NUMERICAL SIMULATION OF STRESS AND DISPLACEMENT BEHAVIOR OF TRC-STRENGTHENED FRP-REINFORCED CORAL CONCRETE PANELS UNDER BLAST LOADING

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Abstract

This article presents a numerical simulation of the stress and displacement responses of coral aggregate concrete (CAC) slabs reinforced with glass fibre-reinforced polymer (GFRP) bars and externally strengthened with textile-reinforced concrete (TRC) under blast loading conditions. The panel consists of a B22.5-grade coral concrete core (equivalent to C35/45), combined with a surface TRC layer composed of a Sigratex Grid 350 carbon textile embedded in high-strength fine-grained concrete (grade M600). The integration of GFRP, TRC, and CAC offers advantages in terms of corrosion resistance, utilisation of locally available marine aggregates, and enhanced dynamic load resistance, making it a promising solution for coastal and island infrastructure subjected to blast effects. The simulation results demonstrate that the inclusion of the TRC layer significantly reduces both stress concentration and peak displacement at the panel's centre. Moreover, it contributes to the confinement of localised damage zones caused by the propagation of blast-induced shock waves. This study provides valuable insights into the potential application of TRC-strengthened CAC structures in marine, military, and defence-related constructions.

Keywords: Coral aggregate concrete; FRP-reinforced concrete; TRC-strengthened FRP-reinforced concrete panel; blast loading; numerical simulation.

1. Introduction

Coral aggregate concrete (CAC) has recently attracted increasing attention due to its potential applicability in coastal, island, and marine infrastructure. Utilising dead coral as coarse aggregate not only contributes to environmental sustainability but also significantly reduces transportation costs for remote areas where conventional construction materials are difficult to access. However, due to its porous structure and limited mechanical performance, CAC generally exhibits lower compressive strength and inferior corrosion resistance compared to conventional concrete. These limitations hinder its broader application unless effective reinforcement strategies are adopted [1].

One promising solution to enhance the mechanical behaviour of CAC is the incorporation of textile-reinforced concrete (TRC) as a surface strengthening layer. TRC

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is an advanced composite material that integrates high-strength fine-grained concrete with fibre textiles (typically glass or carbon). This composite offers superior crack control, enhanced energy absorption, and excellent performance under dynamic loads such as blast and impact [2], [3]. Additionally, TRC has been shown to reduce fragmentation upon failure, which is particularly advantageous for structures requiring high levels of safety [2], [3].

In parallel, fibre-reinforced polymer (FRP) materials, especially glass fibre-reinforced polymer (GFRP), have been recognised as a viable replacement for conventional steel reinforcement in marine environments due to their lightweight nature, high tensile strength, and superior corrosion resistance. Replacing steel with FRP in reinforced concrete has been proven to extend service life and reduce maintenance costs, particularly in chloride-rich conditions [4]-[6].

The combination of coral concrete, FRP reinforcement, and TRC strengthening forms a hybrid material system that is lightweight, durable, and well-suited for harsh coastal and island climates. In this configuration, FRP serves as the main load-carrying component in tension, while TRC provides supplemental reinforcement to control cracking, distribute stress, and enhance dynamic load resistance [4]. These synergistic advantages make the hybrid system highly promising for military infrastructure, coastal facilities, and long-term service applications in demanding environments.

Previous studies have shown that incorporating advanced materials such as UHPC reinforced with FRP [7], fibre-reinforced concrete (FRC) [8], and combined FRP-TRC systems [2], [3], [9] can significantly improve dynamic resistance. TRC plays a critical role in enhancing ductility, limiting the extent of damage, and managing crack propagation, whereas FRP offers a corrosion-resistant alternative to steel. Nevertheless, the widespread application of FRP remains constrained by cost, and numerical investigations on FRP-reinforced CAC slabs strengthened with TRC are still limited [7], [9].

In particular, investigating TRC-strengthened FRP-reinforced CAC slabs under blast loading remains a relatively novel approach. Numerical simulation of such systems poses challenges due to the nonlinear behaviour of materials, interlayer interactions, and complex boundary conditions. However, prior research on TRC-strengthened concrete elements suggests that with properly defined interface models, the TRC layer can significantly enhance load-bearing capacity, mitigate cracking, and improve the overall dynamic response of the structure [10], [11].

Although previous studies have primarily focused on FRP as the load-bearing reinforcement for concrete slabs or on TRC as strengthening solutions for reinforced concrete slabs, the synergistic interaction between TRC and FRP-reinforced coral

aggregate concrete (CAC) slabs has not yet been systematically investigated. In addition, a further novelty of this study is the replacement of conventional concrete with coral concrete. To address this research gap, the present study conducts one of the first numerical assessments of the extent to which TRC enhances the dynamic behaviour of FRP-reinforced coral concrete slabs under blast-induced shock waves. The study is carried out through finite element simulations in Abaqus, in which two models, with and without a TRC layer, are compared in terms of stress distribution and displacement response to quantify the strengthening effect of TRC under dynamic loading. The obtained results are expected to provide scientific insights and practical guidance for the design and application of coral concrete structural systems in both military and civilian constructions in coastal and island regions, where high durability and blast resistance are required.

