1874. In 1878, he had to redesign some parts, creating a highway that traverses the 7.5 kilometers of the steep Asomante slopes, a difference in elevation of 557 meters, with a slope which, at the most, is 5%. This stretch was concluded in 1881. The segment between Cayey and Aibonito, designed by engineer Manuel López-Bayo, was begun in 1879 and completed in 1886, except for the permanent bridges over the Honda and Toíta Creeks. This was the highway's last and most expensive stretch; as in the preceding one, the width of the road was reduced from 6.5 to 6.0 meters to lower its cost.

By 1886, the **Carretera Central** with a length of 134 kilometers, 33 **casillas de camineros** and 13 permanent bridges, had become an example of Spanish and Puerto Rican engineering.

Other highways and bridges constructed from 1880's to 1898

In 1880, the State took charge of the first 14 kilometers of highway between Mayagüez and Ponce, which reached as far as San Germán's Pezuela Bridge over the Guanajibo River. The other 83 kilometers to Ponce had to be traveled along dirt roads. The Torréns Bridge was built in 1878 on the paved road that linked the important and heavily visited Hormigueros Sanctuary with the Mayagüez-San Germán highway. It is the only lattice beam bridge that is still standing in the western half of the island.

Many events occurred in 1881[13] that were beneficial in terms of transportation and communications links between San Juan and the western part of the island: the building of the first stretch of first-order paved highway from Cataño to Mayagüez, the construction of the Mayagüez-Tetuán Bridge stretch, the Reyes Católicos Bridge over the Plata River between Dorado and Toa Alta was finished and the opening of a railway-and-ferry service between San Juan and Bayamón. The Cataño-Bayamón highway, 7 kilometers in length, was an improvement over the preceding wagon road, taking advantage of the De la Serna Bridge. The next 13-kilometer long first-order stretch between Bayamón and the Reyes Católicos Bridge was built between 1883 and 1886 at a cost of 79,760 **pesos.**

The Reyes Católicos Bridge, part of the highway from Bayamón to Vega Alta and of the first order route to Mayagüez, was the longest metal bridge of the Spanish colonial period in Puerto Rico. It had three continuous spans, each 33 meters long, made by the **Cie Participation Belgue**. The construction, made difficult by the piers required in the middle of the island's second largest river, was begun in 1874. It was interrupted by the San Felipe Hurricane in 1877 and was not completed until 1881. Its total cost was 152,119 **pesos**. Later in 1892 part of the earthen causeway that elevated the bridge's access above the height of the river's flood banks was divided by vaults of diverse shapes and sizes to let floods through instead of diverting their water toward the river bed and the bridge. These works were called a "defense of the metal bridge", and their cost was 11,571.75 **pesos**. Ruins of these structures still exist. Despite these precautions, part of the bridge fell as a result of the San Ciriaco Hurricane in 1899.

The construction of a highway between Cayey and Arroyo was begun in 1887. It had reached as far as Guayama by 1898.[14]

By 1888 there were 76 kilometers of highway maintained by the Delegation of Public Works and 28 kilometers administered by the Provincial Public Works. From 1895 to 1896 there were two levels of public works administration: Delegation of Public Works, controlled directly by the Ministry of Overseas Possessions (**Ministerio de Ultramar**) in Spain; and, Provincial Public Works, controlled by the Provincial Council of Deputies, a local advisory body to the governor with no legislative functions. The former handled highways of the first order and the latter, the second order highways.

On the north of the island, the San Juan's San Antonio Bridge was replaced in 1894 by a structure designed by engineer Joaquín Gisbert. This bridge had vaulted masonry access spans and four lattice open-web lateral beam metal spans resting on stone piers. The iron spans had a total length of 55.5 meters. One of these spans could be quickly disassembled to allow better defense of the capital and bay in case of a military attack. The San Antonio Fort's door and superstructure were removed in 1897.

The stretches of paved, first order highways used in 1898 included the **Carretera Central** between San Juan and Ponce up to its port, plus the following stretches: Cataño-past Plata River; Añasco-Mayagüez-San Germán; Ponce-halfway to Adjuntas; Río Piedras-Río Grande; Utuado-halfway to Arecibo; and Cayey to Guayama. At the time of the US invasion of Puerto Rico in 1898, there were 267.4 kilometers of paved highways of first order in "usable" condition in the island, although some stretches had not been opened to the public.[15]

Forty nine metal or masonry bridges ten meters or more in length were serving the first and second order highways of Puerto Rico in 1898. The wooden bridges, many of which served first order highways,must have numbered over one hundred. About twenty additional steel bridges served the existing railroad stretches; Carolina-Martín Peña; San Juan-Camuy; Aguadilla-Hormigueros; Añasco-Alto Sano; Cataño-

Bayamón; Ponce-Yauco.

Construction methods, conservation measures and labor usages for the highways in the 19th century.

The **macadam** method of crushed gravel in an impervious clay matrix was the almost universal method of paving at the time. Angel de Barrios-Román described the method's application in 19th century Puerto Rico: "The stone and gravel were compressed by a roller that weighed 3,000 kilos and pulled presumably by a pair of oxen".[16] Gravel was obtained by crushing rocks manually with hammers, a tedious and hard job that was usually avoided by free men and usually assigned to prisoners sentenced to hard labor.

To assure the preservation of the existing first order pavement, the Spanish government created the system of **camineros.** These men were trained technicians and were provided with good, solid homes along the highways. These **casillas de caminero** were erected about every six kilometers and were always made part of the design of the first order highways. This **corps** was in charge of the road under its supervision.

The labor force used on roads, bridges and highways was composed of prisoners, free laborers and convicted vagrants. Even though wealthy land owners and mayors of neighboring towns often contributed to the labor; these construction projects were generally slow and difficult because of the chronic labor scarcity. However by 1872, Spain began encouraging the building of paved highways in the island by assigning funds and prisoners from other Spanish colonies, including the Philippine Islands. In addition, in 1879 two crushing machines, capable of producing up to 70 cubic meters of gravel a day, were imported to perform the toughest and most labor intensive jobs.

The first railways and the Circumvalation Railroad[17]

Around 1850, sugar plantation owners began to call for a railroad. Spanish-ruled Cuba, had enjoyed railroad service for more than twenty years, and its sugar industry had benefited enormously. It was felt, however, that Puerto Rico, smaller in size and thus having its sugar cane fields located relatively close to the ports, had less need for a railroad. In addition, railway construction costs due to the rugged terrain were estimated to be excessively high. As a result, the several railroad proposals which were made during the next thirty years never got past the cost estimates stage.

The only railroad built before 1880 had been part of private ventures of sugar mill owners and urban transportation companies. The largest sugar mills had installed light, narrow-gage railways to bring the sugar cane from the fields to the mills, mainly using combinations of fixed and portable rail. Some moved the one and two-ton cars with ox teams, while others invested in small steam locomotives. The first urban railway system was the one of Mayagüez, built in 1875; it consisted of passenger cars pulled by horses.[18]

In 1880, Count Pablo Ubarri opened the first intercity railway between San Juan and Río Piedras. A steam locomotive pulled a two-car train over a railway located alongside the **Carretera Central**, and during its first few years it shared the highway's San Antonio Bridge. This railroad service was later extended to Caguas. In 1900, the San Juan-Río Piedras stretch gave way to an electric trolley service which lasted until c.1950.

The **Línea Férrea del Oeste**, property of Alfonso Valdés, laid its one-meter gage rails between Cataño and Bayamón along the highway and the De la Serna Bridge. It received authorization to use the bridge following the reinforcement of the deck between two of its three longitudinal arches.[19] This rail system, which was expected to be extended westward, included a steam boat that took the train cars from a terminal in Cataño to a small rail network located in the port of San Juan. The ferry boat was equipped with rails, and the cars, pushed by small steam locomotives, rolled in and out as in modern container ships.[20]

The goal of Puerto Rican transportation planners was to have a railroad system that would encircle the island. A franchise was granted in 1888 to the French-owned **Compañía Ferrocarrilera de Puerto Rico** (CFPR) to build and operate such a railroad. Construction began under Puerto Rican engineers Tulio Larrinaga and Antonio Ruiz-Quiñones. However, CFPR was short of capital and it sought to first build the stretches expected to have most demand in order to produce the necessary capital to permit further construction. The San Juan-Martín Peña-Camuy, Martín Peña-Carolina, Aguadilla-Hormigueros, and Ponce-Yauco stretches, totaling 270 km., were in service by 1893. However, CFPR's plan did not work due to the successful competition carried out by an existing well organized scheduled coastal steamer service, which transported passengers and cargo around the island's perimeter. Only the aforementioned stretches remained in service until 1902 when a new company, the American Railroad of Puerto Rico (ARR), took over the construction of railways.

As part of this project, a series of significant, well-built bridges was constructed between 1889 and 1893. Of these bridges with rectangular steel double-intersection Pratt through trusses supported by ashlar and brick abutments and piers, that had spans ranging from 35 to 48 meters in length, the most noteworthy examples were those located over the Bayamón, Plata, Manatí, Arecibo, Culebrinas, Añasco, Yagüez, Yauco and Loco Rivers. Of these bridges, only the Cambalache Bridge over the Río Grande de Arecibo remains. Most of the other bridges were dismantled and sold to cover the railroad company's bankruptcy in 1957.

The singularity of Puerto Rico pre-Spanish American War bridges

Because of the scarcity of iron in Puerto Rico, metal bridges were imported from European fabricating shops in-ready-to-be assembled pieces. Between 1869 and 1898, they were bought through Spain's resident engineers in Paris from fabricating shops in France and Belgium. These were erected by local contractors, who also built their piers and abutments. Spain had a resident engineer in Paris who would oversee international bidding for metal bridges for Spain and its colonies. This person was also in charge of inspecting the fabrication, load testing and shipping of the structures.

The first import of French bridge technology was probably the wire cables used in the 1856 Cagüitas suspension bridge. The cables held a wooden truss very similar to the one ilustrated by Vicat in 1837. After the island's first metal bridge, an arch structure, built in 1869, all subsequent ones were either girders or trusses. Girders are made of solid or composite metal plates, while trusses use slender elements connected at their ends. There are many ways of effectively placing the elements of trusses, which are then classified according to these configurations.

The most important bridges built in the United States between 1850 and 1925 were metal trusses. The same situation existed in Puerto Rico between 1872 and 1910. In the United States, the use of all-iron trusses had begun by 1840, as wrought iron which was dependable and tension resistant became economical to produce and fabricate. The elements of the first metal trusses were pinned together, but pins soon gave way to safer and more durable riveted plate connections. At the end of the 19th century, the use of iron was displaced by the introduction of steel in the construction of bridges.

In the mid 19th century, truss patterns were often patented. Of the many truss patents that emerged in the 1840's and 1850's, two types dominated the market by the end of the century. All of the through and pony trusses extant in Puerto Rico today are variations of these two. The **Pratt** rectangular truss was patented by the American Pratt Brothers in 1844. This configuration has diagonals going down from both ends towards the center of the span in such a way that they are subject only to tension. The **Warren** truss was patented in 1848 by two British engineers. This configuration has its diagonals in alternate directions, as the letter "W", and were generally combined with vertical elements. One variation has two diagonal systems in opposite directions, as the letter "X". This variation was popular in Europe, where it was known as the "Eiffel system". The railroad truss bridges built around the early 1890s apparently substituted wrought iron for steel and introduced the rectangular **double-intersection Pratt**, a through truss in which vertical elements are closer to each other and diagonals cross them through their midpoints, ending in the next panel.

Eric Delony, Chief and Principal Architect of the Historic American Engineering Record (HAER) and one of America's foremost authorities on historic American bridges, considers the metal and masonry Puerto Rican bridges of the 19th century as unique within the jurisdiction of the United States.[21] The arch bridges are singular examples of Spanish 19th century bridge technology. The French and Belgian iron and steel truss and beam bridges are the only examples of European metal fabrication in the United States. Puerto Rico's most frequent 19th century truss pattern and girder type, the Eiffel truss and lattice girder respectively, are at least rare in the American mainland.

