DESIGN AND FABRICATION OF A GFRP ROAD PLATE

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SUMMARY

A robust lightweight GFRP plate was developed for temporary hole cover during road works. The sandwich structure, made by vacuum assisted wet layup was validated by FEM analysis and load testing to rupture before issuing to road works teams. Main objective was man handling by one or two men avoiding mechanized aid.

Keywords: GFRP, sandwich, road plate

CONTEXT

As a direct result of a EU directive concerning potable water and the necessity of renovating urban water distribution networks by eliminating lead piping; a considerable campaign of works is underway in the Paris area. The SRBG Company, a subsidiary of Eurovia and specialist in this type of work is playing an active role in a scheme that will last several years. In view of the constraints of this particular site work and the need to minimise public discomfort SRBG has been looking at ways to reduce on-site times. One important blockage identified is the time required to remove and replace hole covers at the beginning and the end of each working day. Traditionally holes are protected by thick steel plates (12, 15, 20 or even 25 mm depending on the size of the hole) that require mechanical assistance to move them. With often 30 or more holes in an average suburban street one can easily imagine the time "lost" in these manœuvres.

The question was to know if it would be possible to have a standard light-weight plate that could replace steel and be handled by 2 (or occasionally 1) persons yet still give the necessary safety guarantees of a steel plate. A point in favour of the standard plate approach was the fact that the holes in the road for this type of work are also standard (800 x 800 mm).

As a result, SRBG contacted Magnytude, to come up with a technically and economically viable answer.

DESIGN APPROACH

The use of steel for hole covers hardly needs justifying and with its many in–built advantages any new solution would be difficult to find. The material is relatively cheap, exists in almost any size that can be subsequently cut on demand for particular applications and in the case of any damage incurred can be cut-up into smaller, useful pieces. It is durable and hard-wearing and eminently suited to the harsh conditions of the work-site and, importantly today, is easy to recycle. Nonetheless it is heavy and this is where composites can come in.

In the global context it clear that the candidate material would be GFRP in some form and that the field of application would have to be carefully circumscribed.

After discussions between SRBG, Magnytude and the technical and scientific services of Eurovia the following specification emerged as the target for the proposed new plate:

- The plate should be limited to a 1 200 mm square with fixing holes on each side and some provision for handling on at least two opposite sides.
- The hole to be covered would be a 800 mm square.
- The weight should be as close to 30 kg as possible.
- The service load should be 6.5 tonnes max which corrresponds to half the maximum axle rating on French roads.
- The deflection of the composite plate under maximum load should be as close to that of an average steel plate as possible.

DESIGN PHILOSOPHY

The accured experience of Magnytude in the field of industrial composites indicates that the design process should include the choice of a moulding technique from the outset. In fact the application would require quite a high performance from the GFRP material thus requiring a reliable technique capable of attaining fairly high glass content. The construction industry is not keen to envisage process development so our preference went for the tried-and-tested method of vacuum bagging which could easily be extended to vacuum infusion if product development warranted it.

In much the same way the combination of part stiffnes and light-weight suggested that some sort of sandwich construction was the only practical answer. However, in view of the high imposed service loads in terms of bending of the plate and the associated compression which would need large skin thickness it would be unlikely to have the usual ratios of skin/core thickness. Moreover the overall thickness of the plate should be minimised to avoid jolts to passing vehicles and undue dynamic loads on the road fixings.

Design work started on the basis of using a fairly bulky mat plus woven-roving complex that would give good mechanical properties with the low-technology moulding technique and the mat would naturally provide a good wear surface on the part.

