

## "Italian Job" cliff-hanger solution: A solution based on the melting point and binding potential of the asphalt road surface

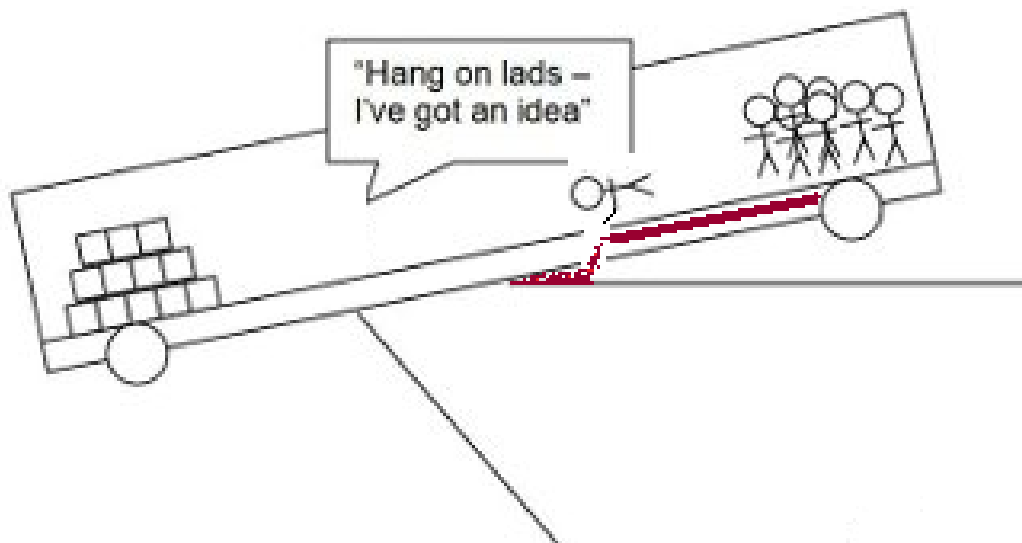
By edging his way down the bus past the fulcrum our hero (Charlie Croker) has established that the bus as it stands is finely balanced and cannot withstand further transfer of weight to the rear. Rather than try to overcome this physical reality our hero should utilise the chemical properties of the materials involved to save his team and the gold. This will be a challenge give the weight of the gold. The gold weights approx. 3000 Kg, based on the following calculation:

Value of gold (dollars)	4,000,000
Weight in troy ounces (value in 1969 : divide by 41.28)	96899
Weight in Kg (1 troy ounce - 0.031 Kg)	3004

The road in question (Ceresole Reale in the Alps) like many roads is surfaced with asphalt a composite material composed of mineral aggregates and a chemical 'binder'. The binder bitumen is a mixture of organic liquids that are highly viscous, black, sticky and composed primarily of highly condensed polycyclic aromatic hydrocarbons. Bitumen was chosen for its viscous nature, which allows the surface to sustain significant plastic deformation without loss of integrity. A disadvantage of bitumen is that the surface tends to become soft and sticky in warmer weather. Indeed bitumen is used in the building trade as a reliable viscoelastic adhesive. A characteristic that our hero can turn to his advantage.

