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REMANUFACTURING OF DEGRADED COMPOSITE SHAPE STEEL HONEYCOMB FROM END-OF-LIFE VEHICLE STEEL SECTIONS

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ABSTRACT

Remanufacturing is a powerful tool for developing ecological approach for many application Degrade honeycomb sheets for architectural use in construction are broadly used for ceiling, cladding and interiors applications End-of-life vehicle steel sections are used as cores to produce honeycomb steel where there are only three sections can be used such sections are attributed in the final products liability and quality. Remanufacturing of steel sections Remanufacturing of end of life steel vehicles sections in to honeycomb cores is targeting to reduce power ,material and fossil carbon emissions of end of life steel vehicles frame is studied and disassembled to classify the suitable parts for Remanufacturing the cores for steel honeycomb steel also thin steel sheets are used to covers. Remanufacturing and testing routes are figured and .Mechanical properties are tested and registered to be used for performance study end of life vehicle sections can be successfully degraded in to honeycomb cores to substitute current consumption of materials. Mechanical properties can be developed to match construction application standards by exploiting of sustainable assembling technology by using screens .As a conclusion reliable steel honeycomb can be matured by exploiting in remanufacturing technology and assembly techniques end –of- life sections can contribute to reduce power, materials consumption and carbon emissions.

KEY WORDS: vehicle end-of-life steel remanufacturing, honeycomb cores, ecological approach.

إعادة تصنيع أجزاء فولاذ السيارات المنتهية العمر لإنتاج الواح الفولاذ سداسية التخريم محدودة الخواص

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الخلاصة

يمثل اعادة التصنيع اداة كفوءة لتطوير التوجه البيئي للعديد من التطبيقات .وعلى سبيل المثال اعادةتصنيع هياكل الفولاذ لانتاجالواح سداسية التخريم تستخدم في مجال البناء والانشاءات كالسقوف والقواطع الداخلية او كألواح تكسية (أكساء) مقاطع الفولاذ ابدان المركبات منتهية العمر استخدمت كلباب لانتاج الواح سداسية التخريم حيث تم أستخدام ثلاث من هذه المقاطع في أنتاج هذه الالواح للتقليل من الطاقة المستهلكة وكذلك المواد والتقليل من انبعاثات الكاربون . أبدان المركبات المنتهية العمر ثم دراستها بعد تفكيكها لتصنيف الاجزاء الملائمة لكي تستخدم في عملية انتاج الواح سداسية الشكل .تمثل المقاطع الفولاذية عنصر تقوية اساسي بينما يستلزم تغليفها بالواح رقيقة من الفولاذ لاكسابها شكل مقبول .اعادة التصنيع وفحص الخواص الميكانيكية تم وفقاً لمسالك موضحة باشكال مرفقة في البحث كما تم تسجيل القيم للخواص الميكانيكية لدراستة السلوك الذي ظهر انه بالامكان وبنجاح أستخدام المقاطع المنتهية العمر لأنتاج الواح سداسية التخريم للاسهام في تخفيض الاستهلاك الحالي للمواد الهندسية .تم اعتماد مبادئ تكلنوجيا التجميع والتفكيك باستخدام اللوالب في انتاج الالواح سداسية التخريم كأجراء مستدام وقد اشارت نتائج الخواص الميكانيكية.

1. INTRODUCTION

Manufacturing is an energy consuming and heavy pollutant process to discharge accountable emissions of Carbon, NOx, SO_2 and some heavy metal as particulate matter, Mohr, et al., 2015. Continuous growth of energy consumption causes combustion of fossil fuels to be continued to increase, and the optimized utilization of energy is one of the greatest challenges, which are required environmental management and sustainable development for mitigation, Capell, et al., 2014. This can help leap out to life the idea of degrading remanufacturing of end-of-life vehicles steel sections into composite shape steel honeycomb. Remanufacturing is the ultimate form of recycling can restore the used products of high value-added which can be evaluated in terms of energy saving, material saving and pollution reduction, which is highly required to innovate great recycling value and potential for remanufacturing and of absolute manufacturability through disassembly, Yanbin, et al., 2012. Honeycomb for construction application is one of the most valued structural innovations developed by the composites industry to be used extensively based on key benefits of low weight, high stiffness, good durability and low production cost. Double flex core, flex core, reinforced hexagonal core, and OX core are derivatives of the standard hexagonal honeycomb. Light weight limitation is exceeded through various applications of composite paper, aluminum and stainless steel honeycomb, Fig. 1.

