CEIMRE
UPE

Prof. Carlos Wellington
Coordenador

Colapso do edifício Champlain Towers, Miami Surfside

Lições Aprendidas

Prof. Paulo Helene
Diretor PhD Engenharia
Diretor Vice-Presidente do IBRACON
Prof. Titular Universidade de São Paulo
Fundador e Ex Presidente ALCONPAT Internacional
Deputy-Chairman fib (CEB-FIP) Model Code for Service Life Design
Conselheiro da CNTU, SEESP, ABNT e PMSP

Recife, 22 de abril de 2025

1

Torres Champlain Towers South

8777 Collins Avenue, Miami Surfside

Inauguração 1981, investidor/construtor Nathan Reiber

Champlain Towers North, 1981 & Champlain Towers East, 1994

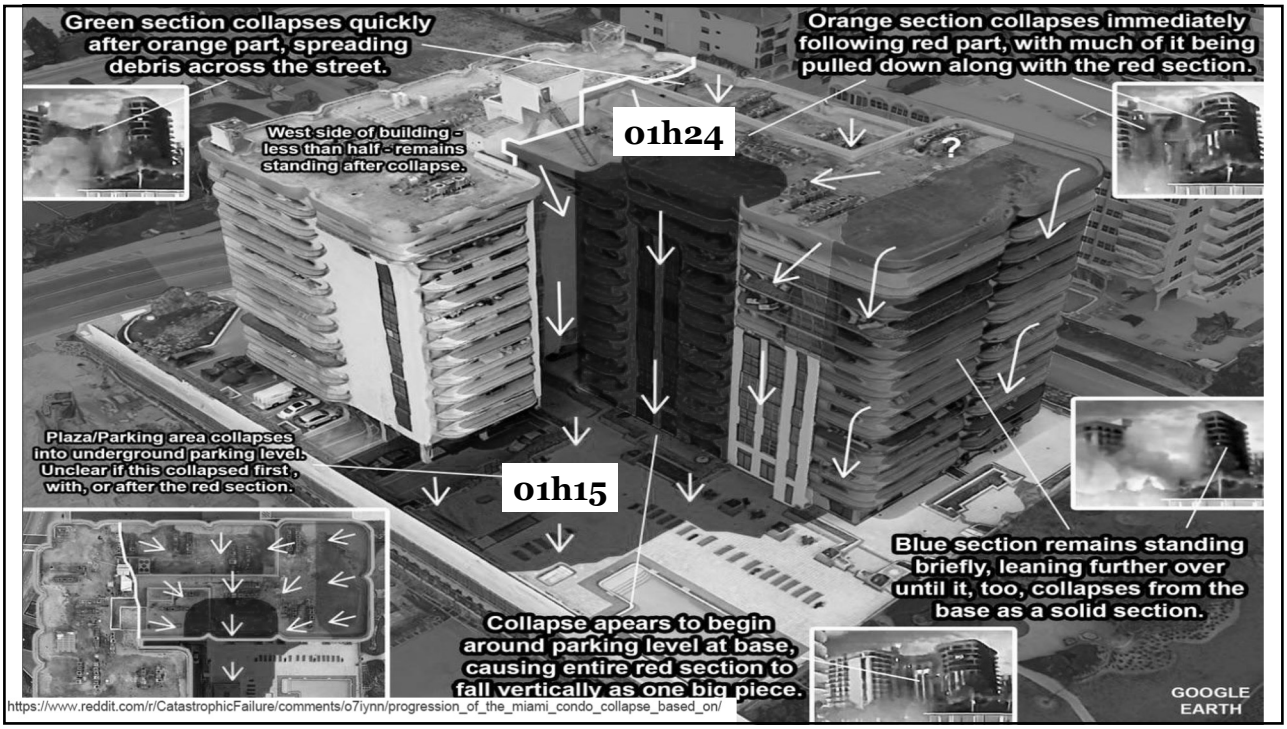
Formato L com 12 andares

Colapso 01h 30

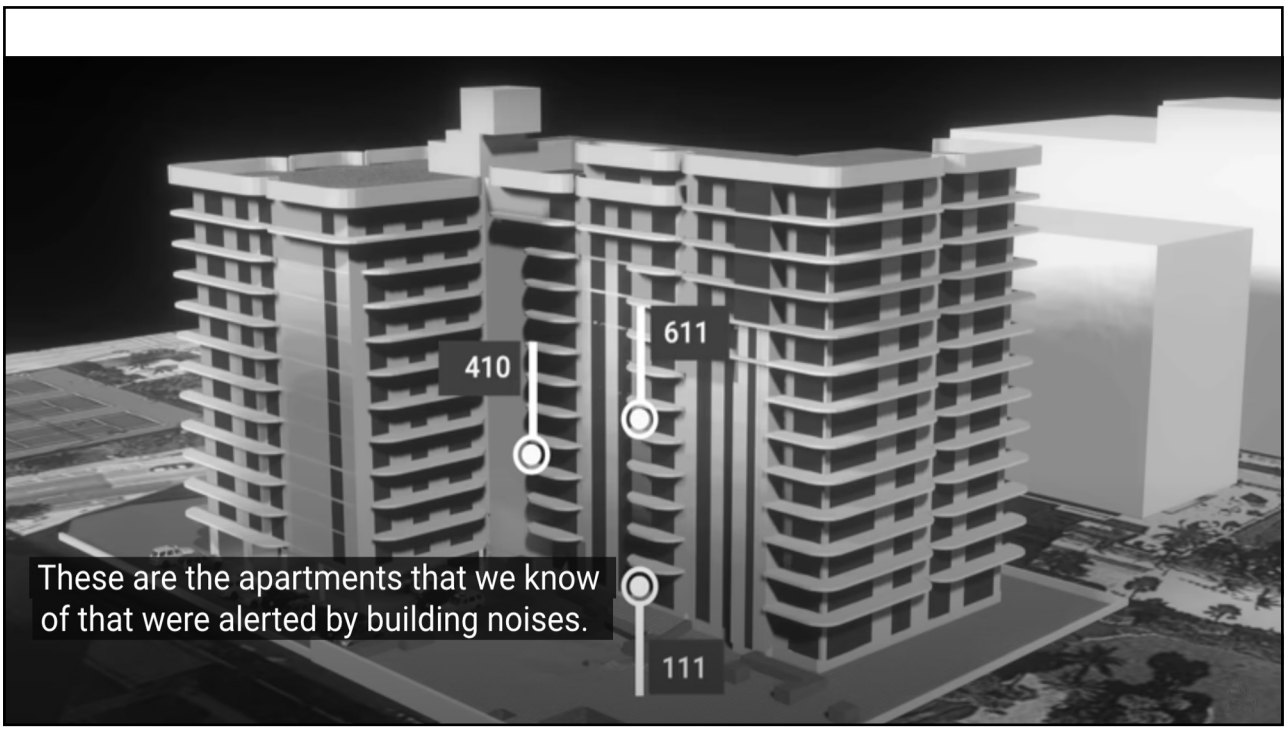
24 de Junho de 2021 40 anos de idade

98 mortos

2


Green section collapses quickly after orange part, spreading debris across the street.
Orange section collapses immediately following red part, with much of it being pulled down along with the red section.
West side of building - less than half - remains standing after collapse.
01h24
?
Plaza/Parking area collapses into underground parking level. Unclear if this collapsed first , with, or after the red section.
01h15
Blue section remains standing briefly, leaning further over until it, too, collapses from the base as a solid section.
Collapse apears to begin around parking level at base, causing entire red section to fall vertically as one big piece.
https://www.reddit.com/r/CatastrophicFailure/comments/o7iynn/progression_of_the_miami_condo_collapse_based_on/
GOOGLE EARTH

3

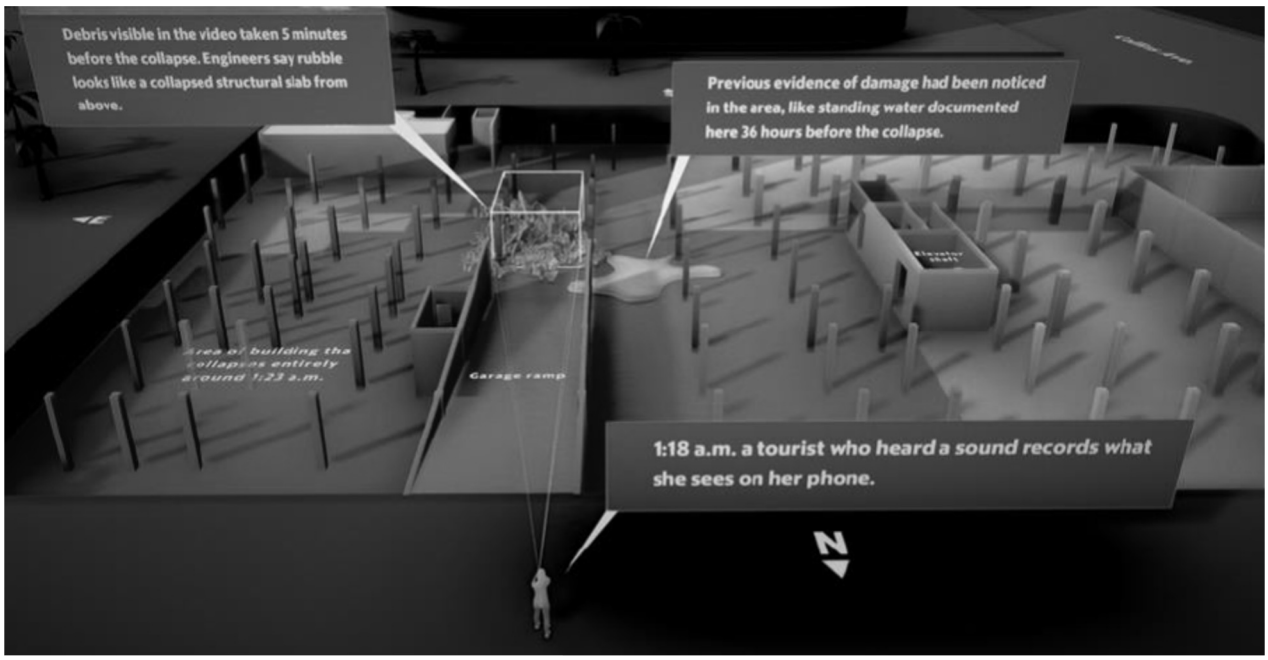

410
611
111
These are the apartments that we know of that were alerted by building noises.

4

Una residente dijo a *The Post* que minutos antes de que se derrumbara **Champlain Towers South** en **Surfside**, se dio cuenta de que una sección de la cubierta de la piscina y una zona de aparcamiento a nivel de la calle se habían derrumbado. El marido de otra residente ha dicho que su esposa, que no ha sido vista desde el desastre, hizo una observación similar en una llamada telefónica poco antes del colapso.

Sara Nir, una residente, dijo a *The Post* que poco antes de la 1 de la madrugada notó fue ruidos de "**golpes**" que supuso eran causados por las obras de construcción. Alrededor de la 1:14 de la madrugada, oyó un ruido que le pareció el de un muro que se derrumbaba, y salió de su apartamento de la planta baja para quejarse a un guardia de seguridad en el vestíbulo.

5



Miami Herald: The last stand of Champlain Towers South. Computer Model, witnesses reconstruct the tragedy". January 2022
SURFSIDE Anatomy of a complex forensic investigation, by Juan Carlos Araiza, PhD, PE February 2023

6

Primeira Lição

Fique atento e escute os gritos da estrutura, pois podem ocorrer acidente graves e colapsos em qualquer idade da estrutura.

Todas as estruturas advertem que estão prestes a colapsar, e o desafio é saber interpreter os sinais da estrutura!

¡somente aqueles que entenderam os avisos foram salvos!

7

CNN US Crime + Justice Energy + Environment Extreme Weather Space + Science

South Florida apartment building evacuated after engineers deem it structurally unsafe

By Amanda Musa and Melissa Alonso, CNN

Updated 1733 GMT (0133 HKT) April 5, 2022

More From CNN

Doja Cat stuns at Grammys red carpet in dreamy Versace gown

Rare black lion tamarin born at Jersey Zoo

REPERCUSSÕES

8

CNN US Crime + Justice Energy + Environment Extreme Weather Space + Science

Related Article: After Surfside tower collapse, condo residents in Florida and beyond wonder if need to worry

belongings. The city will schedule a time for residents to come back later this week to pick up heavier furniture and large items," Cabrera said in an email to CNN.

In July, North Miami Beach ordered the evacuation of a 10-story building, Crestview Towers, after a report determined the building's structure to be unsafe. The residents have not yet returned, Cabrera said.

"The residents at Crestview have not been allowed back to the property because the structural repairs just started two weeks ago," Cabrera told CNN. "The electrical repairs have not started yet. Therefore, the building is still unsafe until the property completes the repairs needed for re-occupancy."

REPERCUSSÕES imediatas !

PAID CONTENT Smartfeed

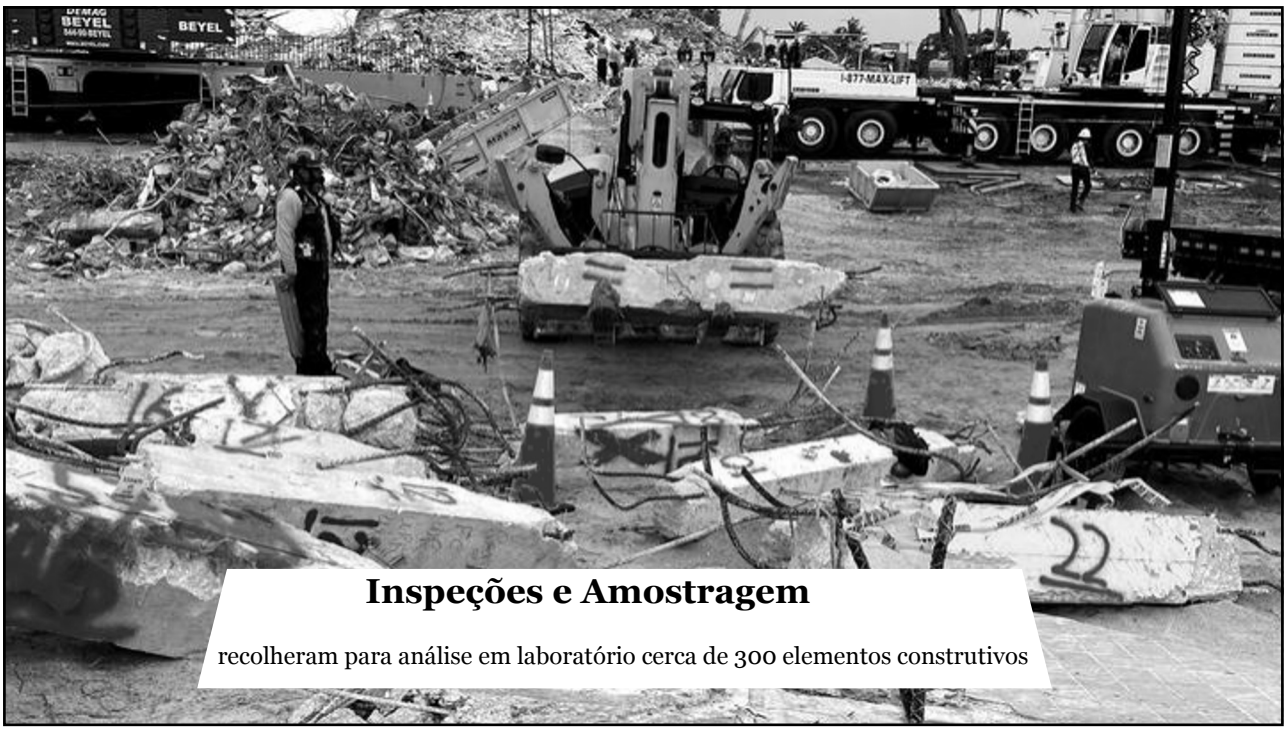
9

10

NIST encourages members of the public to submit any information, including video, photos or other documentation

- ✓June 24, 2021, Champlain Towers South, 12-floor condominium in Surfside, Florida, at 1:30 a.m.
- ✓June 25, NIST began a team of six scientists and engineers to collect firsthand information on the collapse.
- ✓June 30 decided full technical investigation of the collapse by National Construction Safety Team (NCST) Act
- ✓NCST's work will not interfere with the ongoing search-and-rescue operation at the scene of the collapse.
- ✓NCST's role is not to determine any culpability.
- ✓NCST investigation is to determine the technical diagnose and cause of the collapse and, learning from that, to recommend changes to building codes, standards and practices, and appropriate actions to improve the structural safety of buildings.

