

# Micro-Structural Characterization of the bond strength capacity of adhesive material in the alternative of cold-formed steel frame system

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**Abstract.** The introduction of adhesive material in the structural connection of cold-formed steel (CFS) as alternative connection material has a great deal on the strength capacity of bonded joints. This paper evaluates the microstructural characterisation on CFS connection. Two different types of adhesive material, A-SK, and A-3M are taken. The experiment is made to get mechanical properties and is followed by classifying incidence x-ray diffraction (XRD) and scanning electron microscopy (SEM) to study the behaviour inside the adherence. The specimen was penetrated to classify layer surfaces, to present the structural component and to get their morphology. The result is that both materials have similar bonded joints strength capacity which meets the required standard. Quartz and calcite on A-SK are mainly located on the innermost surface separately, while A-3M mostly mixed close to the base steel. In that matter, they have been beneficial for knowing the wide variety of structural characterisation by their elemental composition phases.

## 1. Introduction

The use of cold-formed steel (CFS) for the function of structure element has been established lately due to several advantages over timber, hot-rolled steel and reinforced concrete, such as ease of construction, valuable cost, excellent strength capacity to the weight ratio of the section, high in flexibility and less environmental issues [1]. However, one disadvantage of using CFS is difficulty in improving the capacity and reliable connection due to thin cross sections and a small area of contact. For the CFS system, the screw connection is typically used. In application, when some screws are increased the fracture mechanism expecting to occurred in this connection. This application is received growing attention as many as a failure of the CFS system leads to significant structural failure as well as potential fatalities [2].

There are several alternatives for designing the CFS system connection such as friction welding and mechanical joints, but by far the most suitable method that gives a similar capacity is artificial joint by using adhesive material [3-5]. The adhesive has some enticing benefits for joining components. They do not interrupt the section surface, they spread reaction loads more widely and evenly, have a higher natural sealing capability and in some point lead to lighter designs with active coherency [6]. Fact, the



adhesive material is a complex combination of some chemical and mechanical effects taking place within little surface depth.

With these problems and benefits, experimental research was conducted by comparing test of two of the most popular adhesive material that is implied in Indonesia, first is better known as super glues, water-based and second is well known as retrofitting paste, apparently like cement paste. Both of them are popular for a general using adhesion with no mixing and have quick cure times. This research aimed to compare the bond strength and behaviour of the relative performance of widely available adhesives bonding common substrates. Since surface bonding is an essential element of adhesive use, a significant key to this test in assessing the capacity of each adhesive. Also, speciality experimental methods were tested to determine whether they performed better than general purpose adhesives in their intended application, CFS system.

Staging of the experimental study was conducted correctly. It is maintained to keep the total number of test to a functional level; tensile testing was carried in two phases, where the first phase of a trial process to provide an acceptable result for the second phase. In a first phase, six classes of adhesive from two manufacturers, A-SK and A-3M, were tensile lap coupon tested with a variety of surface preparation methods and common material substrates. Because both adhesive materials are sensitive to moisture and temperature, each combination was also placed in an environmental chamber at elevated humidity. Further, the results of the first phase, a single parameter of adhesive was chosen as the focus of the second phase, in which competitive offerings from different manufacturers were tested in a coupon tensile test. Standardised mould dimension placed there. Subsequently, the structural characterisation test was taken from a cut dimension of coupon tensile test attached to the substrate. They were sized and specified to be analysed in microscopy, in which settings for diffraction analysis and examined the imaging analysis.

## 2. Materials

### 2.1. Adhesive Selection

Two selected adhesive material, A-SK, and A-3M were considered to be analysed for the first reason is to optimise the performance to be bonded, in this case using the CFS section. The second reason is to address the needs of joint condition, such us: fit-up, environmental and type of loading. Two adhesive materials were selected over the familiar brand which both the desired adhesives and primer were readily available at a local constructional supply, while the other products would require to be ordered.

In details for framing construction such roof truss framing system. The A-SK also offers several benefits such as low odour adhesive which is ideal for any setting where harsh fumes or flammability are an issue, serves peel strength and high shear. It is also affirmed for impact resistance, 10 minutes work life and 20 minutes handling strength, bonds oily metals with minimal surface prep and bonds most plastics, composites, and metals. Furthermore, Acrylic adhesives or A-3M often referred to as resin or epoxy glue, are contained two-part adhesive material that offers capacity in strength and durability with the fast installation process, although it implies strong odour of the mechanical and chemical process which mostly heating the area of adhesion.