The combination of mechanical properties such as tensile strength of the cover sheets and outstanding aesthetic features are being highly appreciated by designers, architects and planners to exploit honeycomb. Easily fabricated with perfecto details and great variety of applications is possible with the use of ordinary tools are also becoming increasingly popular in interior design. Honeycomb panels can be used for all types of body panels, floors, supports, ceilings, and partition walls to provide better insulation and sound proof. The panels are also very structurally sound and meet most ratings for fire control. Because of they are non-outgassing, non-particle shedding, and anti-static as well as lightweight and non-combustible, so they are very suitable for construction application to be kind of green and environmental compounded materials of high quality, low density, fire protection, sound insulation and thermal insulation. The interconnected honeycomb cores are distributed on the whole panel, with a good resistance for shearing, bending and compression. The honeycomb core is divided into many sealed rooms, which restrains air circulation in honeycomb panel and greatly prevents the heat transmission and sound propagation. So it is a material of good thermal insulation and sound insulation and is widely used for in furniture and construction materials industry.

Landfill and materials recycling are the most diffused end-of-life practices that delay remanufacturing based sustainable economic, environmental and societal growth of developing countries. Such growth is required major technology, methodology and business oriented innovations to be developed as enablers for remanufacturing. This directly affects the energy footprint and the raw material consumption through closing both supply chain and product lifecycle by remanufacturing as a service, Colledaia, et al., 2014.

Fig. 1. Illustration of composite paper, aluminum and stainless steel honeycomb for construction application.

2. COMPOSITE SHAPE STEEL HONEYCOMB REMANUFACTURING & TESTING

Fig. 2 is illustration of degraded remanufacturing of end-of-life vehicle steel sections into o steel honeycomb sheets, where steel sections are cut fit to size and assembly by using screws (as a cooapphoch) to maintain as can as possible shape continuity and alignment of similarity. Steel sheets are also glued (see Fig. 2) to top and bottom of the formed grid of steel sections for better appearance and increasing strength.

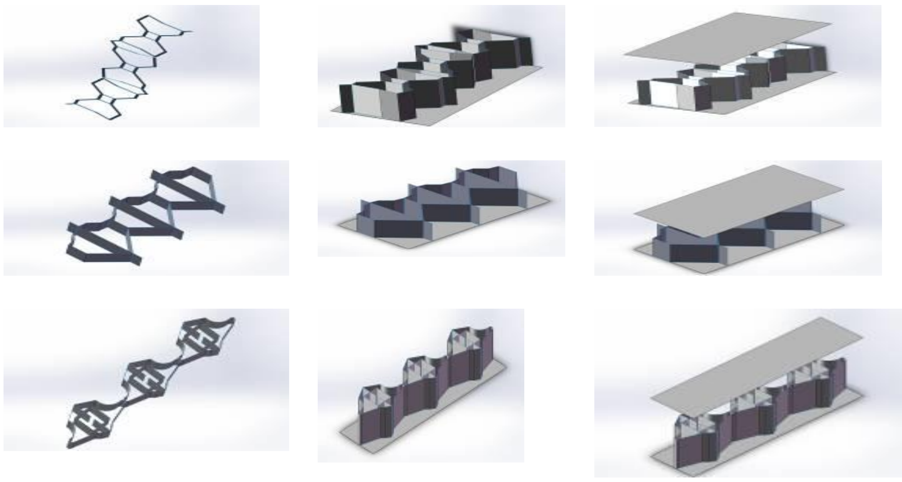

Figure 2. Degradedly remanufactured end-of-life steel Sections into composite shape steel honeycomb eco-idea illustration.

