

Review Article

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New Methods in Portland Concrete & Structural Steel

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Abstract

In this paper, we cover a lot of ground in the science and engineering of Portland concrete and structural steel. We provide a new idea for a deteriorating bridge deck on a bridge. We suggest that the deck could make use of metal filings in place of rebar. Also, we show "why the physical and chemical strengthening of concrete are the way it is." [1].

1. Introduction

There is a four-lane bridge structure that crosses the St John River at Saint John. Harbour. It was constructed by the Federal

government in the 1960's as part of a major Throughway project. See Figure 1 for a picture of the Saint John Harbour Bridge.



Figure 1: Saint John Harbour Bridge

Every year, the bridge has to go to two lanes of traffic to refurbish the expansion joints and the concrete deck. The bridge is a combination of structural steel beams and a Portland concrete deck and piers. I wondered how it could be that the bridge needed repairs every year. Other bridges, such as the Viaduct not far away

from the Harbour Bridge, are refurbished about every 20 years or more. It is a pre-stressed bridge with a bituminous asphalt and concrete deck. There must be something wrong with the design of the Harbour Bridge that it needs to be redone every year. It carries a lot of traffic- probably in the order of 1000 vehicles per lane per

hour all day and night. It forms the major highway for Route 1 that runs along Southern New Brunswick. In addition, there are about 30-40 k residents who live in West Saint John that need to cross one of two bridges to get to the downtown and the shopping district in East Saint John. The second bridge is the Reversing Falls Bridge, which is about 100 years old. It is a steel arch bridge. See Figure 2. (The train bridge is to the right of the picture, not considered here). The Reversing Falls Bridge has been rebuilt, replacing one member at a time three times. They put welders and inspectors under the deck who have no net to refurbish it.

Between the two-lane Reversing Falls bridge and the four lane Harbour Bridge, there are 6 lanes in total -three each way that carry $2000 \times 3 = 6000$ vehicles per hour each way. I understand that there are plans being made for a new bridge at Reversing Falls to run between the train bridge and reversing falls. Bridge. So, I figured that the problem with the annual renewal of the bridge deck at the Harbour Bridge to be a problem with the expansion joints. Despite the harsh sea air salt water and fog environment, the concrete deck should last longer than one year. It doesn't so I did some calculations on the expansion and contraction of the structural steel girders and the Portland concrete deck that follow.



Figure 2: Reversing Falls Bridge (Left)

I think the solution to the bridge deck problem may require a new design for the bridge deck. The steel girders are painted every few years to keep them from rusting out. The bridge has been in service since the late 1960's. The harbour bridge may need to be replaced as well. Since it is part of the Thruway Highway system, the location for a new bridge can't be isolated to Reversing Falls alone. Route 1 must have a bridge too. A deck design should use metal filings embedded through the mix of Portland concrete. Then that concrete deck could sit on rollers, say train chassis or carts, to carry the load through to the piers. If the deck rested on train carriages, there would only be a need for expansion and contraction of the concrete. The steel filings embedded in the concrete need no expansion joints. This technique is frequently used nowadays for slabs in warehouses. The old method of pouring a concrete slab in checker board patterned with rebar in the slab is surpassed by the ease of installation and performance of embedded steel filings. So, a question that arises is: how long is a section of concrete to be before it needs to be saw-cut or isolated from the steel girders? Really, if isolation carriages are used, then it is just the expansion

of the concrete that needs to be considered.

The thermal expansion of Steel $= \alpha_s = 7.2 \times 10^{-6}$
 The thermal expansion of concrete $= \alpha_c = 9 \times 10^{-6} \rightarrow 12 \times 10^{-6}$
 $\alpha_c / \alpha_s = 9/72 = 1.25 = E_{min} \Rightarrow GMP t = 1/2$
 $1.25 \times |60^\circ C| = 75 = 1/s = E$

We know from AT Math that Poisson's Ratio $\nu = 0.26$
 We also know that the critical force is the Super force $SF = 8/3 = 2.67$