In addition, A-3M provide several benefits in the installation process, i.e., practice with a faster-curing speed, have no issue when attaching to the oily surface or no-clean prepared bonding layer and have a high ability to bond many materials such as glass, metals, and plastics. However, recommended applications are implied in the substrate of metals and plastics. Those are customarily taken place for industries or manufacturing.

### 2.2. CFS selection

CFS as a substrate for bonding based primarily on their function and popularity. The CFS was obvious steel choices, as was lightweight steel to represent a structural element.

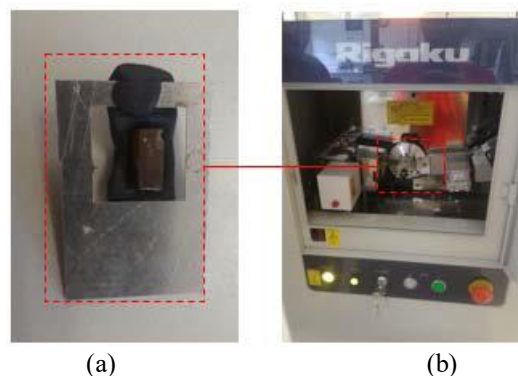
### 3. Methodology

The primary objective was to apply the most consistent processes one could reasonably expect production processes and also to give an alternative adhesive material that achieved a well-bonded in support of the capacity of the CFS connection. It is a significant distinction in all joint testing, but mainly when dealing with adhesive, subtle changes in preparation can have a substantial impact on the result and because the influencing parameters are difficult to quantify. As an example, while the test procedure in this test conforms in principle to ASTM D638-14, the standard protocol for tensile lap coupon test, ASTM D638-14 need that coupons be shaped from the sheet stock to eliminate the potential burrs or twist that are possible in sheet metal shearing or forming. It will minimise the bond gap and maximise adhesion performance.

#### 3.1. XRD Measurement

XRD experimental measurements were taken at Anadolu University, Turkey with a Rigaku MiniFlex 600 diffractometer. It comprehensively equipped with the help of a cobalt X-ray tube, a beam collimator and an XRD laser that concentrated on the fine specimen. The sharp specimen cut in several small sizes which was taken from CFS connection. The substantial cutting was rushed and cleaned then analysed by using a Lynx Eye linear detector with a diameter 500  $\mu\text{m}$ . To support the observation, XRD generator was controlled reducibly from 40 kV and 30 mA.

A fully featured XRD machine was used with a step width  $0.03^\circ$  utilising a counting time 3 s/step over a  $2\theta$  range of  $10\text{-}100^\circ$ . This method performed qualifiedly and quantitatively of polycrystalline materials. First, in qualitative measurement, unknown substances were identified by appealing the diffraction results of every phase. Other, in quantitative analysis, solid mixtures were characterised to assign crystalline compounds.



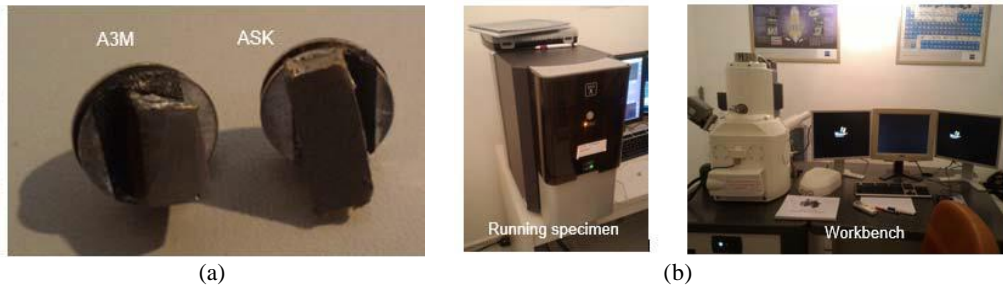
**Figure 1.** Experimental study of diffraction analysis;  
(a) XRD specimen, (b) Diffractometer

#### 3.2. SEM Measurement

SEM was measured with a Phenom Pro-X from Anadolu University. The sample structures were physically examined and magnified the size of observation determined their elemental composition. This observation included viewing three-dimensional images of microscopic structures. This term has exposed the identification of chemical elements.

These observations were divided into several magnifications. Every magnification was enhanced to see various characterisation. In detail, the sample was set in glutinous holder then titling and cooling inside the workbench of mapping line measurement. The siding was also considered for imaging an even greater diversity. Samples were Imaging in light optional with 20 – 135x magnification range and

80 – 100.000x magnification range of electron optical with 12x maximum digital zoom. Then, specified acceleration voltages were also taken from 10 kV to 15 kV with an adjustable range from 9.8 kV and 15.2 kV for imaging and analysis mode, respectively.



