Response of Rubcrete Continuous Deep Beams under Sinusoidal Loads

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Abstract

Continuous deep beams (CDBs) are the most used members in constructions with highly exposing to different types of dynamic loads. It is well known that; the concrete is a brittle material and has a weak resistance to energy absorption. Using scrapped tire rubber enhances the concrete energy absorption for sustainability purposes. Timoshenko beam theory has been used to solve CDBs subjected to sinusoidal load and has been adopted for verification of numerical results of ANSYS APDL V.15.0. Seven concrete mixes have been simulated with different types and amounts of aggregate – rubber replacements. Several parameters have been studied like replacing type, percentages, shear span of beam to depth ratio (a/h) and load intensity. It was found that Timoshenko beam theory can be used for harmonic loading CDBs. Furthermore, replacement in general provided more ductility due to rubber elasticity property. Gravel replacement by 45% has the larger displacement values among the other types. Also, it has been noted that, the sensitive of concrete deep beams towards a/h ratio stills considerable for harmonic loads, i.e. minimizing the ratio leads to decrementing the deflection wave amplitudes.

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NOMENCLATURE

| Symbol | Meaning                          |
|--------|----------------------------------|
| a      | Beam shear span                  |
| b      | Beam width                       |
| c      | Damping factor                   |
| c²     | Correction factor                |
| E      | Concrete elastic modulus         |
| F(t)   | Applied harmonic load (point load) |
| f'c    | Concrete compressive strength    |
| G      | Shear modulus                    |
| I      | Moment of inertia of the section |
| K      | Beam stiffness                    |
| M      | Moment of beam                   |
| m      | Beam mass (Kg)                   |
| Q      | Beam shear                       |
| t      | Applied load time.               |
| w_c   | Concrete weight                  |
| W_o   | Natural frequency                |
| z     | Studied point after pending (or depth of beam) |

Greek Symbols

| Symbol | Meaning                          |
|--------|----------------------------------|
| ε_x   | Strain due to x-axis             |
| γ_x   | Shear strain due to z-x axes     |
| σ_x   | Concrete stress towards x-axis   |
| τ_x   | Shear stress toward z-x axes     |
| ψ     | Rotation angle                   |

Abbreviations

| Abbreviation | Meaning                        |
|--------------|--------------------------------|
| ACI          | American code institute        |
| CDBs         | Continuous deep beams          |
| FR           | Fine replacement                |
| GR           | Gravel replacement              |

1. INTRODUCTION

Concrete continuous deep beams (CDBs) are widely used members as a load distributor (due to its high rigidity and stiffness) in many constructions like bridges, high rise buildings, girders and tanks (as shown in Figure 1) [1-5]. American Concrete Institute (ACI 318-19 code) specified two conditions for considering the concrete beam as a deep, which are, the clear span to total depth ratio does not exceed 4, or the concentrated load lies within the distance 2h from the supporting face [6]. Concrete deep beams largely exposed to dynamic loads in different intensities and since the concrete is a brittle material, then researches nowadays towards to enhance the concrete
energy absorption to dynamic loads. The published researches confirmed that, replacing scrapped tire rubber by a percentage of aggregate (or even adding it into the mix) provides an excellent energy absorption (but decreases the mechanical properties of concrete) [7-16]. The enhancement in impact energy of rubberized concrete (rubcrete) mixes reaches to (138-185-300-396%) for 5, 10, 15, 20% volumetric sand replacement, While (150-204-326-426%) for the same percentages of volumetric gravel replacement [17]. Too many types of dynamic loads may the CDBs exposed to, such as impact, seismic and moving vehicles load.

The simple form of harmonic load may occur by unbalanced rotating machines in building. Also, it may cause by hydrodynamic pressure which is generated due to propeller at the stern of a ship or by inertial effects in reciprocating machinery, and this types is more complex. It is worth to mention that the harmonic wave may come in different types which are: fundamental wave, 3rd harmonic wave and the distorted wave.

CDBs may exposed to harmonic loads at bridges due to vehicle movement and that will cause sin or cosine wave load on it. Adding rubber into concrete mix leads mainly to develop the concrete energy absorption of the bridges and enhance the overall dynamic properties. It can be noted from the next section that, there is no cutting-edge studying results gives us an indication about the CDBs response under harmonic loading. So, this paper consists of three parts, the first one is derived in a theoretical solution for analyzing the CDBs under harmonic loads. While the second part involved using the theoretical solution for checking the accuracy of numerical analysis. The third part studied the effect of adding rubber to concrete mix on the behavior of CDBs using ANSYS V.15.0 software program.