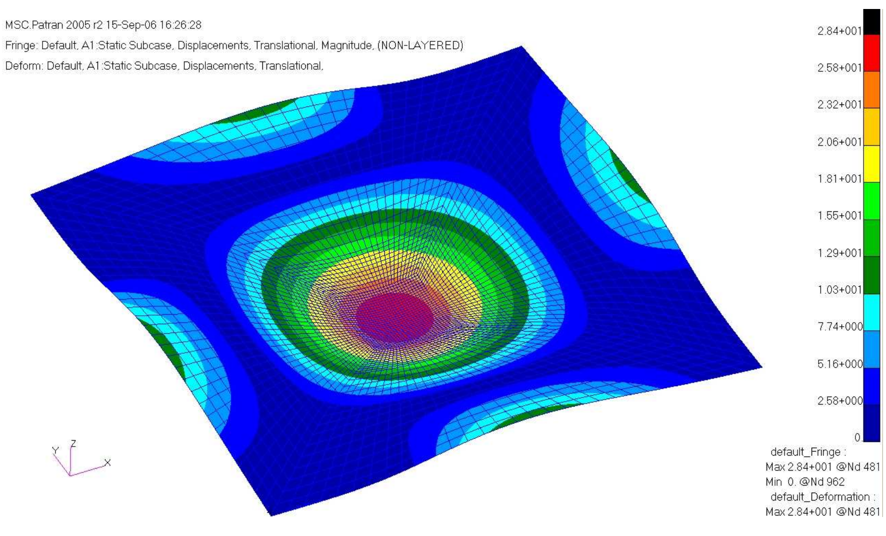

Figure 1: Computation result with MSC Nastran

Finite Element Analysis iterations were performed in the order of: solid plate of uniform thickness, solid plate with variable thickness, sandwich plate with constant thickness skins and finally a sandwich plate with variable thickness skins. The last-mentionned configuration gave the most promising results as was expected and it was on the basis of that the work was pursued.

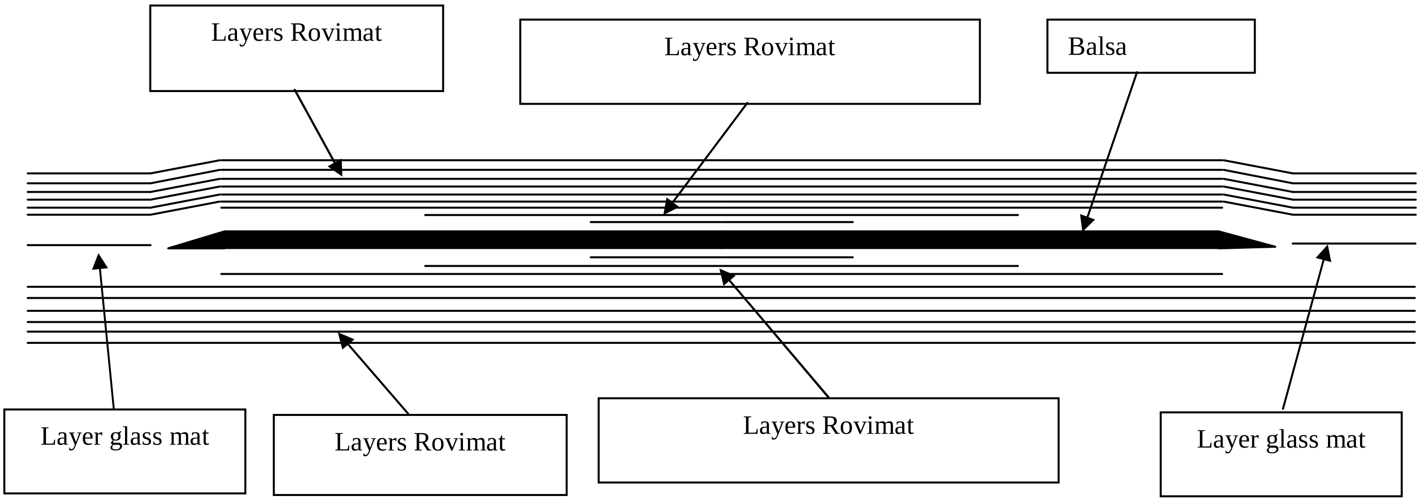

Figure 2: Sandwich plate detail

PROTOTYPE PRODUCTION

A simple mould was constructed using a 18 mm plywood base with a tubular steel frame surround giving a 1 200 x 1 200 mm working area which would eliminate the need to machine the plates after moulding. Regularly spaced holes bored on the inside faces of the frame enable the vacuum to be applied uniformly all around the plate from a single pumping outlet. The hollow frame also provides a convenient resin trap.Vacuum bagging consumables are employed in the usual way, however an absorption layer is placed on both sides of the plate to ensure that the barrier of the core material does not incur any problems with resin distribution throughout the plate thickness.

Isophtalic polyester resin was chosen for the matrix (no gel-coat) and a typical woven roving/mat complex was used for reinforcement; 300 g/m^2 mat + 800 g/m^2 WR.

A first plate was successfully produced using a PU-foam core. Although a carefully calculated quantity of resin was used and very little resin was pulled out of the composite during fabrication, final thickness was found to be less than theoretical (about 13 mm instead of 15 mm). This plate was then placed over a shallow 800 x 800 mm hole located at the entrance to a SRBG depot where mixed traffic would be passing throughout the day. It was held in place by 8 bolts screw-hammered into the asphalt and passing through cone-shaped bushings fitted into moulded holes in the plate. A fully laden lorry with a wheel positionned in the centre of the plate was used to define the initial deflection base by measuring the height of the upper surface with respect to the surrounding ground then it was left to survive as best it could. After a month new readings were taken which showed an increase in deflection under load. On investigation this was explained by a deterioration of the foam core material and the partial subsidence of the sides of the hole. It was reassuring to note that inspite of the considerable relative movement between the plate and the road surface there was virtually no wear on the underside. The upper side was also undamaged and had taken on a slight polish due to the traffic.