**Figure 2.** The mapping line of scan analysis measurement;

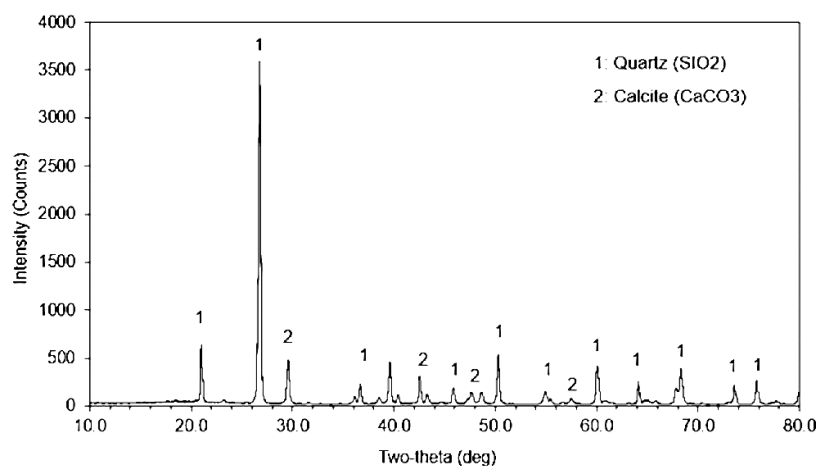
(a) SEM measurement specimens; Coating process and inserted sample to mould, (b) Reading process; running and magnifying process

## 4. Data Analysis and result

### 4.1. XRD analysis

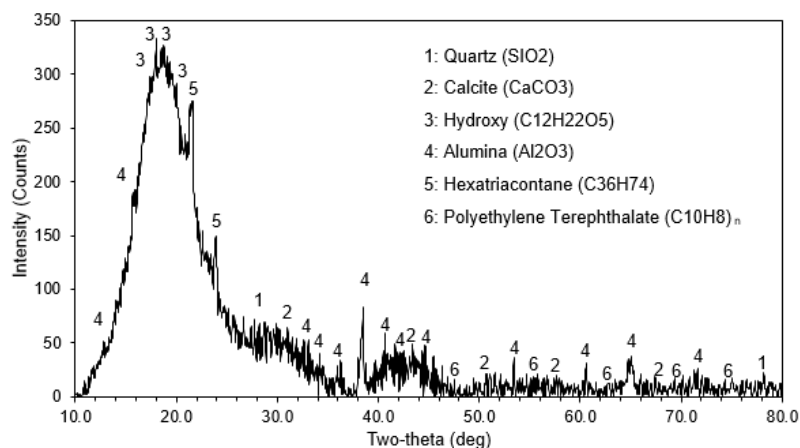
Conventional XRD analysis of solid adhesive material obtained by cutting the CFS connection side-to-side as a part of the connection. It may examine the rigorous surface interaction of the long-range order produced as a consequence of very short-range interactions.

As a result, A-SK layer informed a high content of quartz and calcite and low silicon and carbon materials. It may expect that the surface of the segment, is more abundant in quartz and calcite, rather than another content. All of this seems to confirm that A-SK has no additional element that affects concentration on its composition. Those specimens exhibited under the peaks at  $2\theta = 20^\circ$ -,  $80^\circ$ , which is illustrated in Figure 2. It was well-explained that the more defined peaks of A-SK, demonstrate the region between  $2\theta = 20^\circ$ -  $30^\circ$ .



**Figure 3.** Decomposition peaks of A-SK using peak fitting program

Furthermore, to determine the crystallinity percentage of semi-crystalline adhesion, a well-defined mixture of the amorphous and crystalline region should be assumed. Figure 3 shows the decomposition peaks of A-SK; through peak fitting program, the A-SK crystallinity percentage was around 46%.



**Figure 4.** Decomposition peaks of A-3M using peak fitting program

#### 4.2. SEM Analysis

Another objective is to achieve a morphological characterisation of two different phases of the adhesive material. It was taken to know the proportion of material which could help the strength and fracture behaviour. This research tested to indirectly identify the morphologies by its composition, shaped pattern and unity mixture of each part. This method was made from a penetration process by using a magnifying laser. Preceding research had newly measured an effluence depth of around 200 nm to describe the best condition of steel-to-steel connection [14-15].