$\nu = F_L / FA$
 $0.26 = F_L / (8/3)$
 $FL = 0.693 = Ln 2 = M$
 $t = 2$
 $t^2 - t - 1 = E$
 $2^2 - 2 - 1 = 1$

Résultant force
 $F_L^2 + F_A^2 = R^2$

$$2.666^2 + 0.26^2 = 2.679^2$$

$$R \approx 2.67 \equiv SF$$

$$E = 1/SF = 1/2.679$$

$$E^2 + E - 2 = t$$

$$373.2^2 + 373.2 - 2 = 148.7 \approx 1/G$$

$$E = 1/t = 1/(1/G) = G$$

$$E = G$$

Continuions,

GMP:

$$@t = 0 \quad E = -1$$

$$@t = 1/2 \quad E = -1.25$$

$$\Delta E = 250 = \text{Period } T$$

$$\Delta E \times \Delta t = 250 \times 1/2 = 0.125 = 12.5\%$$

From Economics, the interest formula is:

$$FV = PV(1+i)^N$$

$$FV/1 = (1+0.125)^N$$

$$2.67 = (1.125)^N$$

$$\ln 2.67 = N \ln 1.125$$

$$N = 0.1195 \approx 12 \Rightarrow \text{Magnesium } 24.305 \text{ amu} \times 6.023 = 146.4 = M$$