11



Inspeções e Amostragem

recolheram para análise em laboratório cerca de 300 elementos construtivos

12

Pilares

https://www.nist.gov/disaster-failure-studies/champlain-towers-south-collapse/news-and-updates-

13

Pilares

https://www.nist.gov/disaster-failure-studies/champlain-towers-south-collapse/news-and-updates-

14

Pilares

https://www.nist.gov/disaster-failure-studies/champlain-towers-south-collapse/news-and-updates-

15

Lajes

https://www.nist.gov/disaster-failure-studies/champlain-towers-south-collapse/news-and-updates-

16

Lajes

https://www.nist.gov/disaster-failure-studies/champlain-towers-south-collapse/news-and-updates-

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NIST View as a Web Page

NEWS

May 31, 2023, Champlain Towers South Investigation Update: Second Warehouse Will Allow New Phase of Testing

On May 11, 2023, the Miami-Dade Police Department (MDPD) and the National Construction Safety Team (NCST) finished moving a portion of evidence retrieved from the Champlain Towers South building into a second warehouse. The move provides the team members with the space needed to safely access the specimens and begin the next phase of evidence analysis, which will include extracting samples of concrete and reinforcing steel from the specimens retrieved from the Surfside, Florida, collapse site. The challenging move of more than 300 building specimens was managed by MDPD contractors and subcontractors and overseen by NIST staff.

The first warehouse was not large enough to allow our staff members and others to safely conduct all of the analysis that needs to be done to help us understand the condition of the building materials at the time of the collapse, said Judith Mitrani-Reiser, co-lead of the investigation. This second, larger warehouse will allow us to create sufficient space around each specimen so that we can bring in equipment to safely manipulate, cut and core specimens to extract samples.

18

19

announced at the June 2023 NCST Advisory Committee meeting (see that presentation here).

Specifically, the team found that the number of slab reinforcing bars centered over vertical columns was inadequate and that the reinforcing bars in the top of the slab in the vicinity of the columns were spaced farther apart than the design required.

These deviations weakened the slab-column connections.

20

Cores of concrete and reinforcing steel are extracted from a pool deck slab specimen collected from the collapsed Champlain Towers South condominium, as part of the National Construction Safety Team investigation into the technical cause of the collapse (September 2023).

Credit: NIST

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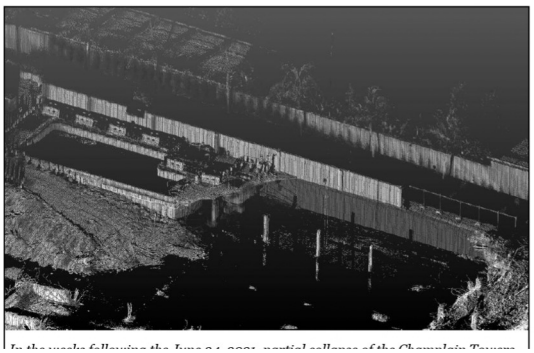
https://www.nist.gov/news-events/news/2025/02/nist-report-congress-provides-update-champlain-towers-south-investigation

NIST National Institute of Standards and Technology U.S. Department of Commerce

NEWS (https://www.nist.gov/news-events/news)

NIST Report to Congress Provides Update on Champlain Towers South Investigation

February 5, 2025



22

NIST plans to provide its next technical presentation on the investigation in early June 2025.

To date, the investigation has included:

- Analysis of **more than 300** potential structural failure points using 25 hypotheses for failure.
- Review of **20,000 records** to establish the building's history and precollapse conditions.
- Receipt of **10s of thousands** of additional civil litigation records since March 2024.
- Archival research review of about **60 gigabytes** of data.
- Interviews with **58 individuals**, with **92 more interviews** and **10 focus groups** planned.
- Structural materials testing on **more than 1,000** concrete and reinforcement samples extracted from the building.
- Geotechnical materials testing completed or underway on **108** soil, rock, foundation and groundwater samples.

Buildings and Construction (https://www.nist.gov/topic-terms/buildings-and-construction), Building codes and standards (https://www.nist.gov/topic-terms/building-codes-and-standards), Building damage and repair (https://www.nist.gov/topic-terms/building-damage-

nist.gov/news-events/news/2025/02/nist-report-congress-provides-update-champlain-towers-south-investigation

23

Champlain Towers South Investigation Team Provides Update to Structural Engineers

On Thursday, April 10, three members of the National Institute of Standards and Technology's (NIST's) National Construction Safety Team (NCST) investigating the June 2021 partial collapse of the Champlain Towers South building in Surfside, Florida, shared technical details of the investigation's progress with members of the structural engineering professional community. This outreach will help ensure that

24

Segunda Lição

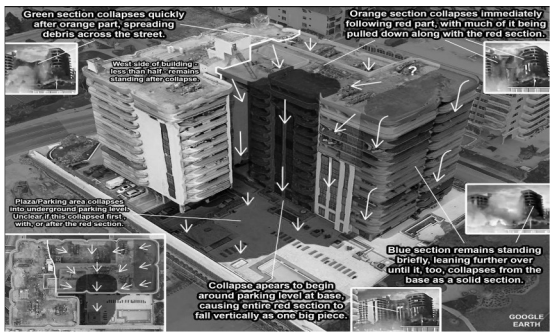
- ✓ Transparência → criar um portal de acesso público com todas as informações e fotos
- ✓ Valorizar a pesquisa tecnocientífica, junto com a polícia e bombeiros, desde o primeiro dia
- ✓ Nomear uma equipe multidisciplinar responsável, com poder e autonomía *("Comitê de Crise do Buraco")*

"públicas e privadas"

25

Sobre a sequência do colapso há consenso:

1. laje de recreação
2. 1ª parte da torre
3. 2ª parte da mesma torre
4. 3ª parte da mesma torre
5. parte lateral da torre



26

...então qual a dúvida?

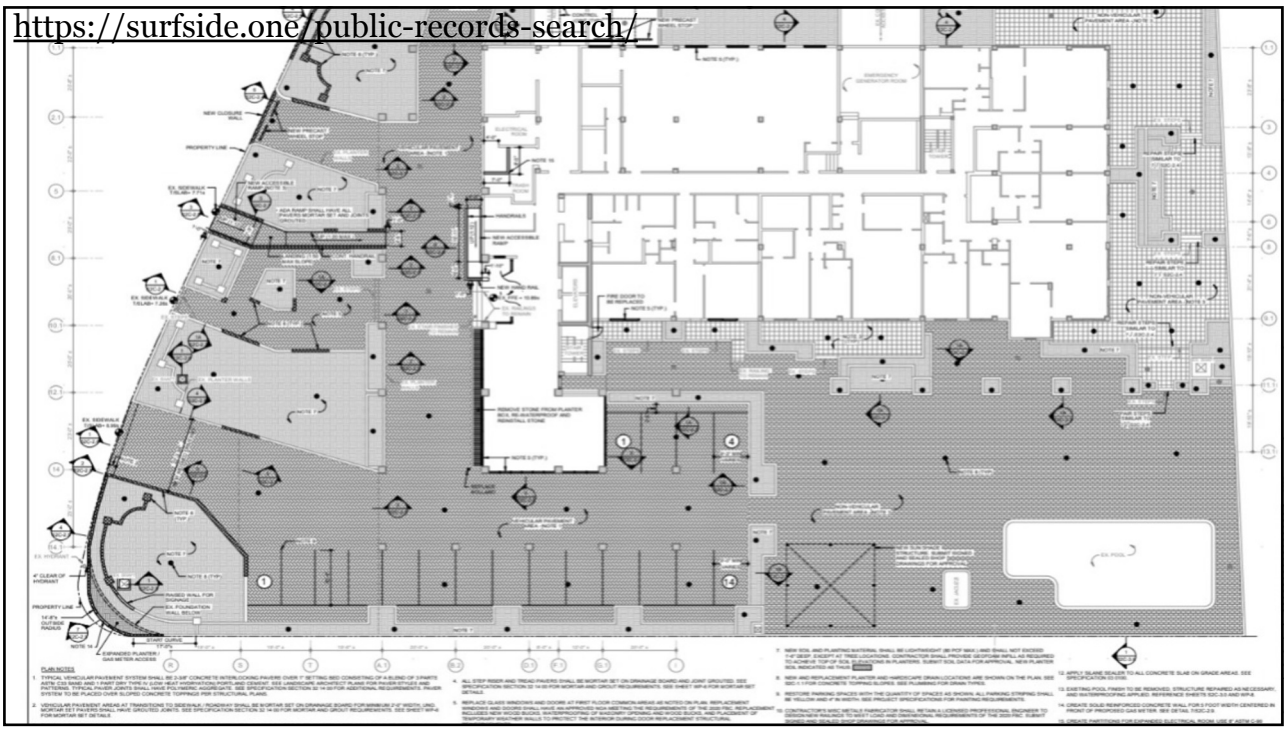
Qual foi o gatilho?

Porquê uma parte se propagou à outra?

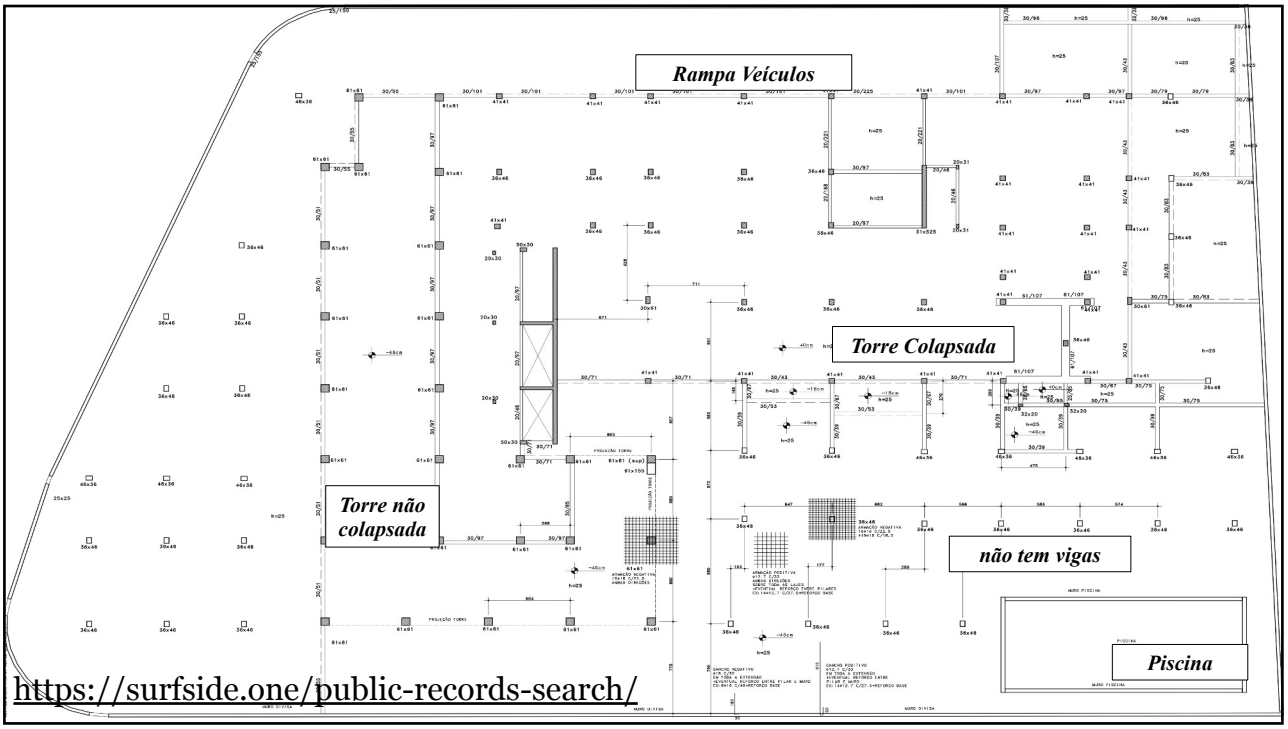
Porquê depois de 40 anos?

27

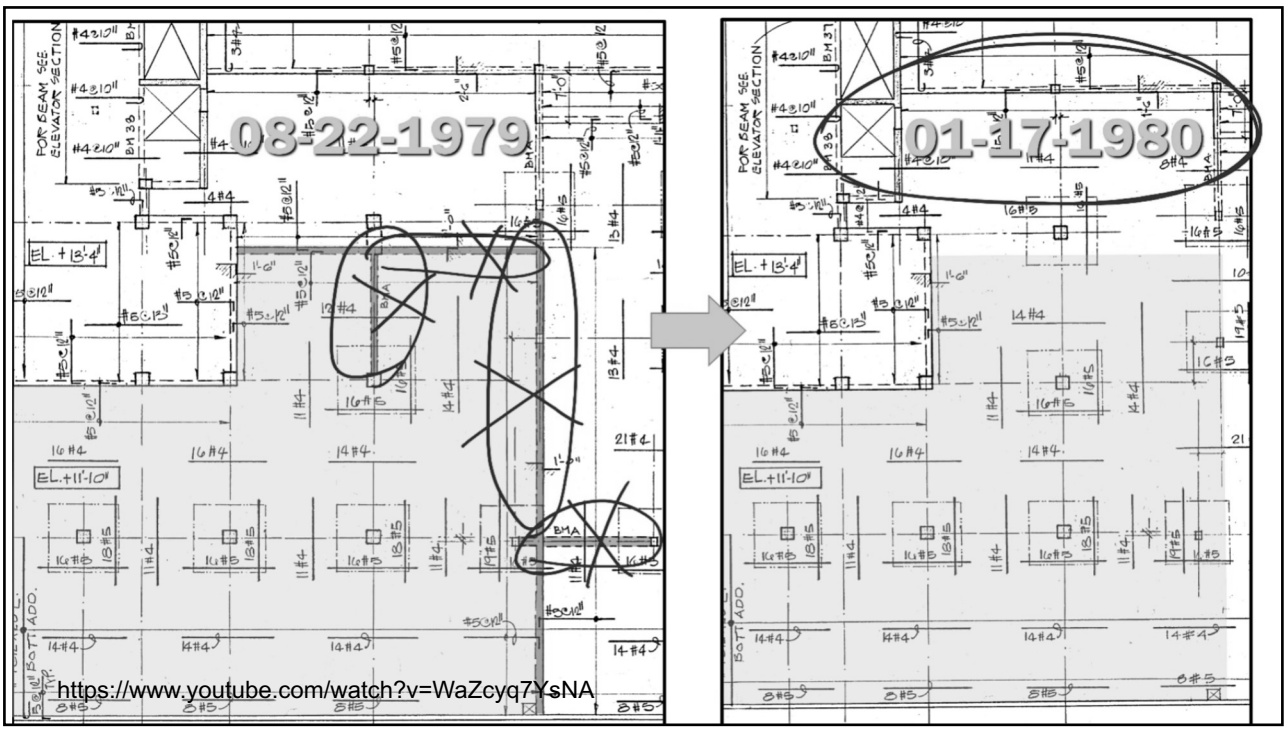
https://surfside.one/public-records-search/



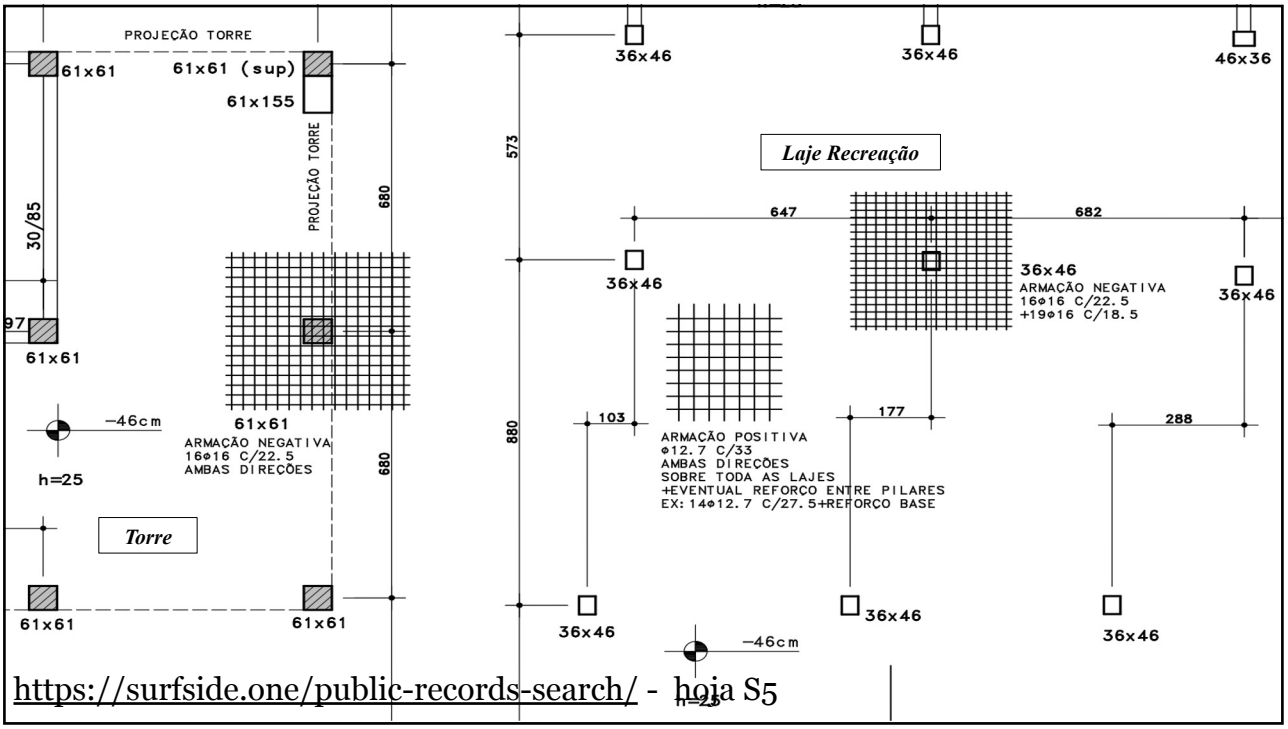
28


Rampa Veículos
Torre Colapsada
Torre não colapsada
não tem vigas
Piscina
https://surfside.one/public-records-search/

