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Studying Some Important Aspects of Corrugated Steel Web in Girders

Maryam I. Jumaa[1]*, Fareed H. Majeed[2]

[1]*PhD student, Civil Engineering Department, University of Basra, Iraq*
[2]*Professor, Civil Engineering Department, University of Basra, Iraq,*
E-mail addresses: pgs.maryam.jumaa@uobasrah.edu.iq[1]
fareed.majeed@uobasrah.edu.iq [2]

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Abstract: As a result of the high advantages of corrugated steel webs, their use has advanced over the conventional plate in recent times. The corrugated web girder has a distinctive geometrical form that enhances the shear buckling behavior of the girder. have a bending and shear behavior different from a conventional plate girder and a higher moment of inertia (I) (secondary axis) than ordinary webs; therefore, corrugated webs provide stiff deflection and rotational motion to the skin in a structure. Corrugated steel webs function similarly to the "accordion effect," especially in the context of bridges. When a bridge is subjected to the weight of vehicles or external forces from the environment, the corrugated steel web can undergo deformation resembling that of an accordion, with expansion and contraction occurring along its corrugated pattern. This behavior is due to the inherent flexibility of the corrugated steel, which allows it to absorb and distribute applied loads more effectively. Although studies are underway to address various aspects such as different loadings or different sections related to their use in civil engineering applications, particularly in bridges.

This paper dealt with various aspects of studying corrugated steel webs, including ways to combine them with reinforced concrete to create a composite structure with high resistance and hardness. Several studies have also been addressed to develop the efficiency of CSW and improve their behavior, especially to resist shear buckling and improve the behavior of bridges under loads in general, which helps engineers improve the design of bridges to suit developments.

Keywords: corrugated steel web; composite girder; review of corrugated; enhance of corrugated.

1. Introduction

Researchers tested steel corrugated sheets. Due to weight reduction and automated corrugated steel web manufacturing, corrugated web girder use has increased in the last 20 years. Corrugated steel web girders allow engineers to optimize the design of structures with a higher ratio of depth to thickness. Single- or multi-span frames for heavy industrial buildings use corrugated steel web plates. Corrugated steel webs in girders and shear walls have been used in various structural applications. Fig. 1 shows different sections of girder with corrugated steel web CSW. A transverse shear load usually travels through a corrugated steel web. Engineers often choose thin parts with webs that have a higher depth-to-thickness ratio so that the flat web doesn't buckle. Flanges possess the highest capability for carrying moments among all hot-rolled sections. The primary advantage of CSW girders compared to hot rolled ones is their versatility in terms of size. Enhancements are necessary to optimize the performance of plate girders. Researchers are currently researching and developing numerous applications, especially for steel plate shear walls using corrugated webs. The item in question has the capability to function as either a plate girder or a mezzanine floor standard beam [1].

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2. Review of the history of corrugated web

2.1 corrugated steel web

High-effective steels, which are evolving into more widely accessible, benefit the applications of highway bridge because of their high resistance, good weldability, outstanding toughness, and corrosion resistance. Despite the light-weight property of steel, its application in traditional flat-plate girders is more susceptible to fatigue failure, excessive deflections, and web instability, thus limiting its use. Researchers have come up with new ways to get around these problems, like using corrugated webs to make shear stability higher and getting rid of the need for crosswise stiffeners. Due to its beneficial qualities, corrugated steel plate has been used since the 1920s and is a commonly used structural element in various sectors of application. It was originally utilized in airplane constructions with very thin web panels, and later it was expanded to civil engineering applications like buildings and bridges. It has been progressively employed in composite bridges and the web of steel over the last 20 years. The Cognac Bridge, constructed in 1986, was the first bridge made with corrugated steel in the world. The bridge had three spans and it was continuous. It was 105 meters long and could span up to 43 meters [2].

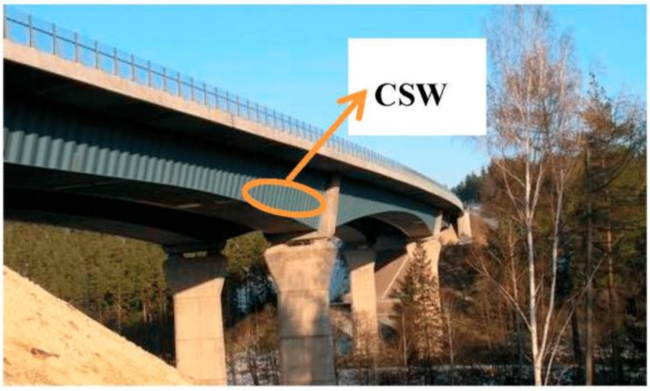


Fig. 1 Bridge constructed using girders with a corrugated steel web.

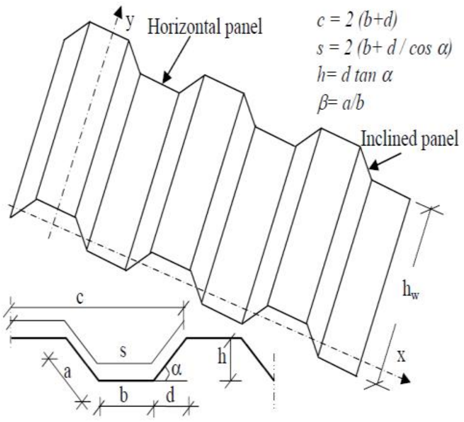


Fig. 2 corrugated steel +webs.

2.2 Why We Use Corrugations

To make the cross-section strong enough to resist in-plane bending, the most material needs to be placed as far away from the neutral axis as possible. As the section depth increases, the web becomes thinner and may buckle in shear, causing premature girder collapse. Instead of utilizing stiffeners to lower the slenderness ratio generated by the web's high depth and thin thickness, the corrugated web can deliver stability against elastic buckling. The profile prevents the beam from failing owing to instability first before the web reaches its ultimate load.

3. Structural of Corrugated Web Girders

Thin-walled of corrugated web and a flange make up the corrugated web girder structure. Flat-web plate girder bridges have the highest moment-bearing capability of all rolled sections when it comes to plate girder bridges. To bear the moments, the segment must be thin, and thin sections are predisposed to web buckling. The web thereby misses its ability to buckle. Therefore, the emphasis was on the supply of corrugations on the web in to prevent this buckling and achieve maximum strength. Corrugated webs are used because they allow for the need for thin sheets, but without using stiffener plates, which lowers the cost of manufacture and increases fatigue life. These corrugated web girders are thought to be 9–13 percent lighter than the standard strengthened girders with plain webs [3].