The study of bridge construction in Puerto Rico reveals the almost exclusive use of iron versus masonry during the last three decades of Spanish rule. Since the metal bridge requires less labor and uses a material that is more expensive, the generalized use of this type of structure was commonly associated with iron-producing countries or countries with high labor costs or scarce labor. Two studies made before 1877 at the behest of the Spanish government determined that iron bridges were more economical for Puerto Rico than masonry bridges.[22]

Engineers, builders and designers of the 19th century

There were several prolific and distinguished engineers, builders and designers in this century whose work on railroad and highway routes and bridges was noteworthy.

Ricardo Camprubí was the engineer responsible for the most difficult stretches of the **Carretera Central**. This highway, together with the San Juan forts, was a world-class engineering work at its time. Camprubí built the Caguas-Cayey highway and built and partly redesigned the Coamo-Aibonito stretch and its Asomante section. In spite of the ruggedness of the terrain traversed, this highway was compared favorably with any in America by the commander of the US forces advancing along it in 1898. Camprubí also designed the earliest two-span lattice girder bridge, Coamo's No. 174, and erected several other single span lattice bridges, including Descalabrado (No. 172) and Calabazas (No. 175), all part of the **Carretera Central**.

Timoteo Luberza, an engineer based in Ponce, was responsible for the 1875 Ponce water supply system, including the dam in Río Portugués and the striking **Calle del Agua** masonry arch aqueduct. He also designed highways, such as the ones between Ponce and Juana Díaz, and between Aibonito and Coamo.

Gustavo Steinacher designed and built the first cable suspension bridge in the Caribbean basin in 1856, only ten years after Roebling had built the first in the world. He was also responsible for the most magnificent masonry arch bridge ever built in Puerto Rico, the extant Norzagaray Viaduct, finished in 1855.

Tulio Larrinaga, an American trained Puerto Rican engineer, assembled the Arenas Bridge Eiffel truss, the longest 19th century single-span in the island. He was also in charge of erecting lattice truss bridges No. 176 and No. 178. All three were part of the **Carretera Central** and remain in use. Larrinaga was one of the two engineers entrusted with the construction of CFPR railroad in 1888. Later on, he designed the narrow gage Alto Sano stretch in 1896.

The **Fundición Abarca** foundry and shop was the most important mechanical support facility for the Puerto Rican sugar industry for more than a century, c.1850-c.1980. Founded by Spaniard Isodoro Abarca, this foundry designed, built, repaired, installed and sold all types of machinery associated with the Sugar industry. The erection of the De la Serna iron arch bridge was one of Mr. Abarca's first projects.

The following are most of the European firms which fabricated metal bridges exported to Puerto Rico through Spain: **Eugene Rollin & Co.** (Braine le Comte, Belgium), **Nicrisse & Decluve** (La Loumiere, Belgium), **Soc. Anon. Internationale de Construccion** (Brussels, Belgium), **Cie Participation Belgue** (Belgium), **Duclos & Co.** (Paris, France), and **Ulince** (France). The first two were the most prolific in terms of extant Puerto Rican bridges. None of the others have more than two bridges documented.

THE AMERICAN REGIME

On July 25, 1898, the US troops landed at the southern coast of Puerto Rico to take over the island within the context of the Spanish-American War. The first American troops landed at Guánica Bay and divided into two columns. One column marched west into San Germán and Mayagüez and up the mountains into Las Marías with the objective of approaching San Juan from the West. The other column went east to Yauco and Ponce, where the major landing and supply operation took place. From there, it marched east and north towards San Juan following the **Carretera Central**. This main column had been engaged by Spanish defenders in the mountainsabove the highway just as an armistice between Spain and the United States went into effect. The western-bound forces under Brigadier General Theodore Schwan were held up for about two hours by sniper fire from crossing the Silva Bridge in Hormigueros. A skirmish occurred a few hundred meters beyond the Padre Iñigo Bridge in Coamo just off the **Carretera Central** that resulted in a number of casualties. In the same action a few kilometers back, the Méndez Vigo Bridge had been blown-up by the retreating Spanish Army to delay the advancing US forces.

Most bridges built during the military occupation (1898-1900) after Puerto Rico was ceded to the United States were made with haste, which explains why so few remain extant.[23] The most important exceptions were the bridges of the **Carretera Central** over the Jacaguas and Guayo rivers between Ponce and Juana Díaz. The military government awarded the construction of both bridges in 1899 to **Keeper & Thecher**, a well known US engineering firm. The two multi-span concrete vault bridges were finished by 1900, and became the first of their kind on the island. The vaults, up to 30 meters in length, were reinforced by two sets of seven continuous steel bands placed parallel to the top and bottom arch surfaces, 2'8" apart. The portions of vault between these reinforcing bands had no additional reinforcement.[24] Although these structures needed many repairs and weight restrictions, they lasted until nearly a decade ago, when they were substituted by wider bridges.

Although concrete had been used in Puerto Rico during the late 19th century, its use in bridges had been mostly limited to foundations due to its relatively high cost. Cement was imported in barrels during the 19th century from Northern Europe. However, under US administration untaxed importation of American cement was allowed at the precise moment when reinforced concrete technology was coming of age. The first decade of the present century saw several other significant concrete bridges built.

Concrete arch bridges were the first to apply US bridge technology and provided the first documented use of concrete in bridge superstructure in Puerto Rico. Although some metal girder bridges were constructed between 1899 and 1900, they exhibit the transverse joist European technology prevalent up to 1898; they probably corresponded to structural elements that had been bought during the Spanish sovereignty and were later erected by the military regime. Other important early transfers of American bridge technology were railroad trestle viaducts and tunnels.

The American Railroad Company and other railways (20th century)

Railroad construction efforts were renewed after the American Railroad Company of Puerto Rico (ARR) had taken over the stagnant railroad franchise. Between 1903 and 1908, the route from Ponce to San Juan was completed with the construction of the San Germán-Lajas mountain stretch and major structures such as the steel trestle-and-beam viaducts over **quebradas** in Isabela and Quebradillas, and the imposing upper-deck truss and trestle viaduct crossing the Guajataca River canyon with its two access tunnels.[25]

The steel viaduct over **Quebrada La Mala** in Quebradillas, contrary to most railroad structures, had to be replaced. In 1922, a spandrel arch concrete bridge, unique in its class in the island and featured in an article in **Engineering News Record** as a novel use of spandrel technology, was erected to replace it.[26] This is still standing, and is referred to as Puente Blanco a property which was listed in the National Register of Historic Places on February 23, 1984.

Sugar Boom of the 1900s and effects on land transportation

By 1900,American sugar corporations had established two large sugar plantations, each with its extensive mill complexes (Guánica and Aguirre Sugar Mills). These corporations exerted a powerful influence over most of the premium sugar lands in the southern coastal region (Guánica-Lajas and Salinas-Guayama) where transportation limitations had hindered earlier development. Five years later, a third American corporation established a sugar mill (Fajardo Sugar Mill) and acquired large tracts of sugar cane fields in the northeast, between the municipalities of Río Grande and Ceiba. As a result of the establishment of these corporations, between 1900 and 1905, tracts of private railways were extended in the south and the east to serve the need of rapid transport of sugar cane from the fields to the mills.

The Ponce & Guayama RR Co., a subsidiary of the Central Aguirre sugar mill, built several steel-and-concrete beam railroad bridges in the southeastern part of the island around 1907. Fajardo Development Co., the railroad company owned by Central Fajardo (which also bought Central Canóvanas), erected a magnificent Pennsylvania through truss steel bridge about the same date over the Loíza River near Central Canóvanas, connecting its railway to the American Railroad's. This structure had to be removed c.1990 after advanced corrosion made it a threat to traffic.

Instead of completing the costly construction of the circumvalation route, the American Railroad Company negotiated with these sugar mills the joint use of their respective railways. The addition of Central

Ejemplo's Fajardo-Humacao railway to this conglomerate left only the mountain-locked southeastern corner of the island without rail connections after c.1910.

Sugar and tobacco were produced in the United States, and were thus protected by tariffs. Coffee, however, was not produced and no protective tariffs were in place for this crop. The American regime proved fatal for Puerto Rico's coffee producers and exporters: Puerto Rican coffee had no protection in the US, while it lost its favored status in Spain and came up against higher taxes as the European countries tried to balance their trade with the United States. A very destructive hurricane, San Ciriaco, hit Puerto Rico in 1899, affecting the coffee trees and their production for the next several years. The economy of the coffee region collapsed; coffee production and wages fell markedly, and the workers emigrated to the coastal regions clustering around the urban centers and the sugar mills.

Although American investors had boosted tobacco production in the eastern highland areas, and coffee production continued to exist in the western highlands, the sugar corporation typically dominated the life of the majority of the Puerto Rican workers. Small farmers lost their land to large planters or sugar corporations and became cane cutters. The sugar cane worker became tied to the cane fields on a year round basis, while only employed seasonally.

Bond issues for highway and bridge construction

Under both colonial regimes, the construction of public works had been carried out using funds taken from the government's annual budget. In 1906, for the first time, bonds were issued for financing public works. Public works bonds assume that highways foster economic growth and therefore raise the government's income enough to allow the payment of principal and interests. The million dollars thus obtained in the first bond issue permitted a considerable increase in the speed of the construction of highways and bridges. A new road system was planned that, according to the priorities of the new regime, responded to an economy based primarily on the intensive and extensive cultivation of sugar cane and to the defense of the strategically located island.

The new way of financing bore fruit quickly. In the year 1908 alone, nine steel bridges were erected, all of them imported from the United States. Some of these replaced bridges that had been destroyed by the 1899 San Ciriaco Hurricane; others served the new stretches of highways that were being built. One of these replaced the Reyes Católicos bridge over the Plata river, but at a point about two kilometers upstream, where a single span polygonal truss avoided the use of piers placed in the riverbed. The surviving iron spans of the Reyes Católicos bridge were placed one over the Camuy River between Camuy and Hatillo, and the other over the Hondo River, between Barranquitas and Comerío. The latter still stands, as Bridge No. 339. The 1908 Reyes Católicos bridge collapsed in 1993, and the only bridges remaining out of those nine are an abandoned two-span Plata through truss near Naranjito and pony truss bridges Nos. 258 and 341. Probably financed by the same issue was the 1907 Utuado Parker truss bridge, No. 154.

As part of Highway No.2, which according to the 1906 plan began in San Juan instead of Cataño, the **Puente de Báscula** (Bascule Bridge) was built in 1915 across the mangroves and swamps lining the southern and eastern edges of San Juan Bay. It was renamed Constitution Bridge in 1952. This 92-meter long structure, no longer in existence, was designed by engineer Rafael Nones. It included a central span in steel with a wooden deck that could be raised mechanically to allow the passage of ships through the Martín Peña channel, to comply with a requirement of the US Army Corps of Engineers.[27]

During the 1910s, concrete became the standard substructure and deck material. By 1918 it was being used in short-span girder bridges, while its arches were displacing steel trusses in mid-size spans. Concrete bridges in general are more flood-resistant and more stable under loads than metal trusses. Unlike steel beams, which had to be imported and fabricated, local contractors and the Department of Public Works could handle all aspects of the construction of concrete bridges. Concrete beam bridges require much less design and construction effort than do concrete arches. Concrete slab bridges require even less, but need even smaller spans (and more piers). In the 1930s, concrete "T-beams" began to displace rolled steel in the standard 10-meter multi-span design. Concrete and steel beam bridges, with their low cost and standardized design and construction, facilitated the main thrust in highway building in Puerto Rico.

Concrete slabs were typically used for multispan structures in locations where piers construction was not expensive. Slab bridges were also employed in short-span viaducts built during World War II. The U.S. Armed Forces had taken over the railroad and they built several of these highway overpasses for strategic rail crossings of highways.