2. LITERATURE REVIEW

Generally, the response of continuous concrete deep beams has not investigated by the past researches especially for rubcrete mixes while it can be found some researches about an empirical equations to solve the seismic loads [18-21]. Numerical solutions by different software programs is interested with the reinforced concrete beams [22]. There are also some theoretical studies about concrete beams which exposed to harmonic loads [23-27] and plate foundation with regarding to Winkler model of subgrade reaction [28-30]. Through literature [25], the cracked and un-cracked concrete cantilever beam was investigated under the effect of harmonic load. It was found that, crack existing near to the fixed end support of the cantilever beam decreases the Eigen frequency compared with crack existing away from the fixed support. Also, displacement will be more for cracked beam compared to healthy beam, because of reduction in stiffness. Chen and Song [27] introduced a theoretical study for solving deep beams which were exposing to distributed harmonic load. Finite element (FE) method (By Mathlab software [31]) has been used for certificating the theoretical solution. It was noticed an excellent matching between the derived equation and the FE results. Continuous deep beams have been studied in many articles with static load [32-35], repeated and cyclic loads on simply supported deep beams [34, 36], rubberized continuous deep beams were statically tested [37, 38], and rubberized deep beams under static loads [39]; but, there was no investigation under the effect of harmonic loads. Therefore, solving the CDBs under the effect of harmonic loads has not been studied yet. Furthermore, the effect of using rubcrete instead of concrete at constructions with highly exposed to dynamic loads vibrations was investigated.

3. METHODS

The problem discussed in this research consists of three solutions. The first two are theoretical analyses which depend on deriving new equations for simulating the deflection of concrete continuous deep beams under sinusoidal loads. These two methods relenting on the dynamic general equation as well as the Timoshenko beam analysis. While the third solution involved a simulation of concrete beam by ANSYS APDL software and comparing the obtained results with the theoretical results then investigates some case studies to get the full description of parameter effect on the CDBs. Figure 2 shows a block diagram of the complete work and Figure 3 shows the selected CDBs model.
3.1. Timoshenko Beam Solution

It is difficult to get a plastic theoretical solution for continuous deep beams under the effect of harmonic load. So, an elastic solution has been derived and adopted for verification the analytical solution (by ANSYS V.15.0). Timoshenko beam theory [22] has been used which satisfied the requirement of deep beams, which are:

- The plane section does not remain plane after bending.
- The normal to the neutral plane after bending will not remain normal to the neutral but have an additional rotation due to high transverse shear deformation.
- Neglecting normal strain along the width.

The deriving equation of deep beam deflection is given in Equation (1).

\[
\frac{d^4w}{dx^4} = \frac{q}{EI} - \frac{1}{c^2GA} \times \frac{d^2q}{dx^2}
\]  

(1)

Let \( w(m) = \sum_{m=1}^{\infty} \sin\left(\frac{2\pi m x}{l}\right) \) to satisfy the boundary conditions of continuous deep beam. Substitute in Equation (1), to get the final equation of CDB deflection under harmonic load (Equation (2))

\[
w_{at \ mid \ span} = 0.09752 \sin(w_n t)
\]  

(2)

3.2. Dynamic Equation Solution

In general, the structural members resist the dynamic load by its mass, stiffness and the magnitude of damping which depend on the material itself [31]. The damping ratio is ignored in most structural calculations for safety. For concrete, the damping factor does not exceed 6%. For solving the CDBs under sinusoidal loads, the dynamic equation response of structures is derived with ignoring the effect of deep beams, and as listed below (Equation (3))

\[my'' + cy' + ky = F(t)\]  

(3)

Applying the same details of beam at Figure 3, to get the time deflection equation for the given beam (Equation (4))

\[y = \frac{F(t)}{m} - \frac{w_n^2}{m}w_{n t}^2\]  

(4)

3.3. Numerical Simulation

Beam 188 element has been used for simulating the CDB in ANSYS APDL software [39] (As shown in Figure 4). After trying some meshing sizes, it was found that, 20 mm meshing length gives a good agreement with the theoretical model in such fast rendering time. External supports were selected to fixed while the internal was of single vertical reaction.