2. Numerical simulation of TRC-strengthened FRP-reinforced coral concrete slabs under blast loading

2.1. Numerical model

The dynamic behaviour of reinforced concrete structures subjected to blast loading differs significantly from static loading, both in terms of reaction nature and damage mechanisms. This is a complex process influenced by many factors, such as material strength degradation, shock wave propagation, and the non-linear mechanical characteristics of the affected structure. In studies related to the mechanical effects of blast waves, some simplifying assumptions can be applied to simplify the calculation model. Specifically, the explosive charge is often assumed to detonate instantaneously, and in an air environment, atmospheric pressure can be neglected due to the very large difference between air pressure and the initial pressure of the explosion products. When the distance from the point of explosion to the structure is less than about 10-15 times the radius of the charge, the effect of the surrounding medium density can be considered negligible. However, at greater distances, air density begins to have a noticeable effect on the propagation of the shock wave, as the density of the explosion products gradually decreases as they move away from the centre of the explosion. The velocity of the moving explosion product particles upon ejection is an important parameter for accurately modelling the wave pressure acting on the structure's surface and predicting the corresponding damage level. According to the law of energy conservation, this velocity in the initial stage immediately after detonation can be determined by the formula:

$$u_0 = \sqrt{2.Q_0}, (\text{m/s}) \tag{1}$$

where Q_0 is the specific heat of the explosive (J/kg), u_0 is the velocity set along the normal direction to the explosive surface (m/s).

It is assumed that air behaves as an ideal gas. When the gas is moving at a velocity u_0 encounters an obstacle at a certain angle, it creates pressure acting on the obstacle's surface. The value of this pressure can be determined by the formula derived from the momentum conservation theorem:

$$p = p_{max} \left(1 - \frac{t}{\tau} \right)^{\nu-1} \tag{2}$$

where p_{max} is the maximum pressure at the point considered on the obstacle surface:

$$p_{max} = p_0 \left(\frac{r_0}{r} \right)^{\nu-1} \cos^2\alpha \tag{3}$$

α is the angle between the normal to the obstacle surface and the radius connecting the point under consideration to the initial explosion centre (Fig. 1), r_0 is the radius of the explosive charge; for a planar charge, the radius is ½ the thickness of the charge (m), r is the distance from the first symmetry centre to the point where density needs to be determined (m), p_0 is the pressure of the explosion products (N/m²), τ is the duration of load action on the research point (s), t is the time of action counted from the moment the first particle of the explosion products meets the point under consideration (s), ν is the degree index of the 1D flow (for a planar charge, the value is 1).
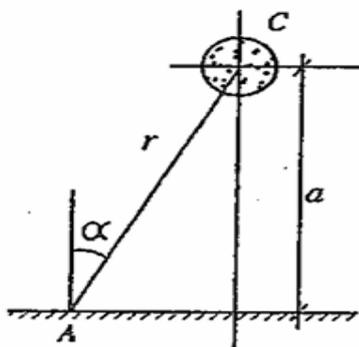

Fig. 1. Schematic layout of the explosive charge relative to the obstacle.

The JWL (Jones-Wilkins-Lee) model is one of the popular models for simulating the explosive behaviour of explosive materials. This model was developed to describe the interaction between explosive energy and the pressure generated during the

explosion process. The core of JWL is the equation of state for the explosive material, where pressure (P) is determined by the relationship with volume (V) and energy from the explosion products. The JWL equation of state is expressed in the form:

$$P = A\left(1 - \frac{\omega}{R_1 V}\right)e^{-R_1 V} + B\left(1 - \frac{\omega}{R_2 V}\right)e^{-R_2 V} + \frac{\omega E}{V} \tag{4}$$

where P is the generated pressure; A and B are model parameters dependent on the type of explosive material; V is the current volume; ω is the Grüneisen coefficient.

The JWL equation of state is often applied in modelling explosive materials, helping to describe the relationship between pressure, volume, and energy of explosion products. It is empirical and allows flexible calibration from experimental data during both the initial expansion phase and the expansion phase of the blast wave region. A, B, R_1, R_2, ω are in principle constants that need to be determined through experimental methods and data analysis. Abaqus software supports the JWL model directly and easily by declaring the JWL parameters in the material definition section. The research conducts a numerical simulation of a blast test on a FRP-reinforced concrete panel subjected to shock wave loading at close range. The experimental setup diagram and geometric shape of the panel are illustrated in Fig. 2.
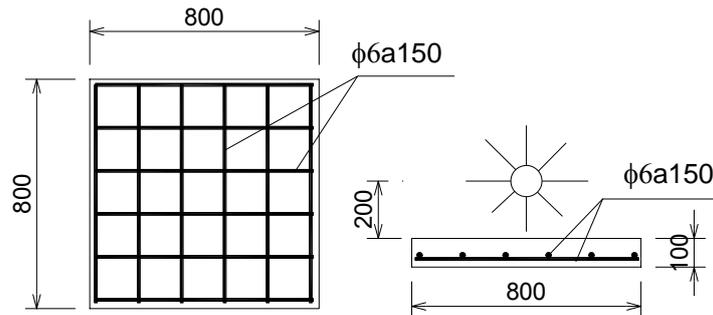

Fig. 2. FRP-reinforced coral concrete panel subjected to blast loading.