4. Key attributes of corrugated web plates include

Increased Stiffness: The corrugated web plates offer higher stiffness compared to flat web plates of the same thickness. The corrugated geometry enhances the structural integrity of the plate, allowing it to resist bending and torsion loads more effectively [4].

1. Reduced Weight: Despite their increased stiffness, corrugated web plates typically weigh less than equivalent flat web plates. helpful for building structures that need to keep dead weight to a minimum, like bridges

2. The corrugated design enhances: the resistance of the web plate to buckling when subjected to compressive loads by providing additional lateral support. This measure aids in mitigating premature deterioration and enhances the overall robustness of the framework.

3. The fatigue performance: is enhanced by the geometry of corrugated web plates, which aids the dissipation of stress concentrations and reduces the accumulation of fatigue damage. This leads to a high performance when compared to flat web plates.

4. Fabrication Simplicity: The corrugated web plates can be easily fabricated using conventional sheet metal forming techniques, resulting in a comparatively straightforward and cost-efficient production process when compared to intricate structural design.

5. Aesthetic Appeal: Corrugated web plates not only provide structural advantages but also enhance the visual appeal and architectural attractiveness of structures, making them a favored option in contemporary architectural projects.

Overall, the main characteristics of corrugated web plates make them well-suited for various structural applications where high stiffness, low weight, and enhanced stability are desired.

5. Effect of the Geometrical of corrugation

De'nan F. and Hashim S. [5] They was Comparing FEA bending results for Flat web and Triangular web (TR_W) steel sections. Both models report the influence of TR W web corrugation angle. From finite element calculations the least amount of bending in the major or minor axes of the Triangular Web steel section was seen at 450 and 750 web corrugation angles. When the edge of the web is 450 or 750 degrees, TR W steel is stiffer. When the web is corrugated in both minor and major axes, TR W steel segment resists bending better. A box girder with trapezoidal corrugated and flat webs was tested by Tohamy et al. [6]. Trapezoidal corrugated web plate girders can carry more and deflect less than strengthened flat web ones of equal weight. A plate girder with a trapezoidal corrugated web and 30 corrugation angles can carry more load. Early out-of-plane deflection is low for minor initial defects. Naji Ragad and Chkheiwer Aqeel [7] found that the increasing thickness of CSW enhance buckling resistance and increase the ultimate load, due to increasing stiffness leads to delay of buckling.

to improve this studying, we are analysis by finite element analysis (ABAQUS 2020) the effect of corrugation angle on deflection of composite box steel-concrete girder. We take the angle of corrugation (30, 45, 75, 90) and the sinusoidal web as shown in the descriptor of all webs in Fig 3. , as in curves according to the angle of trapezoidal web in Fig 4., the mode of failure is different between them, and with rise in angle, the web is stronger, so the failure translates to another part that weakens from web, its slab concrete that cracks in web angles 75^0, 90^0. All five models show modes of failure, as shown in Fig 5.

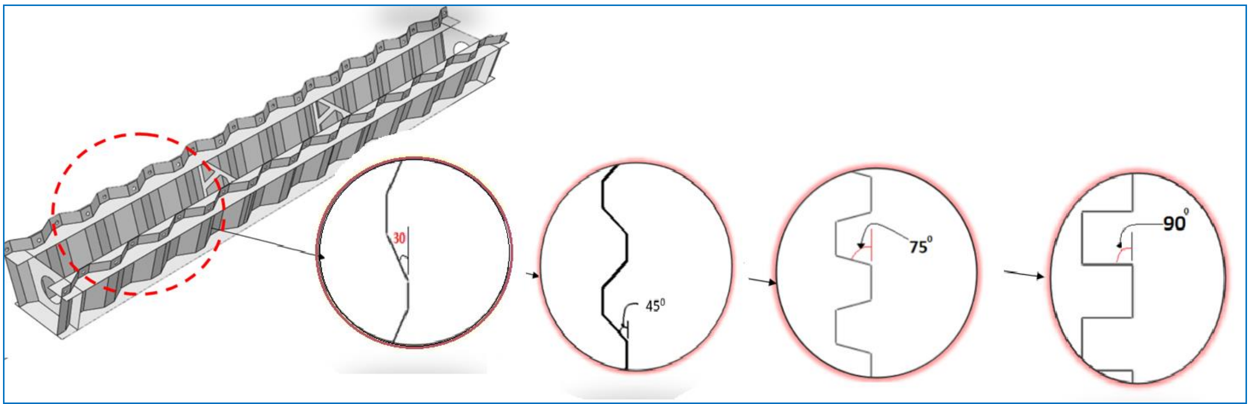


Fig. 3 detail of trapezoidal webs with different angles.