29

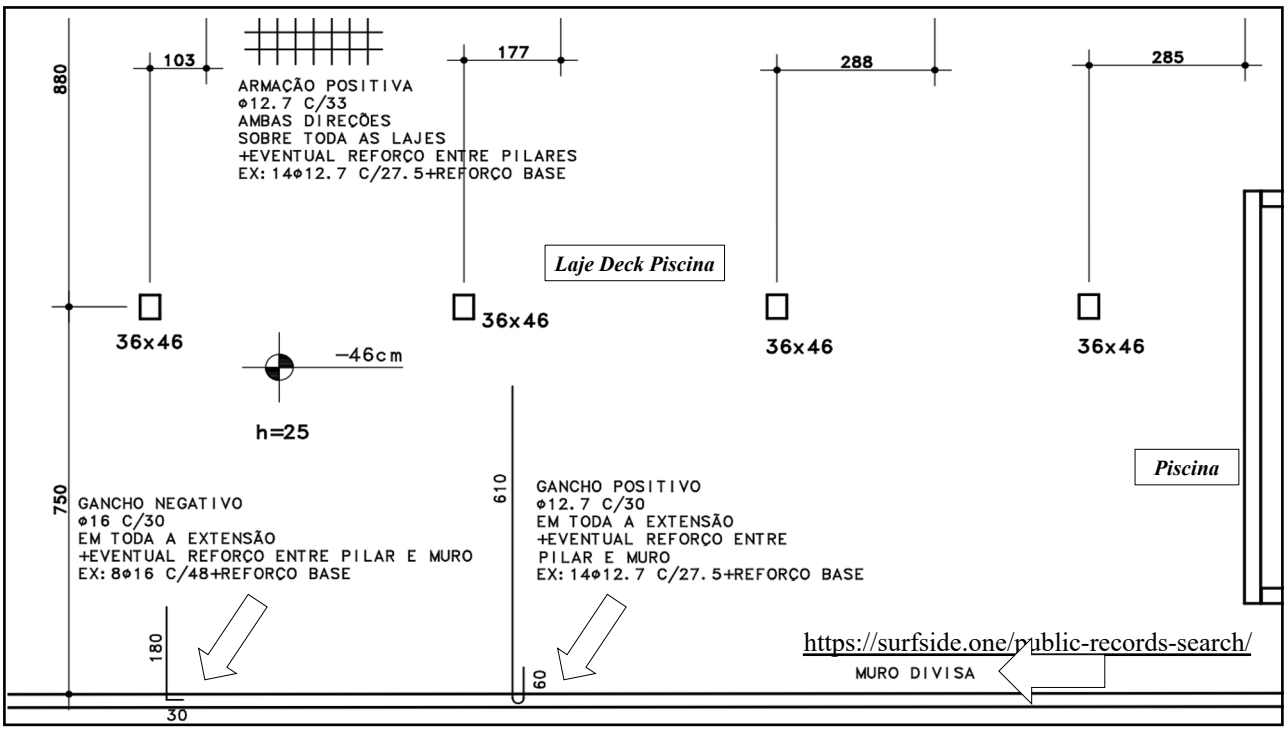

08-22-1979
01-17-1980
https://www.youtube.com/watch?v=WaZcyq7YsNA

30



https://surfside.one/public-records-search/ - hoja S5

31

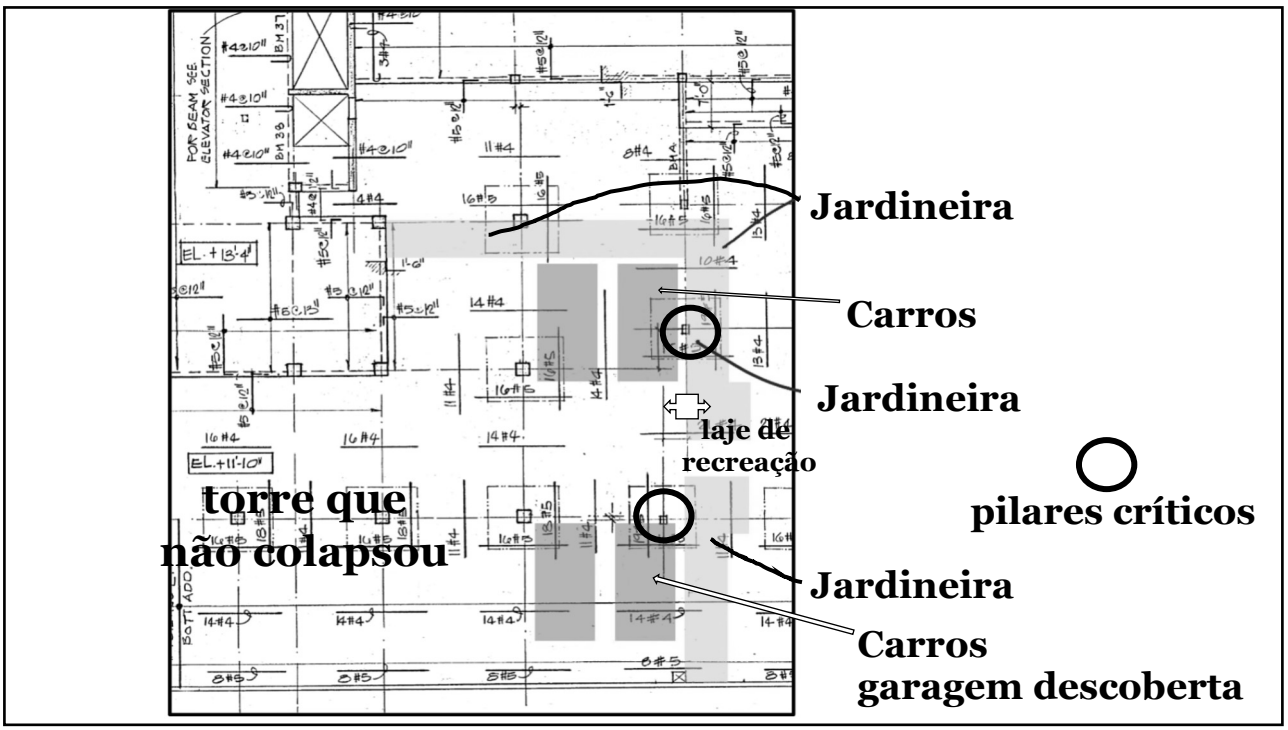


https://surfside.one/public-records-search/

32

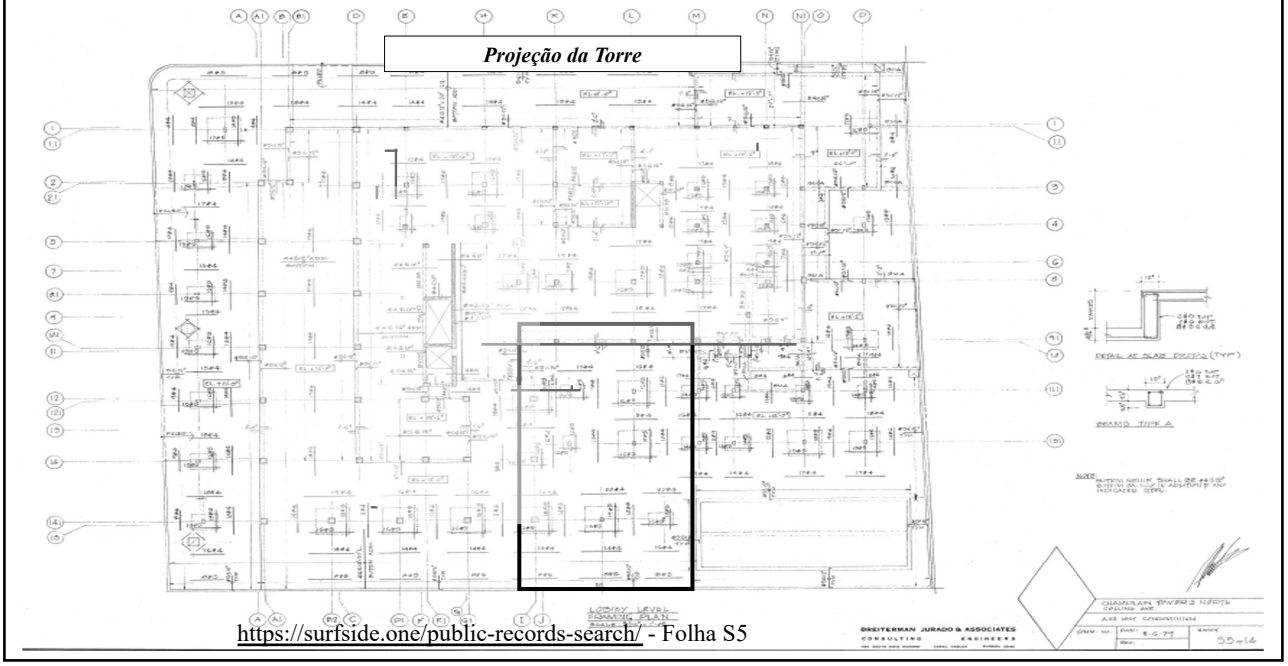

Pilares Críticos

33


Jardineira
Carros
Jardineira
laje de recreação
pilares críticos
torre que não colapsou
Jardineira
Carros
garagem descoberta

34

SurfSide MIAMI 2021 12 andares



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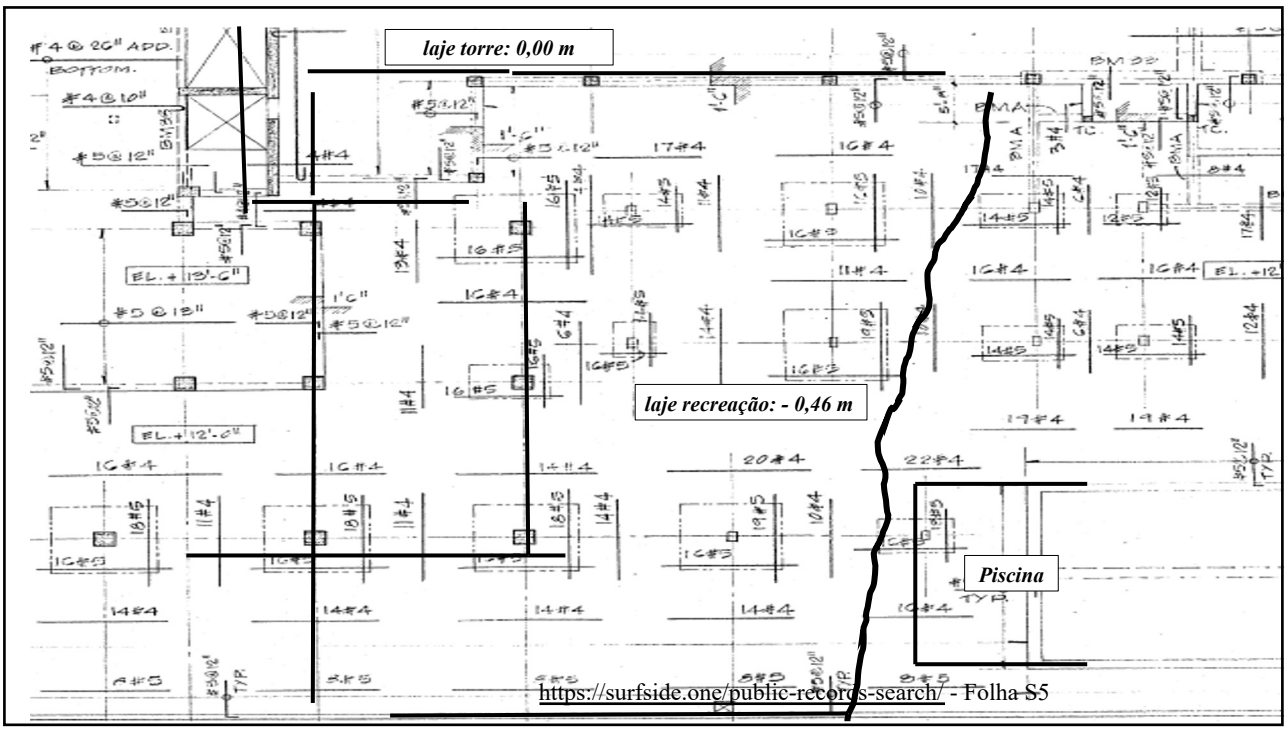
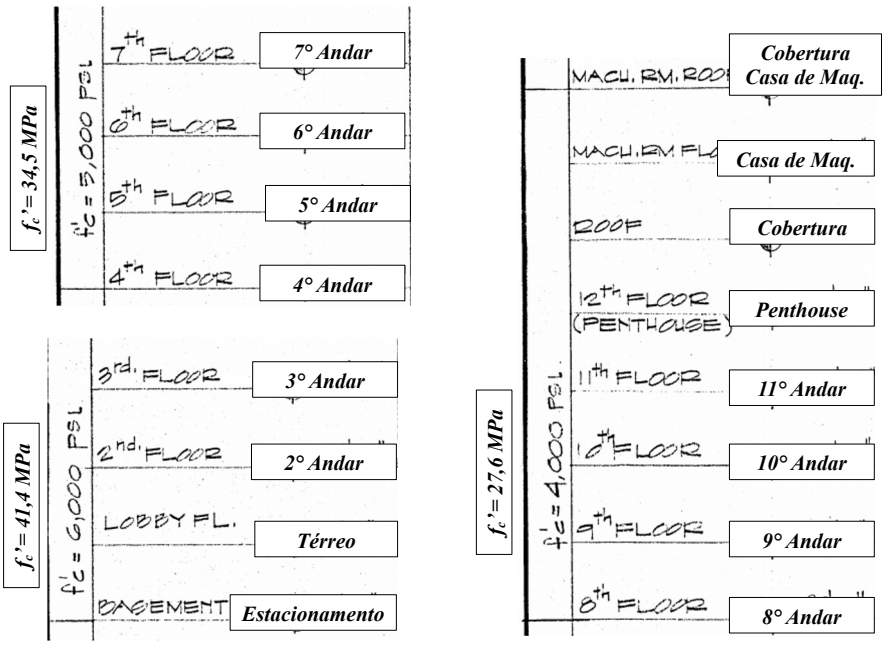


36

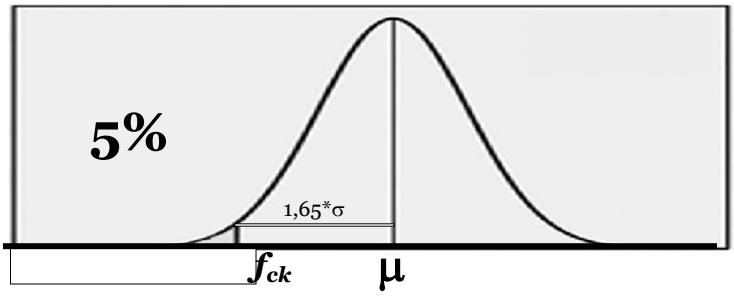
f_c' pilares no decorrer dos pavimentos



https://surfside.one/public-records-search/ - Folha S14

37

ABNT
fib
Eurocode
EHE



$f_{ck} = \mu - 1{,}65 * \sigma_c$

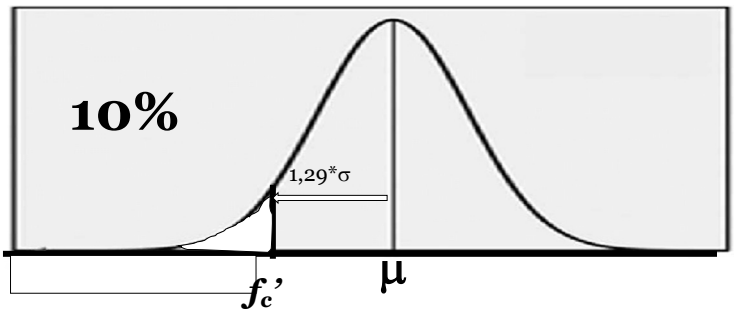
$f_{ck} = f_c' - 0{,}36 * \sigma_c$

$\sigma_c = 4$ MPa

$f_{ck} = f_c' - 1{,}44$

$f_c' = f_{ck} + 1{,}44$

ACI
México
Canadá
Argentina
...



