Aggregate-Cement Bond Strengths:

Concrete can be regarded as a chain in which aggregates are the links bonded together by cement paste. Just as the strength of a chain as a whole is depending upon the strength of welding of the individual links, the strength of concrete as a whole is depending upon the strength (bond strength) of the hydrated hardened cement paste (hcp). By and large the strength of hcp is depending upon w/c ratio which determines the quality, continuity, density, porosity of the products of hydration in particular the C-S-H gel. Stronger the gel bond stronger is the concrete. Aggregates generally being much stronger than the paste (gel bond), its strength is not of consequence in normal strength concrete. The strength of aggregate is of consideration in high strength concrete and light weight concrete.

The explanation that the strength of Concrete is limited by strength of the paste will hold good when we consider concrete as two phase material. If we take a closer look into the structure of the concrete, a third phase comes into consideration i.e., inter-face between the paste and aggregate known as Transition Zone. In the ultimate analysis it is the integrity of the transition zone that influences the strength of concrete.

Bleeding takes place in fresh concrete. The bleeding water in the process of coming up gets intercepted by aggregates, particularly large size flaky and elongated aggregate and gets accumulated at the inter-face between paste and aggregates. The extra water remaining at the inter-face, results in poor paste structure and poor gel bond at the transition zone. The paste shrinks while hardening. The magnitude of shrinkage is higher with higher water content, in which case, a higher shrinkage takes place at the transition zone which results in greater shrinkage cracks at the transition zone.

In case of shrinkage taking place on account of heat of hydration, the weak gel structure at the transition zone also suffers a higher degree of shrinkage. The same situation will take place if the concrete is subjected to heat or cold during the service life.

It can be deduced that there are considerable microcracks or what you call “faults”, exists in the transition zone even before the concrete structures are subjected to any load or stress. When subjected to some stress, the existing micro cracks in transition zone propagate much
faster with tiny jumps and develop bigger cracks than rest of the body of concrete and structure fails much earlier than the general strength of concrete. Therefore, the transition zone is the weakest link of the chain. It is the strength limiting phase in concrete.

The w/c ratio that again influences the quality of transition zone in low and medium strength concrete. The w/c ratio is not exerting the same influence on high strength concrete ie., for very low w/c ratio. It has been seen that for w/c less than 0.3, disproportionately high increase in compressive strength can be achieved for very small reduction in w/c. This phenomenon is attributed mainly to a significant improvement in the strength of transition zone at very low w/c ratio.

Aggregate characteristics other than strength, such as size, shape, surface texture and grading are known to affect the strength of concrete. The increase in strength is generally attributed to indirect change in w/c ratio. Recent studies have shown that the above characteristics of aggregates have independent influence on the strength properties of concrete other than through w/c ratio by improving the quality of transition zone.

J.J Flyover at Mumbai where high strength, high performance concrete 75 MPa was used for the first time in India (2002