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Designs covered by small subdesigns

Given a pairwise balanced design and some subset S of its points, the flat (subdesign) *generated by* S is the intersection of all flats containing S. It is natural to say that the *dimension* of a design is the maximum integer d such that the flat generated by any d points is proper. For instance, affine space $\mathrm{AG}_d(q)$ has dimension d under this definition because all d-point-generated flats have size at most q^{d-1}, but some set of $d+1$ points generate the whole space.

Our main result is that, for any K and d, there exist, for all sufficiently large admissible v, a pairwise balanced design $\mathrm{PBD}(v, K)$ such that all d-point-generated flats are bounded by a constant independent of v. This gives an existence theory for designs of dimension at least d (in a rather strong sense).

For the case $K = \{3, 4, 5\}$ and $d = 3$, it is possible to construct designs of each possible size with a universal upper bound of 94 on all generated flats. This is of independent interest for a certain extremal problem on edge-colourings. An easy transformation from this case also leads to latin squares covered by small subsquares.