https://dx.doi.org/10.22161/ijcmes.4.1.1 *ISSN: 2455-5304*

Further Improvements in Quality of Aluminium on the Structural Applications

Sk.Khaleel[1], SK.Nagul Meera[2]

Assistant professor, Department of Civil Engineering, RGUKT IIIT Basar, India
Assistant professor, Department of Civil Engineering, Adams Engineering College, Palvancha, India

Abstract— *Recently many reports on similar systems such as Aluminium alloys AA6061-T6 has been reported. Base material of Aluminium and its alloys has captured important attention from manufacturing industries, Building materials, Shipbuilding, Automotive, Railway and Aircraft production which include the difference between the series of aluminium alloys has been successfully produced by many researchers. Aluminium and its alloys are widely used in building applications due to their excellent electrical & thermal conductivities, good strength, corrosion & fatigue resistance. The aim of present study was analogy of the improvements in quality of aluminium on structural applications 6061-T6 alloy.*
Keywords— Base material, Aluminium alloy, Building materials, Structural applications, Micro hardness and Mechanical Properties.

I. INTRODUCTION

Although aluminium is a long known structural material, its use is not in accordance with the benefits achieved by its implementation. There are several reasons for such an adverse state. Those that stand out are the late development of a regulative framework for the design of structures, and still the need for improvement, lack of knowledge on application examples and not stressed enough potential areas of use. However, positive trends are present and aluminium alloys are competitive, especially if their positive properties can be utilized and negative properties diminished through purpose oriented design approach. Given examples present good application utilization of aluminium alloys characteristics, and shown new application research can provide directions for further expansion of competitiveness. Structural uses are grouped in suitable areas of application and put into local and global context.
First significant applications of aluminium alloys in civil engineering emerged in the first half of the 20^{th} century, primarily related to bridge engineering. For instance, the reconstruction of a bridge roadway in Pittsburgh, in 1933[1], and the construction of a railway bridge near New York, in 1946[2]. Such activities enticed the publication of aluminium alloys design manuals, of which Alcoa developed the oldest, around 1930 [1]. Application of design methods developed for steel was not possible for aluminium elements, although aluminium alloys have many similarities with steel. One may conclude that this is the reason why first national editions of manuals for aluminium structural design were established relatively late – the German DIN 4113 in 1958, the English BS CP118 in 1969, the French DTU AL76 in 1976, and the Italian UNI 8634 in 1985.

II. MANUFACTURE OF ALUMINIUM PRODUCTS AND STRUCTURAL ALLOYS

With today known reserves of bauxite and current level of usage, aluminium can be utilized for another 1000 years [3], and when the possibility of recycling is considered there are almost no limitations in its exploitation. Aluminium's life cycle is similar to that of steel and consists of four stages [4] - (1) mining and production, (2) manufacturing, (3) usage and (4) waste management and recycling – but the production processes through which ingots are converted to various semi products are not the same. As opposed to rolling, when steel is in question, structural elements of aluminium alloys are most commonly formed by extrusion. In fact, extrusion became a significant production procedure with the beginning of use of aluminium. It is a procedure in which ingots, previously heated to a temperature of around 500 °C [5], are forced through a steel die with desired shape. Another particularity of aluminium in this context is that the production process yields very small amounts of residual stresses, which can be neglected [6]. Elements made by extrusion can have cross sections in dimensions up to 800 mm [5], with an unlimited spectre of shapes. It is why production of aluminium products by extrusion is considered lot more versatile than that of steel by rolling. Since new cross section production prices are negligible in comparison to steel, and the time needed to change a production die minimal [5], it is common practice to design sections for specific projects, in order to adopt to various structural and functional demands.
Aluminium is not just one material, but it gives rise to a family of different groups of alloys whose mechanical properties widely vary from one group to another and also within each group itself. From the point of view of the

https://dx.doi.org/10.22161/ijcmes.4.1.1 *ISSN: 2455-5304*

technological use, the aluminium alloys can be grouped into eight series, according to the American Association classification, the first of the four digits characterizing the main alloying element and the other three the secondary ones.

• 1000 Series: Pure aluminium

In this series the aluminium percentage is very high (98.8 to 99 percent). It can be used in low stressed structures under form of plates. Electrical and chemical industries use this series for cables and tanks, due to the high corrosion resistance of the aluminium itself. Its elastic limit is very low (f0.2≅30 Nmm-2), but its ductility is excellent, being the ultimate elongation εt≅30 to 40 percent. If the material is cold-worked, the strength can increase up to f0.2≅100 Nmm-2, whereas the ductility is drastically reduced (εt≅3 to 4 percent).

• 2000 Series: Aluminium-Copper alloys

These alloys are generally produced under form of profiles, plates and pipes. When submitted to heat-treatment, elastic limit f0.2 can increase up to 300 Nmm-2, with a sufficient ductility, since the corrosion resistance of these alloys is not very high, it is necessary to protect them especially when used in a corrosive environment. Because of their bad weldability, they are not very popular in structural engineering. Basically, they are used in aeronautical industry with riveted connections.