End-of-life vehicle is disassembly by shearing to separate several sections (vechle Hulk section they are three) to be used for composite preparation. The selected sections are cut into small cells of 50mm height that simulates honeycomb for filling of construction application. Six pieces are alignment on base of steel of (0.2mm) thickness. Since sections are of different shapes and thickness, classification can recognize two sections to be very close to have the same width too height ratio of (0.3) and both are of the same thickness wall of (2mm) also , while one section is of high shape width to thickness ratio of (0.8) and also of (1mm) thickness. Sections are assembly by using screws of M8 size and holes are made through the Sections to facility the assembly. Dimensions of prepared samples are measured to conduct mechanical properties testing. Fig. 3 degradedly endo-of-life steel Sections into honeycomb remanufacturing algorithm

Bending and buckling tests are performed by using universal tensile testing machine and recorded data of mechanical properties is obtained. Tested samples are disassembly to help explanation of mechanical properties behavior through failure modes study. Fig.4 degradedly honeycomb remanufacturing testing algorithm. Bending Yield stress, bending ultimate stress, buckling lower yield stress, buckling upper yield stress and stiffness are the highlighted properties.

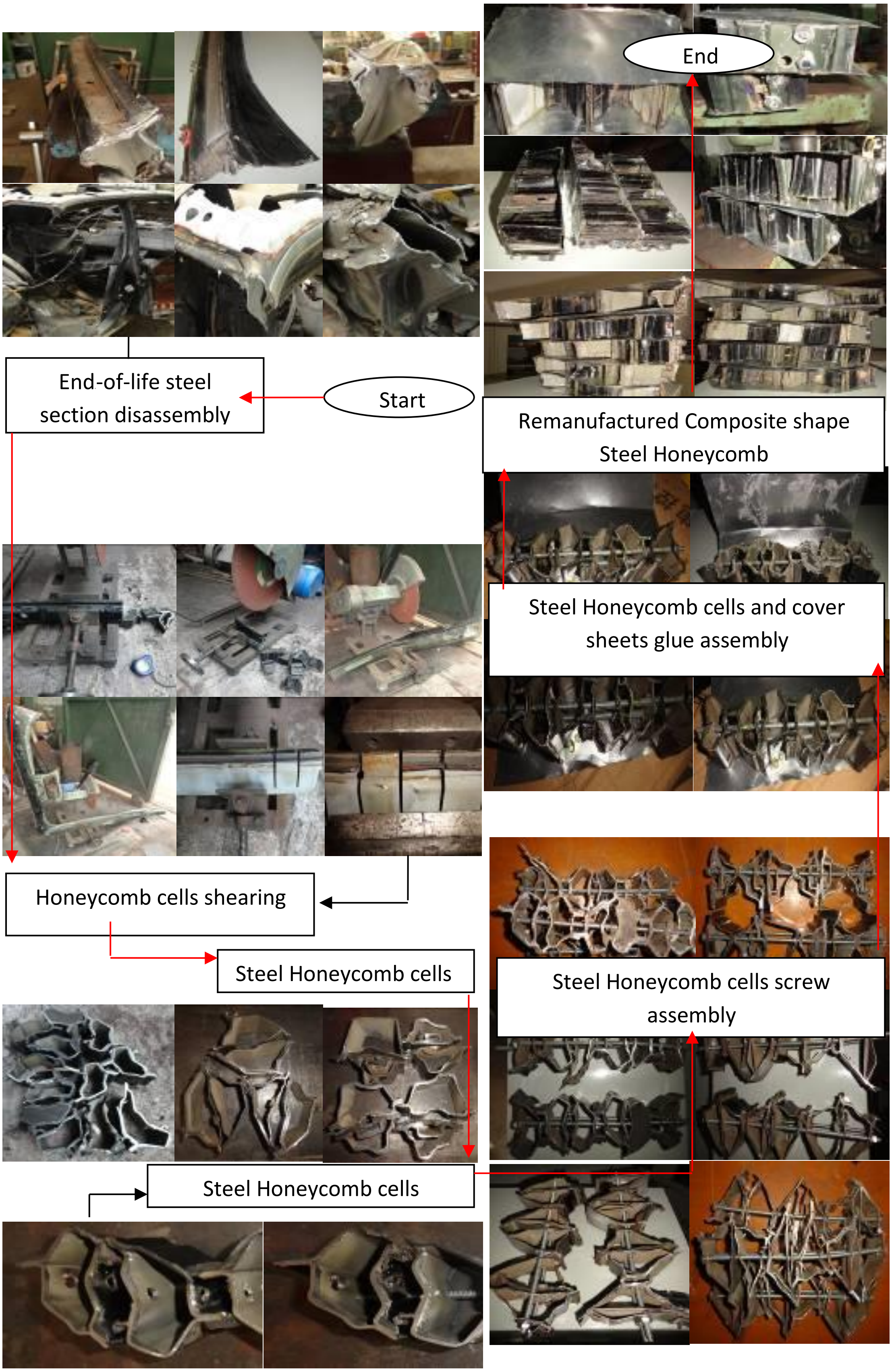

Fig. 3. Degradedly end-of-life steel sections into honeycomb remanufacturing algorithm.

Fig. 4. Degradedly honeycomb remanufacturing testing algorithm.

3. RESULTS AND DISCUSSION