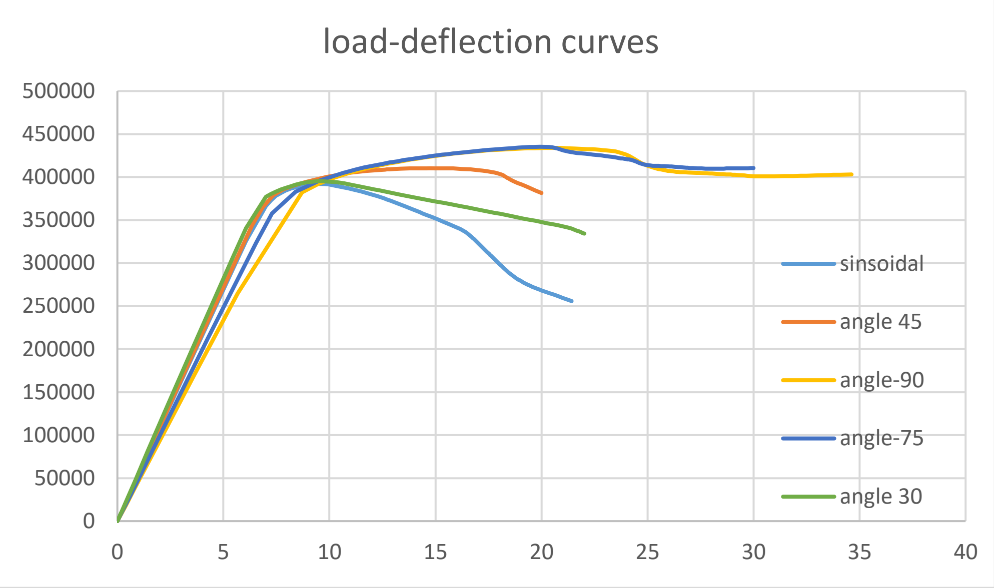
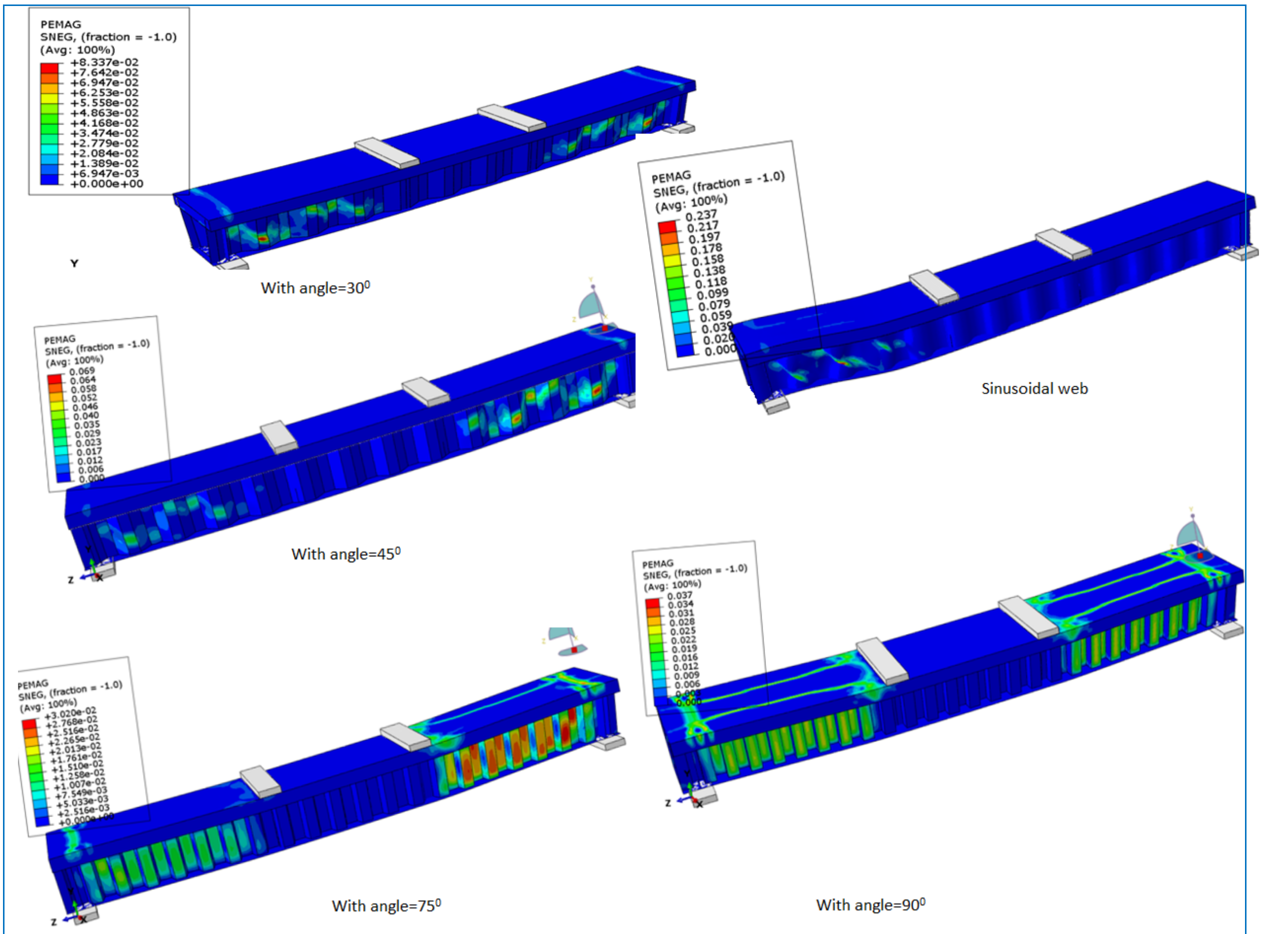


Figure 4. load-deflection curves with different angles of trapezoidal



With angle=30⁰

Sinusoidal web

With angle=45⁰

With angle=75⁰

With angle=90⁰

Figure 5. plastic strain magnitude of box girder with various angle of corrugated

6. Corrugated Web Girder Under Different Loading:

Ghanim G. et al. mention different types of the load depending on the serviceability of the structures. the girder may be corrugated web under one type of load that is purely shear loading, bending moment, and patch load. Or under load combination combined bending moment and shear load, combined loading and shear load or combined load patch, bending moment and shear loading. Each of these load types causes a different mode failure [1].

It is imperative to investigate various load cases of corrugated steel mesh girders in order to gain a comprehensive comprehension of their behavior, which will result in structural designs that are more reliable, efficient, and safe.

6.1 Corrugated web girder shear and buckling behavior:

De'nan Fatimah et al. [8] discovered that by increasing the web thickness while keeping the span length, flange, and web depth constant, the moment buckling resistance became higher when subjected to shear buckling loads. On the other hand, when the span length of the model is increased, it leads to a decrease in shear buckling capacity. Bergfelt A. and Leiva-Aravena L. [9] found that local buckling appears to dictate shear failure when the critical buckling stress is less than or close to the shear yield stress of the material. This appears to be true for shear buckling for girder depths up to the point where global buckling computed using standard formulas may become significant. Sayed Ahmed E. [10] investigated whether CSW buckled locally and globally. Local buckling is the instability of a folded panel. The corrugated web operates as a collection of flat panels that offer mutual support along the vertical boundaries. Horizontal (shorter) flanges support the panels. Employing equations provided for isotropic plates, the phenomenon of local buckling is investigated. The equations obtained by Galambos are used to guess the critical force for elasticity at shear $\tau_{cr,l}$ for the mode of local buckling:

$$\tau_{cr,l} = k_s \cdot \frac{\pi^2 \cdot E}{12 \cdot (1-\upsilon^2)} \cdot \left(\frac{t_w}{b}\right)^2 \text{, where} \quad k_s = 5.34 + 4.0\left(\frac{b}{h_w}\right)^2 \quad \text{................(1)}$$