In 1916, when the United States' automobile industry was beginning its mass production and the entry of the United States into the First World War could be foreseen, the island's legislature authorized a new bond issue, this time for two million dollars. The island's Economic Commission devised the project's priorities according to the economic, industrial and commercial development perceived as most important. Among the bridges financed by this bond issue were Bridge No. 122 and the Adjuntas' Cabañas bridge (No.279). The latter bridge's funding was complemented by the Castañer region coffee growers who were its main beneficiaries.

Yet it was in the 1920s that the construction of highways became more productive. There were many reasons for this turn of events: the rapid expansion of the automobile industry, the continued sugar cane boom, the partial recovery of coffee exportation, the introduction of new machinery and techniques for highway building and their cost-reducing effects, and the introduction near the end of the decade of a new paving technology based on tar and gravel. The 1926-1927 fiscal year was the most productive in terms of highway construction. The bridges erected in that period include the causeway and bridges spanning the delta of the Arecibo River and the replacement of the **Puente del Agua** with the present four-lane version. By 1929 almost all towns, big and small, were linked by paved roads.

Engineers, designers and builders of the 20th century

The most prolific and successful bridge designer in Puerto Rico between 1910 and 1930 was **Eng. Rafael Nones**. He designed many of the most important bridges of the period, including both the San Antonio Channel bridges, Bridge No. 122, and the Bascule Bridge of 1915. He wrote several articles on bridges in the public work journal **Revista de Obras Públicas** and delivered conferences on the subject at the University of Puerto Rico School of Engineering.

The most successful bridge builder was **Eng. Félix Benítez-Rexach**, an eccentric naval engineer who tackled various works of great importance in different parts of the world, such as the docks of Santo Domingo and the Normandie Hotel in San Juan, which he owned. He teamed with Rafael Nones to produce such remarkable bridges as: the unique Las Cabañas bridge (No. 279); and the futuristic bridge No. 122. Also, in cooperation with Rafael Nones and architect Rafael Carmoega, he worked on the monumental Guillermo Esteves bridge (No. 86).

In railroad bridges, the most noteworthy engineer was ARR Chief Engineer **Ettiene Totti**, who designed and built the 1922 innovative concrete spandrel arch over La Mala Creek in Quebradillas. He also contributed to the replacement of the 1890 railroad truss bridge over the San Antonio Channel, which took place between 1923 and 1932.

In the early twentieth century, steel bridges were fabricated in the United States to be assembled in Puerto Rico by American companies. The majority of the larger steel bridges erected in the first decade of this century, whose numbers were boosted by the 1906 million-dollar bond issue, were fabricated by the mammoth **American Bridge Company** and assembled by its subsidiary, **Groton Bridge Co.**

Road and bridge development in the 1930's and 1940's

The economic depression of 1929, together with the unprecedented devastation left behind by the 1928 San Felipe hurricane, stopped the momentum of highway construction. This inactivity ended in the following decade, thanks to the extension of President Roosevelt's New Deal programs to the island, assigning 34 million dollars to the Puerto Rico Emergency Relief Administration (PRERA). A good part of that money was dedicated to the construction of bridges, highways and rural roads. Until that moment, the Federal government had not assigned funds for public works or other necessities in Puerto Rico, except to mitigate the effects of natural disasters.

Some of the public works of this era were the 1938 Aruz Parker truss bridge, the 1939 Trujillo Alto Pennsylvania truss bridge, and the present version of the Martin Peña Bridge, built of concrete and steel in 1939.

In the years that preceded the US entry into World War II, great emphasis was placed on widening, repairing and building highways. Routes Nos. 1, 2 and 3, necessary for the rapid mobilization of troops and military equipment, received great support from Washington. During the war, the US army appropriated the railroad's operation, and built several highway viaducts for the underpasses at important crossings. Some of these are in Lajas, Hormigueros, Quebradillas, Santurce, and Arecibo. Their use was short lived. The bankrupt railroad ceased operating in 1952, and most of its bridges and railways dismantled in 1953.

In the 1930s and the 1940s most bridge construction consisted of improvement and replacement of previous work, the establishment of secondary roads to improve rural accessibility and development, and of new arteries to serve the expanding urban areas. Some of the bridges built in the 1930s replaced structures destroyed by the 1929 and 1932 hurricanes. These included the Aruz Bridge in PR-1 near Ponce and the PR-2 Salcedo Bridge over the Añasco River. After the collapse of Añasco's Tetuán bridge during the 1918 earthquake, vehicles crossed the Añasco river by ferry until the completion of a provisional wooden bridge. This one also fell in 1926 during a tropical storm; it was rebuilt, and fell again under the buffeting of the San Felipe Hurricane of 1928. The ferry was put back in service while another wooden bridge was erected. A steel through truss bridge (No. 65) was built in 1944. Only 2 meters shorter than the truss erected in 1939 over the Loiza River (Trujillo Alto Bridge), No. 65's central truss became the second longest span in Puerto Rico.

There were basically two technologies used in this period for highway bridges: standard concrete girders, beams and slabs over pile-foundation piers for short spans; and steel Parker and Pennsylvania trusses for longer spans. Only the latter technology had engineering significance.

These trusses were assembled locally from steel elements which were fabricated either locally or by the originating American steel mill. The firm which apparently exported most bridges to the island in that period US Steel. The Porto Rico Iron Works Company of Ponce, a foundry which also served the sugar industry, was the leading local firm in bridge fabrication and assembly.

"Operation Bootstrap", unveiled in 1946, sought to improve the standard of living of Puerto Rican workers through industrialization. It was coupled with the active, official stimulation of migration. Industrialization occurred at a rapid rate in the following decades as Puerto Ricans were allowed more power to run their local government through the 1952 constitution. In 1940 manufacturing had generated an income of $27 million; by 1969 manufacturing income was $908 million. Stimulated by US local tax breaks, the number of industrial facilities increased from 798 in 1940 to 2,367 in 1967, mostly near San Juan. The income generated from manufacturing surpassed that of agriculture for the first time in 1955. Agricultural activity, on the other hand, had become for the most part non-profitable between 1960s and 1970s. Commercial-scale tobacco farming disappeared in that period, while sugar and coffee production barely survived at minimum levels by means of heavy government subsidies.

1. "Obras públicas de Puerto Rico: resumen histórico," in Revista de Obras Públicas de Puerto Rico 1:4 (Apr. 1924): 154.

2. Aurelio Tió, "Trazado y construcción de carretera y puentes," Boletín de la Academia Puertorriqueña de la Historia 3:10 (30 June 1973): 81-82.

3. Fernando Picó, Historia General de Puerto Rico (San Juan: Ediciones Huracán, 1986), 149.

4. Lidio Cruz Monclova, Historia de Puerto Rico (Siglo XIX) (San Juan: Editorial de la Universidad de Puerto Rico, 1970), 1:193.

5. Eduardo Neumann, Verdadera y auténtica historia de la ciudad de Ponce (San Juan: Institute of Puerto Rican Culture, 1987), 262. Leonardo Santana Rabell, Historia de Vega Alta de Espinosa (San Juan: Ed. La Torre del Viejo, 1988), 129-130.

6. Angel de Barrios Román, Antropología socioeconómica del Caribe, Mayagüez 1840-1875 (San Juan: Instituto de Estudios del Caribe, n.d.), 129.

7. AGPR L 501, C 2569.

8. María de los Angeles Castro Arroyo, "La Construcción de la Carretera Central en Puerto Rico" (M.A. thesis, University of Puerto Rico, 1969), Chapter 1. Pages are not enumerated but would correspond to pages 10, 11, 23, 24, and 25. The author includes an interesting discussion concerning the military considerations in the General Highway plan (pages 14 and 15).

9. Castro Arroyo, "Carretera Central", 24-25.

10. "Obras Públicas de Puerto Rico", 160.

11. Castillo, "Carretera Central," 7:5 (May 1930): 126-128.

12. *Ibid.*, 143-145.

13. Luis F. Pumarada O'Neill, Los puentes históricos de Puerto Rico (Mayagüez: Engineering Center for Research and Development, Universidad de Puerto Rico, 1991), 26.

14. "Obras públicas de Puerto Rico", 161-162.

15. *Ibid.*, 163-164.

16. de Barrios, Antropología socioeconómica, 202.

17. For background on the Compañía Ferrocarrilera please see Luis Pumarada O'Neill, *"Trasfondo Historico", 8-23.*

18. Luis Pumarada O'Neill, and Rafael Cabrera, "Trasfondo histórico del ferrocarril en Puerto Rico," pt. 1 Contexto histórico del ferrocarril en Puerto Rico e inventario del ferrocarril de circumvalación. Unpublished Report prepared for the Puerto Rico State Historic Preservation Office. (Mayagüez: Engineering Center for Research and Development, University of Puerto Rico, 1988), 9.

19. "...enclosed calculations made to determine the resistance of the bridge that lies over the Bayamón River to the passage of the Cataño railroad, the most favorable solution consists of the construction of a rail between the first two arches to the left, which requires the placing of 5 inch steel girders between the arches, with a weight of 12.25 pounds per foot", transcript from original *Memoirs*, from the bridge's record at the PR Highway Authority.

20. Pumarada, "Trasfondo histórico", 10.

21. Eric Delony, Washington, D.C. to Luis Pumarada O'Neill, Mayagüez, 9 December 1994, Engineering Center for Research and Development, College of Engineering, University of Puerto Rico.

22. Juan E. Castillo, "La Carretera Central," Revista de Obras Públicas 7:3 (Mar. 1930): 68.

23. *Ibid.*, 163.

24. Rafael Nones, "Conferencia en el Colegio de Ingeniería de Mayagüez acerca de algunos puentes construídos en Puerto Rico," Revista de Obras Públicas 9:1 (Jan. 1932): 37.

25. Trestle is a braced framework of timbers, piles, or steel, for carrying a road or railroad.

26. "Porto Rican Concrete Arch Bridge Has Novel Spandrels," in Engineering News Record 89:32 (Dec. 7, 1922): 981. This bridge is already listed in the National Register under the name "Puente Blanco".

27. Nones, "Conferencia de algunos puentes", 38.

SECTION F: ASSOCIATED PROPERTY TYPES

I. Name of property type: ARCH BRIDGES

II. Description

The boundaries for arch bridges, and all other bridge types herein, include the superstructure as all relevant features of the piers, abutments, wingwalls, access ramps, and embankments. Unless otherwise specified, the property types included in this historic context are represented by properties in fair to excellent condition which conserve their historic integrity.

The curvature of an arch or vault allows it to rest on two relatively distant supports by means of materials that resist compression: a force pattern which causes the contraction of the structure by pushing its particles or elements against each other. Similarly supported straight, horizontal structures, such as girders, slabs and trusses, have some parts which are submitted to tension, the force pattern that tends to stretch an object or part of an object, separating its particles or components. Wood and some metals resist tension well, but most other construction materials do not. Stone, brick, and non-reinforced concrete can only be used to span distances by shaping them into vaults and arches which carry the loads down to the supports by compression only. Beams and slabs of reinforced concrete use steel reinforcement to resist tension forces.

Unlike beams and trusses, which push their supports only downward, arches and vaults push their end supports outward as well. The shallower the arch, the stronger is the outward push or "thrust" which it exerts on its supports. The most common vault configurations are the barrel vault, which is easier to build and has less thrust, and the segmented arch, which allows more clear space under the bridge.

Arch bridges in which the arch supports the roadway from beneath are called **deck bridges. Open spandrel** bridges use either trusses or columns to transmit the loads and the weight of the roadway down to the arch. **Filled spandrel** bridges accomplish this by means of an earthen fill contained by **spandrel walls** that rest on the edges of the vault.