Table 1 is a registration of mechanical properties of bending tests; yield stress of bending test is used to find out an indication about the strength of degradedly remanufactured composite shape steel honeycomb. Increasing of width to length ratio has no big effect, where moment of inertia of Sections is not exploited very well to increase the strength of the composite shape material, where assembly screws cannot apply torque through the centroid of the section. The rigidity of the cello depends on thickness of the section which identifies the reduction of strength with increasing of width to length ratio of the honeycomb cell, figure (5,6)o,(figure of bending test include Fig. 5 and Fig. 6 for both of yield bending stress and ultimate bending stress) because two Sections that of (0.3) width to length ratio are of (2mm) cello wall thickness. While the third section of (0.8) width to length ratio is only of (1mm) thickness, so thickness is a high function of rigidity. There is no big difference among the three sections bending ultimate stress, and even the stiffness values are low by comparing with buckling tests stiffness, but the bending ultimate stress is high comparing with low bending yield stress, which points that peak load is applied on the small area of two assembly screws of M8 to be of (100.48mm2).

To generalize both of bending yield stress with bending ultimate stress and bending ultimate stress with stiffness Fig. 7 and Fig. 8 are drawn to find out fitting equations.

Table 1. Shape and Mechanical Properties of Bending Tests

(Section width ratio)	Cell Wall Thickness (mm)	Bending Yield Stress (N/mm^2)	Bending Ultimate Stress (N/mm^2)	Stiffness (N/mm) S_b
0.3	2	0.235	4.503	73.469
0.3	2	0.183	4.649	73.143
0.8	1	0.130	4.109	73.708

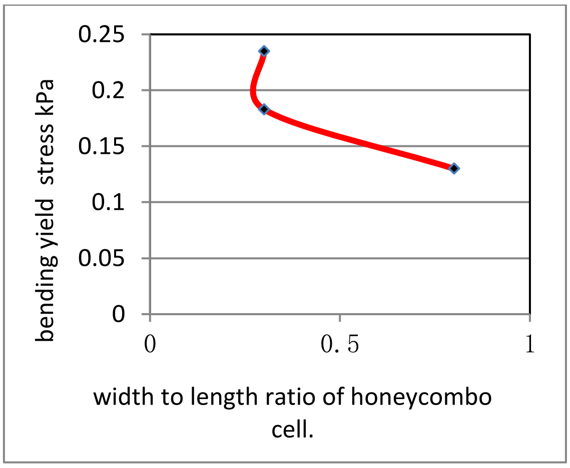

Fig. 5. Variation of bending yield stress with width to length ratio of honeycomb cell.

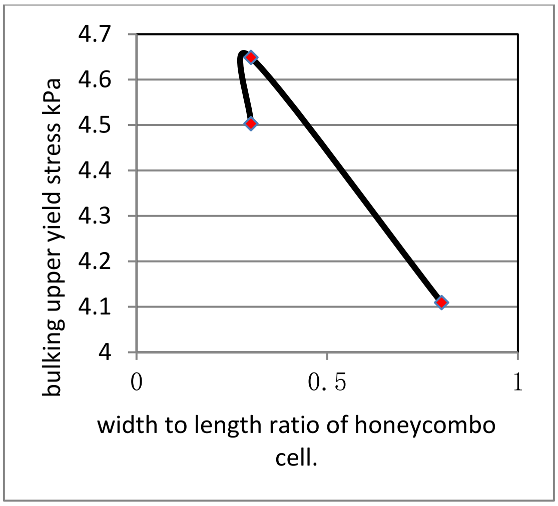

Fig. 6. Variation of bending ultimate stress with width to length ratio of honeycomb cell.