### Thirty minutes to implement the plan

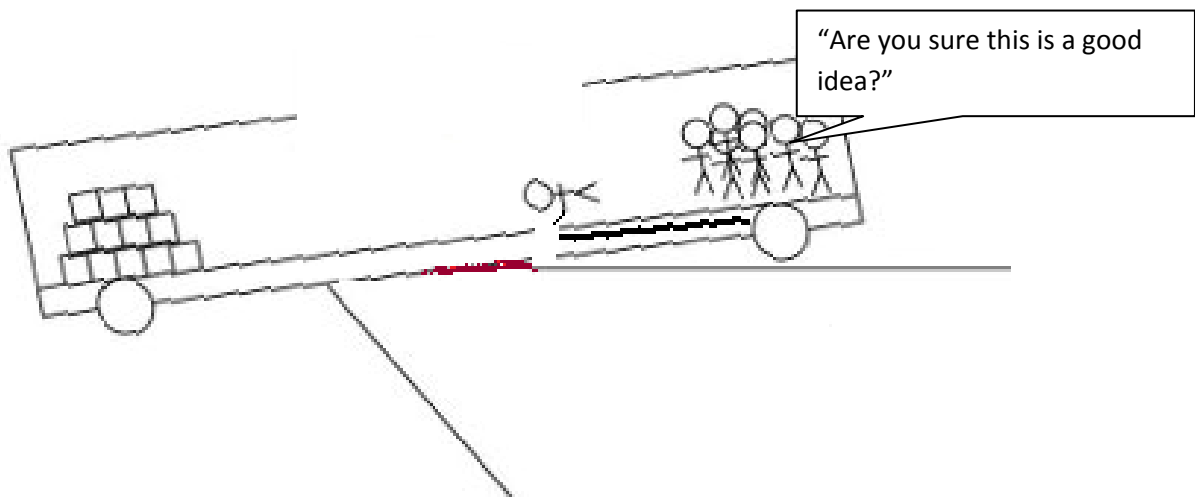
Our hero must return to the front of the bus obtain a cigarette lighter and a cutting implement (both of which appear in the film). Under the instruction of the mechanic (Franky G) he must locate the fuel pipe and cut it open allowing a controlled amount of petrol to fall on the road under the bus. To achieve this our hero will need to seal the pipe on one end and siphon the petrol from the other. Given the elevation the petrol in the front portion of the bus should flow directly to the point where the bus is in contact with the asphalt (see diagram 1).



**Diagram 1 Showing the flow of petrol ( in red) from the fuel pipe onto the asphalt road surface.**

Our hero can then ignite the petrol on the road (taking care to cover the pipe ends to avoid igniting the remaining petrol). The petrol with an ignition temperature of 257 °C and a heat of combustion of about 11.5 Kilocalories per gram will rapidly melt the asphalt without harming the gold or the steel frame of the bus. Bitumen melts at low temperatures typically reaching a semi-crystalline gel phase at 95 -150 °C and does not ignite until 538 °C. The melting point of gold is 1064.43 °C and steel is even higher. Our hero will have to cover his mouth during the process as bitumen typically contains sulfur and several heavy metals such as nickel, vanadium, lead, chromium, mercury and other toxic elements.

As the asphalt melts the bus will sink, increasing the surface area in contact with the asphalt. Once in place the base of the bus will block out oxygen prevent the petrol from burning and allowing the asphalt to cool, thus binding the base of the bus to the road surface. The process can be repeated as necessary. By managing the flow of the petrol our hero should be able to progressively adhere more and more of the bus to the road surface (see diagram 2).



**Diagram 2. Showing the layer of melted bitumen (in red) binding the surface of the bus to the road.**

Bitumen adhesion occurs primarily through hydrogen bonds, with the polar components in the bitumen reacting with electrochemically active sites on the steel surface. According to the Shell Bitumen Handbook (p185), Instron analysis shows a typical asphalt can retain its aggregate up to stress of 2 Newtons . mm<sup>2</sup>. Assuming the bond with the steel is comparable and that the surface in contact with the asphalt covers 1 m<sup>2</sup>. Then the total resistance will be:

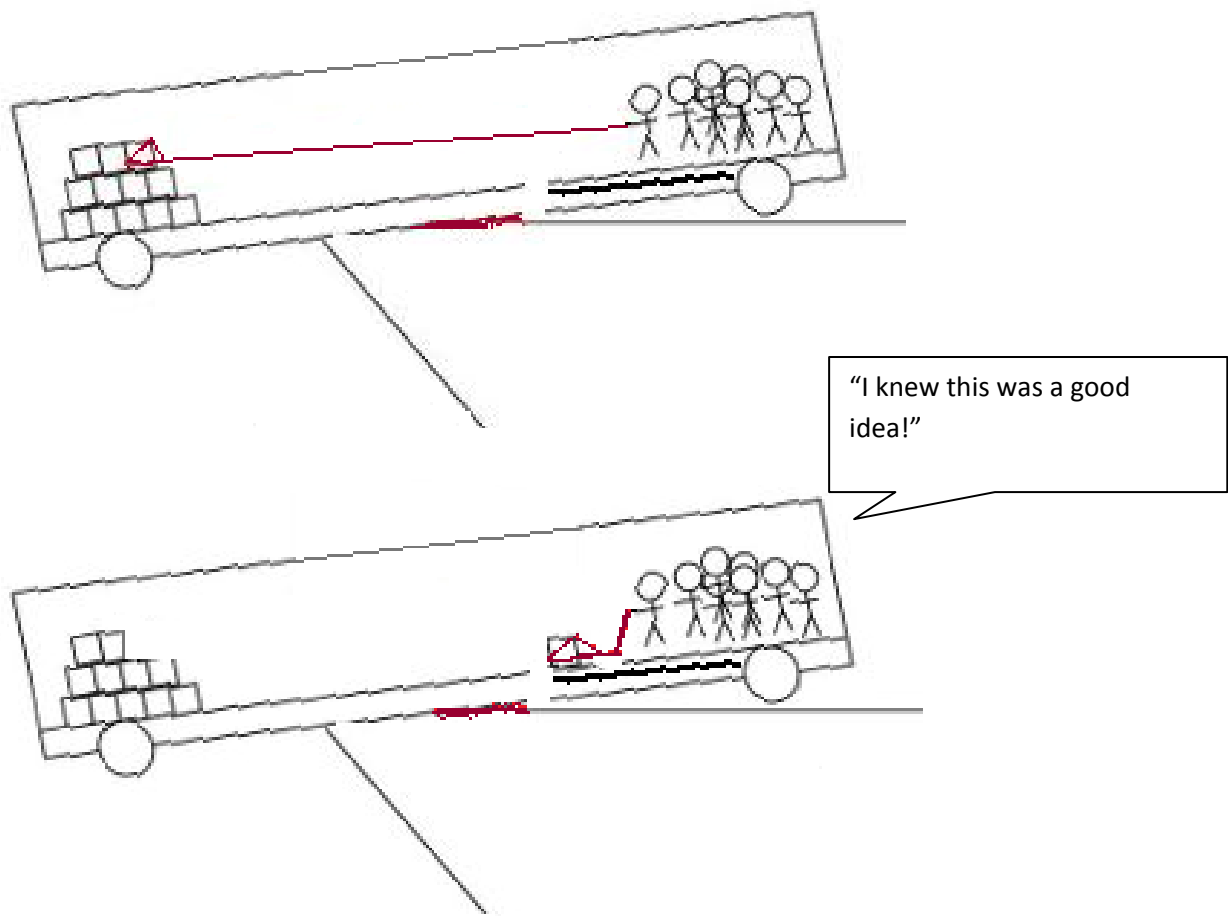
$$2 \text{ N} \cdot \text{mm}^2 \times 1,000,000 \text{ mm}^2 \text{ surface} = 2,000,000 \text{ N in total.}$$

Using Newtons second law, we know that 9.8 Newtons is equivalent to 1 kg . m<sup>2</sup> under typical gravitational conditions at the earth's surface. Therefore the total surface will withstand a force of:

$$2,000,000 / 9.8 = 204081.6 \text{ Kg.}$$

204,082 Kg is more than enough to withstand the full 3000 Kg weight of the gold (although the weight of the bus and the contribution of leverage should also be considered).

Once complete the load bearing capacity provided by the bitumen glue should allow our hero to begin transferring the gold to the front of the bus - either manually or perhaps more prudently using indirect means (e.g. by lassoing the small crates of gold with a rope fashioned from his colleges garments).



**Diagram 3. Showing our joyous crew transferring the gold to the front of the bus. Safe in the knowledge that the bus is firmly fixed to the road surface.**

Once a sufficient proportion of the gold is transferred to the front, the bus will right itself and victory will be won (see diagram 3).