The FRP-reinforced concrete panel has dimensions length × width × thickness = 80 cm × 80 cm × 10 cm. Figure 2 illustrates the explosive charge setup relative to an obstacle reinforced with 6-mm-diameter FRP bars in two perpendicular directions, with a mesh spacing of 150 cm × 150 mm. For the sample with TRC reinforcement, the FRP-reinforced concrete core has dimensions length × width × thickness = 80 cm × 80 cm × 7 cm. A 3 cm thick TRC reinforcement layer is added on top, forming a total panel thickness of 10 cm. The TRC layer consists of Sigratex carbon fibre mesh arranged in the middle of the high-strength fine-grained concrete layer, with a mesh area of 50 cm × 80 cm, as shown in Fig. 3.

In the experiment, 50 g Trinitrotoluene (TNT) explosive blocks were used, with the distance from the explosion centre to the top surface of the panel set to 20 cm. The panel samples were supported in 2 cases: simply supported on 2 edges (Case 1) and simply supported on 4 edges (Case 2); each supported edge has dimensions length × width × height = 80 cm × 15 cm × 15 cm. The numerical simulation results are compared with experimental data to assess their accuracy.

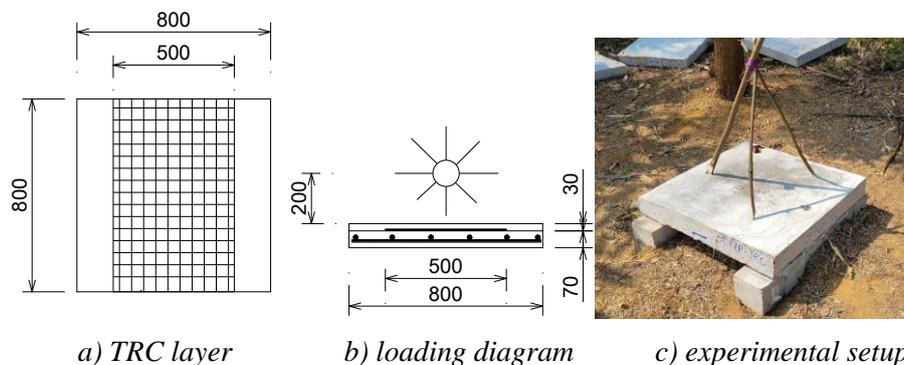*a) TRC layer*   *b) loading diagram*   *c) experimental setup*

Fig. 3. TRC-strengthened FRP-reinforced coral concrete panel subjected to blast loading.

2.2. Material model

* Concrete material

The concrete used in the study has a compressive strength equivalent to B22.5 strength class, with a bulk density ρ = 2.55 g/cm^3, and compressive strength f_c = 39.5 MPa, tensile strength f_t = 4.1 MPa and elastic modulus E = 29.54 GPa. The concrete mix design follows the findings reported in [13], and the detailed material parameters are presented in Tab. 1. To simulate the mechanical behaviour of coral concrete under shock-wave loading, the Concrete Damaged Plasticity (CDP) model was adopted, as it effectively captures the characteristic plastic failure mechanisms of concrete [14]. The specific parameters of coral concrete in the CDP model are referenced and calibrated based on the research of Esfahan *et al*., which was conducted for concrete with a strength class equivalent to B20.

* TRC reinforcement material

The TRC reinforcement layer is composed of Sika Grout 214-11 fine-grained concrete combined with Sigratex Grid 350 carbon textile mesh. Detailed mechanical properties of these two materials are presented in Tab. 1 and referenced from previous studies [9], [15].

In the numerical simulation model, the carbon fibres in the TRC mesh are defined using the HJC (Holmquist-Johnson-Cook) brittle failure model, assuming they carry tension, not compression, and behave linearly within the working range. The parameters

are shown in Tab. 1. This model choice aims to accurately reflect the actual mechanical properties of carbon fibres under dynamic loading conditions.

Tab. 1. Material parameters for two types of concrete and textile fibre

Material	f_c (MPa)	f_t (MPa)	E (MPa)	ν	γ (kg/m³)
Coral concrete B22.5	30.12	3.78	25740	0.20	2271
Fine aggregate concrete Sikagrout 214-11	74.6	15.2	32600	0.18	2400
Sigratex grid 350 textile	-	623	31940	0.22	1740

* FRP reinforcement material

The FRP reinforcement used in the study is made from glass fibres, moulded into 6 mm diameter round bars with ribs, suitable for the actual working conditions of concrete structures. In the numerical simulation, a linear elastic material model is applied for the FRP bars, reflecting the linear mechanical characteristics and dominant elastic behaviour of this material within the working range before failure. To simulate the debonding phenomenon between the FRP and the surrounding concrete layer, a debonding failure model is developed based on the work of Lorenzis and Tegola. This model incorporates the ratio between dynamic and static debonding loads to better reflect the actual behaviour of the reinforcement under rapid loading conditions. Specific input parameters for the FRP material and the debonding model are presented in Tab. 2 [15].