The ideal location for an arch bridge should provide end support conditions able to absorb the lateral thrust of the arches. The arch bridges were better suited for mountain roads, where they find slopes able to absorb the thrust and to allow enough height for water passage. The deep, wide rivers of the plains require massive, expensive piers and abutments plus high access embankments.

In Puerto Rico, there are three arch bridge subtypes:

- **Masonry vaults** (made of brick, masonry, or ashlar). This type of structure was used exclusively by the island's permanent bridges in single or multiple spans up to 1869. It used local materials: mostly brick, limestone or sandstone cut stones, or rubble set with a lime mortar with sand, rubble or gravel. Known survivors date from as early as 1835 and up to 1892. All are deck bridges with filled spandrels. These bridges used traditional Spanish technology with sound local workmanship.

  They were usually located on those areas which were most developed in the 19th century: San Juan and vicinity, Ponce-Coamo and Mayagüez-San Germán. Extant bridges of this subtype are located mainly along or near the old route of the **Carretera Central.**

They range in total length from 6.7 to 120.7 meters, and in span length from 5 to 11.8 meters. Most of them have circular arches; others, segmented arches. Except for Cayey's ashlar-edge Santo Domingo Bridge, the others have very few ornamental details.

This subtype is very prone to attack by tropical vegetation, which grows on its crevices and climbs up its piers and abutments. Extant examples are all currently in use in stretches of road relegated to local or secondary traffic, and are relatively well maintained. However, they are narrow and some may be unsuitable for continued service in the long term.

* **Metal arches.** There is only one bridge of this type, located in Bayamón. It was the first metal bridge erected in Puerto Rico, imported from France in 1869. It is a 25-meter, single-span, open spandrel bridge with trusses not unlike the first metal bridge to be built in the world, in 18th century Coalbrookdale, England. It is being preserved in its original site in a park setting.

* **Reinforced concrete vaults.** These were built between 1899 to about 1930. Except for the open spandrel railroad structure **Puente Blanco**, they are filled spandrel deck arches. The spandrel walls in the most early examples are made of masonry, the others of concrete.

  Extant structures are found in western and central mountain highways. Concrete vault construction technology was transferred from the US in 1899. The filled spandrel arches have span lengths of 10 to 24.8 meters. The open spandrel arch consists of a single 36-meter span. Many of them have ornamental railings and some other architectural details, plus relief ornamentation. Most early examples have stonework ranging from well-executed to excellent.

  Most of these bridges are in service, but are narrow for today's traffic and as such are or may become candidates for replacement or rehabilitation.

III. Significance

Different examples of this property type are eligible for the National Register under Criteria A and/or C. Puerto Rico's arch bridges may be generally significant at the State level in the areas of transportation and engineering. According to the Chief and Principal Architect of the Historic American Engineering Record, Puerto Rico's masonry and metal arches are the only examples of European (and Spanish) arch bridge design and technology under the jurisdiction of the United States. Therefore, at the national level under Criterion C, the masonry and metal arch bridges may be significant in the area of engineering. In addition, specific bridges may be significant at the State level in the area of military.

Land transportation in Puerto Rico relied exclusively on masonry vaults for permanent bridges since the construction of the island's first highway in the 16th century until 1869, when the first metal bridge, also an arch structure, was erected. The oldest extant bridges in Puerto Rico are masonry arches, and the oldest metal bridge is the sole arch imported from France in 1869. All extant arch bridges are in their original locations.

The brick, masonry and ashlar arch bridges, together with the extinct wooden bridges, have been the only bridges built in Puerto Rico using exclusively local materials. Concrete bridges from the 1940s onward used local cement, but the steel reinforcement always relied on imports, either direct or recycled. Economic forces related to commerce and economic development made labor very scarce in the island in the second half of the 19th century. As a result, even though forced labor was used in highway and bridge construction, labor economics forced masonry bridges to give way to metal imports from France and Belgium. Arch bridges, being the most labor intensive type constructed in the late 19th century, are associated with the forced labor of Philippine and Cuban prisoners and Puerto Rican "vagrants".

A masonry arch bridge blown up by the Spanish army to slow down the advancing American forces in the 1898 Spanish American War, rebuilt by the US Army Corps of Engineers, is still in use. The oldest extant bridges entirely built under the US domination are also vault bridges from the first decades of this century, but made in concrete. They correspond to the first three decades of this century. The earliest ones have masonry spandrel walls, but as cement became cheaper in the 1910s, construction was entirely in concrete.

Important engineers, designers, and/or builders responsible for extant examples of this property type are: Gustavo Steinacher, Timoteo Luberza, Ettiene Totti, Rafael Nones, and Félix Benítez-Rexach. Totti designed and built in 1922 a concrete spandrel arch railroad bridge, currently listed in the National Register, that was hailed as an innovative use of the technology by the most important engineering journal in America, the **Engineering News Record**. The US Army Corps of Engineers rebuilt the vault of the Méndez Vigo Bridge as part of its role in military action during the Spanish American War.

IV. Registration Requirements:

Bridges of any type which have been widened by the addition of a contiguous parallel structure under a continuous pavement are considered to have lost historical integrity of design and are not considered significant. On the other hand, those which have been widened by adding cantilevered sections of pavement at the level of the deck are considered to possess an acceptable degree of integrity, unless the cantilevers compete visually with the bridge structure.

Bridges which were put into use have, by necessity, been subject to maintenance, upkeep and repairs. Resulting changes in pavement, paint, and other minor details do not affect the historic integrity of bridges of any type in this multiple nomination. Changes in service (rail, highway, or pedestrian) or in roadway type likewise do not affect the historic integrity of bridges of any type. Integrity of design and materials in bridge superstructure of all types is not diminished by changes in roadway, railway, or pavement as long as these changes do not affect the bridge's other elements or its overall dimensions. Bridge designs are flexible in terms of pavement type and repaving. Moreover, although a specific bridge is designed to carry a specific kind of traffic across an obstacle, its essential service and design remains even if developments in technology and economy of the society served by the bridge bring about changes in the type of roadway, pavement and vehicles carried across.

All extant highway bridges of any type with historical integrity and over fifty years old which were built as part of the public highways or railway system to clear natural obstacles or man-made features played important roles in economic and social development, at least at a local level. Thus, they have made a significant contribution to Puerto Rico's broad historical patterns, and all would be eligible to the National Register under a liberal interpretation of NRHP Criterion A in the area of transportation. In order to discriminate among the bridges that are more than fifty years old and possess integrity, Criterion A has been interpreted to identify bridges which have facilitated major passage to or through a region, or have allowed the settlement and development of any relatively sizable district or region. In the case of Puerto Rico's land transportation, this generally applies to the main early highway and railroad routes circling the island or into and across the mountains. Bridges of any type that possess historical integrity and are over fifty years old could be classified either as well-preserved examples of a once common type or as rare examples of some unusual type. All such bridges would also be significant in the area of engineering under such a liberal interpretation of Criterion C. Section H summarizes the criteria and point system created as part of the Puerto Rico Historic Bridge Inventory to designate historically significant bridges among bridges of all types which could qualify under the indiscriminate application of these two official NRHP criteria.

For a bridge of any type to be eligible under Criterion A in the area of transportation, its historic materials, forms, location, and setting must be intact. A bridge will rarely be significant under this criterion if it has been moved from its original site. Moreover, a bridge which today serves a historically important transportation link, is over fifty years old and possesses historical integrity, but is not the original structure built as part of the link, would rarely qualify under Criterion A in the area of transportation.

Arch bridges are defined in this nomination as structures in which the loads are carried to the supports by arch mechanisms. Structures such as the Guillermo Esteves Bridge, which has longitudinal beams carrying the loads hidden by arches that are mere architectural features of the façade, are not considered arch bridges.

Deck arch bridges which have large parts of their vaults either buried or covered by the normal water level, or which are much narrower than the cantilevered widened roadway supported, do not possess acceptable historic integrity for significance.

The period of significance for arch bridges begins in 1830, which corresponds to the decade in which the island's earliest extant structures of this type are believed to have been built. The period ends in 1944, the 50-year cut-off date for National Register eligibility. Alterations made before that date may be considered part of the bridge's historic fabric.

Specific consideration in the area of transportation under Criterion A:

Important crossing of a major early route: The 19th or early 20th century highways, main early highway routes circling the island or entering or crossing the central mountains, and railroad lines used for general cargo or passenger service are considered historically important parts of the island's transportation system. Those bridges possessing historic integrity, prominently including integrity of location, and built as part of these routes, would be significant at the State level.

Specific consideration in the area of military history under Criterion A:

Transportation system disabled to cover a military retreat. A strategic bridge damaged to slow down a military pursuit, during the Spanish American War of 1898, in the defense of sovereignty or territory in a war would possess historic military significance at a State level.

Specific considerations in the area of engineering under Criterion C:

Early well-preserved structure of its subtype. Such a structure would be significant at a State level.

Exceptional examples of work by an important engineer or firm: Prominent builders and designers identified as significant in arch bridge construction in Puerto Rico are : Gustavo Steinacher, Timoteo Luberza, Rafael Nones, Ettiene Totti, and Félix Benitez-Rexach. Structures for which these persons were responsible would be significant under engineering at the State level. Structures repaired by the US Army Corps of Engineers during the Spanish American War would be significant at a state level.

Technology rare or unique in the jurisdiction of the United States: The 19th century masonry arch bridges are the only examples of Spanish arch bridge technology in the US jurisdiction; so is the 1869 iron arch bridge. Both property subtypes would be significant at a national level in the area of engineering.

Bridge with exceptional aesthetic merit: Most arch bridges are inherently attractive because of their form. They require a higher degree of craftsmanship than beam bridges or concrete slabs. In addition, most of them do have at least some ornamentation. Occasionally, a structure stands out because of its design, ornamentation, or exceptional craftsmanship. Such a structure would be significant at a State level.

I. **Name of property type: METAL BEAM BRIDGES**

II. **Description:**

A beam is a horizontal structure that supports loads between two supports without creating lateral thrust on them. In a beam supported at both ends, compression is developed in its upper part and tension in the lower part. Wood and most metals (cast iron is a notable exception) are capable of resisting both types of forces. Reinforced concrete uses steel bars to support tension, while the concrete provides the compression capability, the monolithic bonding between the tension and compression elements, and a protective envelope for the steel reinforcement.

Beam bridges can be classified into subtypes according to the material, fabrication and placement pattern of their beams. Metal beam bridges are classified according to beam fabrication as **rolled girder** or **built-up girder.** Rolled girder bridges are very common. They use the most economical metal objects production technology, but are limited to spans of less than 12 meters because of the maximum practical transverse section sizes which can be produced by the steel mill's rolling equipment. They can be so simple to design and utilize that this subtype has not been considered to embody engineering significance. This span limitation can be overcome by fabricating an I-beam by joining together rolled metal plates into **built-up girders.** Girder bridge spans are limited by economic considerations, not by maximum beam size. The first metal girder bridge was made of wrought iron in England in the 1840s. Early metal bridges kept using wood plank decks, but when iron production improved and prices decreased they began to use decks assembled from domed metal plates. The 1910s saw the introduction of reinforced concrete slabs. These were cast over the longitudinal steel beams or girders, and served both as decks and floors.

Metal beam bridges are also classified according to structural system. In **longitudinal** beam bridges, the structure has its main beams running under the deck. In **transverse joist** bridges, the main beams are placed along the sides, with a system of transverse joist supporting the deck. Most beam bridges use rolled beams or girders longitudinally, spaced approximately every two feet and supporting the deck directly from underneath. In narrow metal bridges of specific sizes and periods, it was more economical to use two girders along the opposite sides of the bridge and support the deck from these by means of transverse joist, as is usually done in other types of metal bridges. The transverse joist system was used in Puerto Rico's first metal beam bridges and it became rather common. However, the increasing volume of traffic demanded wider roadways, and only longitudinal beam bridges were being built after the first decade of the 20th century.