In this equation, t_w: is the thickness of the corrugated web, b: is the width of the panel, E: the modulus of Young, v: Poisson's ratio of the steel and k_s: the local shear buckling parameter. Global buckling refers to the phenomenon of diagonal buckling that occurs across several corrugations. Consider the corrugated web as an orthotropic plate to measure it's shear stress. (Galambos) defines $\tau_{cr,g}$ as follows

$$\tau_{cr,g} = k_g \cdot \frac{\left(D_y \cdot D_x^3\right)^{1/4}}{h_w^2 \cdot t_w} \quad \text{.. (2)}$$

$$D_x = \frac{E}{b+d} \cdot \left(\frac{b \cdot t_w \cdot [d \cdot \tan\alpha]^2}{4} + \frac{t_w \cdot [d \cdot \tan\alpha]^3}{12 \cdot \sin\alpha}\right) \text{,and} \quad D_y = \left(\frac{b+d}{b+d/\cos\alpha}\right) \cdot \left(\frac{E \cdot t_w^3}{12}\right)$$

Where h_w and t_w represent web height and thickness, D_x and D_y represent flexural stiffness per unit corrugated on the x- and y-axes, and kg represents the global shear buckling coefficient based on web top and bottom limitations. The weight of steel girders is 36 k_g (according to figure 2).

Padmanaban P. and Henderson J H. [11] found that for girders with holes, Increasing the height of the girder leads to a 25% rise in shear buckling. strength. Initial specimen rigidity diminishes as the ratio of web depth to thickness increases.
Hassanein and Kharoob [12] discovered that girder sections with stiff flanges ($t_f/t_w < 3.0$) experience shear failure mechanisms. In contrast, flange deformation controls girder strength if a corrugated web plate is stiff ($t_f/t_w > 3.0$). Cao et al. [13] tested the corrugated web H-girder. Two global & local buckling modes were found in experiments. Full and half stiffeners were used to parametrize web thickness and stiffeners. The average corrugated web shear-capacity increased by 45% with web thickness. Completely stiffened 3mm corrugated steel web specimens showed significant shear bearing ability. At the same corrugation web and thickness, the shear strength of the full stiffener limit became 3% greater compared with the semi-stiffener limit. Huang Haiyang [14] employed analysis Nonlinear buckling analysis was to compare the critical loads. It shows the general stability of the steel's elasticity and plasticity, the force-lateral displacement charts, and the stress distribution on the top flange of all three kinds consisting of a steel girder with a wave-shaped web plate with the same steel volumes. The results show that the piecewise waveform-shaped web plate steel beam is better at supporting weight and keeping its shape overall related to the trapezoidal as well as sinusoidal wave profiles.

6.2 CW Girder Behavior Under Patch Load:

When studying the maximum resistance of steel plate beams with trapezoidal corrugated webs, Luo R. and Edlund B. [15] found that the load-carrying capacity of a girder is greatly influenced by the applied load, specifically the patch length. According to the analysis, the maximum load capacity of a girder under a Patch load is found to be around 40% and 20% lower compared to when the Patch load is replaced with a uniformly distributed patch carry of length (c= 115.2 and 50) mm, respectively.

6.3 Corrugated Web girder under combined loading

R. Luo and B. Edlund [15] conducted a study on the buckling behavior of trapezoidal corrugated plate under loading. An investigation was conducted to examine the impact of several factors, such as loading forms, geometry, and boundary conditions, on the buckled elastic load. According to the report, the buckling load for longitudinal compression only increases with a maximum buckling load, and the corrugation angle is achieved when the "proportion parameter" Υ is equal to 1. Similarly, the buckling load and shear loading, raises as the angle rises, and the greatest buckling load is reached when Υ is equal to 2. Finally, when combining shear and compression loading, interactive plots can be estimated using unit circles as shown in Figure 6, with the angle α varying.

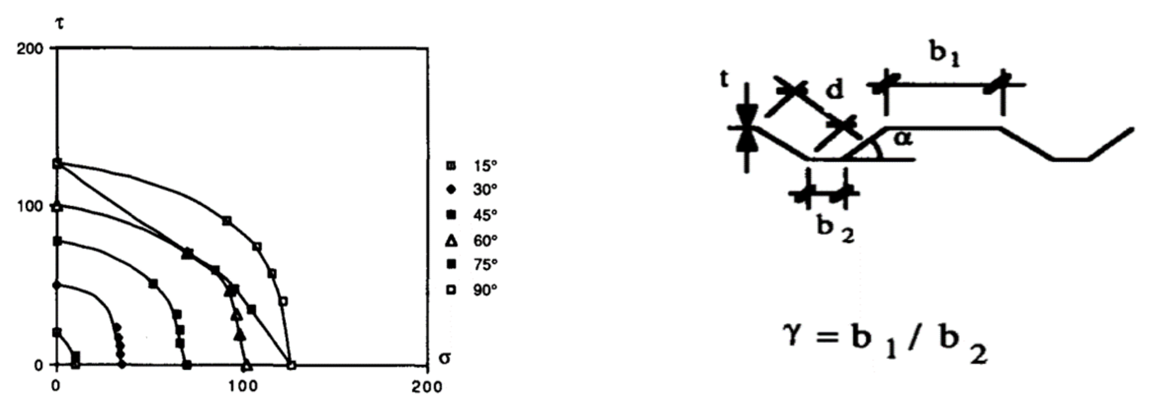


Fig. 6 Compression-shear interaction curves with many angles.