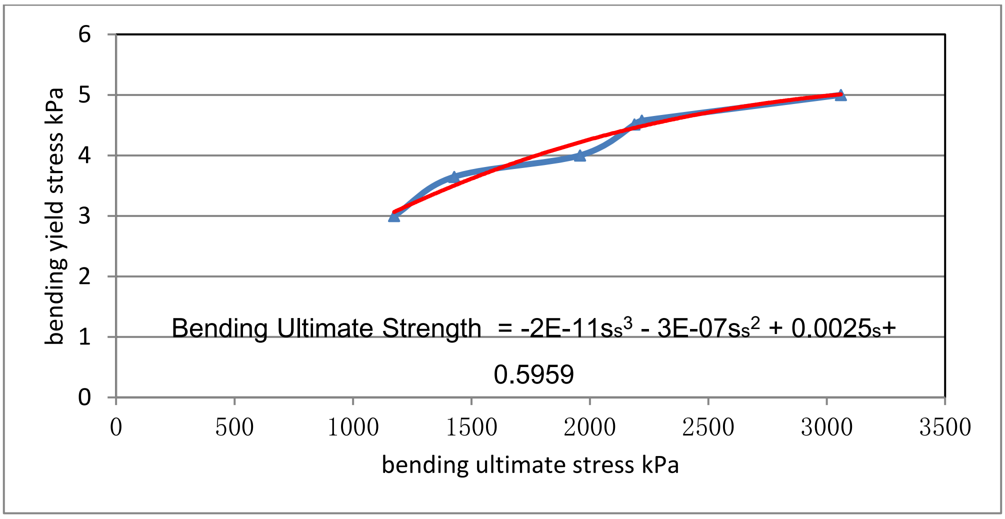

Fig. 7. Variation of bending yield stress with bending ultimate stress (Su).

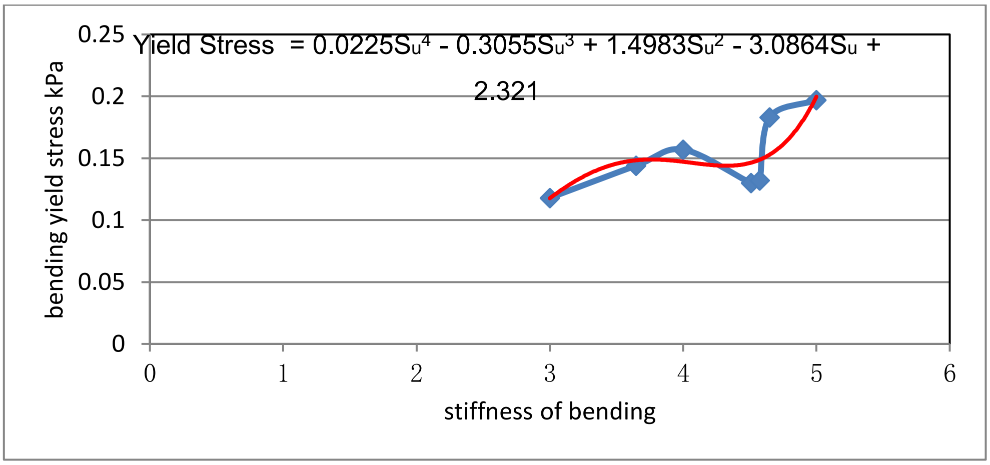

Fig. 8. Variation of bending ultimate stress with stiffness of bending.

Table 2 is a registration of mechanical properties of buckling tests, there is low variation between buckling lower yield stress and buckling upper yield stress and booth of the them are low comparing with bending ultimate stress, and even buckling stiffness value are very high comparing with that of bending. This is due to high buckling areas of (5500mm2, 3825mm^2, 7800mm^2) of the three Sections respectively. Thickness of wall (mm) of width to length rati of (0.3) of(1mm) keeps buckling lower yield stress as upper and lower bounds for the buckling lower yield stress of the third section honeycomb of (0.8) width to length ratio and (1mm) wall thickness which lay to reach the mid pinto of this limits, Figs. 9 and 10. The limits still can be seen in figure but the third section honeycomb of (0.8) exceeds these limits to reflect some of section and area properties of this high to length on.