Tab. 2. Mechanical properties of GFRP bars

Symbol	Parameter	GFRP
p	Density	1.80 g/cm³
E_a	Elastic modulus along the longitudinal direction	30.9 GPa
X_C	Compressive strength along the longitudinal direction	480 MPa
X_T	Tensile strength along the longitudinal direction	983 MPa
Y_C	Compressive strength along the transverse direction	140 MPa
Y_T	Tensile strength along the transverse direction	40 MPa
S_C	Shear strength	70 MPa
v_s	Poisson's ratio	0.2

2.3. Numerical simulation

Through numerical simulation, the study analysed the mechanical behaviour of FRP-reinforced coral concrete panels reinforced with TRC when subjected to blast waves at close range. The simulation process was performed on a 3D model using ABAQUS software, where the Coupled Eulerian-Lagrangian (CEL) method was applied to accurately simulate the propagation of explosion products and the impact of shock waves on the panel structure

* The following modelling assumptions were accepted:

The bond between the TRC layer and the FRP-reinforced coral concrete is assumed to be perfect (perfect bond), with no slip occurring between the two material layers.

The FRP glass fibre reinforcement is considered an ideal linear-elastic material, perfectly bonded to the coral concrete.

The FRP-reinforced coral concrete panel behaves linearly elastic until failure.

Air is modelled as an ideal gas.

Blast loading is simulated using the CEL method instead of simpler models like Conwep, because close-range blast conditions require considering the direct interaction process between explosion products and the structure [16].

* The bonding model between the materials is established as follows:

Coral concrete & FRP reinforcement: Since the FRP reinforcement is cast together with the concrete using traditional construction methods, the bond between the two materials is simulated using the Embedded Region Constraint, where the coral concrete is the master and the FRP reinforcement is the slave. This bond allows the FRP bars to function like steel reinforcement in traditional concrete without relative slip. The panel structure and FRP reinforcement are simulated using the Lagrangian method.

Contact between the coral concrete and the TRC layer (Sika Grout 214-11) was modelled as a perfect bond, assuming no separation between the two materials. The simulation uses a Tie Constraint to ensure effective force transfer between the two layers.

For the carbon fibre textile mesh in the TRC layer, the textile fibres were positioned at the mid-depth of the Sika Grout 214-11 layer and modelled using the Embedded Region constraint, enabling the mesh to act integrally with the fine-grained concrete layer without local slip.

* Blast load model and boundary conditions:

Since the explosion occurs at a close distance, idealised models like Conwep Blast Load do not fully reflect the complex interaction process between explosion products and

the structure. Therefore, the Coupled Eulerian-Lagrangian (CEL) method is applied to directly simulate the explosion process and wave propagation in the surrounding air medium. The air in the simulation is set up with non-reflecting boundaries to limit reflection effects from the model boundaries. The support areas of the panel are fixed in displacement and deformation, simulating the boundary conditions from the actual experiment.

* 3D model parameters:

Two models are constructed corresponding to panels with and without TRC reinforcement (Figs. 4 and 5). The model structure includes:

Coral concrete: 8000 elements;

FRP reinforcement: 390 elements;

TRC mesh and fine-grained concrete: 2660 elements;

Main structural element size: 2 cm × 2 cm × 2 cm (ensuring calculation accuracy and simulation efficiency).

Explosive charge simulation: uses 8000 Eulerian elements, with each element size 1.5 mm × 1.5 mm × 1.5 mm to ensure accurate simulation of the expansion process and the impact of explosion products.

* Conduct a simulation for 2 cases of panels supported on 2 edges and 4 edges for 2 samples of FRP-reinforced coral concrete with and without TRC reinforcement.
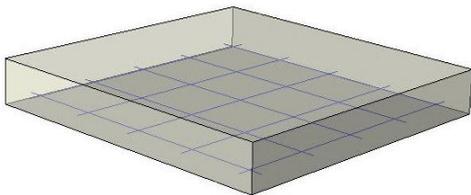

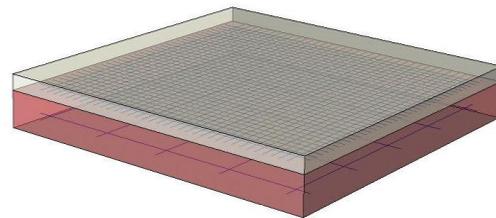*Fig. 4. FRP-reinforced coral concrete panel model using Abaqus software.*

Fig. 5. TRC-strengthened FRP-reinforced coral concrete panel model using Abaqus software.

2.4. Simulation results

• Case 1: 2-edge supported panel

Displacement: Displacement over time steps for FRP-reinforced coral concrete panels (abbreviated as panels) with and without TRC reinforcement subjected to blast wave loading are shown in Figs. 6a and 6b. The displacement comparison graph for the two panels is shown in Fig. 7.

In comparison with the experimental measurements (Fig. 8), the numerical simulations consistently predict higher displacement values. Specifically, the experimental and simulated displacements are 1.4 and 2.5 mm, respectively, for the