$f_c' = \mu - 1{,}29 * \sigma_c$

38

- ✓ Concreto pilares da garagem até o terceiro andar: 6.000psi (41,4 MPa)
- ✓ Concreto lajes até o 8 andar: 4.000psi (27,6 MPa)
- ✓ Armadura pilar 61x61cm : 12Ø32 → As=98,28cm² →ρ=2,64%
- ✓ Armadura pilar 41x41 cm : 8Ø36 → As=80,48cm² →ρ=4,79%
- ✓ Armadura pilar 36x46 cm: 10Ø32→As=81,9cm² →ρ=4,95%
- ✓ Espessura lajes: 25cm (térreo), 20cm (tipo)
- ✓ Armadura inferior lajes: Ø12,7 C/30cm→ ρ=0,17% (térreo), 0,19% (tipo)
- ✓ Não foi encontrado em projeto detalhe de armadura de punção

https://surfside.one/public-records-search/ - Folhas S14 e S6

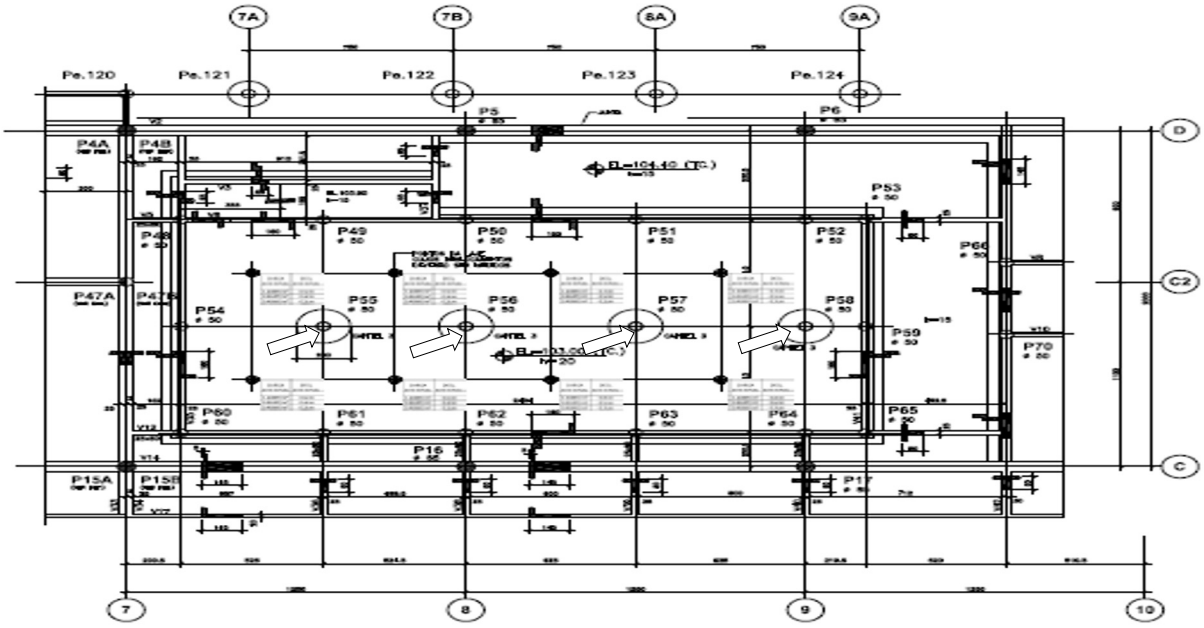
39

Punção
ilustração

40

41

Piscina de Centro Esportivo



42

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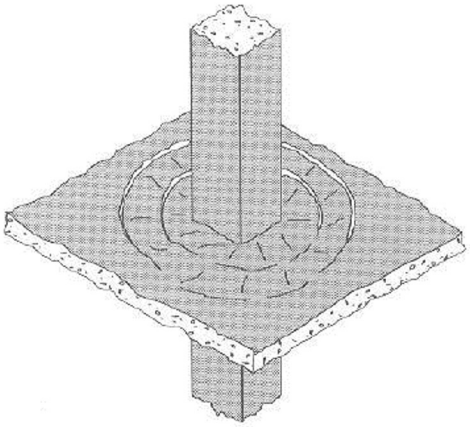
45

46

Punção

Manifestação Típica



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Laje

https://www.nist.gov/disaster-failure-studies/champlain-towers-south-collapse/news-and-updates-

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MENU G1 ESPÍRITO SANTO tvgazeta

19/07/2016 09h49 - Atualizado em 19/07/2016 19h32

Área de lazer em condomínio de luxo desaba e porteiro é achado morto

Drone mostra o estrago no Grand Parc, na Enseada do Suá, em Vitória. Suspeita é de vazamento de gás, segundo Corpo de Bombeiros.

Viviane Machado e Victoria Varejão
Do G1 ES

FACEBOOK

As torres do condomínio de luxo Grand Parc Residencial Resort, na Enseada do Suá, em Vitória, foram esvaziadas após toda a **área de lazer desabar, na manhã desta terça-feira (19)**. Quatro pessoas ficaram feridas e **um porteiro ficou desaparecido até as 17h.** Ele **foi encontrado morto**. O desabamento aconteceu por volta de 3h.

Exemplo de acidente com punção mas, com robustez que evitou uma tragédia

http://g1.globo.com/espirito-santo/noticia/2016/07/torres-de-condominio-de-luxo-no-es-sao-evacuadas-apos-desabamento.html

49

http://www1.folha.uol.com.br/cotidiano/2016/07/1793137-bombeiros-buscam-desaparecido-apos-desabamento-em-predio-no-es-diz-tv.shtml

50

http://g1.globo.com/espirito-santo/noticia/2016/07/desabamento-em-condominio-fere-3-e-deixa-desaparecido-em-vitoria-es.html

51

52

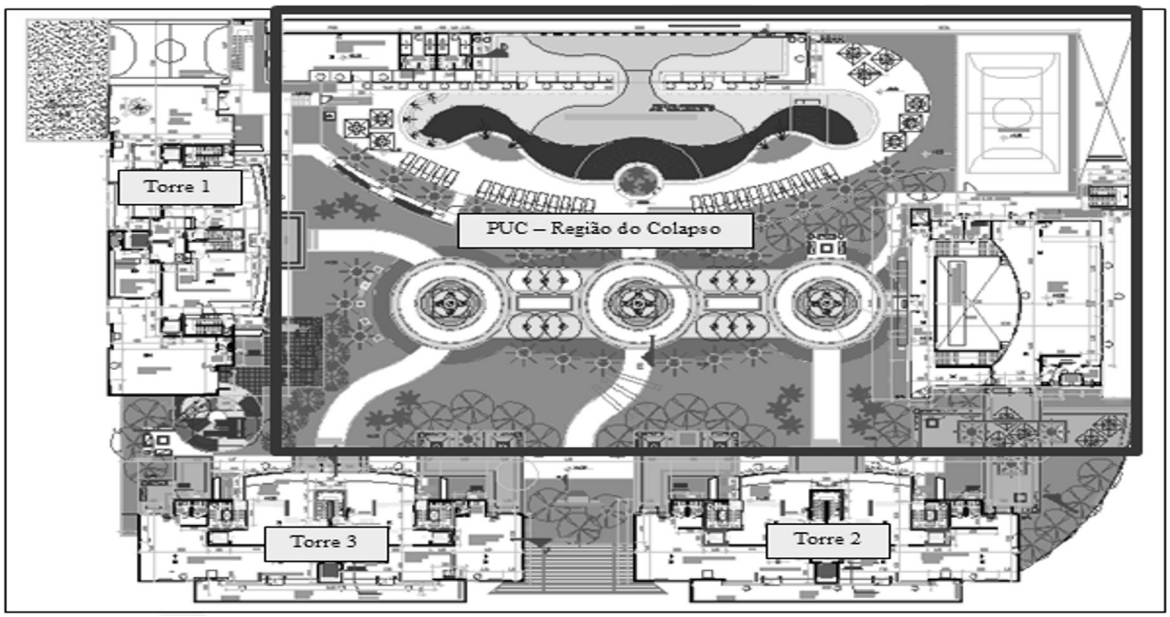

19-07-2016 01:42:21
CUIDADO COM NOSSAS CRIANÇAS
CAM25
19-07-2016 01:56:49
CUIDADO COM NOSSAS CRIANÇAS
CAM25
19-07-2016 02:57:41
CUIDADO COM NOSSAS CRIANÇAS
CAM25
19-07-2016 03:02:00
CUIDADO COM NOSSAS CRIANÇAS
CAM25

53


19-07-2016 01:00:04
19-07-2016 03:00:08

54

- **19.07.2016 (03 h)**
- **6 anos de idade**



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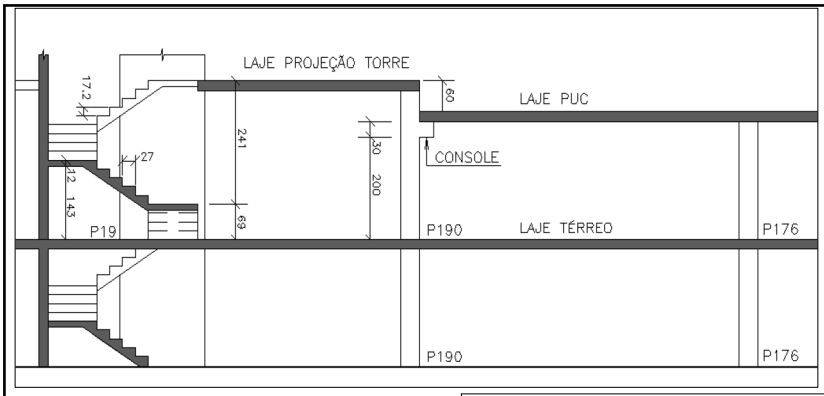
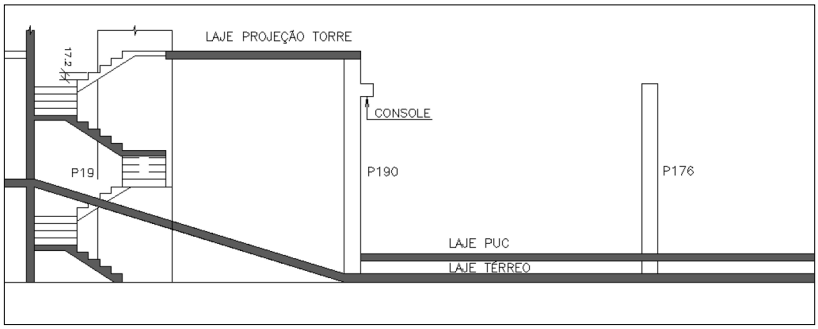


antes do colapso

após colapso



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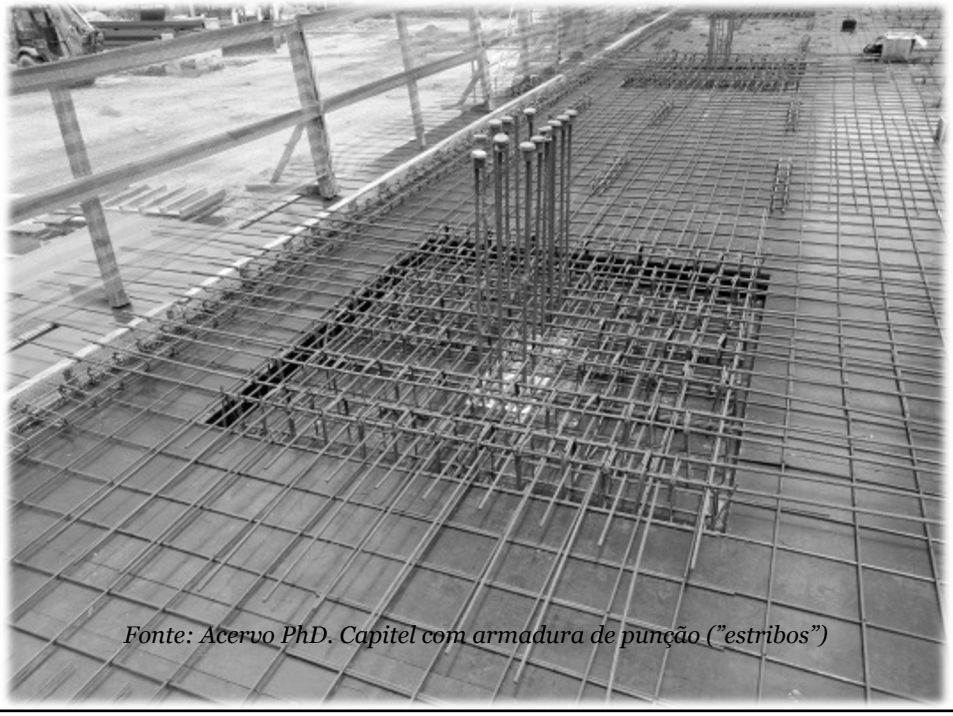
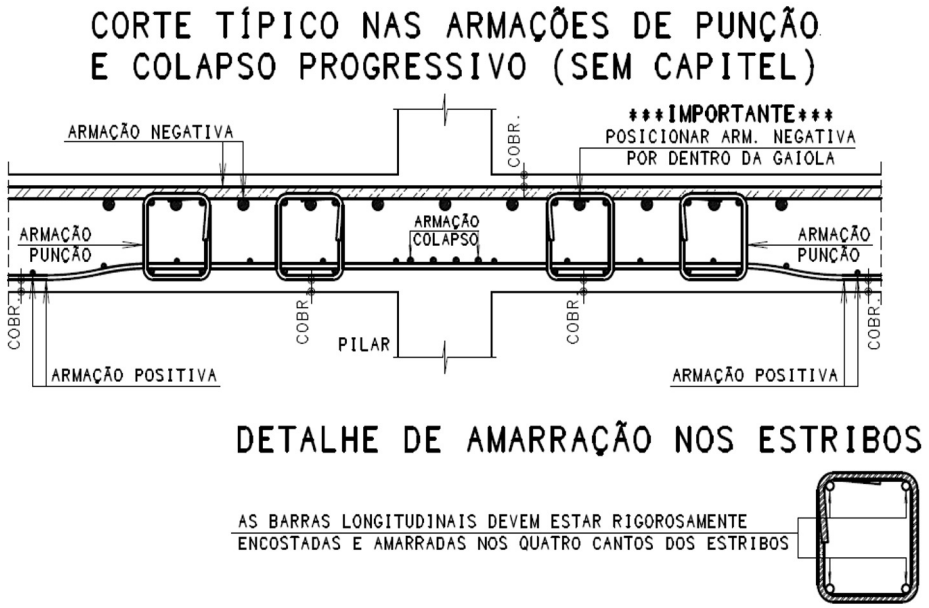


Fonte: Acervo PhD. Capitel com armadura de punção ("estribos")

62



Fonte: Ricardo França & Associados

63

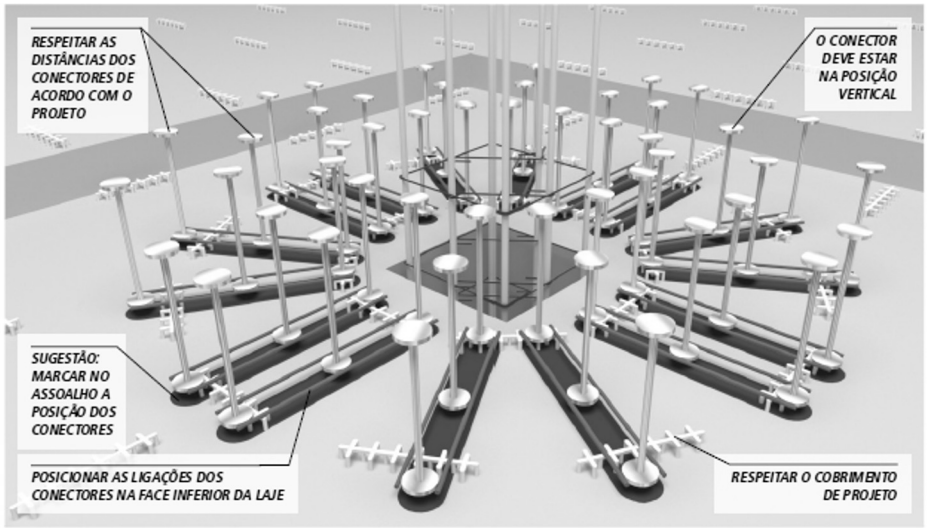
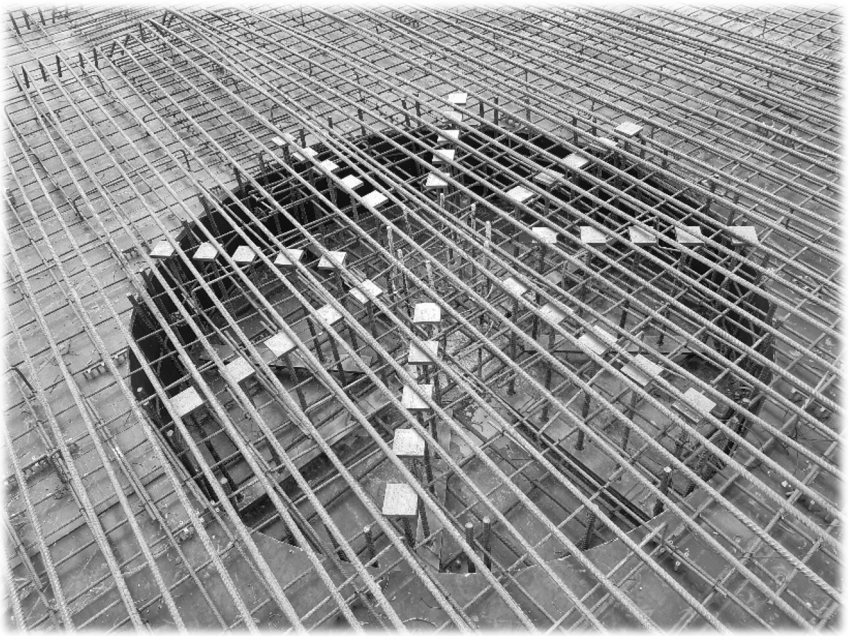


Figura 5.8
ETAPA 1 | Posicionamento dos conectores/studs

Fonte: Manual de Boas Práticas. Montagem das Armaduras de Estruturas de Concreto Armado. Jorge Nakashima (Sartoro) & Larissa Arakawa Martins. 2021

64



Fonte: Acervo PhD. Capitel com armadura de punção ("studs").