The study conducted by B. Jáger et al. [16] examined the structural response to bending-shear-patch (M–V–F) loading. The interactions between M-V, M-F, and V-F are studied separately. A total of 160 simulations are conducted to study the connection between V-M bending. Common failure is characterized by localized buckling of the flange during bending. Bending failure typically occurs at the center of the compressed flange, where the parallel fold of the web bears the largest load of the flange. The minor reduction in resistance can be disregarded when designing a corrugated web girder. 400 simulations were conducted to examine the interaction in the M-F plane. The public occurrence of bending failure is accompanied by localized flange buckling. Web malfunction caused by the patch loading. A total of 400 simulations are conducted to analyze the interaction between variables V and F. Demonstrates the process of loading patches without any impurities and the phenomenon of shear buckling. When using the Finite Element Method to determine shear buckling, bending, and patch loading resistances, it is found that the proposed M-V-F interaction curve (Equation 3) gives a reliable estimation of the lower limit interaction surface when compared to the numerical results. MR, VR, and FR, respectively, represent the measures of resistance to bending, shear buckling, and patch loading. The final results of all the numerical calculations are appear in Fig. 7.

$$max\begin{bmatrix} \left(\frac{M}{M_R}\right)+\left(\frac{F}{F_R}\right)^{2.9}\leq 1.0 \\ \left(\frac{V-0.5F}{V_R}\right)^{1.2}+\left(\frac{F}{F_R}\right)^{1.2}\leq 1.0 \end{bmatrix} \qquad \dots\dots\dots\dots\dots\dots (3)$$

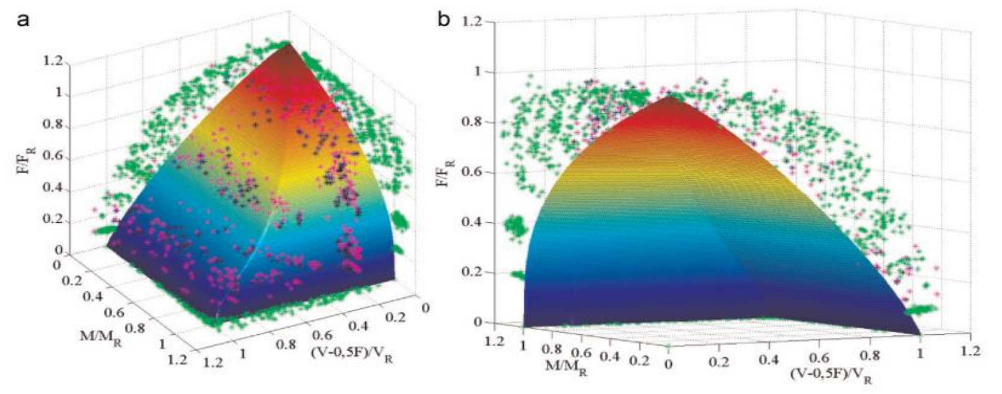


Fig. 7 Proposed interaction surface.

7. Composite girder steel-concrete with corrugated web:

Chen et al. [17] (2018) A proposal was made for a steel-concrete composite box girder bridge. Based on Figure 5, the structure consists of a lower arrangement of trusses, a top concrete slab, steel tubes filled with concrete, corrugated steel webs, and lower slabs. The composite box girder with CSWs (cross-sectional webs) and trusses offers several advantages, such as simplified construction, reduced weight, and enhanced resilience to localized joint failure. Furthermore, each resource is effectively utilized in this particular form of construction. The primary load-bearing components responsible for carrying the bending moment are the concrete slabs, CFSTs (Concrete Filled Steel Tubes), and bottom trusses. On the other hand, corrugated steel webs primarily bear the shear force.

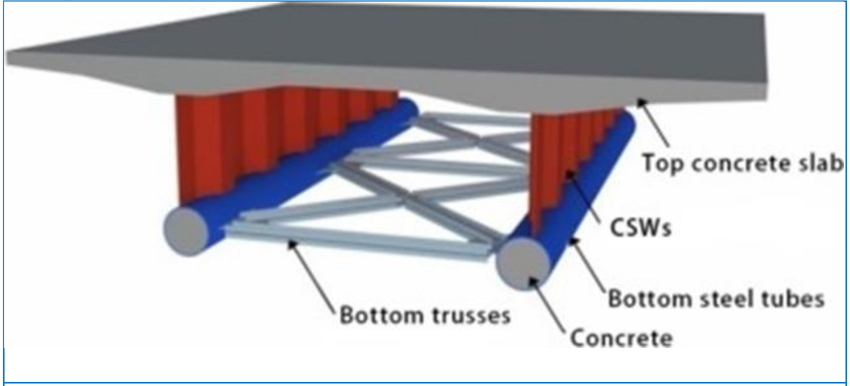


Fig. 5 Composite box girder with CSWs and trusses.

To minimize web cracking and reduce self-weight, a full-scale novel manufactured composite box girder - CSW and a concrete-filled steel pipe was introduced by Jun He et al. [18] (2019). This innovative design is particularly suitable for long-span buildings. To assess the load-bearing capacity as well as the decrease in stiffness.

The model test results show adequate loading capacity and ductility. The yield load of steel was 5.5 on the design load and twice the serviceability load, respectively. Because linking two box girders together with a diaphragm increases lateral stiffness, they are effective for spreading live loads, especially under eccentricity load conditions.

In January 2020, Zuhdiy Zahraa S. and Abbas Ali L. [19] studied reinforced concrete box girders with corrugated steel plates. Corrugated steel plates with vertical and horizontal corrugations, different shape of box rectangular, as shown in Fig. 8, have the same web width were used to study cell shape. Flat plates reinforced the circular cell. Self-compacting concrete was used to build five box girders with simple supports. These girders were tested under four-point loads. Compared to the control box girder, vertical and horizontal corrugated steel plate strengthening increased ultimate load by 7.14 percent and 11.03 percent, respectively. Additionally, crack width decreased.