unstrengthened panel, and 1.05 and 1.17 mm for the TRC-strengthened panel. Despite the difference in absolute values, both methods exhibit a high degree of consistency in terms of overall behavioural trends and the relative performance between the two panel types, with the TRC-strengthened panel consistently demonstrating reduced deformation and displacement. This level of agreement suggests that the numerical model, although based on idealised assumptions, remains a reliable tool for evaluating structural behaviour. It is particularly valuable during the design, optimisation, and scaling stages, where full-scale experimental testing may be impractical due to economic or technical constraints.
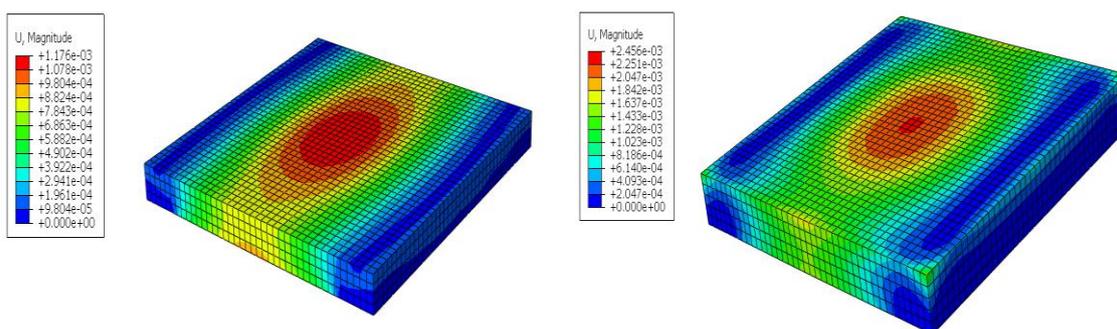

Fig. 6. Displacement at the centre of the panel:
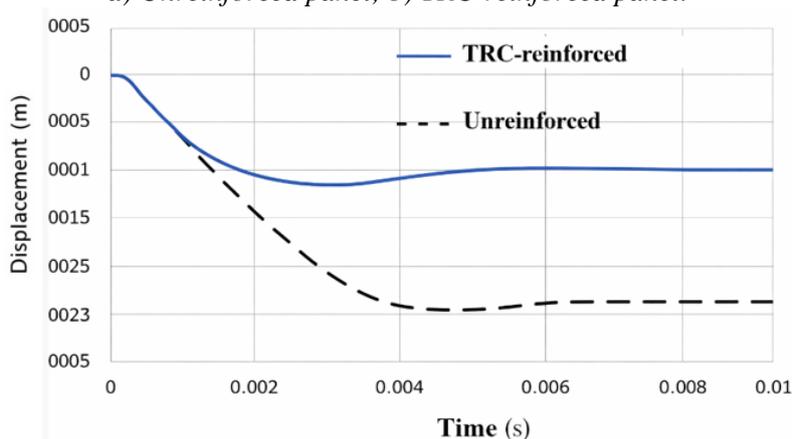*a) Unreinforced panel; b) TRC-reinforced panel.*

Fig. 7. Comparison of displacement at the centre of the underside
of TRC-reinforced and unreinforced panels.

From the numerical simulation results, it is observed that the maximum displacement of the TRC-strengthened panel is 1.17 mm, while the displacement of the unreinforced panel is 2.5 mm. Thus, with TRC and fine-grained concrete reinforcement, the displacement of the panel is reduced by about 53% compared to the unreinforced case. Simultaneously, observing the displacement-time graph of the unreinforced panel, the displacement increases, but the recovery is very small (about 0.3 mm); conversely,

the graph for the reinforced panel shows a larger recovery (about 0.7 mm) compared to the maximum displacement.
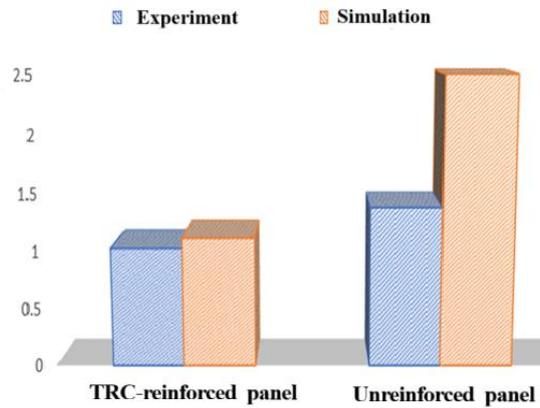

Fig. 8. Experimental vs. numerical displacement comparison.

Stress: The stress at the underside of FRP-reinforced coral concrete panels, with and without TRC reinforcement, under blast loading is shown in Figs. 9a and 9b. The stress comparison graph for the two panels is shown in Fig. 10.
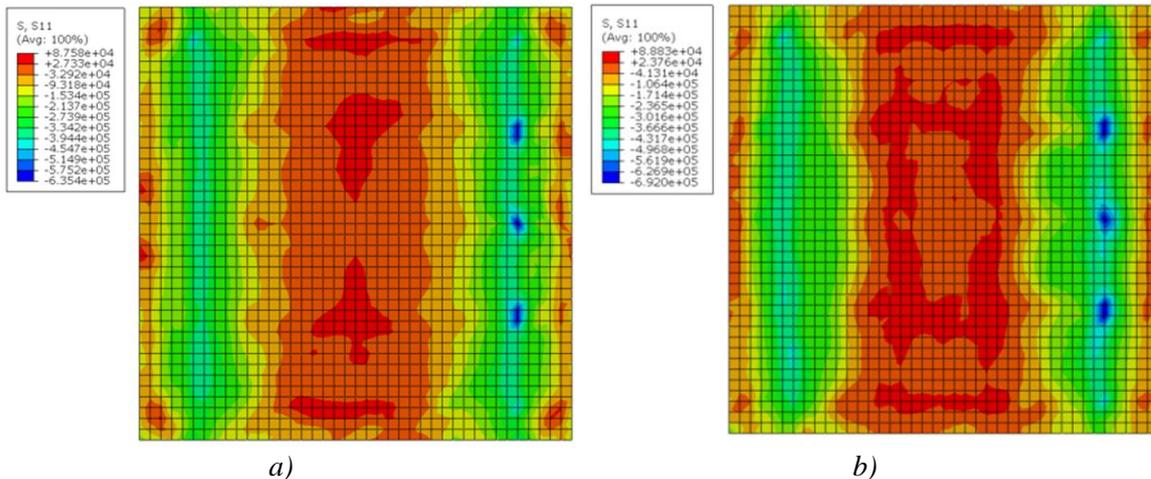