Generalization of properties required that buckling lower yield stress with buckling upper yield stress and buckling upper yield stress with stiffness, Fig. 11 to Fig. 12 are drawn to find out fitting equations.

Stiffness of bending tends to increase with the increasing of width to length ratio of honeycomb cell to show interaction with thickness of honeycomb cellos. While increasing of the section and area properties leads to decrease stiffness of buckling due to deformation through sections of the honeycomb cellos. Fig. 13 and 14.

Table 2. Shape and Mechanical Properties of Buckling Tests

(Section height ratio)	Cell Wall Thickness (mm)	Buckling Lower Yield Stress (N/mm^2)	Buckling Upper Yield Stress (N/mm^2)	Stiffness (N/mm) S_b
0.3	2	0.099	0.141	2981.180
0.3	2	0.142	0.189	4261.425
0.8	1	0.111	0.201	3042.637

The role of steel honeycomb can be extended not to only overcome and stop of using of paper as honeycomb and what are related on that of both forestry destroying and Carbon emissions, but also composite shape steel honeycomb is better in both power and C emission mitigation as shown in Fig. 15 and Fig.16.

Table 3. Energies (MJ/Kg) of virgin recycled and remanufacture materials based on, Michal 2013, Abdullah 2015.

Virgin Material			Recycled materials			
Stainless Steel	Aluminium	Steel	Stainless Steel	Aluminium	Steel	Remanufactured steel
91-100	214.3-232.68	39-42	11-13	22-30	6.6-8	0.26-0.4

Table 4. Carbon emissions (kg/Kg) of virgin recycled and remanufacture materials based on Michal, 2013, Abdullah, 2015.

Virgin Material			Recycled materials			
Stainless Steel	Aluminium	Steel	Stainless Steel	Aluminium	Steel	Remanufactured steel
5.9-6.9	12.01-14.14	2.72-3.26	0.65-0.8	1.9-2.3	0.4-0.48	0.86-1.01

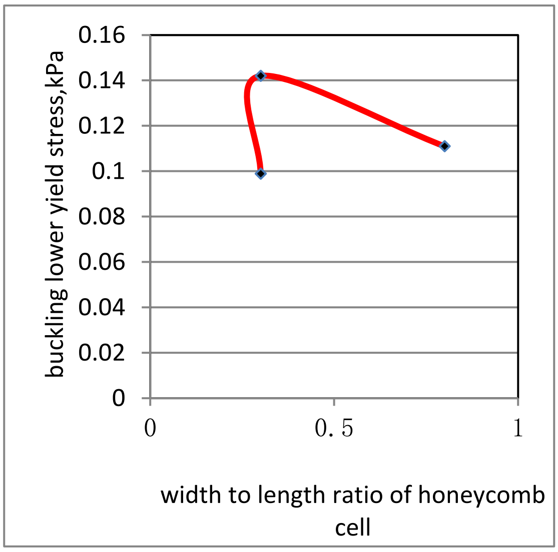

Fig. 9. Variation of buckling lower yield stress with width to length ratio of honeycomb cell.

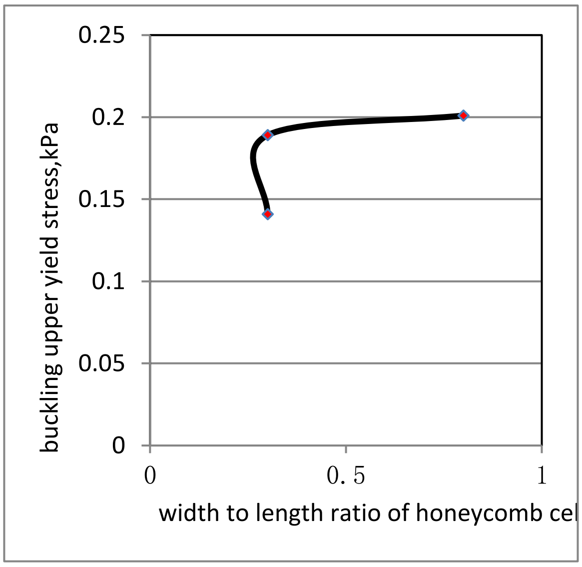

Fig. 10. Variation of buckling upper yield stress with width to length ratio of honeycomb cell.