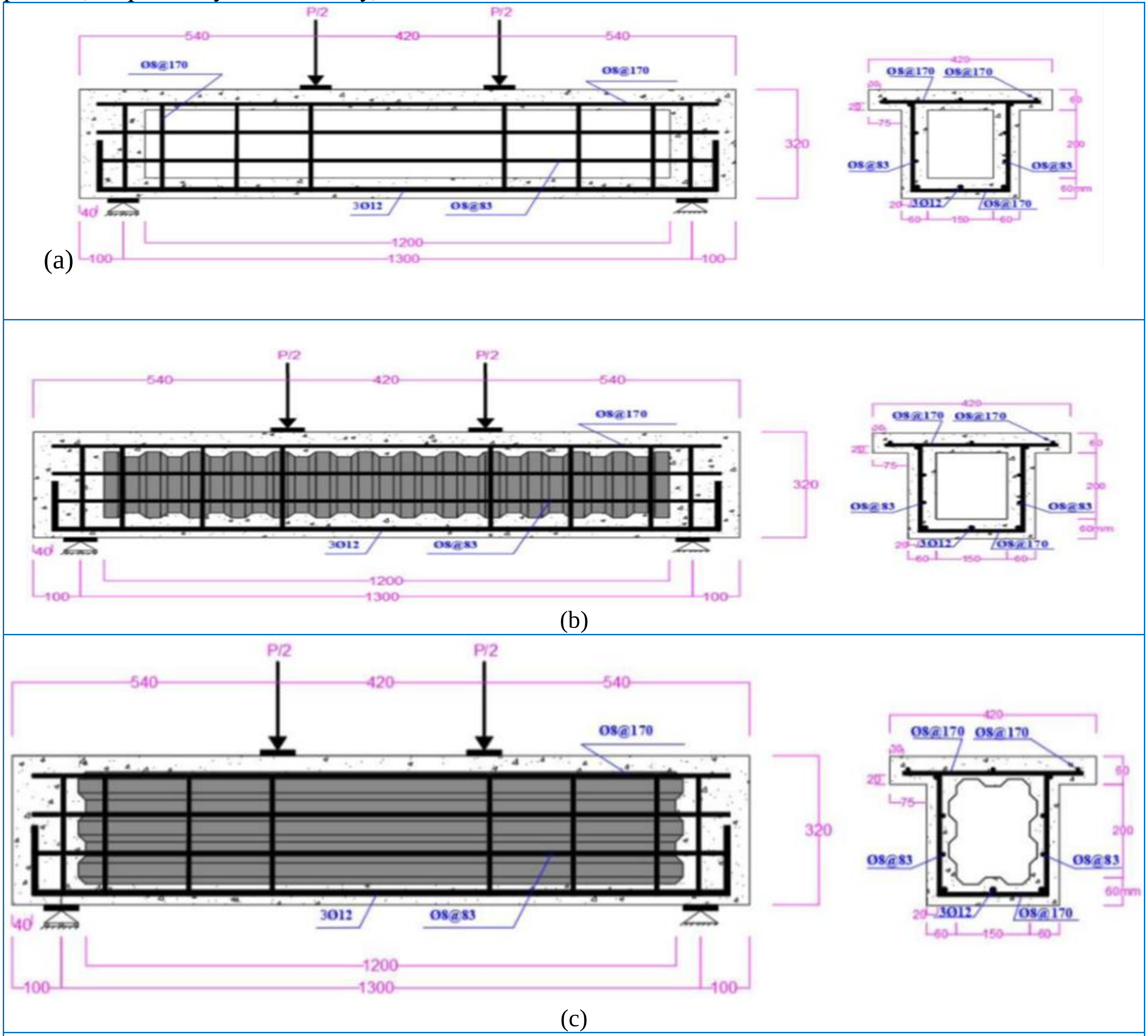


Fig. 8 show three type of strength box girder: (a) Flat plate. (b) Vertical corrugated steel. (c) Horizontal corrugated steel.

K. Ledziewski and M. Górecki [20] (2020) studied a sinusoidal web under shear buckling until failure numerically. The study also evaluated how a reinforced concrete slab stabilized the web. Steel and composite girders with reinforced concrete slab top flanges were analyzed. Nonlinear finite element calculations showed that shear stress in the composite girder's Sinusoidal Web (SW) appear and propagate similarly to those in a non-composite steel beam (Fig. 9). With identical steel cross-section characteristics, the composite girder has 15% higher strength of shear than the non-composite girder. Bracing the upper flanges increased shear strength and shifted starting loads. Global buckling diagonally across many folds was the sinusoidal web's main failure mode, regardless of the concrete slab. Due to its rigidity, the composite steel-concrete girder had smaller elastic deflections than the steel girder.

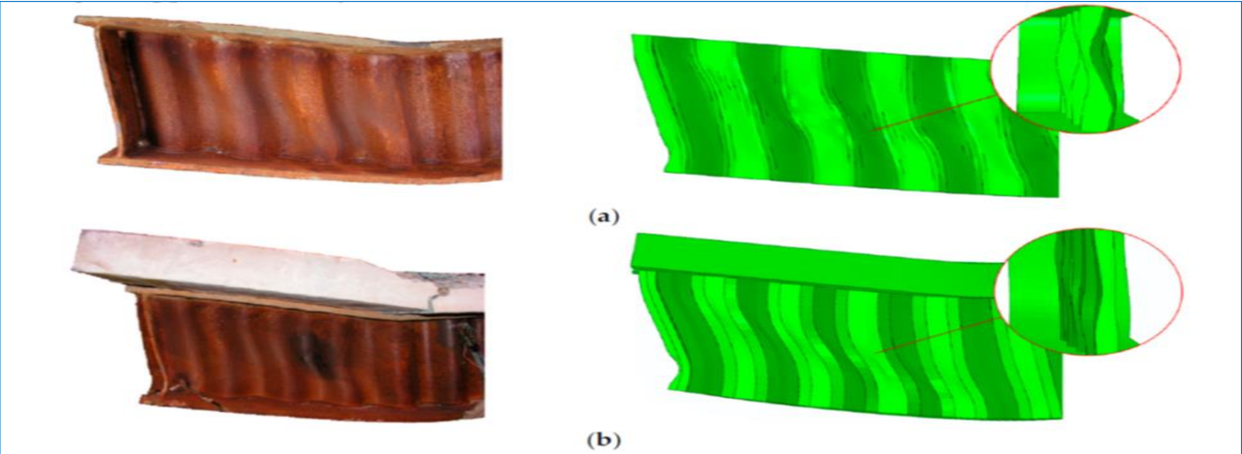


Fig. 9 (a) steel girder; (b) the composite girder with a concrete slab.

8. Investigating the GCSW under Dynamic loading

Ibrahima S. A. et al. (2006) [21] Investigated the fatigue behavior of girders with CSW and found from their study a plate girder with CW exhibit significantly Offers a significantly extended fatigue life when compared to traditional stiffened plate girders. with full-depth stiffeners, with an increase of 49%–78% under the Similar stress range. When compared to traditional plate girders with stiffeners cut short by about four times the web thickness to the tension flange, the fatigue life is higher by 28%–53%.