Fig. 9. Stress distribution on the underside of the panel under blast loading:
a) Unreinforced panel; b) TRC-reinforced panel

From the graph, it is observed that the maximum stress at the centre of the FRP reinforcement in the TRC-reinforced FRP-reinforced coral concrete panel is approximately 16.5 GPa. In contrast, in the unreinforced panel, it is approximately 27 GPa (stress reduction of about 40%). In addition, the stress response of the TRC-reinforced panel exhibits greater stability during the recovery phase compared with the unreinforced panel, consistent with the behaviour observed in the four-edge-supported configuration (Case 2).
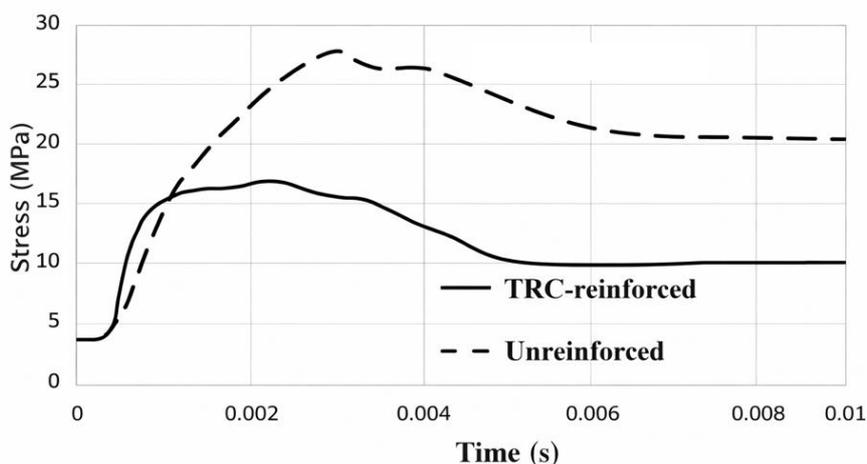
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Fig. 10. Comparison of stress in FRP reinforcement at the centre of the underside of TRC-reinforced and unreinforced panels.

• *Case 2: 4-edge supported panel*

Displacement: Displacement over time steps for FRP-reinforced coral concrete panels with and without TRC reinforcement subjected to blast wave loading are shown in Figs. 11a and 11b. The displacement comparison graph for the two panels is shown in Fig. 12.
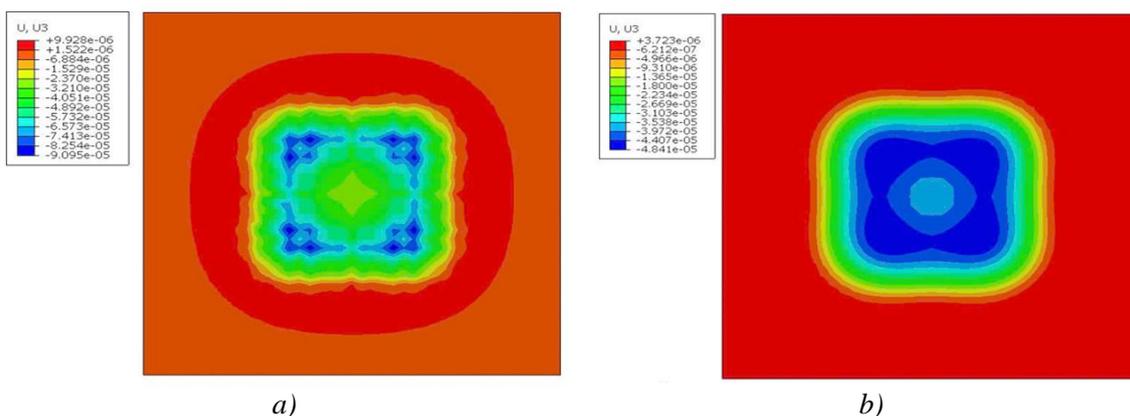

a)   b)

Fig. 11. Displacement distribution on the underside of the panel under blast loading: a) Unreinforced panel; b) TRC-reinforced panel.

