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A t1·eatment report by Conservation Solutions, Inc., on a terra-cotta cornice adorning the Capitol Building in San Juan, Puerto Rico, shows the potentially catastrophic effects of corrosion ṁm a ma1·ine environment, and offers some innovative solutions to the problem.

by Joseph Sembrat, *Hca,I Ct•JJ!'t'ri't1/11r dud Pr,::--1d,·11t ,,f Cc,11!-c'ri•11ti1,11 St,l11tio11!>, In(.*

onservation Solutions, Inc., was contracted by the government of Puerto Rico to assist Pablo Quinones of OPQ & Associates in the investigation of the main terra-cotta cornice at the base o(the dome of San Juan's Capitol Building.

CSI subcontracted the sen·ices of 1\•lartin \Vea,·er, President of Nlartin \Veavcr nnd Associ.ites International Conservation Consultants (MIVAICC), who pcriormed investigative work and partial disassembly of a 6-fL section of thL cornice. This was done in order to prennt the collapse of this section of the cornice, determine the cause ;md nature of the failure, better undcrst„nd the mc1tcrials and technique!'> used in its construction, and pro\'ide the t1rchill-d with ,·arious design solutions cost esti1nah•s, and c1ssistilnce with the writing of specific.itions.

The C.ipitol Building uf Puerto Rico was inaugurated on February 11, 1929, ils the scat oi the Legislatin· Br;inch oi the Puerto Ric.u, Go,·crnmcnt. A ,·ast m;irble st;iirca e face Ponce de Le,)n AvcnuL' and give acces to thl' building to the south. Eight Corinthian columns rise at both m1in entrances and even imposing doors gin acces to ib inlL•rior tt the north and outh. At the center of th• structure there is., rotunda which exotcnds up„·ard tu the three flours of the building, ;111d in the center of the first floor then• l> a displar c1se which has the original Constitution of Puerto Rico permanently on display. The cornice adorns the base of the dome which rises tll thL center of the building on an uct:igon I drum.

To help understand the condition of both the lerm-cotta anchoring system and tht' concrete substrut:turc that supporb it, nnd to nssist the clients in their portico-restoration project, CSI conducted an on-site in,·L·stig,1tion of the tcrrc1-cottc1 cornice nd concrete substructure from scafiolding. CSI and Nlartin \VtM\er pcriormcd written and photobraphic documentation of the „·or and pro,·ided field drnwings to OPQ & Associates.