65

"Falsas" hipóteses do "Gatilho"

1. Corrosão das armaduras dos pilares
2. Estrutura com lajes planas sem vigas
3. Efeitos ambientais de sumidouros
4. Corrosão de armadura da laje perto piscina

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October 8, 2018

Re: Champlain Towers South Condominium
Structural Field Survey Report
MC Job# 18217

Page 8

O Relatório estrutural de Morabito, 2018, demonstra que a corrosão das armaduras nos pilares era inicial e jamais suficiente para justificar um colapso

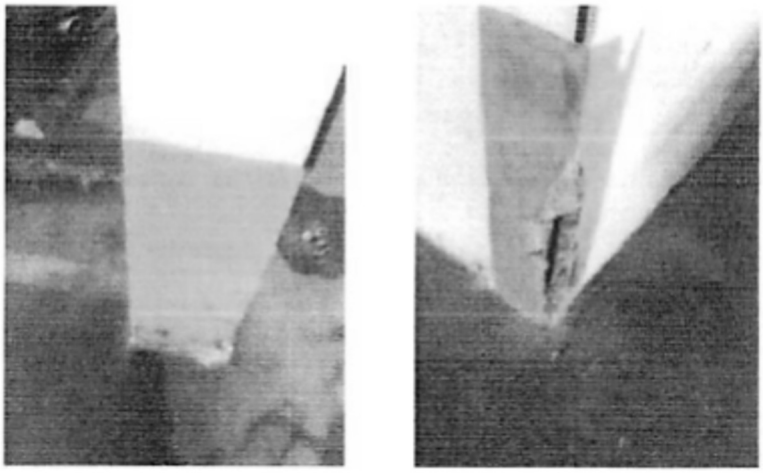
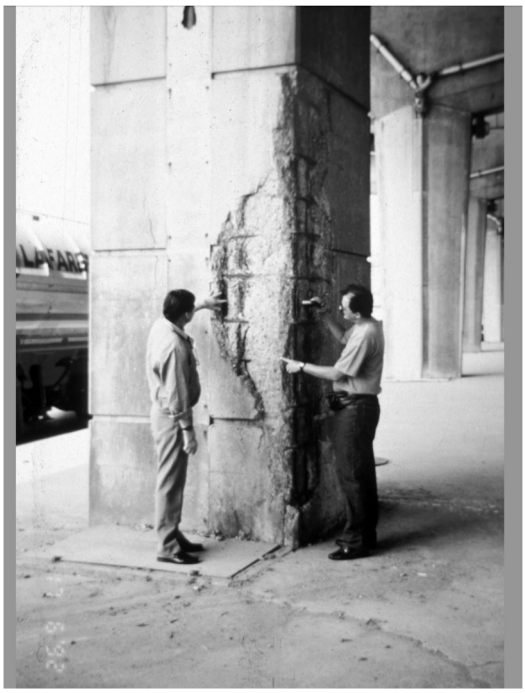
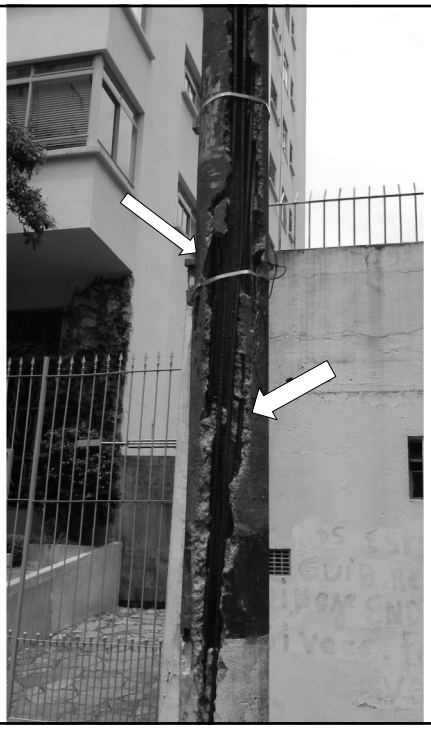


Figure J1: Typical cracking and spalling at parking garage columns

67



68



69

Falsas hipóteses do "Gatilho"

1. Corrosão das armaduras dos pilares → Negativo
2. Estrutura com lajes planas sem vigas → Negativo
3. Efeitos ambientais de sumidouros
4. Corrosão de armadura da laje perto piscina

70

71

The NIST Team, in September 2023, has been studying subsurface conditions of the site to determine if sinkholes or excessive settling of the pile foundations might have contributed to the collapse, concluding:

The preliminary evaluation of the data collected indicates that approximately one quarter of an inch or less of settling occurred in the pile foundations supporting the pool deck structure and basement, which would have had minimal impact on the pool deck structure.

The preliminary evaluation did not reveal evidence of sinkholes that could have created voids under the foundation.

72

O **geofísico Mika McKinnon** apontou uma série de falhas no plano de **Elon Musk** para cavar túneis em **Miami**, como a sua empresa **The Boring Company** tem feito em várias outras cidades dos **Estados Unidos**. Em entrevista ao site *Curbed*, McKinnon explicou que o solo embaixo da cidade da Flórida é composto de um cárstico de calcário altamente dissolvível, que é cheio de cavidades e cavernas – assim como o solo do oceano.

Esse seria o motivo pelo qual Miami não possui um sistema de metrô, e também porque a grande maioria das casas da cidade não tem porões. Essa característica geográfica também faz com que a cidade seja particularmente suscetível a inundações.

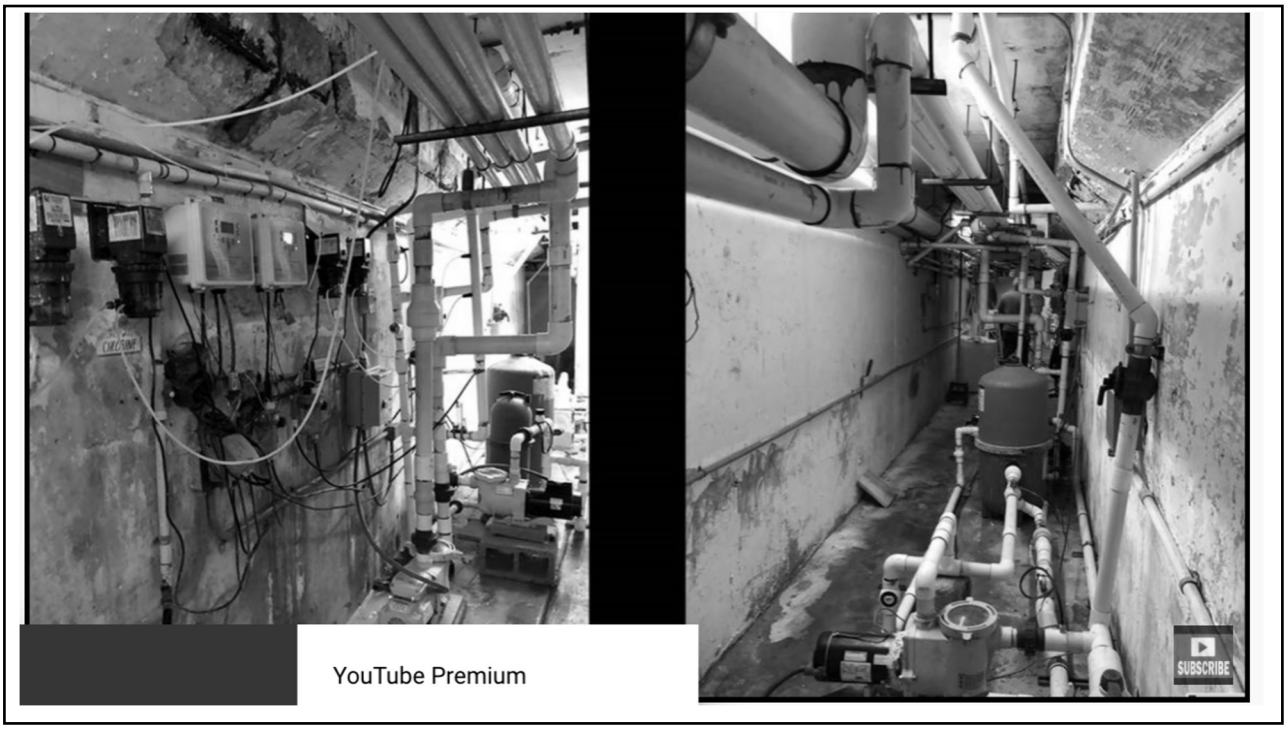
Por causa disso, ela necessita de um complexo sistema de bombeamento apenas para garantir que suas ruas são navegáveis por carros. Isso mesmo em épocas em que não há grandes tempestades na região.

73

Falsas hipóteses do "Gatilho"

1. Corrosão das armaduras dos pilares → Negativo
2. Estrutura com lajes planas sem vigas → Negativo
3. Efeitos ambientais de sumidouros → Negativo
4. Corrosão de armadura da laje perto piscina

74



75

76

Hipóteses FALSAS do "Gatilho"

1. Corrosão das armaduras dos pilares → Negativo
2. Estrutura com lajes planas sem vigas → Negativo
3. Efeitos ambientais de sumidouros → Negativo
4. Corrosão de armadura da laje perto piscina → Negativo

77

Terceira Lição

✓ Mantenha visão crítica das noticias na mídia por mais que pareçam verdadeiras

78

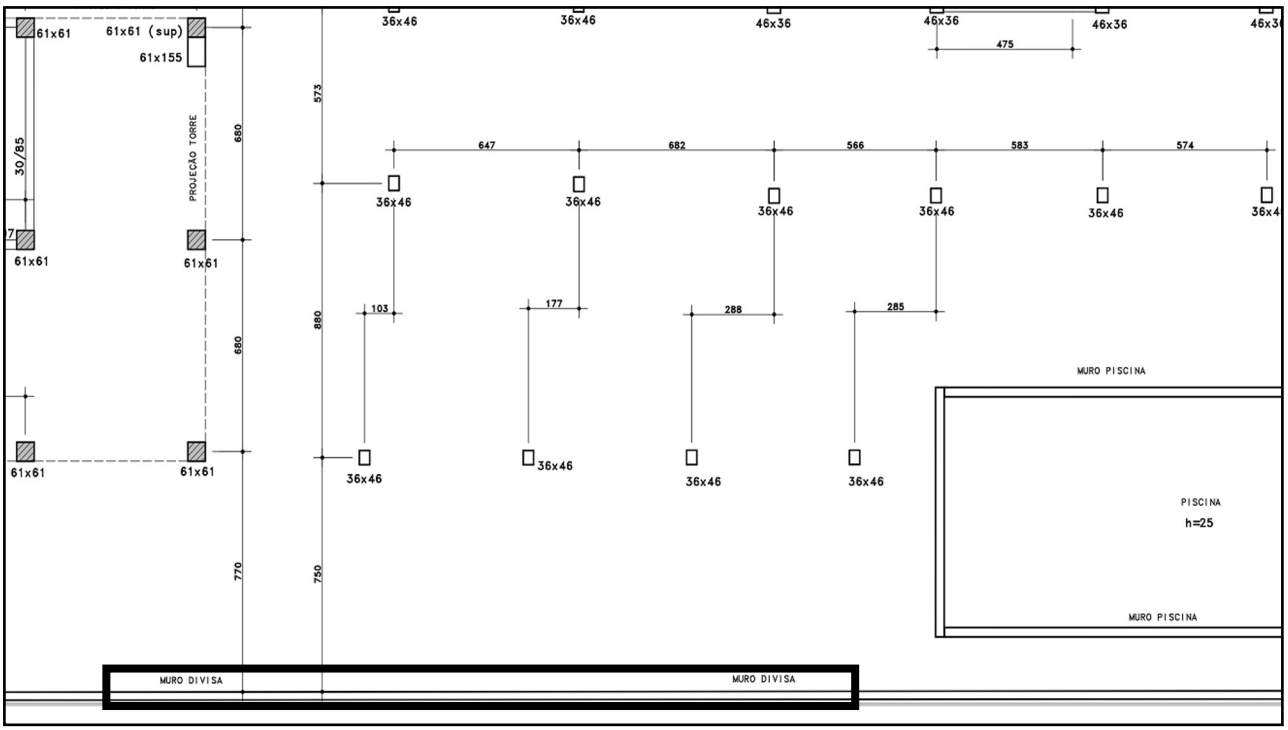
“Verdadeiras” hipóteses do “Gatilho”