From the graph, it is observed that the maximum displacement of the TRC-reinforced panel is 1.7 mm, while the displacement of the unreinforced panel is 3.84 mm. This clearly shows that with TRC and fine-grained concrete reinforcement, the displacement of the panel is reduced by more than 50% compared to the unreinforced case. Furthermore, observing the displacement-time graph of the unreinforced panel, the

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displacement increases, but there is no recovery. Conversely, the graph for the reinforced panel shows significant recovery compared to the maximum displacement (after recovery, the displacement is about 1 mm).
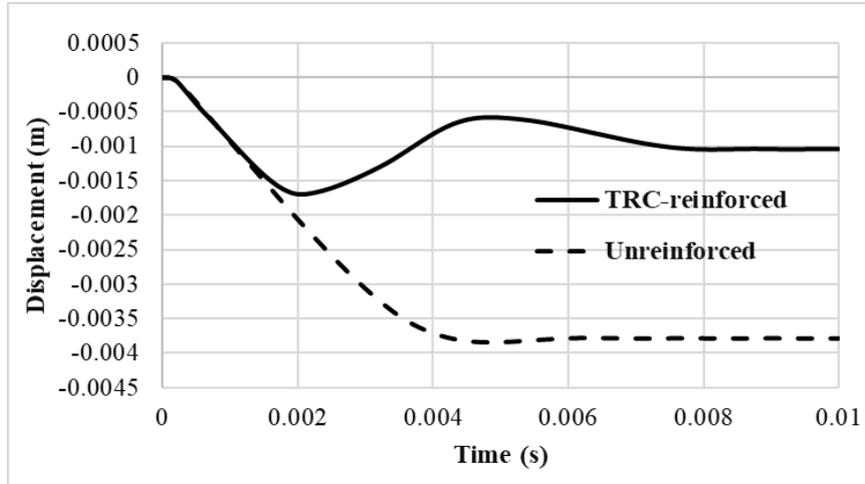

Fig. 12. Comparison of displacement at the centre of the underside of TRC-reinforced and unreinforced panels.

Stress: The stress at the centre of the underside of FRP-reinforced coral concrete panels with and without TRC reinforcement is shown in Figs. 13a and 13b. The stress comparison graph for the two panels is shown in Fig. 14.

From the graph, it is observed that the maximum stress at the centre of the FRP reinforcement in the TRC-reinforced FRP-reinforced coral concrete panel is approximately 38 GPa. In contrast, in the unreinforced panel, it is approximately 52 GPa (stress reduction of about 30%). Simultaneously, the stress graph of the TRC-reinforced panel shows clearer stability during the recovery phase than the unreinforced panel.

From the comparison graphs of stress for the two types of FRP-reinforced coral concrete panels, reinforced and unreinforced with TRC, in the two cases of 2-edge and 4-edge support, a common observation can be easily made:

- The displacement at the centre of both panels in both cases shows positive results regarding the effectiveness of the TRC system reinforcement, as the maximum displacement values are significantly reduced (reduced by about 50% for the reinforced panel). The elastic phase of the unreinforced and TRC-reinforced panels develops similarly. However, in the unreinforced panel, the recovery phase has a much smaller value than in the TRC-reinforced panel. From this, it can be assessed that significant plastic deformations occur in the unreinforced panel, and the reinforcement system has a clear effect in improving the flexural capacity of the panel.

- The stress in the FRP reinforcement of both panels in both cases also shows similar results, as the TRC system helps to distribute stress evenly over the panel surface, resulting in a much lower stress value for the TRC-reinforced panel compared to the unreinforced panel (about 30-40%). Furthermore, the stress graph at the FRP reinforcement of the TRC-reinforced panel shows clearer stability during the recovery phase. Thus, it can be seen that the reinforcement significantly increases the panel's stiffness when subjected to blast loading, thereby limiting the impact of blast waves on the structure and increasing its load-bearing capacity and durability.
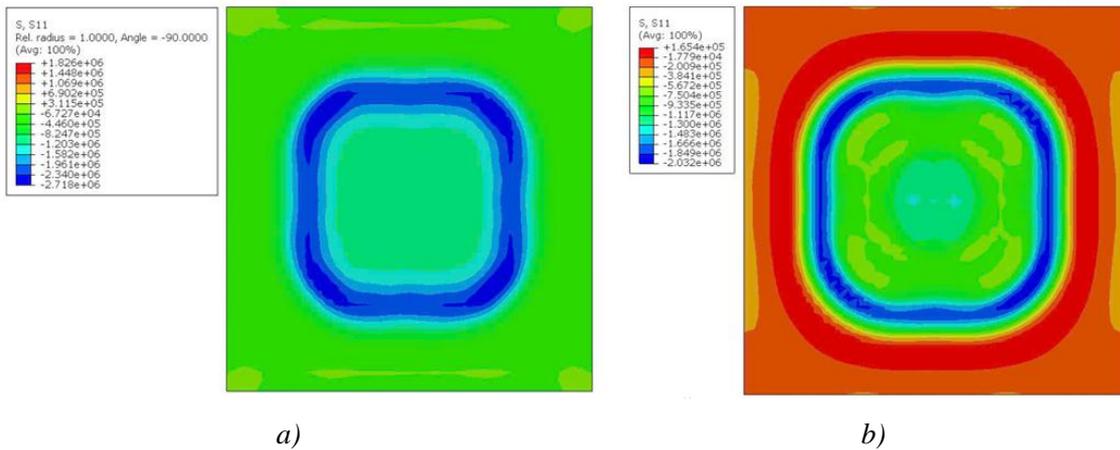