Steel beams, whether they are built-up girders or rolled shapes, have two types of elements: a vertical element, or "web", and two horizontal "flanges" centered above and below the web. The usual transverse section which results is described as a "I"-shape. In a loaded beam supported at the ends, the upper flange is put into compression and the lower flange into tension; the web develops shear stresses as it ties the flanges and makes them work together. Built-up girders can be subdivided by web type: while some girders have **solid webs**, others, called **lattice girders**, use webs consisting totally or partially of thin elements placed diagonally. A lattice web lightens the girders over long spans and reduces their use and cost of materials. For short spans, the solid-web girder was preferred because of its lower assembly labor cost. According to the Director of the Historic American Engineering Record, although wood lattice trusses were being used for bridges in America, metal girders were not.

From an engineering standpoint, the most interesting metal girder bridges in the island were steel trestle viaducts erected over the Bellaca and Cedros Creeks, in the railroad stretch between Camuy and Aguadilla, by the American Railroad Co. between 1906 and 1908. These were disassembled and sold following the railroad's bankruptcy in 1953.

In Puerto Rico, the following subtypes of metal beam bridges are identified:

* **longitudinal rolled beam (no engineering significance)**. This became the most common type of highway bridge structural system in the period from 1915 to 1930, although many short spans were already being used in the 1903 ARR railroad stretch between Hormigueros and Yauco. The Ponce & Guayama RR Co., a subsidiary of the Central Aguirre sugar mill, built several steel beam bridges in the southern part of the island around 1907, most of which still stand. The standard highway bridge used pile-supported piers every 9 to 11 meters. Their beams were imported from American mills or fabricating shops. Once in place, they were often encased in concrete for protection. This property type was used all over the island, and over fifty are still in service, although with varying degrees of integrity. Many of them have ornamental railings and some other architectural detail. Total lengths range from 6.2 to 100.9 meters, and the longest spans reach 10.9 meters. Most of them are in service, but are narrow for most of today's traffic and as such may become candidates for replacement or rehabilitation. Those with exposed beams will suffer the most if abandoned and denied maintenance.

* **longitudinal built-up girder (little engineering significance)**. These bridges were never common and don't have a specific pattern of geographic distribution. Several were built for railroads, with the girders running roughly beneath the rails, separated by the ties. The oldest extant one is from c.1910; almost all of these are abandoned and in deteriorated or ruinous condition, with the only known exception serving an agricultural road. A few were built for specific conditions affecting spans, such as the 1927 Guillermo Esteves Bridge (No. 86) which needed to span 17.8 meters to be able to use piers built for an earlier structure. Some were built privately in the 1940s to early 50s for rural roads or for highways that were eventually turned over to the State. Some of these bridges, especially the railroad structures, have no ornamentation. Esteves Bridge, an ornate landmark structure designed by an

architect, is a notable exception. Most of these bridges are in service, but are narrow for today's traffic and as such are or may become candidates for replacement or rehabilitation. The steel girders inherently have crevices and irregularities; if exposed, abandoned, and denied maintenance, they are very prone to quick deterioration.

* **solid web girders with transverse joist.** These bridges were used in highways between 1879 and the first decade of the 20th century. Most are prior 1898, and they are found in most of the stretches of first-order highways built under Spain and in the old Moca-San Sebastián road. They are only one or two span structures, ranging in lengths from 7.9 to 19.9 meters. The 19th century structures, and also perhaps the ones erected in 1901, were imported from France and Belgium. Those dated 1905 and after were imported from the United States. Ornamentation may be present in the abutments, especially in the 19th century structures. Some conserve stone corner pieces, which were provided to protect the ends of the girders. Some keep original railings. The structure across the Cibuco River was encased in concrete in 1917 to stop deterioration. Most of these bridges are in service, but are narrow for today's traffic and as such are or may become candidates for replacement. The metal girders inherently have crevices and irregularities; if exposed, abandoned, and denied maintenance, they are prone to quick deterioration. The wrought iron beams are expected to be more resistant.

* **lattice girders with transverse joists.** These bridges, unique in the jurisdiction of the United States, were erected as early as 1877 and as late as 1892. They were imported from France and Belgium. Most of them are found between Juana Díaz and Cayey in the **Carretera Central**, plus one in the East and another one in the West. Ornamentation is usually present in the abutments, while the lattice girder itself is inherently attractive. Some conserve stone corner pieces, which were provided to protect the ends of the girders. In all cases the substructure evidences superior workmanship. All except two are single span structures, with lengths ranging from 13.1 to 21.5 meters. The others have two spans, with the longest totalling 53.2 meters overall. Except for one structure in which all of the web is a lattice (Liendre Bridge), the lower part, usually nearly one third, is solid. Most of these bridges are in service, but are too narrow for today's traffic and as such are or may become candidates for replacement. The iron girders are exposed and inherently have crevices and irregularities; if abandoned and denied maintenance, they are prone to deterioration.

III. Significance:

Different examples of this property type are eligible for the National Register under Criteria A and/or C. Representative examples of standard steel beam bridges may be significant at the State level in the area of engineering. Exceptional metal beam bridges, including rare subtypes, may be significant at the State level in the areas of engineering and transportation. According to the Chief and Principal Architect of the Historic American Engineering Record, Puerto Rico's iron lattice girder bridges are the only examples of this European bridge design and technology under the jurisdiction of the United States. Therefore, lattice bridges may be significant at the national level in the area of engineering under Criterion C.

The first bridges in Puerto Rico were beam bridges: tree trunks fallen across streams or laid there by Indians. The stream crossings of the conquerors' foot paths must have been similar in nature, while their bridle paths and wagon roads demanded a deck of planks over wood or lumber beams. Exposed wood is not durable in tropical climates, and even the more elaborate wood truss bridges were considered to be provisional structures by the colony's Spanish authorities. Beam bridges adopted stronger, longer-lasting, wrought iron beams when these became available in the 19th century, and steel beams at the turn of the century. The beam bridges that exist today in Puerto Rico are made of metal or reinforced concrete.

Up to 1898, Puerto Rico's metal bridges were all imported from European metal shops, mostly from France and Belgium. These beam and truss bridges were assembled locally and set on abutments and piers.

Puerto Rico's longest spans, due to the absence of large-scale rivers or gorges, do not surpasss 340 ft. That is why there are no examples of long-span bridge technolgy, such as suspension bridges, through arches, or cantilever trusses. Given these circumstances, common beam and slab bridges which rely on the repetition of short, standard spans and whose design and construction are purely conventional, and thus have no inherent engineering significance, become relatively more important than in other places.

Engineers, designers, fabricators, and/or builders who were renowned professionals and/or did important or frequent work in Puerto Rico and who are responsible for extant examples of this property type are: fabricating shops **Niccrise & Decluve** and **Eugene Rollin & Cia.** from Belgium; **Duclos & Co.** from Paris, and US Steel; designers and builders Raimundo Camprubí and Tulio Larrinaga, Spanish regime highway, bridge and railroad engineers who assembled imported trusses and built magnificent abutments, and Rafael Nones and Félix Benítez-Rexach, who were respectively the designer and builder of the most remarkable bridges of the first decades of the 20th century.

IV. Registration requirements:

The period of significance for metal beam bridges begins in 1877, the year in which the island's earliest extant structure of this type was built. The period ends in 1944, the fifty-year cutoff date maintained by the National Register. Alterations made during this period may be considered part of the bridge's historic fabric.

Since metal beam bridges were brought in pieces to be assembled on site, and one of their features is precisely their mobility, application of the latter cannot be a disqualifying factor for compliance with Criterion C under engineering. For metal beam bridges to be eligible under Criterion C for their engineeering significance, it is not necessary for them to retain their original location as long as an appropriate setting is provided and their engineering features are retained.

Because most of the structure of longitudinal beam or girder bridges is visible only from beneath, the survival of original railings, piers, and other details is of particular importance to the integrity of these subtypes. Changes in the deck system of a metal bridge are considered to have only minor effects in terms of the structure's historic integrity in bridges which have very visible characteristic elements such as lattice girders. In bridges with hardly visible elements, such as longitudinal beam or girder bridges and low-profile solid web girder with tranverse joists, the decks make a more important contribution to their overall sense of past time and place. Those bridges fitting this description whose metal decks have been replaced will rarely qualify because of integrity considerations.

Since standard longitudinal rolled beam and longitudinal built-up girder bridges are not considered significant engineering structures, they do not qualify individually as bridges under Criterion A (although they could be part of a qualifying stretch of highway). Under Criterion C in the area of engineering, one exceptionally representative bridge would qualify to illustrate the technology which was most used in the

1900s-1920s.

<u>Specific consideration in the area of transportation under Criterion A:</u>

Important crossing of a major early route: The 19th or early 20th century highways, main early highway routes circling the island or entering or crossing the central mountains, and railroad lines used for general cargo or passenger service are considered historically important parts of the island's transportation system. Those girder bridges with transverse joists and exceptional longitudinal beam bridges which possess historic integrity, prominently including integrity of location, and built as part of these routes, may be significant at the State level.

<u>Specific considerations in the area of engineering under Criterion C:</u>

Exceptional example of work by an important engineer or firm: The known prominent builders and designers responsible for extant metal beam bridges in Puerto Rico are: Raimundo Camprubí, Tulio Larrinaga, Rafael Nones, and Félix Benítez-Rexach. Structures for which these persons were responsible would be significant under engineering at the State level. International and mainland firms proficient in the Puerto Rican context include: **Nicrisse & Decluve, Eugene Rolling & Cia, Duclos &Co.** and **US Steel.**

Technology rare or unique in the jurisdiction of the United States: The European technology of Puerto Rico's lattice-web transverse joist girder bridges is unique in the jurisdiction of the United States. Examples of this subtype may be significant at a national level in the area of engineering.

Technology rare or unique in Puerto Rico: The use of concrete trestle combined with steel beams is rare at least in Puerto Rico and would be significant at the State level.

Well-preserved, typical example of a subtype: Specific examples of subtypes which have little or no inherent engineering significance may be eligible at the State level to illustrate the prevailing standard technology of a period. The selection criteria for such type representatives are explained in section H.

Bridge with exceptional aesthetic merit: The lines of lattice girders are inherently attractive. The railings and relief ornamentation of some bridges can also be appealing. Some girder bridges from the 19th century and early 1900s have beautiful masonry abutments. Some important beam bridges were designed as landmark structures and feature attractive ornamention. These structures would be significant at State level.

I. <u>Name of property type</u>: METAL TRUSS BRIDGES

II. Description:

A truss can be visualized structurally as a girder composed of distinct elements interconnected at their ends that are relatively short and slender. In a truss bridge, the constant weight of the pavement and deck, plus the variable weights of crossing vehicles, are transmitted by transverse joist directly to the connections of the truss. Depending on the load pattern, in the diverse configurations created by truss designers, elements may be in tension or compression, but are never subjected to bending, which requires a very inefficient use of material. This system allows metal structures that span from thirty to more than 100 meters at a reasonable cost with minimum material utilization. These distances are economically unfeasible for structures based on bending, such as beams or girders.

As happens in a girder supported at its ends, the elements that make up the lower line of elements or **chord** of a similarly supported truss are in tension, as is the lower flange of a girder, and the top chord in compression. The vertical and diagonal elements that connect the chords to each other are loaded either in tension or compression according to the truss configuration and the position of the moving loads. Elements subject only to tension under all possible load patterns may be very slender. The remaining elements are more massive; they can be either box sections or assemblies made up of thin elements in triangular patterns. In polygonal trusses the upper chord has a polygonal shape with its greater depth in the center; the lower chord is usually horizontal.

When the bridge floor is at the level of the trusses' upper chord, the bridge is known as a **deck truss**. None of these exist in Puerto Rico today, but some railroad bridges were of this type. When the deck is at the level of the lower chord, and the upper chords of the trusses on each side are not connected, the bridge is called **pony truss**. When the upper chords (and often the vertical elements) are tied together above the level of vehicular traffic, it is called a **through truss**.