Huang H. et al. (2022) [22] used model tests and numerical analysis to compare the fatigue showing of composite girders with CSW-CFST (Corrugated Steel Web -Concrete Filled Steel Tube) chord trusses to those with CSW-ST. Concrete-filling chords offered several benefits. First, the implementation of this technique reduced radial chord deformation and decreased hotspot stress in the meeting weld zones of composite girders with CSW-ST truss chords by a significant range of 18.5% to 60.1%. During crack propagation and failure, composite girders by CSW-CFST chord truss had decreased crack development rates in depth and length. Importantly, filling chords with concrete extended the composite girder fatigue life by CSW-ST chords truss through 61.5% under the same fatigue load.

Xu Jun et al. [23] found from the fatigue tests that the majority of fatigue fractures in thirteen locations originated at the constant moment location near the S-point (Hot spot) (Fig. 10). However, the critical fatigue fracture originated in the paired bending-shear location at the S-point. This result contradicts the test results reported in the literature, which indicate that the critical fracture typically commenced in a location of constant moment.

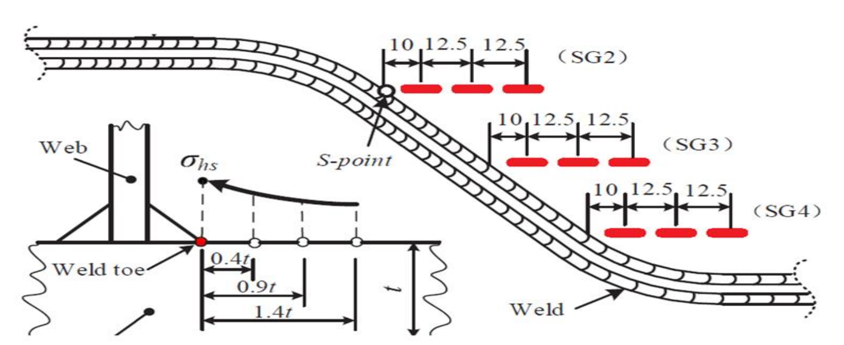


Fig. 10 S- point in corrugated web.

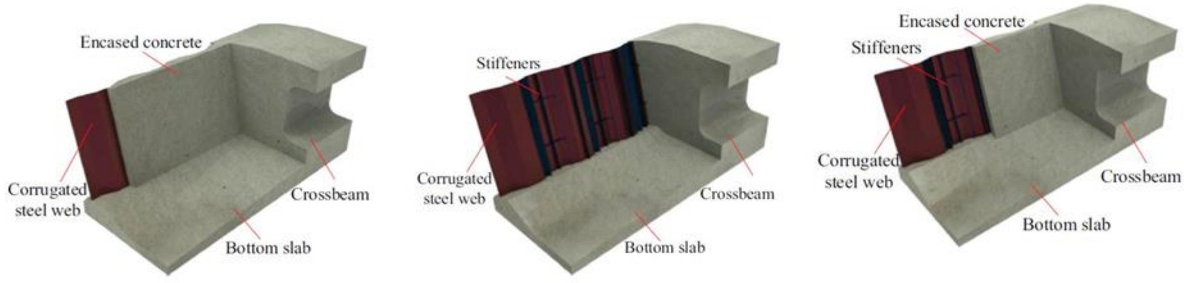
Sayed, A.M. et al. (2022) [24] found that for flexure displacement mode shapes, the best corrugated web was the rectangular one, followed by the triangular, and then the trapezoidal. In terms of natural frequency resistance, the best corrugated web was the triangular one, followed by the rectangular, and then the trapezoidal for any mode shape. It is possible to obtain a section resistance for the same values of displacement mode shapes and natural frequencies while saving on the thickness of the web by 33% when using the corrugated web instead of the flat web. The angle of the corrugated web in the triangular type significantly affects the resistance to displacement mode shapes and natural frequencies, resulting in a reduction ratio of 0.60 and 0.78, respectively, at an angle of 60 degrees.

Kövesdi B. and Dunai L. (2014) [25] conducted (6) large-scale test models to analyze the behavior of fatigue for CW girders. The tests evaluated the life of fatigue for the girder under shear loading, combined bending, and pure bending.

The fatigue tests involved a nominal stress range of 100.6 to 159.9 MPa, dependent on the kind of loading and sample dimensions. measured the stresses through 5000 cycles of fatigue loading to observe the structural behavior of the girder throughout its lifespan. The maximum normal stress in the constant bending moment region or the average normal stress in the parallel fold were considered potential factors contributing to crack initiation. ultimately considered, the stresses measured in the parallel fold because they closely resembled the stress distribution at the crack initiation location.

7. Enhanced corrugated web of girder

He Jun et al. [26] investigated Encased concrete close to an intermediate Long-span composite bridges with CSW in the support section making the beam heavier, decreasing the efficacy of pre-stressing, and complicating the construction process. A CSW featuring horizontal and/or vertical stiffeners was suggested as a potential substitute for concrete encasement or as a means to reduce its length. Implementing horizontal stiffeners induces local buckling in advance, whereas vertical stiffeners can delay its occurrence. As the vertical stiffeners' height and thickness increased, so did the strength of shear of the stiffened CSW, as shown in Fig. 11.



(a) Web with encased concrete (b) Web with stiffeners (c) Web with a combination of encased concrete and stiffeners

Fig. 11 Configuring a website close to intermediate supports.

Two identical models were made by Chen [27], one with hollow steel tubes and the other with concrete-filled steel tubes. Both models showed high ductility and collapsed ductility. It was discovered that steel tubes filled with concrete increased yield load and reduced deflection

the composite action of steel and concrete results in a higher section modulus, enhancing bending resistance and increasing the yield load capacity. Additionally, by increasing overall stiffness, the concrete core helps to reduce deflection.

According to Huang H. et al. [28] the two models were compared to the composite girders using chords truss. They discovered that filling the chords with concrete reduced the radial deformation of the chords and comforted hot-spot stress in composite girders by 18.5% to 60.1%. It also slowed downward the growth of cracks through the propagation of fractures and failure and made the fatigue life 61.5% longer.