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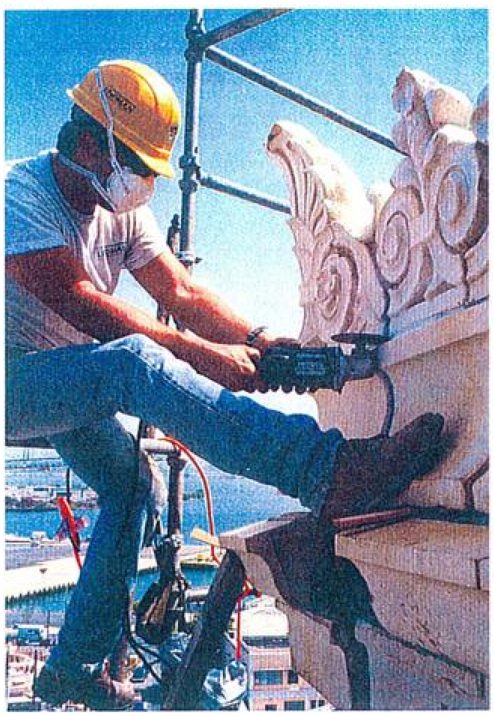
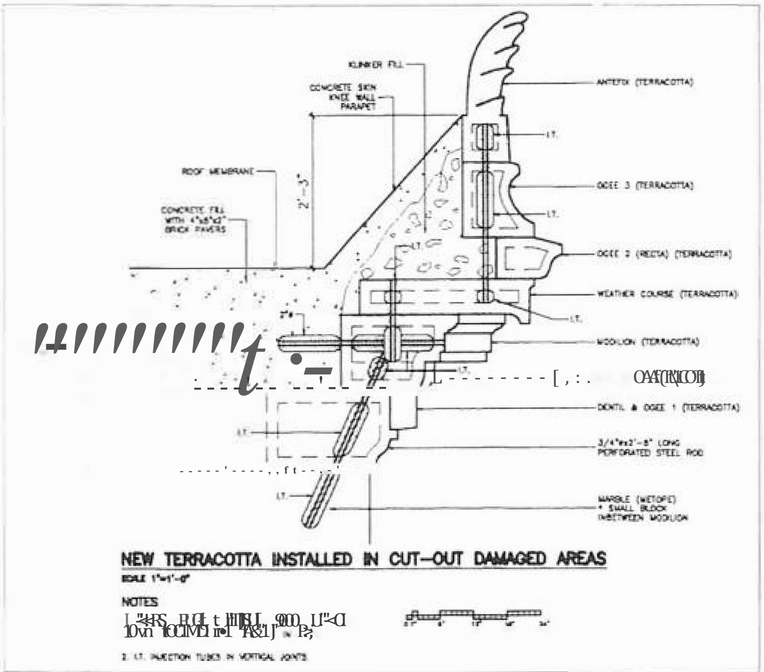
Puerto Rico's Capitol Building, or "El C:.pilOlio," in San Ju111, w;:. completed and inaugura,cJ in 1929. A major pun ot\', San Juan focs thL Atlantic O001l1 to the 1rnrtl. 'Thi marine cn\ironmcnt wa<>;1 111tjn fottor in ttl• Jalliftt'OU: \UITOSion or the ;111dluirtlg l<>:'3lll uf till' huilji11i;' lOTa•GUIa Oll'llitc.

The proI· 1cmditio11 of the terra-coua coI·11ite is e;ident in this ,iew. The separation of the tcrr::i-cotta units is clue tu not onls dw failure of the anchoring system, but also the expansion of the corroded material.

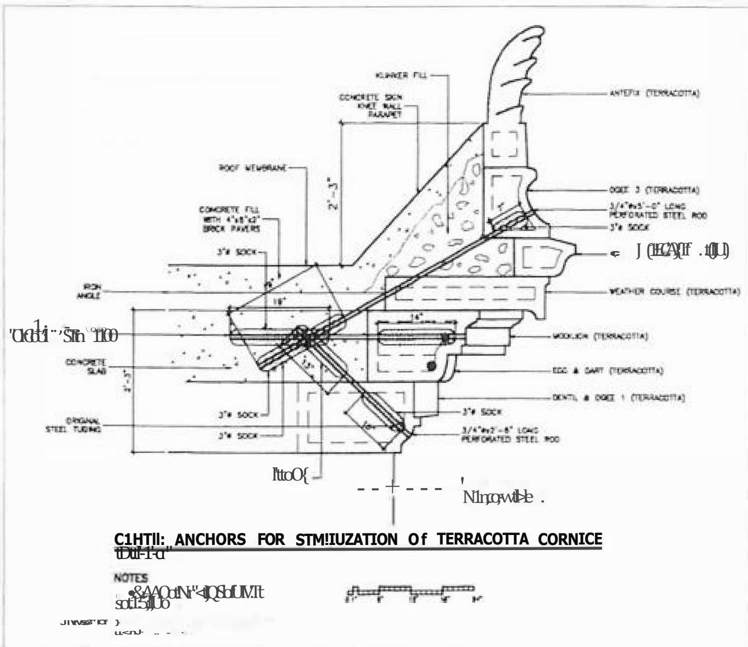
Once the cornice had hccn partially disassemI1led, the materials ;md techniques used in its cons11·uction could be casilv idcntilied. Note the clinker concreu-, or Ncindcrcrete," between the terra-cona blocks and the luick hackup material. and the scc1·c deterioration of th• steel supports. CSI rccommcmle-l dlat nll new tcclwork be t\ISI 1ypc 316 stainlcss steel, a non-corroding type, which is esenti;J in thi chloride-rich maritime environment.



