Crimean Bridge blast: Experts assess the damage

October 10 2022, by Colin Caprani and Sam Rigby

Kerch. Crimean Bridge. Credit: Alexxx1979/Wikimedia Commons, CC BY-SA

Early on Saturday, local time, a massive blast shook the Crimean Bridge (also known as the Kerch Bridge). Shocking images of the burnt rail bridge and collapsed road bridge have been shown around the world.

But Russia has moved quickly to return the bridge to operations, even though it appears to be significantly damaged.

Observers have been left wondering: what was the effect of the blast and fire on the surviving bridge elements, what repairs could be required, and when is it safe to re-open a bridge after such an event?

As experts in bridge safety and blast engineering, we have (some) answers.

The bridge

Built by Russia at a cost of some US$3.7 billion after the annexation of Crimea in 2014, the Crimean Bridge is Europe's longest, linking Russia to Crimea across the Kerch Strait.

The 19-kilometer connection is a vital artery for economic and social links, and since Russia's invasion of Ukraine it has also become a critical military asset for Russian supplies and telecommunications.

Despite the name, the Crimean Bridge is actually two bridges: one for road and one for rail. The road bridge is itself two independent bridge structures, while the rail bridge is a single bridge structure supporting two ballasted rail tracks.

Some general drawings and information on the bridge are available online.

The attack

The attacked section lies between Tuzla Island and Kerch, Crimea, on an east-west heading, and is midway between the island and the main arch

span over the navigable waterway.

At this point the rail and road bridges are of a similar form of construction, known as a "composite slab orthotropic deck steel plate girder bridge," spanning about 64 meters. This means there is a 20 centimeter concrete slab cast onto flat steel plates, stiffened with steel ribs, all supported by about 3.2 meter deep steel plate girders.

It is important to know this because the effect of the blast and inferno, and the subsequent repair and likely safety of the structure is very sensitive to the form of construction.

The aftermath

The blast caused one span to rupture at its middle. The adjacent span on the Crimean side remained intact, but was pulled off its bearings and also collapsed into the sea. A third span on the Tuzla side remains standing, while the next span over fell off its far bearings.

It appears the girders are continuous over the piers, with expansion joints only every four spans. Just like picking up a table cloth in the middle, the massive vertical force due to the blast would pull in the ends of the continuous steel girders, popping them off their supports.

> #Satelliteimagery today at 11:01 AM local time of the aftermath of the explosion that damaged the #Crimea Bridge which connects the Crimean peninsula with the Russian mainland. Damage is apparent on the bridge span that carries vehicle traffic and the span that has a rail line. pic.twitter.com/2QbtE9dZ7C
>
> — Maxar Technologies (@Maxar) October 8, 2022

The blast ignited what is presumably fuel in a tanker train on the

adjacent rail bridge, causing an inferno that burned for at least an hour. Blazing fuel poured down over the southern side of the bridge, and was blown back in a northerly direction by the wind, exposing nearly all steel surfaces to the fire.

> Closer look at the collapsed road span of the Crimean bridge pic.twitter.com/ZW1OOAKdns
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> — OSINTtechnical (@Osinttechnical) October 8, 2022

What could have caused it?

There is much debate as to the cause of the explosion. It is clear it originated at the road bridge, and the blast started the fire on the fuel train on the nearby rail bridge. It is not clear whether it originated above the bridge deck, or below.

> Additional footage pic.twitter.com/w5ngstLp5m
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> — OSINTtechnical (@Osinttechnical) October 8, 2022

Video images show a semi-trailer truck on the bridge at the time, and another angle shows what may be a wave caused by the bow of a boat below the bridge. Either could plausibly have been the source of the explosion.

Just after the explosion, a lot of sparks are visible. This may indicate the use of thermite in the explosives, which burns at temperatures hot enough to damage steel and cause fires in surrounding flammable objects.

What are the structural effects?

There is a long history of bridge failures due to fire and blast damage. High temperatures can weaken both steel and concrete, while blast shockwaves can result in violent fractures.

While steel can bend under high load without breaking, and the surviving girders of the Crimean Bridge may still be usable, the blast has likely caused severe localized damage. To determine how much life is left in the surviving road bridge, investigators ought to conduct detailed inspections and metallurgical sampling.

The fuel fire is also likely to have weakened the girders on the rail bridge, as well as those on the road bridge (as they were on the windward side of the inferno). The concrete pier shows extensive burn marks too, and so the concrete will be weakened, and the reinforcement inside it more susceptible to corrosion over the longer term.

Can it be repaired?

Sections of the upper structure of the rail and road bridges can be replaced. There are floating cranes with sufficient capacity to lift in replacement pre-fabricated steelwork.

The road and rail concrete decks and fitments can then be reinstalled. Such work would of course render the bridge inoperable for an extended period.

Is the bridge safe?

In structural engineering, safety is not an either-or proposition. It is measured on a continuum known as the probability of failure, or more positively, the reliability index of a structure.

There are guidelines on acceptable levels of safety for different types of structure, and different costs of providing safety. Engineers design new bridges to standards that aim to provide a very, very small probability of a failure occurring.

In assessing existing bridges for safety, engineers will aim for that same level of safety to be provided to the public.

For ordinary bridges, surrounded by a dense road network of alternative routes, there is no need to reduce the level of safety deemed acceptable. However, for key bridges such as the Crimean Bridge, it may be reasonable to accept a reduced level of safety when the costs associated with a disruption are very high.

These considerations are for normal civilian use. For military purposes, the levels of safety or risk to human life that are acceptable are dramatically different. The reasoning used in a normal civilian situation does not apply.

Where to from here?

The remaining road bridge has re-opened to car-only traffic. This may be reasonable, as the weight added by the cars is negligible compared to the weight of the bridge itself—and the political decision-making around acceptable levels of safety seems out of the ordinary.

Cranes have been shown lifting the fuel tanker wagon wreckage off the Crimea-bound rail line. It remains to be seen how the steel girders will perform under train travel. It is likely the trains will be instructed to go slow to reduce vibratory effects, and that wagons will not be fully-loaded.

Under normal circumstances, the blast and damage we have seen would

result in an extended closure and repair works. Clearly, however, the circumstances are far from normal.

Provided by The Conversation