Seven concrete mixes were simulated depending on Topcu’s tested mixes [40], three percentages which are (15, 30, 45) % for sand and gravel replacement besides the ordinary conventional mix. All concrete properties were extracted from literature [40]. Compressive strength, tensile strength, concrete unit weight and young’s modulus for all mixes were summarized in Table 1. The input stress versus strain curve is shown in Figure 5. Young’s modulus was
4. RESULTS

4.1. Theoretical Results and Numerical Verification The validation between numerical and theoretical beam solutions were investigated as illustrated in Figure 6. It can be noted that, a good match in beam response between the numerical and the Timoshenko beam solutions with slight differences in the amplitude between them caused due to that, the nonlinear simulation gives more accurate results. Because it simulates the problem as it is in the nature in a matter accurate than the theoretical solutions. This nonlinear model has been considered to use for simulating a parametric study for rubcrete beams. While, the solution using the general dynamic equation also gives the same response but with less accurate due to ignoring the effect of deep beam effect. It causes an error in deflection magnitudes but the good point, it also gives the same response.

4.2. Rubberized CDBs Results Nonlinear solution was investigated to study the effect of sinusoidal harmonic load for seven beams. One beam was simulated without any rubber replacement in order to be the reference model, the first group was of three beams with 15, 30, 45% of gravel replacement (GR) and the second group was of the same percentages of fine aggregate replacement (FR). The results for the seven beams as illustrated in Figures 6 to 9, the displacement, velocity and acceleration are discussed. From Figure 6, it can be noted that, the beam of normal concrete (NC) deflects in the less magnitude than the other beam due to its high compressive strength and low elasticity. Beam GR45 showed the maximum values of displacement due to the sinusoidal load because of its low compressive strength, elastic property, and large ability to absorb energy. Also, the negative values of deflection were higher than the positive, which is refers to that the beam approaches from cracking, in another word, if all-deflection points were in negative zone, then the beam is fully cracked. For all beams, the time period does not change in contract with the amplitude.

Velocity of beams data are also presented in Figure 7. It can be noted that, the velocity wave formed as distorted wave (the latter is a combination between fundamental and the third harmonic wave). The same arrangement of amplitude appears at both velocity and acceleration responses, as shown in Figures 7 and 8.

4.3. Case Studies’ Results

4.3.1. a/h Ratio Influence The beam GR 45 showed the weakest model due to its low compressive strength and its high elasticity, so it has been considered for modelling the effect of changing a/h ratio because it represents the more dangerous case of rubcrete. Theoretically, the CDB behavior approaches to be flexural with a smaller a/h ratio, and its shear strength capacity increased linearly with a/h reduction [19]. The smaller a/h

Table 1 shows the details of elastic modulus values for all selected mixes. The analysis was displacement control with a tolerance factor equals 6%.

\[ E_c = 0.043 \times w_c^{1.5} \times \sqrt{f_c} \]  
(5)

considered using ACI 318-19 (Equation (5)) which is proportional to rubcrete weight (and as adopted for rubcrete mixes reported in literature [41]).

Figure 4. CDB modelling at ANSYS software

![Table 1](image)

**TABLE 1. Mechanical concrete properties**

| Mix  | \( w_c \) (Kg/m³) | \( f_c \) (MPa) | \( E_c \) (MPa) |
|------|------------------|----------------|---------------|
| NC   | 2300             | 23.48          | 22983         |
| G15  | 2220             | 16.18          | 18092         |
| G30  | 2140             | 12.62          | 15122         |
| G45  | 2010             | 9.9            | 12192         |
| S15  | 2220             | 24.22          | 22135         |
| S30  | 2140             | 19.7           | 18894         |
| S45  | 2010             | 14.77          | 14892         |

Figure 5. Inserted stress-strain curve into program
ratio shows minimum deformation capacity of CDB also ductility and beam load capacity [20, 21]. This fact was also noticed in the dynamic analysis of the rubcrete beams. The model of a/h=0.5 showed less displacement against the same load and rubcrete properties. The time durations of waves were still deposit but there was a visible difference in beams’ amplitudes for all the given deep beams due to a/h difference, as shown in Figure 9.