/\ worker is seen here cuuing the mo11ar joims between the tcrrt• coll.t 61ocks iu preparation for the disassembly of the cornice.



Cons c n·, tion Solution<: in cull alm,·, tion wid, the p1ogic1 ,rchit c ct and co nscn :ui o n consult ant 1\\a n in \\"c:\\cr, dccignc] cll. cc 1wo new omdhming systems fo· ck' coinic c. Th<' ck<sign for 1hc dism antlcl cl cction (ih o, ·c) 11·C1 ,\ISi TypC 16 non,cor-roding 'l a inl<'ss-<tccl mls in a gr out-injection and1 o r system hy CINTEC. Small injecti o n tulics a 1c p o. iti o n:cl in cl1(joint" between tl1(tcrr:i-cotti units for in n, 1inn wih grout a ru•r '.1<>cmhly. The tahilizing and1 o n• (hdow) alc designed co he installed in situ liy m e ans or t Jiff c r c nt typC or Cl :\TEC grn111-injection s\\stem, al,o using ,\ISi Typ<' i 16 s tainlcss, stccl rod s.



Most 11nportantly, we disassembled approximately 6 reel of the cornice to re\·eal its construction and its anchoring system. \Ve also exposed a portion of the parapet decking to determ111e the condition of the underlying concrete substructure. In collaboration \·ith the architect rlrd Nlartin \o\1eaver, a nc,,· anchoring system \\'dS designed. \Ve also worked with the noted terra·cott;i manufacturer, Gladding, iv1cl3can, to determine which sections of terra cotta would need to be replicated.

f-inally, after our mvestigative work was done, CSI made the opening in the cornice \\'atertight.

Following ob!-en·ation of severe cracking and mo\·ement al the corners of the main terra·cotta cornice of the octc1gonal lower drum of the dome, it was Jointly decided to erect scaffolding and to carefully make an exploratory opening inlo the tcrra-cotta work.

The purpo es of this inter\'ention were to establish if the cracking and movement were evidence of a dangerous sihrntion, to establish the types, locations, and conditions of the hidden steel support structure and anchors, and to establish the type, location, and condition of the reinforced concrete sub·structure.

\\'e selected the southeast corner of the octagonal lower drum, apparently the area of the cornice with the worst conditions, as the best site for our investigations. Pablo Quinones and ivtartin \\lea\·er had noted what appenred to be e\·idence of SC\·erc damage in this same area m 1998.

f\s the careful cutting a\\'ay commenced at the cornice's upper len·1, we found tlmt the cornice was backed·up by a m;iss of "clinker concrete" or "cindercrete." This material is based on an aggregate of furnace ash and large fragrnents of clinker. Its use has been suspended for many yea1rs because the large quantities of sulfur compounds present in the ash and clinker have been found to cause Se\·erc corrosion of adja·cent steel in the presence of moisture.

After remo\·al of the cindercrete from the adjacent cnea, the cutting·out proceeded and it was noted that the mon·ment of the term cotta \\'IS beginning to accelerate. The terr,,·cotta mass at the corner - probably weighing in excess of 500 lbs. - \\'as pulling away from the mc1in mass of the cornice by acti\·e diagonal cracks propagating down on either side of the corner. The unstable mass was immediatdy secured by ropes and temporar· supports and was carefully cut (,part and remo\·ed.

\\later had penetrated down into the cornice, and all its steel structural supports and anchors had been totillly destroyed by corrosion. The total failure of the structural-support steel and anchor svstem had led to the structural failure of the can·tilevered, and now unreinforced, terra·cotta cornice. The onlv reason that it had not collapsed \\'as a combination of thl' cohesive 1nd frictional effects of the mort.ir and brick frag·n'lCnls used as back·up to the hollo\,· terra·cotla um ts.