→Fissura + corrosão + punção → muro de divisa

→Corrosão + punção → laje recreação

→Recalque diferencial + punção → laje recreação

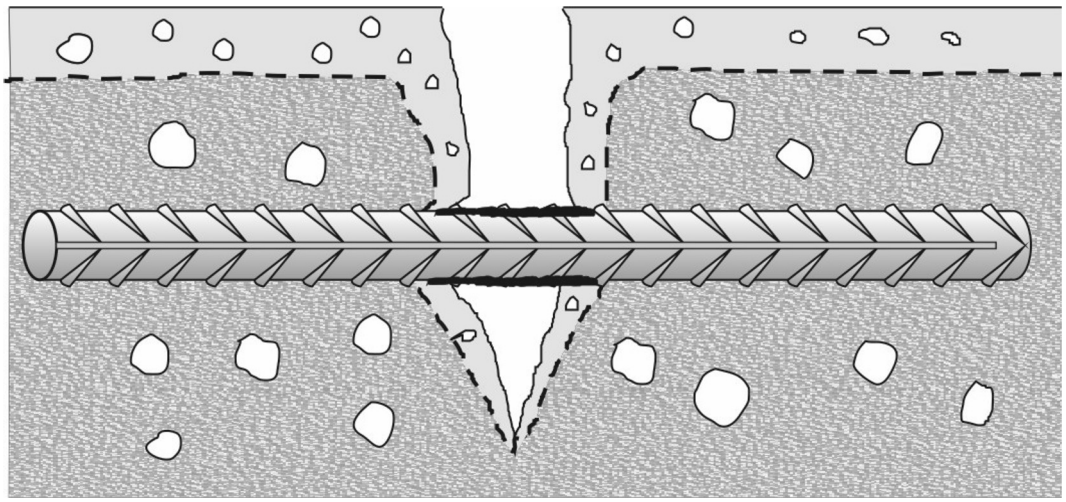
79



80

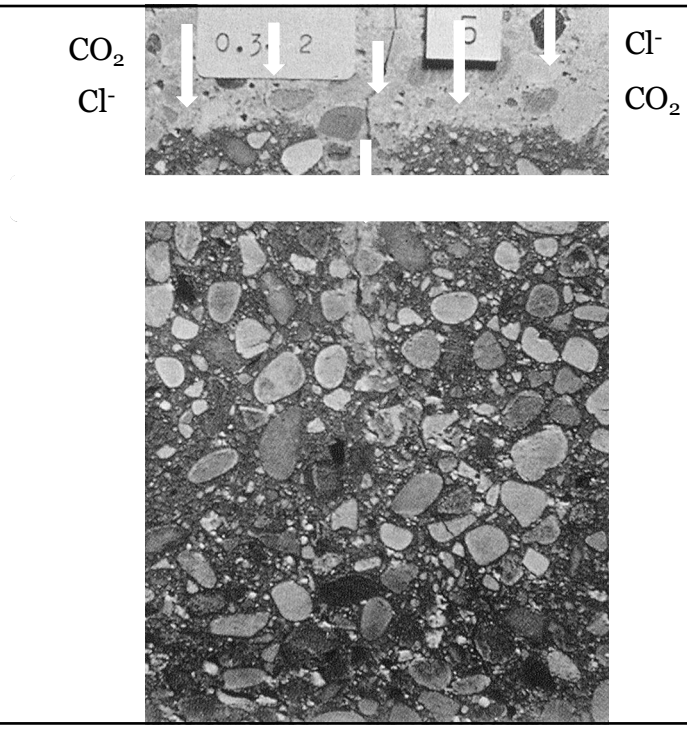
81

Fisuración bajo Carbonatación y/o Cloruro

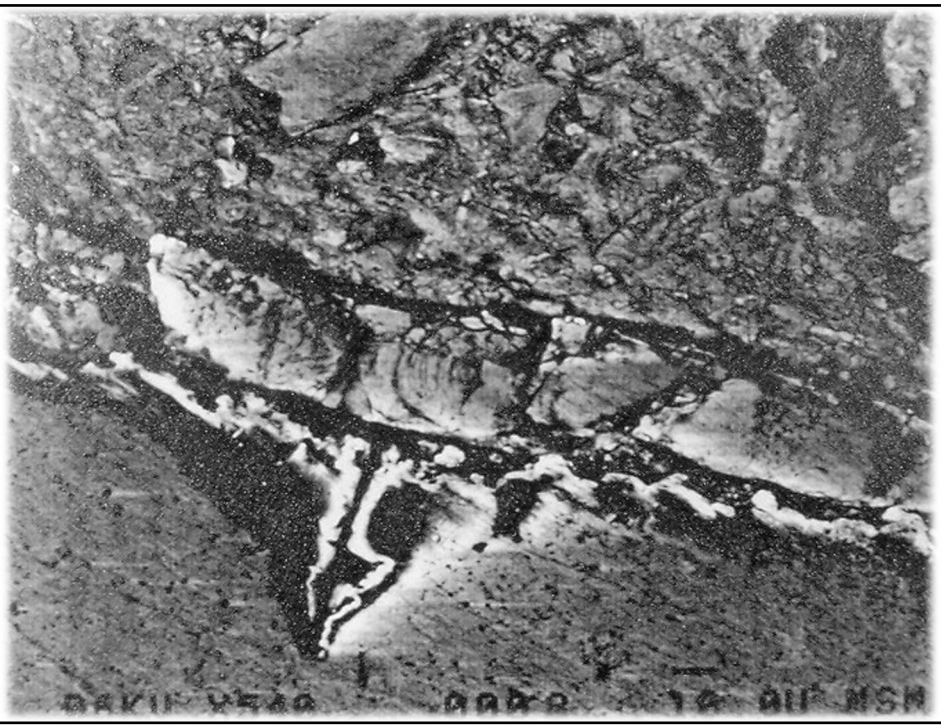


w_k ânodo pequeño vs cátodo enorme

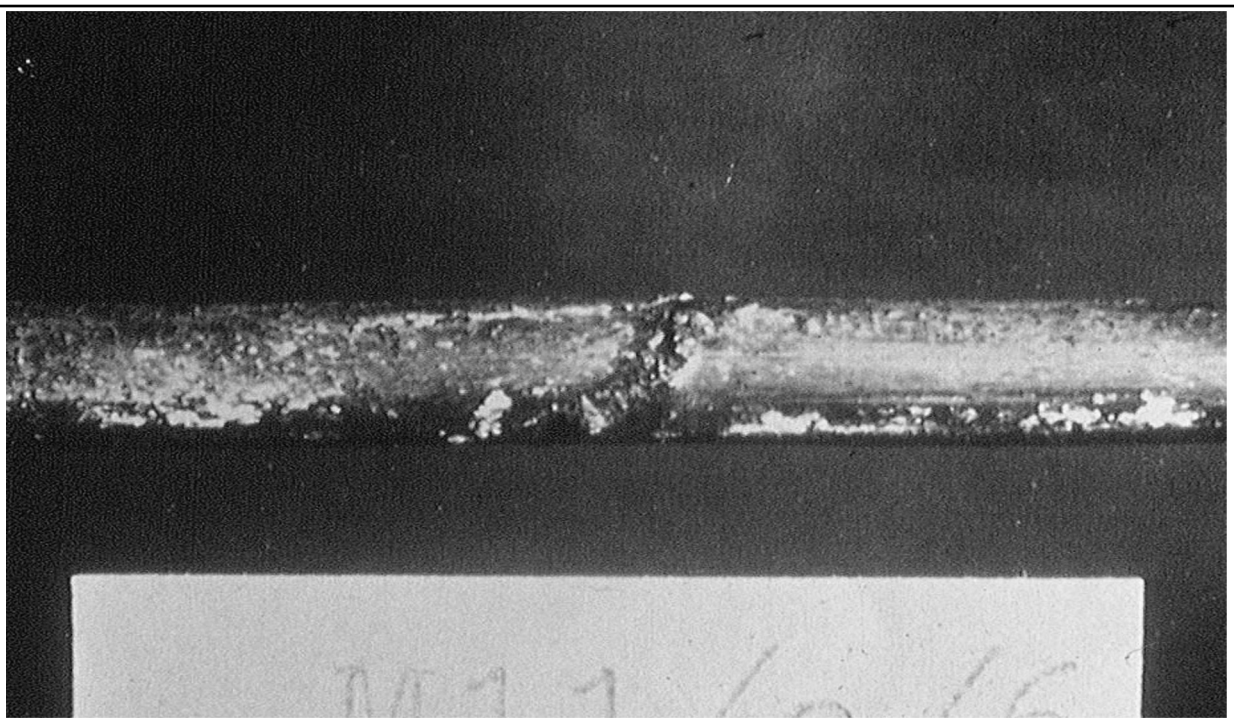
82



83



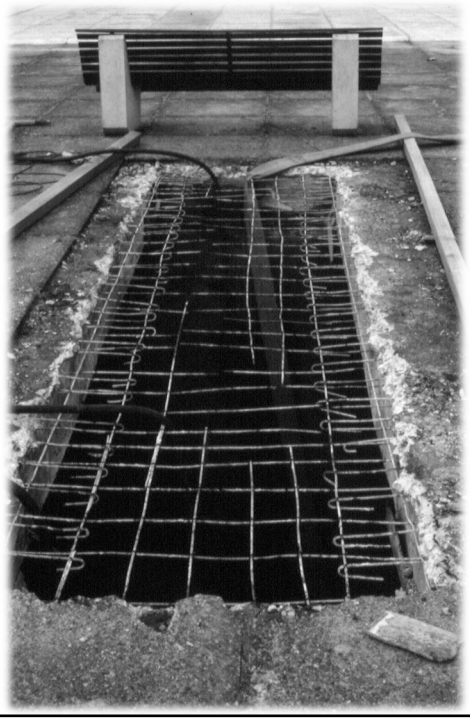
84



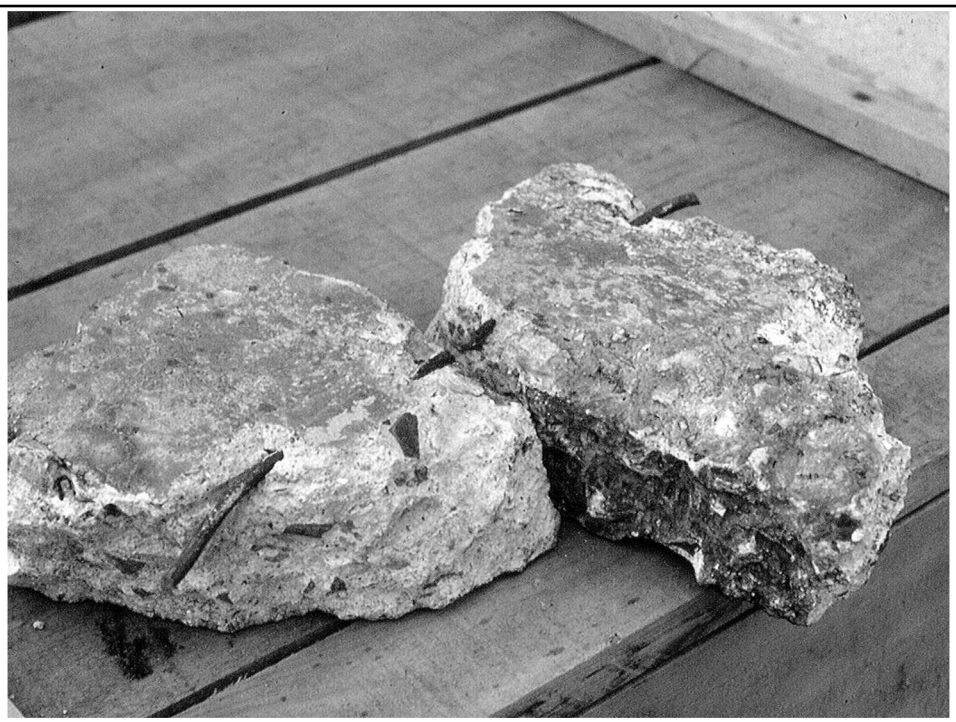
85

86

87



88



89


https://www.enr.com/articles/52001-engineers-piece-together-champlain-towers-probable-collapse-sequence

90


https://www.enr.com/articles/52001-engineers-piece-together-champlain-towers-probable-collapse-sequence

91


TWITTER/@SENPIZZO
https://www.eng-tips.com/viewthread.cfm?qid=484915

92


gettyimages
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https://www.gettyimages.com.br/fotos/viera-fl?assettype=image&phrase=viera%20fl&sort=mostpopular&license=rf%2Crm

93


gettyimages
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https://www.gettyimages.com.br/fotos/viera-fl?assettype=image&phrase=viera%20fl&sort=mostpopular&license=rf%2Crm

94

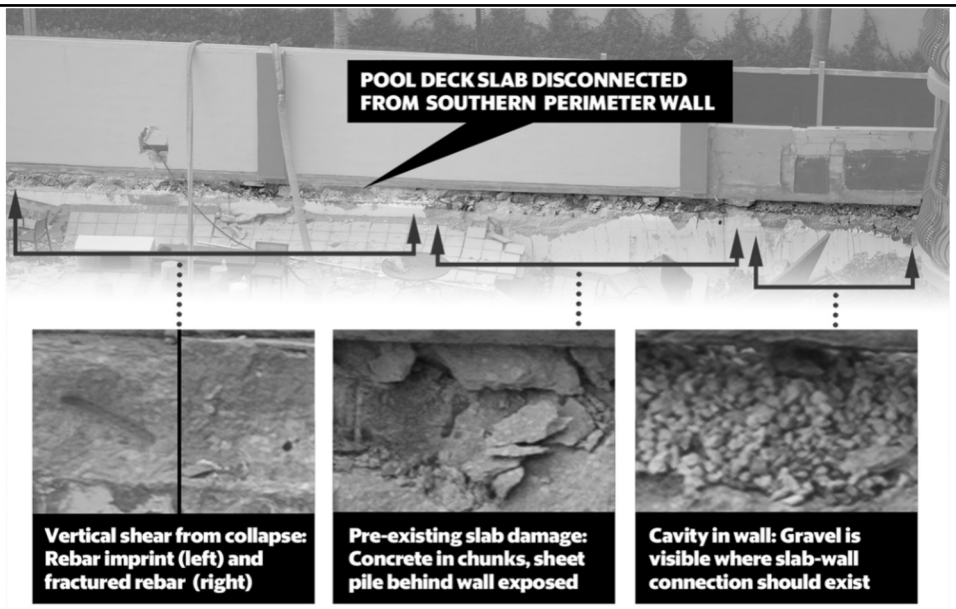
Thursday
April 21, 2022

MIAMI
HERALD

A photo of the Champlain Towers South pool deck shows the slab disconnected from the southern wall during the June 24 collapse. Damage in the failure plain is not uniform, indicating pre-existing damage to portions of the slab at the connection, according to engineer Dawn Lehman. Robert Lisman

https://www.miamiherald.com/news/special-reports/surfside-investigation/article260418037.html

95



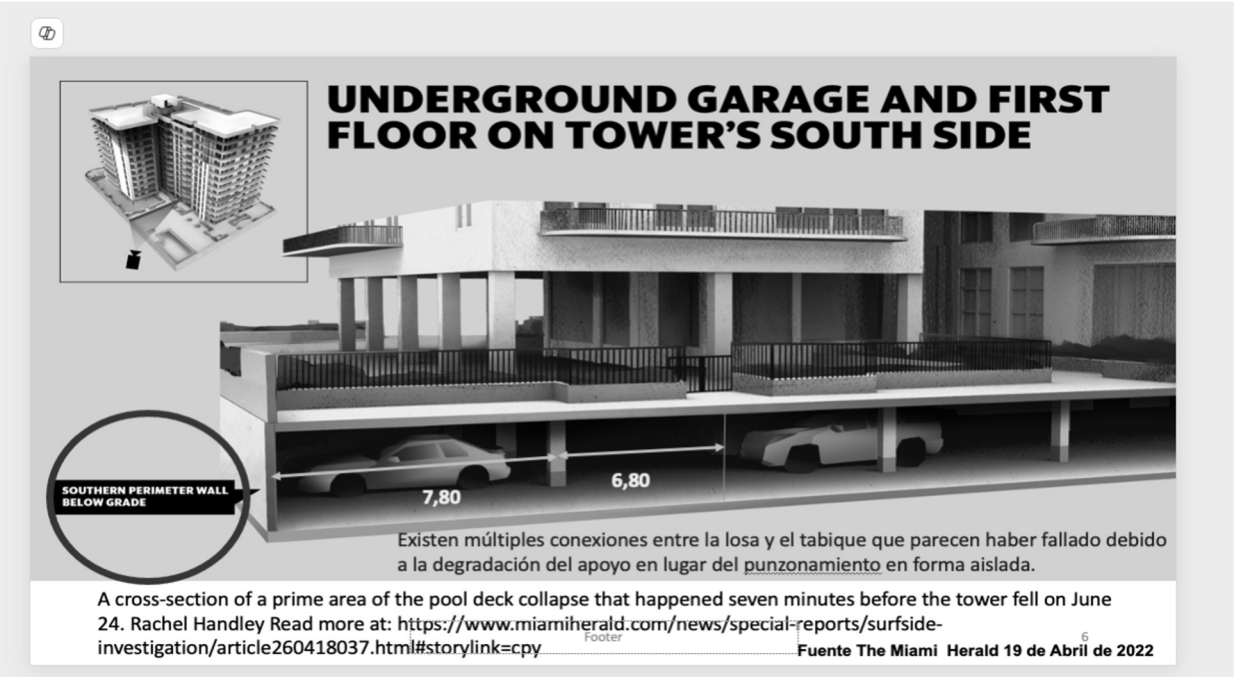
A July 1 photo of the collapse site shows distinct damage patterns in the area where the pool deck slab disconnected from the southern perimeter wall. *EDUARDO ALVAREZ AND SARAH BLASKEY*

Thursday
April 21, 2022

MIAMI
HERALD

https://www.miamiherald.com/news/special-reports/surfside-investigation/article260418037.html

96


UNDERGROUND GARAGE AND FIRST FLOOR ON TOWER'S SOUTH SIDE
SOUTHERN PERIMETER WALL BELOW GRADE
7,80
6,80
Existen múltiples conexiones entre la losa y el tabique que parecen haber fallado debido a la degradación del apoyo en lugar del punzonamiento en forma aislada.
A cross-section of a prime area of the pool deck collapse that happened seven minutes before the tower fell on June 24. Rachel Handley Read more at: https://www.miamiherald.com/news/special-reports/surfside-investigation/article260418037.html#storylink=cpy
Footer
6
Fuente The Miami Herald 19 de Abril de 2022

97


56 m
laje recreação
torre

98

morabito consultants

October 8, 2018

Champlain Towers South
8777 Collins Avenue
Surfside, FL 33154

Attention: Ms. Maggie Manrara
Treasurer

Re: ***Champlain Towers South Condominium***
Structural Field Survey Report
MC Job# 18217

Dear Ms. Manrara:

Morabito Consultants, Inc. (MC) is pleased to submit this structural engineering report of the Field Survey completed at the existing Champlain Towers South Condominium Complex (CTS) in Surfside, FL. The scope of this project includes a review of the existing 12 story plus penthouse 136-unit residential building, below-grade parking garage and at-grade exterior entrance drive, pool and recreation area. MC reviewed a representative sample of ~68 condominium units (half of the total units found in the building) along with the roof, exterior facade (observed from the balconies surveyed), parking garage,

99

https://www.townofsurfsidefl.gov/docs/default-source/default-document-library/town-clerk-documents/champlain-towers-south-public-records/8777-collins-ave---structural-field-survey-report.pdf?sfvrsn=882a1194_2

" The Pool Deck and Entrance Drive areas were reviewed ....