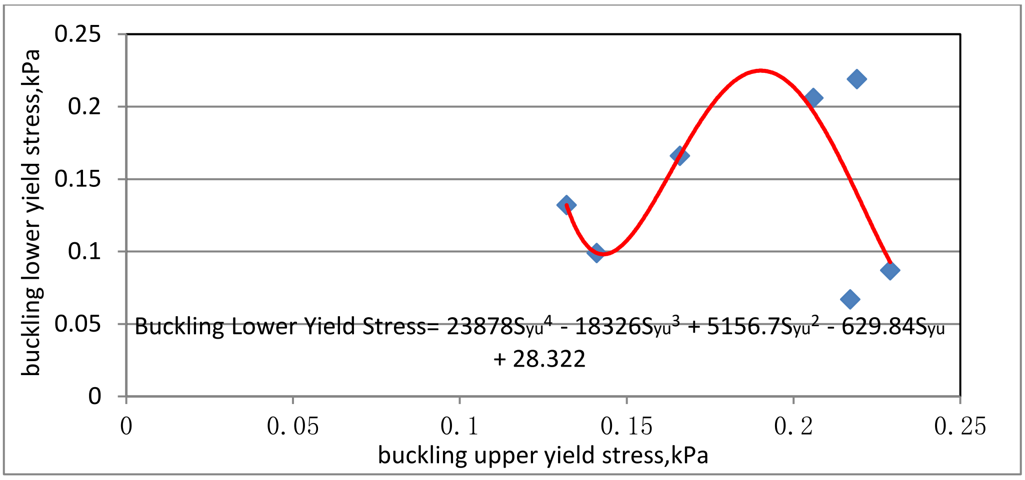

Fig. 11. Variation of buckling lower yield stress with buckling upper yield Stress (Syu).

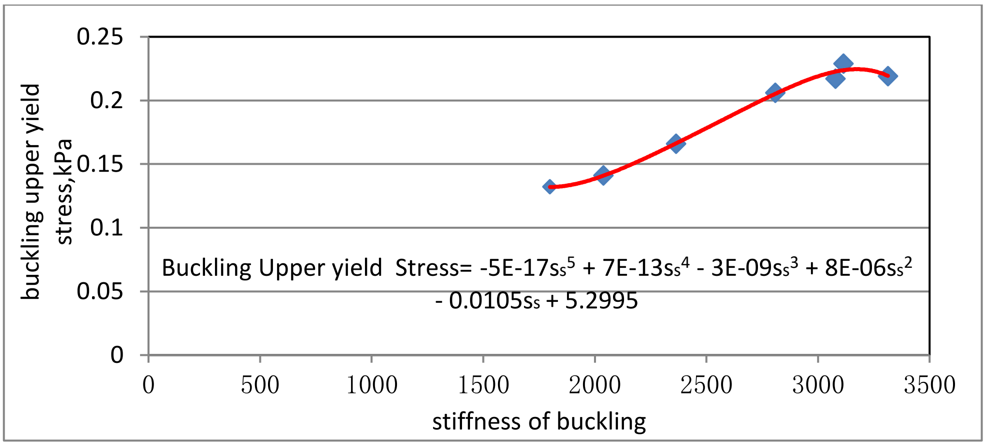

Fig. 12. Variation of buckling upper yield stress with stiffness of buckling (ss).

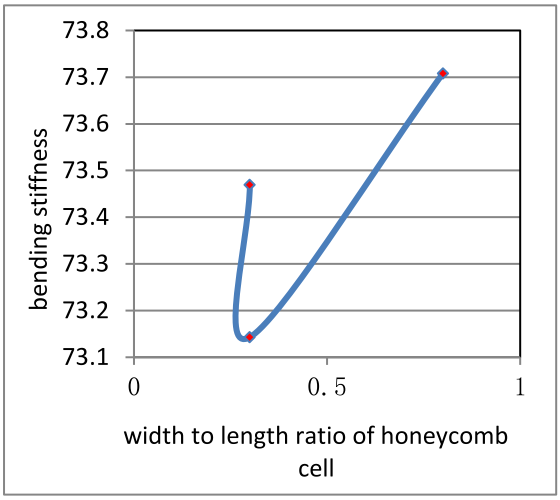

Fig. 13. Variation of bending stiffness with width to length ratio of honeycomb cell.