The main conclusion at this stage was that the application needed a better performing core material as the foam was slowly being reduced to powder by the repeated load cycles.

MODIFICATIONS TO THE PROTOTYPE

It was decided to substitute balsa core, noted for its high transversal compresssion strength, for the PU-foam. It would also ensure a better transfer of shear stresses between skins. In addition two slots were moulded into two opposing sides of the plate to provide handgrips but with no impact on performance.

Two plates were produced with the new core material, one reserved for mechanical testing and the other to replace the first one in order to continue on-site evaluation.

PROTOTYPE TESTING

Testing was carried out on a 50-tonnes load frame equipped with a hydraulic actuator and appropriate load cell. A square base made from rectangular tube was made with a 800 x 800mm passage to simulate a hole in the road. Rubber buffer strips between the road plate and the steel base to avoid local high compression spots they might have initiated a failure crack. In the same way rubber sheeting was piled under a central loading plate, 200 x 300 mm, to simulate the behaviour of tyre action.

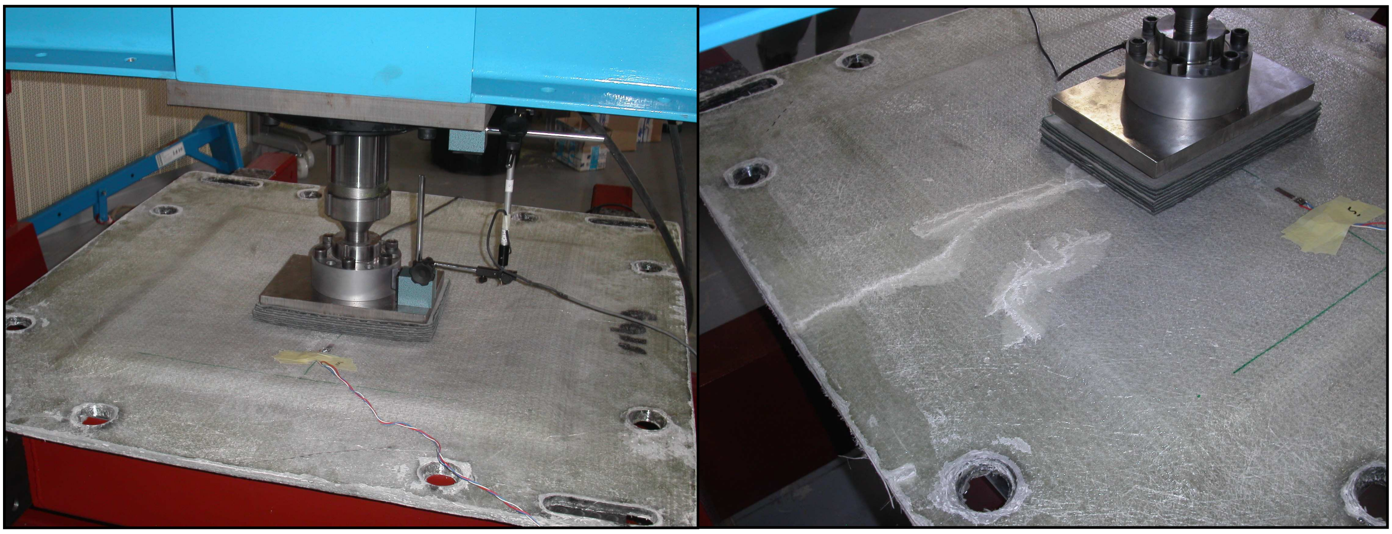

Figure 3: Characterization tests

The load plan consisted of a series of ratcheting load increases with pauses up to rupture. The whole test lasted only 20 mn. A series of strain gauges (X) were placed in order to measure principal strains throughout the test; the results are presented in FIGURE 4, and show the failure mode of the plate.