Figure 6. Verification of deflection by theoretical and analytical solutions

Figure 7. Rubcrete CDB deflections

Figure 8. Velocity of beams under sinusoidal loading (mm/s)
But in case of using a shallow beam (a/d=3), the velocity and acceleration amplitudes and periods changed (Figures 10 and 11). The time periods shift to the left with staying on the overall general wave shape. While the deflection (Figure 9) of shallow beam still keeps the periods and the overall general wave shape but with a significant large displacement comparing with the deep beams due to its higher bending capacity.

4. 3. 2. Load Intensity

The specimen GR45 was selected to study the influence of incrementing load intensity. The original selected load was doubled, tripled, quadruple and quintuple. It can be seen that, the relatively low loads vibrate the beam about the original zero displacement axis but the higher ((300 and 400) × sin \( W_n t \)) the same wave shape occurred with high negative displacement only. Quintuple load forced the rubcrete model to a plastic flow. Also, from curves in Figure 12, it can be concluded that, the vibration amplitude of rubcrete CDBs depends in the first degree on a/h ratio, beams’ natural frequency and the load intensity. The last conclusion also matched with literature discussions.

The higher displacement occurred when quadrupling the load, the beam deflects more by 80%, and 19.8% comparing with literature. Figures (13-18) shows the stress versus time for CDBs. It can be noting that, the stress waves gets bigger when increasing harmonic load intensity on beams.
Figure 11. Velocity of CDBs of different beams depth

Figure 12. Acceleration of CDBs of different depths (\(\text{mm/s}^2\))

Figure 13. Effect of load increment on CDB deflection response
5. DISCUSSION

CDBs may be exposed to harmonic loads due to many reasons like vehicle movement on bridges. The solution of CDBs under sinusoidal load and the behaviour of it has not been discovered yet. Timoshenko beam theory was used to discover the behaviour and finding the deflection response along beams. It provided the best match when comparing with the numerical solution. Concrete is a weak material against energy absorption. So, adding rubber for the mix enhances the dynamic properties. Timoshenko beam theory can be used for harmonic load with a significant degree of exact to the elastic response of CDBs. Also, solving the beam using the general dynamic equations gives a correct estimation for the beam response but an error value of displacement due to ignoring the deep beam effect so it is unfavoured to be used in CDBs analysis. From the numerical analysis, it was found that, Beam element 188 (in spite of its nonlinearity and it is a 2D model) offers a great degree of validation and the exactly same response with the theoretical method. It was found that, the replacement causes a large deflection capacity under the same load. That means the rubberized beam is more flexible against load. Generally, replacing rubber by aggregate leads to an increase in energy absorption and therefore enhanced the beam resistance for dynamic loading.

6. CONCLUSIONS AND FUTURE WORK

From the results, it can be concluded that, using rubber in concrete beams rises the beam deflection and enhances the ductility of beam against dynamic loads. Knowing that,
replacing rubber of a coarse aggregate provides more energy absorption than that of the same percentage of fine aggregate replacement. The sensitivity of concrete deep beams towards a/h ratio is still considerable for harmonic loads, i.e., minimizing the ratio leads to decrementing the deflection wave amplitudes. It was also found that, higher load vibration intensity produces larger displacement amounts, and excessive loads may cause a plastic flow. Furthermore, the vibration amplitude of rubcrete CDBs depends mainly on a/h ratio, beams natural frequency and the load intensity. It is recommended in the future to study the nonlinear theoretical analysis of CDBs under the effect of dynamic loads to find the beam capacity under such conditions.