Moisture had entered \'ia open joints rind crr1cks c1nd, to a lesser extent, through leaks in the roof above and behind the cornice.The rec1son for the extreme corrosion of the steel was a combination of chlorides from sea spray and the sulfuric ilcid formed when saline moisture saturated and then passed through the contaminated cindercrele. The corrosion had been so severe that it was no longer possible to establish the exact dimensions of anv of the former steel elements. Some had disappeared totally; lea,·ing only rusty stains in the terra-cotta work.

It should be noted that anv corrosion of embedded steel is associated with massi\'e exp nsion of the corrosion products. In the case of the Capitol Building, this expansion had result-ed, and will continue lo result, in the shattering of the imme-diately adjacent term cotta. Thus, all stabilization, consen·a·hon, dnd restor.ition work must in\·olvc the removal of all cor·roding steel and/or the prevention of any further corrosion and associated c,pansi\·e effects. !\II new steelwork n1t1st be AISI Tvpe 316 stainless steel. which is non-corroding in the chloride-rich maritime environment present here. /\ISi Type 30J stainless steel is attacked by chlorides and cannot be used here under any circumstances because it will corrode.

On the basis of our observations, we concluded that in anv ilntl dJ (oL<1liOll whc1e lhe lt:llil·t.ull.t lOrlliCeS ShOW evidence of cracking and movement, with open joints and possibly rust staining on the lower surfaces, then this terra·cotta work has had c1ll or most, of its structural·support steel and anchoring system so severely corroded that it is either totally gone or is so seriously deteriorated that the whole cornice, or parts thereof, arc liable to become dangerous and could collapse suddenly and without further evidence of failure.

The extreme nature of the deterioration process \\'IS such that it will inevitably lead to catastrophic failure, with col·lapse of the terra cotta onto, and possibly through, the open-ings 111 the roof below. Accordingly, we recommended that all cracked and deformed areas of the cornice should be carefully dismantled as soon as possible. Shattered terra·cotta units should be replaced with high-quality nrntching new units from a well·established tcrra·colta n,anufacturer such as Gladding, Mc13ean of California. This firm has been in contin-uous practice since before the erection of the Capitol and is known for the high quality of its architectural terracotta.

The dismantled corners should be rebuilt using AISI Type 316, non-corroding stainless-steel rods in a grout-injection anchor system b)• CINTEC. specially designed with small injection tubes positioned in the joints between the terra-cotta units for inflation with grout after assembly.

Undam;iged areas of term cott1 may be stabilized in·silu by n1car,s of a different type of CINTEC grout-111jection anchor system, also using ;\ISi Type 316 stainless-steel rods. It will be necessary to open up a series of areas in the tcrra-cotta work at random locations to determine if, in fact, the i!pparently undamaged terracotta can be safely stabilized in this \\'ay.

Once the water has been prevented from getting into the top of the cor-nices and other details. and the CINTEC in-situ stabilization svstem has been applied 111 diamond-tipped core-drilled holes, the crucial factor then will be whether any existing embedded steel can be left in-situ. All in-situ stabilization work must in\·oh·e dry·drilling with adn,nced .iir·coolcd drilling equipment. Under no circumstances can water-cooled drilling sys-tems be used because of the danger of the water causing further deteriora-tion.

It was recommended that a complete condition sur\'ey of all the tcrra-cotta work should be earried out as soon as possible to locate .iny other danger-ous areas which may already exist.•

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CINTEC
REINFORCEMENT SYSTEMS

NORTH AMERICA

Cintec Reinforcement Systems Ltd
38 Auriga Drive,Suite 200,
Nepean, Ontario Canada K2E8A5
Tel 1-613-225-3381 1-800 363-6066
Fax 1-613-224-9042 1-800461-1862

URL :-www.cintec.com E Mail solutions@cintec.com

EUROPE

Cintec International Ltd,
Cintec House,
11 Gold Tops,Newport,NP204PH
South Wales,UK
Tel +44 [0]1633-246614
Fax +44[0]1633-246610