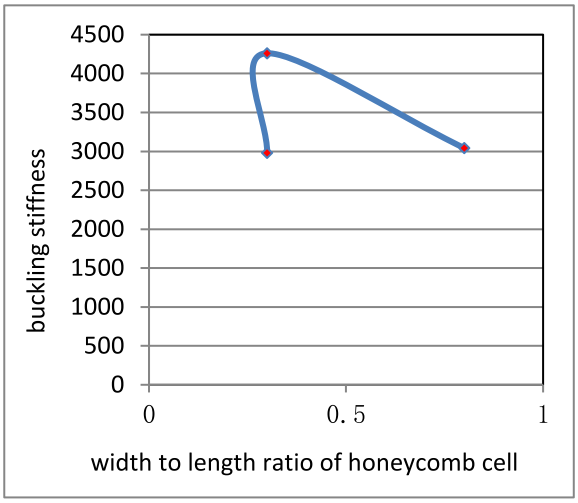

Fig. 14. Variation of buckling stiffness with width to length ratio of honeycomb cell.

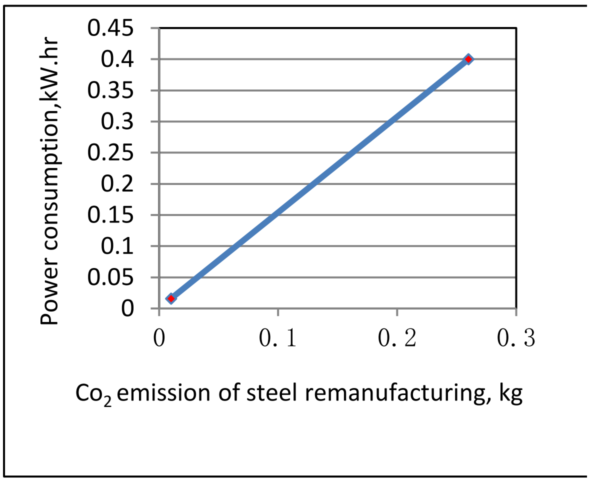

Fig. 15. Power consumption and related CO_2 emission of steel remanufacturing.

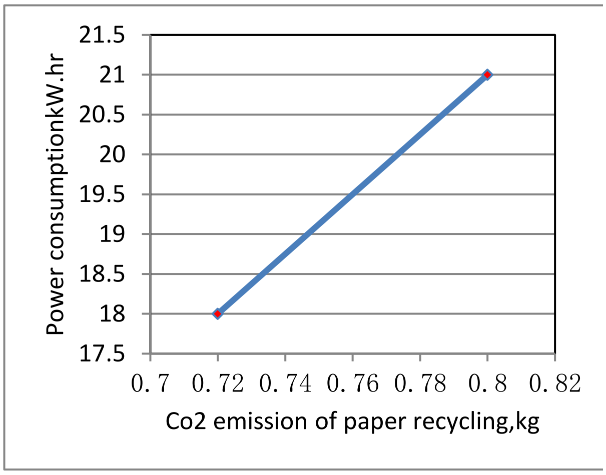

Fig. 16. Power consumption and related CO_2 emission of paper recycling.

4. CONCLUSION

Three types of honeycomb are used in field of construction to make comparison which include recycled paper, aluminum and stainless steel. further to remanufactured honeycomb Except the high consuming of resources and power and high related Carbon emission, recycled paper represent sustainable approach. To extend the use of honeycomb for construction application, where the increase in weight due to steel sections exploiting have no effect comparing with construction materials such as brick, composite shape steel honeycomb can provide enough strength to substitute leak in strength of the recycled paper which is only used as filling material for doors. Thus sandwich panels can be strengthened through embedding of steel honeycomb through heat isolation materials to be one unit.

The role of steel honeycomb can be extended not to only overcome and stop of using of paper as honeycomb but also composite shape steel honeycomb is better in both power and C emission mitigation.

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