7. REFERENCES

1. Rogowsky, D.M., MacGregor, J.G. and Ong, S.Y., "Tests of reinforced concrete deep beams", (1983).
2. Salman, W.D., "Nonlinear behavior of reinforced concrete continuous deep beam", International Journal of Engineering Research & Technology, Vol. 4, (2015), 2278-2281, doi: 10.17577/ijertv4is040460.
3. Abdul-Razzag, K.S., Jalil, A.M. and Dawood, A.A., "Reinforced concrete continuous deep beams under the effect of different parameters", in AIP Conference Proceedings, AIP Publishing LLC. Vol. 2213, No. 1, (2020), 020127.
4. 426, J.A.-A.C., "Shear strength of reinforced concrete members (aci 426-74)", in Proceedings ASCE. Vol. 99, No. ST6, (1973), 1148-1157.
5. Khatab, M.A., Ashour, A.F., Sheehan, T. and Lam, D., "Experimental investigation on continuous reinforced scc deep beams and comparisons with code provisions and models", Engineering Structures, Vol. 131, (2017), 264-274, doi: 10.1016/j.engstruct.2016.11.005.
6. Qaedi, H., "Desain modifikasi skrutt gedung kampus iii unim aman bonjol padang menggunakan metode beton pracetak dengan sambubungan basa berdasarkan aci 318m-19", Institut Teknologi Sepuluh Nopember, (2021).
7. Khan, S. and Singh, A., "Behavior of crumb rubber concrete", International Journal of Research in Engineering, Vol. 8, (2018), 86-92, doi: https://www.researchgate.net/publication/333044437_Behavior_of_Crumb_Rubber_Concrete.
8. Shah, S., Shrestha, S., Maharjan, S., Karki, N. and Shrestha, R., "Evaluation of performance of rubber concrete", in Proceedings of IOE Graduate Conference. Vol. 6, (2019), 599-603.
9. Raj, A., Nagarajan, P. and Shashikala, A., "Behaviour of fibre-reinforced crubcrete beams subjected to impact loading", Journal of the Institution of Engineers (India): Series A, Vol. 101, No. 4, (2020), 597-617, doi: 10.1007/s40030-020-00470-4.
10. Najim, K.B. and Hall, M.R., "Mechanical and dynamic properties of self-compacting crumb rubber modified concrete", Construction and Building Materials, Vol. 27, No. 1, (2012), 521-530, doi: 10.1016/j.conbuildmat.2011.07.013.
11. Sukontasukkul, P., "Use of crumb rubber to improve thermal and sound properties of pre-cast concrete panel", Construction and Building Materials, Vol. 23, No. 2, (2009), 1084-1092, doi: 10.1016/j.conbuildmat.2008.05.021.
12. Elshazly, F.A., Mustafa, S.A. and Fawzy, H.M., "Rubberized concrete properties and its structural engineering applications—an overview", Egyptian Journal for Engineering Sciences and Technology, Vol. 30, No. Civil and Architectural Engineering, (2020), 1-11, doi: 10.21608/ejscet.2020.35823.1000.
13. Rahul, G.T., "Enhancing the properties of crumb rubber modified concrete with synthetic resin", (2020).
14. Grinys, A., Augonis, A., Daštikys, M. and Pepeckis, D., "Mechanical properties and durability of rubberized and sbr latex modified rubberized concrete", Construction and Building Materials, Vol. 248, (2020), 118584, doi: 10.1016/j.conbuildmat.2020.118584.
15. Beiram, A. and Al-Mutairee, H., "Effect of using waste rubber as partial replacement of coarse aggregate on torsional strength of square reinforced concrete beam", doi: 10.5829/ije.2022.35.02b.16.
16. Al-Mutairee, H.M. and Makki, O.M., "Rubberized concrete mix–discussions for literature review", in Journal of Physics: Conference Series, IOP Publishing. Vol. 1895, No. 1, (2021), 012011.
17. Kadhim, A.A. and Kadhim, H.M., "Experimental investigation of rubberized reinforced concrete continuous deep beams", Journal of King Saud University-Engineering Sciences, (2021).
18. Li, S., Yu, T. and Jia, I., "Empirical seismic vulnerability and damage of bottom frame seismic wall masonry structure: A case study in dujiangyan (china) region", International Journal of Engineering, Vol. 32, No. 9, (2019), 1260-1268, doi: 10.5829/ije.2019.32.09c.05.
19. Siqi, L., Tianlai, Y. and Junfeng, J., "Investigation and analysis of empirical field seismic damage to bottom frame seismic wall masonry structure", International Journal of Engineering, Vol. 32, No. 8, (2019), 1082-1089, doi: 10.5829/ije.2019.32.08b.04.