• 3000 Series: Aluminium-Manganese alloys

These alloys cannot be heat-treated and they have a slightly higher strength than pure aluminium by keeping a very high ductility, which allows very hard cold-forming processes for increasing strength. They are corrosion resistant. Specific applications are panels and trapezoidal sheeting for roofing systems.

• 4000 Series: Aluminium-Silicon alloys

The properties of these alloys are similar to those of the 3000 series. However, they are not often used, except for welding wires.

• 5000 Series: Aluminium-Magnesium alloys (5000 series)

Even though these alloys cannot be heat-treated, their mechanical properties could be higher than those corresponding to the 1000, 3000 e 4000 series. The strength can be increased when they are cold worked, being the elastic limit f0.2 up to 200 Nmm-2 and the ductility still quite high (εt up to 10 percent). The corrosion resistance is also high, especially in marine environment, when the amount of Mg is less than 6 percent. These alloys are often used in welded structures, since their strength is not drastically reduced in the heat-affected zone.

• 6000 Series: Aluminium-Silicon-Magnesium alloys

By means heat-treatment the strength of these alloys is increased, with a quite good ductility, being up to 12 percent. These alloys are corrosion resistant. They are particularly suitable for extrusion, but also rolled sections as well as tubes can be produced. These alloys are used either in welded structures or in bolted or riveted connections.

• 7000 Series: Aluminium-Zinc alloys

These alloys are produced under form of both extruded and rolled heat-treated profiles. They can be subdivided into two sub-families depending upon the percentage of copper as the third alloying element: - AlZnMg alloys reach a remarkable strength, being the elastic limit f0.2 greater than 250 Nmm-2, with a quite good ductility .They are also corrosion resistant. These alloys are generally used in structural applications, because they are particularly suitable in welded structures owing to their self-tempering behaviour, which allows to recover the initial strength in the heat-affected zone. - AlZnMgCu alloys are the highest resistance alloys after heat-treatment, conversely, they have low weldability and are not corrosion resistant, because of the presence of copper, therefore requiring protection by plating or painting.

• 8000 Series: Aluminium-Iron-Silicon alloys

This series is preferably used as material for packaging but, due to its advantages in fabrication, it finds more and more application in building industry especially for facades.

III. STRUCTURAL APPLICATIONS

Although a material's price is often paramount for the choice of its use, comparisons based on price per unit of mass lead to questionable conclusions – due to different strengths, densities and other properties in question. In addition, costs of cutting, handling, transport, erection and maintenance during use should be considered, which are all in favour of aluminium if compared to steel. With these factors considered, aluminium alloy structures can be even more cost effective, although the price of aluminium is about one and a half times [7] higher than that of steel.

Possible price reductions, but also aesthetic gains, are possible due to utilization of one or more of the following properties [7, 8]: low self-weight, resistance to corrosion, cross sections shape functionality, large number of possible surface finishing, reflection of light. Certain unique properties of aluminium like stability of properties in extremely low temperatures, non-magnetism and no spark discharge on impact, make aluminium a high priority choice for various special applications.

In accordance to the given facts, most impactful economic benefits can be attained through the following applications [9,10]:

- Large span roof systems in which variable loads are low in comparison with permanent loads;

- Structures located in inaccessible places for which transport and ease of erection are of great importance;
- Special structures for which maintenance is hard to carry out;
- Structures in aggressive environments;
- Structures with movable parts;
- Structures that are exposed to extremely low temperatures,
- Refurbishment of historic building for which increase of usable load is needed without significant increase of dead loads.

Certain applications of aluminium cannot be assigned to a group such as the listed above. That is the case with the use of aluminium in seismic protection, curtain wall systems or as a part of the sustainability efforts. Namely, Efthymiou [11] gave an overview of some the most popular aluminium systems that contribute to the sustainability of a structure and Panico [12] investigated the use aluminium shear panels for seismic protection. Research papers concerning curtain wall systems are scarce, probably due to overlapping of various interested parties and professions.

IV. COMPARISON WITH STEEL

Since most engineers are familiar with steel, it is worth mentioning what the most important differences between steel and aluminium are

- As opposed to steel, aluminium is not magnetic and does not spark on impact,
- Aluminium is not susceptible to corrosion even without any coating,
- due to its lower modulus value, aluminium elements exhibit larger deformations than those of steel, which makes serviceability limit state more significant,
- Aluminium is suitable for applications at very low temperatures (it is not prone to brittle failure),
- with the increase of temperature aluminium loses its properties faster than steel – modulus of elasticity is 67 000 MPa at 100 °C and 59 000 MPa at 200 °C,
- Elements made of aluminium are more prone to fatigue than those made of steel,

temperature makes aluminium contract and expand twice as much as steel, but the increase of stress induced by limited displacement is less (lower modulus value),

- If aluminium is connected with other metals (most often steel) there is a possibility of contact corrosion so special attention is needed during the design phase,
- aluminium is more resistant to impulse loads due to its lower modulus value, which means that aluminium alloy structures can absorb more deformation work and dampen oscillations,
- fire insulation materials for aluminium alloys structures need to be efficient in the range from 175 to 350 °C, need to have low density, low heat conductivity and need to be adequately flexible to enable relatively high deformations of aluminium.