The **Pratt** rectangular truss, patented in 1844, has diagonals going down from both ends towards the center of the span in such a way that they are subject only to tension. A truss having a similar configuration but with a polygonal upper chord is called **Parker**. A polygonal truss can have additional diagonals that do not reach from chord to chord, called "sub-diagonals", and the truss is then the **Pennsylvania**. The **double-intersection Pratt**, patented in 1847, is a through truss in which vertical elements are closer to each other and diagonals cross them through their midpoints, ending in the next panel.

The **Warren** truss was patented in 1848 by two British engineers. This configuration has its diagonals in alternate directions, as the letter "W", and were generally combined with vertical elements. One variation has two diagonals systems in opposite directions, as the letter "X". This variation was popular in Europe, where it was known as the "Eiffel system". The "lattice truss" is a Warren variation which has three parallel, superimposed diagonal systems. The railroad trusses built in the early 1890s apparently substituted wrought iron for steel and introduced the rectangular double-intersection Pratt.

Puerto Rico's extant truss subtypes are:[28]

- **Pony trusses.** The pony trusses known to have existed in Puerto Rico were either Eiffel, Pratt, Lattice, or Warren rectangular trusses. The first pony truss bridge known to be finished in Puerto Rico was a lattice pony truss erected in 1876, the only existing example of such truss. An Eiffel pony truss had been ordered in 1874 for the Plata River, but its erection was delayed by a hurricane and other difficulties until 1881. The latest existing Eiffel truss is from 1896. The Pratt pony truss bridge which still crosses the Guanajibo River in Hormigueros, erected in 1897, is the only known example of this truss of the Spanish regime. There is only one more example, dating from 1936. A Warren truss railroad bridge which exists in Añasco seems to be from 1893. All known Warren truss highway bridges are from this century, built between 1908 and 1936.

All extant pony trusses have a single span. For the Eiffels, this span ranges between 15.3 and 34.1 meters; for the Warrens, 18.3-45.4 meters; for the Pratts, 27.3-33.2 meters. The unique lattice truss span is 39.8 meters long. The bridges built on or before 1908, especially those built during the Spanish regime, have interesting architectural details, such as stone corner pillars protecting the truss ends and masonry, brick, or ashlar abutments decorated with features such as cornices and brick edges. After this date the abutments were made of mostly plain concrete. The pre-1898 trusses also evidence superior workmanship and elegantly curved connection details. Most of the 19th century pony trusses, with the possible exception of the Silva bridge, seem to have been made of wrought iron; the others are steel. These bridges illustrate readily how European technology was being imported during the Spanish regime and how that changed after the US took over in 1898. The first bond issue in the colony's history in 1906 was a major export breakthrough for the American Bridge Company, the largest such American firm of the period which fabricated the majority of the bridges erected in 1907 and 1908 in the island. The American-made pony trusses have gusset plates, in contrast with the European trusses' deep upper and lower chords, to which post and diagonals were riveted directly. It seems that these trusses eventually displaced the lattice girders, the latest documented use of which was in 1892, and which had overlapping span ranges.

Today's extant pony trusses are found mostly in the mountains highways. This probably reflects the historic distribution pattern because these trusses are easy to move and assemble at remote locations and have relatively short spans.

Many of the bridges have been abandoned, removed and/or relocated as part of bridge replacement projects because they are too narrow for modern traffic and unfit for widening. Most extant ones will probably follow suit in the next ten years. As all metal bridges, once they are abandoned and not provided further maintenance by Public Works Departments crew, they deteriorate very rapidly. With the help of encroaching tropical vegetation, this process can affect integrity quickly.

- **Rectangular through trusses.** Three types of rectangular through trusses have been documented in Puerto Rico: Eiffel, Warren and Double-intersection Pratt. There is an Eiffel through truss from 1894 which is still in use near Cayey; its single 62.4 meter span was the longest span built by the Spanish regime. No other such trusses are known to have been used for highways, but a 25-meter, single span Double Warren through truss sugar mill railroad bridge still exists near Naguabo. More than ten Double-intersection Pratt truss bridges were built between 1890-93 along the coastal plains between San Juan and Ponce for the French-owned railroad company, but only the one across the Arecibo River remains today. It is a two-span structure totaling 96 meters in length, abandoned and deteriorated. Ciales' **Mata de Plátano** Bridge (No.321) seems to be the only one of this truss type in highway use. Built in 1905 in a spectacular setting, its 82-meter single span still carries traffic.

The abutments of the 19th century through truss bridges show very good stonework. The 20th century structures have rather plain concrete supports. Although the structural terminology of the 1890s in Puerto Rico may be misleading, it appears that all of these bridges were made of steel. The Arenas bridge superstructure also has truly beautiful metal work.

The two highway bridges in use are too narrow, and will probably be replaced in a few years. This will bring them to the status of the other two, the abandoned railroad bridges, and propitiate the menacing, accelerated deterioration of unmantained metal structures. The Arecibo bridge is so deteriorated that it may collapse.

* **Polygonal through trusses.** Three types of polygonal through trusses have been documented in the island: Parker, Pennsylvania, and Warren. All of these types were introduced during the US regime and imported from the American mainland. The Parkers were the first polygonal trusses used. The earliest known, was built in 1907 to replace a bridge in Utuado affected by the 1899 hurricane. At least three of the many bridges finished in 1908 as a result of the 1906 bond issue were Parker trusses. One of these, Plata Bridge, with its two 42-meter spans, has been abandoned in its original location near Naranjito. The longest Parker was 96 meters long, built in 1908. The shortest one, 50 meters long, is also the most recent. Built in 1938 in Juana Díaz, its width is totally inadequate and will be replaced in a few years. The first Pennsylvania truss was a railroad bridge built c.1906. All other known Pennsylvania trusses belong to highway bridges, and were built in the 1930s and 40s. All of these bridges feature single spans. The two still standing have been abandoned in their original location and are slated for demolition: the 100-meter Salcedo bridge with two 20-meter steel girder approach spans, and 102.3-meter Trujillo Alto Bridge, the longest single span structure built in the island.

  The only polygonal Warren through truss known is the 41.8-meter, single span Río Blanco Bridge in Naguabo, which is still in use. Built in 1928, it is barely polygonal, with an almost flat top chord.

  Except for Plata Bridge's impressive stonework, the extant properties of this subtype have plain concrete supports. It was actually the high cost of piers, due to the flood, water depth, and/or soil conditions, which favored the construction of these long-span structures. Unsurprisingly, they were located over the largest and most troublesome rivers, such as Loíza, Plata, Añasco and Arecibo.
  As happens to all metal bridges, once they are abandoned and not provided further maintenance by Public Works Department crews, they deteriorate very rapidly. There have been attempts to relocate the two bridges which are slated for demolition, but their size make this so costly that it has been an insurmountable problem so far.

III. Significance

Examples of this property type are eligible for the National Register under Criteria A and/or C. Puerto Rico's metal truss bridges may be generally significant at State level in the areas of transportation and engineering. According to the Director of the Historic American Engineering Record, Puerto Rico's 19th century truss bridges are the only examples of European truss bridge design and technology under the jurisdiction of the United States. Therefore, these bridges may be significant at the national level in the area of engineering under Criterion C. In addition, specific bridges may be significant at the state level in the area of military under criterion A.

Truss bridges, made in wood, started to become popular in the 1820s in the United States with the Town truss. By 1840, as dependable, tension-resistant wrought iron became economical to produce and fabricate, all-iron trusses became practical. The elements of the first metal trusses were pinned together, but pins soon gave way to safer and more durable rivet connections. Near the end of the 19th century, wrought iron was being displaced by steel.

The earliest documentation known of wood truss bridges in Puerto Rico is from 1853, under the name of "Paladio system"[29]. A "Tower system" wood truss is mentioned as existing in 1862. However, in the climatic conditions of the island, wood deteriorates so fast that the wooden bridges were considered temporary structures. Most bridges of importance built in Puerto Rico between 1872 and 1915 were riveted metal trusses. With the labor shortage existing in the late 19th century Puerto Rico, the metal truss bridges were vital in allowing the construction of highways at the reasonably fast rate achieved after 1876. The railroad construction work carried on by **Compañía Ferrocarrilera de Puerto Rico** (CFPR) during between 1889 and 1893 relied on steel truss bridges for almost all significant obstacles. The railroad's rectangular Double Pratt trusses were the first through trusses documented in Puerto Rico.

One of the events of the Spanish American War in Puerto Rico was the thick sniper fire directed at advancing American troops under Brigadier General Theodore Schwan by Spanish Army unitsand Puerto Rican volunteers or **guerrillas** as the former approached the Silva Bridge in Hormigueros on August 10, 1898.

The use of steel trusses allowed quick results in medium and long spans after the 1906 public works bond issue. These included the first known polygonal trusses erected in the island. The island's only documented upper deck truss belonged to a trestle viaduct built by the ARR for the Guajataca Canyon c.1908. An application of the steel truss which was unusual in Puerto Rico was designed by Eng. Rafael Nones; a lift span with a wooden deck in the 1915 Bascule Bridge.

Important engineers and firms responsible for extant truss bridges include 19th century fabricators: Belgian firms **Eugene Rollin, Cia Participation Belgue**, and **Niccrise Decluve**, and the French firm **Ulince**. The French-Spanish railroad firm CFPR, which imported its bridges from France, was the most important erector of this type of bridge at that time. Engineer Tulio Larrinaga was a noteworthy bridge erector. In the 20th century the most prolific fabricators were: American Bridge Co. in the 1910's US Steel from the early 20th century until the 1930s, and Puerto Rico Iron Works in the 1930s. Groton Bridge Co. and ARR erected important trusses in the 1910's.

A crucial year in truss bridge technology was 1898. The change in sovereignty displaced European in favor of American technology. Warren pony trusses and polygonal Parker on less elaborate abutments, displaced Eiffel ponies and rectangular Double Pratts on elaborate supports. The 1920s saw concrete arches displace trusses in medium spans and steel beam bridges of multiple spans of 10 meters clearing almost all but the most formidable obstacles. The 1940s saw the last steel trusses used only for spans of the order of a hundred meters.

IV. Registration Requirements:

The period of significance for metal truss bridges begins in 1876, the year which saw Puerto Rico's earliest documented superstructure of this type. The period ends with the year 1944, the fifty-year NRHP cut-off date. Alterations made during this period may be considered part of the bridge's historic fabric.

Since metal truss bridges were brought in pieces to be assembled on site, and one of their features is precisely their mobility, application of the latter cannot be a disqualifying factor for compliance with Criterion C under engineering. For metal truss bridges to be eligible under Criterion C for their engineering significance, it is not necessary for them to retain their original location as long as an appropriate setting is provided and their engineering features are retained.

A truss bridge is considered to be comprised of a group of distinct structural systems: the superstructure, the substructure, the floor and deck and the approach spans, if any. The superstructure, the truss, provides the bridge its character and is its main source of significance. The super-and-substructure of a bridge, for instance, may have retained a high degree of physical integrity, while the floor system and approach spans may have been altered, replaced or even removed, and the bridge may still be considered eligible under Criterion C in the area of engineering.

Specific consideration in the area of military under Criterion A:

Sites of military skirmishes during the Spanish-American War of 1898: Bridges associated with clashes between the Spanish regular army and the U.S. forces are considered significant at state level.

Specific considerations in the area of transportation under Criterion A:

Prominent product of Puerto Rico's first public work bond issue: The steel truss bridges erected in 1907 and 1908 are significant at the State level as part of the first major financing thrust of 1906.

Important crossing of a major early route: The 19th or early 20th century highways, main early highway routes circling the island or entering or crossing the central mountains, and railroad lines used for general cargo or passenger service are considered historically important parts of the island's transportation system. Those bridges possessing historic integrity, prominently including integrity location, and built as part of these routes may be significant at the State level.