20. Li, S.-Q. and Chen, Y.-S., "Analysis of the probability matrix model for the seismic damage vulnerability of empirical structures", Natural Hazards, Vol. 104, No. 1, (2020), 705-730, doi: 10.1007/s11069-020-04187-2.
21. Gautam, D., Adhikari, R., Rupakhetty, R. and Koirala, P., "An empirical method for seismic vulnerability assessment of nepali school buildings", Bulletin of Earthquake Engineering, Vol. 18, No. 13, (2020), 5965-5982, doi: 10.1007/s10518-020-00922-z.
22. Stoyanova, I., "Vibration analysis of the simply supported rc beam", in IOP Conference Series: Materials Science and Engineering, IOP Publishing. Vol. 1141, No. 1, (2021), 012036.
23. Chen, G., Hu, M. and Yang, X., "Dynamic responses of rc beams under slowly swept harmonic loads", (2000).
24. Şimşek, M. and Kocatürk, T., "Dynamic analysis of eccentrically prestressed damped beam under moving harmonic force using higher order shear deformation theory", Journal of Structural Engineering, Vol. 133, No. 12, (2007), 1733-1741.
25. Sushmitha, N. and Hegde, M.N., "Harmonic analysis of cantilever beam with and without cracks", International Research Journal of Engineering and Technology, Vol. 6, No. 9, (2019), 692-695, doi: 10.17577/ijrjet.2019.09.020.
26. Mohammadzadeh, S., Esmaili, M. and Mehrali, M., "Dynamic response of double beam rested on stochastic foundation under harmonic moving load", International Journal for Numerical and Analytical Methods in Geomechanics, Vol. 38, No. 6, (2014), 572-592, doi: 10.1002/nag.
27. Chen, Y., Song, Y., Yang, J. and Teng, T., "A new method of forced vibration problem of deep beams under distributed harmonic load", International Journal of Materials and Structural Integrity, Vol. 12, No. 1-3, (2018), 179-193.
28. Civelek, O., Ozturk, B. and Yavas, A., "Nonlinear transient dynamic response of clamped rectangular plates on two-parameter foundations by the algorithm of the singular convolution", International Journal of Science and Technology, Vol. 2, No. 2, (2007), 165-177.
چکیده
تیپهای عضق پیوسته (CDB) پیکاریابترین اعضا در ساختمانهای سازه هستند و به شدت در معرض انواع مختلف بارهای دینامیکی هستند. معروف است که: بتن ماده این شکل‌های است و مقاومت ضعیفی در برابر جذب انرژی دارد. استفاده از لاستیک نارنجی یا خاکستری برای افزایش مقاومت سازی شده است. مشخص شده است که تئوری تیپ CDB تحت تأثیر تغییرات شکل، برای مثال، تغییر ناگهانی عمق و بار مورد مطالعه قرار گرفته است. مشخص شده است که تئوری تیپ CDB تحت تأثیر تغییرات شکل، برای مثال، تغییر ناگهانی عمق و بار مورد مطالعه قرار گرفته است. مشخص شده است که تئوری تیپ CDB تحت تأثیر تغییرات شکل، برای مثال، تغییر ناگهانی عمق و بار مورد مطالعه قرار گرفته است. مشخص شده است که تئوری تیپ CDB تحت تأثیر تغییرات شکل، برای مثال، تغییر ناگهانی عمق و بار مورد مطالعه قرار گرفته است. مشخص شده است که تئوری تیپ CDB تحت تأثیر تغییرات شکل، برای مثال، تغییر ناگهانی عمق و بار مورد مطالعه قرار گرفته است. مشخص شده است که تئوری تیپ CDB تحت تأثیر تغییرات شکل، برای مثال، تغییر ناگهانی عمق و بار مورد مطالعه قرار گرفته است. مشخص شده است که تئوری تیپ CDB تحت تأثیر تغییرات شکل، برای مثال، تغییر ناگهانی عمق و بار مورد مطالعه قرار گرفته است. مشخص شده است که تئوری تیپ CDB تحت تأثیر تغییرات شکل، برای مثال، تغییر ناگهانی عمق و بار مورد مطالعه قرار گرفته است. مشخص شده است که تئوری تیپ CDB تحت تأثیر تغییرات شکل، برای مثال، تغییر ناگهانی عمق و بار مورد مطالعه قرار گرفته است. مشخص شده است که تئوری T

** Persian Abstract **

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** English Abstract **

The CDB (Composite Deep Beams) are the most powerful components in structures and are subjected to various types of dynamic loads. It is known that concrete is weaker than steel in terms of energy absorption. The use of rubber or elastomers has been reported to improve the energy absorption capacity of these components. This paper investigates the behavior of CDB under static loads: A review study, in IOP Conference Series: Earth and Environmental Science, IOP Publishing. Vol. 961, No. 1, (2022), 012034.