$$M = 81$$

$$146/81 = 180.7 = \pi = t$$

$$\pi^2 - \pi - 1 = 57.29^\circ = 1 \text{ rad} = E$$

$$\int F = \int 1/E = \ln E$$

$$E = 1$$

$$F = 0$$

$$E = 1.125$$

$$F = 11778$$

$$1.1778/1.25 = 942.26 = M \text{ p+}$$

$$942.26 - 5.1099 \text{ e-} = 937.15$$

$$\int E = E^2/2 = \pi$$

$$E = \sqrt{[2\pi]}$$

$$= 2.67 = SF$$

$$E = F$$

$$GMP \Rightarrow E = 712$$

$$t^2 - t - 8.12 = 0$$

$$t = 153.73$$

$$t + e = 1 = E$$

$$t - 7128 = (1-e)$$

$$t + E = 1$$

$$t = -2.718 = -e1$$

$$GMP \Rightarrow E = 9.107$$

$$E^2 + E - 2 = t = 0.9107$$

$$c^2 = t$$

$$c = \sqrt{t} = \sqrt{3} \text{ eigenvector } (e\vec{v})$$

$$F = \sin \theta$$

$$\int F = \int \sin \theta = \cos \theta$$

$$F = \int F$$

$$\sin \theta = \cos \theta$$

$$\theta = \pi/4 = t$$

$$GMP \Rightarrow (\pi/4)^2 - (\pi/4) - 1 = -1.168$$

$$[1. -1.168/\sqrt{3} = 0.4943 \approx 1/2 = t_{\min}]$$

$$\alpha = 0.9(60^\circ\text{C})$$

$$= 4 = M$$

$$TE = 1.5Mc^2$$

$$= 1.5(4)(9)$$

$$= 54$$

$$L^2 = 54$$

$$L = \sqrt{54} = 0.7348$$

$$\sqrt{0.7348} = 1/1.618$$

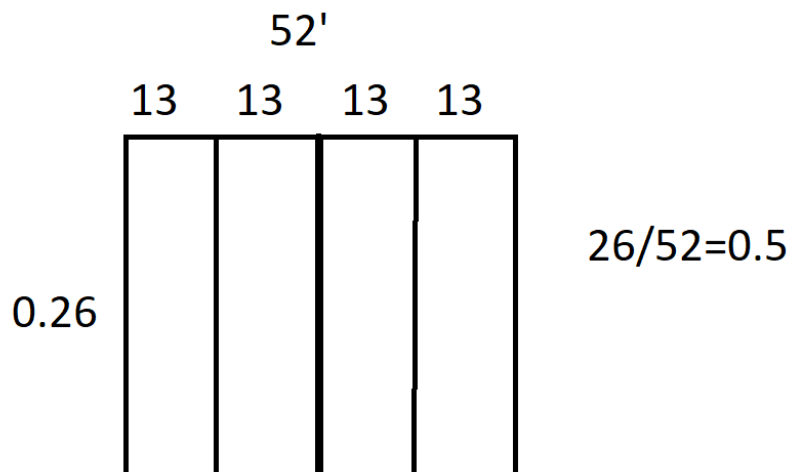


Figure 3

$$E^2 + E - 2 = t$$

$$13^2 + 13 - 2 = 180 = \pi = t$$

$$\ln t = \ln \pi = 1.1447$$

$$8/3(14.47\%) = 385 = 1/26$$

$$52/3.281 = 1585 = \text{Moment}$$

$$\text{Moment} = 1 - \sin 1 = F \times s$$

$$15.85 = 8/3(s)$$

$$s = 0.594 \approx 0.6$$

Concrete Constituents: 90% of cement is made up of:

$$\text{CaO } 40.078 + 16 = 56.1$$

$$\text{Si O}_2 \text{ } 28.086 + 2(16) = 60.086$$

10% of Cement is made up of:

AlO₃

FeO₃

SO₃

$$E = 56.1 + 60.086 = 6.996 \approx 7$$

$$M = 1/81 = 0.02345679$$

$$= 7(1) + 2 = 9 = c^2$$

$$\int \text{MdM}/dt = c^2$$

$$M = 9 = 90\%$$

Steel\ Constituents

$$98\% \text{ Fe } 55.728 \times 98\% = 54.781$$

$$2\% \text{ C } 12 \times 2\% = 0.24022$$

$$54.95 \sim 55 = 1/\pi = E$$

$$54.95/116.164 = 1/2.11 = 0.473$$

$$1 - 0.211 = 1.11399 = 1/c^2 = M$$

$$M = 1/9$$

Ca #20

Si #14

Fe #26

C#6

$$66 \times 6.023 = 397.5 \approx 4 = M$$

$$Et = 4\pi = 1.2566 = 1/8 = 1/t$$

$$1/9 \times 7.2 \times 10^{-6} = 0.8 = t$$

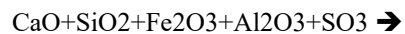
Steel is 10 x's stronger than Concrete.

$$10 \times [\text{Fe} + \text{Cl}] / [\text{Ca} + \text{Si}]$$

$$= 10 [0.98\% (55.845 + 2\% (12))] / [67\% (40.078) + 23\% (28.086)]$$

$$= 10 \times (=54.968/0.333)$$

$$= 1/6$$



	Concrete	Amu		Mass as Percent
67%	CaO	40.078 + 16	56.078	3.75
23%	SiO ₂	28.086 + 32	60.086	13.81
2%	Fe ₂ O ₃	2(55.845) + 48	159.69	3.1938
5%	Al ₂ O ₃	2(26.982) + 48	101.964	5.0982
3%	SO ₃	32.065 + 48	80.065	2.40195
100%				62.00