Specific consideration in the area of industry under Criterion A:

Important part of a sugar mill's railway system: Bridges owned, made and/or used by sugar mills for transporting sugar cane and/or cane sugar may be eligible at the local level. If they were also used by general cargo and passengers with a lease agreement with ARR, they may be significant at the State level.

Specific considerations under Criterion C:

Example of a type rare or unique in Puerto Rico: The Eiffel pony truss in highways and the double Pratt through truss in railroads were the most common truss types in the 19th century. In the early 20th century, the Warren rectangular pony truss and the Parker polygonal through truss became the most common truss types. Only one double-intersection Pratt seems to have been erected for highway use in the island. In the 1930s and 40s the most common truss type was the Pennsylvania. These examples may be significant at the State level.

Exceptional example of work by an important engineer or firm: The known local prominent engineers and firms responsible for extant metal truss bridges in Puerto Rico are Tulio Larrinaga, CFPR, ARR, and Puerto Rico Iron Works. Exceptional examples for which these persons and firms were responsible may be significant under engineering at the State level. International firms proficient in the Puerto Rican context include: **Cia Participation Belgue, Niccrise & Decluve, Eugene Rollin & Cia, Duclos & Co.**, plus the mainland firms **American Bridge Co.**, **Groton Bridge Co.**, and **US Steel.**

Technology rare or unique in the jurisdiction of the United States: The European technology of Puerto Rico's Eiffel trusses is unique in the jurisdiction of the United States. Examples of this subtype may be significant at a national level in the area of engineering. Only one lattice truss iron bridge is known to have been erected in Puerto Rico, and it was likewise imported from Europe.

Technology rare or unique in Puerto Rico: The use of Double-intersection Pratt trusses in highway bridges was rare in Puerto Rico, with only one occurrence documented. A structure illustrating such technology may be significant at the State level.

Early well-preserved structures of its subtype. Such a structure would be significant at a State level.

Bridge with exceptional aesthetic merit: The lines of some trusses are inherently attractive. Some truss bridges from the 19th century and early 1900s have beautiful masonry abutments. Ocassionally, one of these structures stands out because of its design, ornamentation, or exceptional craftmanship. Such a structure would be significant at a State level.

I. Name of property type: REINFORCED CONCRETE BEAM & SLAB BRIDGES

II. Description:

In concrete beam bridges, the main girders run longitudinally under a concrete deck and support it directly. The girders are usually placed two or three feet apart, and the deck above is reinforced transversely. When the deck contains longitudinal reinforcement over each beam, and both are cast together, it is called a "T-beam" system. In concrete slab bridges, a thicker, uniform deck is reinforced longitudinally, becoming a wide beam that supports itself and its loads. It is used for shorter spans, generally over a series of piers.

Concrete beam bridges have been used since after 1915. The earliest known significant structure is a 1918 multi-span bridge over Naguabo's Santiago River. Another early use of concrete bridges around this same period was the substitution of wood beam superstructures over their original brick or masonry supports. These had spans of the order of 7 meters. Such is the case of the 1918 beam bridge No. 1701 (Cidra), and the 1921 Madre Vieja bridge (Aguadilla), which use a continuous slab. Concrete slabs have typically been cast continuously over their supports, with spans usually between 7 and 8 meters. Early beams were cast between the supports, with the deck laid on later; their spans were between 5.3 and 7.1 meters. Many concrete beam and slab bridges up to the 1920s had some architectural detailing, usually at the top of the piers and the railings.

As concrete design and technology advanced, beams and deck slabs became monolithic **T-beams**, which allowed spans of over 12 meters. The 1950s saw the first applications of what became today's prevailing concrete bridge technology: pre-cast beams, actually shaped as "T's", reinforced with pre-stressed or post-tensioned steel tendons.

Concrete beams and slab bridges are typically multi-span structures. Their relatively short span length requires many piers. Originally they were limited to dry or shallow river beds with stable soil conditions, but as pile and other foundation technologies developed, their use became economical for deeper rivers and less stable soils. In the 1920s concrete competed with steel in standard girder bridges, and in the late 1930s it had displaced the latter.

Some short, single span ARR viaducts and bridges of the 1920s and 30s used a slab/beam combination to support the railway. Their spans were uniformly thicker in the section corresponding to the width under the rails. Single-span slab bridges were also employed in strategic highway viaducts built during World War II. The U.S. Armed Forces had taken over the ARR railroad and they built several underpasses at important rail-highway crossings. These viaducts were typically single-span concrete frames, with the slabs and walls cast monolithically.

Concrete slabs were typically used for multispan structures in locations where pier construction was not expensive.

Concrete beam and slab bridges are still relatively abundant in all parts of the island. Although some of them were built as a result of the 1916 bond issue, the majority date mostly from the 1920s and 1930s. Most of them have widths that are acceptable for secondary roads and thus are not slated for short term replacement. As concrete is fairly durable in mild climates, even the few abandoned bridges are rather well-preserved. Many of them, especially the older structures, have some architectural details. Those of Bridge No.122 are especially noteworthy.

III. Significance:

Concrete beam and slab bridges may be eligible for the National Register under Criteria A and/or C. Representative examples of standard concrete beam or slab bridges may be significant at the State level in the area of engineering. Exceptional concrete beam or slab bridges, including rare subtypes, may be significant at the State level in the areas of engineering and transportation. In addition, specific bridges may be significant at the national level in the military area.

The first applications of concrete to bridges were in the foundations of late 19th century bridge supports, where its advantages over lime mansory overcame the high costs. Cement then was being imported in barrels from Northern Europe. The first known bridge superstructures in concrete were in 1899 arch bridges. American sovereignty allowed the untaxed importation of American cement at the precise point in time in which reinforced concrete technology was coming of age. The first decade of the present century saw several significant concrete arch bridges built. During the 1910s, concrete became the standard substructure and deck material. The two million dollar bond issue of 1916 came just in time to boost concrete beam and slab construction. This technology had become competitive with steel beams, and many of the bridges built up to 1921 financed by this bond issue were concrete beam or slab bridges. Many of them were part of the effort to link all of the island's towns with roads, a network which culminated in the 1920s with the completion of such roads as Yauco-Lares and Naguabo-Humacao. The standard design, quick construction, and rigidity of concrete frames (slabs cast monolithically with supporting walls) favored their use in short, single-span railroad underpasses built by the Armed Forces for strategic mobility during World War II.

Concrete beam and slab bridges require much less design and construction effort than do concrete arches. Standard concrete beam and slab bridges are considered to have little or no inherent engineering importance, but because of their low cost, local control, and standarized design and contruction, they greatly facilitated highway building in Puerto Rico from the 1920s into the 1950s.

Rafael Nones, Puerto Rico's noted bridge designer of the 1910s to 1930s designed some important concrete beam bridges. Some were also constructed by the very successful builder Félix Benitez-Rexach.

IV. Registration Requirements:

The period of significance for concrete beam and slab bridges begins in the mid-1910s, from which Puerto Rico's first extant structures of this type date. The period ends with the year 1944, the National Register's fifty-year cutoff date. Alterations made during this period may be considered part of the bridge's historic fabric.

Concrete beam bridges are defined in this nomination as structures which are supported by parallel longitudinal beams of concrete reinforced with steel bars. This subtype includes "T-beams", in which the floor slab works monolithically with the beam to support loads. It does not include elements which consist of steel beams encased in concrete. Slabs are defined here as continuous bodies that are totally flat underneath and are reinforced longitudinally.

Because most of the structure of longitudinal beam and slab bridges is visible only from beneath, the survival of original railings, piers, and other details is of particular importance to the integrity of these types.

Since standard concrete beam and slab bridges are not considered significant engineering structures, they do not qualify as individual bridges under Criterion A (although they could be part of a qualifying stretch of highway). Under Criterion C in the area of engineering, one exceptionally representative bridge would qualify to illustrate the technology which was most used in the 1920s-1940s.

Specific considerations in the area of transportation under Criterion A:

Important crossing of major early route: The 19th or early 20th century highways, main early highway routes circling the island or entering or crossing the central mountains, and railroad lines used for general cargo or passenger service are considered historically important parts of the island's transportation system. Exceptional concrete beam and slab bridges possessing historic integrity, prominently including integrity of location, and built as part of these routes, may be significant at the State level.

Prominent product of Puerto Rico's second public works bond issue: Puerto Rico's colonial government issued bonds to finance the construction of public works for the second time in 1916. Part of this money went into bridge construction. Most bridges financed by this bond issue were completed on or before 1919. The most prominent may be eligible at the State level.

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Specific consideration in the military area under Criterion A:

Transportation system enhancement for strategic mobility. Exceptional examples of the railroad underpasses built by the Armed Forces for strategic mobility during the World War II may be eligible for their military importance at the local level.

Specific considerations in the area of engineering under Criterion C:

Well-preserved, typical example of a subtype: Specific examples of subtypes which have little or no inherent engineering significance may be eligible at the State level to illustrate the prevailing standard technology of a period. The selection criteria for such type representatives are explained in Section H.

Exceptional example of work by an important engineer or firm: The known prominent designers and builders responsible for extant concrete beam and slab bridges in Puerto Rico are Rafael Nones and Félix Benítez-Rexach. Exceptional structures for which these persons were responsible may be significant under engineering at the State level, and the national level in the area of Hispanic engineering.

Bridges with exceptional aesthetic merit: These may be eligible at the State or local level.

28. Luis F. Pumarada O'Neill, Los puentes históricos de Puerto Rico, Mayagüez: Centro de Investigación y Desarrollo, Universidad de Puerto Rico, 1991, 153-154.

29. Andrea Palladio was the Italian architect who first included trusses in a treatise.

SECTION G: GEOGRAPHICAL DATA

The Commonwealth of Puerto Rico

SECTION H: SUMMARY OF IDENTIFICATION AND EVALUATION METHODS

The Puerto Rico Historic Bridge Inventory, which forms the basis of this Multiple Property Submission, was produced in 1988-90 by the University of Puerto Rico Mayagüez Campus' Engineering Research Center for the Puerto Rico Highway Authority and the Federal Highway Administration with the full collaboration of the State Historic Preservation Office and the Institute of Puerto Rican Culture. This work presents an inventory and evaluation of pre-1945 highway and railroad bridges in the Commonwealth of Puerto Rico which were in preservable condition.

This inventory covered 640 highway bridges and viaducts built in Puerto Rico on or before 1945 belonging to two basic administrative classifications: the Federal Aid primary system and the Federal Aid secondary system. It also includes standing highway and railroad bridges closed to vehicular traffic or on private roads. Several significant structures built on or before 1950 with typically pre-1945 technology, were also inventoried.

The typology of significant property types was based on superstructural type, categorized by material and configuration. The inventory includes all pre-1945 structural types and subtypes represented in Puerto Rico, except for the concrete-box culvert, which is composed of spans which do not meet the 20-foot definition of a bridge. This nomination weighs carefully the project's original criteria so that they conform to the requirements of the Criteria of the National Register of Historic Places. This multiple submission organizes and combines the inventory's 24 types into **four** types with subtypes. These **four** types are associated with the single context presented in Section E. The 24 types and subtypes represented in the inventory, are:

metal arch
spandrel arch
single span concrete arch, semi-circular
single span concrete arch, other
single span brick arch, semi-circular
single span brick arch, other
two-span concrete arch
two-span brick arch
multiple-span brick arch
steel lattice pony truss
Warren pony truss
Warren double intersection pony truss
Pratt pony truss
Warren through truss
Warren double intersection through truss
Pratt double intersection through truss
Parker through truss
Pennsylvania through truss
concrete slab, continous or simply supported
concrete beams, continous or simply supported, rectangular or "T"-beams
steel beams, two beams under deck

steel beams, multiple beams under deck
steel beams, lateral girders with joist floor system
steel beams, lateral lattice-web beams with joist floor system

The Puerto Rico Historic Bridge Inventory was comprised of three components: inventory, documentation, and evaluation. The P.R. Highway Authority provided a computer data base with relevant information on all the island's bridges and access to its bridge records and photographs. This data base was processed in order to yield a relevant listing of pre-1945 bridges organized in a manner consistent with the project objectives. Based on the information on this list, on the "Puerto Rico Historical Inventory of Industry and Engineering", a survey conducted in 1977, and on a list of candidate bridges, classified and prepared by Eng. Laboy of the P.R. Highway Authority, a blue-ribbon interdisciplinary panel established the criteria to be used in selecting the bridges, assigned weights to the criteria, and selected a set of bridges consistent with an aggregate measure reflecting bridge characteristic, judgements, criteria and weights.