a)   *b)*

Fig. 13. Stress distribution on the underside of the panel under blast loading:
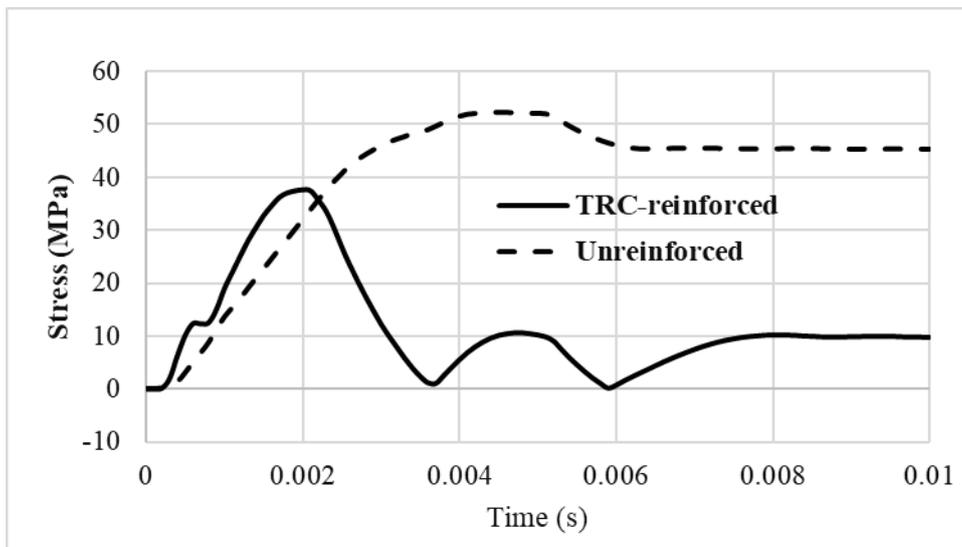*a) Unreinforced panel; b) TRC-reinforced panel.*

Fig. 14. Comparison of stress in FRP reinforcement at the centre of the underside
of TRC-reinforced and unreinforced panels.

- The reduction in displacement and peak stress observed in the TRC-strengthened panel can be attributed to several mechanisms: (1) the additional TRC layer with higher stiffness increases the overall stiffness of the panel; (2) the multi-cracking mechanism effectively controls crack development; and (3) energy is absorbed through fibre pull-out and friction rather than through brittle failure.

3. Conclusion

The study presents the results of numerical simulations of FRP-reinforced coral concrete panels, with and without TRC reinforcement, subjected to blast wave action in two cases: 4-edge-supported and 2-edge-supported. The stress and displacement results for both cases show that their development process is similar, with two stages: linear elastic and linear plastic. However, the displacement value of the TRC-strengthened FRP-reinforced panel is much smaller than that of the unreinforced panel. Simultaneously, the stress graphs of the reinforced and unreinforced panels also show similarity in the process of increasing blast wave loading, but the stress value of the reinforced panel is clearly reduced. This confirms the effectiveness of using the TRC layer for strengthening FRP-reinforced coral concrete panel structures. This behaviour is attributed to the increased structural stiffness provided by the TRC layer, effective crack control through multiple cracking, and energy dissipation via stretching and friction instead of brittle failure. The current study focuses on investigating a specific problem with a fixed explosive charge mass and distance. For future work, we will investigate parameters such as material type, explosive charge mass, and the distance between the explosive charge and the structure surface. In addition, the performance of each reinforcement technique individually (e.g., TRC-only, FRP-only) will be evaluated. Besides, the stress state, deformation, and crack development in the coral concrete panel will also be emphasised in subsequent studies. The results from this research will provide an important basis for improving the design and enhancing the performance of coral concrete, TRC-FRP reinforcement systems, compared to reinforced concrete in practical applications.

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NGHIÊN CỨU MÔ PHỎNG TRẠNG THÁI ỨNG SUẤT VÀ CHUYỂN VỊ CỦA TẤM BÊ TÔNG SAN HÔ CỐT FRP GIA CƯỜNG TRC CHỊU TẢI TRỌNG SÓNG NỔ

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Tóm tắt: Bài báo trình bày kết quả mô phỏng trạng thái ứng suất và chuyển vị của tấm bê tông san hô cốt sợi thủy tinh FRP, được gia cường bằng lớp bê tông cốt lưới dệt TRC dưới tác động của tải trọng sóng nổ. Tấm bê tông sử dụng bê tông san hô cấp độ bền B22,5 làm lớp lõi, kết hợp với lưới dệt Sigratex Grid 350 đặt trong lớp bê tông hạt mịn mác 600 làm lớp gia cường bề mặt. Việc kết hợp giữa vật liệu FRP, TRC và bê tông san hô không chỉ đáp ứng yêu cầu chống ăn mòn, tận dụng cốt liệu địa phương mà còn nâng cao khả năng chịu tải trọng động cho kết cấu. Đây là hướng nghiên cứu mới, có ý nghĩa thiết thực trong thiết kế và xây dựng công trình biển đảo phục vụ phát triển kinh tế và đảm bảo quốc phòng - an ninh. Kết quả mô phỏng cho thấy lớp TRC có hiệu quả rõ rệt trong việc giảm ứng suất và chuyển vị tại tâm tấm, đồng thời thu hẹp vùng phá hoại cục bộ khi chịu tác động của sóng xung kích.

Từ khóa: *Bê tông san hô; bê tông cốt FRP; tấm bê tông cốt FRP gia cường TRC; tải trọng sóng nổ; mô phỏng số.*

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