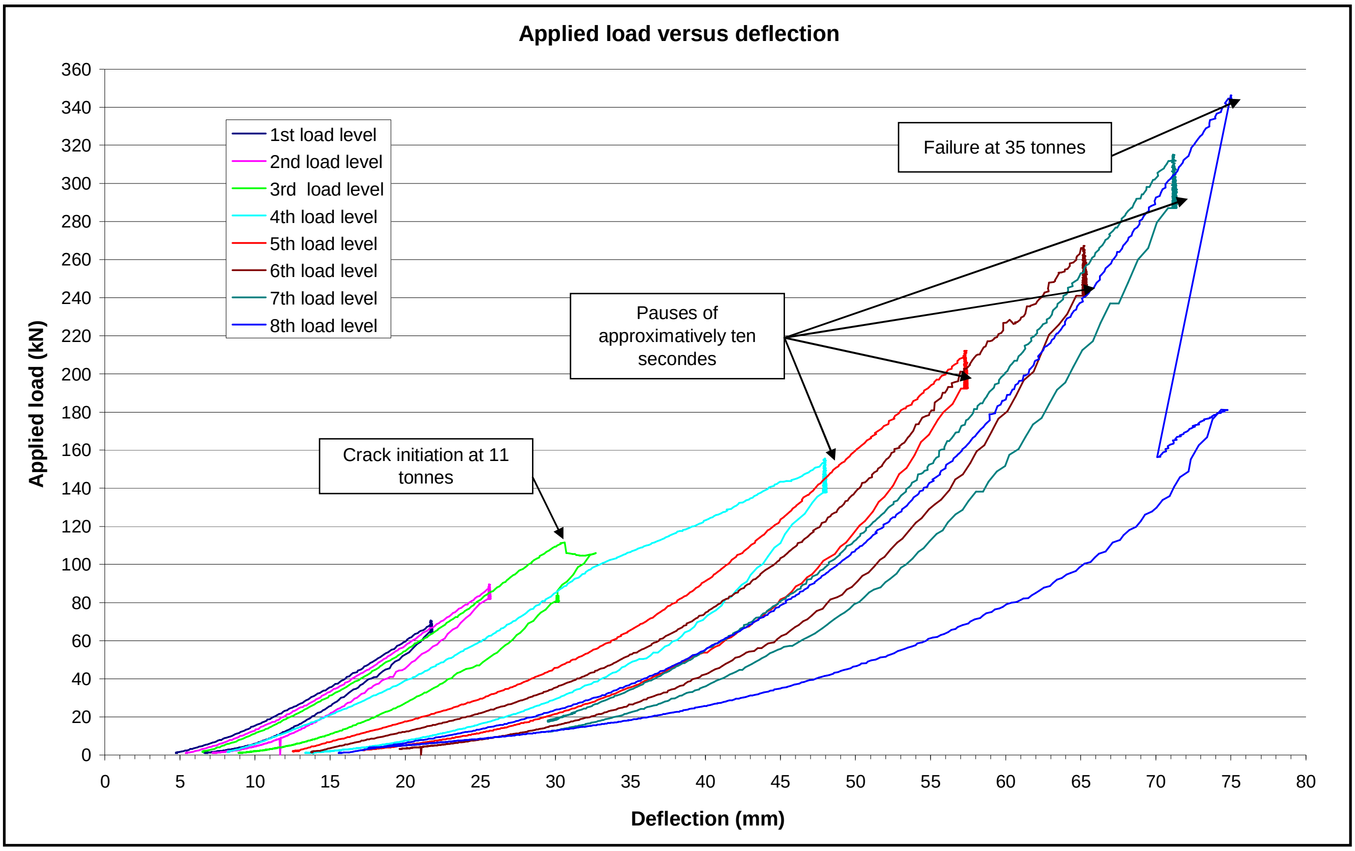

Figure 4: Stress/Strain curves

Behaviour is linear and reversible up to a load of 11 tonnes when some internal damage occurred. The sound emitted at this event suggested delamination between the upper skin and the core due to compressive buckling. However the part was able to carry load in an orderly manner up to 35 tonnes when the two skins (forming a 200 mm wide band at the periphery of the plate) separated and subsequently buckled and failed locally in bending.

In re-running the test it was established that even a damaged plate retained a substantial residual strength that would enable it to continue to be seviceable at the design load and present no real danger to traffic.

This encouraging result lead to SRBG ordering a small production series of 15 identical plates to be allocated to various work teams already on site and deciding that certain selected plates would be tested at regular intervals by Magnytude to monitor the load/deflection curves. At the same time a French patent was obtained.

Figure 5: Use of composite plate

CONCLUSION

A working version of a hole cover in GFRP has been quickly developped in response to a particular and urgent need. We were able to meet the need and although the plate (cover) was slightly overweight compared to the initial specification but, it is still easily handled by one man. The application meant that there was no need to consider such effects as fatigue strength, creep failure or weathering.

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