The panel reduced the set of candidate bridges with the following cut-off requirements:

-the 6-meter minimum length used to define a bridge by the highway agencies would be kept;
-the selected set of historic bridges should demonstrate bridge-building technologies and materials used in Puerto Rico until the pre-World War II era.
-concrete slabs, and multi-beam structures of steel or concrete were discarded as having routine, unchallenging structural systems; bridges of those types were considered solely as examples of their respective technologies and materials, and only the longest or otherwise exceptional ones were included as candidates.

Approximately 110 candidate bridges were visited, photographed and evaluated in terms of observation-related criteria. Historical research was conducted on these bridges in the PR Highway Authority Bridge Records and in the **Archivo General de Puerto Rico.**

Quantified criteria-reflecting scales were created. All scales had a 5 to 0 range, with 5 representing the most favorable conditions. The final scales and weights are shown below.

During the course of the project, the criteria, scales and weights were adjusted and recalculated in order to yield an aggregate index of historical value which would be in accordance with the panel's selections and opinions.

The final set of criteria and their relative weights (in parenthesis), with their respective scales are the following:

Representative Index (weight 3.6): This index and its weight guarantee that the best representative of each bridge type will make the list of historic bridges. Those criteria below which appear marked with an asterisk were aggregated to reflect the value of the bridge as a representative of its type.

A scale score of **5** corresponds to the bridge with the highest point total within each type. All the others score 0.

***Integrity with respect to the original structure (2.5):**
a **5** corresponds to a minimum of alterations, losses, or damage.

Date of construction (2.5):
Before 1860:**5**. 1861-85:**4**. 1886-98:**3**. 1899-1915:**2**. 1916-32:**1**. More recent:**0**.

Structural systems (2.5):
Elliptical arches:**5**. Other non-semi-circular arches and through trusses:**4**. Pony trusses and lattice-web beams:**3**. Semi-circular arches and lateral girders:**2**. Other steel beams:**1**. Other systems:**0**.

Associated historical events or figures (2.5):
An important figure or event is closely associated to the existing bridge:**5**. An important figure or event is closely associated to a bridge which once existed at the same site:**2**. An important event took place in the vicinity of the actual bridge site:**1**. None of the above:**0**.

***Roadway visibility of the bridge form (2):**
The bridge can be seen well in elevation from the same road it serves:**5**. Can be seen well in elevation from a parallel road:**4**. Can be appreciated from the curb or immediate vicinity of the road served:**3**. Can be appreciated to some extent while crossing it:**2**. It is evident that one is crossing a bridge while doing it, although its form can't be inferred:**1**. One can cross it and not notice it:**0**.

Total length (2): Over 130 meters long:**5**. 100.1m to 130m:**4**. 70.1m to 100m:**3**. 40.1m to 70m:**2**. 10.1m to 40m:**1**. 10m or less:**0**.

Materials (2): Structural use of brick or masonry both on supports and superstructure:**5**. Brick or masonry on one of the two, and metal on the other:**4**. Brick or masonry on one and concrete on the other:**3**. Steel on both:**2**. Metal on one; concrete in the other:**1**. All concrete:**0**.

***Clearance over the stream surface or bottom of gully (2):**
Over 24m:**5**. Between 17.1m-24m:**4**. Between 10.1-17m:**3**. Between 3.1m-10m:**2**. Between 1.8m-3m:**1**. Less than 1.7m:**0**.

Beauty of bridge lines (1.5):
A **5** corresponds to the most esthetically pleasing bridges.

***Decorative or special elements (1.5):**
Presence of 5 or more types of decorative or special elements:**5**. Less than 5 types of elements, equal to the corresponding number. The element types were identified as: decorative access, arch **façade**, structural arch, parapets or railing, plaques, relief dates, relief side decorations, decorative supports, textures, corner features, lamps, drains and decorative edges.

Belonging to the Spanish regime (1.5):
If built during the Spanish regime with minimum post-1898 alterations:**5**. Less altered, according to extent. Otherwise:**0**.

Historical importance of the road served and its integrity (1.5):
The **Carretera Central** and the **Circunvalación** Railroad:**5.** Spanish regime roads on coastal regions:**4.** Other Spanish regime roads:**3.** Main roads built 1899-1930 which joined main cities or opened the interior:**2.** Other roads built before 1930 and private roads:**1.** Others:**0.** Less in each category to reflect the degree of alteration.

Intervention of a prominent engineer (1.5):
T. Larrinaga:**4.** R. Nones, F. Benítez Rexach, E. Totti, I. Abarca, R. Carmoega; Echevarría:**3.** P.R. Iron Works; Niccrise Decluve, US Army Engineer Batallion, E. Rollin, Duclos & Co., American Bridge Co., Groton Bridge Co., Virginia Bridge Co., G. Steinacher, Camprubí, Comte, American Railroad Co., **Compañía Ferrocarrilera de Puerto Rico**:**2.** Other known:**1.** Unknown:**0.** (For combinations of engineers in the first three categories, add 1 to the highest value.)

***Length of the longest span (1.5):**
Over 60m:**5.** Between 45m-59.9m:**4.** Between 30m-44.9m:**3.** Between 15m-29.9m:**2.** Between 8m-14.9m:**1.** Less than 7.9m:**0.**

***Oldest existing structure of its type (1):**
The oldest existing bridge of its structural system has **5**. The next oldest has **3**, and all others, **0**.

***Integrity of setting (1):**
A **5** corresponds to the bridges whose surroundings have maintained the historic character present during their period of significance.

***Scenic value (1):**
A **5** corresponds to those bridges whose surroundings have scenic value.

The panel's methodology, criteria, weights, and scales were accepted by the highway and cultural preservation agencies. A final set of bridges was agreed on and the weights and scales were modified to remain consistent with these judgements.

The following list includes the selected bridges. Those appearing in bold have relocated after inclusion in this list.

List of Historic Bridges

No.	Name	Date	Type & subtype	Span	Municipality	Index
174	Padre Iñigo (de Coamo)	1877	lattice, transverse joist	2	Coamo	129.0
466	de Arenas	1893	Eiffel pony truss	1	Cayey	120.5
71	Silvia (Isabel II)	1897	Pratt pony truss	1	Hormigueros	110.0
3	Río Piedras	1853	brick arch	3	San Juan	109.5
6	Río Cañas	1854	brick arch	3	San Juan	109.5
379	de la Serna (R. Bayamón)	1869	metal arch	1	Bayamón	108.5
99	Villarán (Canóvanas)	1892	Eiffel pony truss	1	Canóvanas	107.0
513	del R. Cibuco	1886	solid girder, transv. joist	1	Vega Baja	104.5
73	**Pezuela (Colorado)**	**1879**	**solid girder, transv. joist**	**1**	**Hormigueros**	**102.5**
321	J. Jiménez (Mata Platano)	1905	Double intersection Pratt	1	Ciales	99.0
354	Mavilla	1903	reinforced concrete arch	1	Corozal	99.0
279	de las Cabañas	1919	concrete vault trestle/ steel beam	3	Adjuntas	97.0
172	Descalabrado	1878	lattice, transverse joist	1	Coamo	96.0
4	Norzagaray (Frailes)	1854	brick arch	8	San Juan	95.5
173	Méndez Vigo	1862	brick arch	1	Coamo	95.0
1112	Blanco (Q. la Mala)	1922	concrete spandrel arch	1	Quebradillas	95.0
467	de la Liendre	1877	lattice, transverse joist	1	Cayey	94.0
86	G.Esteves (del Agua)	1927	longitudinal rolled beam	5	San Juan	94.0
427	Trujillo Alto	1939	Pennsylvania through truss	1	Trujillo Alto	94.0
262	Blanco	1921	reinforced concrete arch	2	Lares	93.5
341	El Higüero	1908	Warren pony truss	1	Comerío	92.0
175	Calabazas	1878	lattice, transverse joist	1	Coamo	91.0
181	de Cayey	1891	lattice, transverse joist	2	Guayama	87.5
59	**Carrizal**	**1894**	**Eiffel pony truss**	**1**	**Aguada/ Aguadilla**	**87.0**
180	Santo Domingo	1881	brick arch	2	Cayey	86.0
374	Plata	1908	Parker through truss	2	Naranjito/ Bayamón	85.5
503	del Riachuelo	1925	reinforced concrete arch	1	Corozal	85.0
176	de Hierro; Q. Honda	1892	lattice, transverse joist	1	Aibonito	84.5
178	Toíta	1892	lattice, transverse joist	1	Cayey	84.5
11	-	1879	solid girder, transv. joist	1	Caguas	83.5
C.C.	Cambalache	1893	Double intersection Pratt	6	Arecibo	82.0
177	Río Matón	1886	solid girder, transv. joist	1	Cayey	81.0
122	-	1918	reinforced concrete beams	9	Naguabo	81.0
194	Río Blanco (Naguabo)	1928	Warren through truss	1	Naguabo	80.0
517	-	1876	brick arch	1	Dorado	78.0
1456	-	1910	reinforced concrete arch	1	Juana Díaz	78.0
65	Salcedo	1944	Pennsylvania through truss	1	Mayagüez/ Añasco	77.0
261	del 30	1924	longitudinal rolled beam	3	Maricao	76.5
79	**de Hierro Cristobal Colón**	**1915**	**lattice pony truss**	**1**	**Yauco**	**76.0**
Cñ.P.	Caño La Puente	1893	Warren pony truss	1	Añasco	75.5
213	Orama	1922	reinforced concrete arch	1	Maricao	72.5
208	Torréns	1878	lattice, transverse joist	1	Hormigueros	71.5
271	Alonso	1911	reinforced concrete arch	1	Guayanilla/ Peñuelas	68.5
1142	de Coloso	1928	Warren pony truss	1	Aguada/ Aguadilla	68.5

150	Chavier	1901	reinforced concrete arch	1	Adjuntas	68.0
1572	Guajataca	1896	Eiffel pony truss	1	Isabela/ Quebradillas	68.0
2047	Maginas	1900	reinforced concrete arch	1	Sabana Grande	67.5
358	de La Llorona	1908	Warren pony truss	1	Barranquitas/ Aibonito	67.0
152	Blanco	1924	reinforced concrete arch	1	Utuado	66.5
A.A.	Añasco Arriba	1905	reinforced concrete arch	2	Añasco	65.5
1571	San Antonio	1932	longitudinal rolled beam	12	San Juan	65.0
508	-	1943	longitudinal built-up girder	5	Utuado	65.0
316	de La Piedra	1924	reinforced concrete arch	2	Ciales/ Orocovis	63.5
339	Río Hondo	1908	Eiffel pony truss	1	Comerío	63.5
185	Martín Peña	1939	longitudinal rolled beam	5	San Juan	62.5
214	Guaba	1925	reinforced concrete arch	1	Maricao	62.5
1	San Antonio	1925	longitudinal rolled beam	10	San Juan	62.0
277	Sifonte	1924	reinforced concrete arch	1	Adjuntas/ Lares	62.0
24	Aruz	1938	Parker through truss	1	Juana Díaz	61.5
157	-	1892	solid girder, transv. joist	1	Utuado	61.5
154	de hierro	1907	Parker through truss	1	Utuado	61.0
21	Los Poleos	1939	reinforced concrete slabs	8	Salinas	61.0

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