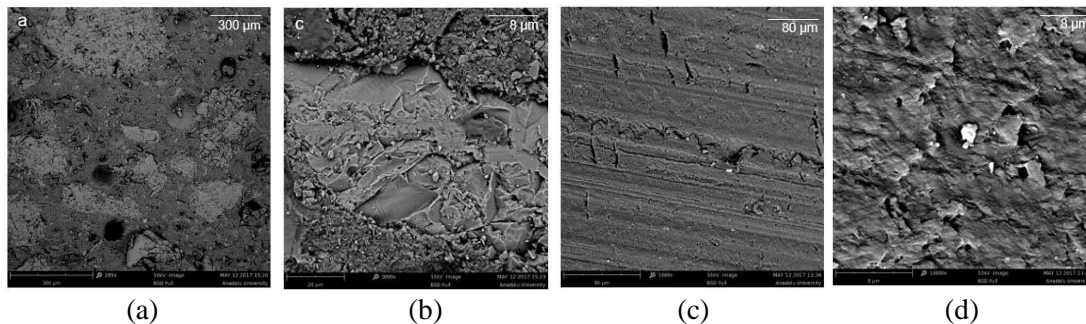
The appearance of A-3M surface was reasonably uniform based on the clear diffracting result as expressed in Figure 5. It gains information of hydroxyl and hexatriacontane as a primary phase, respectively. Calcite was added but in impoverished part and the alumina seen filling the small peak of the portion. Quartz was also given considered percentage while the polyethylene terephthalate perchance examined negligibly. This analysis acquired by smoothing the solid layer that performs in steel to steel connection. Its connection indicated high contents of quartz and calcite, and gain some elements from CFS, i.e., magnesium and calcium were also classified, 1.5% and 2.2% respectively. The results of A-SK were not similar (seen in Figure 5). The results diffraction was excellent with only detected the majority quartz and calcite, signify that the outermost layer surface is loaded in the silicon and oxygen.

Clarifying images of scan is hard to be taken due to a small size pointed material. First, a comprehensive early scan of the solid surface was conducted. Second, identify a dot scan by highlighting the most prepared surface of the morphologies. Bear in mind, the selected surface, the typically small size of the observed zone, does not represent to contain all the given morphologies as XRD did but should lid those that are most prodigal. Fourth, Find the spot then Magnify the resolution which increased until the different part of layer morphologies could be naturally observed, spotting the area of the morphological feature, e.g., quartz, calcite, and another particle, where the spectrum would subsequently be studied. The 256 times magnification of amplification were increased gradually with different frequency. Then, this spot was performed at the previously identified area of the morphological feature by 10000x magnification.

A3M contained a little portion of calcite; it is proofed that no similar crystalline shape to ASK. Calcite in ASK itself is relatively indicated as a significant proportion analogously with XRD analysis. A particular dispersion was studied in the (cm-1) wavelength shifts of the characteristic peaks of the studies above.

Thus, deal with the evaluations obtained by XRD, it looks like to be confirmed that each adhesive material is preferentially contained calcite and silicon even with different proportion which seems represent the globular formation of various morphologies. The sharp one is classified as calcite. The structure located furthest presented a rock-like with scarping two major colour appearance in ASK,

while another was fine paste with unshaped of thin reminiscent of the goethite crystals illustrated in A3M.



**Figure 5.** SEM images of A-SK and A-3M;  
 (a) A-SK 256x magnification, (b) A-SK 10000x magnification, (c) A-3M 256x magnification,  
 (d) A-3M 10000x magnification

In addition, the A3M surface showed a very same firm dark reddish-purple colour and its appearance was almost similar in all the marked area. Still, in these surfaces, A-3M is more disparate, informing different classification from one marked area to another. Figure 5 above illustrate, the different morphologies scanned in several marked regions of the surface including vary magnification. Different from A3M, ASK explained light colour, a bit grey to dark and its appearance was not uniform. Some holes also presented in this layer. Contrariwise, other observed areas were characterized by an extensive background of blackish colour, possibly silicon, mottled with the whites' globular formation of different morphologies. The sharp one is classified as calcite.

## 5. Conclusion

Several number properties affect bonding quality besides joints formed with the adhesive and adherents. Two aspects that important as a bonded parameter are the strength capacity and composition of the adhesive material. From this study, it successfully obtained that both adhesive materials fitted as an acceptable alternative material for CFS system connection. It was proved by the bond strength capacity to raise the standard of its specification. On the other hand, structural characterisation on A-SK and A-3M occurred different result, while A-3M given highly diverse morphology through peak fitting program the A-SK crystallinity percentage was around 46%. The same distribution of phase contents to the previous surface of both adhesive, A-SK data is considerably accepted since only two implied element which will be easy to be modified on the field.

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