Table 1

$$M = \text{Ln } t$$

$$62 = \text{Ln } t$$

$$t = 492.4 \sim 5 = E \Rightarrow y = y'$$

$$6.2(6.023) = 373.426 \sim 1/267 = 1/\text{SF} = E$$

Now for the Concrete

$$E = e \cdot t$$

$$E = 1/t$$

$$T = et$$

$$\text{TE} = \text{PE} + \text{KE}$$

$$= M + t$$

$$E = \sqrt{2} = \sin t + \cos t = \text{Ln } t + et$$

$$\text{Ma} + \text{Mv} = \text{Ln } t + et$$

$$M(v + v) = M + et$$

$$M(2v) - M = et$$

$$M(2v-1) = et$$

$$v = s/t = 1 \text{ when } s = t \text{ } t = 1$$

$$M(2t-1)et$$

$$\text{My}' = E$$

$$y' = E/M = c^2$$

$$y = \int c^2 = c^3/6$$

$$= 3^3/6 = 4.5$$

$$\text{TE} = 1.5\text{Mc}^2 = 4.5$$

$$3\text{Mc}^2 = 3\text{PE}$$

$$= 3\text{CaO} \cdot \text{SiO}_2 =$$

$$= 3([40.078 + 16] \cdot 60.086 + 32)$$

$$= 444.492$$

$$444.492 \times 6.023 = 2.67 = \text{SF}$$

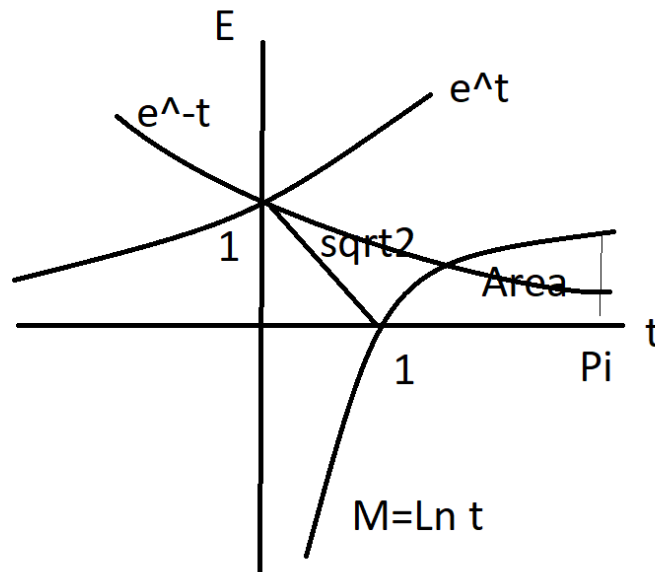


Figure 4

$$s = t; E = 1/\sin t = \csc t = c$$

$$TE = 1.5Mc = 1.5(4)c = 18 = t = KE$$

Structural Steel has a yield strength of 250 MPa, whereas steel-reinforced concrete has a compressive strength of 20 MPa. Steel essentially costs the same as reinforced concrete per megapascal. Steel = \$1387/m³ vs Reinforced concrete = \$135/m³. The concrete itself has zero tensile strength, but when we add rebar, the steel and concrete will carry the same load per dollar.

Steel performs better in earthquakes, which isn't always a worry for many projects. Concrete performs better in fire protection, which is always a concern. In many cases, structures are under 15 stories, so concrete isn't ruled out for that reason. Concrete is not as environmentally friendly since it can't really be recycled, including the rebar. Concrete requires onsite workman ship which is lower quality than a steel fabrication shop, which is environmentally controlled. Cement is manufactured as is steel. Some claim the Earth is running out of sand usable for concrete. I'm not sure why desert sand cannot be used. Iron is abundant in the Earth's crust. Steel can be recycled at the end of its life cycle. So, steel seems to be the better choice unless fire resistance is not a concern. Concrete uses up wood for formwork. The Twin Towers came down like a house of cards when the airplanes melted

the steel. Concrete buildings stand in war zones independently of the whole structure. Concrete is better for terrorism concerns. Concrete will always be used for foundations or things that touch the Earth. The steel would be preferred for the superstructure, except for hotels and residential buildings where fire resistance is paramount. Steel may be preferred for colder climates. In our case, in the comparison of the steel bridge vs the concrete bridge, the steel wins out. It is easier to refurbish. Prestressed concrete greatly outpaces cast-in-place structures. The girders are maintenance-free until the bridge deck needs to be replaced.

2. Conclusion

We have provided an engineering solution to the perennial problem of replacing a concrete bridge deck with concrete filled with metal filings instead of rebar. We have isolated the bridge deck from the steel substructure so that there is not an expansion problem. We have shown that the concrete must be saw cut every 52 feet. We have provided an analysis as to why concrete hardens as it does which was hitherto unknown [2].

References

1. Czernin, W. (1962). Cement Chemistry and Physics for Civil Engineers. Crosby Lockwood & Son London.
2. The Modulus of Elasticity of Steel - Is It 200 GPa? (mst.edu).

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