...

Many of the existing pavers on the pool deck are cracked

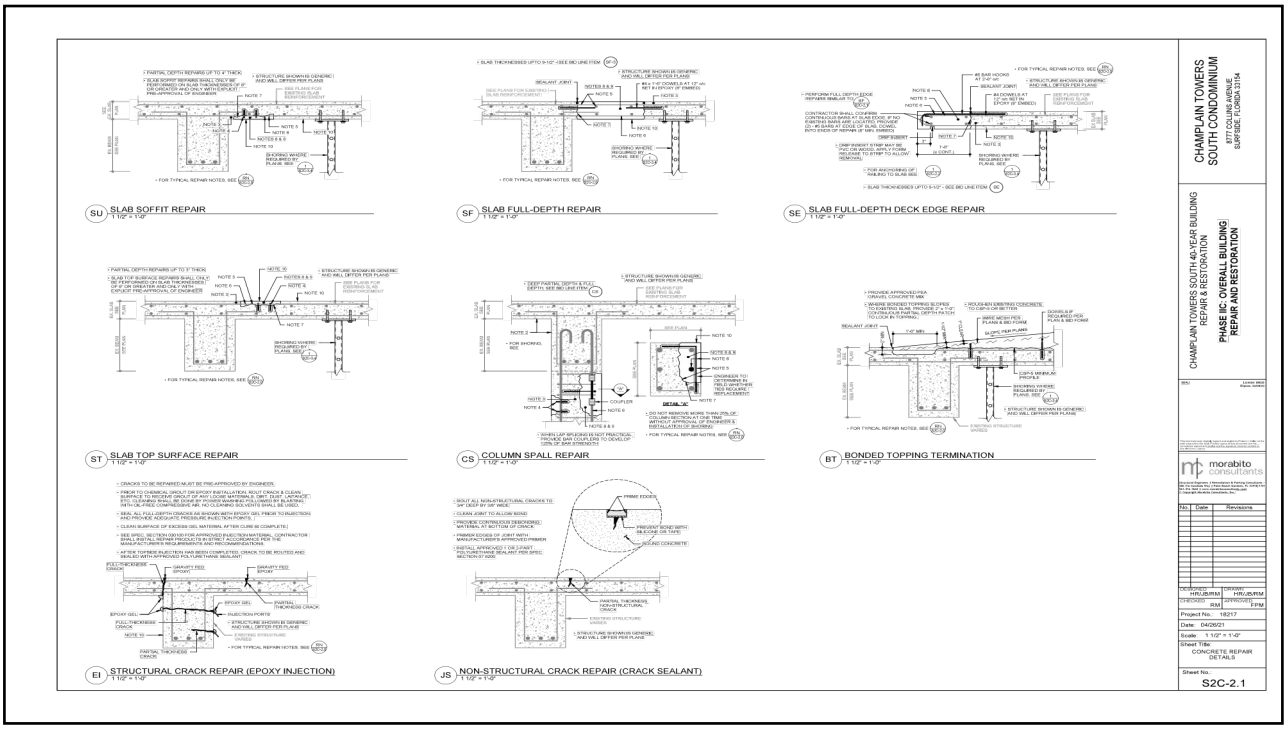
...

The joint sealant was observed to be beyond its useful life and are in need to complete replacement

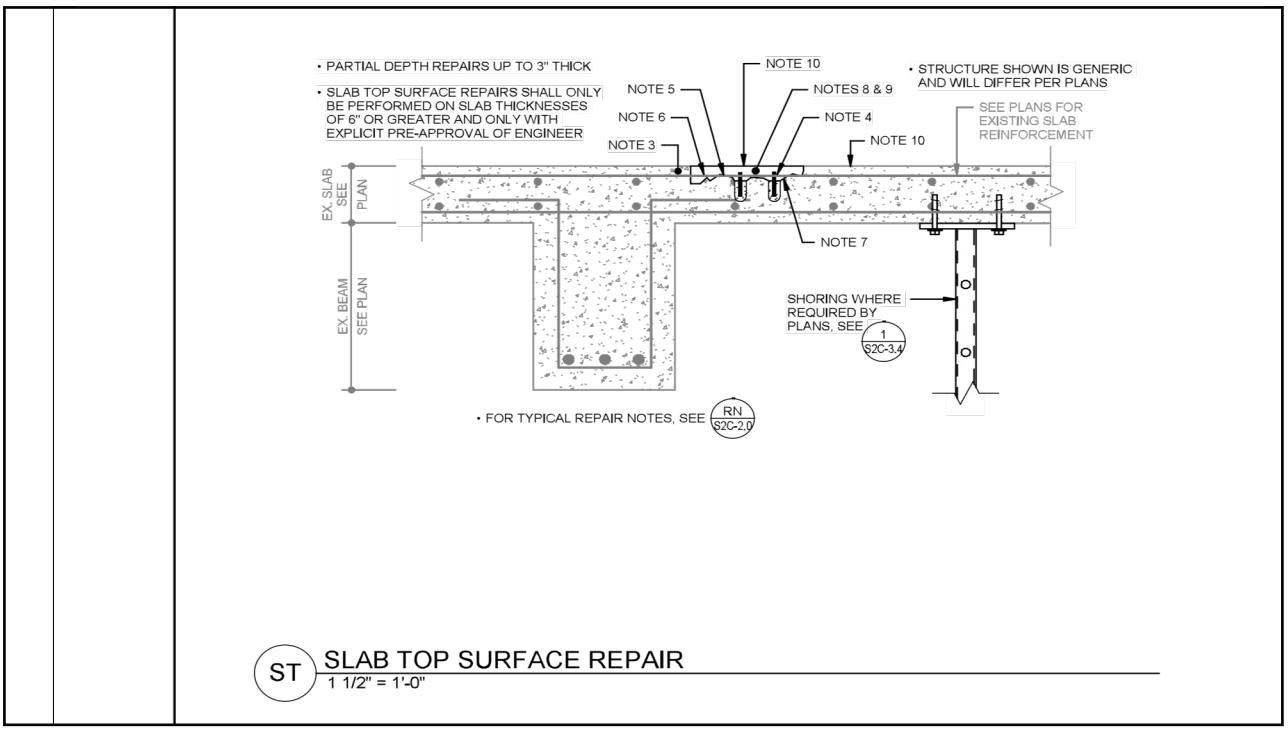
...

The failed waterproofing is causing major structural damage to the concrete structural slab below these areas "

100


SU SLAB SOFFIT REPAIR
1 1/2" = 1'-0"
SF SLAB FULL-DEPTH REPAIR
1 1/2" = 1'-0"
SE SLAB FULL-DEPTH DECK EDGE REPAIR
1 1/2" = 1'-0"
ST SLAB TOP SURFACE REPAIR
1 1/2" = 1'-0"
CS COLUMN SPALL REPAIR
1 1/2" = 1'-0"
BT BONDED TOPPING TERMINATION
1 1/2" = 1'-0"
EI STRUCTURAL CRACK REPAIR (EPOXY INJECTION)
1 1/2" = 1'-0"
JS NON-STRUCTURAL CRACK REPAIR (CRACK SEALANT)
1 1/2" = 1'-0"
CHAMPLAIN TOWERS SOUTH CONDOMINIUM
8777 COLLINS AVENUE
SURFSIDE, FLORIDA 33154
CHAMPLAIN TOWERS SOUTH 40-YEAR BUILDING REPAIR & RESTORATION
PHASE IIC: OVERALL BUILDING REPAIR AND RESTORATION
morabito consultants
No. Date Revisions
DESIGNED HR/JB/RM
DRAWN HR/JB/RM
CHECKED RM
APPROVED FPM
Project No. 18217
Date: 04/26/21
Scale: 1 1/2" = 1'-0"
Sheet Title: CONCRETE REPAIR DETAILS
Sheet No. S2C-2.1

101


• PARTIAL DEPTH REPAIRS UP TO 3" THICK
• SLAB TOP SURFACE REPAIRS SHALL ONLY BE PERFORMED ON SLAB THICKNESSES OF 6" OR GREATER AND ONLY WITH EXPLICIT PRE-APPROVAL OF ENGINEER
NOTE 10
NOTE 5
NOTES 8 & 9
NOTE 6
NOTE 4
NOTE 3
NOTE 10
• STRUCTURE SHOWN IS GENERIC AND WILL DIFFER PER PLANS
SEE PLANS FOR EXISTING SLAB REINFORCEMENT
EX. SLAB SEE PLAN
EX. BEAM SEE PLAN
NOTE 7
SHORING WHERE REQUIRED BY PLANS, SEE 1 S2C-3.4
• FOR TYPICAL REPAIR NOTES, SEE RN S2C-2.0
ST SLAB TOP SURFACE REPAIR
1 1/2" = 1'-0"

102

- ❖Pacometría – posição das armaduras
- ❖Esclerometria - dureza superficial
- ❖Ultrasom – ninhos de concretagem
- ❖Testemunhos - f'_c e modulo do concreto
- ❖Cobrimento
- ❖Espessura de carbonatação
- ❖Presença e perfil de cloreto
- ❖Geometria de fissuras
- ❖**Identificação de áreas problemáticas**

103

Quarta Lição

- ✓ É fundamental proceder a uma inspeção correta e detalhada, realizada por profissionais experientes e certificados que saibam identificar os pontos críticos da estrutura que está sendo inspecionada

"...tudo o que diz a Red DURAR, a ALCONPAT, os CTs do IBRACON, ABNT, ... anamenese, ensaios, conhecimento do projeto estrutural, cloretos, prospecção..."

104

“Verdaderas” hipóteses do “Gatilho”

→Fissura + corrosão + punção → muro de divisa OK

→ Corrosão + punção → Laje recreação

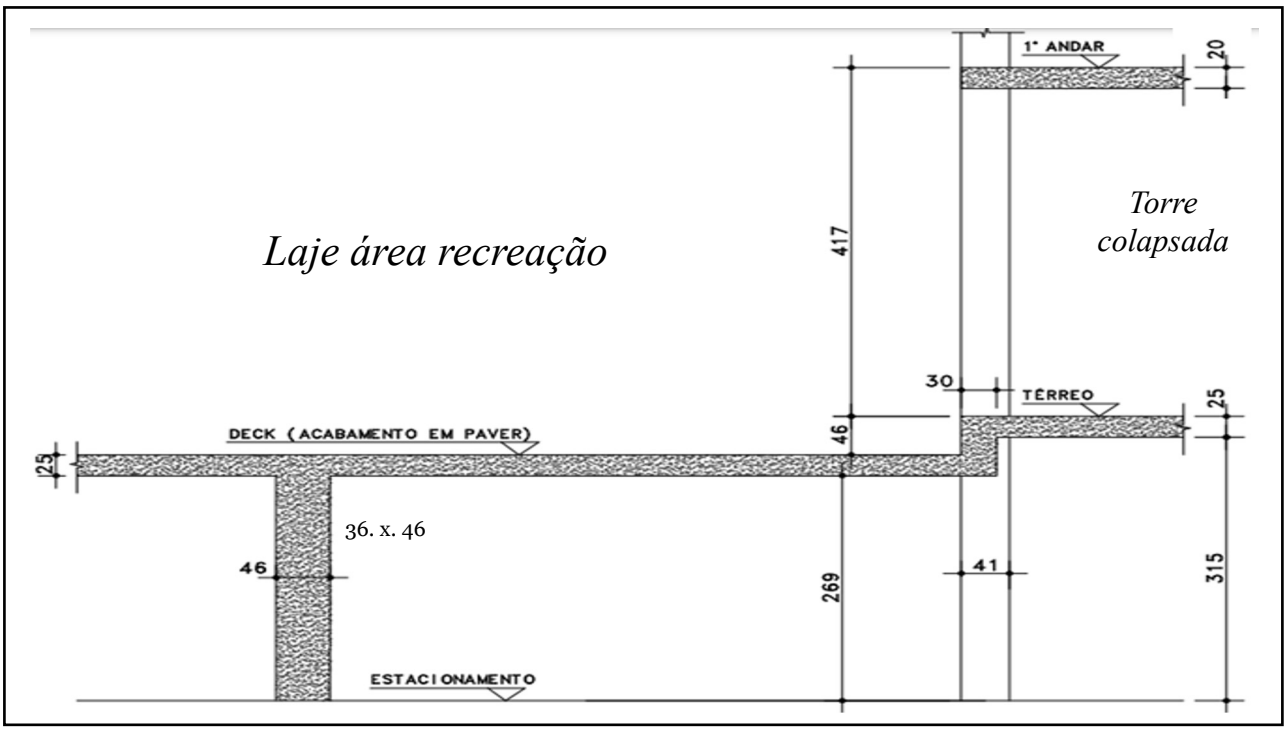
→ Recalque diferencial + punção

105

106

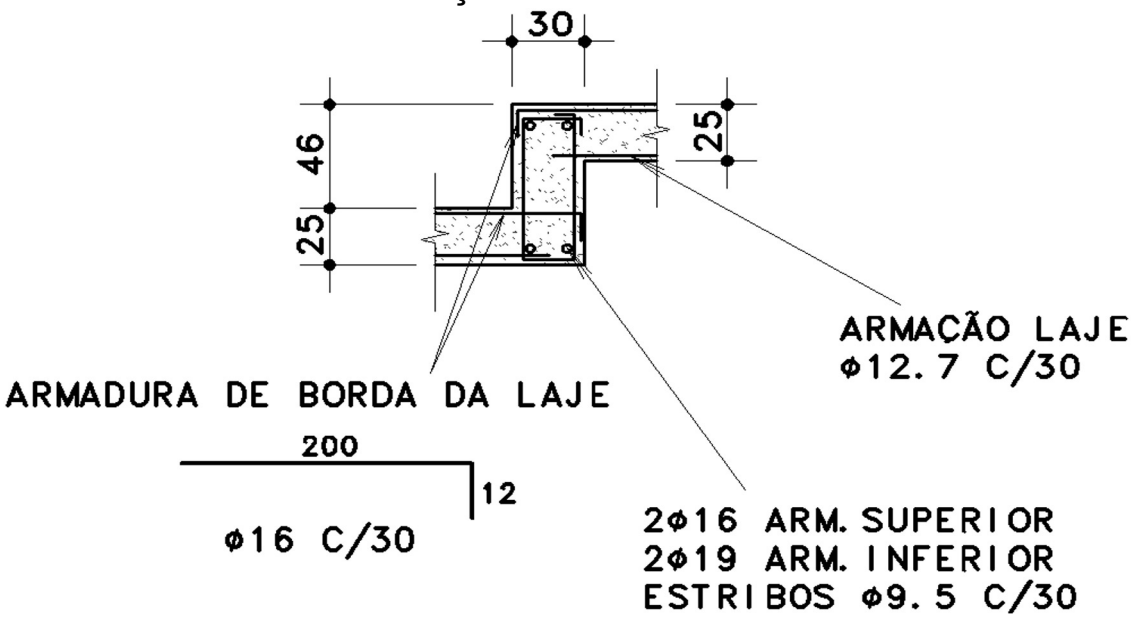

© 2021 Google
Data das imagens: 3/2015 25°52'22.42"N 80°07'16.36"O elev 7 m

107


1° ANDAR
20
Torre colapsada
Laje área recreação
417
30
TÉRREO
25
DECK (ACABAMENTO EM PAVER)
46
25
36. x. 46
46
269
41
315
ESTACIONAMENTO