Nie Jian et al. [29] present innovative optimization schemes aimed at improving the efficiency of traditional continuous compound girder bridges with CSW. The positive moment region, the steel plate with ribbed is proposed as a substitute for the reinforced concrete bottom flange to optimize the bridge design. Finite-element analysis, validated through a case study of the Dongbaohe Xinan Grand Bridge, demonstrates the advantages of this system, including reduced self-weight, prevention of bottom flange cracking, and simplified construction. Additionally, the use of a properly sized steel plate enhances flexural stiffness and load capacity. In the region of negative moment, two optimization systems (I & II) are introduced, incorporating the corrugated steel plate with concrete composite webs and a steel–concrete lowest flange, as shown in Fig. 12. These schemes significantly reduce shear stress in the CSW and steel concrete edge, enhancing shear capacity and overall load-bearing capabilities while improving girder ductility. Improving Things Scheme II is easier to build than Scheme I and traditional methods which makes it an advancement forward in bridge engineering design.

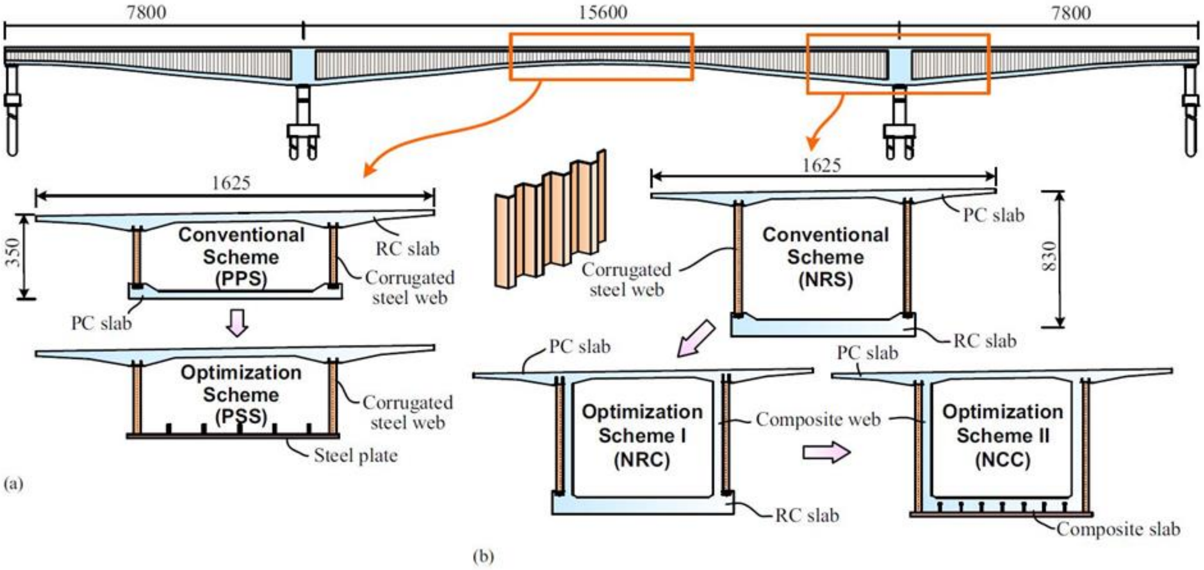


Fig. 12 replacing the conventional section with optimization section.

8. Conclusions

Conclusions drawn from research on Composite Steel Plate Girders with CWs can vary based on the research's specific findings and objectives. Nonetheless, a conclusion might encompass:

- It turns out from one of the studies that the area between the two central load points is an area that does not need to corrugated web steel plate because it’s not subjected to shearing, but only in bends (M Zone) Fig. 13. Therefore, it is possible to place flat steel plates, and this makes them more economical.

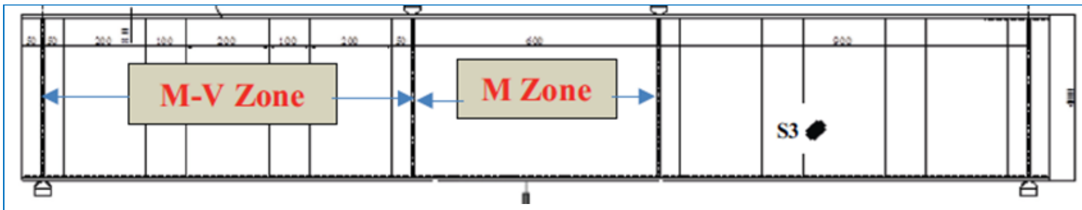


Fig. 13 illustrate the (M & V) Zone in girder..

- detected from an experimental study that combines the stiffeners vertical and horizontal stiffeners with corrugated web to improve the section and decrease the geometric imperfections, this way more welding to connect the stiffeners causes nonlinearity early, so its uneasy work and not economical.
- when used in some research, the steel tube filled with concrete in the bottom flange reduces the

deflection, this manner reduces the weight of the structure and gives it Aesthetic appearance, comparing with conventual section with CSW gives further Aesthetic appearance.

- optimization section in the negative and positive region in the -girder, when using composite section concrete -steel in negative, and just steel-bottom flange in the tension zone. The researcher intelligently used the features of the material properties in the suitable place, as it gave good performance at a lower cost.

Finally, many researchers have dealt with improving the performance of corrugated steel by combining it with other sections or welding stiffeners with it. Research continues in this field because of its wide resonance in recent years, and the use of corrugated steel instead of regular plate has begun to spread widely, almost eliminating the use of flat stiffener sheets because of their superior properties and many features.

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suggestion:

Below is some underexplored study fields in civil engineering related to (corrugated steel web):

1. Cost and economic return:
    - Analysis of the total cost and return on investment when using corrugated web netting compared to traditional materials.
    - Economic feasibility study of using corrugated cardboard netting in large and small projects.
2. Maintenance and restoration:
    - Develop new strategies for the maintenance and restoration of structures using corrugated steel web netting.
    - Study the effect of environmental factors and time on the durability of corrugated steel web and find solutions to improve its service life.
3. Dynamic behavior under variable loads:
    - Investigate the dynamic behavior of corrugated web under variable loads such as wind and earthquake.
    - Develop new models to predict the performance of corrugated web under dynamic conditions.

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