Table.2: Advantages and shortcomings of adhesion joining.

Advantages	Shortcomings
• joining is done without holes and heat is not introduced; • distribution of stress and deformation is uniform; • concentration of stresses is at a lower level than with mechanical joining, which is especially important in constructions with cyclic loading (fatigue conditions) – this enables a larger lifespan; • aluminium alloys can be joined with other materials; • adhesion provides more freedom in connection design; • thin and small elements can be connected; • connections are gas and liquid tight; • the used glue can be insulators or conductors; • the glue dampens vibrations; • adhesion lowers the total mass of the construction.	• forming and design of such connections is not common in practice; • before glue application the surface in question needs preparation: • glue requires time to attain its final properties (hardening time) • adhesion is difficult to monitor; • dismantling and repair of connected elements is difficult; • Limited behaviour when exposed to high temperatures.

V. CONCLUSIONS

Aluminium alloys have been available as a structural material for a while now, but the degree of usage does not reflect the advantages possible to exploit by its application.

Requirements needed to correct current conditions are existent in the form of contemporary design manuals and production cost reduction enabled by a larger degree of recycling. Evidence of usage possibilities is present in various structural applications, which embody advantages of aluminium in the form of low self-weight, corrosion resistance and cross section functionality. Such examples are shown in various engineering areas, with emphasized advantages of certain usage. These are also shown in a local context, of Croatia. Although the usage of aluminium alloys is in rise, given examples show that certain areas are still undervalued. Current application expansion research indicates that there is still room for progress, beyond the field tested areas. It should be noted that the decision on using aluminium alloys should be weighed more than it currently is, especially in Croatia. Namely, given examples show lack of usage of aluminium as a primary structural element, but show promise through structural facades applications. The same trend can be said to be existent in the world, but with existent examples for guidance in other areas.

REFERENCES

[1] Kissell, J. R.; Ferry, R. L. Aluminum structures: a guide to their specifications and design. John Wiley & Sons, Inc., New York City, New York, USA, 2002.

[2] Ye, L.; Qian, P.; Feng, P. CFRP-aluminum alloy composite structures: a new type of composite structures in future. // Third International Conference on FRP Composites in Civil Engineering, Proceedings CFRP-aluminum alloy composite structures: a new type of composite structures in future / Miami, Florida, USA, 2006, pp. 709-712.

[3] Efthymiou, E.; Cöcen, Ö. N.; Ermolli, S. R. Sustainable Aluminium Systems. // Sustainability. 2, 9 (2010), pp. 3100-3109. https://doi.org/10.3390/su2093100

[4] European Committee for Standardization (CEN). EN 1999-1-1, Eurocode 9: Design of aluminium structures - Part 1-1: General structural rules. CEN, Brussels, Belgium, 2007.

[5] European Committee for Standardization (CEN). EN 1999-1-2, Eurocode 9: Design of aluminium structures - Part 1-2: Structural fire design. CEN, Brussels, Belgium, 2007.

[6] European Committee for Standardization (CEN). EN 1999-1-3, Eurocode 9: Design of aluminium structures - Part 1-3: Structures susceptible to fatigue. CEN, Brussels, Belgium, 2007.

[7] European Committee for Standardization (CEN). EN 1999-1-4, Eurocode 9: Design of aluminium structures - Part 1-4: Cold-formed structural sheeting. CEN, Brussels, Belgium, 2007.

[8] European Committee for Standardization (CEN). EN 1999-1-5, Eurocode 9: Design of aluminium structures - Part 1-5: Shell structures. CEN, Brussels, Belgium, 2007.

[9] The Aluminum Association (AA). Aluminum Design Manual. AA, Washington, District of Columbia, USA, 2010.

[10] D. Maneiah, Dr. K. Prahlada Rao, Dr. K. Brahma Raju(2017).Experimental Investigation on Mechanical Properties of Friction Stir Butt Welded Joints of Aluminium 6061-T6 under Oblique Loading . International Journal of Advanced Engineering Research and Science(ISSN : 2349-6495(P) | 2456-1908(O)),4(12), 053-057. http://dx.doi.org/10.22161/ijaers.4.12.10

[11] Mazzolani, F. M. Structural Applications of Aluminium in Civil Engineering. // Structural engineering international. 16, 4(2006), pp. 280-285. https://doi.org/10.2749/101686606778995128

[12] Gitter, R. Design of Aluminium structures: Selection of Structural Alloys. // EUROCODES - Background and Applications, Proceedings Design of Aluminium structures: Selection of Structural Alloys / Brussels, Belgium, 2008.

[13] Dwight, J. Aluminium Design and Construction. Routledge, New York City, New York, USA, 1999. https://doi.org/10.4324/9780203028193.