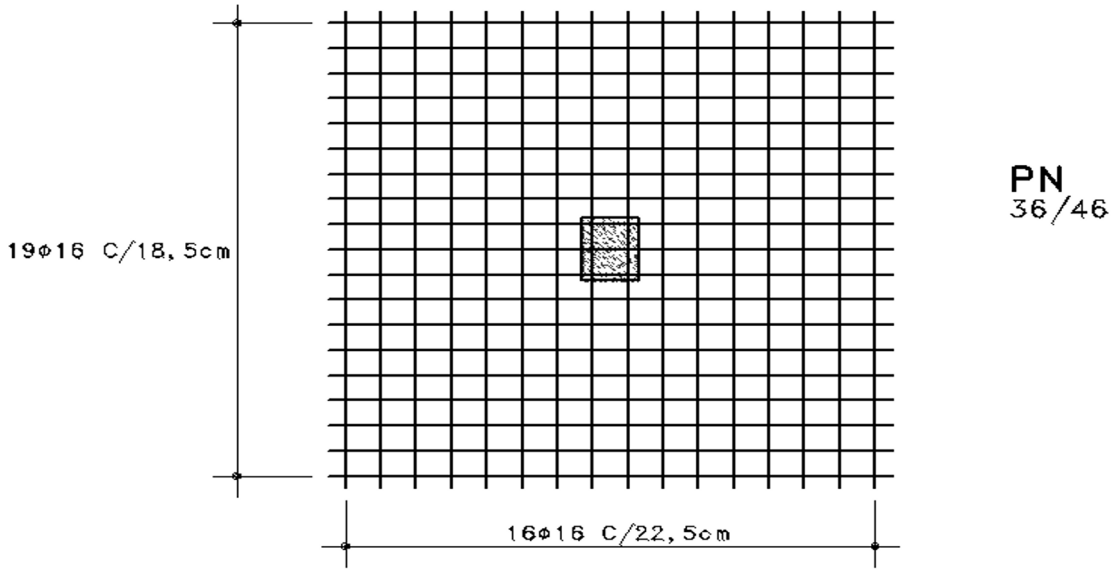
108

ARMADURA LAJE RECREAÇÃO com TÉRREO



109

Armadura SUPERIOR pilares 36x46 cm
Laje área lazer, plana, sem capitel



110

Laje Recreação/Estacionamento → Punção

$e_{nominal}$ = 25 cm → altura útil → d = 22 cm

Carga peso próprio = 625 kgf/m²

Carga permanente= 325 kgf/m² Total : 1.200 kgf/m²

Carga acidental= 250 kgf/m²

"área de influencia" ou modelo

Carga no pilar = 50.000 kgf (50tf)

Nota: não foi considerado efeito de momento na cabeça do pilar, nem flexão, portanto uma verificação aproximada da realidade

111

Laje Recreação/Estacionamento → Punção

$f_{ck,laje}$ = 27,6 MPa (N/mm²)

$f_{ck,pilar}$ = 41,4 MPa (N/mm²)

Armadura em x = ϕ16 cada 15,3cm ρx = 0,60%

Armadura em y = ϕ16 cada 17,5cm ρy = 0,52%

$$\rho = \sqrt{\rho x * \rho y}$$

Taxa de Armadura = 0,0056 = 0,56%

112

Laje Recreação/Estacionamento → Punção
resumo

$f_{ck,laje}$ = 27,6 MPa (N/mm²)

$f_{ck,pilar}$ = 41,4 MPa (N/mm²)

Taxa armadura = ρ =0,0056 = 0,56%

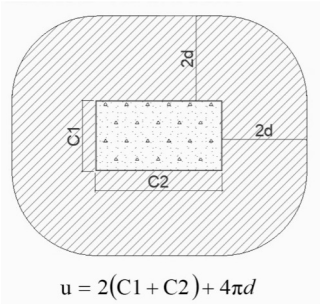
Normal solicitante → F_{sd} = 500* γ_f (kN)

Perímetro crítico → μ = 440 cm

Altura útil d = 22 cm

C1 = 36 cm C2 = 46 cm

Contorno C'



113

apartado 20.12

"Punzonamiento"

pág. 418 a 422

Hormigón Armado
14º Edición
Refere-se a EHE
Publicada em 2000

Pedro Jiménez Montoya
Álvaro García Meseguer
Francisco Morán Cabre

114

EHE 2000 → Punção

$$\tau_{Rd} = 0{,}12 * (1 + \sqrt{\frac{200}{d}}) * \sqrt[3]{(100 * \rho * f_{ck})}$$

$$\tau_{sd} = \frac{\beta * Fsd}{\mu * d}$$

Contorno C'

115

Norma Espanhola EHE 2000→ Punção

$$\tau_{Rd} = 0{,}12 * \left(1 + \sqrt{200/220}\right) * (100 * 0{,}0056 * 27{,}6)^{1/3} = \mathbf{0{,}58\ MPa}$$

$$\tau_{Rd} = 0{,}12 * \left(1 + \sqrt{200/220}\right) * (100 * 0{,}0056 * 41{,}4)^{1/3} = \mathbf{0{,}63\ MPa}$$

$$\tau_{Sd} = \frac{\beta * F_{Sd}}{u * d} = \frac{1{,}15 * 500kN * \gamma_f}{440cm * 22cm} = 0{,}59\ \text{MPa} * y_f$$

116

EHE 2000 → Punção

$$\tau_{Sd} < \tau_{Rd}$$

$$\tau_{Rd} = \mathbf{0,58 \text{ a } 0,63} \text{ MPa}$$

$$\tau_{Sd} = \mathbf{0{,}59} * \gamma_f$$

(1,5 ?!)

$$\gamma_f = \mathbf{0{,}98 \text{ a } 1{,}07}$$

117

NBR 6118:2014 Cálculo da Solicitante à Punção

Pilar interno, carregamento simétrico (sem efeito de momento)

$$\tau_{Rd} = 0{,}13 * \left(1 + \sqrt{20/d}\right) * (100 * \rho * f_{ck})^{1/3} =$$

$$= 0{,}13 * \left(1 + \sqrt{20/22}\right) * (100 * 0{,}56\% * 27{,}6)^{1/3} = 0{,}63 \text{ MPa}$$

41,4 → 0,72 MPa

$$\tau_{Sd} = \frac{F_{Sd}}{u \times d} = \frac{500kN * \gamma_f}{440cm * 22cm} = 0{,}52 \text{ MPa } * yf$$

(1,4 ?!)

$$\gamma_f = \mathbf{1{,}21 \text{ a } 1{,}38}$$

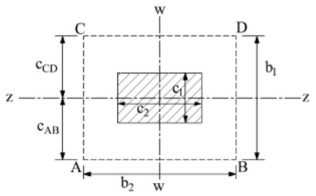
118

ACI 318:14 Punção

$\tau_{Rd} = 0{,}25 * \sqrt{f_{ck}}$

$\tau_{Rd} = 0{,}25 * \sqrt{27{,}6} = 1{,}31$ MPa

$\tau_{Rd} = 0{,}25 * \sqrt{41{,}4} = 1{,}60$ MPa



$$\tau_{sd} = \frac{F_{sd}}{u_1 \times d} + \frac{\gamma_v * M_{Sd} * b_1/2}{J_c}$$

$$\tau_{sd} = \frac{F_{sd}}{u_1 * d} = \frac{500kN * y_f}{252cm * 22cm} = 0{,}90 \text{ MPa} * y_f$$

119

ACI 318:14 Punção

$\tau_{Rd} = 1{,}31$ MPa

$\tau_{Rd} = 1{,}60$ MPa

$\tau_{Sd} = 0{,}90 \text{ MPa} * y_f$

(1,4 ?!)

γ_f **= 1,45 a 1,77**

Obs.: ACI é muito diferente. Neste caso não passa a armadura de flexão, por exemplo.

120

fib Model Code:2010 Punção

$$F_{Rd} = k_{\Psi} * \frac{\sqrt{fck}}{\gamma_c} * b_0 * d$$

$$F_{Rd} = 0{,}214 * \frac{\sqrt{27{,}6}}{1{,}5} * 2100mm * 220mm = 347 \text{ kN}$$

$$F_{Rd} = 0{,}214 * \frac{\sqrt{41{,}4}}{1{,}5} * 2100mm * 220mm = 424 \text{ kN}$$

$$F_{Sd} = 500 \text{ kN} * y_f$$

121

fib Model Code:2010 Punção

$$F_{Rd} = 347 \text{ kN}$$

$$F_{Rd} = 424 \text{ kN}$$

$$F_{Sd} = 500 * y_f$$

(1,5 ?!)

$$\gamma_f = \mathbf{0{,}69 \text{ a } 0{,}85}$$

Obs.: comparativo de esforços resistente versus solicitante.

122

ACI 318: γ_f **= 1,45 a 1,77**

fib Model Code:2010: γ_f **= 0,69 a 0,85**

Norma Espanhola EHE.2000: γ_f **= 0,98 a 1,07**

NBR 6118:2014 → contorno C' γ_f **= 1,21 a 1,38**

+retração + efeitos térmicos + recalque diferencial + corrosão

123

Quinta Lição

- ✓ As normas não são iguais, evite usar só um pedaço de uma misturado com outra
- ✓ É essencial proceder com uma revisão por pares do projeto estrutural antes de começar a construir, realizada por especialistas que saibam identificar os pontos críticos da estrutura.

" ...norma brasileira ABNT NBR 6118 prescreve ATP..."

124

“Verdadeiras” hipóteses do “Gatilho”

→Fissura + corrosão + punção → muro de divisa - OK

→Corrosão + punção → laje recreação - OK

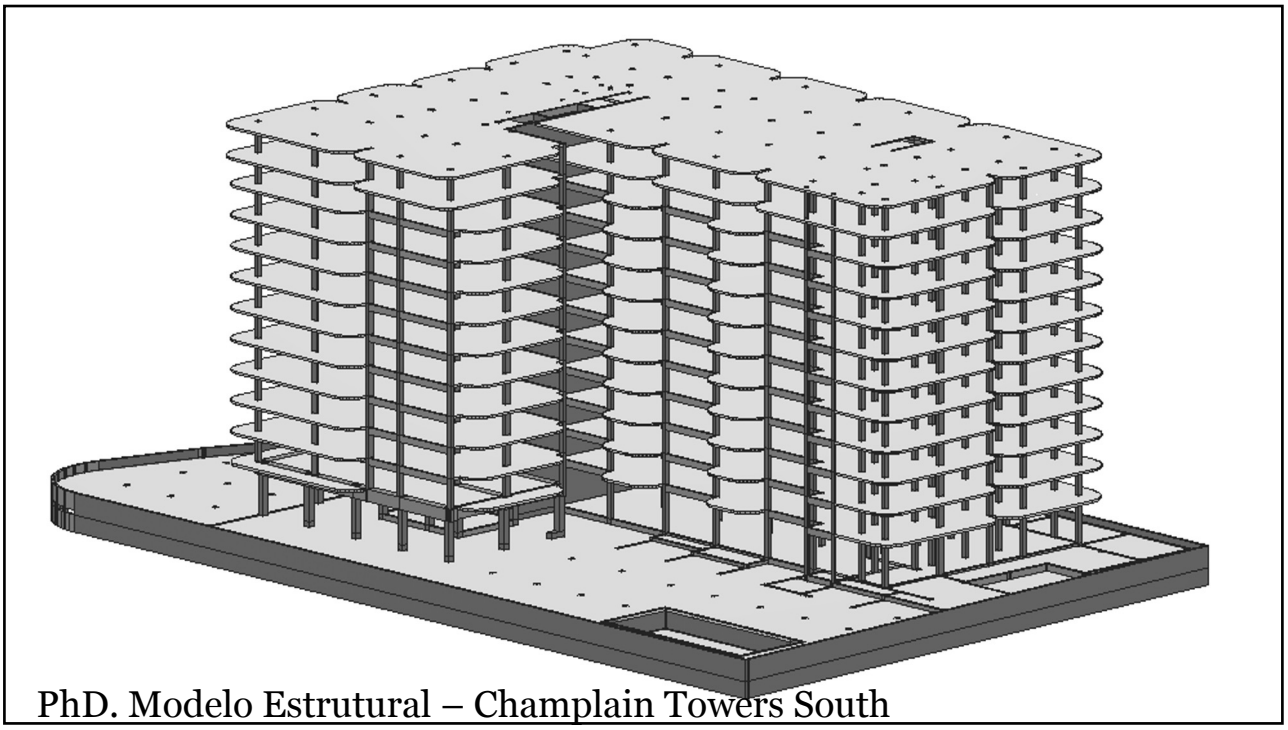
→**Recalque diferencial + punção**

125

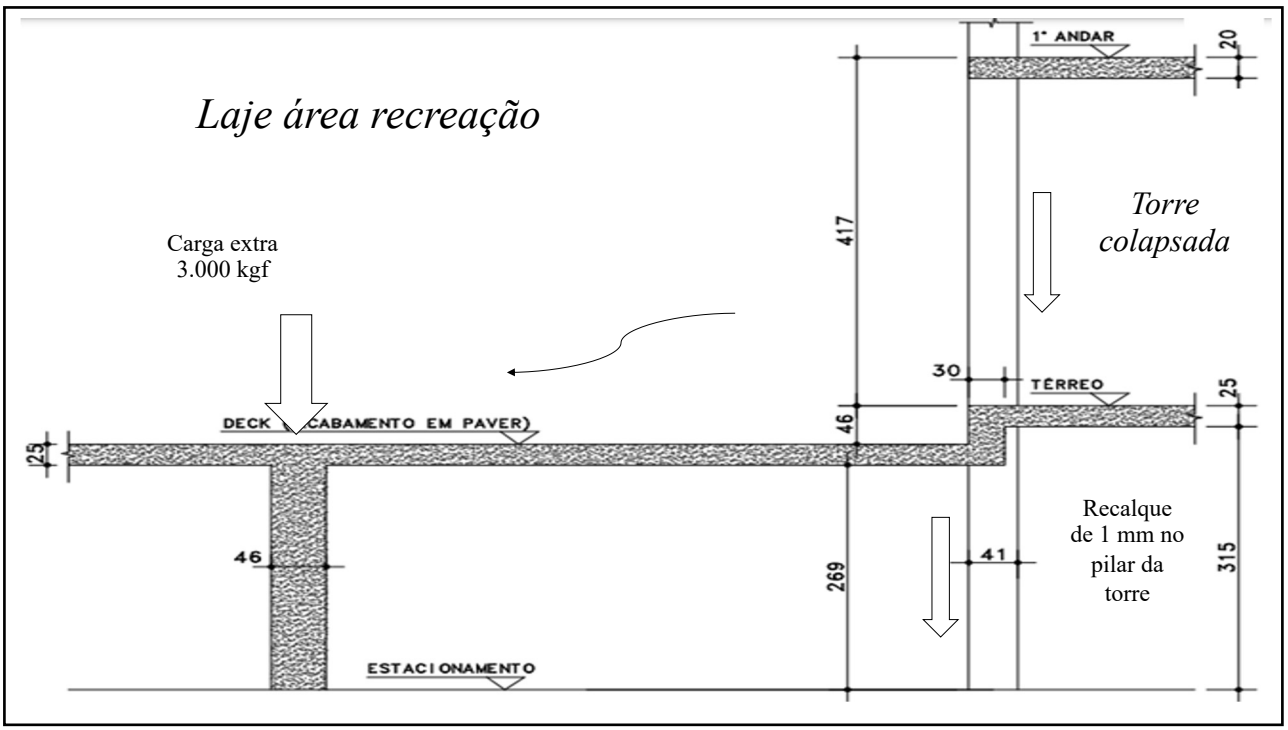
56 m

Laje recreação **torre**

126


PhD. Modelo Estrutural – Champlain Towers South

127


Laje área recreação
Carga extra
3.000 kgf
Torre
colapsada
1° ANDAR
20
417
30
TÉRREO
25
46
DECK (ACABAMENTO EM PAVER)
25
46
269
41
315
Recalque
de 1 mm no
pilar da
torre
ESTACIONAMENTO

128

EHE 2000 Recalque Diferencial

γ_f **= 0,69; 0,98; 1,21 e 1,45 = 1,09**

Carga nos pilares = 50.000 kgf

Recalque 1 mm → carga extra ≈ 3.000 kgf

γ_f **= 1,02**

129

EHE 2000 Recalque Diferencial

γ_f **= 0,69; 0,98; 1,21 e 1,45 = 1,09**

Carga no Pilar = 50.000 kgf

Recalque 2 mm → carga extra ≈ 6.300 kgf

γ_F **= 0,97**

130

131

O que recomendar à Champlain Towers North ??

1. Proibir estacionar carro
2. Revisar projeto
3. Inspecionar fisuras (muro e cabeça pilar)
4. Promover junta dilatação (consoles)
5. Verificar conceito de robustez

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Shoring is visible around at least 11 columns at Champlain Towers North, sister building to the Champlain Towers South condo that collapsed in June 2021.

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Lições Aprendidas

- Transparência para a Sociedade e valorização da Engenharia
- ATP (análise técnica de projeto, revisão por pares)
- ATO (acompanhamento técnico de obra, supervisão e controle)
- ATU (acompanhamento técnico do uso, inspeção periódica)
- Obras de manutenção preventiva e corretiva – vida útil
- Cuidado com água e não menosprezar corrosão
- Escolher profissionais bem preparados (certificação, CV)

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